MONTREAL PROTOCOL
ON SUBSTANCES THAT
DEPLETE
THE OZONE LAYER

UNEP

Report of the
Halon Fire Extinguishing Agents
Technical Options Committee

December 1994

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Report of the 1994 Halon Fire Extinguishing Agents Technical Options Committee

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Executive summary and conclusions

Alternatives to halon fixed systems

New and existing alternatives exist for most halon 1301 total flooding applications. Where replacement of halon 1301 is especially difficult (ground combat vehicle crew bays and certain aviation applications) substantial research and development is underway. The commercial availability of zero ODP halocarbon replacements and new technologies based on water and other extinguishing agents, enabled the early phaseout of halons and an early transition to alternative fire suppression agents.

Alternatives to halon portable fire extinguishers

Although halons provided excellent characteristics as fire extinguishing agents for use in portable fire extinguishers, the use of alternatives for this application has been less problematic than use of alternatives in fixed fire protection systems. In general portable fire extinguishing agents are only applied to actual fires and they can be easily directed at the burning object. As such secondary damage concerns are somewhat less in recognition that fire damage to the object has already occurred. For most applications, multipurpose dry chemical has been the agent of choice, however there are important applications where visibility concerns during firefighting operations and/or ability to permeate are of vital importance.

Current HCFC based alternative streaming agents are considerably less effective on a weight and volume basis to halon 1211. As a result HCFC alternatives have not found wide acceptance for use in portable fire extinguishers. There may be some potential use of HCFC based alternatives in large capacity, manually applied fire protection equipment for military flight line operations.

Halocarbon replacement agents - environmental factors to be considered

The primary environmental factors to be considered for halocarbon agents are ODP, GWP, and atmospheric lifetime. Comparison of halocarbon replacements with other alternatives should be based on consideration of the environmental impact of each alternative. This should include the impact of production of the agent and hardware, transportation, and storage as well as other factors which determine the total impact of a technology on the environment.

While GWP and atmospheric lifetime are potentially important environmental factors of halon replacement agents, the objective of replacing halons with non-ozone depleting substances is paramount to the goals of the Protocol. Therefore, the use of controlled, non-zero ODP compounds, including HCFCs and HBFCs, as halon replacements is not a wise decision if it can be avoided. As controlled substances, these agents are unlikely to be produced in sufficient quantities that recycled material would be available for long-term support of fire protection systems.

The impact of high atmospheric lifetime, and related high GWP, should be evaluated in the context of the use quantity and emission pattern of chemicals used as halon replacement fire extinguishants. When used only as fire suppressants, there is no likely emission scenario of these compounds which results in measurable environmental impact. However, fire protection represents only one of the potential uses for these substances, and therefore total usage could exceed environmentally acceptable levels. As a result, several governments have already restricted or banned the use of HFCs and PFCs. Such actions may restrict the commercial availability of these agents, and cause shortfalls in the availability of recycled material necessary for the long-term support of fire protection systems.

Recognizing persuasive environmental concerns, the Halons Technical Options Committee does not endorse the widespread use of HCFCs and HBFCs, or promote the indiscriminate use of PFCs, in preference to other, effective, new or existing technological alternatives for fire protection, which are discussed later in this chapter. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes, with consequences to long-term availability of the compound and subsequent support for installed fire protection systems.

Explosion Protection

Halons have been widely used to suppress deflagrations, a class of combustion events characterized by rapid flameball growth and high rates of energy release. Explosions are events resulting in personal injury or destruction of property. Explosion protection is achieved through methods to prevent or mitigate deflagrations. Effective protection of systems and personnel at risk from such events requires operating systems which:

i. Create inerted atmospheres, or

ii. Respond automatically to the incipient event and achieve extinguishing agent concentrations to suppress a deflagration in time scales of the order of 100 milliseconds, and which require agent concentrations much higher than typically employed in total flooding fire suppression applications.

Halons have been specified in industrial, commercial, and military explosion protection applications where either "clean" or people-safe agents were essential. Halon 1301 has the unique property of being able to inert an enclosed space or suppress deflagrations at vapour concentrations which are safe for brief human exposures. Replacement of halon 1301 in such applications presents a significant challenge in fire or explosion protection situations involving human life safety for at present there are no approved alternative agents which have this property. Work is in progress to identify alternative agents which may be approved for these applications. Progress has been made in some applications in designing new explosion protection systems with out specifying halons. Retrofitting of some halon based deflagration suppression systems with environmentally benign agents is occurring though in some cases an unclassified lower ODP clean agent (Halon 1011) is being specified.

Halon emission reduction strategies

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimised if a concerted effort is made by the fire protection community, with support from national governments. In reviewing reduction strategies, the Committee recommends the following:

- Reduce halon usage to essential applications only.
- Discontinue protection system discharge testing using halon as the test gas.
- Discontinue the discharge of portable halon fire extinguishers for training purposes.
- Discontinue the discharging to the atmosphere of portable halon extinguishers and system cylinders during equipment servicing.

- Introduce the use of halon recycling equipment to recover all surplus or reusable material.
- Encourage users of automatic detection/release equipment to take advantage of the latest technology.
- Encourage the application of risk management strategies and good engineering design to take advantage of alternative protection schemes.

Halon recycling and bank management

The phase out of halon production in the developed countries took place before substitutes and alternatives became available for all critical halon uses. This has been a positive motivation to achieve best use of existing halons and has encouraged the establishment of halon banks and bank management procedures to wisely manage the remaining stocks. Past experience has also shown that 'recycled' halon cannot compete with newly produced material, and thus a prerequisite of any national bank management programme is a commitment to cease production first.

An increasing number of countries, both developed and developing, have initiated or are operating bank management programmes. These programmes take different forms in different countries but, whilst similarities exist, the Halons Technical Options Committee has concluded that no universal template for a bank programme can be produced. This is primarily because the key element of the banking process is the reversal of the original supply/distribution process and this varied from country to country.

Of the bank programmes reviewed, the majority resemble an information clearinghouse. That is, the operators maintain lists of halon users who no longer require halon and those who do but have or will have insufficient stocks to meet their needs. This information is traded between the users who then make the necessary arrangements for 'recycling' of the halon and its sale/purchase. Physical banks that require warehouses and storage tanks are a minority, although it is apparent that large private and military users are forming strategic banks on these lines.

For any banking scheme to work, the fire equipment industry, users and/or government have to agree that a need for a halon bank exists, otherwise there is unlikely to be enough energy, enthusiasm and finance to get a bank started. Governments are also uniquely placed to act as facilitators and to provide a non-commercial forum for discussion and the development of strategies.

Users who obtain 'recycled' halon have to be assured that what they buy is fit for use in fire protection applications. This can best be provided by requiring material to be 'recycled' to a certain agreed standard, or by knowing its provenance. This is particularly import when international trade is involved, as the requirements of the Basel Convention have the potential to be a serious impediment to the transshipment of 'recycled' halons across international boundaries. For this reason, the Halons Technical Options Committee recommends that the Parties to the Montreal Protocol consider:

International cooperation on the movement of 'recycled' halons facilitates access to a bigger market for the sale or purchase of halons, and provides the ability to recharge critical halon systems, such as onboard ships and aircraft, while in a foreign territory. It is therefore important that Parties insure that national regulations that were implemented to restrict imports and exports of newly produced halons do not impede the international trade in 'recycled' halons or their premature destruction.

Need to further facilitate halon recycling and bank management

The Halon Fire Extinguishing Agents Technical Options Committee, having evaluated recycled halon bank management programmes, offers the following recommendations for consideration by the Parties to the Montreal Protocol as possible means of further facilitating international recycled halon bank management:

a) Adopting a decision that recycled halons that are certified to the usable purity specifications ISO 7201 or ASTM ES 24-93 are considered recycled material and not a waste.

b) Adopting a decision that international transfers of halons that cannot meet the purity specifications of ISO 7201 or ASTM ES 24-93 should only be allowed if the recipient country has 'recycling' facilities that can process the received halon to either of these standards.

c) Adopting a decision that 'recycled' halons not be destroyed before all means of transferring them to a country that has a critical need for halons, particularly if that country is still producing or importing new halons, have been explored.

d) Adopting a decision that the Director of UNEP IE/PAC convene a meeting of the current national halon bank managers to share information and develop cooperative procedures to further facilitate access to 'recycled' halons by those countries with limited surplus or those who are still producing new halons.

Review of industry case studies

The review of the case studies recognised the need to obtain opinions of industry on the strategies developed internally to protect their business interests prior to the cessation of halon production and how they see a future without this agent.

The response to the survey request in terms of returns received was excellent. This highlighted the level of responsibility exercised by a large number of industries, by ensuring they have put in place strategies that are achievable in terms of short, medium and long goals to meet the objectives of the Montreal Protocol.

Life without halon can be described in terms of a baby taking its first steps to walk without the aid of its guardian. Some industries have moved very quickly in declaring they can protect their risks scenarios without halons. Consequently they have developed alternative strategies, by way of improving their internal housekeeping practices, and introducing alternative fire protection measures such as improved passive protection, early smoke detection, water and gaseous systems. Other industries are moving a little slower in this process, but ground rules are in place to bring about change, this will continue to gain speed in the foreseeable future.

It is very obvious that there is a current and future need for halons in areas that involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. However, it has also been determined by the results of this industry survey that with well planned fire protection strategies in place it is possible to conserve and make available surplus stocks of halons that can be recycled, banked and made available for areas of critical need.

Eliminating halon dependency in developing countries

The elimination of halon dependency is a logical, step by step procedure, that should be implemented in the following order:

1) Build awareness of the problem of ozone depletion

2) Commit to phase out of halons

3) Reduce unnecessary emissions and uses of halons

4) Switch to alternative fire protection methods

5) Develop halon bank management and recycling - eliminate need for newly manufactured halons

6) End halon production

The production or conversion to use of HCFC and PFC compounds would be an unwise selection for a developing country as it is unlikely that these alternatives will have commercial lifetimes sufficient to justify capital investment.

Essential uses and their needs

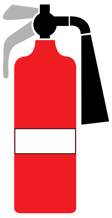
The Committee recognises that there are a few fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These risk scenarios involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. At the same time, the Committee is of the qualified opinion that, with proper management, the future needs of the majority of these risk scenarios can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires. The Committee also notes that application specific, replacement extinguishing agents and alternative technologies are now commercially available, although environmental and toxicological concerns have limited the acceptability of some promising replacements. However, it is believed that in the long term, use of the current replacements and alternatives, and others that will be developed in the future, will likely restore the capability to provide fire protection with similar desirable characteristics to those of the present halons for all risk scenarios.

With the possible exception of halon 2402 applications in countries whose economies are in transition, the requirement to produce new halons for critical applications can be avoided by use of halon recycling and banking schemes, and by the early introduction of halon replacements and alternative technologies. Although it may be necessary to reconsider this issue again in the future, the combination of successful bank management, the proper utilisation of zero ODP, environmentally acceptable halon replacements, and the acceptance of alternative technologies, offers the best potential to eliminate the need for a production exemption for essential uses in the foreseeable future.

Establishing a fixed list of risk scenarios that would qualify for a production exemption is neither appropriate or necessary at this time. Continued use of the criteria detailed in this section is the best option at this time and for the foreseeable future. Parties are encouraged to co-operate with the international fire protection community on bank management, emission reduction and the wise future allocation of the banked halons, and to use their national resources to assist the research community in the development of acceptable halon alternatives.

1 Introduction

Halons are halogenated hydrocarbons that exhibit exceptional fire fighting and explosion prevention/suppression effectiveness. They are electrically nonconductive, dissipate quickly



and leave no residue. Halon 1211 and halon 1301 have proven remarkably safe for human exposure. This unique combination of properties has led to their selection as an agent of choice for many fire protection situations: computer, communications, and electronic equipment facilities, museums; engine and ancillary spaces on ships and aircraft; ground protection of aircraft; general office fire protection, industrial applications and residential use. Halon 2402 is primarily used in Russia. Russia began to develop gaseous fire extinguishants in 1937 as a result of military firefighting needs during World War II. In Russia, halon 2402 has been used extensively on ships and other critical fire protection applications.

On January 1, 1994, halon production ceased in the developed countries.

This report is part of the UNEP review under Article 6 of the Montreal Protocol. Article 6 specifically directs Parties (nations that have ratified the Protocol) to assess whether the control measures, as provided for in Article 2 of the Protocol, are sufficient to meet the goals for reducing ozone depletion, based on a review of the current state of knowledge on technical, scientific, environmental and economic issues related to stratospheric ozone protection

Technical and Economic Assessment tasks are undertaken by seven Technical Options Committees:

(1) Rigid and Flexible Foams Technical Options Committee

(2) Solvents, Coatings and Adhesives Technical Options Committee

(3) Halon Fire Extinguishing Agents Technical Options Committee

(4) Economic Options Committee

(5) Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

(6) Aerosols, Sterilants, Miscellaneous Uses and Carbon tetrachloride Technical Options Committee

(7) Methyl Bromide Technical Options Committee

The 1994 Halons Technical Options Committee consist of some members of the 1989, 1991 and 1993 Committees and additional new experts, to provide the widest possible international participation in the review. Experts from industry, government, academic institutions and non-government organizations were invited to prepare this comprehensive and technically specific "Options Report". UNEP staff, Technical and Economics Panel Chairpersons and the Halons Technical Options Committee Co-chairs contacted producers, equipment manufacturers, trade associations, users, research institutions, fire protection organizations, standards making organizations and others to arrange for technical input.

In 1981, in response to the growing scientific consensus that CFCs and halons would ultimately deplete the ozone layer, the United Nations Environment Program (UNEP) began negotiations to develop multilateral protection of the ozone layer. These negotiations resulted in the Vienna Convention for the Protection of the Ozone Layer, in March 1985. The convention provided a framework for international cooperation in research, environmental monitoring and information exchange. In September 1987, 24 nations signed the Montreal Protocol on Substances that Deplete the Ozone Layer. As of April 1, 1991, 68 nations have ratified the Protocol. These countries represent over 90 percent of the world's production of CFCs and halons. The Montreal Protocol entered into force on January 1, 1989. This international environmental agreement limited production of specified CFCs to 50 percent of 1986 levels by the year 1998 and called for a freeze in production of specified halons at 1986 levels starting in 1992. A list of CFCs, halons and other substances controlled under the Montreal Protocol is shown in Table 1-1, at the end of this section.

Since the 1987 Protocol was negotiated, new scientific evidence conclusively linked CFCs to depletion of the ozone layer and indicated that depletion had already occurred. Consequently, many countries called for further actions to protect the ozone layer by expanding and strengthening the original control provisions of the Montreal Protocol. In June 1990, the Parties to the Montreal Protocol met in London and agreed to Protocol adjustments requiring more stringent controls on the CFCs and halons specified in the original agreement and amendments placing controls on other ozone depleting substances, including carbon tetrachloride and 1,1,1-trichloroethane. The Parties met again in Copenhagen in November of 1992. Table 1-2 outlines control measures provided by the Montreal Protocol, as of 1994.

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Table 1-1
Substances Controlled by the Montreal Protocol
(ODP values are relative to CFC-11)

Annex A

Group I		**ODP**
CFC - 11	Trichlorofluoromethane	1.00
CFC - 12	Dichlorodifluoromethane	1.00
CFC - 113	1,1,2-Trichloro-1,2,2-trifluoroethane	0.80
CFC - 114	1,2-Dichlorotetrafluoroethane	1.00
CFC - 115	Chloropentafluoroethane	0.60
Group II		
Halon 1211	Bromochlorodifluoromethane	3.0
Halon 1301	Bromotrifluoromethane	10.0
Halon 2402	Dibromotetrafluoroethane	6.0

Annex B

Group I		
CFC - 13	Chlorotrifluoromethane	1.00
CFC - 111	Pentachlorofluoroethane	1.00
CFC - 112	Tetrachlordifluoroethane	1.00
CFC - 211	Heptachlorofluoropropane	1.00
CFC - 212	Hexachlorodifluoropropane	1.00
CFC - 213	Pentachlorotrifluoropropane	1.00
CFC - 214	Tetrachlorotetrafluoropropane	1.00
CFC - 215	Trichloropentafluoropropane	1.00
CFC - 216	Dichlorohexafluoropropane	1.00
CFC - 217	Chloroheptafluoropropane	1.00
Group II		
CCl_4	Carbon Tetrachloride (Tetrachloromethane)	1.10
Group III		
1,1,1-Trichloroethane	Methyl Chloroform (1,1,1-Trichloroethane)	0.10

Annex C

Under Annex C, the Montreal Protocol defines partially halogenated fluorocarbons, (including HCFCs)

Group I Hydrochlorofluorocarbons(HCFCs)

Group II
Hydrobromofluorocarbons

Annex E

MeBr	Methyl Bromide	0.6

Table 1-2
Control Measures Status 1994

Annex A - Group I
Chlorofluorocarbons: CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115
Reference year: 1986
75 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex A - Group II
Halons: halon 1211, halon 1301 and halon 2402
Reference year: 1986
100 percent reduction by January 1, 1994 (with possible exemptions for essential uses)

Annex B - Group I
Other fully halogenated CFCs
CFC-13, CFC-111, CFC-112, CFC-211, CFC-212, CFC-213, CFC-214, CFC-215, CFC-216, CFC-217
Reference year: 1986
Freeze at 1986 levels by July 1992
85 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex B - Group II
Carbon Tetrachloride
Reference year: 1989
85 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex B - Group III
1,1,1-trichloroethane
Reference year: 1989
50 percent reduction by January 1, 1994
100 percent reduction by January 1, 1996

Annex C - Group I
HCFCs
Reference year: 1989
Freeze in 1996 based on 3.1% of 1989 CFC ODP Consumption PLUS Calculated level of 1989 HCFC Consumption
35 percent reduction by January 1, 2004
65 percent reduction by January 1, 2010
90 percent reduction by January 1, 2015
99.5 percent reduction by January 1, 2020
100 percent reduction by January 1, 2030

Annex C, Group II
HBFCs
100 percent reduction by 1996

Annex E
Methyl Bromide
Reference year: 1991
Freeze at 1991 levels by January 1, 1995, with exemptions for quarantine and pre-shipment applications

2 Fire protection alternatives for fixed halon systems

2.1 Introduction

The use of traditional non-halon fire protection systems protecting hazards has been promoted as a means of reducing halon use. The degree to which these traditional not-in-kind alternatives (see Section 2.5) successfully replace halon is driven by the details of the hazard being protected, the characteristics of the alternative method, and the risk management philosophy of the user. Clean agent replacement chemicals and new "not-in-kind" alternative technologies have been introduced at a rapid pace. The objective of this section is to summarize the status of these halon alternatives and replacements.

The classes and categories of new technology replacements include the following:

1. Gaseous Alternatives

    a. HFC/PFC/HCFC/HBFC compounds (Robin (1991, 1992), Hanauska (1991), Ferreira (1992), DiNenno et al. (1992, 1993), Fernandez (1991), Sheinson (1994)).

    b. HCFC, HFC, and PFC blends (Andersson (1992), Gugliemi (1992)).

    c. Possible moderate-term second generation agents (Gann et al. (1991), Pitts et al. (1991), Tapscott et al. (1989, 1992, 1993), Skaggs (1993), Nimitz et al. (1991)).

    d. Inert gases ((Riley 1992), Nicholas (1993), Grindstead (1993), Scheffey et al. (1989)).

2. Water Mist Technologies

    a. Single Fluid Systems

        - generic systems utilizing industrial specialty nozzles and proprietary systems including Marioff, Ultra Fog, and Baumac International, Kidde Graviner, Kidde Fenwal (Jackman et al. (1993), Marttila (1993), Turner (1993), Hill et al. (1991, 1993), Arvindson and Ryderman (1992), Marker (1991), Spring et al. (1993), Hills et al. (1993)).

    b. Twin Fluid Systems

        - generic (water with air/N_2/CHF_3) utilizing modified industrial spray nozzles. These generic technologies include systems designed and developed by the National Research Council of Canada (NRCC), and U.S. Naval Research Laboratory. Several proprietary systems will also be evaluated including Securiplex (BP), Kidde-Graviner, Kidde-Fenwal, and ADA Technologies (Mawhinney (1993), Gameiro (1993), Butz (1992), Papavergos (1991), Soja (1990), Cousin (1992), Wighus (1992)).

3. Combustion Generated Aerosols

- proprietary systems (Kopylov (1993), Kibert (1993), Kidde-Graviner (Spring (1993)), Walter Kidde Harrison (1993), Sheinson (1993, 1994)).

2.2 Gaseous Alternatives for Fixed Systems

2.2.1 Halocarbon Agents

These agents share several common characteristics, with the details varying between chemicals. These common characteristics include the following:

(1) All are electrically non-conductive;

(2) All are clean agents; they vaporize readily and leave no residue;

(3) All are liquified gases or display analogous behavior (e.g., compressible liquid);

(4) All can be stored and discharged from typical Halon 1301 hardware (with the possible exception of HFC-23 which more closely resembles 600 psig (40 bar) superpressurized halon systems);

(5) All (except HFC-23) use nitrogen superpressurization for discharge purposes;

(6) All (except CF_3I) are less efficient fire extinguishants than Halon 1301 in terms of storage volume and agent weight. The use of most of these agents requires increased storage capacity;

(7) All are total flooding gases after discharge. Many require additional care relative to nozzle design and mixing;

(8) All (except CF_3I) produce more decomposition products (primarily HF) than Halon 1301 given similar fire type, fire size, and discharge time; and

(9) All are more expensive at present than Halon 1301 on a weight (mass) basis.

These agents differ widely in the 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.
Table 2.2.1 summarizes relevant data for halocarbon agents.

HCFC Blend A has been proposed by its manufacturer as a "drop in" replacement for Halon 1301. This implies that the replacement of Halon 1301 in cylinders with a similar quantity of the blend will result in a functioning system. There are many technical problems with this drop-in replacement claim. The HTOC does not believe that HCFC Blend A is a demonstrated, proven drop-in replacement. The reasons are outlined below.

(1) The design concentration proposed is less than the cup burner extinguishing concentration which is widely accepted as the minimum basis for a design concentration;

(2) The flow and mixing characteristics of HCFC Blend A are sufficiently different from Halon 1301 to require, as a minimum, change out of all nozzles. Nozzles for use with HCFC Blend A should be demonstrated by third party, independent testing to give adequate performance;

(3) Elastomeric materials used with Halon 1301 may not be acceptable for use with HCFC Blend A; and

(4) Toxicity information on HCFC Blend A implies that use of agent at or above the cup burner minimum concentration is not acceptable for normally occupied areas.

Any claims of "drop in" replacement capability of any agent must be carefully scrutinized, and adequate test and technical data available to make an informed judgement.

Toxicity

Table 2.2.1 summarizes the toxicity information available on each chemical. The NOAEL is the No Observed Adverse Effect Level. This is the concentration at which no adverse effect was observed in the test specimen. For halocarbon agents, this is usually driven by the cardiosensitization level of the agent. Several compounds including HFC-23 and FC-3-1-10 have little or no cardiotoxicity. Halon replacement agents should not be used at concentrations above the NOAEL in occupied areas.

Use of any agent at a design concentration (extinguishing concentration + safety factor + leakage factor) below its NOAEL can be considered suitable for use in occupied areas. Hence for normally occupied areas, the NOAEL concentration should exceed the design agent concentration. Typical safety factors are 20% above the extinguishing concentrations.

2.2.1-A
Physical Properties for New Technology Chemical Gaseous Alternatives

Trade Name	Designation	Formula	BP ˚C	Store Press. PSI @20ºC
Halon 1301	Halon 1301	CF_3Br	-57.75	360
CEA 410	FC-3-1-10	C_4F_{10}	-2	360
FM200	HFC 227ea	C_3F_7H	-16.4	360
FE13	HFC-23	CHF_3	-82.1	609
FE241	HCFC-124	C_2HClF_4	-11	195
FE25	HFC-125	C_2HF_5	-48.5	166
NAF S III	HCFC Blend A	HCFC-22 82% HCFC-123 4.75% HCFC-124 9.5% Organic 3.75%	-38.3	360
Triodide, Idoguard	FIC-13I1	CF_3I	-22.5	---

2.2.1-B
Fire Extinguishing Properties for New Technology Chemical Gaseous Alternatives

Trade Name	**Designation**	**Cup Burner % V/V** (7)	**Min Design Conc. (% V/V)**	**Ratio Agent Storage Vol Req'd to H1301**(6)	**Ratio Agent Mass Req'd to H1301** (5)
Halon 1301	Halon 1301	2.9 - 3.9	5 (4)	1	1
CEA 410	FC-3-1-10	5.0 - 5.9	6 (1,2)	1.7	1.9
FM200	HFC 227ea	5.8 - 6.6	7 (1,2)	1.6	1.7
FE13	HFC-23	12 - 13	16 (1)	2.2	1.7
FE24	HCFC-124	?	8.5 (1,2)	1.6	1.6
FE25	HFC-125	8.1 - 9.4	10.9 (1)	2.3	1.9
NAF S III	HCFC Blend A	>11%	8.6 (3)	1.4	1.1
Triodide, Idoguard	FIC-13I1	2.7 - 3.2	5.0	1.0	1.1

2.2.1-C
Comparison of Fire Extinguishing Values and Toxicology Values for New Technology Chemical Gaseous Alternatives

Trade Name	**Designation**	**Cup Burner % V/V** (7)	**Min Design Conc. (% V/V)**	**NOAEL% V/V**	**LOAEL % V/V**
Halon 1301	Halon 1301	2.9 - 3.9	5 (4)	5.0	7.5
CEA 410	FC-3-1-10	5.0 - 5.9	6 (1,2)	40	>40
FM200	HFC 227ea	5.8 - 6.6	7 (1,2)	9.0	10.5
FE13	HFC-23	12 - 13	16 (1)	30	>50
FE241	HCFC-124	?	8.5 (1,2)	1	2.5
FE25	HFC-125	8.1 - 9.4	10.9 (1)	7.5	10
NAF S III	HCFC Blend A	>11%	8.6 (3)	10	>10
Triodide, Idoguard	FIC-13I1	2.7 - 3.2	5.0	0.2	0.4

2.2.1-D
Environmental Factors for New Technology Chemical Gaseous Alternatives

Trade Name	Designation	ODP	GWP (100 yr) vs CO_2	Atmos[c] Life-Time
Halon 1301	Halon 1301	16	4900	77
CEA 410	FC-3-1-10	0	5500	2600
FM200	HFC 227ea	0	2050	31
FE13	HFC-23	0	9000	280
FE241	HCFC-124	0.022	440	7
FE25	HFC-125	0	3400	41
NAF S III	HCFC Blend A	0.05	1600	16
CF_3I	Halon 13001	0.008 max	0	1.15 days

NOTES TO TABLES

(1) Based on 120% of cup burner value for n-heptane.
(2) Based on 120% of cup burner value for n-heptane, verified by listing/approval tests.
(3) Based on listing/approval tests.
(4) Minimum design concentration per NFPA 12A, cup burner value approx. 3%.
(5) Ratio of halon design concentration 20.6 lb/ft3 at 70°C to new agent.
(6) Ratio of halon storage volume required at minimum design concentration (max. fill density 70 lb/ft^3) to new agent.
(7) Range of independently established values.

The LOAEL is the Lowest Observed Adverse Effect Level. It is the lowest tested concentration at which an adverse effect was noted. The true NOAEL may be between the reported NOAEL and the LOAEL. Similarly, the true LOAEL may approach the NOAEL value. These differences are driven by the discrete concentrations at which the agents were tested.

There are three agents that meet the criterion that the design concentration (for example, 1.2 times extinguishing concentration) must be below the NOAEL (at least for heptane fires). These are the following:

FC-3-1-10,
HFC-23, and
HFC-227ea.

HCFC Blend A is not included here due to unresolved technical concerns over the use of the agent below its cup burner extinguishing value. All other agents are used at a minimum of 120 percent of the cup burner concentration.

These agents may be considered to have sufficiently low toxicity to be safe for use in occupied spaces.

Environmental Factors

The primary environmental factors to be considered for these agents are ODP, GWP, and atmospheric lifetime, and these are summarized in Table 2.2.1. Comparison of halocarbon replacements with other alternatives should be based on consideration of the environmental impact of each alternative. This should include the impact of production of the agent and hardware, transportation, and storage as well as other factors which determine the total impact of a technology on the environment.

While GWP and atmospheric lifetime are potentially important environmental factors of halon replacement agents, the objective of replacing halons with non-ozone depleting substances is paramount to the goals of the Protocol. Therefore, the use of controlled, non-zero ODP compounds, including HCFCs and HBFCs, as halon replacements is not a wise decision if it can be avoided. As controlled substances, these agents are unlikely to be produced in sufficient quantities that recycled material would be available for long-term support of fire protection systems.

The impact of high atmospheric lifetime, and related high GWP, should be evaluated in the context of the use quantity and emission pattern of chemicals used as halon replacement fire extinguishants. When used only as fire suppressants, there is no likely emission scenario of these compounds which results in measurable environmental impact. However, fire protection represents only one of the potential uses for these substances, and therefore total usage could exceed environmentally acceptable levels. As a result, several governments have already restricted or banned the use of HFCs and PFCs. Such actions may restrict the commercial availability of these agents, and cause shortfalls in the availability of recycled material necessary for the long-term support of fire protection systems.

Recognizing persuasive environmental concerns, the Halons Technical Options Committee does not endorse the widespread use of HCFCs and HBFCs, or promote the indiscriminate use of PFCs, in preference to other, effective, new or existing technological alternatives for fire protection, which are discussed later in this chapter. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes, with consequences to long-term availability of the compound and subsequent support for installed fire protection systems.

2.2.2 Inert Gas Mixtures

There have been at least two inert gas mixtures commercialized as clean total flooding fire suppression agents. Inert gases are used in design concentrations of 35-50% by volume which reduces the ambient oxygen concentration to between 14% to 10% by volume respectively. It is known that oxygen concentrations below 12-14% will not support flaming combustion. The inert gas mixtures proposed both contain nitrogen and argon; one blend utilizes a low (<5%) concentration of carbon dioxide. Carbon dioxide is not an inert gas. Proposed commercialized inert gas mixtures are summarized in Table 2.2.2.

These agents are electrically non-conductive clean fire suppressants. They differ from halocarbon agents in the following ways.

(1) They are not liquified gases. They are stored as high pressure gases and hence require high pressure storage cylinders and have large storage volume and

storage weight penalties. In this way, they resemble high pressure CO_2 systems.

(2) These systems use pressure reducing devices at or near the discharge manifold. This reduces the pipe thickness requirements and alleviates concerns regarding high pressure discharges.

(3) Since the quantity of agent release is so large, the discharge times are on the order of one to two minutes. This may limit some applications involving very rapidly developing fires.

(4) Inert gas agents are not subject to thermal decomposition and hence form no byproducts; however, the use of inert gases with long discharge times and resultant long time durations of contaminated, reduced oxygen atmospheres may result in increased carbon monoxide production in some cases.

2.2.2-A
Physical Properties for New Technology Inert Gas Alternatives

Trade Name	**Designation**	**Formula**	**Storage Pressure PSI (Bar) 20^{0}C.**
Halon 1301	Halon 1301	CF_3Br	360 (25)
Inergen	IG541	N_2 52% A 40% CO_2 8%	2180 (150)
Argonite	IG55	N_2 50% A 50%	2220 (153)
Argon	IG01	A 100%	2370 (163)

2.2.2-B
Fire Extinguishing Properties for New Technology Inert Gas Alternatives

Trade Name	**Designation**	**Cup Burner % V/V (Heptane)**	**Min Design Conc. (% V/V)**	**Ratio Agent Mass Req'd to H1301 (2)**	**Ratio Agent Storage Vol Req'd to H1301 (4)**
Halon 1301	Halon 1301	2.9 - 3.9 (3)	5 (1)	1	1
Inergen	IG541	29.1 (3)	35 (6)	2.0	10.0 (5)
Argonite	IG55	30 (5)	~36 (6)	2.0	10.0 (5)
Argon	IG01	30 (5)	~36 (6)	2.0	8.0 (5)

2.2.1-C
Comparison of Fire Extinguishing Values and Toxicology Values for New Technology Inert Gas Alternatives

Trade Name	Designation	Cup Burner % V/V (7)	Min Design Conc. (% V/V)	NOAEL % V/V at Room Design Conc.	LOAEL % V/V at Room Design Conc.
Halon 1301	Halon 1301	2.9 - 3.9	5 (4)	5	7
Inergen	IG541	29.1 (3)	35 (6)	43 (5)	52 (5)
Argonite	IG55	30 (5)	~36 (6)	43 (5)	52 (5)
Argon	IG01	30 (5)	~36 (6)	33 (5)	43 (5)

2.2.2-D
Environmental Factors for New Technology Inert Gas Alternatives

Trade Name	Designation	ODP	GWP (100 yr) vs CO_2	Atmos[c] Life-Time
Halon 1301	Halon 1301	16	5800	100
Inergen	IG541	---	---	---
Argonite	IG55	---	---	---
Argon	IG01	---	---	---

NOTES

(1) Minimum design concentration per NFPA 12A, cup burner value approx. 3%.
(2) Ratio of halon design concentration 20.6 lb/ft^3 at 70^{o}C to new agent.
(3) Range of independently established values.
(4) Ratio of halon storage volume required at minimum design concentration (max. fill density 70 lb/ft^3) to new agent
(5) Manufacturers figures.
(6) Based on 120% of cup burner value for n-heptane.

Physiological Effects

The primary health concern relative to the use of these agents 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. Several countries have granted approval for use of inert gases in occupied areas in the workplace. One product specifically uses a limited concentration of carbon dioxide to counter the effects of reduced oxygen.

Concern has also been expressed regarding exposure to people with respiratory and circulatory impairments. Limited medical peer review studies have indicated that no excessive risk would be posed by these mixtures at the concentrations required for use.

Care is required in design and installation of these systems in order to maintain agent and oxygen concentrations within relatively narrow bounds that ensure extinguishing effectiveness and human safety.

Environmental Factors

Inert gas systems pose no environmental risk due to ozone depletion. The GWP associated with the use of inert gases should be evaluated in the context of the life cycle environmental impact including production of agent, cylinders and other hardware, transportation, and storage relative to halocarbon replacements.

Gelled Halocarbon/Dry Chemical Suspension

Another unique category of fine solid particulate technology is classified as Gelled Halocarbon/Dry Chemical Suspension by the US EPA SNAP Program. PGA is the working symbol for an agent designed to replace Halons 1301 and 1211 in unoccupied spaces and in streaming applications. PGA is a propellant generated solid particulate aerosol consisting of a finely ground dry powder extinguishant, a halocarbon propellant/extinguishant, and a unique gelling agent. By suspending the dry powder in a liquefied gas gel, PGA achieves distribution characteristics and long-term stability unattainable with dry powder alone. PGA formulations vary. Halocarbons used in different PGA formulations include zero ODP compounds such as HFC-134a, HFC-125, and HFC-227ea (FM-200). A variety of dry chemical components are available, including ammonium polyphosphate, monoammonium phosphate (MAP), potassium bicarbonate, and sodium bicarbonate. These powders have been considered generally nontoxic, although if not used according to manufacturers directions they can cause a temporary breathing difficulty during and immediately after discharge. Discharge in large quantities may decrease visibility. These powders typically have particle sizes of less than 10 microns up to 75 microns, with most being optimized at 20 to 25 microns. The manufacturer’s data indicate that there are two mixtures of ammonium polyphosphate. The P40 mixture has a particle size distribution with 50 percent of the particles less than 10 microns. The intended market for this agent is military applications. The P30 mixture has a distribution with 20 percent of particles less than 10 microns and 50 percent less than 30 microns. The intended market for this agent is for use in domestic and industrial kitchens. PGA will extinguish Class B, Class C, or combination A/B fires. The effectiveness of PGA has been tested by several organizations.

The discharge of powders obscures vision; therefore, evacuation could be impeded. The US EPA is asking manufacturers of total flooding systems using powdered aerosols to submit to the Agency a review of the medical implications of inhaling atmospheres flooded with fine powder particulates.

2.3 Water Mist Technology

One of the nontraditional halon replacements which has been developed and partially commercialized is fine water mist technology. Fine water mist relies on relatively small (less than 200 µm) droplet sprays to extinguish fires. The mechanisms of extinguishment include the following:

- gas phase cooling (like a total flooding "inert"),
- oxygen dilution by steam expansion,
- wetting of surfaces, and
- flame blow-off.

Water mist systems have attracted a great deal of attention and are under very 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. While this technology is under active development, several systems have been approved by national authorities for use in relatively narrow application areas.

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 (NBFU (1955), Rasbash (1960), Carhart (1977)). 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.
Theoretical analysis of water droplet suppression efficiencies has indicated that water liquid volume concentrations on the order of 0.1 L (water)/m^3 (air) is sufficient to extinguish fires in the gas phase. Similar results have been shown by Ewing et al. (1984), Beyler (1992), and Williams (1974). This represents a potential 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 deposition and gravity dropout. The suppression mechanism of water mist is primarily gas phase cooling of the flame reaction zone below the limiting flame temperature. Other mechanisms are important in certain applications; for example, steam expansion/O_2 deletion 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 the ability to generate sufficiently small droplet sizes and distribute adequate quantities of water throughout the compartment (Mawhinney (1993), Cousins (1992), Jackman (1992)). This depends on the droplet size, velocity, distribution, the spray pattern geometry as well as the momentum and mixing characteristics of the spray jet and the geometry and other characteristics of the protected risk.

The efficacy of water mist fire suppression systems has been indicated in a wide range of applications and by numerous experimental programs. These applications have included Class B spray and pool fires (Papavergos (1991), Butz (19920, Wighus (1991, 1992), Cousin (1992)), aircraft cabins (Hill et al. (1991, 1993), Whitfield (1988)), shipboard machinery and engine room spaces (Mawhinney (1992), Turner (1993), Arvindson and Ryderman (1992), Tuomissari (1992), Soja (1990), Gameiro (1993)), shipboard accommodation spaces (Arvindson and Ryderman (1992)), and computer and electronics applications (Hill et al. (1993), Tuomissari (1992)).

An increased theoretical understanding of important processes has been developed by Jackman and coworkers (1992, 1993). The ability of water mist systems to suppress fires is much more dependant in the nozzle design, flow rate operating pressure, and resultant spray characteristics than total flooding gases. Hence, water mist must be evaluated in the context of a system not just an extinguishing agent.

There is no current theoretical basis for designing the optimum drop size and velocity distribution, spray momentum, distribution pattern, and other important system parameters. This is of course 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.

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

Water mist systems are reasonably weight efficient. The use of small diameter distribution tubing and the possible use of composite, lightweight, high-pressure storage cylinders would increase this efficiency. It may also be possible to integrate a "central storage" of agent for use in several potential fire locations (for example, cargo and passenger cabin locations). This would further increase the benefit.

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 drops. Engineering analysis and evaluation of droplet loss and fallout as well as optimum drop size ranges and concentrations can be used effectively to minimize the uncertainty and direct the experimental program.

Water mist cannot, at present, be considered as a fire suppression agent in isolation of the system, particularly the nozzle that delivers it. Wide variations in performance of mist systems have been observed. The interrelationship between fire suppression effectiveness, drop size and velocity, distribution, spray momentum, spray mixing, and water loss rates defy complete theoretical treatment at this time. Hence, near term development and evaluation will be largely empirical facilitated by theory and analysis that can be brought to bear.

The complex relationship between the sprinkler/mist and fire will not yield easily to generic off-the-shelf nozzle technology in many applications. Hence, proprietary hardware, particularly nozzle designs, may form the most promising near term candidates. This poses special problems for standards making and regulatory authorities.

These systems have received some acceptance from approval authorities for limited applications. Approval testing and standardization efforts have begun.

Table 2.3-1 summarizes the current manufacturers of commercial water mist systems for fire suppression use. Some of these manufacturers are in the R&D phase with their particular hardware.

Table 2.3-1
Water Mist Hardware Manufacturers

Company	Type of System
Reliable Automatic Sprinkler/Baumac International	High Pressure
Kidde International/KFP/KF	Single and Dual Fluid
Ginge Kerr	Dual Fluid
Semco	High Pressure
Marioff Hi-fog	High Pressure
Microguard-Unifog	High Pressure
Securiplex	Dual Fluid
Grinnell	Low Pressure
GW Sprinkler	Low Pressure

Physiological Effects

Concern has been expressed by some regulatory authorities that very fine mist (<10 µm) droplets may cause health effects since sub-10 µm drops can be inhaled quite deeply into the respiratory tract. While the degree of this problem is not clear at this time, it does appear that none of the systems currently proposed produces sufficient quantities of sub-10 µm drops to be a potential concern. Transport of pathogens (viral, fungal, bacterial) within the mist into the lungs has also been identified as a potential problem. The ability of small drops to dissolve or adsorb products of combustion may be a potential problem.

Environmental Factors

There is no concern regarding the ozone depletion or global warming potential of water mist systems.

2.4 Fine Solid Particulate Technology

Another category of new technologies being developed and introduced are those related to fine solid particulate and aerosols. These take advantage of the well established fire suppression capability of solid particulates, with potentially reduced or eliminated collateral damage associated with traditional dry powders. A range of proprietary technologies is being offered.

This technology is being pursued independently by several groups and is proprietary. Ongoing work includes efforts by Spring and Ball (1993), Kibert (1993), Harrison (1993), Spectronix Inc. (1992), and several Russian laboratories. To date, a number of aerosol generating extinguishing compositions and aerosol extinguishing means have been developed in Russia. They are in mass production and are used to protect a range of hazards.

The 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 warming-up and evaporation in the flame front as well as a chemical action on the radical level. Solid aerosol is directly involved in an extinguishment acting upon a flame. Gases serve as a mechanism for delivering aerosol towards a seat of a fire.

The compositions are low in cost and use relatively simple hardware. A wide range of research into aerosol generating compositions was carried out to define their extinguishing properties, corrosion activity, toxicity, effect upon the ozone layer as well as electronics equipment.

At the same time, the compositions have several disadvantages. They are unsuitable for explosion suppression or inerting since pyrotechnic/combustion ignited aerosols are ignition sources. These agents have low extinguishing efficiency on smoldering materials.

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

While solid particulates and chemicals have very high effectiveness/weight ratios (Persson (1992), Ewing et al. (1989)), they pose potential collateral damage problems to electronics, engines, and other sensitive equipment. In addition, the ability to distribute a particulate cloud uniformly throughout a complex geometry must be evaluated further. They have the advantage of reduced wall and surface losses relative to water mist, and the particle size distribution is easier to control and optimize. Technical problems including high temperature, high energy output of combustion generated aerosols and the inability to produce a uniform mixture of aerosol throughout a compartment remain to be solved.

Physiological Effects

There are several potential problems associated with the use of these agents. While none of these problems has been proven, they remain, as in the case of water mist, potential concerns. These effects include inhalation of particulate, blockage of airways, elevated pH, visibility, and the products of combustion from combustion generated aerosols, such as HCl, CO, and NO_x.

Environmental Factors

The primary environmental effects are local and are similar to those expected from burning a small quantity of solid rocket propellant.

2.5 Alternatives to Halon Systems

The advantages and disadvantages of new and existing fire suppression technology relative to replacing Halon 1301 total flooding systems depend largely on the details of the hazard being protected. It is not possible to offer detailed guidance on a particular hazard, but general guidance is given in this section. In addition to the new alternative technologies previously discussed, there are a range of traditional fire protection systems which may be used. These are briefly discussed in this section.

The alternative fire protection choices offered may not provide the same level of fire protection offered by the use of present halons. In some circumstances, greater loss and risk to people and property may result from the use of the alternatives outlined. However, concerns regarding environmental risk associated with the continued use of halons and lack of their availability necessitate the serious evaluation of all fire protection options.

Examples of alternative, fixed fire protection systems are as follows:

- Water sprinkler systems,
- Carbon dioxide systems,
- Foam systems, and
- Dry powder systems.

Water sprinkler systems are the most common type of fixed fire protection system. Carbon dioxide, foam, and dry powder systems are used in more specialized applications, especially where flammable liquid fires could occur.

Water sprinkler systems are connected to municipal or private water supplies. Piping is installed to connect heat sensitive heads located throughout the protected area to the water supply. Sprinkler heads are normally held closed by a heat sensitive element. Heat from a fire destroys the heat sensitive element allowing water to flow from the sprinkler head. Normally, water flows only from the heads that have been operated by the fire. In over 97% of the actual fires extinguished by sprinkler systems, less than three heads actually opened. Much less water is required to extinguish fires with sprinklers than by fire department operations because sprinklers operate early in the development of a fire and spray water directly at the fire. There are a number of different types of sprinkler systems, including some that can be activated by separate fire detection systems, and others that turn off automatically once a fire has been extinguished. Water sprinkler systems are generally not capable of extinguishing fires involving flammable liquids and can spread pool fires; however, the cooling effect of water sprinkler application is usually sufficient to limit structural damage.

Fixed foam systems mix water with foam concentrate and then aerate the mixture. The resulting foam is light enough to blanket and smother flammable liquid pool fires. Foams also cool hot surfaces. Foams extinguish and prevent fires involving flammable liquids because the foam blanket that is formed on top of the flammable liquid drastically reduces propagation of flammable vapors. Various types of foams are used for different types of flammable liquid fires. There are even special foams for use in fighting alcohol fires.

Dry powder systems use nitrogen to expel finely divided dry powders through a piping network to discharge nozzles. Dry powder systems are especially effective in extinguishing fires involving flammable and combustible liquids, including three-dimensional fires involving spraying fuels. Dry powder systems have been widely used to protect off-road equipment in the forestry and mining industries and for protection of commercial cooking equipment and associated grease exhaust systems. Special dry powders are used to control or extinguish fires involving combustible metals such as sodium, lithium, and magnesium. Although dry powders are capable of very rapid extinguishment they provide little cooling effect and agent application must continue past the point of extinguishment to allow hot surfaces to cool, preventing reignition.

Carbon dioxide extinguishes fire by oxygen displacement. Carbon dioxide (CO_2) systems ar used to provide areas where the ability of a gaseous agent to permeate is important, where inerting of the atmosphere is required, or where secondary damage due to agent application is very important. Separate detection systems are used to actuate carbon dioxide systems. Carbon dioxide systems must be used with care because carbon dioxide, when used at extinguishing concentrations, is toxic to people. Typical applications include shipboard machinery spaces and electrical switch gear rooms.

2.6 Guidance on Halon Alternatives and Replacements

This section covers general guidance on the selection of halon alternatives for the protection of specific hazards. This guidance is by its nature generic and the section of the optimum fire protection system will be largely driven by the details and requirements for a particular facility.

There are a number of alternative technologies which already exist to replace halon fixed systems:

- water sprinklers,
- carbon dioxide,
- foam (high and low expansion), and
- dry powder.

Each has some deficiencies compared to halon either the agent is not clean, leaving some residue on discharge, or has limited penetration. CO_2 overcomes these issues but is toxic.

2.6.1 Evaluating alternative systems

The ability of an agent or system to serve as a Halon 1301 replacement can be evaluated in simple terms by considering the following attributes and comparing them to the hazard requiring protection.

- Weight - The typical weight of the agent and hardware required. Lower weight scores higher.

- Ability to Limit Damage - A measure of a system's response time and the potential damage resulting from agent application. Cleaner agents that can be applied at an early stage of fire development by use of fast response detection systems score highest.

- Occupant Risk - The risk to the health and safety of occupants due to the fire suppression system.

- Ability to Extinguish Flammable Liquid Fires - A measure of the ability of the agent to extinguish fires involving two-dimension flammable liquid fires (pool fires) and three-dimensional fires involving liquid spray fires and gas jet fires.

- Efficacy - This factor is a combination of the reliability and effectiveness of the system and agent. Automatic sprinklers score highest for hazards.

- Suitability for Use on Energized Electrical Equipment - A measure of the safety risk to people and the risk of causing secondary damage to equipment. In many cases, the need for this feature can be minimized by shutting power off before application.

- Installed Cost - This factor includes both the installed cost and maintenance costs over the life of the system.

- Ability to Permeate - This characteristic refers to the ability of an agent to extinguish fires throughout the protected volume including equipment enclosures, obstructed fires, etc.

To assist in selecting from these alternatives, the following typical halon system applications are described below:

2.6.2 Electronic Equipment Rooms (e.g., computer suites, telecommunications rooms, control rooms, electrical switchgear rooms, broadcasting facilities)

2.6.2.1 Preaction water sprinkler systems using early warning detection

Preaction water sprinkler systems using early warning of fire from sensitive detection (usually smoke) to activate a water deluge valve to fill the system pipework. When the temperature of the fire exceeds the rupture point of the sprinkler head, the water flows onto the fire area. Such systems enable the risk area to be protected with an early alarm system connected to an extinguishing system of last resort in the event that the fire gets out of control and beyond first aid firefighting. The detection system would be expected to include double knock (coincidence) smoke detectors and fast response sprinkler heads.

2.6.2.2 Partial flooding with CO_2

Partial flooding with CO_2 in floor voids and electrical/electronic cabinets provides clean, penetrating, and effective fire protection. The risk to personnel associated with CO_2 in such systems, while minimized, is still a concern and the necessary safety precautions should still be maintained.

2.6.2.3 Very high sensitivity smoke detection (HSSD) systems

Very high sensitivity smoke detection (HSSD) systems offer the practical opportunity to eliminate the need for active protection systems. Instead they rely on the early warning of an incident well before it has reached damaging proportions outside the immediate area of defect and allow prompt shut down of the power to the affected circuits removing the source of energy causing the potential fire. This approach has particular advantages in manned areas where immediate attendance to the incident can take place. The use of HSSD has been adopted by UK/USA telecommunications companies to replace conventional detectors and eliminate halon protection.

2.6.2.4 New clean agents

New clean agents with low toxicity including HFC-227ea and the inert gases are being widely used for protection of electronics facilities.

2.6.2.5 Eliminate the need for an active fire protection system

Extensive evaluation of the risks can sometimes identify the opportunity to eliminate the need for any active fire protection measures relying instead on the occupants to attend to an alarm from conventional fire detection system. Such a system would not be appropriate for a nonmanned area or one adjacent to a higher risk.

2.6.3 Ground Vehicles

2.6.3.1 Armored Fighting Vehicle Crew Bays

This application is unusual in that, on the one hand, a high level of hazard approaching an explosion may be encountered following a combat penetration which also passes through a fuel or hydraulic reservoir, and on the other, the protected volume is manned. To date, no replacement has been proven which is both sufficiently effective and acceptably man safe (see Section 4.5). Tests are underway by the U.S. Army, but for the time being, Halon 1301 will continue to be specified. The quantities of halon required are not large and it is expected that all of the Halon 1301 for this application will be provided from recycled material. Some countries report that they are removing and storing their crew compartment explosion suppression systems with the intent of refitting them only in case of combat.

2.6.3.2 Armored Fighting Vehicle Engine Bays

Trials are in progress on a wide range of alternative agents by the Defence Research Agency for the UK MoD and by the Tank-Automotive and Armament Command for the U.S. Army. Results are expected to be available by early 1995. Meanwhile, systems have already been successfully designed and fitted on both UK and US newly manufactured vehicles using sodium bicarbonate based dry chemical agents with minimal effect on space and weight. Using an alternative agent, such as dry powders, on new designs is considerably easier than for retrofit of current designs. In addition to space and weight limitations, established vehicle designs have specific material compatibility aspects, corrosivity issues, clean-up requirements, etc. that must be addressed. The current evaluations of potential alternatives by the US and the UK are also providing insight into these concurrent engineering alternatives that may be specified that best match the overall requirements of the application.

2.6.3.3 Railway Locomotive Engines

Low expansion AFFF has already replaced the Halon 1211 systems protecting the underslung engines on Diesel Multiple Units operated by British Rail. These systems include a linear heat detector to sense a fire and signal the driver to effectively discharge through the spray pipes over the engine and its accessories. Although this application is very similar to armored fighting vehicle engine bays, dry chemical has so far been perceived to suffer from compaction and clean-up problems.

In more powerful locomotives with enclosed engines, carbon dioxide and gaseous halocarbons have been considered. The former creates a significant space and weight problem in replacing existing Halon 1301 systems, but could be viable in new installations providing suitable safety precautions are taken to protect operators. HFC-227ea and inert gases (clean agents) are considered suitable for both new and retrofit total flood systems in diesel and electric locomotives, and tests will shortly take place with British Rail to confirm the system design criteria.

2.6.3.4 Railway Rolling Stock

Water fog systems are being considered in new application for protecting carriage passengers from fire occurring in tunnels and also sleeping cars although this is not strictly a halon replacement application.

2.6.4 <u>Aviation Applications</u>

Aviation applications are amongst the most demanding, and some of them require all of the good characteristics of Halon 1301, e.g., low toxicity, low weight and volume, no clean-up or corrosion problems, electrically nonconductive, stable, easily stored, good low temperature performance, and three-dimensional dispersion. It is no surprise therefore that it is a market area which is proving difficult to satisfy. The approach to identifying viable replacements is being coordinated by an International Halon Replacements Working Group initiated by the U.S. Federal Aviation Administration, together with Transport Canada and the UK Civil

Aviation Authority representing the European Joint Airworthiness Authorities. The position relating to the various specific application areas is set out below. In the meantime, it will be necessary to conserve and recycle halon to support existing aircraft systems, and this approach is being actively pursued by a number of airlines and equipment suppliers.

2.6.4.1 Engine Nacelles

Airworthiness regulations require a fire protection system to be fitted to engine bays of commercial air transports; the use of Halon 1301 is not mandated, but in practice, all such aircraft are protected in this way, and the same applies to many military aircraft.

2.6.4.2 Cargo Bays

Airworthiness regulations require a fire protection system to be fitted in the cargo bays of commercial air transports; the use of Halon 1301 is not mandated, but the advisory documentation which accompanies the regulations describes the methods of designing, testing, and certifying this agent, and the same applies to most military aircraft which have compartments of this kind.

An experimental program is in progress at the FAA's Technical Center to evaluate the available alternatives.

2.6.4.3 Dry Bays

This application is unique to military aircraft. Its aim is to protect the bays located between fuel tanks and the outer skin of the aircraft against fire and explosions resulting from combat damage.

An experimental program is in progress at Wright-Patterson AFB, Army, and Navy to evaluate the available alternatives. A short list of three candidates (PFC-38, FE-25, and CF_3I) has already been selected, and a further down-selection to one or possibly two is scheduled for October 1994. Development of design and certification codes is targeted for one year later.

2.6.4.4 Lavatory Compartments

Airworthiness regulations require a fire protection system to be fitted in the waste bins in toilet compartments of commercial air transports.
Suppliers of these systems are offering systems based on some of the new halocarbons.

2.6.4.5 Fuel Tank Inerting

This application is largely unique to military aircraft and mainly applies to certain existing aircraft. Its aim is to inert the ullage in the head space of fuel tanks prior to entering a battle zone to protect against the risk of explosion following combat damage. [Tom Morehouse was to supply data on alternatives under this topic.]

2.6.5 Flammable Liquid Storage and Handling

2.6.5.1 Return to CO_2

Return to CO_2 has been the first choice in many applications including marine in recent years. Given sufficient space and proper supervision of system operation, CO_2 is and has been safe where occupants are evacuated before discharge. However, CO_2 is still killing people where such safeguards are not implemented. Furthermore, many modern ship have just not been designed with enough space to retrofit a CO_2 system.

2.6.5.2 Low expansion foam

Low expansion foam has extended into areas previously the domain of Halon 1301/1211 where clean-up is not a problem and access to the base of the fire can be achieved.

2.6.5.3 Water fog systems

Water fog systems have been effectively demonstrated on the types of fire expected in these applications, offering the twin advantages of dramatic reduction in flame temperature with substantial reduction in required water quantity over traditional sprinklers/deluge systems. There are not, however, replacements for halon where penetration is important and are much less effective when the nozzle is unable to direct the water droplets into the flames.

2.6.5.4 Dry chemical systems

Like foam, dry chemical systems are proven and effective for flammable liquid fires; however, they do have residual cleaning problems and may not be safe in manned areas.

2.6.5.5 Other total flooding clean agents

Total flooding clean agents including halocarbon and inert gases have been demonstrated to be effective on these hazards. An unresolved debate on the use of inerting concentrations versus flame extinguishing concentrations for low flashpoint flammable liquid fires has implications for the use of halocarbon agents below the NOAEL. The use of inert gases on these hazards must be evaluated given the long (approximately 1 minute) discharge times of these systems.

2.6.5.6 Fine solid particulate technology

Combustion and pyrotechnically generated aerosols have been demonstrated to be effective fire suppressants for these hazards subjects to concerns regarding generation rate and mixing.

2.6.5.7 Application of alternative in the shipboard environment

Application of alternatives in the shipboard environment is driven by agent space and weight concerns. This is especially important in evaluating retrofit application in military ships where ship and weight are often critical.

2.6.6 <u>Record Storage and Cultural Heritage</u>

2.6.6.1 Detection and fire department response

If an incident can be responded to within a matter of minutes and the risk is not highly flammable, then HSSD alone could be considered.

2.6.6.2 Water sprinklers

Water sprinklers are a possibility using fast response heads in preaction mode to minimize the risk of inadvertent operation. The advantages and shortcomings which have already covered.

2.6.6.3 Carbon dioxide

In most cases, avoidance of consequential damage will be of major concern which limits the choice to clean agents such as CO_2. CO_2 is clean and able to penetrate into obscured corners discharged in sufficient quantity will deal with deep-seated Class A fires provided the concentration can be maintained long enough. However, CO_2 is toxic, and great care must be taken to protect exposed personnel. It is not advisable to use CO_2.

2.6.6.4 Inert gases/HFC-227ea

The inert gases provide the same type of protection as CO_2 but without the toxic hazard although they may be used in sufficient quantity to be asphixiants. They will also require a greater number of cylinders than CO_2. FM-200 would also provide a suitable agent providing the fire was not allowed to become deep seated.

2.7 Conclusions

New and existing alternatives exist for most Halon 1301 total flooding applications. Where replacement of Halon 1301 is especially difficult (ground combat vehicle crew bays and certain aviation applications) substantial research and development is underway.

The commercial availability of zero ODP halocarbon replacements enabled the early phaseout of halons and an early transition to alternative fire suppression agents with no impact on the ozone layer.

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3 Fire protection alternatives to halon portable fire extinguishers

3.1 Halon portable fire extinguishers

3.1.1 Halon 1211

Halon 1211 was the halon of choice for use in portable fire extinguishers. In commercial and industrial applications halon 1211 portable fire extinguishers have been used in computer rooms, museums, art galleries and in offices for the protection of equipment. As well large capacity, manually applied halon 1211 fire equipment has been used by some military organizations for fire fighting use during aircraft ground support operations. Halon 1211 portable fire extinguishers are carried on-board virtually all commercial aircraft in use today. Warning labels on halon 1211 portable fire extinguishers are usually provided to prevent use within small enclosures where safe human exposure limits could be exceeded during use.

For the most part the void left by the phaseout of production of halon 1211 has been met by an increased use of multipurpose dry chemical fire extinguishers. Multipurpose dry chemical has equal weight effectiveness to halon 1211 and the technology to produce this agent has been well known for many years. There are a few notable exceptions where recycled halon 1211 continues to be used to fill particular critical needs, such as on-board aircraft fire extinguishers. HCFC blends are available, however environmental concerns and lower effectiveness by weight than halon 1211 have discouraged market acceptance. Commercially available, water mist portable fire extinguishers are expected in the near future. Test results for water mist portable fire extinguishers are not yet available however it is expected that this technology will support further progress in eliminating halon 1211 dependency.

3.1.1.1 Portable halon 1211 extinguishers for use on-board aircraft

Airworthiness regulations require the carriage of portable extinguishers on board passenger-carrying commercial air transports; the use of halon 1211 "or equivalent" is mandated. Many military aircraft also carry halon 1211 portables. Although the bulk of fires against which these extinguishers are used could readily be addressed with other agents, there are documented instances of "hidden" fires beneath the floors or behind the wall panels of the passenger compartment and inaccessible in flight which have been successfully extinguished using halon 1211 portables. Such fires are potentially fatal for the aircraft, and achieving a performance similar to that of halon 1211 in these conditions is perceived as essential for any potential replacement agent in addition to the normal requirements for portable extinguishers.

3.1.2 Military handheld halon 1301 fire extinguishers

There is a unique use of halon 1301 portable fire extinguishers within some military organizations. These units have a capacity of 2.75 pounds of halon 1301, with a Underwriters Laboratories rating of 2-B:C. Although halon 1301 does not exhibit good performance as a streaming agent, other considerations including use in confined spaces and logistical support considerations resulted in the use of halon 1301 as the agent of choice.

3.1.3 Military flightline fire extinguishers

Many military organizations use halon 1211 on the flightline in portable 20-lb and 150-lb (wheeled units) extinguishers. The 20-lb portables are usually carried on the crash rescue trucks. While the 150-lb extinguishers are used as standby units during servicing of aircraft and while planes are on the tarmac. The use of halon 1211 for small fires has been attributed to its minimal effects on aircraft components (i.e., secondary or collateral damage). When discharged, the agent converts from a liquid to a gas and can penetrate into enclosed spaces such as engines, nacelles and electronic equipment cabinets and consoles.

3.2 Alternatives to halon portable fire extinguishers

Examples of alternative, portable fire extinguisher types are as follows:

- Straight stream water,
- Water fog,
- Aqueous Film Forming Foam (AFFF),
- Carbon dioxide,
- Dry powder (chemical)
- Halocarbon replacement agents

<u>Straight stream water</u>

Straight steam 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 electrical circuits are present.

<u>Water fog (spray)</u>

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.

<u>Aqueous Film Forming Foam (AFFF)</u>

AFFF extinguishers generally may increase the effectiveness of water on fires of ordinary combustibles such as wood, paper, and fabrics and provide a limited capability to extinguish fires involving flammable or combustible liquids. Depending upon the stream pattern, this type of extinguisher may not be safe for use on fires where live electrical circuits are present.

<u>Carbon dioxide</u>

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

Dry powder (chemical)

Dry chemical extinguishers are of two types. Ordinary dry chemicals are suitable for fires involving combustible liquids and flammable liquids and gases. Multipurpose dry chemicals are suitable for use on fires of ordinary combustibles such as wood, paper, and fabrics and fires involving combustible liquids and 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.

Halocarbon replacement agents

Extinguishers employing halocarbon replacement agents are suitable for fires involving combustible liquids and flammable liquids and gases. Replacement halocarbons, like halons, do not conduct electricity and can therefore be used safely on fires involving live electrical circuits.

The primary environmental factors to be considered for these agents are ODP, GWP, and atmospheric lifetime. Comparison of halocarbon replacements with other alternatives should be based on consideration of the environmental impact of each alternative. This should include the impact of production of the agent and hardware, transportation, and storage as well as other factors which determine the total impact of a technology on the environment.

While GWP and atmospheric lifetime are potentially important environmental factors of halon replacement agents, the objective of replacing halons with non-ozone depleting substances is paramount to the goals of the Protocol. Therefore, the use of controlled, non-zero ODP compounds, including HCFCs and HBFCs, as halon replacements is not a wise decision if it can be avoided. As controlled substances, these agents are unlikely to be produced in sufficient quantities that recycled material would be available for long-term support of fire protection systems.

The impact of high atmospheric lifetime, and related high GWP, should be evaluated in the context of the use quantity and emission pattern of chemicals used as halon replacement fire extinguishants. When used only as fire suppressants, there is no likely emission scenario of these compounds which results in measurable environmental impact. However, fire protection represents only one of the potential uses for these substances, and therefore total usage could exceed environmentally acceptable levels. As a result, several governments have already restricted or banned the use of HFCs and PFCs. Such actions may restrict the commercial availability of these agents, and cause shortfalls in the availability of recycled material necessary for the long-term support of fire protection systems.

Recognizing persuasive environmental concerns, the Halons Technical Options Committee does not endorse the widespread use of HCFCs and HBFCs, or promote the indiscriminate use of PFCs, in preference to other, effective, new or existing technological alternatives for fire protection, which are discussed later in this chapter. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes, with consequences to long-term availability of the compound and subsequent support for installed fire protection systems.

3.3 Evaluating alternative portable fire extinguishers

The important features of alterative, manually applied fire protection equipment choices are described, but the weighting of the relative importance of these features is not rigorously derived. It is the result of the consensus opinion of the Halon Technical Options Committee. The parameters evaluated are discussed below.

Effectiveness on Ordinary Combustibles

This parameter considers the ability of the agent to extinguish fires in ordinary solid polymer combustibles, including cellulosics. It includes consideration of deep seated burning. Carbon dioxide is ranked lowest with the highest rank achieved by water based and multipurpose dry powder extinguishers.

Effectiveness on Flammable/Combustible Liquid Fires

An evaluation of the ability to extinguish flames above liquid fuels is. No consideration is given to preventing reignition. The ability to extinguish three dimensional liquid fires (sprays or fuels cascades) is evaluated. The most effective agent is multipurpose dry powder, HCFC blend is next highest and straight stream water ranks lowest.

Electrical Conductivity

The electrical conductivity of the agent is evaluated in this category.

Ability to Permeate

This parameter reflects the ability of the agent as typically discharged to extinguish fires in locations where direct application to the fuel surface or flame reaction zone is not possible, for example, inside an electronics equipment cabinet. As expected, the gaseous agents rank highest in this category.

Range

This parameter reflects the ability of the agent to maintain a coherent effective stream over a modest distance. The highest rank is given to straight stream water extinguishers, the lowest to carbon dioxide. The HCFC blend is ranked just beneath water.

Effectiveness to Weight Ratio

This parameter considers the relative fire suppression capability across all fuels per unit weight of agent. In this category, multipurpose dry powder is rated highest.

Secondary Damage

This category refers to the "clean agent" aspects of the agents, i.e. secondary damage caused by the suppressant agent itself. Here carbon dioxide is rated highest, the lowest score is given to multipurpose dry powder.

3.4 Use of alternatives

Portable Fire Extinguisher Capability Comparison							
Type	Ordnry Combst	Flam Liquids	Elect Non-cond	Ability To Perm	Stream Range	Effectiv/ Wght	2ndry Damage
CO_2	Poor	Fair	Yes	Good	Fair	Poor	Good
Multipurpose Dry Powder (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

3.4.1 Halon portable fire extinguishers

Although halons provided excellent characteristics as fire extinguishing agents for use in portable fire extinguishers, the use of alternatives for this application has been less problematic than use of alternatives in fixed fire protection systems. In general portable fire extinguishing agents are only applied to actual fires and they can be easily directed at the burning object. As such secondary damage concerns are somewhat less in recognition that fire damage to the object has already occurred. For most applications, multipurpose dry chemical has been the agent of choice, however there are important applications where visibility concerns during firefighting operations and/or ability to permeate are of vital importance. Two of these applications are outlined below.

3.4.2 Portable halon 1211 extinguishers for use on-board aircraft

An experimental program is in progress at the FAA's Technical Center to evaluate the available alternatives.

As the use of halon 1211 for aviation type hand portable fire extinguishers is very small in relationship to the magnitude of existing stocks and this use represents a high value application recycled halon 1211 should be available in adequate supplies for several years to fulfil the needs of this application until acceptable alternatives are available.

3.4.3 Military handheld halon 1301 fire extinguishers

The United States Army has assessed the alternative options available following the analysis provided later in this chapter to determine what other immediately available choices could be considered. Their assessment indicated that CO_2 was the best, immediately available, acceptable alternative. They did not consider the use of low ODP agents due to the extremely long economic lifetime of military vehicles and the impending phase-out of HCFC based agents.

Based on this assessment, a search was made for CO_2 handheld extinguisher that met the specific performance requirement of an Underwriters Laboratories 2-B:C rating and an operating temperature of -40^{0}F to 120^{0}F. The result was that this performance requirement could be met with a 2.5 pound CO_2 handheld extinguisher. The United States Army, in conjunction with the fire equipment industry, developed a Commercial Item Description (CID), A-A-52471B, and has begun to purchase these 2.5 pound CO2 handheld extinguishers to eliminate some of the use of halon 1301 for this application, where the higher toxicity of CO_2 can be managed safely.

3.5 Conclusions

Although halons provided excellent characteristics as fire extinguishing agents for use in portable fire extinguishers, the use of alternatives for this application has been less problematic than use of alternatives in fixed fire protection systems. In general portable fire extinguishing agents are only applied to actual fires and they can be easily directed at the burning object. As such secondary damage concerns are somewhat less in recognition that fire damage to the object has already occurred. For most applications, multipurpose dry chemical has been the agent of choice, however there are important applications where visibility concerns during firefighting operations and/or ability to permeate are of vital importance.

Current HCFC based alternative streaming agents are considerably less effective on a weight and volume basis to halon 1211. As a result HCFC alternatives have not found wide acceptance for use in portable fire extinguishers. There may be some potential use of HCFC based alternatives in large capacity, manually applied fire protection equipment for military flight line operations.

4 Explosion Protection

4.1 Introduction

Working spaces, whether manned or not, which may contain dispersed mixtures of fuel and air are at risk of severe loss of property or life should ignition occur. The propagation of flames through such spaces occurs so rapidly that evacuation of personnel is generally not possible. Enclosed spaces are subject to extremely rapid rates of pressure increase leading possibly to explosion of the enclosure. Explosions may lead to fatalities in the immediate area or in areas adjacent to the risk areas. Explosions may cause catastrophic failure of plant components leading to major fires, toxic releases, or environmental damage. The subject of this section is the protection of life and property from such explosive events.

4.2 Definitions

Deflagration

A combustion process propagated at sub-sonic velocity through a fuel-oxidizer mixture usually consisting of air and a dispersed fuel component which may be a flammable vapour, mist, or dust. Energy release rates are usually limited by the fundamental burning velocity (thermal and reaction kinetic feedback mechanisms) of the mixture and the extent of the surface area of the flame sheet. Deflagration flame velocities begin at about 0.5 m/s and will rapidly accelerate in the presence of turbulence. Transition to detonation is possible under some conditions. Rates of energy release are typically several orders of magnitude higher than for diffusion flame processes.

Detonation

A combustion process propagated at sonic or super-sonic velocity through a fuel-oxidizer mixture. The speed of the combustion wave then becomes supersonic relative to the unreacted medium. Flame velocities in excess of 1000m/s prevail.

Explosion

The damage or injury-producing event which may result from a deflagration or detonation or other pressure-elevating process.

Fire

A combustion process most often characterized by diffusion flame behaviour where the rate of energy release is limited by the molecular scale mixing of fuel and oxidant species.

Inertion

The prevention of the initiation of combustion of an otherwise flammable atmosphere by means of the addition of an inhibiting or diluting agent.

Suppression

The termination of combustion processes through inerting, chemical inhibition, or thermal quenching effects of extinguishing agents.

4.3 Explosion Protection Methods

Spaces at risk of a potential explosion may be protected in the following ways:

i. Prevention

a. through application of appropriate principles of safe engineering design, construction, operation, and maintenance of process systems.

b. through application of inerting agents to atmospheres which are, or may become, flammable.

c. through high-rate mechanical ventilation of atmospheres which are, or may become, flammable to eliminate combustible conditions.

ii. Mitigation, which may be achieved by designing spaces at risk for:

a. Containment of the pressure developed.

b. Pressure relief venting, i.e., release of gas through relieving panels to avoid attainment of pressures which would cause the process enclosure to fail.

c. Combustion isolation, i.e., prevention of the transmission of the combustion process to associated equipment spaces.

d. Deflagration suppression, i.e., detection and extinguishment of the deflagration front prior to attainment of a condition resulting in equipment damage or personal injury.

Several extinguishing agents including halons, dry chemicals, and water have been or are currently used, where appropriate, in deflagration suppression, inertion and, in chemical isolation of duct systems.

4.4 Fundamentals of Deflagration Suppression

Deflagration suppression is a special case of fire suppression characterized by very early detection of the onset of combustion followed by the rapid delivery of an appropriate extinguishing agent. Situations in which application of deflagration suppression is generally appropriate are of two types:

Type A — Presents the risk of development of a rise in pressure sufficient to cause failure of a confining enclosure, or

Type B — Poses a direct threat to people in the vicinity of a deflagrating cloud of combustible gases, mists, or dusts.

The mechanisms of deflagration suppression include chemical effects ("inhibition", or interference in flame chemistry by free radical mechanisms) and physical effects (thermal quenching of the advancing flame front and dilution of fuel and air by agent vapours, e.g., steam dilution upon evaporation of water droplets). The relative importance of chemical inhibition in addition to thermal effects to achieve flame extinction depends on the nature of the agent employed. When water is employed as an agent the extinguishing mechanism is entirely thermal. Significant chemical inhibition comes into play in addition to thermal effects when the agents employed are halons or dry chemicals. (See Appendix D for a discussion of flame inhibition chemistry of halons.)

An important feature of a deflagration suppression agent is its ability to prevent re-ignition of the combustible atmosphere due to the continued presence of an ignition source such as heated surfaces, flying sparks, embers, electrical shorts, or electrostatic hazards. Water has little or no effectiveness in this regard when the combustible is a gas. Dry chemical agents offer significant short-term re-ignition protection against combustible gases. This protection is lost when the agent dust settles out. halons, and other gaseous agents, offer sustained re-ignition protection due to the persistence of agent vapours in the protected space.

In order to extinguish a deflagration in progress, deflagration suppression systems deliver much larger amounts of agent in much shorter times than do fire extinguishing systems. In fire protection applications the quantity of halon 1301 delivered is generally sufficient to achieve an agent vapour concentration in the vicinity of 5 to 6 vol%, which includes a significant safety margin. In contrast with fire suppression, deflagration suppression requires much higher effective concentrations of agent in order to achieve successful extinguishment of a growing fire ball. These systems, therefore, generally deliver much larger amounts of agent, often to achieve halon 1301 concentrations of up to 15 vol%.

The elapsed time for agent delivery in fire protection is quite varied depending on the application. Halon total flooding systems typically discharge in 10 s. Water sprinkler systems can be designed to operate in very short time scales, tens of seconds, to long time scales, tens of minutes. In contrast, deflagration suppression must be accomplished in extremely short time frames and total agent discharge is typically achieved in 100 milliseconds or less. Deflagration suppression systems are always operated by automatic sensing and actuation due to the short time scales in which these systems must function in order to achieve successful suppression.

4.5 Applications of Deflagration Suppression

Examples of Type A situations (property damage) include protection of industrial process spaces such as dust collectors, silos, grinding and milling equipment, solvent storage rooms, crude oil pump rooms, solvent vapour headers and pneumatic dust transfer ducts, and municipal waste shredders.

Examples of Type B situations (personal injury) include commercial aerosol filling operations, solvent storage or pump rooms, oil and gas processing facilities, aircraft dry bays, crew bays of military vehicles, naval machinery spaces, and any application in which personnel may reasonably be expected to be present at the time of a catastrophic system failure with a subsequent risk of initiation of a deflagration. Material or structural damage in Type A incidents may also lead to personal injury.

Prevention of flame propagation in pipes and ducts is often achieved by chemical isolation, i.e., by dispersing an agent into a pipe system. Protection in pipes and ducts and in many other Type A situations (above) may be achieved by halons or other agents which may be delivered rapidly to achieve extinguishing concentrations. The toxicity of the agent at its extinguishing concentration is not usually an important factor in these applications. Toxic agents, or agents which decompose in a flame to form toxic compounds, may, in some Type A situations, pose significant health risks to personnel involved in necessary service, maintenance, or post-fire activities.

Agent toxicity is generally a major consideration in Type B situations. Such applications are routinely manned or may be manned at the time of actuation of the suppression system. The agent of choice in such situations is halon 1301 due to its low toxicity, extinguishing effectiveness, and protection against re-ignition. There is at present no approved alternative extinguishing agent for these applications. However, work is in progress to identify the applicability of low-toxicity alternative agents. See Table 2.2.1.

The processing of hydrocarbons in areas where extreme low temperature climatic conditions occur has led to the enclosing of hydrocarbon process facilities. The early detection of hydrocarbon leaks allows the deployment of an inerting agent in to the enclosure prior to the attainment of combustible conditions. The unique flame-inhibiting and low toxicity properties of halon 1301 allow creation of an inert, yet habitable, atmosphere in the enclosure which prevents combustion from occurring should an ignition source be present.

4.6 Recent Activities in Replacing Halons in Deflagration Suppression Systems

Industrial Applications: Subsequent to passage of the Copenhagen Amendments to the Montreal Protocol actions have been taken by providers of halon industrial deflagration suppression systems to both offer non-Halon based systems in new sales and to also urge owners of halon suppression systems to retrofit them with extinguishers using environmentally acceptable agents. Either dry chemical or water, with or without additives, can serve as a satisfactory, or even superior, agent to halon 1301 or halon 2402 in many dust explosion or hydrocarbon vapour explosion protection applications. There remain certain applications where a "clean" extinguishing agent (evaporates leaving no residue) is important. In these cases a high-ODP agent can often be replaced with chlorobromomethane, referred to as CB or halon 1011. This chemical has been widely used in deflagration suppression systems in non-occupied areas . CB is produced in low volume and has no officially reported ODP value. It has been estimated that CB does have an ODP value of about 0.4 and an atmospheric lifetime of about 1 year. While production of CB is not presently restricted, its use explosion protection may be at risk should CB be more carefully studied and then classified as an Annex A -Group II (Halons) or Annex C-Group II (HBFCs) chemical.

Commercial Applications: The principal application of deflagration suppression systems is in protection of aerosol can filling rooms, and hydrocarbon pump and transfer stations of moderate size, i.e., of the order of 100 m^3 volume. Protection of aerosol fill operations constitutes an important use of halon 1301 among Type B situations. This special protection need arose due to the abandonment of the use of non-flammable CFCs as propellants in aerosol products. This transition in propellant technology took place in 1975 as an early outgrowth of the discovery of the catalytic role of chlorine in ozone depletion. Most CFC based propellants were replaced by hydrocarbon formulations which were typically mixtures of propane and isobutane. The advent of combustible propellants coupled with, in many cases, the combustible products being delivered presented an extreme potential hazard in the manufacturing environment. This new hazard gave rise to the use of halon 1301 based suppression systems. Some recent research has shown that in some applications water (without additives) appears to offer effective personnel protection against localized hydrocarbon vapour deflagrations involving less than a 0.5 kg of propane in air. One provider of deflagration suppression systems does offer water as an alternative to halon 1301 in these applications.

Military Vehicles: The crew bays of military vehicles, such as armoured personnel carriers and tanks, face a potential mist cloud deflagration threat should one of the vehicle's fuel tanks be penetrated by armour piercing rounds. Naval machinery spaces face a hazard from deflagrations of combustible machinery fluids in both peace time and war time. These occupied spaces continue to require halon 1301 for protection. Research has been conducted on alternatives. Water is not acceptable due to freezing at low temperatures. Water with non-toxic additives, which depress the freezing point, has been shown by one supplier of military vehicle systems to offer suppression effectiveness nearly similar to halon 1301. Thus, while not an accepted replacement agent, water with additives shows promise for use in vehicle systems.

4.7 Conclusion

Halons have been widely used to suppress deflagrations, a class of combustion events characterized by rapid flameball growth and high rates of energy release. Explosions are events resulting in personal injury or destruction of property. Explosion protection is achieved through methods to prevent or mitigate deflagrations. Effective protection of systems and personnel at risk from such events requires operating systems which:

i. Create inerted atmospheres, or

ii. Respond automatically to the incipient event and achieve extinguishing agent concentrations to suppress a deflagration in time scales of the order of 100 milliseconds, and which require agent concentrations much higher than typically employed in total flooding fire suppression applications.

Halons have been specified in industrial, commercial, and military explosion protection applications where either "clean" or people-safe agents were essential. Halon 1301 has the unique property of being able to inert an enclosed space or suppress deflagrations at vapour concentrations which are safe for brief human exposures. Replacement of halon 1301 in such applications presents a significant challenge in fire or explosion protection situations involving human life safety for at present there are no approved alternative agents which have this property. Work is in progress to identify alternative agents which may be approved for these applications. Progress has been made in some applications in designing new explosion protection systems with out specifying halons. Retrofitting of some halon based deflagration suppression systems with environmentally benign agents is occurring though in some cases an unclassified lower ODP clean agent (Halon 1011) is being specified.

5 Halon emission reduction strategies

5.1 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 realized by improving maintenance procedures, detection and control devices, etc. as outlined in this Section. Predictions of the future effectiveness of these measures will be found in Appendix B.

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

- Alternative Fire Protection Strategies
- Halon Use Minimisation
- Maintenance Program
- Personnel And Documentation
- Halon Transfers And Storage
- Halon Discharging

5.2 Alternative Fire Protection Strategies

Apply halon to critical uses ONLY. Do not install or use halon where alternatives can be employed. 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:

i) 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.

ii) 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 critical equipment before evacuation of the area and manual intervention can take place.

iii) 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.

iv) Passive Protection

Critical 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.

v) Equipment Duplication

Critical 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.

vi) Detection

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

vii) 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.

5.3 Halon Use Minimisation

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

i) 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.

ii) Reserve Systems

Reserve systems should only be installed when:

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

If it is feasible to do so, consideration should be given to leaving reserve supplies unconnected, which can help avoid unwarranted release of the reserve supply. If possible, keep reserve agent in a single large storage tank to reduce the risk of accidental release and minimize the chance of leaking. Note, if the reserve 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 is no on-site capabilities for the storage and transfer of halon agent nor 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.

iii) 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.

iv) 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.

5.4 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 produce or purchase 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 utilize improvements and new technology, scheduling equipment replacement, proper design, regular maintenance, and periodic system checks.

i) 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.

ii) 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.

iii) Design and Regular Maintenance

In many cases, inadvertent discharges represent the largest source of halon emissions, and they can often be eliminated through improved maintenance.

Inadvertent discharges are mostly attributed to:

- Automatic detectors responding to transient changes in environmental conditions (i.e. humidity, airborne dust, etc.).
- Electronic unreliability or poor circuit protection from outside interference.
- Irregular and/or inadequate personnel training.
- Inadequate maintenance procedures and documentation.
- Accidents during system servicing or testing (see note below).

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:

- Systems assembled from a mixture of components from different manufacturers, none of whom takes overall responsibility, should be avoided.

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

- Equipment chosen conforms to internationally accepted specifications incorporating suppression of airborne and electrical interference. BS7273 1990 covers the electrical actuation of total flooding extinguishing systems, introduced to improve the reliability of control systems to reduce the likelihood of accidental discharges [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.) to EC Directive 89/336/EEC [2].

- Existing detection systems be upgraded to take advantage of the latest technology.

- User and service company engineers are fully familiar with the system operation and the equipment fitted.

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.

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, contents of 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 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.

iv) 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 optimum method.) Valves and fittings etc. 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.

Where on-site maintenance personnel are not available, an alternative is a maintenance servicing contract. Whether on-site personnel are utilized or a maintenance servicing contract, always insist on trained and licensed service engineers.

It is imperative in cases where halon is still being used that considerable effort be given to developing better maintenance methods for the equipment. Improved discharge system reliability is achieved through enhanced maintenance procedures and/or replacement with new technology. Development of a maintenance program should be done in parallel with performing a Risk Assessment of the facility and operations. Once a Risk Assessment has been performed on an operation, the fire protection needs are then determined. In cases where automatic fire detection or suppression is determined necessary, maintenance becomes a significant and integral part of the Risk Management.

5.5 Personnel 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 informed of the proper operation of the system and cautioned on 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.

Risk Management includes establishing good system documentation and maintenance procedures. Ensure there is documentation to follow in performing system maintenance and system checks. 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, utilize a computer database for tracking quantities and component failures.

5.6 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 an approved standard and be compatible for halon use.

Environmental and operator safety dictates that all filling procedures should be carried out 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 directly to the outside atmosphere. All equipment, particularly flexible connects, 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.

Current 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 thereby enhancing recycling possibilities. Although halon recovery/recycling techniques are covered in Section Six, it is worth noting here that halon 1211 recovery systems with an efficiency of 98% and halon 1301 recovery systems with efficiencies >96% are readily available today [3]. The UK Fire Industry Council has issued a Code of Practice covering the recovery of halons [4]. The following table lists halon recovery equipment and the manufacturer:

Table of Halon Recycling, Recovery, and Reclamation Equipment Manufacturers

Type	Product Name	Manufacturer
Halon 1211	Halon 1211 Recovery System	AES Nitron
Halon 1211	Recovery and Conditioning for Halon (REACH)	Walter Kidde Aerospace Inc.
Halon 1211	Defender 2000/M-1	FRC International, Inc.
Halon 1211	Model HR-1	Getz Manufacturing
Halon 1301	Model H1301	AES Nitron
Halon 1301	Model ERS-130 Halon	Global Ozone Solutions, Inc.
Halon 1301	HAL	Team Aer Lingus Sales
Halon 1301	Recovery and Conditioning for Halon (REACH)	Walter Kidde Aerospace Inc.
Halon 1301	Halon Recovery System	Pacific Scientific
Halon 1301	VaporSep system	Membrane Technology & research, Inc.
Halon 2402	Recovery and Conditioning for Halon (REACH)	Walter Kidde Aerospace Inc.

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 critical, 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. By recovering all on-site halon that is not used in critical, primary systems, the risk of accidental discharge or agent leakage is minimized. 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.
- Provide good storage conditions for both in service systems/cylinders and backup systems or bulk agent, and install leak detection for storage atmospheres.

5.7 Halon Discharging

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 - 1992, Halon 1301 Fire Extinguishing Systems [5]. 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 [6], 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. Similar requirements can be found in British Standards [7]. Only systems with complex piping arrangements should require additional agent distribution testing. If you must test, use a surrogate gas. SF_6 has been proposed as a candidate alternative to halon 1301 for such tests, but it should be noted that this gas has a high Global Warming Potential.

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 believed to have been substantial. 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.

Portable Fire Extinguishers:

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

The Committee believes that it may now be 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 only one is discharged. With the increase in awareness of the environmental problems associated with halon, many users are switching to CO_2, dry powder, or AFFF spray extinguishers. Thus, the demand for training in the use of portable halon extinguishers is declining. A pressurised water extinguisher system has been developed for the U.S. military for fire fighter training. The handling behaviour is similar to a halon 1211 system [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 [8]. The U.K. military in conjunction with the Civil Aviation Authority has also developed and utilises interactive video training [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 provides requirements for the construction and performance of portable halon type fire extinguishers [10].

5.8 Conclusions

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimised, as quantified in Appendix B, if a concerted effort is made by the fire protection community, with support from national governments. In reviewing reduction strategies, the Committee recommends the following:

- Reduce halon usage to critical applications only.
- Encourage the application of risk management strategies and good engineering design to take advantage of alternative protection schemes.
- Encourage users of automatic detection/release equipment to take advantage of the latest technology.
- Implement a regular maintenance program.
- Verify system design and requirements when changes in hazard have occurred.
- Educate and train personnel and improve documentation.
- Introduce the use of halon recycling equipment to recover all surplus or reusable material.
- Discontinue the discharging to the atmosphere of portable halon extinguishers and system cylinders during equipment servicing.
- Utilize 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 discharge of portable halon fire extinguishers for training purposes.

5.9 References

1. British Standard, BS7273 1990.

2. European Community Directive 89/336/EEC.

3. Preliminary List of Halon Recycling, Recovery and Reclaim Equipment Manufacturers, UNEP IE/PAC, 30 March 1994, Telephone (33-1) 44 37 14 50, Fax (33-1) 44 37 14 74.

4. UK Fire Industry Council Code of Practice for Reclaiming halon, 1993.

5. NFPA: ALERT Number 91-2, halon 1301 Discharge Testing Alternatives. National Fire Protection Association, 1 Batterymarch Park , Quincy, Massachusetts 02269-9101, USA.

6. Underwriters Laboratories Inc., UL 1058, Standard For Halogenated Agent Extinguishing System Units, Second Edition, 22 March 1991, ISBN 1-55989-024-X. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, Illinois 60062-2096, USA.

7. British Standard, BS 5306: Section 5.1: Halon 1301 Total Flooding Systems.

8. Hughes Associates, Inc., 6770 Oak Hall Lane, Suite 125, Columbia, Maryland 21045, USA.

9. U.K.

10. Underwriters Laboratories Inc., UL 1093, Standard For Halogenated Agent Fire Extinguishers, Fourth Edition, 11 October 1991, ISBN 1-55989-109-2. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, Illinois 60062-2096, USA.

6 Halon recycling, bank management, and trade

6.1 Background

On January 1, 1994, authorised production of halons 1211, 1301, and 2402 ceased in countries that are Parties to the Montreal Protocol, except in those countries operating under Article 5, Paragraph 1 who have a 10-year grace period and production for their basic domestic needs is still allowed. Parties can ask for an exemption on production and consumption for 'essential uses' under certain conditions, however to date no such exemptions have been recommended by the Halons Technical Options Committee and the Technology and Economic Assessment Panel, or granted by the Parties.

The phase out of halon production in the developed countries took place before substitutes and alternatives became available for all critical halon uses. This has been a positive motivation to achieve best use of existing halons and has encouraged the establishment of halon banks and bank management procedures. To further encourage the use of existing halons, the Parties decided to allow unrestricted trade of recycled halons provided that the relevant data are reported to UNEP under the procedures of the Protocol.

The above events have made it important to plan for the recycling and reuse of halons in all countries that are Parties to the Protocol. If the 'global bank' can be made productive, it will mean that halon will be available for many years to come.

Decision IV/26 of the Parties asked the Halons Technical Options Committee to evaluate and compare existing and proposed recycled halon bank management programmes, and to identify possible means of further facilitating international recycled halon bank management. Appendix C provides a summary of the various country programmes that have been reviewed to date, and the rest of this section is devoted to providing guidance to those contemplating the establishment of a halon bank management scheme in their country.

6.2 Definitions

Throughout this Section and Appendix C the term 'recycling' includes recovery, recycling and reclamation per Decision IV/24 of the Parties, as below:

a) Recovery: The collection and storage of controlled substances from machinery, equipment, containment vessels, etc., during servicing or prior to disposal.

b) Recycling: The re-use of a recovered controlled substance following a basic cleaning process such as filtering and drying. For refrigerants, recycling normally involves recharge back into the original equipment. It often occurs "on-site".

c) Reclamation: The re-processing and upgrading of a recovered controlled substance through such mechanisms as filtering, drying, distillation and chemical treatment, in order to restore the substance to a specified standard of performance. It often involves processing "off-site" at a central facility.

6.3 Introduction

The quantities of halons stored in existing containers, portable fire extinguishers and mobile units is far greater than the quantities that were produced annually in the past. It has been estimated that at the end of 1993, when production ceased in the developed countries, the global bank of halons 1211 and 1301 was approximately 80,000 metric tonnes and 60,000 metric tonnes respectively. This existing stock of halons slowly becomes available for 'recycling' as installations are closed down or alternative fire protection measures are introduced. This halon 'bank' is therefore a valuable asset and it seems prudent to manage it at the national level. In its simplest form, bank management consists of keeping track of halon quantities at each stage: initial filling, installation, and 'recycling'.

An increasing number of countries, both developed and developing, have initiated or are operating bank management programmes. These programmes take different forms in different countries, and indeed one could argue that they must be different because of the different conditions in each country. A country's political structure, economic structure, and industry pattern will shape its programme, and thus each 'bank' will be tailor made.

There are many factors which will enable the decision to form a bank, whether physical or information clearinghouse. They can be political - a government wishes to control use and/or the phase out of halons within its country; economic - alternatives meet most needs and create a surplus, or conversely they do not and create a demand; or strategic - certain applications, both commercial and military, for which there are no alternatives need long term support. In all cases, however, it appears that governments, users, and the fire equipment industry will be involved in the decision making process.

6.4 Physical Banks And Clearinghouses

Most halon bank management schemes can be reduced to one of two categories, a physical bank or a clearinghouse, even though some programmes do attempt to provide elements of both services.

The physical bank concept requires warehouses and storage tanks, and may require the 'bank' to purchase halons, 'recycle' it and have it ready for resale. A large private user or a country's military may have its own strategic bank based on these lines. When considering this option, it is important that there be known uses for the material before collection and storage begins. This is particularly true for halon 1211 where much of the material is contained in small portable fire extinguishers whose collection and removal of halon could be an expensive undertaking. In this instance, users may wish to consider the redeployment of halon 1211 portable extinguishers from non-critical applications to more critical applications instead of recharging the existing extinguishers following use or sending them for recertification.

The most popular banking schemes however, consist of lists of halon users who no longer require their extinguishing agent, and of users who still need halons but do not have (or will not have in the future) sufficient stock. Detailed inventories of stocks available (or becoming available) at the owner's premises may be maintained along with the anticipated demand. Such banks trade information on the availability of, and demand for, halons but leave the process of sale, 'recycling', and purchase to the individuals concerned. This activity resembles an information clearinghouse.

6.5 Bank Objectives

Halon banking is a concept to manage a nation's existing halon stocks wisely, and to insure that the needs of the few critical applications that truly require halon can be met. Halon banking should not be viewed as a programme that reduces dependency on halon, as that can only come about if the many currently available alternatives to halon are perceived as true replacements by users. Indeed, banking can prolong the unnecessary use of halon if alternatives are not perceived to be economically viable. Nevertheless, for those applications for which there are no alternatives to halon, 'recycling' and banking are important concepts.

Accepting the above, then the primary objectives of a prudent plan to 'recycle' halons should be, as a minimum, the following:

- Facilitate the transfer of available halon from one user to satisfy the needs of another.
- Discourage emissions to atmosphere.
- Provide a reasonable time period for the development of replacements and the implementation of alternative fire protection strategies by extending the useful life of banked halons.
- Mitigate the need for consumption/production exemptions for 'essential uses'.

6.6 Basic Elements Of A Halon Bank Strategy

From the wide range of schemes that have been proposed/implemented to date (see Appendix C), it is clear that there is no universal template for halon banks. This is primarily because the key element of the banking process is the reversal of the original supply/distribution process which varied from country to country. The solution is not to 'buy' a ready made strategy, but to have one tailored for the situation in any given country. It is, however, possible to pare the elements of the schemes proposed/implemented to date down to a certain number of minimum requirements to which other 'elements' can be added depending on the regulatory aims of the country concerned and/or goals of the participants.

6.6.1 Key Players

Within organisations the impetus for involvement with halon banking often comes from a 'champion', that is an individual who sees the need for such a scheme and sells the idea to colleagues. The organization with such a 'champion' often becomes the 'champion' of the idea itself within a group of organisations of a similar nature; that group often takes on a lead role at national level. For example, in Denmark, Switzerland and the UK the fire equipment suppliers have played a major role in establishing their national banks, whereas in the US they have played a very minor role, the impetus coming from users with critical applications such as aircraft protection or explosion prevention.

'Champions' also come from government whose function in these schemes differs widely from country to country. In some cases, e.g. Malaysia, the government imposes a regulatory framework because they wish to control the management of the halon stocks within their country. On the other hand, UK and US governments have left it to the participants to define the operating framework and permit market forces to prevail. However, in all cases it is governments who are uniquely placed to act as facilitators of the process, to provide as a minimum a forum for discussion so that a strategy can be prepared. It is also important that initiatives taken by governments do not hinder the collection, transportation and judicious management of 'recycled' halons.

6.6.2 Inventory and brokerage

As a minimum, any banking strategy must have a list of those enterprises with available halon, and one of those who have a need for halon but who do not have a sufficient stock. There must then be a method of matching the two.

Some banking strategies are based on a detailed inventory of the halon held in a country, e.g. Malaysia; some are based on an inventory of halons held by the members of the bank, e.g. The Netherlands and Switzerland; yet others simply allow members to report halon for sale as it becomes available or is projected to become available, e.g. UK and US.

The brokering of the material to the end user also differs from country to country, and is dependent upon national trading regulations. For example, in the US free market forces govern the trade of halons, and there are competition regulations that prohibit restrictions on that trade and the establishment of monopoly banks. However, in Denmark the Danish Halon Bank fixes the internal price it pays and charges the certified operators who do the actual collection, storage and selling of halons on behalf of the bank.

6.6.3 Recycling And Standards Of Material

Halon for transfer may need to be 'recycled', so that any strategy must provide access to such facilities. At the most basic level this would be a list of companies who have or have access to 'recycling' equipment. At the other end of the spectrum, a central bank that holds all material would likely have its own recertification process and quality control procedures for halon accepted for resale.

It is important to note that users who need halon have to be assured that what they buy is fit for use in fire protection applications, and therefore there has to be some level of confidence in the material. This can best be provided by requiring material to be 'recycled' to a certain agreed standard, e.g. ISO 7021 or ASTM ES 24-93, or by knowing its provenance - the history of its origin, storage, and use. However, in all cases, purchasers of 'recycled' halon should operate under the buyer beware principle.

6.7 Additional Features Of Halon Banks

In addition to the basic features described above, any bank management scheme can be tailored to meet the special requirements of its participants by the provision of one or more of the following features. All of the currently proposed/existing national halon banks incorporate some of these features.

Inventories: Detailed inventories of the halon held including quantities, site and installation specifications. This will permit the long-term management of the magnitude and quality of halon stocks and could also simplify the logistical controls.

Certification: As mentioned above, certifying the quality of 'recycled' material to an accepted international standard assures users that the halon is fit for use in fire protection applications. It also makes material more readily transferable between applications and/or banks in other countries.

Standards: Standards and codes of practice for handling the material. This allows for inspections and tighter controls of potential losses (emissions) from aging or poorly maintained systems.

Criticality: Methods of determining 'criticality' of uses and of allocating material to those uses. This permits sellers having concerns about sound environmental use of their surplus halons to evaluate potential purchasers and to be assured of the halons use for only critical applications.

Physical bank: A physical bank, central or distributed, with deposits and withdrawals allows a tighter control of the quality and supply of halons.

Disposal: Advice or facilities for disposal/destruction of severely contaminated material. This measure prevents environmental damage and the use of substandard materials. In the longer term it provides a route for destruction if halons are no longer needed.

International trade: Access to other national halon banks through an international clearing house facilitates access to a bigger market for the sale or purchase of halons.

6.8 Factors To Be Considered

Bank management is still in its infancy and many nations experienced 'growing pains' while establishing their banks (see Appendix C). The factors detailed below should be carefully considered by any group proposing a national halon bank:

a) Unless and until the fire equipment industry, users and/or government agree that a need for a halon bank exists, there is unlikely to be enough energy, enthusiasm and finance to get a bank started. It should also be remembered that 'recycled' halon cannot commercially compete with newly produced, and thus a prerequisite of any national bank management programme is a commitment to cease production first.

b) Halon users and fire equipment suppliers need a 'non-commercial' forum for discussion and the development of strategies. In such an atmosphere, policy development and decision making are left to the accountable people, political pressure is alleviated, and decisions can be implemented as soon as they are made. Often it is governments who are uniquely placed to act as facilitators of the process and who can provide this necessary forum.

c) A national halon 'store' with collection and delivery of redundant cylinders is a major industrial undertaking, and is not likely to be a preferred option on financial, logistical or environmental grounds unless heavily supported by government. Also, the ownership of severely contaminated halons is potentially a major liability.

d) Particularly with regard to halon 1211 portable fire extinguishers, organizers may wish to consider the redeployment of extinguishers from non-critical applications to more critical applications as an alternative to recharging existing extinguishers with 'recycled' halon.

e) It is important to establish the 'credibility' of any scheme from the outset. Involving influential organisations in the early stages of setting up a halon bank can help its general perception by other potential members. These organisations could include large trade associations, insurance bodies, government departments who are halon users, and government departments who have responsibility for the environment, health, safety, trade and industry.

f) The objectives of a halon banking scheme must be agreed early on and kept as simple as possible. The bad environmental image of halons may make some companies reluctant to join a sophisticated bank management scheme. All banks will live or die by the service they give to their customers.

g) If the bank is set up as part of a larger 'umbrella' organization, care should be taken that there is no clash of policies or demonstrable vested interest.

h) Company, tax, liability and competition law must be studied carefully to determine the best legal structure for the banking organization. All countries are different in this regard as are the size and distribution of the installed halon stocks. Each national halon banking system will therefore be unique, although some aspects will be common to all.

i) If the military forms a separate bank from the private and public sectors, it is important that they be coordinated to avoid disrupting the availability of supplies and to avoid surplus liability.

6.9 Conservation

Although it is estimated that the existing, worldwide bank of halon can meet the needs of critical uses for many years, this will not happen unless governments and users act responsibly. This year has seen the loss of three potential halon replacements due to adverse environmental or toxicological factors. Therefore, users should be encouraged to avoid depleting a nation's halon stocks for uses for which there are acceptable alternatives, and countries with a surplus of halons should not destroy them if others have a need - particularly if they are continuing to produce halons to meet that need.

6.10 International Trade And The Basel Convention

The international clearing house scheme operated by the United Nations Environmental Programme, Industry and Environmental Programme Activity Centre (IE/PAC) provides access to other national halon banks. This facilitates access to a bigger market for the sale or purchase of halons, and the necessary ability to recharge critical halon systems, such as onboard ships and aircraft, while in a foreign territory. Depending on the situation, the incremental cost to Article 5, Paragraph 1 countries of buying 'recycled' halon rather than producing it could be paid for by the Multilateral Fund on a case-by-case basis.

Upon request, IE/PAC will provide a regularly updated list of implemented and working halon banks with contact addresses, phone and fax numbers and, if available, the requirements for exports and the quantities registered at its office. This networking of national halon banks has been established to facilitate access to 'recycled' halons by those countries with limited surplus and thus avoids the need for new production. Given the number of halon bank management schemes that are now, or will soon be, operating, it will be particularly beneficial if IE/PAC convenes a meeting of halon bank managers to share information and develop cooperative procedures.

> **Note:** Decision IV/26, while urging the Parties to encourage 'recycling' of halons to meet the needs of all Parties, also calls upon Parties importing 'recycled' halons, when deciding on their use, to apply the essential use criteria set out in the 1991 report of the Halons Technical Options Committee. Each halon bank or country may have a different policy about using the essential-use criteria, and some may require certain assurances before allowing exports and imports. Whilst 'essentiality' is not a required prerequisite for international trade, the purpose of the essential use criteria is to minimise the use of halons in non-critical applications. It should be noted that the Halons Technical Options Committee has revised its essential use criteria (see Section Nine) to conform with Decision IV/25 of the Parties, and this revision may prove more useful to countries importing halon.

The Basel Convention has the potential to be a serious impediment to the transshipment of 'recycled' halons, or halons to be 'recycled', across international boundaries if misapplied. Whilst the Montreal Protocol allows unrestricted trade in 'recycled' halons between signatories, as described below, the Basel Convention could be used to restrict trade. This is further complicated by the fact that not all signatories to the Montreal Protocol are signatories to the Basel Convention, and that technically signatories cannot trade with non-signatories unless a bilateral agreement exists which is no less stringent than the Basel Convention requirements. The following interpretation of the impact of the Basel Convention, and the recommendations to the Parties to the Montreal Protocol by the Halons Technical Options Committee, are based upon the best available advice at this time and should not be considered as a definitive or a legal opinion.

In general, if either party in a trade (exporter or importer) of halon, or country through which a shipment must pass, considers recyclable or 'recycled' halon to be a 'hazardous waste', as determined by their national law, then the trade is covered by the Basel Convention. This means that transshipment of the material is allowed only if an agreement complying with the Basel regime is executed by all parties involved. This will involve notification, consent, and the establishment of sound environmental management of the waste. However, the Basel Convention does not specifically list halon as a 'hazardous waste' and the Halons Technical Options Committee is working in cooperation with the Basel Technical Working Group to ensure that if 'recycled' halon is uncontaminated, or has already been reprocessed to service specification, then it will not be considered a 'hazardous waste' or waste at all, and hence exports of the material would be unaffected by the Basel Convention. For this reason, the Halons Technical Options Committee recommends that the Parties to the Montreal Protocol consider:

a) Adopting a decision that recycled halons that are certified to the usable purity specifications ISO 7201 or ASTM ES 24-93 are considered recycled material and not a waste.

b) Adopting a decision that international transfers of halons that cannot meet the purity specifications of ISO 7201 or ASTM ES 24-93 should only be allowed if the recipient country has 'recycling' facilities that can process the received halon to either of these standards.

The Halons Technical Options Committee believes that this recommendation will achieve the results desired by both the Basel Convention and the Montreal Protocol, and will remove the current confusion regarding permitted international trade in 'recycled' halons.

A separate decision of the Basel Convention will ban exports of 'hazardous wastes' from OECD[1] to non-OECD countries after 1997. Again, if the Parties to the Montreal Protocol accept recommendations a) and b) above, this will greatly assist non-OECD countries in meeting their needs with 'recycled' halons instead of with new production.

6.11 International Cooperation

In adopting Decision VI/26, the Parties recognized the importance of the unrestricted trade in 'recycled' halons between Parties to the early phase out of halon production. It is therefore necessary that Parties ensure that national regulations that were implemented to restrict imports and exports of newly produced halons do not impede the international trade in 'recycled' halons. Further, and with particular reference to international air and marine transportation, as well as military cooperation, it is important that national regulations do not impede the recharge of foreign critical halon systems from national stocks. It will also be beneficial to establish a NATO mechanism to help facilitate transfers of 'recycled' halons under normal or emergency conditions for military uses in both developed and developing countries.

International cooperation on the movement of 'recycled' halons can greatly assist in reducing the need for essential use production exemptions and the unnecessary destruction of surplus halons. It is environmentally counter productive for one nation to produce halon for critical applications while another destroys its surplus. Governments should therefore encourage their users and owners of halons to contact their national bank(s), or the international clearinghouse scheme operated by IE/PAC, when they have a need for, or surplus of, halons.

6.12 Conclusions

The phase out of halon production in the developed countries took place before substitutes and alternatives became available for all critical halon uses. This has been a positive motivation to achieve best use of existing halons and has encouraged the establishment of halon banks and bank management procedures to manage remaining stocks wisely. Past experience has also shown that 'recycled' halon cannot commercially compete with newly produced material, and thus a prerequisite of any national bank management programme is a commitment to cease production first.

An increasing number of countries, both developed and developing, have initiated or are operating bank management programmes. These programmes take different forms in different countries but, whilst similarities exist, the Halons Technical Options Committee has concluded that no universal template for a bank programme can be produced. This is primarily because the key element of the banking process is the reversal of the original supply/distribution process and this varied from country to country.

Of the bank programmes reviewed, the majority resemble an information clearinghouse. That is, the operators maintain lists of halon users who no longer require halon and those who do but have or will have insufficient stocks to meet their needs. This information is traded between the users who then make the necessary arrangements for 'recycling' of the halon and its sale/purchase. Physical banks that require warehouses and storage tanks are a minority,

[1]Organization for Economic Cooperation and Development

although it is apparent that large private and military users are forming strategic banks on these lines.

For any banking scheme to work, the fire equipment industry, users and/or government have to agree that a need for a halon bank exists, otherwise there is unlikely to be enough energy, enthusiasm and finance to get a bank started. Governments are also uniquely placed to act as facilitators and to provide a non-commercial forum for discussion and the development of strategies.

Users who obtain 'recycled' halon have to be assured that what they buy is fit for use in fire protection applications. This can best be provided by requiring material to be 'recycled' to a certain agreed standard, or by knowing its provenance. This is particularly important when international trade is involved.

International cooperation on the movement of 'recycled' halons facilitates access to a bigger market for the sale or purchase of halons, and provides the ability to recharge critical halon systems, such as those onboard ships and aircraft, while in a foreign territory. It is therefore important that Parties ensure that national regulations that were implemented to restrict imports and exports of newly produced halons do not impede the international trade in 'recycled' halons or their premature destruction.

6.12 Recommendations

The Halons Technical Options Committee, having evaluated the recycled halon bank management programmes summarized in Appendix C, offers the following recommendations for consideration by the Parties to the Montreal Protocol as possible means of further facilitating international recycled halon bank management:

a) Adopting a decision that recycled halons that are certified to the usable purity specifications ISO 7201 or ASTM ES 24-93 are considered recycled material and not a waste.

b) Adopting a decision that international transfers of halons that cannot meet the purity specifications of ISO 7201 or ASTM ES 24-93 should only be allowed if the recipient country has 'recycling' facilities that can process the received halon to either of these standards.

c) Adopting a decision that 'recycled' halons not be destroyed before all means of transferring them to a country that has a critical need for halons, particularly if that country is still producing or importing new halons, have been explored.

d) Adopting a decision that the Director of UNEP IE/PAC convene a meeting of the current national halon bank managers to share information and develop cooperative procedures to further facilitate access to 'recycled' halons by those countries with limited surplus or those who are still producing new halons.

6.13 References

1. Handbook for the Montreal Protocol On Substances That Deplete The Ozone Layer, August 1993

2. ISO 7201: International Organization for Standardization Specifications for halon 1211 and halon 1301, 1989

3. ASTM ES 24 - 93: American Society for Testing and Materials Emergency Standard Specification for Halon 1301, Bromotrifluoromethane (CF_3Br), May 1993

7 Review of industry case studies

7.1 Introduction

As part of this study, a survey of businesses and organisations that make use of fixed halon fire extinguishing systems and/or halon portable fire extinguishing appliances was undertaken. The survey sought detailed information to address a range of issues including:

- Halon uses eliminated.
- What alternative methods of fire protection have been used.
- Are there other risks currently protected by halon for which alternative protection measures are being considered.
- Are plans 1 years (short) 5 years (medium) 10 years (Long term).
- Is there any critical use for which you have not yet identified an alternative means of protection.
- Describe actions to be taken to find suitable alternatives.
- When do you expect to have an alternative in place.
- Do you belong to a halon bank facility.
- How will your company support both it's short and long term needs.
- Describe what you would have done differently to manage change-out of halon.

The survey was targeted at a range of key industries. The request for information was by way of a questionnaire.

The survey sample was structured to achieve a range of respondents in the major user sectors. This included both public sector bodies and private sector users. It is not implied that the proportion of surveyed organisations in each sector is representative of the total user population. Due to the short time available, with its wide international bases, and extensive range of industry sectors involved and level of information required, make it impossible to undertake a large survey.

There were a total of 64 Questionnaires distributed and 45 were returned.

The Fire Industry Council (UK) also distributed the questionnaire to their membership, they returned 27.

7.2 Aviation

7.2.1 Airline 'A'

Aircraft for many years used halon fire extinguishing agents as the principle and primary means of dealing with any fire scenario that may develop on-board. The agent was available in both fixed systems and portable units. It was part of the Aircraft Operators Certificate that this agent was available for firefighting purposes.

In the late 1960's and early 1970's when research was being carried out to find new extinguishing agents to replace traditional agents such as carbon dioxide, dry chemicals, etc. to protect new high technology electronic equipment, key ground operation facilities and aircraft ramp areas, it was established that halon 1211 and halon 1301 offered the most efficient level of protection for this risk.

Over a period of 20 years a total of 200 inbuilt systems were installed to protect key ground installations and 15,000 portable fire extinguishers.

In keeping with corporate policy an extensive staff training programme was undertaken, this included both flight and ground based personnel to comply with statutory requirements and corporate policy and this necessitated the use of halon 1211 to successfully complete this task.

Due to the nature of its operations and to comply with Aircraft Operator's Certificate of Airworthiness all the aircraft fleet are fitted with halon 1301 in fixed systems and halon 1211 portable fire extinguishers within the aircraft cabin.

To ensure aircraft, customers and staff are offered the highest level of fire protection whilst aircraft are being prepared for service on the ground, large halon 1211 extinguishers were positioned on the ramp areas to protect this risk.

In 1988 we commenced a review of our use of halons to examine ways of using less media, whilst not increasing risk to our operations from subsequent fire damage.

In 1990 we ceased dumping halon 1301 when commissioning new installations. This was replaced with the introduction of pressure testing of halon 1301 protected enclosures.

We examined the need for halon 1301 systems to be on automatic or manual, and where it was not considered necessary we placed those systems into manual operation only, therefore reducing the risk of accidental discharge.

Being proactive it examined the market place to identify any new trends to protect key technical centres. As there was no ready made replacement it decided to proceed with internal evaluations to develop systems that would maintain fire protection standards, and minimise damage to key electrical installations. Discussions took place with interested parties within the company, and externally with insurers and technical organisations.

As a result of this study it introduced a policy of protecting key electronic data centres with a very early warning smoke detection system, supported by pre-action water sprinkler systems. It is the intent to proceed with this type of specification for the future (where appropriate). Also introduced are contracts to improve monitoring and implementation of passive fire protection measures for improved fire control. By the year 2000 it expects to have 95% of ground based fixed systems removed.

When old systems are taken out of service an arrangement is in place with a fire engineering contractor to remove the material and have it recycled, therefore preventing unwanted emissions into the atmosphere.

Stocks of portable fire extinguishers containing halon 1211 is approximately 15,000 and they range in size from 1.5 kg to 50 kg. A plan is now in place to have all of these units removed by 1997 from ground based facilities. The material will be returned to the contractor for recycling, and stored in our bank for future aircraft needs.

It has instigated improved internal housekeeping practices to reduce the unnecessary discharge of halon 1211 (BCF) into the atmosphere, which includes:

- Evaluated each risk and to assess the level of protection required for the facility.

- Replaced halon extinguishers with water, AFFF, CO2, dry chemical, as appropriate.

- Returning all time expired extinguishers to our contractor to recycle the media.

- Extinguishers with partial discharge are returned to the contractor for recycling.

- Crew training - fire sized reduced so that the minimum amount of agent is only used.

- Agreed with the CAA that one small extinguishers be used to train 20 persons, as against one per trainee previously.

It has commenced a phase out of all halon 1211 extinguishers on aircraft ramp areas on its worldwide network. Halon is being replaced with foam based products, dry chemical, and CO2. The type of replacement unit used is determined by the environmental circumstances prevailing at each station.

It has evaluated new training practices which will negate the need of having to use halon 1211 agent for training. To meet its statutory responsibilities they are purchasing active fire training simulators which will have water as the primary extinguishing agent. These units will be in operation on 01 January 1995.

The company is a founder member of the U.K. Halon Users National Consortium and it shall continue to give this its support.

As an airline it knows that requirements for halon shall continue into the next century. This is due to the critical need of its operations to meet obligatory responsibilities. To ensure they meet these objectives they have set up its own banking system and will support this until such time as suitable and equally efficient replacement medias are commercially marketed.

We also have within our plans a policy for the removal and destruction of halons should alternative drop-in replacement agents be developed and commercially available in the near future.

The company is an active member of many halon alternative review groups to research new agents. Working with the fire engineering industry on a worldwide basis to develop new fire engineering solutions, and help the implementation of this process where applicable to our industry.

7.2.2 Airline 'B'

Currently there is a need to use halons 1211 and 1301. They are presently reviewing their internal risks with a view to seeking alternative methods of fire protection. It is the intention for this plan to be in place within one year.

They identified as their key critical areas for protection as aircraft and their computer facility.

Presently they are working with the Industry Halon Replacement Working Group and hold membership of a halon banking facility.

On current estimates they envisage having a critical need for halons up to the year 2015.

It is indicated that they will be able to support their critical needs by recycling from their existing stocks.

Currently they do not have any surplus halons, consequently they do not have a disposal strategy for any surplus media.

If they had to manage change-out of halon, their plan would be to exempt the airline business, because it is less than 1% of the problem in global terms.

7.2.3 Airline 'C'

Have discontinued using halon for training purposes and for new ground based applications including new buildings and computer centres.

For staff training CO_2 is now the preferred alternative agent. Currently there are no other risks for which alternative protection measures need to be introduced.

Presently medium to long term strategy is being worked on for critical applications.

The most critical need the company has is aircraft fire extinguishing systems and to date no suitable alternative agent has been produced.

They are participants of FAA International Halon Replacement Work Group for aviation applications. As there are no viable alternatives available no date has been set to introduce alternative agents.
The company is a member of the Dutch Halon bank system. Their needs are going to be met from the National Halon Bank for the next 5 years.

7.2.4 Airline 'D'

The company needs are for aircraft maintenance and ground support equipment.

Currently being phased out are halon 1211 extinguishers in general office areas. These are being replaced with CO_2 and dry chemical agents.

Actions being taken to find suitable alternatives is through a communication process with potential suppliers of alternatives.

Not aware of a halon banking facility and do not belong to any.

The company intends to support its short and long term needs by use of recycling halons for aircraft, by using a locally manufactured rig, using their own surplus halon 1211/1301.

The present strategy is for surplus agent removed from none critical areas to be recycled for aircraft use.

As the New Zealand government were swift to introduce the Montreal Protocol halon strategies it may be difficult to acquire stocks of halons. However, if longer time scales for phase out were agreed it would have allowed the development of alternatives.

7.2.5 Airline 'E'

The companies main requirements for halons are for aircraft operations.

Halon uses have been eliminated for the protection of computer rooms and ground based vehicles.

Alternative methods of protection to key ground operations, include the use of CO2, dry chemical extinguishers, with the introduction of very early warning smoke detection and point detection fire and smoke systems.

At this time they have no time scale for the introduction of alternative agents for aircraft.

Discussions are taking place on a national halon bank facility. There is no in-house bank currently but investigating the establishment of a facility.

It is not intended to have any surplus agents.

7.2.6 Airline 'F'

Halon 1211 portable fire extinguishers are used in ground operations these are being replaced as and when they become unserviceable.
Replacement agents for ground based facilities used, are CO2 and dry chemical.
There are no short, medium or long term plans in place.

In-house there are no actions to find suitable alternative products. Will let the Fire Engineering Industry lead the market.

The company is aware of banking schemes, but it does not belong to one.

The short term needs will be met by purchase of halon from recycling/recovery companies. Also most of the halon protected premises are also protected by pre-action sprinkler installations.

Should they have a surplus of halon the disposal strategy is to sell it to the halon recycling/recovery companies.

7.2.7 Aircraft Manufacturer 'A'

As a major aircraft manufacturer they have reviewed the companies needs and are working on a continual improvement programme for halon replacements.

Halons have been removed from production lines and buildings.

Early warning fire detection systems have replaced halon 1301 on aircraft production lines. Multi-purpose dry chemical extinguishers have replaced halon 1211 in buildings. Flight simulators are being protected by early warning fire detection and fast response sprinklers.

All their major computer centres are protected by halon 1301 for which no alternatives are being considered at present.

Any changes made are of a long term nature. We are now into the fifth year of change.

On the replacement front they are evaluating options, monitoring of R & D and co-ordination with chemical manufacturers and government regulatory agencies.

It may be possible by 1998 for aircraft going into production to have alternative agents used in the primary fire control systems.

The company is a member of HARC.

Halon suppliers have agreed to meet the companies production needs i short to medium terms. Also available is a small bank with supplies. Long term needs will be small, it is the intention to support this with recycled halons from other sources.

A local vendor maintains a bank to meet ground operational needs. Fire equipment suppliers maintain banks for aircraft fly away systems.

Disposal strategy for surplus halons is to suppliers for placement in banks to meet aircraft needs.
On the management of change, the company would have preferred initiatives from regulators for early search for alternatives, this could be better co-ordinated giving timely solutions.

7.2.8 Aircraft Manufacturer 'B'

A major aircraft manufacturer and consequently halons are essential to ensure aircraft put into service comply with regulatory controls.

Halons have not at this time been eliminated from any of the companies operations.

On the finding of suitable alternatives it is working and participating in worldwide review groups on this subject.

The company does not have its own halon bank. It works indirectly through fire extinguishing system vendors.

To support its short to long term needs it will look to vendors with recycling facilities to supply halons for their essential use.

As the quantity of halons used in aircraft business is small, this purpose group should have been excluded from the Protocol. But other precautions could be taken within other areas of the industry such as crew training.

7.3 Oil and Gas Industry

7.3.1 Company 'A'

Halon protection has been eliminated for the following uses, computer rooms, telecommunication centres, switch gear and transformer rooms and turbine enclosures.

Alternative methods of fire protection introduced includes, manual intervention and early warning fire detection in computer and equipment rooms.

It has developed a fine water spray system for the protection of turbines, fire pumps and emergency generators.

During 1992/93 extensive studies and development work was carried out to look at alternative forms of fire protection. The recommendations derived from this work are being implemented and no further action is planned for the near future.

Are aware of halon banks but no longer applicable to the operations due to the initiatives put in place by the company.

All halon removed has been sold for recycling and reuse by other companies.

On the question of change-out - this is a catch 22. The company was able to solve the problem early, but had the disadvantage of being 'first out' thus incurring a large development cost impact. With proper co-ordination this could have been controlled more effectively to the benefit of the whole industry.

7.3.2 Company 'B'

Many of the actions taken by company 'A' have also been put in place by company 'B'. However, there are areas of exception where explosion protection is necessary and some floor void protection, when the fire escalation is high.

Current risks being protected by halon include turbine enclosures, pump rooms, switch gear, and utility areas.

Halon plans currently are to meet short and long term objectives.

There are some critical areas needing halon protection for which no alternative solutions have yet been found. This includes explosion protection in process areas, and other areas where gas migration can occur.

The company is funding research into first and second generation replacement chemicals. With particular interest CF_3I.

At this time it is not clear when alternatives are going to be in place. This can only be determined on the known results of the current chemicals undergoing testing.

The company is a founding member of HARC.

To support the short and long term needs it is intended to purchase recycled halon 1301 and also by the removal of in-house halon systems taken out of service.

Initiated some engineering studies in the late 1980's. The results of this work seems to fit, somewhat, unique situation.

7.3.3 Company 'C'

Type of use up until 1987:

Control rooms, switchgear rooms, turbine enclosures.

The elimination of some halon has been achieved by:

Enhanced detection + manual response.
CO_2

Fine water spray.

Research currently in progress is:

Evaluation of risk with view of eliminating halon from existing applications wherever possible.

Maintain essential use for likely life of plan.

Management of plan for the next 5 years will consist of the following actions:

Maintain strategic reserve until halon eliminated from facilities.

Ongoing evaluation of fine water systems.

Some are not considering synthetic substances.

Concentrating on prevention rather than protection on future projects.

Many are founder members of HUNC.

Currently establishing own banks from surplus systems.

Have/are changing portables to CO_2, AFFF, dry powder.

Have not yet established disposal strategy.

7.4 UK Industries

Telecommunications - Group 'A'

Areas of the industry protected up to 1987 were:

Switch rooms, computer control rooms, plant rooms.

Change of protection has been introduced by way of:

Enhanced detection + manual response.

Future work to be undertaken consists of:

Evaluation of risk with view of eliminating halon from existing applications wherever possible.

Maintain essential use for likely life of plant.

Changes forecast for next 5 years will include:

Maintain strategic reserve until halon eliminated from facilities.

Ongoing evaluation of fine water systems and keeping open mind on new gaseous systems until proven.

Concentrating on prevention rather than protection on future projects.

Main players are members of HUNC.

Currently establishing own banks from surplus systems.

Much of the industry has a plan to:-

Have/are changing portables to CO_2, AFFF.

Have not yet established disposal strategy.

Metro/Underground Transport - Group 'B'

Up until 1987 the following areas were protected by Switch rooms, computer control rooms, relay rooms, electric sub stations.

Areas of change are:

Enhanced detection + manual response.

Better compartmentation.

Use of water fog systems.

Some internal housekeeping practices have been introduced, these include:

Evaluation of risk with view of eliminating halon from existing applications wherever possible.

Maintain essential use until suitable replacement identified and proved.

(Old relay rooms).

Maintain strategic reserve until halon eliminated from facilities.

Ongoing evaluation of fine water systems and keeping open mind on new gaseous systems until proven.
Concentrating on prevention rather than protection on future projects.

Member of HUNC.

Plans are in place to change first aid fire extinguishers:

Extinguishers to be used are CO_2, AFFF.

Some additional work is required for the formation of the disposal strategy.

Railways - Group 'C'

Types of use up until 1987:

Locomotives, Diesel Multiple Units (DMU's), Central signalling rooms.

AFFF on DMU's, no change on loco's due to space/weight constraints.

Signalling rooms under review.

Evaluation of risk with view of eliminating halon from existing applications wherever possible.

Maintain essential use for likely life of vehicle.

Maintain strategic reserve until halon eliminated from its facilities.

Ongoing evaluation of alternative systems for new vehicles.

Member of HUNC.

Established own bank.

Have/are changing portables to AFFF.

Have not yet established disposal strategy.

Shipping - Group 'D'

Mainly used for the protection of Engine rooms and machinery spaces.

Plans are to change to:

CO2 on new ships.

Retrofit limited by allowable space/weight footprint in existing ships.

Some limited use of water fog systems on new ships.

Evaluation of new gaseous systems with approval agencies.

Maintain essential use for likely life of vessel.

Maintain strategic reserve from redundant systems.

Ongoing evaluation of fine water systems and new gaseous systems until proven.

New projects likely to continue with CO2 until an approved alternative becomes available.

Some owners are members of HUNC.

Have not yet established disposal strategy.

Owners considered very vulnerable to a discharge while "enroute" and their routine refill port has no halon.

Process Industry - Group 'E'

Halons have been used to protect switchgear rooms, computer/control rooms, plant rooms, process plant, fire tenders.

Plans are to:

Remove and rely on existing detection/personnel.

Progressively introduce enhanced detection + manual response.

Use CO2 in limited applications.

Evaluate HFC's/PFC's as alternatives.

Evaluation of risk with view of eliminating halon from existing applications wherever possible.

Maintain essential use for likely life of plant or until a suitable gaseous replacement has been demonstrated.

Maintain strategic reserve until halon eliminated from facilities.

Concentrating on prevention rather than protection on future projects.

Monitoring the introduction of new agents.

Member of HUNC.

Currently established own bank.

Have/are changing portables to water, CO2, AFFF, dry powder.

Have not yet established disposal strategy.

7.5 Defence Services

7.5.1 Service 'A'

It's use of Halon is for high levels of life safety to be maintained for all personnel on board.

Ships under construction will continue to use Halons. Future designs shall eliminate halons in winch rooms with combustible liquids, gas turbine engines encased in modules, combustible pump rooms in which no hot surfaces are present. The alternative forms of protection shall include AFFF sprinkler systems and CO_2 where there is no personnel exposure.

In other areas Halon 1301 will be replaced with first generation alternatives (FM-200, FE-13 or PFC 410) this will effect new designs which will come into service about 1999.

There is no budget available to remove or replace existing installations. This will be supported by supplies from its own bank.

Testing of first generation alternative agents is underway, but not yet completed. It is envisaged that these tests will be completed during 1994.

The expectation is to have new systems in operation by 1999.

Halon is obtained from its own bank which is large enough to meet its operational needs.

The bank operates in the following way:

Halon can be ordered only by authorized users on a list. Ordering requires turn-in of a like quantity of empty containers. There is one central management facility for the bank. And it has its own reclaiming capability.

There is no disposal strategy, since surplus agents are not expected until after 2010.

The big draw-back is that, no options were available for fire protection change-out. Also banking facilities should have been put in place a lot earlier.

7.5.2 Service 'B'

Some applications of halon are unique to the military but many others are similar to those found in either the public or private sectors. Military organisations typically operate bases which contain industrial, administrative, residential, telecommunications, computer, and other functions similar to those found in the civilian sectors.

In some military organisations strategies have been developed to reduce existing uses and eventually eliminate any future dependence on halon.

For some militaries those strategies include:

- Determining the extent of deployment of halon throughout an organisations;
- Categorising those uses as critical or non critical to the application;
- Conserving existing stocks by restricting or banning venting during purging or testing systems and during fire fighting demonstration or training;
- Promoting responsible management through recovery, recycling and reclamation of installed halon.
- Banking decommissioned halon to support critical applications;
- Instigating programmes to identify suitable alternatives;
- The modification of standards and specifications.
- Examining destruction technologies.

Other examples:

The following are examples of steps being taken by some militaries to reduce or eliminate the use of halon.

Shipboard Fire Protection:

One military has identified alternative fire protection measures for future design equipment. These include AFFF sprinkling systems in areas such as winch rooms with combustible liquids and combustible liquid pump rooms in which no hot surfaces are present. CO2 has been selected for use in enclosed areas, such as gas turbine engine encased in modules, to minimise the risk of exposure to personnel.

Alternatives such as FM-200, FE-13, PFC-410 and fine water mist spray are being trailed to replace other uses of halon 1301 in new design equipment due for commissioning towards the end of the century.

Other Defence Applications:

Some military organisations have implemented plans to eliminate halon 1301 from computer rooms, electronic and communications facilities. This decommissioned halon will support critical applications on aircraft, ships and combat vehicles.

A single alternative fire protection method may not, in itself, be sufficient to replace a halon suppression system; however, the more single steps that can be combined to provide overall fire protection options to halon the better.

For the protection of building spaces, such as corridors, known technologies such as water, Dry powder and CO2 are being adopted.

Some militaries have established their own banking and recycling facilities to support critical equipment until suitable alternatives become available. Others are members of national banking organisations.

What would you have done differently: Set up banking operations earlier.

7.5.3 Service 'C'

Have eliminated and are in the process of eliminating halon 1301 from buildings. This involves computer rooms, electronic and communication facilities. Have implemented a four year plan to decommission all systems in infrastructure. Will continue to use halon 1301 in aircraft, ships, and combat vehicles.

The requirement to replace the level of protection required for halon fire protection systems is determined on the merits of a risk analysis. The replacement can range from a reinforced fire prevention program to a full engineered automatic system. In locations where there is a 24/7 hour watch by the operators of the equipment, expensive automatic protection may not be required, therefore, there will be no replacement of existing automatic suppression system. In areas where operators work normal day routines, it is possible to provide protection without automatic protection by providing a good early detection system reporting to the fire department. In most cases adequate protection can be provided by the use of smoke and fire detection system; fire resistive barriers; low flammability cable and wire insulation; minimize combustible load of contents, emergency shut-down systems and procedures; control of smoking materials and other appropriate measures for the hazard. The application of a single alternative fire protection method may not, in itself, be sufficient to replace a halon suppression system; however, the more single steps that can be combined to provide overall fire protection options to halon the better.

They are conducting R & D into fine mist water spray as a possible means to protect certain compartments onboard Naval vessels.

Plans are medium (4 years) for replacement of non-essential systems and extinguishers. Critical systems will be replaced as part of a long term plan.

Conduction of R & D in the area of early detection and fine water mist sprinkler systems, is continuing.

They are setting up own independent bank to provide regenerated halon for essential operations.

The bank will contain halon 1211 and 1301 from systems and extinguishers that has been removed from use.

The bank operates by the gas being removed from the various size cylinders, recycled to Military specification and stored in large tanks - 25 tonne capacity - until it is required. No disposal of gas is planned at this time.

7.5.4 Service 'D'

Replacing all halon 1211 extinguishers with CO2, dry chemical (as applicable) within a 5 year programme.

Removing halon 1301 systems as funds become available. This agent is only used in electronic equipment areas.

Where water based systems are considered acceptable, they will replace Halon 1301 installations. Most remaining halon systems will be replaced with NFPA-2001 agents.

All plans for change out are long term.

One critical use for which no alternative has yet been identified is the Special Research Unit.

To help find suitable alternatives it has funded a 3 years study under "Small Business Innovate Research" programme. Project identified Perfluorocarbons as an alternative.

Many systems being installed. Government approved for 1995.

The service has its own bank management programme in place.

Any halon 1301 cylinders removed from service are sent to contractors where the agent is reclaimed into large storage cylinders.

There is no disposal strategy plan in place. Should any surplus be declared it will be turned over to the U.S. Military.

The Company is very pleased with the efforts to date to manage change.

7.6 National Power Industry

7.6.1 Company 'A'

Halon 1301 has been eliminated from the control rooms and uninterruptable power supply room.

Currently working on a plan to put modular CO2 injection into unoccupied areas.

Presently are assessing the best way to protect gas turbine enclosures and localised control panels for gas turbines.

All changes to be made are long term.

The most critical area needing protection is the control room of power stations, and associated control gear in the equipment room.

On the way to find suitable alternatives they are interacting with various international consultants, manufacturers and utilities.

A timeframe has not been set for the implementation process for alternatives.

The company does not belong to a halon bank.

Industry suppliers have been able to meet all needs up to 1993. For the future NTPC will use halon that is recycled.

There will be no surplus halon 1301 available until such time as a suitable alternative is developed and commercially available.

Should we have been able to put the clock back to manage change out, the ideal solution would have been the development of water hardened cabinets for fire control, this would have allowed the use of more sprinkler systems.

7.6.2 Company 'B'

The best available information on halon use by our company is based on a survey that we carried out in 1989; a new survey is presently being carried out. The 1989 survey indicates that our company has approximately 27,000 kgs of halon 1211 and 15,000 kgs of halon 1301. We expect that our total holdings will be higher as purchases continued until 1991.

Halon 1301 total flooding systems have not been replaced, except within our "Grid" Business Unit. The "Grid" has changed-out 6 of 12 halon 1301 total flooding systems with an alternative agent (HFC 227ea). The halon 1301 was sold to a certified halon recycling contractor. This Business Unit is presently looking at inert gas mixtures as another alternative agent due to the costs associated with HFC 227ea.

After carrying out a preliminary inventory, we are now finding that halon 1211 is more widely used than first thought; especially in non-critical areas. Some Business Units may have surplus halon 1211, while others may not have adequate supplies to supplement critical applications.

Halons will be managed in the short-term to meet our needs with respect to firefighting capability. In the long term, environmentally sound management practices will be pursued and when necessary, may include destruction of halons. The following is our approach to halon management:

Short term objectives:

- purchase of any new or recycled halon discontinued
- UNEP criteria used as a guide to determine "critical applications"
- non-critical applications for halon removed from service and placed in a licensed storage facility managed by our company
- halons held in storage used to supplement systems in critical areas based on expected discharge frequency and facility life expectancy
- excess halon surplused to a certified recycling contractor for recycling and allocated to an essential user

Long term objectives:

- A division of our company is to identify opportunities for the development of destruction technologies capable of destroying CFCs and halons
- retire critical use halon and place it in storage when applicable drop-in alternatives become available
- Destroy critical use halon held in storage when necessary

7.7 Electronic Industry

7.7.1 Company 'A'

The company has eliminated halons from computer rooms, offices, warehouses, electrical power stations and central control station.

Alternative methods of protection have been achieved by the introduction of improve automatic detection systems.

Currently are looking at alternative methods of protection for the central station and a small warehouse for flammable liquids store.

All plans for change are short term and should be in place within two years.

Discussions are taking place with the 3M Company to find suitable alternatives.

The Company is not aware of the existence of halon bank schemes.

It does not have any support for its existing halon systems within the country.

The disposal strategy has to be developed.

7.8 Conclusions

The review of these case studies recognised the need to obtain opinions of industry on the strategies developed internally to protect their business interests prior to the cessation of halon production and how they see a future without this agent.

The response to the survey request in terms of returns received was excellent. This highlighted the level of responsibility exercised by a large number of industries, by ensuring they have put in place strategies that are achievable in terms of short, medium and long goals to meet the objectives of the Montreal Protocol.

Life without halon can be described in terms of a baby taking its first steps to walk without the aid of its guardian. Some industries have moved very quickly in declaring they can protect their risks scenarios without halons. Consequently they have developed alternative strategies, by way of improving their internal housekeeping practices, and introducing alternative fire protection measures such as improved passive protection, early smoke detection, water and gaseous systems. Other industries are moving a little slower in this process, but ground rules are in place to bring about change, this will continue to gain speed in the foreseeable future.

It is very obvious that there is a current and future need for halons in areas that involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. However, it has also been determined by the results of this industry survey that with well planned fire protection strategies in place it is possible to conserve and make available surplus stocks of halons that can be recycled, banked and made available for areas of critical need.

8 Eliminating halon dependency in developing countries

Fire protection is a basic service of a community. Public fire departments have evolved due to community efforts to protect inhabitants from the risk of personal injury or death from fire and the risk of catastrophic loss resulting from fire. In order to provide this basic service to communities fire brigades are organised and basic fire protection rules are developed. The fire brigade usually has the dual responsibility of fighting fires and ensuring that fire prevention measures are enforced.

Where values warrant it, many people insure themselves against the potential catastrophic results of fire. Insurance companies may require that measures, in addition to those required by law, be instituted in order for the property to be eligible for insurance.

In addition some property owners, especially those with high values or those providing an important public service may apply their own more stringent fire protection measures.

To fight a fire equipment is required, as a result enterprises or agencies are established to supply fire equipment.

In general fire equipment must meet certain established standards, verified by test. Standards for such testing are therefore developed within the country or technical standards developed externally are used. As well testing agencies may be established within the country or the mark applied by an independent testing agency in another country accepted.

We are therefore beginning to see an established structure that encompasses public fire protection authorities, insurers, important users, fire equipment suppliers, testing agencies and standards writing agencies. This structure is typical, at least in part, in virtually every country. This structured fire protection community has the resources and the ability to control the use of halons.

Country Categories

It may be practical to consider the following three categories to describe typical situation:

A. Countries that produce halon(s) and manufacture halon based fire equipment.

B. Countries that consume (import) halon and manufacture halon based fire equipment.

C. Countries that consume (halon) and import halon based fire equipment.

Use of import data for bulk consumption of halons as a basis for categorizing countries may result in an erroneous basis for developing a viable country programme. Many countries may appear to be "small" however they may have very important halon installations that were imported pre-charged and are used to provide fire protection for very important installations such as telephone exchanges, power generating facilities and military equipment/facilities. As a result, although their imports of bulk halon may have been quite small, their installed system base (bank) and holdings of portable halon extinguishers (bank) may be larger than their bulk import data would reflect. This idea of categorizing "Small Halon Consuming Countries" based on import data of bulk halon will often be an incorrect basis for an assumption, because in all cases of Category C countries (see above) bulk imports will be much less than halon shipped into the country in fire equipment and for the purposes of Import it would not be classified as a bulk import. The Montreal Protocol also does not classify halon contained in fire equipment as a bulk import and therefore does not require reporting of imports of halon contained in fire equipment. In summary, much of the data that would be used to determine consumption as defined by the Montreal Protocol will be seriously flawed because it will not reflect the actual use or stocks held within the country.

Assessing uses and stocks of halons within a country

Halons have been used in much the same applications all over the world. Major use has been in the Petroleum and Chemical Industry, Defence, Telephone and Telecommunications, Financial Sector, Aviation, Cultural Heritage, Power Generation and Distribution, Industrial Control Rooms and general applications in Computer Facilities operated by businesses. Halon systems are also typically found in private telephone exchanges operated by hotels and financial services companies. Although this is not an inclusive list, in general it is the list that provides a good place to start in assessing the halon stocks that may exist within a country.

Action plan

The elimination of halon dependency is a logical, step by step procedure, that should be implemented in the following order:

1) Build awareness of the problem of ozone depletion

2) Commit to phase out of halons

3) Reduce unnecessary emissions and uses of halons

4) Switch to alternative fire protection methods

5) Develop halon bank management and recycling - eliminate need for newly manufactured halons

6) End halon production

Build awareness of the problem of ozone depletion

The fire protection community within the country must be made aware that in addition to posing an environmental threat, halon based fire protection equipment is a poor investment because it will be unsupportable in the future. Therefore the first step is to build awareness within the fire protection community. This can be accomplished by informing the public fire service, insurers, fire equipment manufacturers and suppliers, standards writing organizations, testing agencies and halon users.

Commit to phase out of halons

It would be wise for the fire protection community and the national government to agree to cap halon availability at existing levels, as soon as possible. It would also be wise to agree to a schedule to reduce availability of halons annually and eliminate dependency on newly produced halons in as timely a manner as feasible.

Reduce unnecessary emissions and uses of halons

An obvious first step is to reduce unnecessary atmospheric emissions of halons. The following may be of assistance in accomplishing this:

Portable Fire Extinguishers

Change regulations to ensure that halon 1211 portable fire extinguishers are not used to achieve compliance with legal fire protection requirements, this will encourage use only for cases where a clean fire extinguishing agent is actually required.

Ensure that during maintenance and when internal inspection of portable fire is required, recycling equipment is used to capture and recycle halon 1211.

Fixed Halon Systems

Discharge testing of halon systems can be virtually eliminated by use of a door fan test to check ability of the protected enclosure to contain the halon and by use of other non-destructive testing procedures.

Improved detection systems and maintenance procedures have been shown to reduce unnecessary emissions of halon resulting from leakage and inadvertent discharge.

Switch to alternative fire protection methods

The process of eliminating halon dependency can begin by carefully considering each proposed use of halon fire fighting equipment.

The following criteria should be satisfied before reaching the conclusion that a halon use is essential:

A critical need must exist to minimise damage due to fire, explosions or extinguishing agent application, which would otherwise result in serious impairment of an essential service to society, or pose an unacceptable threat to life, the environment, or national security

and

All other appropriate fire protection measures have been taken.

It should be noted that “critical needs” does not mean all uses. Users should recognize that existing stocks of halons are a finite fire protection asset. This asset must be used wisely.

In the developed countries, dependency on newly produced halons has been eliminated without a replacement chemical for halon 1211. For most applications, conventional alternatives such as water, dry powder and carbon dioxide provide adequate fire protection capability. The alternative for portable fire extinguishers is phase out of manufacture of halon extinguishers and increase in the manufacture of multipurpose dry chemical fire extinguishers. Development of a water fog fire extinguisher is also a relatively simple option.

For fixed system applications, in the majority of cases where halons had traditionally been used, early warning fire detection systems combined with conventional alternative fire protection systems such as water sprinklers and carbon dioxide systems have been the alternate of choice. Where a municipal water supply is available, the cost of a conventional sprinkler system is lower than halon protection.

As well innovative fire protection systems using readily available fire extinguishants such as water mist and inert gas mixtures have been developed and rapidly commercialized in countries that required early phase out of halon imports.

Presently available clean agent alternatives are:

- Inert gas mixtures
- HFC-227ea
- HFC-23 — for countries that presently produce HCFC-22, HFC-23 may be an alternative for halon 1301 as it is often produced as a by-product when HCFC-22 is produced.
- HCFCs — Although HCFCs are an available option, those presently available are not considered as having advantages over other alternatives. The Halons Technical Options Committee does not consider the use of HCFCs as necessary to achieve halon phaseout for Article 5 countries.
- PFCs — Although PFCs are an available option, those presently available are not considered as having advantages over other alternatives. The Halon Fire Extinguishing Agents Technical Options Committee does not consider the use of PFCs as necessary to achieve halon phaseout for Article 5 countries.

For Category A Countries there will be a need for conversion projects for production facilities. HFC 227ea and HFC 23 are both chemical alternatives that can be used in fixed systems and may be considered as they would typically be produced in a similar manner to halons. The production of HCFC and PFC compounds would be an unwise selection for conversion to by a developing country as it is unlikely that these alternatives will have commercial lifetimes sufficient to justify capital investment. It is also unlikely that the use of either HFC compound previously mentioned in this paragraph will be produced at the same production level as halon 1301 or halon 1211. In the future, other alternatives such as dry chemical, inert gas mixtures, carbon dioxide and fine water mist systems are likely to be used as alternatives in well over 50% of the applications that would of been protected by halons had their use continued. Conversion projects must be examined very carefully because the type of enterprise that produced halon will not likely be the same enterprise that produces alternatives.

For Category C and B Countries that produced halon fire equipment, the manufacturing operations that fabricated halon portable fire equipment and those that fabricated halon fixed systems equipment will likely make up for the loss of production of halon fire equipment by manufacturing alternative based equipment. For portable fire extinguishers the overwhelming choice has been a switch to multipurpose dry chemical fire extinguishers. Often the same enterprise that manufactured halon fire extinguishers also made dry chemical fire extinguishers. For manufacturers of halon fixed systems, HFC 227ea can be used in halon type fixed system hardware with minor modification - more cylinders are required to achieve equivalent areas. For inert gases and HFC 23, carbon dioxide systems type hardware can be used. In some cases, similar pressure vessels, typically used for halons, could be employed to fabricate self-contained fine water mist hardware. Conversion projects for fire equipment manufacturers should be examined carefully. In some cases halon fire equipment was produced in competition with conventional non-halon fire equipment. In some cases there may be sufficient existing manufacturing to fulfil needs for alternatives and in fact funding could create an unfair situation where an existing manufacturer based on private funding is suddenly faced with a new competitor whose costs have been subsidised.

Develop halon bank management and recycling - eliminate need for newly manufactured halons

Once halon supply is restricted, recycling becomes a cost effective way to extend the life of halon fire equipment, protect capital, investment and meet critical fire protection needs. Typically critical needs have accounted for less than 10% of halon usage.

An example of the elements that have been used in a successful halon bank management programme include the following:

1. Establish a Steering Group consisting of representatives from interested organizations within the country. This will typically involve the public fire authorities, insurers loss prevention engineers, fire equipment companies, large users.

2. Undertake a study of the likely applications where halons have been used within the country and prepare an estimate of the size of the installed base of both halon 1211 and halon 1301.

3. Examine any changes in regulations that will reduce unnecessary emissions of halons. This may include requirements for internal inspection of cylinders, discharge test and training regulations, etc. In some cases there may be regulations that require the installation of halon fire equipment. Work with the appropriate organizations such as standards writers, public fire protection authorities to ensure that regulations do not require unnecessary discharge or use.

4. Develop preliminary plans for recycling including who will operate equipment, who will act as a clearinghouse, how cost recovery will be achieved, how people will be advised of the fact that recycled halons will be available and how they will know who to contact to either provide or receive halons. Develop simple brochures to be distributed by trade associations and industry groups. Develop labels to be applied to halon fire equipment to advise users to recycle their halon when they no longer require the equipment. Provide news releases to trade magazines to explain to users what action is being taken.

5. Hold workshops to explain the problem of ozone depletion and the efforts made by the Fire Protection Community as represented by the members of the steering group to reduce use and emissions and explain plans for recycling of halons. Educate users about alternatives that can be used.

6. Develop final plans for halon banking and acquire halon recycling equipment and computer programs to manage the Halon Information Clearinghouse

7. Conduct engineering training programmes for fire equipment companies, large users, specifiers, fire authorities and loss prevention engineers to provide them with the knowledge to implement alternatives safely and effectively.

8. Hold large scale workshops to explain the final halon banking and recycling programme and provide users with an overview of alternatives.

9. Follow up with Steering Group to continue technology transfer and monitor the effectiveness of the programme.

Where to get assistance

Financial and technical assistance is available to developing countries wishing to eliminate halon dependency. The Montreal Protocol Multilateral Fund has been established to help.

The Montreal Protocol implementing agencies are the World Bank , United Nations Environment Programme Industry and Environment Programme Activity Centre, UNIDO and UNDP. Each of these agencies offers particular expertise in assisting developing countries in eliminating the need to use ozone depleting substances, including halons.

Conclusions

The elimination of halon dependency is a logical, step by step procedure, that should be implemented in the following order:

1) Build awareness of the problem of ozone depletion

2) Commit to phase out of halons

3) Reduce unnecessary emissions and uses of halons

4) Switch to alternative fire protection methods

5) Develop halon bank management and recycling - eliminate need for newly manufactured halons

6) End halon production

The production or conversion to use of HCFC and PFC compounds would be an unwise selection for a developing country as it is unlikely that these alternatives will have commercial lifetimes sufficient to justify capital investment.

9 Essential uses and their needs

9.1 Introduction

Halogenated fire suppression systems have been installed primarily to provide a very high level of property protection with minimal secondary damage and minimal disruption to resumption of operations. In some cases, halon systems are installed principally to protect human life from death or traumatic injury due to fire or explosions.

Decision IV/25 gave a special meaning to the designation 'essential' under the terms of the Protocol. The protection afforded by halon must be deemed 'essential' by the Parties in order for them to approve an application for an exemption to the halon control measures.

When considering whether or not protection afforded by halon is 'essential', it is necessary to balance the environmental risk posed by the ozone depletion potential of the agent against the social implications of the immediate affect on human life, the environment, and national security. Ultimately the decision must be made by policy makers, after full consideration of all factors. Nevertheless, it is the opinion of the Halons Technical Options Committee that there are fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halon or a yet to be developed gaseous agent with similar properties. Examples of such situations can be found in military applications (e.g. armoured personnel carriers, command centres, etc.), the industrial processing of flammable liquids and gases (e.g. crude oil production, flammable liquids pumping facilities, etc.) in certain geographic regions, and aviation (e.g. aircraft engine nacelles, cargo bays, etc.). In each case, human beings are likely to be subjected to life threatening situations should a fire or explosion occur that could not be rapidly suppressed. It is the unique ability of the halons to provide this function that renders the protection afforded by their use 'essential'.

A minority of current uses of halon fall into this category, but for those that do, such needs are ongoing and must be addressed now that halon production has been phased out in the developed countries. It is also noted that in some cases existing facilities have been designed and constructed in such a manner that reduction of fire risk to acceptable levels is dependent on the use of halons over the life of the facility. Design and construction of future facilities providing similar functions offers the opportunity to reduce halon dependency by utilising other appropriate fire protection measures. Therefore all appropriate fire prevention and protection options must be considered before arriving at a conclusion that halon use is necessary for the protection of facilities designed and constructed in the future.

Although some protection scenarios are obvious, such as the examples previously listed, others will be affected by geographical location, climate, changes in technology, and the individual needs of a nation's security. Also, the criticality of facilities to be protected can change. For example, telephone exchanges are very important in providing essential public services, but new technology now allows for redundant or alternative communication paths. Is their protection by halon still essential, or does the availability of alternative communication paths reduce the dependency on a given facility?

9.2 Essential Use Criteria

The term 'essential' should be qualified in that it is not the halon that is essential but rather the criticality of a particular facility or piece of equipment afforded protection by halon, or the mitigation of a threat to life, that is of concern.

The key benefit of the halons is that from a fire protection stand-point they, unlike other extinguishing agents, do not cause secondary damage to protected facilities and do not constitute an unacceptable risk to persons in the immediate vicinity when discharge occurs. As such the halons can be applied at a very early stage of fire development without risk of physical damage to the facility or equipment, or an unacceptable risk to the occupants. This is of particular importance for facilities where there is a critical need to minimise service interruption.

A second important ability offered by the halons is their suitability to prevent and/or suppress explosions. For certain facilities where flammable gases/liquids are processed or transferred, halons are used to 'inert' in the event of an accidental release of the flammable gas/liquid. The release of halon into the enclosure prevents an explosion from occurring, allows personnel to evacuate, and corrective actions to be undertaken (see Section 4 for more information on explosion protection).

Although the use of halon is desirable in a wide range of facilities where the important characteristics indicated above are valuable, the importance of protecting the ozone layer is critical. It is for this reason that the Parties decided in Decision IV/25 to apply the following criteria in assessing an essential use for the purpose of control measures:

that a use of a controlled substance [halon] should qualify 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.

9.3 Meeting The Needs Of 'Essential Uses'

Having established that there are fire/explosion risk scenarios that require protection through the use of halon or halon-like substances, the next question is how best to meet those needs following halon production phase out in the developed countries, and prior to the phase out in the countries operating under Article 5, Paragraph 1 of the Protocol. This question can be best addressed by considering three options:

9.3.1 Newly Developed Alternatives

Several replacement clean agents and new 'not-in-kind' alternative technologies are now commercially available. These alternatives, which include inert gas mixtures, HFCs, and water mist technologies, meet the needs of many critical use applications. Aggressive programs to find other clean, chemical replacement agents, and to commercialise other technologies such combustion generated aerosols, continues (see Sections 2 and 3, and Appendix D).

Despite the limited success of the current alternatives, the Committee notes that its support for an early phase out of halons was based, in part, on the commercial availability of fire fighting chemicals whose environmental or toxicological properties have subsequently been determined to be unacceptable. Research to date has not produced the anticipated environmentally and toxicologically acceptable alternatives required to meet the needs of some critical applications, placing increased pressure on the banked halons. The Committee believes, therefore, that the contribution of the resources of national governments in helping with basic research, toxicology testing and fire testing is necessary to assist in speeding the commercialisation and availability of other, yet to be developed, replacement extinguishing agents.

9.3.2 Recycled Halon

There is a large inventory of halon stored in fire extinguishers and system containers awaiting use. At the end of the useful life of an extinguisher or fire/explosion suppression system, and as public awareness grows, it is important that this halon becomes available for transfer from one use to another. It is estimated that in the case of halon 1301, as much as 20% of the amount supplied in 1986 will be available annually for at least the next 20 years by recycling alone. The problem is one of establishing recycling facilities and procedures for managing what is known as the "Halon Bank".

Leadership and funding by agencies of national governments, believed to be the largest users of halon in critical applications, is crucial to the effort to encourage investment in recycling facilities and the formation of national halon banks, as discussed in Section 6 and Appendix C of this report. Recycled halon has the best potential for meeting the fire and explosion protection needs of critical facilities and human life safety now and in the foreseeable future. For this reason, it is also important that halons not be destroyed if they can be recycled and redeployed for critical applications. Co-operation at the international level must be established to ensure that a nation with surplus halon does not destroy what amounts to another nation's future supply. The recycle and reuse of an important fire protection asset avoids or delays the need for production exemptions, or production to meet the basic domestic needs of countries operating under Article 5, Paragraph 1 of the Protocol.

9.3.3 Additional New Production of Halons 1211 and 1301

Avoiding the production of additional halon after normal production in the developed countries has ceased, even to meet the needs of essential uses, is important for two reasons. First, because of the potential for greater ozone depletion. Second, allowing additional production, after the production phase out date, may not encourage recycling, bank management and the rapid commercialisation of environmentally acceptable replacement fire extinguishing agents. The Committee believes that, on the basis of the nominations submitted for 1995, there is no need to make provision for additional new halon 1211 or halon 1301 production to meet the needs of essential uses for the year 1995. However, the Committee also believes that it is inappropriate to make a decision on the long term need for additional production at this time, and recommends that the current annual review process continues.

9.3.4 Special Needs Related to Halon 2402

Halon 2402 has only been used and produced in significant quantities in Eastern Europe but, due to international trading, some equipment protected by halon 2402 is also in use elsewhere. However, by far the majority of the uses of halon 2402 have been for critical military applications, and it is therefore believed that the 'bank' of 'recyclable' halon 2402 is very small and may not meet current and future needs. In the former USSR, halon 2402 consumption amounted to some 4000 tonnes per year, including imports from both Japan and Italy. At present, the consumption of halon 2402 in Russia has been reduced by 90% to 400 tonnes per year. It is believed that Russia is now the only producer of halon 2402, that stocks are small, and recycling and banking are just beginning. In Russia, halon 2402 is used only where fire protection needs are critical and, according to Russian experts, there is an ongoing need for about 400 tonnes per year.

The Halons Technical Options Committee notes that there are technical reasons why the phase out of halon 2402 in countries whose economies are in transition may not happen without assistance. For these reasons, the Committee believes that, although no nominations were received, additional production of halon 2402 may be required in 1995 and later years whilst an orderly phase out program in these countries is implemented.

9.4 Special needs of Parties operating under Article 5, Paragraph 1

The Halons Technical Options Committee recognises the special needs of countries operating under Article 5, Paragraph 1 of the Protocol that will not have adequate halon banks to support the protection needs of critical facilities and life safety. In particular, now that the production facilities for halon 1301 have been closed in the major industrialised nations, the 10 year grace period for production and importation of halons afforded these countries may not be of any assistance to them in meeting their basic domestic needs. This is likely to become a major problem unless they are encouraged away from investment in halon 1301 protection systems. The Parties may therefore wish to consider special measures to address these concerns, as outlined in Section 8 of this report, and to assist in providing ready access to recycled halons.

9.5 Conclusions

The Committee recognises that there are a few fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These risk scenarios involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. At the same time, the Committee is of the qualified opinion that, with proper management, the future needs of the majority of these risk scenarios can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires. The Committee also notes that application specific, replacement extinguishing agents and alternative technologies are now commercially available, although environmental and toxicological concerns have limited the acceptability of some promising replacements. However, it is believed that in the long term, use of the current replacements and alternatives, and others that will be developed in the future, will likely restore the capability to provide fire protection with similar desirable characteristics to those of the present halons for all risk scenarios.

With the possible exception of halon 2402 applications in countries whose economies are in transition, the requirement to produce new halons for critical applications can be avoided by use of halon recycling and banking schemes, and by the early introduction of halon replacements and alternative technologies. Although it may be necessary to reconsider this issue again in the future, the combination of successful bank management, the proper utilisation of zero ODP, environmentally acceptable halon replacements, and the acceptance of alternative technologies, offers the best potential to eliminate the need for a production exemption for essential uses in the foreseeable future.

Establishing a fixed list of risk scenarios that would qualify for a production exemption is neither appropriate or necessary at this time. Continued use of the criteria detailed in this section is the best option at this time and for the foreseeable future. Parties are encouraged to co-operate with the international fire protection community on bank management, emission reduction and the wise future allocation of the banked halons, and to use their national resources to assist the research community in the development of acceptable halon alternatives.

Appendix A

The development of halon fire extinguishing agents and uses of halons for fire extinguishing

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; i.e. fluorine, chlorine, bromine, 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. Valence requirements not accounted for are assumed to be hydrogen atoms.

# of hydrogen atoms = [((# of carbon atoms x 2)+2)-(Sum of halogen atoms)].

Example: Bromotrifluoromethane - CF_3Br - halon 1301

Halons extinguish fires by interfering with the complex chemical chain reactions of fires and explosions. For most other fire extinguishing agents physical effects, such as cooling or smothering are the means employed to suppress fires.

The first halon to be used as fire extinguishant was carbon tetrachloride (halon 104). Initial use probably occurred before 1900 and by 1910 portable fire extinguishers had appeared. The growing popularity of the automobile and other uses of internal combustion engines signalled an increasing need for fire extinguishants, such as carbon tetrachloride, suitable for use on flammable liquid fires.

By 1917, discussions began regarding the possible effects that carbon tetrachloride could have on the human system. In 1919 the first recorded deaths due to carbon tetrachloride use occurred. Two men working on the construction of a submarine were killed. One man's clothing caught fire and his colleague extinguished the fire with a carbon tetrachloride fire extinguisher. Both were overcome by the fumes and later died.

Methyl bromide (halon 1001) was discovered in the late 1920s. Due to its high toxicity it was never popular for use in portable extinguishers although it was used in British and German aircraft and ships during World War II. During World War II Germany developed chlorobromomethane (halon 1011) to replace methyl bromide. Toxicity of these early halons was of growing concern.

In order to meet the new fire protection challenges of World War II, engineers of the Central Fire Research Institute, Ministry of the Interior of Russia began formulating new gas extinguishing agents, including halon 2402, in 1937. Later, halon 2402 became the main extinguishing agent to protect Russian premises of top priority, especially those of the Ministry of Defence. Halon 2402 continues to be the halon of choice in Russia. Current uses of 2402 in Russia are in fixed extinguishing systems installed in computer centres, engine rooms of atomic ice breakers, aircraft and submarines and armoured carriers.

In the post World War II era, the addition of stearate to dry powder fire extinguishing agents improved flow and moisture repellency characteristics. This in turn encouraged the use of portable dry powder fire extinguishers as a viable alternative to vaporising liquid extinguishers that used carbon tetrachloride or other early halons as fire extinguishing agents.

By the 1950's use of the early halons (halons 104, 1001 and 1011) was ending. Increased popularity of dry powder and growing concerns with the toxic effects of the early halons resulted in their substantial phase-out by the 1960's.

In 1947, the Purdue Research Foundation (USA) performed a systematic evaluation of more than 60 new candidate extinguishing agents. Simultaneously, the US. Army undertook toxicological studies of these same compounds. As a result four halons were selected for further study: dibromodifluoromethane (halon 1202), bromochlorodifluoromethane (halon 1211), bromotrifluoromethane (halon 1301) and dibromotetrafluoroethane (halon 2402). Testing indicated that halon 1202 was the most effective fire extinguishant however it was also the most toxic. Halon 1301 ranked second in fire extinguishing effectiveness and was the least toxic. As a direct result of this program a portable fire extinguisher employing halon 1301 was developed for use by the US Army, primarily for use inside armoured personnel carriers and tanks. The US Air Force selected halon 1202 for military aircraft engine protection and the US Federal Aviation Administration approved the use of halon 1301 for commercial aircraft engine fire protection.

In the early 1960's the growing use of computers and other electronic equipment created a demand for fire extinguishing agents that would not cause secondary damage. Human tolerance to exposure was also viewed as a necessity as electronic equipment facilities were often occupied by people. Halons 1211 and 1301 combined these two desirable characteristics and were the only extinguishing agents that were considered as both "clean" and people safe. This combination of characteristics was of further benefit because it enabled automatic application of these agents at a very early stage of fire development using early warning type fire detection systems. This had been very difficult to achieve in the past due to concerns about human exposure to carbon dioxide systems, the only other clean agent known at the time, or concerns regarding secondary damage that could result from the use of water sprinkler systems.

The halons also exhibit excellent performance when used in applications involving the suppression or prevention of explosions involving flammable vapour/air mixtures.

Extensive studies on toxicological effects indicate that little, if any, risk is attached to the use of halon 1301 or halon 1211 when used in accordance with provisions of technical standards governing application of these fire fighting agents. Halon 1211 and halon 1301, when used in accordance with accepted technical guidelines, have a record of excellent fire fighting performance. As a result, the use of halon 1301 and halon 1211 grew significantly until it was recognised that halons were ozone depleting substances.

Halon 1211

Halon 1211 has an Ozone Depletion Potential (ODP) of 3 and has been the halon of choice for use in portable fire extinguishers. In commercial and industrial applications halon 1211 portable fire extinguishers have been used in computer rooms, museums, art galleries and in offices for the protection of equipment. Halon 1211 is not used in total flooding systems for areas where people would usually be present. Halon 1211 total flooding systems have been used to a limited extent in normally unoccupied areas where egress of personnel can be accomplished in less than 30 seconds. For all halon 1211 local application systems to be used in normally occupied confined spaces, a concentration calculation must be performed to ensure that halon 1211 levels do not exceed 2 percent concentration by volume within the confined space. Warning labels on halon 1211 portable fire extinguishers are usually provided to prevent use within small enclosures.

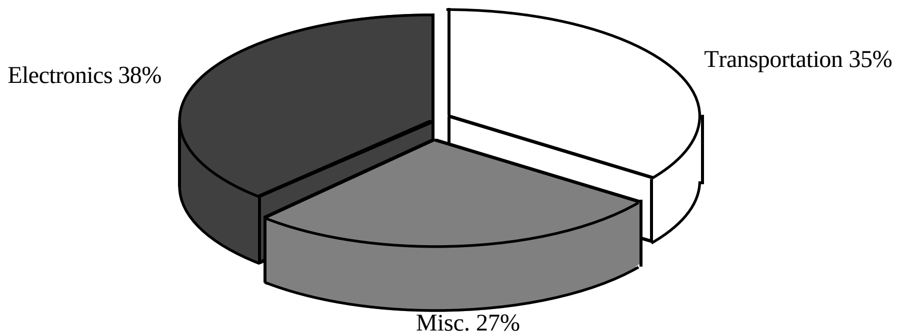
Halon 1301

Halon 1301 has an ODP of 10 and has been used in total flood, fixed systems, primarily for the protection of vital electronics facilities, such as computer rooms and communications equipment rooms. Other significant applications for halon 1301 systems have included: museums and art galleries; aircraft and shipboard engine spaces and hydrocarbon processing and pumping facilities. Most fires in normally occupied areas can be extinguished using concentrations of less than 7 percent halon 1301. Some fuels, such as toluene, require higher concentrations of halon 1301. For normally occupied applications requiring 7 to 10 percent halon 1301, evacuation must be accomplished within 1 minute. Halon 1301 total flooding systems utilising concentrations greater than 10 percent, but not exceeding 15 percent may be used in areas not normally occupied, provided egress can be accomplished within 30 seconds.

Halon 2402

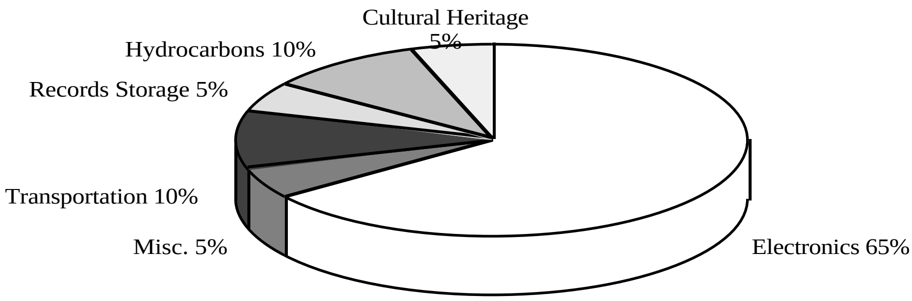
Has an ODP of 6 and has been used in both outdoor local application systems with personnel safeguards and inside spaces. In North America and Europe halon 2402 is used indoors only if not occupied by persons. Halon 2402 has also been used in manually applied fire equipment. The NFPA 12-C(T) standard required a fixed ventilation system to exhaust the halon 2402 after use. A warning alarm and other measures were also required by the NFPA 12-C(T) standard to prevent personnel from being exposed to halon 2402 vapours in concentrations of greater than 0.05 (500 ppm) percent by volume for ten minutes or 0.10 (1000 ppm) percent for 1 minute. Although halon 2402 is an effective fire extinguishing agent, use in North America and Europe has been very limited due to safety concerns.

Estimated 1990 Usage of Halon 1211 by Application



Note: The use pattern charts are provided for general information only and are based on the collective opinion of the members of the Halon Fire Extinguishing Agents Technical Options Committee.

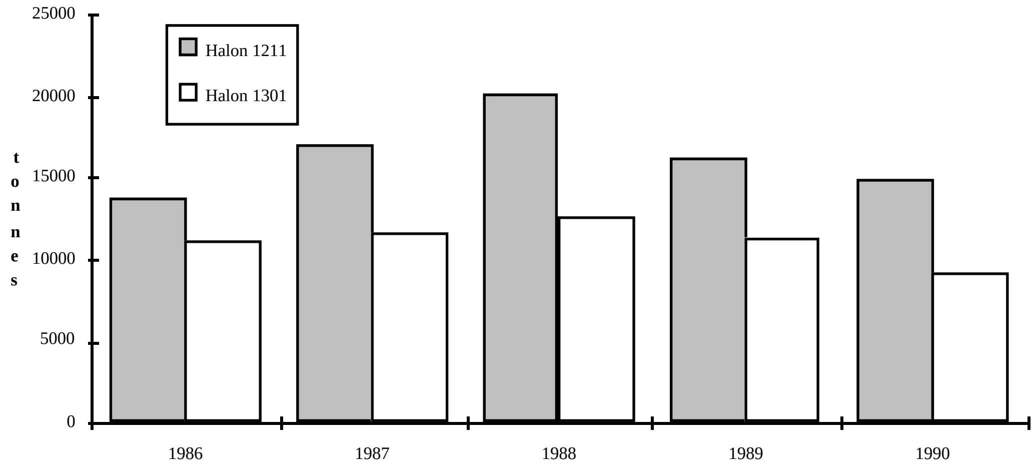
Estimated 1990 Usage of Halon 1301 by Application



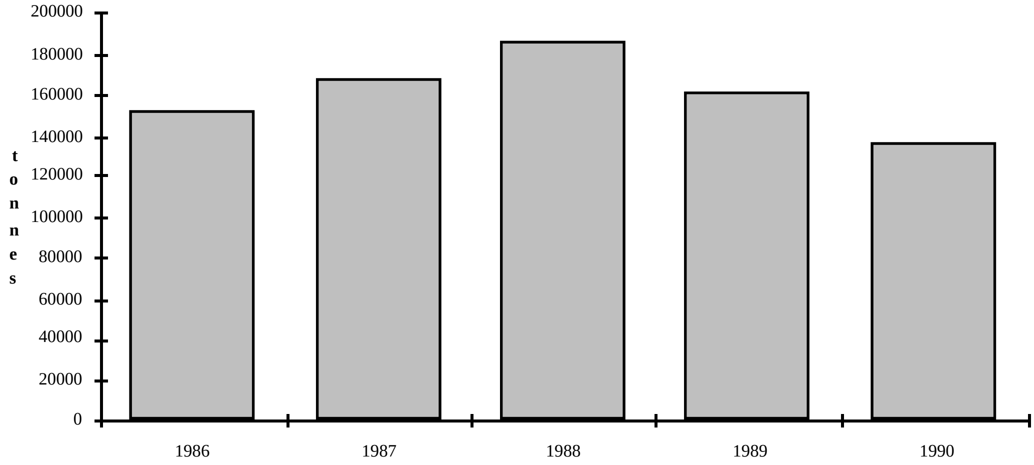
Note: The use pattern charts are provided for general information only and are based on the collective opinion of the members of the Halon Fire Extinguishing Agents Technical Options Committee.

Many fire protection organisations have been involved in public information programmes to reduce halon use and encourage the use of alternative fire protection means. As of January 1, 1994 all production of halon 1211, halon 1301 and halon 2402 by developed countries has ceased. Production of halon 1211 and very limited production of halon 1301 continues in some Article 5, Paragraph 1 countries.

Estimated World Production of Halons - 1986 to 1990 by actual weight (metric tonnes)



Estimated World Production of Halons - 1986 to 1990
(ODP weighted)



Halon 2402

In the former USSR halon 2402 consumption amounted to some 4000 tonnes per year, including imports from Japan and Italy. To date, after the break-up of the USSR and awareness of the ozone depleting potential of this halon, consumption in Russia has been reduced by 90%. It is likely that Russia is now the only producer of halon 2402. Russian experts state that there is practically no sufficient stock of halon 2402 in the country and recycling is in its infancy. Currently halon 2402 is used in Russia only for fire protection of objects of top priority. According to Russian experts evaluating needs of the country there is an ongoing need for 400 tonnes per year of halon 2402.

References

1. The SFPE Handbook of Fire Protection Engineering, Philip DiNenno ed., National Fire Protection Association and Society of Fire Protection Engineers, Quincy, Massachusetts, U.S.A.

2. An Appraisal of Halogenated Fire Extinguishing Agents - Proceedings of a Symposium, April 11 - 12, 1972, National Academy of Sciences, Washington, D.C., U.S.A.

3. Fire Protection by Halons, A compilation of articles from Fire Journal and Fire Technology, National Fire Protection Association, Quincy, Massachusetts, U.S.A.

4. Fire Protection Handbook, National Fire Protection Association, Quincy, Massachusetts, U.S.A.

5. Traite Pratique de Securite Incendie, Centre National de Prevention et de Protection, Paris, France

Appendix B

Estimated historic and future halon supplies

Annual supply

The total annual supply equals annual **Production**, plus annual **Recycle** in metric tonnes. **Production:** The term Production has been used in lieu of the Montreal Protocol term "consumption" to avoid confusion when used in conjunction with recycle of halons. The global production data were developed on the basis of audited, CEFIC production data with estimates for other world production data added. **Recycle**: Theoretically all halon that has been banked eventually becomes available for recycle. After extensive interviews and discussions regarding usable equipment life it became apparent that the life of the facility being protected was the governing factor rather than the life of the equipment. In many computer facilities, rapid technological change results in relatively short usable life times (as low as one year). In other applications, such as shipboard machinery spaces, longer usable lifetimes are to be expected. The term recycle includes recycle of the halon, either as a bulk chemical, or in the original system container. In the latter case, when a system is reconfigured, or reuse of system containers occurs, recycle is considered to have occurred. Halon 1211 recovered and recycled when internal inspection of portable fire extinguishers is undertaken is not included in this category. After 1994 annual Recycle is the major component of annual Supply. The graphs provided in this section show total supply as a percentage of the supply in 1986, the base year used by the Montreal Protocol.

Annual emissions

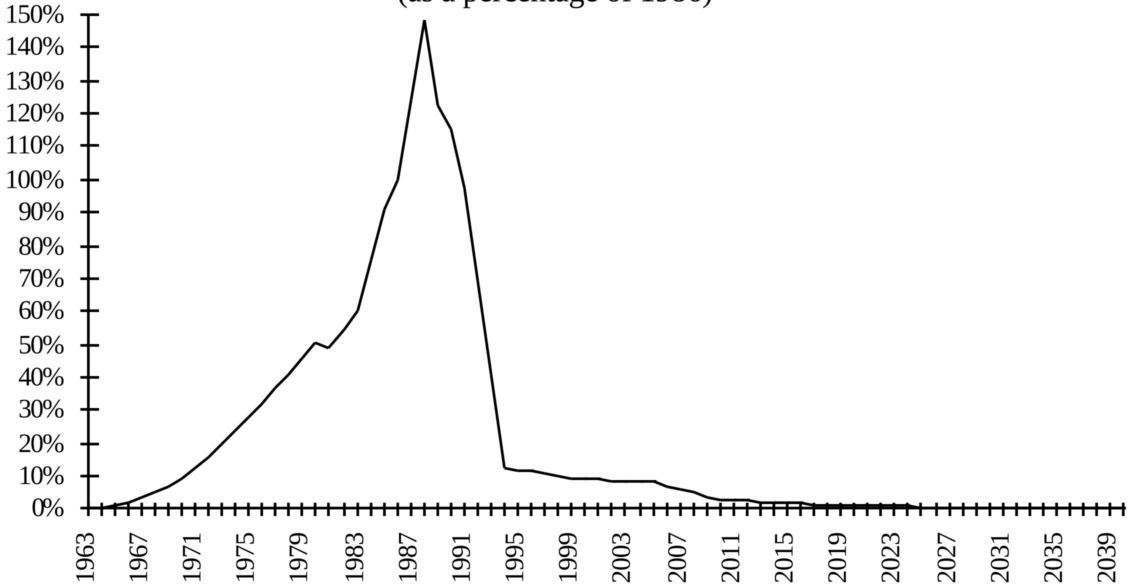
Annual emissions are derived from the total emissions from following sources: **Fires** - this is the quantity of halon used annually to extinguish fires. The quantity used is a factor of the bank size at the start of the year. Factors were developed from industry studies conducted in the United States and Europe. **Testing and Training** - in the case of halon 1301, this is the quantity of halon used to test fixed systems. In the case of halon 1211 this is the annual quantity used to train people in the use of fire equipment that utilizes halon 1211. **Other emissions** - these include service losses, leakage, false and unwanted discharges and the halon that is not recovered for recycle when the equipment that contains it reaches the end of its useful life.

Bank at the end of the year

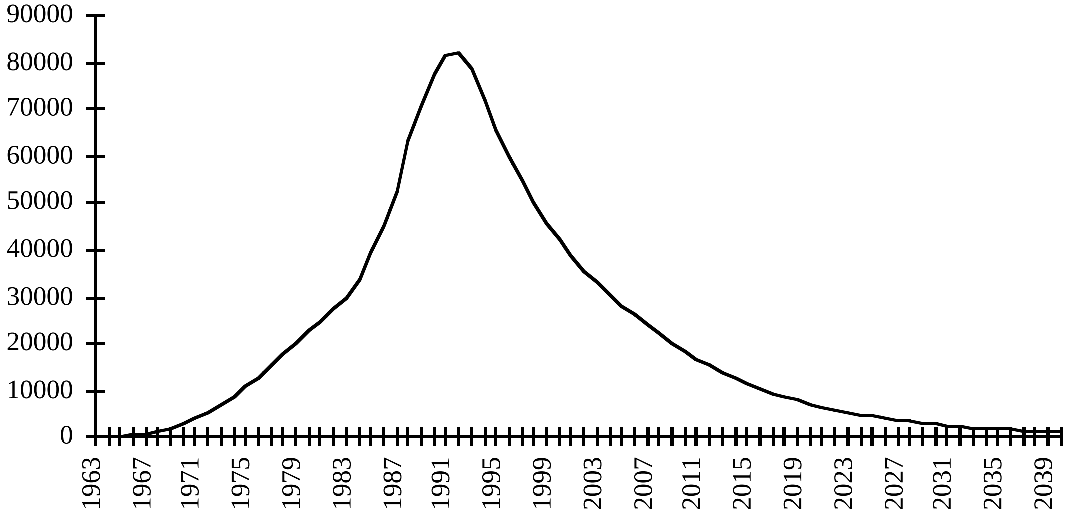
This is equal to the bank at the end of the previous year, plus new production (if any) and less all annual emissions.

Annual Supply of Halon 1211

(as a percentage of 1986)

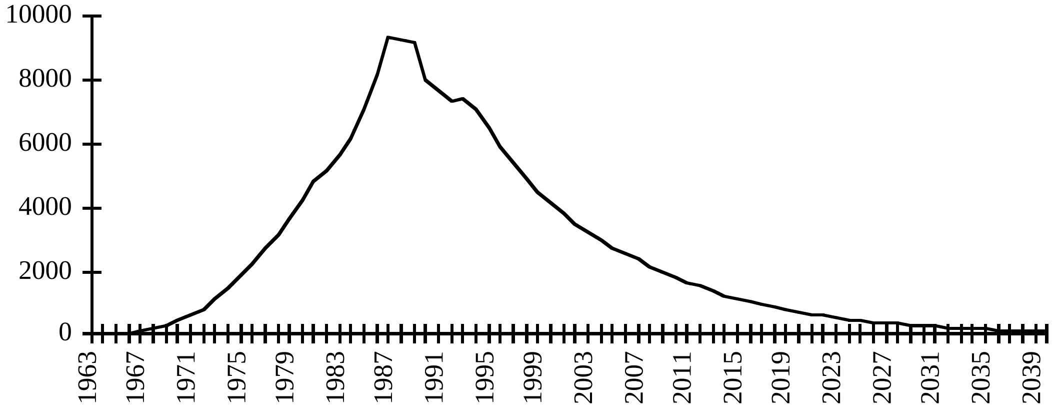


Bank of Halon 1211



(quantities are in metric tonnes)

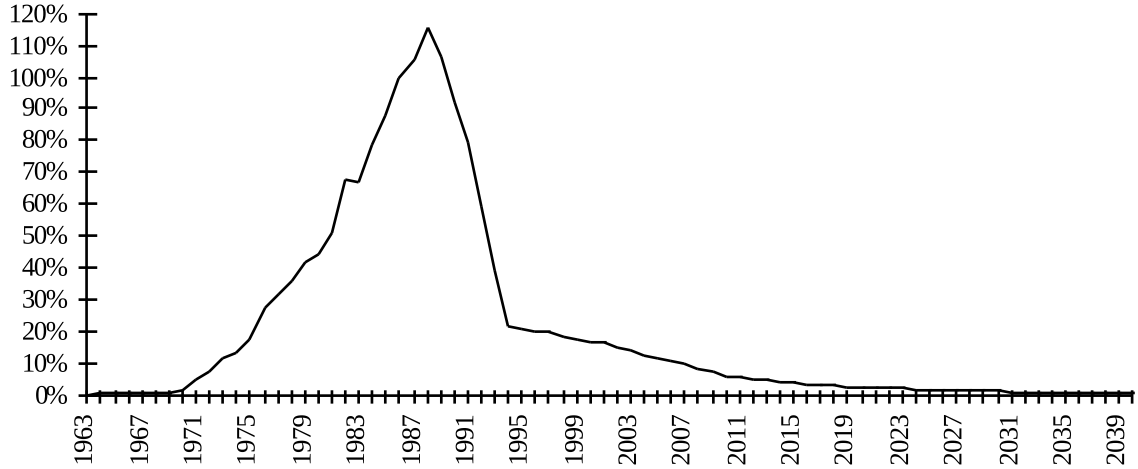
Halon 1211 Annual Emissions



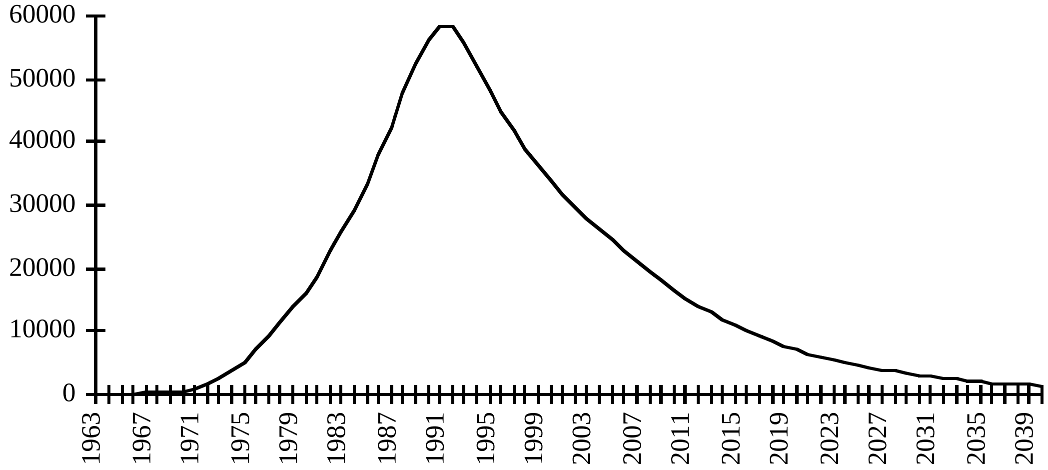
(quantities are in metric tonnes)

Annual Supply of Halon 1301

(As a percentage of 1986)

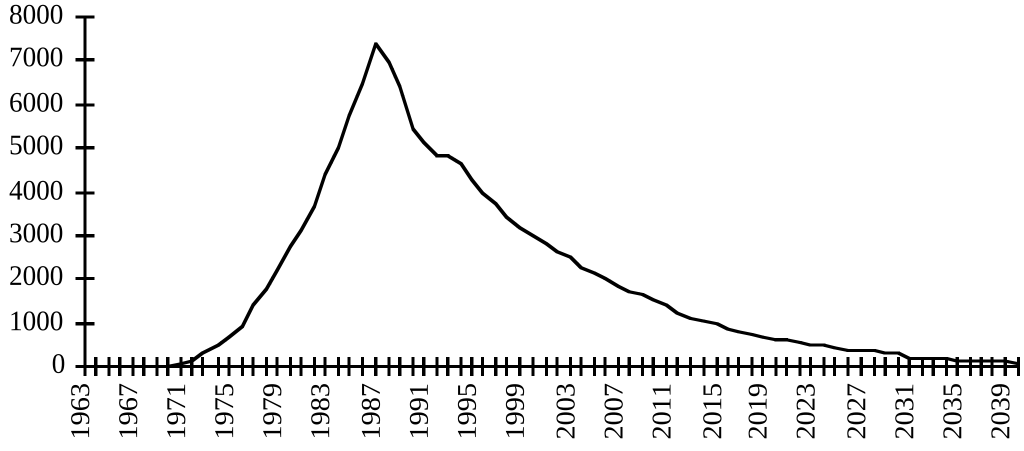


Bank of Halon 1301



(quantities are in metric tonnes)

Halon 1301 Annual Emissions



(quantities are in metric tonnes)

The computer program BANK generated the calculated quantities used to produce the graphs shown in this section of the report.

For halon 1211 based fire equipment the following base assumptions were used by the computer program. Equipment life has been estimated as 25 years. The computer program calculates that 4% of the additions to the bank for a year reach the end of useful life for each of

25 years thereafter. This 4% per year becomes the theoretical maximum available for recovery and recycle. The calculations for halon 1211 assume that before 1988 there was 10% recovery. Between 1988 and 1992 the recovery rate increases to a maximum of 50%. Interviews with North American fire equipment suppliers were the basis for these estimates and are much lower than for halon 1301 based fire equipment. This is not an indication of lack of effort by industry or others it is merely a reflection of the difficulty of recovering the typical small amounts found in a great number of widely dispersed hand held fire extinguishers.

For halon 1301 based fire equipment the following base assumptions were used by the computer program. Equipment life has been estimated as 20 years. The computer program calculates that 5% of the additions to the bank for a year reach the end of useful life for each of 20 years thereafter. This 5% per year becomes the theoretical maximum available for recovery and recycle. The calculations for halon 1301 assume that before 1988 there was a 50% recovery. Between 1988 and 1992 the recovery rate increases to a maximum of 75%. The shorter equipment life is due to application dependence. The study of North American and European halon use patterns used in the development of the computer program indicated that the useful life of the protected facilities was the factor that governed the life of the halon 1301 fire protection systems used to provide protection. The significantly higher recovery rates reflect the higher storage capacities of halon 1301 systems containers. A typical fixed system may provide a single source of more than 50 times the recoverable halon from a portable fire extinguisher.

Discussion

Estimates of total emissions of halons have been developed by two, independent methods. The first method developed by A. McCulloch of ICI Chemicals & Polymers Ltd. has been proposed in the paper "Global Production and Emissions of Bromochlorodifluoromethane and Bromotrifluoromethane (Halons 1211 and 1301). The second method was developed by Gary Taylor of Taylor/Wagner Inc. and was published as "Halon Bank Management, A Rationale to Evaluate Future World Supplies", Proceedings of Halon and Environment Conference '90, Geneva, Switzerland, October 1 - 3, 1990. Sponsored by BVD/SPI, CFPA Europe and NFPA.

Mr. McCulloch examined the estimates of production and emissions provided by chemical manufacturers to arrive at an estimate of total halon emissions, which was consistent with atmospheric concentrations. Mr. Taylor examined North American and European industry statistics relating to emissions of halons. These two methods produced order of magnitude estimates of total emissions that were similar. Both original papers presented at the Geneva Conference by Mr. McCulloch and Mr. Taylor have since been revised. The following chart compares the estimates of total cumulative emissions to the end of 1990 on the basis of atmospheric concentration and on the basis of emission estimates.

Estimated Total Cumulative Halon Emissions to the end of 1990

	On the Basis of Atmospheric Concentration	On the Basis of Emission Estimates
Halon 1211	102 165	101 894
Halon 1301	49 033	55 973

Note: All quantities are in metric tonnes

Appendix C

Country specific existing and proposed recycled halon bank management programmes

In Decision IV/26 the Parties to the Montreal Protocol asked the Halons Technical Options Committee to evaluate and compare existing and proposed recycled halon bank management programmes. An increasing number of countries, both developed and developing, have initiated or are operating bank management programmes. These programmes take different forms in different countries, and indeed one could argue that they must be different because of the different conditions in each country. A country's political structure, economic structure, and industry pattern will shape its programme, and thus each 'bank' will be tailor made.

All of the 'banks' set out below are in stages of relative infancy, and some are only in the conceptual stage. The descriptions and experiences are intended primarily as illustrations of what has been done in order to act as a guide for those who are thinking of starting a bank management scheme, whether they be Governments, users or suppliers of recycled halons. In addition, as further advice some of the descriptions also include lessons which those setting up the schemes have learned and initial operational experiences.

C.1 Australia

C.1.1 Introduction

Australia is a signatory to the international Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer. To support this commitment the Prime Minister in his "Statement On The Environment" in December 1992, announced the establishment of the Halon Bank to collect, store, decant and eventually destroy halon. Some halon may also be recycled for essential use purposes.

The Halon Bank provides a means of responsible disposal for users of halon, is fully operational and has been collecting halon since May 1993. With receipt of halon deposit costs (direct or subsidy) the Halon Bank assumes ownership and legal responsibility for the halon. There are Halon Bank Depots in each capital city and more will be established as required.

The Halon Bank as of February 1994 has deposited stocks of approximately 20 tonnes Halon 1301 and 50 tonnes Halon 1211.

The Australian Environment Council's "Strategy for Ozone Protection" provided the basis for Australian regulations. It recommended the phase out of non-essential use halon by 31 December 1995. The "Strategy for Ozone Protection" is currently under review and has been released for public comment.

The Commonwealth Environment Protection Agency (CEPA) has set in place limitations and licensing requirements for import, export or manufacture of halon to control its use and help meet Australia's obligations to the Montreal Protocol on Substances that Deplete the Ozone Layer.   Imports or manufacture of halon are no longer permitted in Australia.Each state has an environmental protection authority that is responsible for their state regulations controlling the use of halons. The regulations in place generally agree that:

- Containers that have reached their test inspection time are not to be re-commissioned.
- Containers can only be refilled for essential uses as agreed by the National Halon Essential Uses Panel.
- Personnel who maintain halon equipment need to have appropriate accreditation or permits.

The legislation in various States is also still being revised.

Business owners and managers must also consider that if an extinguisher is discharged (legitimately or not) it cannot normally be refilled (even if a supplier could be found) and so will compromise the business' fire protection system. Occupational Health and Safety (OH&S) Legislation and Duty of Care, must also be considered as the results of using halon are now clearly known.

The National Halon Bank is part of the Department of the Arts and Administrative Services, Centre for Environmental Management (DASCEM) and has been set up on a commercial basis. DASCEM was set up to deal with national environmental problems and is also currently active in energy management and the clean up of contaminated sites.

C.1.2 Factors Which Influenced The Type Of Bank Chosen

In Australia, three key factors determined the type of bank chosen:

a) The need for a safe final repository.
b) The inability to export.
c) The determination by Government to destroy rather than recycle.

C.1.3 Objectives

The primary objectives of the Halon Bank are to:

a) Secure the nations stocks of halon.
b) Efficiently dispose of non essential use halon.
c) Increase public awareness of the halon/ozone depletion problem.
d) provide a source of unbiased information on the issue.
e) Operate on a commercial bases in completing these objectives while minimising the cost to the country.

C.1.4 How The Organization Functions

The Halon Bank operates as a section of DASCEM, with direct access to technical specialists and office support. At present it has two dedicated full time head office management staff plus individual representatives located in the state capitals. Other DASCEM staff assist operations, particularly with promotional functions, in conjunction with other DASCEM projects. Collection handling, storage and transport is contracted to a Government distribution business, which has established an infrastructure and other complementary businesses to effect an efficient operation. Fire protection equipment suppliers and Fire Stations are also acting as deposit points for halon users.

Funding is provided by a deposit charged to the halon owners, who are invoiced on the contents rating of the deposited container whether discharged or not. At present the Federal government is providing a subsidy to cover the disposal cost for small businesses and community users of halon. In one state, South Australia, the state government is providing a subsidy for the disposal costs for those not covered by the federal subsidy.

C.1.5 Lessons Learned During Establishment

a) Convenient deposit centres must be established before public awareness and publicity programs.
b) Information on replacement alternatives should be made available.
c) Local community advertisements appear to be the most effective.
d) Follow up messages in different media (radio, local press, television, pamphlet, etc.) has been very effective. Radio and television news articles are the most effective.
e) Have the Fire protection maintenance industry adopt a code of practice that they make holders of halon aware of the issue. This effectively gets the message to bigger business.
f) In Australia, destroying rather than recycling is an advantage in persuading users to give up their halon.

C.1.6 Operational Experience.

The targets set for collection have not been achieved although a substantial amount of halon has been recovered. Some of the reasons for this are:

a) Cost (more for replacement than disposal).
b) Availability of replacements.
c) Convenience or lack of it.
d) Awareness of the issue is not widespread.
e) The Halon Bank not having its own decanting operation in place. This means that the Halon Bank is not seen to be a better storage option than self storage by some of the larger halon users, and thus not serious about preventing leaks from suspect/damaged containers.
f) Some states were slow in getting legislation in place.
g) Stockpiling by other organisations.
h) The limits of legislation.

C.1.7 Quality Control.

The Australian legislation regarding Ozone Depleting Substances limits handling of halon to trained specialists and so has maintained a high standard of operations.
Testing laboratories have the capacity to provide all the testing required to date.

C.1.8 Contact Information

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C.2 Canada

C.2.1 Introduction

The Halons Round Table came into existence at the invitation of Environment Canada. This is a voluntary forum that has worked towards the development of strategies for the management of halons in Canada. The Round Table welcomes representatives from all sectors of fire prevention and protection: agent/equipment industry (distributors, installers and manufacturers), certification agencies, legislators, environmental interest groups and users.

C.2.2 Factors Which Influenced The Type Of Bank Chosen

A halon bank has now been established in Canada, and the concept of halon banking is developing on the following premise:

- a) It is estimated that relatively few holders (20%) hold large inventories (80%) of all halons.
- b) The physical size of Canada tends to favour the centralisation of information exchange, but not that of physical facilities.

C.2.3 Objectives

The first meeting of the Halons Round Table drew a remarkable consensus on the objectives and the future needs of a halon banking scheme. The following objectives were identified:

- a) To prevent emissions (environmental liability).
- b) To meet "critical" needs of users (short term liability).
- c) To address quality control/quality assurance (recycled product liability).
- d) To address the destruction issues (long term liability).
- e) To set up a tracking system to monitor the transfers of halons between users.

The following needs of the halon banking scheme were also identified:

- a) Certification requirements for recycling (product, equipment, service organization).
- b) Tracking and monitoring the movement of halons.
- c) An information clearinghouse to monitor transfers of recycled halons and to exchange information.

The Halons Round Table issued a press release at the 4th Meeting of the Parties to the Montreal Protocol to announce that the Canadian fire protection community is currently developing a national program to recover and recycle halons. This program, an industry initiative and a joint venture (industry, government and environmental groups), was designed to counteract the anticipated phase-out of halons. The Canadian fire protection industry has pledged to use recycled halons in preference to newly manufactured halons and to require that maintenance and service work be done by certified companies. The industry’s halon management program includes initiatives to certify recycling of halons, to monitor transfers of recycled halons, to set up an information “clearinghouse” and to develop a Code of Practice.

At the second meeting of the Halons Round Table, different aspects of a certification program were raised and a small working group was mandated for further development. The mandate required a certification framework, to look into certifying service companies (acknowledging the wide range of services offered by those companies) and to explore certifying recycling equipment. The working group was also mandated to address the clearinghouse issues:

operation (establishment of a toll free telephone number), not-for-profit cost recovery basis, etc.

Different aspects of a certification program have been developed Underwriters' Laboratories of Canada (ULC), and requirements for the certification of service companies were published in August of 1993. Requirements for the certification of recycling equipment were also developed in parallel with this document, and published concurrently. ULC has also established a toll-free telephone service to provide a clearinghouse function and information source.

C.2.4 How The Organization Functions

The Halons Round Table is intended to be a discussion forum at which the fire protection community raises issues and finds solutions by sharing ideas and exchanging information.

Environment Canada, representing the regulatory agency, limits its role to that of a catalyst or facilitator while keeping an eye on the long term environmentally sound resolution of the issues presented to the table.

The working atmosphere is one of co-operation; Environment Canada reports on the latest changes in the international control of halons and limits its regulatory intervention to the minimum. The fire protection industry raises the impact on the business and everyone attempts to find a workable solution.
Tremendous work has been accomplished in only three sessions and the commitment of all participants attending these meetings is to be commended. The approach taken to find solutions is one of consensus building.

C.2.5 Lessons Learned During Establishment

The Round Table approach taken to develop strategies to manage existing stocks of halons provides several benefits:

a) Policy development and decision making are left to the accountable people.
b) Political pressure is alleviated.
c) Decisions can be implemented as soon as they are made.

Other issues that need to be addressed include:

a) Essentiality - the clearinghouse does not provide a list of essential uses or essential use criteria. The Round Table has determined that, at present, there are no known truly essential uses. Nevertheless, the establishment of a formal mechanism to assess priorities for halon uses may eventually be required. An Industry Code of Practice, which is expected to be prepared within the next year, may provide the direction for such a move. Any assessment of essential uses by the Parties to the Montreal Protocol will require a continued effort from national bodies.

b) Destruction - surplus quantities of halons will result from two main streams; unwanted halons as the result of severe contamination, or as the result of an economic decision (too expensive to reclaim). Excess halons will be the result of a good assessment of the quantities that Canada requires to make an orderly transition to halon free fire protection. Excess halons will most likely be exported to countries in need of halons; unwanted halons will most likely be destroyed.

Acceptable methods of destruction are known. The ultimate responsibility for destruction is yet to be determined.

C.2.6 Operational Experience

N/A

C.2.7 Quality Control

N/A

C.2.8 Contact Information

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C.3 China

C.3.1 Introduction

China is the largest consumer and producer of ozone depleting substances in the developing countries. In 1991, the consumption of ODS was about 70,000 tons (ODP weighted value) and 24% of them were halons, about 16,800 tons.

Industrial and civil construction has rapidly increased over the past decade, and this growth in development is expected to continue for decades to come. To account for this, related engineering construction codes and standards have been issued and implemented. The result is that there will be a large increase in the requirement for halon extinguishing equipment. Estimated halon consumption is as follows:

Not Controlled	**1991**	**1996**	**2000**	**2005**	**2010**
1211	4000	6552	9055	13136	19187
1301	50	124	227	456	916
Total	**4050**	**6676**	**9282**	**13592**	**20103**
Controlled					
1211	4000	2840	1000	500	0
1301	50	50	30	20	0
Total	**4050**	**2890**	**1030**	**520**	**0**

As yet there are no control measures to regulate halon use. A leading group, the Substitution And Transfer Plan Of Halon (SATPH) has been set up in the Ministry of Public Security (MPS). SATPH is responsible for organizing the regulation and phase out of halon in China on a day to day basis. The organization from which the Chinese halon banking scheme will grow from will be nominated by SATPH.

C.3.2 Factors Which Influence The Type Of Bank Chosen

SATPH organized a group of experts to design the halon part of the National Program to Phase out Ozone Depleting Substances in China in 1992. The following unique features concerning the halon issue in China were taken into consideration:

a) China is a developing country and a late starter in halon use.
b) Chinese codes and regulations allow the use of Halon 1211 in total flooding systems, and most user designed systems use Halon 1211.
c) The Chinese economy is growing fast.
d) The size of the territory and large population.
e) The multiple industrial infrastructure. Most halon plants and equipment manufacturers are small scale. There are more than 30 Halon 1211 plants, 80 equipment manufacturers, and 90 maintenance facilities dispersed across the country.

China has not established its banking scheme yet. The most probable alternative that will be chosen will be government controlled stations. Bank stations will be dispersed in the provinces or administration areas.

C.3.3 Objectives

The main objectives of the bank stations will be to:

a) Control the recycling and supply of recovered halons.
b) Meet the needs of "essential uses".
c) Mainly recycle Halon 1211 and some Halon 1301.

C.3.4 How The Organization Functions

N/A

C.3.5 Lessons Learned during Establishment

N/A

C.3.6 Operational Experience

N/A

C.3.7 Quality Control

N/A

C.3.8 Contact Information

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C.4 Denmark

C.4.1 Introduction

The Danish Halon Banking System (DHBS) is an independent company with shareholders from industry, insurance and fire equipment manufacturers. Financial support is provided by the Danish government.

Up until 1992 the annual Danish import of Halon 1301 was 120 tonnes. From January 1, 1993, only recycled halons can be used and no new installations can be installed. The annual consumption after January 1, 1993 is estimated to be 10 to 15 tonnes. At present, the DHBS has 5 to 10 tonnes stored at the operators.

C.4.2 Factors Which Influenced The Type Of Bank Chosen

N/A

C.4.3 Objectives

N/A

C.4.4 How The Organization Functions

The DHBS collects, stores and sells recovered halons to users in Denmark. It is also allowed to import and export recovered halons. All halons belong to the DHBS and the DHBS has established a data base which is updated monthly and provides a record of halons stored at each of the operators. At present only 1301 is covered by the DHBS, but collection of 1211 will start in Autumn 1994.

DHBS operates through a number of certified operators (seven at present) who do the actual collection, storage and selling of halons. Each of the operators have signed a contract with the DHBS specifying the obligations and rights of each party.

DHBS pays the operators for collecting halons and the operators pay the DHBS when selling the halons. DHBS fixes the internal price between operators and the DHBS each quarter. Based on the monthly report from the operators, the balance is settled between the operator and the DHBS.

When halon users contact the DHBS they can make a registration of their halons or they can receive a list of operators who can give them a collection cost/selling price. The operator can independently set the price between themselves and their customer.

C.4.5 Lessons Learned during Establishment

N/A

C.4.6 Operational Experience

After a period of approximately one year, the operation of the bank is running smoothly, and during the whole period the bank has been able to supply all customers. The latter is considered essential, and therefore the intention is to build up a stock of approximately 10 tonnes of halon 1301 and approximately 1 tonne of halon 1211. This goal is expected to be reached by the end of 1994, and after this date the bank will probably be able to export recycled halons.

C.4.7 Quality Control

Quality control is at present done by the operators. Precise requirements will be decided upon in the near future and is considered essential for export to be possible.

C.4.8 Contact Information

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C.5 France

C.5.1 Introduction

The Comité Technique Français Halons-Environnement (CTFHE) was set up in 1988. Its members were representatives from the Environment Ministry, halon manufacturers, agreed national laboratory, fire equipment manufacturers association, the appropriate technical division of the insurers association, some larger users and three user Trade Associations. The aims of the CTFHE were to provide information for all concerned(mainly users); to ensure compliance with the Montreal Protocol and other more stringent regulations; and halon banking.

In 1989 CTFHE published a guidance note "Using halons in a better way", to provide information on the following main items:

a) encourage users to keep their own records of halon installed and how much they used, for example on testing, in unwanted discharges,on fires. This was to raise awareness of the halon issue;
b) improve maintenance of existing installations;
c) ban tests practices;
d) study alternatives solutions before choosing halons for any new installation.

During 1991, CTFHE was able to report good progress, such as :

a) testing with halons had stopped,
b) unwanted discharges appeared to be three times lower,
c) new installations were cut by more than half by halon weight,
d) recovery of halons started.

The French halon bank is managed by CTFHE, the secretariat of which is held by the Centre National de Prévention et de Protection (CNPP).

Halons 1211 and 1301 are concerned. Halon 2402 is not used in France.

The estimated quantity of halon installed since 1975 is about 6,000 tonnes.

C.5.2 Factors Which Influenced The Type Of Bank Chosen

During 1991 and 1992, CTFHE tried to set up a bank management scheme as part of the voluntary agreement made between the users and the fire industry, and the Ministries of Environment and Industry.

It was intended to be a detailed and tightly controlled scheme, controlling recovery, recycling and delivery flows, requiring ISO standard for recycled material and certification of recycling bodies. However, the pressure against halons as ozone destroyers was such that equipment manufacturers and installers would not join the scheme as it needed large investments without any certainty of return - there might be no customers for recycled halons. Therefore, in 1993 a more pragmatic approach was adopted.

A charter was set up to define what the recycling companies undertake to do in the field of quality of the installation, quality of the recycled product, report to CTFHE, storage and/or destruction of non recyclable products.

This charter was signed by CTFHE and eleven recycling companies at the Ministry of Environment in March 1994.

C.5.3 Objectives

The objectives of the charter are to:

a) Protect the ozone layer from environmentally harmful venting of halons.
b) Find a practical, simple, feasible scheme, and advise users.
c) Provide information on the status of substitutes and alternative solutions.
d) Inform users of this recycling policy.

Two main recommendations were given to users:

a) If you decide to keep your existing installation, installers/fire equipment companies will supply recycled halons. If they cannot, contact any of the recyclers on the CTFHE list.
b) If you decide to remove your existing installation, give the halon to one of those same bodies, to allow users who need halon to get it, and to protect the ozone layer by not releasing it to atmosphere.

C.5.4 How The Organization Functions

Eleven recycling companies, scattered throughout the country, are listed. No special funds are dedicated to physical storage of recyclable or recycled halons. It is anticipated that market forces will balance supply and demand, because there will be no physical "bank".

Installers and users have to contact directly the recycling companies. No user membership scheme is planned. It appears unrealistic.

There is interest in trade with banks in other countries (mainly within the EU) in order to balance peaks of supply and demand. This will depend on administrative constraints due to trans-frontier shipment of used halons that may be treated as a "waste" inside the EU.

C.5.5 Lessons Learned During Establishment.

Investments costs needed to recycle existing halon to existing purity standards were lower than expected, so the eleven recycling companies have agreed to be in compliance with ISO 7201.

C.5.6 Operational Experience

At the time of writing this report, no information on operational experiences is available, but is expected in the coming months.

C.5.7 Quality Control

Quality control is maintained by CTFHE (or sub-contracted) by qualifying each company in the following areas: adequate recycling equipment; minimum product quality (ISO 7201), training, reporting to the CTFHE.

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C.6 India

C.6.1 Introduction

India signed the Montreal Protocol in 1992, and became a Party to it as an Article 5 country. India's 1991 consumption of halon was 750 tonnes (500 tonnes of Halon 1211 and 250 tonnes of Halon 1301). All this requirement was met through imports, either as halon gas (mostly Halon 1211) or both gas and systems (Halon 1301). India started using halons in the early 1980's, and the total quantity was imported up to 1990 when one facility, with a capacity of 300 tonnes of Halon 1211, started production. Halon 1301 is not yet in production in India. From some rough estimates, and a preliminary survey by the Defence Institute of Fire Research and WWF India, about 750 tonnes of Halon 1301 and 3000 tonnes of Halon 1211 is banked in existing systems and portable extinguishers. A small quantity of about 2 - 3 tonnes of Halon 2402 is also stocked with some users. The major holders of the above halons are power, oil and fire equipment companies, the Defence department and general consumers. Owing to the vast size of the country, the exact quantity held, its age, condition, and applications, e.g. essential or non-essential uses, is not known at this time. However, there is a requirement to survey various facilities in order to get correct information as part of the Halon Management and Banking System project.

C.6.2 Factors Which Influenced The Type Of Bank To Be Chosen

Unlike in many developed countries, halon use in India is not regulated/mandated by either insurance or Fire Protection acts or laws. Options are open for users to employ halon CO_2 powder, etc. However, because of its excellent properties, halons became very popular in the Indian market. There are no measures as yet to regulate halon use. The Indian Country Program suggests the formation of a halon management and banking system, and regulations through standards and codes of practice that authorities, such as factory inspectors, insurance companies, and Fire officers etc., can use to restrict halon use to critical sectors. This is currently under review.

A pilot survey on halon market trends, conducted jointly by the Defence Institute of Fire Research and the World Wide Fund for Nature (India), made the following observations:

a) The Bureau of Indian Standards organization, responsible for the preparation of specifications and operation of the ISI mark on fire fighting equipment, has dropped the standard for aerosol halon extinguishers and mobile equipment of 25 to 50 kilograms capacity.
b) India has at present one facility for Halon 1211 production and does not produce any Halon 1301. Halon production is currently 50 - 60 tonnes per annum.
c) Owing to dwindling supplies and increasing cost of Halon 1301, a few users are switching over to Halon 1211 for some applications, and to carbon dioxide for new installations.
d) The usage of Halon 1301 systems is limited to essential applications such as the military, shipping, offshore platforms, the power industry etc., and the needs are being met by existing stocks which are very limited.
e) No imports of either Halon 1211 or 1301 have been made in the last year.

Other factors influencing the type and organization of the bank are:

a) In India, the halon users are mainly in the government sector, and most halon is deployed in government and public sector industries. Therefore a private organization may not be able to operate a bank.
b) The major suppliers of halon and halon systems are private fire equipment companies. However, these companies have their business in almost all types of fire fighting equipment and systems, and the halon business is estimated to account for only 5% of their total output. Thus these companies' business is not affected by the phase out of halons. Also, due to public and user concern over the environmental problems associated with halons, no private sector company wants to undertake a project where business is uncertain and profits are negligible. Halon producers might take up the work at a later stage one the feasibility and economic viability is ascertained.
c) The production of halon has stopped in the developed countries, and no country capable of producing halon has asked for a production exemption specifically to meet the requirements of developing countries. The Halons Technical Options Committee and the Technology and Economics Panel of UNEP believe that there will be sufficient recycled halon available to meet the future requirements of the World's essential uses.
d) There is no real halon replacement in sight even in developed countries, and the transition substitutes proposed are very costly.
e) It is also understood that international trade in recycled halon will be through national halon banks, who will also be responsible for certifying the quality of the halon and the essentiality of the application for which it is being asked.

In India, the above mentioned conditions can only be satisfied when the management of the bank is undertaken by Government agencies with the support of the National Government.

A halon management and banking system does not exist at present. However, the Defense Institute of Fire Research has taken the lead in preparing a project proposal to establish a Halon Management and Banking system in India. Important groups/partners in the planning activity are: the National Thermal Power Corporation, the Oil & Natural Gas Commission, the Loss Prevention Association, leading halon extinguisher and system suppliers, and the Ministry of Environment and Forest, who will be the national implementing agency.

C.6.3 Objectives

The short term objectives are:

a) To ascertain the actual quantities of banked halon in India.
b) Raise the awareness of the intelligent use of halon by redeployment, and the avoidance of emissions to the atmosphere through testing, training and inadvertent leakage.

The long term objective is the formation of a halon banking organization which will be responsible for keeping track of halon quantities and matching the users who still need it with those who want to surplus it. In other words, a clearinghouse that functions both at the national and international level, through UNEP IE/PAC, to reduce the overall dependency on newly produced halons. The bank will also identify essential uses of halons.

C.6.4 How The Organization Will Function

Although there is no Halon Bank in India at present, it is proposed that it will function as follows:

a) The major halon users in the country such as Defence, power plants, and ONGC will join together and start a clearinghouse activity at DIFR.
b) The clearinghouse will also help in suggesting suitable methods for conservation of halons by various users.
c) The clearinghouse will match those who want to buy halon with those who want to sell it.
d) DIFR will undertake the recycling/reclaiming of halon, if needed, before clearing/certifying it for reuse by the purchaser.
e) A limited physical bank of halons will be maintained at a central place, if required, for recycling, testing, and redeployment.
f) The bank will act as the interface to the UNEP IE/PAC halon bank clearing house, and will also be responsible for contacting the halon banks of other countries.

It is anticipated that the bank will have a secretariat run by 2 or 3 engineers. The users and consumers will become permanent members and will register their annual requirements for halon with the bank. They will also register their stock holdings and the quantity they want to sell to other users. The bank secretariat will maintain all these records as well as act as the clearinghouse for access to other National banks. The bank will also have the test facility to certify the quality of recycled halon and will determine the criticality of the uses for which they have been requested.

It is also planned that the bank will assist in the redeployment and sale of halon withdrawn by fire fighting companies from non essential extinguishers, such as the aerosol type and others that can be replaced by ABC powder or other alternatives. The bank will operate as a non profit organization.

As India is a developing country it qualifies for financial assistance from the Multilateral Fund. Therefore, this bank project proposal has been submitted through the Ministry of Environment & Forest, Government of India, for the sanction of project funding. It is believed that without this financial assistance the bank project will remain a non-starter.

C.6.5 Lessons Learned during Establishment

N/A

C.6.6 Operational Experience

N/A

C.6.7 Quality Control

N/A

C.6.8 Contact Information

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C.7 Japan

C.7.1 Introduction

The use of halon for fire suppression purposes is stipulated in the Fire Services Law as one of the recommended choices, and therefore they have been used in various existing facilities where the installation of fire suppression systems is compulsory. In the light of the growing concern over the depletion of the ozone layer, and following the London meeting of the Parties to the Montreal Protocol, the Fire Defence Agency issued a guideline (Fire Defence Protection No 161, August 15 1991) instructing all concerned that the employment of halons for new installations should be restricted to specified areas only, and that all other new installations should be protected by non-halon systems.

This ordinance, which came into effect on January 1st. 1992, allows the use of halon for communication facilities, historical heritage, and for some other uses specifically designated as essential. At the same time, it prohibits their use in building car parks and machine rooms where the past use of halons has been particularly substantial in Japan.

Further, in response to the recommendations of the Halons Technical Options Committee, and the subsequent decision taken at the Copenhagen meeting of the Parties to the Montreal Protocol in November 1992 that called for the phase out of both production and consumption of halons in developed countries beginning January 1st. 1994, the Fire Defense Agency issued a guideline to the businesses concerned advising them that the availability of newly produced halons would be limited, and that the use of halons for new installations and for maintenance of existing installations should be by re-deploying existing halons through recycling and reclamation.

Also in response to the Copenhagen decision, a study group was organised within the Fire Extinguishing Systems Manufacturers Association to prepare for the founding of an organization responsible for Halon Bank management nationwide. This study group, the Halon Bank Preparatory Committee, with the co-operation of the Fire Defence Agency, worked on the proposed structure and functions of the bank management scheme. Following completion of the preparatory work made by the study groups, the Halon Bank management body, named the Halon Recycling & Banking Support Committee (HRBSC), was formally inaugurated on July 19th. 1993.

C.7.2 Factors Which Influenced The Type Of Bank Chosen

Maintaining fire suppression systems in active service is a legally requirement when such installations are compulsory to comply with the Fire Services Law. Halon 1301 installations (mostly total flooding systems), of both compulsory and voluntary nature, were estimated to be more than 50,000 in number, or approximately 17,000 tonnes in quantity at the end of 1993. In order to meet legal requirements, Halon 1301 cylinders that are emptied by reason of release on a fire, or through any other cause, must be refilled and maintained throughout the life of the relevant buildings/facilities.

On the other hand, the modification or demolition of existing building/facilities will create surplus halon that can be redeployed to either refill existing but emptied cylinders, or for new applications that are considered essential. Many concerned with the halon fire fighting business, recognising the necessity of maintaining the balance between supply and demand by making flexible use of the nationwide inventory of halons, approved of the formation of the bank management programme proposed by the Fire Extinguishing Systems Manufacturers Association. The deployment of Halon 1301 in 1991 was roughly divided into the usage patterns shown below. This can be extrapolated to the application pattern of the 17,000 tonnes of Halon 1301 at the end of 1993.

	Application of Halon 1301	Share (%)
Car parks	Car repair shops, car parks, etc.	25.2
Communications	Communication rooms, studio, control rooms etc.	42.8
Hazardous Installations	Reservoir, paint rooms etc.	12.8
Art objects	Galleries, museums	2.4
Miscellaneous	Processing workrooms, research laboratories, etc.	16.5
Aircraft	On board aircraft	0.3

C.7.3 Objectives

The Halon Recycling & Banking Support Committee (HRBSC) is a non-profit organization formed to manage the inventory of halons with the following general objectives:

a) Avoid the unnecessary emissions of halons.

b) Act as a clearinghouse and watchdog to ensure the best use of the limited amount of halons nationwide through recycling/reclamation (see7.4 for details).
c) Act as Japan's link with UNEP IE/PAC in Paris.

C.7.4 How The Organisation Functions

C.7.4.1 Formation of the organisation

HRBSC was founded as an independent and non-profit organization, and its operation is supported primarily by dues paid by members. The membership consists of regular members and supporting members, the former being typically represented by fire equipment manufacturers and major users, and the latter being the individuals or companies who give approval to the intent of halon bank management.

C.7.4.2 Structure of the organization

HRBSC is structured as follows:

Chairman	The Chairman is selected and appointed by Board.
Board	The Board consists of representatives from member companies and also selected people of academic standing. Board meetings deal with the managing policy of HRBSC.
Halon management commission	Examines and decides on the operating standard to be followed by HRBSC.
Halon bank promotion commission management.	Is responsible for public relations relative to halon bank
Secretariat	Consists of permanent staff responsible for routine operations.

C.7.4.3 Funding of the organization

The operating costs of HRBSC are covered by funds obtained as follows:

a) Enrollment fees paid by regular members.
b) Annual membership fees paid by both regular members and supporting members.
c) A subsidy from the Earth Environment Fund.
d) Commissions paid by recipients of halons.

C.7.4.4 Operation of the organization

HRBSC, with the co-operation of the Fire Defense Agency, performed a nationwide survey of the inventory of halons, and built a data base for them. HRBSC came into full operation on March 1st. 1994. At this time, 17,000 tonnes of Halon 1301, 100 tonnes of Halon 1211, and 400 tonnes of Halon 2402 were registered in the data base. With this data on hand, which is continuously updated to reflect current status, HRBSC conducts the regulatory and information clearinghouse functions as follows:

Functions concerning halon supply

a) HRBSC receives from a user an application for the supply of halons.
b) HRBSC examines the application, approves/disapproves the relevant supply, and notifies its decision to the user.
c) Based on HRBSC's approval, the installer concerned provides the supply of halon to the user. HRBSC however, is not involved in the trade between installer and user.
d) The installer then notifies HRBSC that the halon has been supplied, and HRBSC updates the data base accordingly.

Functions concerning halon recovery/reclamation

a) HRBSC receives from the user or through the relevant fire authorities a notification that an existing halon installation is to be removed/disposed of.
b) HRBSC instructs the installer concerned to recover the halon.
c) The installer recovers the halon. The recovered halon will be kept at the installer's site, pending its redeployment for a future application.
d) The installer notifies HRBSC that halon recovery has been completed and HRBSC updates the data base accordingly.

Maintaining HRBSC's data base

a) All of the halon cylinders nationwide that are in HRBSC's data base are protected from unnecessary emissions by attaching a warning label on the outer face of each cylinder. This label is produced by HRBSC and distributed to holders of halon free of charge. These labels are also aimed at assisting owners of cylinders to promote the fact that their halons are registered in HRBSC's data base.
b) From time to time, the fire authorities conduct inspections of halon installations at users' sites to verify that they are in agreement with the data kept by HRBSC. If any discrepancy is confirmed, then HRBSC makes a change to the data base accordingly.
c) HRBSC, based on its data base, prepares a periodic report of updated information on the nationwide status of the halon bank, and submits it to the local fire authorities.

C.7.5 Lessons Learned During Establishment

Most of the halon in Japan is in fire extinguishing installations that are compulsory according to the Fire Services Law, and therefore are under the jurisdiction of fire authorities located nationwide who are responsible for enforcement of the Fire Services Law. For this reason, these fire authorities are obligated to monitor the state of all fire extinguishing installations under their respective jurisdictions to ensure that they are in conformity with legal provisions. It is important to note therefore, that HRBSC's first job of preparing the data base of halon installations nationwide was only successful because of the cooperation of the fire authorities. Without such a concerted effort, it would have taken far longer and cost much more, and may not even have been feasible, for HRBSC to successfully complete compilation of the data base.

There are many portable halon extinguishers in installations which are outside the jurisdiction of the fire authorities, and HRBSC has been finding some difficulty in locating them and inviting the users to be members of HRBSC. Further effort is being made.

C.7.6 Operational Experience

It appears that HRBSC has started off rather smoothly. However, further effort will be required to ensure a continued smooth and harmonious operation.

C.7.7 Quality Control

HRBSC is currently working on a quality standard for re-deploying recycled and reclaimed halons.

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C.8 Malaysia (Based on 1993 information)

C.8.1 Introduction

There are 20,000 - 25,000 Halon 1301 fixed installations in Malaysia which constitute about 95% of all fixed installations other than automatic sprinkler systems. The halon installations pose a major problem in that their installation was required under Government regulatory measures and building codes. Special provisions allow control and introduction of alternate systems by administrative orders.

The first stage of control meant that new Halon 1301 installations were banned after June 1 1990 except by special permission. This would include projects contractually committed prior to the cut off date. The decision was taken on the presumption that halon availability would be dependent on the market economy and that the options provided for Article 5 countries would not ensure future supply. Product scarcity would force prices up and consequently increase cost of maintenance and affect the economic life of these systems.

The second stage involved management of fire-risk and halon installations to prolong the life of existing installations and minimise the emission of halon into the atmosphere. These included:

a) Design of buildings, separation and isolation of fire risks.
b) Installation of alternative systems of fire protection including automatic sprinkler systems, automatic detectors, and water mist systems.
c) Requiring the testing of systems without release of halons.

The third stage consists of inspection and maintenance of halon systems by qualified, certified people and the upgrading of halon systems to required standards to minimise accidental emission.

C.8.2 Factors Which Influenced The Type Of Bank Chosen

N/A

C.8.3 Objectives

N/A

C.8.4 How The Organization Will Function

The organisational stage of the system is at present under consideration, but the proposals are for a centralised system. The next stage would include an inventory of all existing halon banks and systems. There would be mandatory reporting to the Central Bank of the status of systems, halon releases both accidental and during fire. The quality of the halon in banks would be verified.

The final stage would include the prioritization of halon 1301 installations according to the criticality of the situation. The criteria would cover social life safety, national interests including security and economic factors. A stage by stage phase out programme would then be prepared which is expected to extend over 15 or 20 years. The maintenance of the bank of halons installed in cylinders and taken out of service would be carried out regularly through inspections and certification by registered qualified people. The cylinders would remain in their original location. The halon supply would be sourced from halon banks taken out of service at the discretion of the Department of the Environment and the Fire Service Department.

The programme is based on a most economic phase out schedule prolonging the life span of existing installations, minimising life safety and fire risk, economic loss due to fire and achieving the level of fire safety required by alternate systems of fire protection, fire prevention, compartmentation and segregation of fire risks.

C.8.5 Lessons Learned during Establishment

N/A

C.8.6 Operational Experience

N/A

C.8.7 Quality Control

N/A

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C.9 The Netherlands

C.9.1 Introduction

From January 1, 1994 halons may no longer be produced in The Netherlands, nor may newly produced halons be imported. It will however, still be permitted to refill existing installations as well as new installations, with halons originating from reclamation. From January 1, 1993, new installations with halons may only be installed in cases of essential applications, designated by the minister of Housing, Physical Planning and Environment. Collection and recycling of halons can be done for legal reasons only by companies which are licensed under the Chemical Waste Act.

C.9.2 Factors Which Influenced The Type Of Bank Chosen

N/A

C.9.3 Objectives

N/A

C.9.4 How The Organization Functions

For the collection and recycling of halons, a co-operative association with excluded liability has been set up, with the objective to provide for the halon needs of its members. Only members can buy halons that have been collected by the association and made suitable for reuse. The association will build up a stock in order to cover the halon needs of its members. The stock policy will be submitted to the meeting of members and they have to approve the policy.

For its technical work the association makes use of a specialised company. The halons recycled by this company meet the usual standards for the aviation industry and military purposes.

The association has an independent status and its activities are paid for by the fees of the members. The Ministry of Housing, Physical Planning and Environment accelerated the start up of the activities by initial financial support. The capital needed to start up the association was DFl 650,000.

The association will cooperate as much as possible with halon banks in other countries in order to realize its objective. In achieving this objective it will try to make a contribution to an environmentally justified use of halons and to the destruction of halons if the are no longer necessary at some time in the future.

All halon owners who want to get rid of their halon stock can report this directly to the association or indirectly via their suppliers. All halon that is offered -free of charge- from existing installations in the Netherlands will be taken back by the association. If the supply should be larger than the quantity the association would like to take on the basis of the demand of its members, the association will act in conformity with an agreement with the ministry of Housing, Planning and Environment. This is in order to prevent the association being faced with the eventual costs for destruction of surplus halons that are not required for its members.

Only members can buy halon from the association. All users of halon can become members of the association - either directly or via their suppliers. Membership will be valid for at least five years. There are two possibilities for membership. When applying for membership one can either state how much halon will be required in the next five years (volume member) or name the installations to be recharged if necessary (installation members). In the latter case the association makes an estimate of the volume needed over the next five years.

The association takes into account that a situation can arise where there will no longer be any demand for halons and the remaining stocks must be destroyed. To this end the association reserves funds out of the members contributions. In case of a lower purchase of halons the association will get in touch with other halon banks to investigate whether there are shortages elsewhere. Such an exchange fits within international agreements.

C.9.5 Lessons Learned During Establishment

N/A

C.9.6 Operational Experience

The association (Co-operative Vereniginge Halonen, U.A.) was officially set up on April 5th 1993. The activities started in the same month with collecting halon. The recycling unit was started up in April 1994. As of April 1994 there were 113 members from the following areas:

- aircraft manufacturing companies
- airlines
- ministry of defence
- public works
- chemical industry
- ship owners
- service industries (banks, insurance companies etc.)

Since the start-up of the bank the demand for Halon 1301 has been low, but at the same time, the amount offered to the association has been less than expected. It is believed that large stocks of Halon 1301 are being held by members. Only small quantities of Halon 1211 have been requested by members but larger quantities have been offered to the association.

C.9.7 Quality Control

Quality control is maintained by the association using the services a specialised company. The halons recycled by this company meet the usual standards for the aviation industry and military purposes.

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C.10 Norway

C.10. Introduction

Effective July 1st. 1994, halon is defined as a "Special hazardous waste" by law. All movements of halon require the approval of the State Pollution Control Authority (SFT). A national halon bank was established and began operations in July 1994.

C.10.2 Factors Which Influenced The Solution Chosen

SFT wanted to have full control of halon transfers during the phase out, and wanted halon included in "Special hazardous waste" handling.

C.10.3 Objectives

Traceability of all halon; control of use, storage, treatment, movement, dismantling of systems, sale, and destruction. No "accidental" releases.

C.10.4 How The Organisations Functions

One company, Bergen Renholdsverk, Spesialavfallsstasjon Flesland, has been approved by SFT to conduct national halon banking activities. Except for transportation costs, all halon can be delivered to Bergen Renholdsverk free of charge. Halon owners are to follow regulations and are required to deposit their halon with a "bank". In principle, as far as Norwegian users are concerned, this is a one way bank - only in, no return to Norwegian users. Ownership of the halon will remain with the original user until sold.

C.10.5 Lessons Learned during Establishment

To avoid unintended releases of halon, a high level of skill/QA on the part of the companies involved is required. Halon cylinders/valves have to be safety pinned and plugged before transportation.

C.10.6 Operational Experience

At the time of this report, only small amounts of halon have been sent to the bank.

C.10.7 Quality Control

No special problems have been identified. All halon received meets international specification.

C.10.8 Contact Information

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C.11 Poland

C.11.1 Introduction

The use of halons in Poland began relatively late, towards the end of the 1970's, and has not reached a significant level. At present, the estimated amount of Halon 1211 and 1301 in installations is approximately 180 - 200 tonnes, and 2 - 3 tonnes of Halon 2402 is still in use in equipment from the former Soviet Union. Poland never produced halons or halon total flooding system equipment. There are a few distributors of foreign equipment and several installation and servicing companies. However, these companies are not organized through any kind of industry association, and therefore there is no strong group which could promote activities related to environmentally sound halon management during this transitional period, especially when no profits may be expected.

Consequently, the Polish Fire Service (PFS) has undertaken the role of promoting the reduction of halon emissions and the control of halon use. Regulations related to halon emission reduction and halon use controls are implemented through orders, recommendations, and decisions issued by departments of the Fire Service Headquarters.

Emission reductions are accomplished through:

a) Periodic inspections of existing installations by experts from the district and local fire services.
b) A ban on the live testing of halon installations that would result in the release of halon.

It is the policy of the PFS to certify all halon fire fighting equipment, and this has contributed to a reduction in the use of halons. Under the Fire Protection Act, all fire fighting equipment must be certified before it can enter the market place. The only institution authorized to test and issue certificates, as well as develop relevant standards, is the Science and Research Centre for Fire Protection, which is supervised by the PFS Headquarters. This policy has been effective since:

a) No certificates for portable halon extinguishers have been issued since 1992. This has eliminated the import and domestic production of portable halon extinguishers.

b) Certificates for the installation of fixed halon systems are only granted if two criteria are met:

   - the equipment must meet relevant standards for high quality.
   - "essential/critical halon use" for the place to be protected.

c) All construction designs must be reviewed by experts from the PFS with regard to fire safety and the limitations governing halon installation.

C.11.2 Factors Which Influenced The Solution Chosen

The lack of halon producers in Poland, as well as a lack of interest by the few distributors operating in Poland and the insurance companies, are the reasons that this simple but efficient solution was chosen.

C.11.3 Objectives

The Polish policy objectives are as follows:

a) The promotion and distribution of information on environmentally sound halon management.
b) Halon emission reduction.
c) The inventorying of all halon installations.
d) The promotion of alternative fire suppression technologies and agents.

C.11.4 How The Organisations Functions

A consumer who wishes to purchase halon is advised by the Polish member of the Halons Technical Options Committee on the existing European halon banks and the halon bank clearinghouse services of UNEP IE/PAC in Paris. Additionally, each consumer is informed about the impacts resulting from the use of halons, in particular:

a) The obligation to obtain a certificate confirming a condition for essential/critical use.
b) The obligation to confirm that the halon purchased is recycled or recovered and meets relevant standards.
c) The expected difficulties in obtaining halon in the future and anticipated high price.
d) Issues related to halon destruction.

To date, no consumer considering removing halon from service has inquired about halon recycling or storage facilities.

C.11.5 Lessons Learned during Establishment

N/A

C.11.6 Operational Experience

N/A

C.11.7 Quality Control

N/A

C.11.8 Contact Information

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C.12 Russia

C.12.1 Introduction

According to a decision of the Russian Federation government, the Ozone Layer Protection Joint Committee was set up in 1993. The aim of this Committee is to coordinate the activities of the Russian ministries and departments on fulfilment of the obligations of the Vienna Convention and the Montreal Protocol. The Committee consists of several Subcommittees, each being responsible for a group of substances controlled by the Montreal Protocol.

The Fire Extinguishing Halons Subcommittee is a voluntary forum that develops tactics and strategies for halon usage in Russia. In 1994 there have been two meetings of the Subcommittee. Halon consumers, manufacturers and those enterprises involved in the installation and maintenance of halon fire extinguishing systems took part in the meetings.

C.12.2 Factors Which Influenced The Type Of Bank Chosen

Although as yet no formal halon bank has been established in Russia, the concept of halon banking is being developed on the basis of the following premises:

a) The physical size of Russia tends to favour a centralized information exchange rather than physical facilities.
b) It is estimated that four departments in Russia have more than 90% of all halon stocks.

C.12.3 Objectives

At the Subcommittee meetings that were held in 1994, a remarkable consensus on the objectives of highest priority was achieved. As a result of these meetings, the following were accomplished:

a) A list of top priority items requiring fire protection by halons was issued.
b) A minimum halon production volume to meet the requirements of essential use purposes was determined. According to current information, for halon 2402 this is 400 tonnes per year.
c) The need for annual halon production decreases for essential uses was ascertained. It is expected that halon production will have ceased by 2003.

It is the opinion of the members of the Subcommittee that it will be necessary to fulfil the following in order to set up a halon bank management scheme in Russia:

a) Identify those regions in Russia with the largest stocks of halon. This will allow selection of the sites for recycling equipment installation.
b) Monitor transfers of halon between users.
c) Establish a centralised registration and information exchange system for recycled halons.
d) Improve the maintenance of existing fire extinguishing systems.
e) Prohibit the testing of fire extinguishing systems that may cause the release of halons.
f) Introduce legislation to limit halon use.
g) Perform research into economical and ecologically safe equipment for halon destruction.

C.12.4 How The Organization Functions

The Fire Extinguishing Halons Subcommittee is intended to be a consultative body where representatives from State fire and rescue services, ministries and departments, major enterprises, and fire equipment designers and halon manufacturers, raise issues and find solutions by collectively discussing plans and exchanging information.

The Ministry of the Environment of Russia plays the role of a regulatory body, and insures that decisions on issues presented to the Subcommittee are correct from the standpoint of ecology and long-term prospects. The Ministry also reports on the latest changes to the international control of fire extinguishing halons.

The first two meetings of the Subcommittee have shown that members raise the problems that they are faced with and try to find workable solutions.

C.12.5 Lessons Learned during Establishment

The formation of the Fire Extinguishing Halons Subcommittee made it possible to involve competent people in the strategy development and decision making process of Ozone Layer protection, and to develop the concepts of managing existing halon stocks and the establishment of a halon bank.

C.12.6 Operational Experience

Legislation to limit the use of substances that deplete the Ozone Layer in industry and everyday life is still under development. Investment in the development of ozone safe fire extinguishing substitutes to halon, as well as ecologically clean technology for halon destruction, is insufficient and should be increased.

C.12.7 Quality Control

N/A

C.12.8 Contact Information

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C.13 Sweden (Based on 1993 information)

C.13.1 Introduction

The Swedish Environmental Protection Agency is responsible for issuing regulations on handling halon. Under the Swedish ordinance on CFCs, halons etc., from the 1st. July 1991 all new halon installations were prohibited. There are exemptions are for aircraft, submarines, combat vehicles and action information centres belonging to the Defence Forces on vessels and below ground. Hand held fire extinguishers using Halon 1211 may not be sold, manufactured, recharged or imported. From 1st. January 1998 halons may not be used on a professional basis in fire extinguishing systems. Halons may only be exported with permission from the EPA.

The amount of halons in existing installations is between 1500 and 2000 tonnes. About 5-10% is Halon 1211 and the rest is Halon 1301. Import has dropped from 130 tonnes in 1988 to about 35 tonnes in 1991. About 5% of the total use (50-100 tonnes a year) is needed for exempted applications.

New regulations to control emissions of halon are at present out for public consultation. According to those proposals everyone with a halon system containing more than 20 kg must register the system at a county authority. The amount has to be confirmed to the authority every year. Decommissioning of systems and releases also have to be reported. Other reporting requirements are: the origin of new halon purchased; where it is being sold or exported. If there are no purchasers, then unwanted halons can be sent to a national depot for storage until it is destroyed. All halon systems are subject to inspection once a year by authorised companies.

C.13.2 Factors Which Influenced The Type Of Bank Chosen

There is as yet no centralised banking system in Sweden. Interest has been expressed by very few halon users. Some companies who sell fire protection equipment have indicated that they will arrange a bank operation for their customers on a voluntary basis. The Swedish EPA are ready to support initiatives for a national bank should interest from users increase. The Swedish military will arrange a bank for their own needs. Halon in that bank will come from their own systems no longer in service or applications where there are alternatives.

C.13.3 Objectives

N/A

C.13.4 How The Organization Functions

N/A

C.13.5 Lessons Learned during Establishment

N/A

C.13.6 Operational Experience

N/A

C.13.7 Quality Control

N/A

C.13.8 Contact Information

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C.14 Switzerland

C.14.1 Introduction

In August 1991, the Swiss Government enacted strict regulations for substances that deplete the ozone layer. As Switzerland does not produce any CFCs or halons, the regulations govern imports and usage within the country.

The ordinance contains the following provisions which became effective on January 1, 1992:

- All imports of halon are banned, and the export of halon is allowed only for destruction or recycling and re-import.
- The installation of new halon 1301 fixed systems is allowed only for essential applications, and the sale of halon 1211 portable extinguishers is banned - except for essential applications.
- All existing fixed fire protection systems using halon have to be registered with the government by the middle of 1992.
- Existing halon 1301 fixed systems may be recharged until the end of 1997.
- Surplus halon is designated a hazardous waste, and must be destroyed within 10 years.

Until the end of 1997, the recharging of existing installations is permitted. For recharging, the essentiality criteria do not apply; free trade in halon is therefore allowed. However, as the supply is limited to the existing halon bank, measures have to be taken to match supply and demand. The key to the success of any recycling program in Switzerland are the fire equipment manufacturers and, being a small country, only a few exist. No separate fire protection equipment distributors operate in the country. The fire protection community in Switzerland has been working co-operatively with the Federal Office of Environmental Protection (FOEP) to find a solution to the problem of bank management.

C.14.2 Factors Which Influenced The Type Of Bank Chosen

Establishing a centralised halon pool, i.e. a physical halon bank, was found to be too expensive to be feasible. The annual costs were estimated at SFr. 4.5/kg (or US$ 3/kg). A centralised pool would also run the risk of ending up with a large amount of material which might be considered a hazardous waste. Also, as there is no restriction on the trade of halon 1301 for recharging existing installations, a centralised halon bank would not have a monopoly on offering the extinguishant needed for recharging systems. These reasons resulted in the decision to opt for a clearinghouse solution where only information is traded between the partners involved.

C.14.3 Objectives

The objective of the bank is to provide the fire equipment manufacturers with the necessary amount of halon 1301 to recharge existing systems. As Switzerland is a small country, less then 10 manufacturers exist. Nearly all systems installed in Switzerland were originally provided through one of these companies. Clients normally have a maintenance contract with the original supplier which guarantees recharging of their systems. The Manufacturers Association drew up a mandatory agreement with all its members to keep records of available surplus and reclaimed halon 1301. This information is to be shared with the other members upon demand. The halon is then traded between the parties to this agreement.

The agreement worked satisfactorily for about a year, but once the economic conditions became more difficult, the willingness to trade information diminished and the clearinghouse no longer functioned to every one's satisfaction. The clearinghouse function will therefore be transferred to a consulting company working on behalf of the Federal Office of Environmental Protection.

C.14.4 How The Organization Functions

Owners of recyclable halon are encouraged to store the agent on their premises for sale upon demand. They have to register the decommissioning of the system and the availability of surplus halon with the government's national halon register as "no longer used halon". Until the reclaimed halon is sold to a new owner, the original owner keeps title and therefore the legal responsibility for the halon. Large halon users like banks and insurance companies run their own bank management programmes. They rely on their in-house supply of halon from decommissioned systems. Equipment manufacturers maintain a small but adequate halon supply for servicing and refilling.

The government's halon register is used as a national inventory of halon available for reclamation and recycling. Starting in mid 1994, it fulfils the role of a national clearing-house as it can provide manufacturers with additional information on the potential availability of halon. The total amount of halon 1301 registered by the end of 1993 was about 520 tonnes. The register will also be the source of information for an eventual international trade of recycled halon. However, at the moment this is not possible under Swiss law.

C.14.5 Lessons Learned During Establishment

The co-operative effort of the Federal Office of Environmental Protection with the Fire Equipment Manufacturers Association proved to be a very productive starting approach. The regulatory demands and the commercial interests and concerns appeared to be balanced in the process. Several different solutions for the establishment of a clearinghouse were evaluated and a solution was found that both sides could agree to. The federal government funded part of the work that had to be done to get the process started.

However, it has become clear that such a solution is strongly dependent on the economic conditions of a certain market. The willingness to cooperate decreased drastically as conditions got worse, and assigning the clearinghouse function to a neutral consulting company has proved to be the better solution at this time. Still, the process followed appears to be applicable to small countries with fairly tight markets and internal regulations. It is based on the willingness of commercial competitors to work together to find a solution. It also requires government authorities to allow a solution to develop without interfering strongly from the beginning.

C.14.6 Operational Experience

The national halon register suffers somewhat from the lack of enthusiasm of owners to report the decommissioning of their systems. Until now, providing such information has not been perceived as a benefit. This perception might well change with the possibility of exporting surplus halon and with the registering and clearinghouse functions merged into one operation.

C.14.7 Quality Control

N/A

C.14.8 Contact Information

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C.15 United Kingdom

C.15.1 Introduction

As a Member State of the European Community, the UK is bound by EC Regulations 594/91 and 3952/92 which implement the Montreal Protocol within the Community. These Regulations are directly applicable in UK law and take the approach of the Protocol itself, controlling the production and supply of ozone depleting substances, including halons, rather than their use. There are no additional controls within the UK. Market forces govern trade in halons and their use within the UK.

Changes in UK waste law in mid 1992 mean that halon can no longer be vented during equipment servicing. In most cases, when halons are discarded or removed from equipment in the course of maintenance they become controlled wastes. Section 33 of the UK Environmental Protection Act 1990 states that it is illegal to 'treat, keep or dispose of controlled wastes in a manner likely to cause pollution to the environment or harm to human health'. This added impetus to recycling efforts already underway.

The use of halons has never been mandatory, but it has been the agent of choice in many applications since the mid 1970's.

A study carried out for the UK Department of the Environment by C S Todd and Associates in 1991 (Halon use in the UK and the scope for substitution; HMSO) estimated that the installed UK bank of halons in 1990 was some 6,655 tonnes of 1211 and 3,800 tonnes of 1301.

Halon banking procedures in the UK developed from the Government's consultation process with industry on ozone depleting substances. A series of sector groups was created in late 1990/early 1991 to make the existing consultation process more subject specific, and to shadow the UNEP Assessment Panels.

The Halon Sector Group (HSG), chaired by the Government Department responsible for ozone layer issues (Department of Environment - DoE), was set up in March 1991. The initial group included representatives from the Fire Industry Council (FIC -the trade association which represents a large number of fire equipment manufacturers), the halon producers, the oil industry, transport, and insurance. Other Government Departments were also represented, some as regulatory or sponsoring bodies, others as major users of halons. The Departments were: the Department of Trade and Industry (DTI); the Department of Transport (DoT); the Ministry of Defence (MoD); the Home Office (HO - responsible for the Fire Service in the UK); and the Health and Safety Executive (HSE).

Two major halon using organisations were already looking at how they might organize themselves to meet their needs beyond the phase out of halon production. These were the MoD and the UK Offshore Operators Association (UKOOA - one of the trade associations for the

North Sea oil companies), both of whom had existing critical installations which would need halons possibly into the next century. Separately, these organisations were going through the same process of taking an inventory of their existing stocks and making plans for moving stocks from less critical to critical applications. In doing this they were taking advice from fire equipment suppliers on the best methods of storage and handling.

C.15.2 Factors Which Influenced The Type Of Bank Chosen

Very few UK halon users could organize themselves as the MoD and UKOOA had. Although most fire equipment manufacturers belonged to one trade association or another, there was no forum for the fire industry to talk to users as a group to find out what their banking and recycling needs might be. Once this problem had been identified, the HSG was enlarged to cover all the major halon using sectors in the UK including refrigeration (1301 is the low temperature refrigerant R13b1).

The HSG set up a small working group, the Halon Banking Group (HBG), consisting of representatives from aviation, oil industry, fire industry, transport, finance and defence, chaired by DoE. They reviewed information on banking schemes elsewhere in the world, and drew up proposals for halon banking in the UK. Competition policy in the EC and in the UK effectively prohibit a restriction on trade and the creation of a monopoly in recycled halons. This had considerable influence on the system devised.

The proposals were for the establishment of the Halon Users' National Consortium (HUNC) - an organization acting as a clearing house which would put those who wanted to buy halons in touch with those who wanted to sell. The organization would own no halon of its own. It would be non-profit making, funded by members' subscriptions rather than by a levy on sales. It was also thought important that the data on halon holdings in the UK should be kept commercially confidential between the manager of HUNC and the company concerned. There were two major reasons for this: one was to ensure no company could be put at a commercial disadvantage; the other was to allay users' fears that Government might use the information to requisition users' stocks.

The HBG presented these proposals to the HSG in September 1992. They came as a package: DoE would fund the publicity for the scheme, including a questionnaire, the creation of a database and the processing of the information (by an independent consultant) from that questionnaire (estimated cost of £130,000) if industry would fund the start up costs (estimated at £80,000). Although HSG accepted the proposals for HUNC it took until mid December for the start up costs to be pledged.

The HUNC project phase was launched in February 1993. Over a quarter of a million publicity leaflets with questionnaires were distributed through journals, trade associations and to individual inquirers. The Civil Aviation Authority provided free office, telephone and fax facilities for the HUNC manager for the project phase after which the manager moved into HUNC's own offices.

C.15.3 Objectives

HUNC activities are controlled by its Constitution which effectively sets the objectives for the organization as follows:

a) to identify and record existing stocks of halon
b) to keep a register of users and their requirements
c) to act as a conduit for sales of halons
d) to list recycling stations
e) to act as the UK link with UNEP IE/PAC in Paris

f) to maintain current information on international requirements for halons

Over and above all else HUNC is primarily a service organization and aims at excellence in serving its members. Constitutional, financial and other policy matters of general interest including election of Council members are addressed through an Annual or Extraordinary General Meeting, as appropriate, of HUNC membership.

C.15.4 How The Organization Functions

HUNC was initially constituted as an unincorporated Association bound by its constitution. In November 1993, in order to limit the general liabilities of its Council, the organization became a company limited by guarantee. The company is now run by a Board of Directors which has delegated power to the Council. HUNC is run 'by its members for its members'. In practice this means that policy is made and budgets approved by the HUNC Council comprised of members' representatives. Other, non-voting, Council members can be co-opted when specific technical expertise is required.

Day to day operation of HUNC is carried out by a Manager appointed by the Council and reporting to them. The manager is supported by a Personal Assistant who carries out secretarial duties. Together they cover all aspects of operation and attendant administration.

Membership of HUNC is available to any company or organization that wishes to join, provided they are prepared to abide by the Constitution. There is one class of membership and fees are fixed regardless of the size of the member organization or use it makes of HUNC services. Membership fees are the sole source of income and are averaged over successive years so that all members benefit when the membership level brings in more income than necessary budget.

The manager's role is to operate HUNC to achieve the objectives set out in the Constitution. On policy matters the manager refers to the Council. On technical matters the manager refers to the appropriate specialist. Many issues are tangential to the HUNC operation (requirements under the Environmental Protection Act, halon alternatives) and the HUNC manager has to know the best sources of advice on these issues to which a member could be referred. The HUNC manager does not give advice personally unless it falls within the objectives of the Constitution. However, general information is offered to members, including the best sources of further information, although without warranty.

HUNC is considering the possibility of compiling various guides for HUNC members covering such issues as the Montreal Protocol and EC Regulation, steps to consider when rationalising a companies' own halon bank and other topics which might be suggested by members.

HUNC will also be open to trade with banks in other countries, through UNEP IE/PAC in Paris. It will act as the intermediary between the seller or buyer in the UK and the buyer or seller in another bank. It will do no trading itself, it will own no halon.

C.15.5 Lessons Learned During Establishment

a) Unless and until the fire equipment industry and halon users agree that a need for a halon bank exists, there is unlikely to be enough energy, enthusiasm and finance to get a bank started. Halon users and fire equipment suppliers need a 'non-commercial' forum for discussion.

b) A national halon store with collection and delivery of redundant cylinders is a major industrial undertaking and is not likely to be a preferred option on financial, logistical or environmental grounds.

c) It is important to establish the 'credibility' of any scheme from the outset. Involving influential organisations in the early stages of setting up a halon bank can help its general perception by other potential members. These organisations could include large trade associations, insurance bodies, Government Departments who are halon users, Government Departments who have responsibility for the environment, health, safety, trade and industry.

d) The objectives of a halon banking scheme must be agreed early on and kept as simple as possible. Any bank will live or die by the service it gives to its customers. It must meet their needs and not attempt to 'regulate' their 'environment' in any way. Regulation is the job of Government, not of halon banks.

e) If the bank is set up as part of a larger 'umbrella' organization, care should be taken that there is no clash of policies or demonstrable vested interest.

f) Company, tax, liability and competition law must be studied carefully to determine the best legal structure for the banking organization.

C.15.6 Operational Experience

From the initial founder membership of 65 organisations HUNC now has a membership of 130. Halon users form the bulk of the members; the remainder are fire protection companies.

Since its launch, HUNC has received in excess of 300 telephone inquiries. These break down into the following categories:

a) Halon transactions: HUNC has facilitated some 70 transactions, varying in quantities, of both halon 1301 and 1211 totalling approximate 40 tonnes (at a ratio of about five tonnes of halon 1301 to one tonne of 1211).

b) Membership inquiries: Membership inquiries are resulting in a steady 2-3 additional members per month.

c) General advice: This ranges from updates on legislation to where to seek advice on alternatives. To aid the membership HUNC has now produced a Halon Handbook. Its aim is to provide the most up to date information on topics such as: the Montreal Protocol and EC Regulations; List of associated Regulations/standards; Codes of Practice; Risk assessment and options; Destruction; Pricing variables; Publications and articles on halon and Points of contact from both commercial and Government sectors.

HUNC continues to develop as its Members' needs change. HUNC has now embraced other ozone depleting substances, namely CFCs. Under the umbrella of HUNC Ltd there are now two organisations with similar constitutions and objectives: the founder organization deals uniquely with halon issues; the newly established Refrigerants Users Group (RUG) provides a similar service for refrigerant users.

The Halon Sector Group has now been reformed into the Halon Alternatives Group to address the needs of the future whether they lie with the continued use of halon or some other media. HAG aims to offer guidance on possible halon replacements, to help in speeding up acceptance of replacements and to act as a general forum for information exchange.

The group has already made major progress towards identifying and providing information, through a government sponsored booklet, on a whole range of alternatives to halon.

A sub-committee of HAG is now evaluating toxicological data supplied by the manufactures on candidate replacement agents. A report, due for publication at the end of 1994, aims to offer advice and recommendations on replacements for halon 1211 and 1301 in fixed systems. Further studies are likely into the fire fighting ability of each agent and the issue of decomposition products.

C.15.7 Quality Control

UK law promotes the non-restrictive "let the buyer beware" principle - it is the responsibility of the parties entering into a halon transaction to set the terms of the contract.
HUNC recommends that the halon transacted and the recycling facility, if used, should comply with relevant British or ISO Standards. At the very least the buyer should have confidence in the past history of the halon being traded. The Fire Industries Council, FIC, are in the process of writing "Codes of Practice" covering these points.

C.15.8 Contact Information

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C.16 United States of America

C.16.1 Introduction

Controls on the production, import, transport and use of halons are governed by the US Clean Air Act Amendments of 1990 (CAA), as implemented by the US Environmental Protection Agency (EPA). In addition, individual states and/or municipalities can implement local regulations that are more, but not less, restrictive than the CAA. In 1993 the EPA published regulations to implement the Copenhagen changes to the Montreal Protocol which banned the production and import of newly produced halons into the US, except for essential uses approved by the Parties to the Protocol, effective January 1, 1994. As yet there are no CAA regulations controlling the transport or use of halons except for certain labelling requirements. However, the EPA is required to implement regulations by the end of 1994 that include requirements to reduce the use and emission of halons to the lowest achievable level, and to maximize the recapture and recycling of halons. Also, some states have implemented emission restrictions to stop unnecessary discharge testing, and others are restricting the refilling of halon 1211 portable fire extinguishers.

In late 1991 the Halon Alternatives Research Corporation (HARC), a non-profit industry sponsored corporation, recognised the need to plan for the recycling and reuse of halons. As a result, in 1992 they funded a study to provide an update on the current status of halon recycle and recovery, usage, emissions and bank size in the US. The study report also provided suggestions and recommendations for future management of the US halon bank. The report estimated that the US halon bank at the end of 1993 would be approximately 22,000 tonnes of halon 1211 and 28,000 tonnes of halon 1301. There has been no mandated recording of inventories to confirm these estimates.

C.16.2 Factors Which Influenced The Type Of Bank Chosen

In the US, free market forces govern the trade of halons, and there are competition regulations that prohibit restrictions on that trade and the establishment of monopoly banks. In addition, the US halon bank is distributed over a vast area and network, and it is therefore reasonable to assume that more than one bank will eventually be established, and that the recycling of small quantities of halons will continue to occur at the local distributor level. Indeed the HARC study recognised the importance of the latter, particularly for the recycling of the halon 1211 contained in small portable extinguishers, and the halon 1301 in systems used by small companies. The study also identified three important needs that directly affect the transfer of large quantities of halon:

a) Some present bank holders, who would be in a position to contribute halons, wanted an assurance that their halons would be used wisely and only for critical uses.
b) Users would require an assurance that the recovered halons that they purchase met the same purity specifications as newly produced halons.
c) There was a greater need to establish a methodology for the transfer of ownership of halon 1301 than for halon 1211.

It was also recognised by HARC that, given the current uncertainty with respect to halon destruction technology, the availability of replacement chemicals, the size of the market and future demands, it would not be practical for a halon bank organization to directly collect halon for redistribution. Consequently, the halon 'bank' that HARC established, and which is the subject of this section, is a clearinghouse scheme which attempts to match halon consumers with halon donors, and which, if requested, will provide an independent critical use review of a consumer's halon application. This bank is known as the Halon Recycling Corporation (HRC).

C.16.3 Objectives

HRC is a voluntary, non-profit trade association formed to assist users of halon fire fighting chemicals to inventory and redeploy the existing bank of halon 1301. HRC's objectives are to:

a) Act as a broker for sales of recycled halon 1301.
b) Provide guidelines and procedures for a self determination of critical halon use.
c) Provide an independent review and critical halon use certification if requested.
d) Act as a clearinghouse for information on standards of recycled halon, and regulations or legislation that affects halon recycling, equipment, or technology.
e) Act as the link between halon users in the US and halon banks in other countries.

C.16.4 How The Organization Functions

HRC brokers halon 1301 through a two-tier system. This system was developed to provide a practical method of assuring that recycled halon is directed to critical applications, and not to unnecessary uses. In order to assist owners who no longer need their halon and who wish to transfer it to environmentally responsible users, HRC created a voluntary certification system for identifying potential buyers whose needs may reasonably be determined to be justifiable. Potential buyers meeting the necessary criteria are granted one of two designations, 'Certified' or 'Registered'.

The 'Certified' label is an assurance to sellers that, in the opinion of HRC's independent review committee, the buyer's use of halon is legitimate and conforms to the critical use criteria accepted by the United Nations Environment Programme. The committee is a balanced representation from the fire protection community, industrial users, the United States EPA, and non-profit environmental groups. The fire protection specialists are paid for their services, but other members of the committee are volunteers.

The 'Registered' label is an assurance to sellers that, in the opinion of the buyer, all reasonable economic measures possible to minimise halon use and emissions have been taken, and that the buyer considers the protection provided by halon to be critical.

HRC has a voluntary board of directors currently consisting of the founding members of HRC. The board has appointed a paid Executive Director to administer the day to day operation of HRC.

HRC maintains a database of sellers and buyers, and provides updated listings to each group on a regular basis. HRC operates as a non-profit organization, funded by fees set annually by its board of directors as follows:

a) Founding members donated funds to cover initial set up and incorporation costs.
b) Each seller pays a listing/joining fee based upon the quantity of halon available to be sold to cover processing costs. Sellers wishing to donate halon free of charge are not assessed this fee.
c) Each buyer pays a 'Registered' or 'Certified' user joining/listing fee to cover processing costs.
d) A brokerage fee, which is a fixed cost per pound of halon transferred, is charged to cover operating costs. Upon consummation of a deal, the buyer and seller forward copies of the contract indicating the quantity of halon transferred. The appropriate brokerage fee is then assessed on the buyer. Note, subsequent deals between the parties are assessed the brokerage fee at the then prevailing rate.

HRC encourages trade through other national banks where national and international laws permit. Brokerage fees to cover costs, and restrictions on buyers (in accordance with HRC's two-tier system), will be negotiated with other banks when alliances are established.

C.16.5 Lessons Learned During Establishment

The HARC study made the following two recommendations which have proved impractical to implement for the given reasons, although they may be desirable and/or potentially beneficial:

a) HRC would either undertake or contract with a large scale facility, the refurbishment of severely contaminated halons to ensure product purity. To do this would probably have required HRC to take ownership of the contaminated halon, and assume all or a portion of the liability for its disposal. To avoid potential legal problems, it was decided that it would be preferable to refer buyers and sellers to facilities that could undertake the refurbishment.
b) The HRC independent review panel would assist in balancing supply and demand by an application for use review procedure which would select those applications that best met the definition of critical use.

This was considered to be a restraint of trade that would likely be determined to be illegal in the US The voluntary application of the critical use review committee was deemed to be more acceptable.

C.16.6 Operational Experience

HRC has been in operation since September 1993, but did not facilitate its first halon transfer until early 1994. Through March 1994 there have been three transactions that, when completed, will total over 50,00 pounds of recycled halon 1301. Activity and interest have increased since the end of halon production on January 1, 1994. HRC has facilitated international transactions.

Owing to a federal tax on newly-produced halon for sale (that dramatically increased January 1, 1994), there was a great incentive in the US to sell all newly-produced halon before the end of 1993. Many users advance purchased enough halon to recharge their systems in the event of discharge, and this has limited the market for recycled halon in early 1994. Also, in the US there are many other avenues available for the purchase of recycled halon, particularly small quantities, and thus some companies have met their needs without the assistance of HRC. Of interest is a delay in one international transaction facilitated by HRC that occurred when a US import specialist held the halon at the border. The situation was resolved once it was confirmed to the import specialist that the halon was recycled.

C.16.7 Quality Control

Most of the halon in the US is being recycled to meet the traditional military specification MIL-M-12218C. However, users are being advised that halon recycled to the new ASTM standard ES 24-93, developed to replace the military specification, or the ISO standard 7201 is also acceptable.

There are only a small number of companies in the US that have equipment to properly recycle halon 1301, and even their equipment has limitations on the impurities that can be removed (only one company can reclaim severely contaminated halon). HRC has only recorded one transaction where the quality of halon was a problem, and this was quickly resolved between buyer and seller. HRC recommends that all purchasers of recycled halon operate under the buyer beware principle, and that where practical, a chemical analysis of the recycled halon be performed for all transactions to assure purity of the agent.

C.16.8 Contact Information

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Appendix D

Halon replacement agents

D.1 Halon Substitutes

Halon substitutes fall into two classes — replacements and alternatives. Replacements are halon-like materials — i.e., halocarbons. Alternatives are non-halon-like ("not-in-kind") agents — e.g., carbon dioxide, water, foam, inert gases, dry chemicals. Particulate aerosols (Reference [1]), inert gas blends (Reference [2]), and misting systems (Reference [3]) are three advanced technology halon alternatives under development. This section, however, concerns only replacements.

Ideal halon replacements have (1) a low or zero ozone depletion potential (ODP), (2) no residue upon evaporation, (3) a low toxicity, and (4) an acceptable effectiveness. It is relatively easy to find replacements that meet any three of these criteria, but difficult to identify halocarbons meeting all four. Reasonable cost, storage stability, compatibility with equipment materials, a low global warming potential (GWP), and a low atmospheric lifetime are also desirable.

Replacements extinguish fires, suppress explosions, and inert enclosed areas by two mechanisms — physical and chemical. Physical action agents (PAAs) act primarily by cooling and dilution. Chemical action agents (CAAs) act primarily by inhibiting the chain reactions that maintain combustion. PAAs are generally less effective than CAAs.

"First generation" halon replacements are CAA and PAA halocarbons that are currently available in sufficient quantities for installation in fire suppression systems. "Second generation" replacements are CAAs that offer improved extinguishment and environmental characteristics, but are still under development and have an unproved viability.

D.2 Halon Replacements

Families

Five chemical families comprise first generation replacements—hydrobromofluorocarbons (HBFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (FCs or PFCs), and fluoroiodocarbons (FICs). Many compounds being considered as chlorofluorocarbon (CFC) replacements in refrigeration, air conditioning, foam blowing, and solvents are found in the HCFC, HFC, and FC families. The HBFCs and FICs are CAAs and are very effective extinguishing agents. Consumption of the HBFC materials is scheduled to be phased out under the 1992 Amendment to the Montreal Protocol. PAAs, chemical families other than HBFCs or FICs, are generally less effective fire extinguishants and inerting agents than the existing halons; they may, however, be as effective in suppressing explosions (as opposed to inerting an area to prevent an explosion).

HBFCs and HCFCs have non-zero ODPs, with HBFCs having the highest. HFCs and FCs have zero ODPs, but can have relatively long atmospheric lifetimes and high GWPs, particularly in the case of the FCs. The FICs meet the effectiveness, low atmospheric lifetime, near zero ODP, and availability criteria; however, their toxicity will limit their use.

Halon Replacements — Chemical Families

Family	Extinguishment Mechanism	Toxicity	ODP Lifetime	Atmospheric	Extinguishment Effectiveness	Protocol Restrictions
HBFC	CAA	Moderate	High	Low	Excellent	Phaseout 1996
HCFC	PAA	Low	Low	Low	Fair to Good	Phaseout 2030
HFC	PAA	Low	Zero	Moderate	Fair	No Restrictions
FC	PAA	Very Low	Zero	High	Fair	No Restrictions
FIC	CAA	Moderate to High	Very Low	Very Low	Excellent	No Restrictions

Toxicity

Halon replacements must have a toxicity commensurate with their use. Three considerations must be addressed in assessing toxicity—(1) the toxicity of the replacement agent itself, (2) toxicity of agent decomposition products, and (3) problems associated with oxygen reduction. Only the first two of these will be discussed in any detail, since they are phenomena due to the agents themselves.

Replacement agent toxicity can be roughly divided into two types based upon length of exposure—acute and chronic. Acute toxicity concerns consequences of short-term exposures; chronic toxicity relates to effects from long-term exposures. Chronic toxicity is a concern for personnel exposed over many years, e.g., those involved in agent manufacturing and handling. Acute toxicity is a major concern in determining safety for personnel exposed to fire extinguishing agents during use.

Human and animal research indicates several possible adverse effects of halocarbon halon replacements. Not all halocarbons elicit each effect and a wide concentration differential exists in order for the effect to be manifested. First, they can stimulate or suppress the central nervous system (CNS) to produce symptoms ranging from lethargy and unconsciousness to convulsions and tremors (Reference [4]). Second, halocarbons can cause cardiac arrhythmias and can sensitize the heart to epinephrine (adrenaline). Third, inhalation of halocarbons can produce bronchioconstriction, reduce pulmonary compliance, depress respiratory volume, reduce mean arterial blood pressure, and produce tachycardia (rapid heartbeat). Fourth, these agents can cause organ damage by degradation products of metabolism (Reference [5]). Fifth, halocarbons can produce reproductive or developmental problems ranging from infertility to birth defects. Lastly, halocarbons can produce cancerous or mutagenic effects. CNS effects, cardiac sensitization, and pulmonary disorders appear to be reversible upon termination of exposure to these chemicals. Organ toxicity, cancer, reproductive and developmental toxicity, and mutagenicity, on the other hand, are latent effects, and sequelae (delayed effects due to the compound or its metabolites) are usual.

The immediate effects of halocarbon exposure on the nervous system, cardiovascular system, and respiratory system appear to be caused by the compound itself. However, it is thought that the latent effects that take place in specific organs, such as the liver, kidneys, and lungs, are possibly caused by the degradative products formed when the halocarbons enter into metabolic processes. Both the immediate effects and the latent damage must be considered when evaluating firefighting agent candidates. Although generalization to the entire class of halocarbons would be convenient, toxicity information on each candidate must be individually assessed to determine fully its potential health hazards.

In general, acute toxicity has been the primary consideration when assessing halon replacements. Acceptable acute toxicity for replacement agents varies with use. Most halon applications are either streaming or total flooding. Streaming agents, such as Halons 1211 and 2402, are discharged directly onto a fire, usually from portable extinguishers. Total-flooding agents, such as halon 1301, fill a room to the concentration required for extinguishment or inertion, usually from a fixed system. In normal use, streaming agents do not come into direct contact with people, though indirect contact is possible. Exposure to total-flood agents could, however, be significant. Replacement streaming agents have less stringent acute toxicity requirements than do substances for total flooding of normally occupied areas.

Four acute toxicological indices are widely used in assessing halon replacements. These include the LC_{50}, ALC, LOAEL, and NOAEL values. The LC_{50} value is the concentration of a chemical that causes death in 50% of an animal population for a specified time period. Normally, LC_{50} values are determined from 4-hr rat exposures. Most researchers feel that 4-hour exposures do not adequately represent exposures during halon use, which are likely to be very short, on the order of minutes and not usually repeated. Therefore, 15-min exposure values are being determined for halon replacement candidates. LC_{50} values are best used to compare the toxicological profile of various agents. They have only limited applicability in the assessment of design concentration risks.

The approximate lethal concentration (ALC) is the chemical concentration at which lethality is first observed. ALC values are lower than LC_{50} values. Like the LC_{50}, the ALC is not usually the most important consideration in assessing design concentration risks.

The lowest observed adverse effect level (LOAEL) is the lowest concentration at which an adverse toxicological effect is observed. The no observed adverse effect level (NOAEL) is the highest concentration at which no adverse toxicological effect has been observed. Since the first acute adverse physiological effect observed for most halocarbons is heart arrhythmias, cardiac sensitization has been chosen as the adverse effect on which NOAEL and LOAEL values for most halon replacements are based (Reference [6]).

Cardiac sensitization is the term used for the sudden onset of cardiac arrhythmias caused by a sensitization of the heart to epinephrine (adrenaline) in the presence of some concentration of a chemical. Cardiac sensitization (specifically leading to ventricular fibrillation) was first demonstrated in 1912 in cats exposed to chloroform in the presence of epinephrine, which without epinephrine was nonhazardous (Reference [7]). Since then, cardiac sensitization has been demonstrated in man as well as laboratory animals.

When comparing concentrations necessary to elicit toxic responses such as anesthesia, cardiac sensitization, or lethality, cardiac sensitization occurs at a lower concentration than the other two endpoints. Therefore, regulatory and standard-making authorities have used cardiac sensitization thresholds as the criterion for determining a chemical’s acceptability for use in areas where human occupancy may occur. In addition, the phenomenon of cardiac sensitization is particularly important in firefighting because under the stress of the fire event, higher levels of epinephrine are secreted by the body which increases the possibility of sensitization. Because an understanding of cardiac sensitization is critical for halon replacements a discussion of the experimental protocol follows.

The accepted experimental procedure used to investigate the cardiac sensitization potential of a chemical involves outfitting dogs with electrocardiographic (ECG) measurement devices and exposing the animals to a sequence of agent and epinephrine (Reference [8]). Healthy male beagle dogs (generally 6 or more animals per exposure concentration), between the age of 1 to 2 years, are trained to stand in a cloth sling and to wear a snout mask. The dogs learn to accept venipuncture and ECG monitoring. Thus, they are minimally stressed during the experiment. The usual sequence of exposure is that the animal is monitored in a baseline condition without any intervention for 2 minutes. Epinephrine is then intravenously infused to determine the effect of this catecholamine on the cardiac system. The dose and time period for infusion varies slightly between laboratories; however, the levels of epinephrine given are always in the pharmacological rather than the physiological range. After approximately 5 minute from the initial epinephrine administration, the agent is given as a continuous inhalation exposure either through a mask fitting over the dog's snout or in an exposure chamber. After a 5 minute agent exposure, epinephrine is administered ("epinephrine challenge") intravenously along with the continuous agent exposure. The animals is monitored for another 5 minutes to determine the effect of epinephrine and agent. This protocol is performed at increasingly higher chemical doses until a "marked adverse response" occurs.

Protocol for Testing Cardiac Sensitization in Dogs

Time, minutes	Procedure
0	Start ECG recording
2	Administer Epinephrine Dose
7	Start Inhalation of Test Gas or Air
12	Administer Epinephrine Challenge Dose
17	Stop Test Gas Inhalation; Stop ECG Recording

A "marked adverse response" is considered as the appearance of 5 or more multifocal ventricular ectopic beats or ventricular fibrillation (Reference [9]). A "mild response" is described as an increase in the number of isolated abnormal beats (less than 5 consecutive beats) following the epinephrine challenge (second epinephrine administration). The threshold level is the lowest concentration at which cardiac sensitization occurs. No definitive rule exists indicating the number of animals that must experience a marked response to determine the threshold value. In most cases, even one animal experiencing a marked response constitutes establishment of a threshold value. This level is also called the LOAEL. The highest concentration at which no marked responses occur is called the NOAEL. These values are used when determining safe exposure levels for humans. However, it is not known with certainty whether the LOAEL and NOAEL in dogs accurately represent these values in humans since a study directly comparing cardiac sensitization levels in dogs and humans is not available.

Cardiotoxic thresholds determined in dogs are considered conservative for humans even in high-stress situations (Reference [10]). The conservative nature of these values arise based on several factors: 1) no certainty that dogs are a good model for humans, 2) very high doses of epinephrine used in the test method, 3) some dogs, and presumably some humans, are more susceptible to sensitization than others. Nevertheless, regulatory and standard-making authorities are using results of cardiac sensitization tests to determine the acceptability of halon replacements for use in normally occupied total flood applications. If the cardiac sensitization value (LOAEL for US EPA or NOAEL for NFPA) is below the fire suppression or inertion design concentration, then the candidate is not acceptable for use in normally occupied total flood applications.

For streaming applications, where exposure of personnel is difficult to determine and highly scenario-dependent, risks are difficult to assess. To date, there has been no general agreement on toxicological requirements for streaming agents. However, the following discussion is presented. Because design concentrations are not typically thought of for streaming agents, the U.S. EPA has used models and air monitoring data to determine if the firefighter exposure level will exceed the cardiac sensitization threshold during discharge of a portable extinguisher. Based on breathing zone personnel monitoring studies of other halon replacement agents, personnel are exposed to less than 1000 ppm (0.1%) in simulated aircraft hangar exposures during discharge of 20- or 150-lb fire extinguishers in T-dock aircraft hangers (Reference [11]) and in open pit, outdoor fire scenarios fought with 20- or 150-lb fire extinguishers (Reference [12]). U.S. EPA modeled peak concentrations of Halon 1211 in a scenario where a 1-lb extinguisher was discharged in a single-person office. The estimated peak concentrations of Halon 1211 in this situation was 2,450 ppm (0.25%). Imperial Chemical Industries (ICI) performed breathing zone measurements using a Miran portable gas analyzer for a 3-lb Halon 1211 extinguisher discharged in an office with dimensions of 22.25 ft by 10 ft by 8 ft (1,780 ft^3) (Reference [13]). The measured concentration of Halon 1211 was 0.38%. Accordingly, it is anticipated that in streaming scenarios similar to those indicated above, firefighter exposure would not exceed concentrations greater than 0.4%.

Central nervous system (CNS) effects (perception problems, dizziness, and, in severe cases, unconsciousness) may also be of concern. Since cardiac sensitization generally occurs at lower concentrations than CNS effects decreased attention has been given to CNS effects. CNS effects are significant in scenarios where performance is essential to maintaining life such as in aircraft cockpits.

Decomposition Products

The toxicity of the neat agent is not the only toxicological aspect that must be considered; decomposition product generation must also be investigated. The principal toxic species produced in carbon-based fuel fires is carbon monoxide (CO). The yield is strongly dependent on the burning conditions and the availability of air. Levels typically range from a few 10 ppm to several 100 ppm. Other toxics may be present depending upon the material(s) being combusted. Wood and paper fires typically produce CO, as do hydrocarbon fuel fires. Plastics from circuit boards, cables, and fabrics, however, tend to generate other toxic products, such as hydrochloric acid (HCl) and hydrogen cyanide (HCN), in addition to CO.

Adding halocarbon fire extinguishing agents to fires increases the amount and types of combustion products. The resulting species generated are characterized as decomposition products and can be severely toxic. In addition to increased CO, acid gases, such as hydrogen fluoride (HF), hydrogen bromide (HBr), and hydrogen chloride (HCl), as well as carbonyl halides ($COCl_2$ and COF_2) are formed. Chemical intermediaries (e.g., perfluoropropene from HFC-227ea) have also been identified. Generated during the suppression event, concentrations of decomposition products have been measured to be 10 to 1000 times those limits set by the U.S. Occupational Safety and Health Administration (OSHA) and other safety and health organizations. The concentration of toxic products generated by the current first generation halon replacements exceeds levels generated by the existing halons by 5 to 10 times (Reference [14]). Whether the increased amounts of these decomposition products will cause problems is still under investigation. End use (application specific) assessment of all exposures and associated risks are critical in determining the proper design concentration and for agent selection.

Most halocarbon replacements are used at concentrations such that serious oxygen deprivation does not occur. In the past, oxygen levels below 16 percent were considered to be cause for concern; however, there are now indications that short-term exposure to oxygen concentrations somewhat lower than this can be experienced without significant risk, at least for healthy individuals. Oxygen deprivation becomes a concern when considering using inert gases as fire extinguishing agents.

Effectiveness

Many different tests are used to judge the relative effectiveness of fire extinguishing agents. For total flooding agents, the cup burner apparatus is widely used at the laboratory scale (Reference [15]). Note, however, that this apparatus and the technique used has not been standardized. There is some variation in apparatuses and results between testing laboratories. Larger scale tests also provide important data; however, the results of such tests are highly scenario dependent and may not be comparable between organizations without extensive temporal and spatial concentration analysis. This is especially true for agent distribution and oxygen levels. In the discussion herein, the extinguishment concentrations as determined by cup burner using *n*-heptane fuel are given. Concentration values differ depending upon the fuel used. The concentrations are expressed as volume percent of gaseous agent in air. A more meaningful parameter is the relative amounts (weight or storage volume) of agents needed to achieve the same degree of fire protection.

For streaming agents, the cup burner is less effective in determining performance since physical properties that predict streaming ability are at least as important as inherent fire suppression ability. Nevertheless, cup burner values are often used to make an initial prediction of fire suppression ability.

The spherical bomb is usually used to determine inerting effectiveness (Reference [16]). This apparatus allows the measurement of the agent concentration required to ensure that no explosion occurs when a gaseous fuel is ignited.

Specific Replacement Candidates

The refrigeration industry designate various halocarbons with a number. This “Halocarbon Numbering System” is widely used in both national and international regulations, not only for refrigerants, but often for other materials including halon replacements. The Halocarbon Numbering System (sometimes called the CFC, Freon®, or Refrigerant Numbering System) was developed by Du Pont for Freon® chemicals in the late 1930s. The system was later expanded and formalized into a standard by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the American National Standards Institute (ANSI) (Reference [17]). The nomenclature for the commercially announced halon replacement agents is shown below. (Halons 1301 and 1211, which are named using the halon nomenclature rather than the halocarbon nomenclature, are given for reference).

The following tables give information on the principal halocarbons announced as total flooding and streaming agents. The ODPs are taken from Reference [18], cup burner values from Reference [19], and inertion values from Reference 16. Most toxicological indices are those provided by chemical manufacturers. High values in the table are obtained with supplemental oxygen (e.g., values of 80% are obtained with 20% oxygen to prevent asphyxiation).

Halon Replacement Candidates

Candidate	Name (manufactures designation)	Formula
Halon 1301	Bromotrifluoromethane	$CBrF_3$
Halon 1211	Bromochlorodifluoromethane (BCF)	$CBrClF_2$
HBFC-22B1	Bromodifluoromethane	$CHBrF_2$
HFC-23	Trifluoromethane	CHF_3
HCFC-123	2,2-Dichloro-1,1,1-trifluoroethane	$CHCl_2CF_3$
HCFC-124	2-Chloro-1,1,1,2-tetrafluoroethane	$CHClFCF_3$
HFC-125	1,1,1,2,2-Pentafluoroethane	CHF_2CF_3
HFC-227ea	1,1,1,2,3,3,3-Heptafluoropropane	CF_3CHFCF_3
FC-3-1-10	Perfluorobutane	$CF_3CF_2CF_2CF_3$
FC-5-1-14	Perfluorohexane	$CF_3CF_2CF_2CF_2CF_2CF_3$
FIC-13I1	Trifluoroiodomethane	CF_3I
HCFC Blend A	HCFC-22	82% $CHClF_2$
	HCFC-123	4.75% $CHCl_2CF_3$
	HCFC-124	4.5% $CHClFCF_3$
		3.75% terpene
HCFC-Blend B	Primarily HCFC-123	Primarily $CHCl_2CF_3$

Primary Total Flooding Halon Replacement Candidates

Candidate	Exting Conc, %	Propane Inertion Concentration, %	ODP[a]	GWP[b]	Atmospheric Lifetime, yrs
Halon 1301	2.9	6.2	~16	---	
HFC-23	12.6	19.8	0	9000	280
FC-3-1-10	5.0	9.8	0	5500	2600
HBFC-22B1	4.4	8.0	0.74	---	9
HCFC-124	8.2	12.0	0.022	440	7
HFC-125	9.4	14.7	0	3400	41
HFC-227ea	6.3	11.5	0	2050	31
CF_3I	3.2	6.5	<0.008	~1	1.15 days
HCFC Blend A	8.6[c]	11.8			
HCFC-123	7.2	---	0.02	90	2
HCFC-22	11.6	18.8	0.05	1600	16
HCFC-124	8.2	12.0	0.022	440	7

[a] Relative to CFC-11.

[b]Based upon a 100-yr horizon, relative to CO_2.

[c]Based on manufacturers large-scale test results rather than cup burner values.

Primary Streaming Halon Replacement Candidates

Candidate	Extinguishment Concentration, %	ODP	GWP	Atmospheric Lifetime, yrs
Halon 1211	3.2	~4	---	---
HBFC-22B1	4.4	0.74	---	9
HCFC-123	7.1	0.02	90	2
HCFC-124	8.2	0.02	440	7
HCFC Blend B	~7			
HCFC-123	7.1	0.02	90	2
HFC-227ea	6.3	0	2050	31
FC-5-1-14	4.4	0	5200	~3000
CF_3I	3.0	<0.008		~1.15 days

Toxicological Summary of Total Flooding Halon Replacement Candidates

Candidate Agent	Acute Toxicity (LC_{50} or ALC), %	Cardiac Sensitization,		Developmental Toxicity, NOAEL, %	Subchronic Toxicity (13-wk), NOAEL, %
		NOAEL, %	LOAEL, %		
Halon 1301	>80 (Estimated)	5.0	7.5	4.95	<2.3[a]
HFC-23	66.3[b]	50	>50	N/A[c]	1
HFC-125	>70[b]	7.5	10	5	5
HFC-227ea	>80	9.0	10.5	>10.5	>10.5
FC-3-1-10	>80[b]	40	>40	N/A	N/A
HCFC-124	23-29[b]	1.0	2.5	5	10
HCFC BlendA	64[d]	10.0	>10	N/A	N/A
CF_3I	27.4[e]	0.2	0.4	N/A	N/A

a 18-wk exposure
b ALC
c N/A = not available
d LC_{50} 4-hr exposure
e LC_{50} 15-min exposure

Toxicological Summary of Streaming Halon Replacement Candidates

Candidate Agent	Acute Toxicity(LC_{50} or ALC), %	Cardiac Sensitization, NOAEL, %	Cardiac Sensitization, LOAEL, %	Developmental Toxicity, NOAEL, %	Subchronic Toxicity (13-wk.), NOAEL, %
Halon 1211	10-13[a]	0.5	1.0	N/A[b]	0.33[c]
HCFC-123	3.2[a]	1.0	2.0	1.0	<0.5
HCFC Blend B	~3.2[a] (estimated)	~1.0 (estimated)	2.0 (estimated)	N/A	N/A
FC-5-1-14	>80	>40	>40	N/A	30.5[d]
HFC-227ea	>80	9.0	10.5	>10.5	>10.5
CF_3I	27.4[e]	0.2	0.4	N/A	N/A

a LC_{50} 4-hr exposure
b N/A = Not Available
c 3-wk exposure
d 30-day exposure
e LC_{50} 15-min. exposure

All of the first generation candidates have tradeoffs. Of the agents listed above, only HBFC-22B1 and CF_3I has an effectiveness similar to that of the present halons across a broad range of applications. However, HBFC-22B1 will soon be phased out owing to its high ODP. The low cardiotoxcity value of CF_3I limits its use to unoccupied total flooding applications (its acceptability as a streaming agent is under consideration). For most (but not all) applications, two to three times more of the other first-generation replacement candidates will be needed to provide the same degree of protection compared to the present halons. In addition, most of the first generation agents have some global environmental impact: (global warming, long atmospheric lifetime, and/or ozone depletion) and all have increased emissions of toxic combustion products during fire extinguishment relative to halons.

D.3 Second Generation Halon Replacements

Researchers are now investigating possible “second generation” agents materials that are highly effective, yet have low global environmental impacts. These materials are CAAs, but have chemical features that promote very low atmospheric lifetimes, a property that reduces the ODPs and GWPs to near zero. Many second generation candidates have been identified (examples are fluoroiodocarbons, bromoalkenes, and polar-substituted bromocarbons, Reference [20]), and several have been shown to have very low or zero ODPs and GWPs while maintaining or exceeding the effectiveness of the present halons. The problem is that little is known about manufacturability, toxicity, emissions, materials compatibility, and storage stability, and the market may not be sufficiently large to justify the cost of determining these unknowns. The viability of second generation agents will not likely be known for 3-5 yrs.

D.4 Conclusions

No single substance has been proven to serve as a suitable replacement for halons in all applications. Multiple agents, varying according to application, are a likely outcome.

All near-term agents have some drawbacks. The HBFCs are effective, but will be phased out under the 1992 Amendment to the Montreal Protocol. The FICs are effective, but their toxicity restricts their use. The HCFCs, HFCs, and FCs are less effective than the existing halons in most applications. Furthermore, the HCFCs have a non-zero ODP and their consumption is regulated under the Montreal Protocol. Many HFCs and, in particular, FCs have higher than desirable atmospheric lifetimes and GWPs.

The first generation halon replacement candidates have been tested under a number of different toxicological protocols. For the total flood replacements, cardiac sensitization is used to evaluate whether the chemical can be applied in occupied areas where human contact is possible. Cardiotoxicity is the toxic effect that occurs at the lowest concentration. The cardiac sensitization threshold is compared to the fire extinguishing design concentration and only those chemicals with threshold levels above the design concentration can be used in normally occupied areas. Consequently, HFC-23, HFC-227ea, FC-3-1-10, and HCFC Blend A are suitable for use in occupied areas as total flood agents based upon toxicity.

For streaming agent replacements, toxic endpoints are compared to realistic exposure concentrations based on personnel monitoring levels rather than design concentrations. ALthough the candidates may appear more toxic than Halon 1211, the levels at which humans would likely be exposed under proper use as streaming agents are much lower than the toxic levels (again, cardiac sensitization threshold). The suitable streaming replacements based upon toxicity are HCFC-123, HCFC Blend B, and FC-5-1-14 (CF_3I acceptability as a streaming agent is under consideration).

In addition to the neat agent toxicity, toxic species produced during the fire suppression event must be considered. Decomposition products have been shown to increase with type of fuel, fire size, system discharge time (extinguishment time), and type of agent used. The current first generation halon replacements generate 5 to 10 times greater concentrations of CO, HF, and COF_2 than Halons 1211 and 1301. In total flood applications with the current halon replacements, the toxic species have been shown to be minimized by using a 40% safety factor above cup burner values, remembering that with Halon 1301 a 70% safety factor has typically been the norm.

Second generation agents have a high effectiveness coupled with low global environmental impacts; however, these materials are still under development and may not prove commercially viable for 3-5 yrs.

Appendix E

Combustion and extinguishment - an overview of the science

Introduction

An understanding of the issues in identifying low or non-ozone depleting fire extinguishing agents as replacements for halons requires some knowledge of fire extinguishment processes. This paper is to help serve in giving and using that understanding of combustion, as well as of the factors involved in halon replacement research. In no way should it be regarded as a detailed or complete treatment. Further information is contained in Reference 1 and its literature references.

Combustion

Combustion is an oxidation/reduction reaction sufficiently intense to generate heat and light. Fire is a combustion process most often characterized by diffusion flame behaviour. A diffusion flame is one in which fuel and oxidizer are not mixed before combustion. In contrast, deflagration and possible transition to detonation (explosion) occur in premixed fuel-oxidizer mixtures (See Section Five). An unwanted fire is uncontrolled combustion.

The oxidizer for nearly all unwanted fires is oxygen from the air. In specific hazard cases, the oxidizer may be pure or enriched oxygen, hydrogen peroxide, organic peroxides, ozone, metal peroxides, dinitrogen tetroxide, fluorine, or other strong oxidants. The reducing agents (fuels) are typically solid, cellulosic materials (paper, wood), which give Class A fires; liquid fuels (gasoline, alcohol, kerosine, aviation fuels, other petroleum products), which give Class B, flammable gases that give Class C fires; and metals (magnesium, lithium, sodium, titanium), which give Class D fires. A typical fire threat is an unwanted Class A, Class B or Class C fire where the oxidation agent is air that enters the flame zone by diffusion. Halon fire extinguishing agents are not suitable for Class D fires, nor for deep seated, smouldering Class A fires.

There are several other characteristics that are used to describe combustion processes and fire types. These do bear on fire fighting and prevention approaches but will not be described in detail. The usually encountered flaming combustion occurs primarily in the gas phase, as opposed to smouldering combustion which is a surface process. Deep seated smouldering can be hard to reach with extinguishing agents and can lead to the more vigourous flaming combustion.

The energy release rates of diffusion flames are limited by mixing rates of fuel and oxidizer. Turbulence, fluctuations in fluid flow velocity, can significantly increase mixing and thus cause more intense fires. The turbulence can be from an external flow, or self generated for large fires. Flow in small fires, such as small candles or laboratory burners, is usually laminar. Pre-mixed gas mixtures, depending on the ratio of fuel to oxidizer, can range from fuel lean to fuel rich concentrations. Stoichiometric refers to the ratio required for complete consumption of fuel and oxidizer, which produces final products only. Flame speed and fire intensity are functions of the ratio and concentrations. Depending on conditions, a pre-mixed gas fire can lead to an explosion. The time scale and energy release rates make much more rigorous demands on extinguishing agents for explosion protection.

Suppression Mechanisms

Chemistry (molecular reactions) is usually more important in fire initiation and suppression, while physics (macroscopic, dynamics) has a dominant role in fire spread. Both are involved in fire extinguishment. Fires can be suppressed by a number of mechanisms, usually occurring in combinations. The Fire Tetrahedron with sides of fuel, oxidizer, energy, and free radicals (reactive intermediates) can be further elucidated as related to suppressant action. The extinguishment pathways listed in Table 1 serve as a convenient framework for discussion. A more detailed molecular description will follow.

Table 1

Extinguishment Pathways

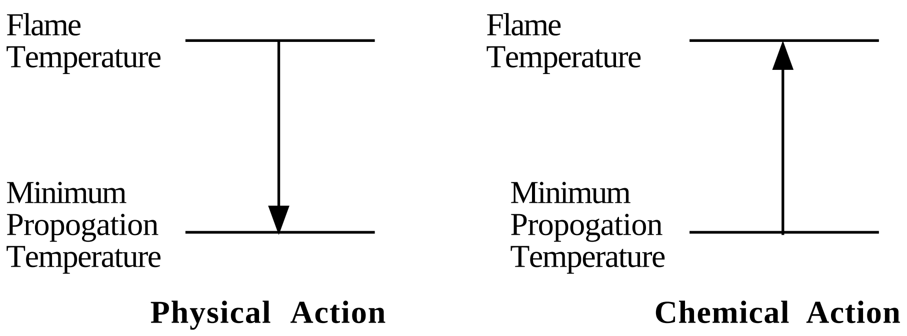
Physical - Non-Reactive		Chemical - Reactive
Energy	**Spatial**	
Heat Capacity	Dilution	Scavenging/Catalytic
Thermal Conductivity	Separation	Third-Body Effects
Decomposition	Decoupling	Ionic

Physical - Energy:

An organic fuel flame can normally exist only between two temperature limits (See Figure 1). The adiabatic flame temperature is the highest temperature to which the reaction exoergicity (released energy) can heat the product gases. The minimum propagation temperature is the lowest temperature that will allow sufficiently rapid chemical reactions to maintain the flame. When energy losses, such as heat capacity or thermal conductivity processes, lower the flame zone temperature below the minimum propagation temperature (approximately 1600 K)[2], chemical reaction rates slow and extinguishment results. Agent decomposition also requires energy input to break bonds. This mode, but not possible inhibiting reactions of the decomposition products, is usually considered a physical process.

Figure 1

Flame Suppression



Physical - Spatial:

Dilution slows reaction rates by the Law of Mass Action. Addition of an agent at 10 percent means dilution of all other components by 10 percent. Bimolecular reaction rates are then slowed to 81 percent (0.9 x 0.9) of their former rate. Separation is the classical concept of isolation of fuel from oxidizer. A blanket and a foam layer are examples. Decreasing energy feedback to unburnt fuel reduces fuel vaporization and decomposition. Examples of decoupling of the energy and radical rich zone from the unburnt gases are blowing out a candle or blasting out an oil-well fire. Another example of decoupling is the creation of an ionic wind by employing a high voltage direct current field to blow out the flame. In total flooding applications, separation and decoupling mechanisms are not usually significant.

Chemical:

Gaseous fire suppression agents will always have some degree of physical extinguishment action. Agent chemical structure and components may also provide chemical extinguishment action. Chemical pathways can be very efficient. The radical species responsible for flame propagation are directly removed from supporting combustion by establishing alternative reaction paths. In order for the combustion chemistry to maintain itself and overcome unproductive thermal diffusion, radical diffusion, and radical reaction, it must generate additional reactive radicals to keep their concentrations above the required minimums. Chemical activity on the part of bromine is a primary reason for employing the bromine containing halons. Due to the endothermic (energy requiring) character of the reactions that generate such species, an increased minimum propagation temperature is required. Very rapid radical removal requiring a minimum propagation temperature above the adiabatic flame temperature will cause extinguishment (See Figure 1).

A suppressant that removes one radical acts as a radical scavenger. Formation of HF by a fluorine containing agent is an example. A species that can remove more than one radical may be functioning as a catalyst, having a much greater suppressant impact. HBr, formed by a bromine containing species combining with a hydrogen atom, can react with a second hydrogen atom to form a much less reactive hydrogen molecule, while generating the bromine radical to continue its chemical suppression action.

Facilitation of recombination reactions by agent acting as a third-body has a measurable effect, but not as significant. Such interaction could be called physical as there are no agent chemical changes involved. The significance of ionic suppression pathways has not been adequately demonstrated.

Combustion Chemistry

Thermodynamics deals with energy and determines the extent to which, if at all, a reaction can occur. Kinetics deals with the rates of achieving those final conditions. Thermodynamics predicts a mixture of methane and air will generate carbon dioxide, water, and excess energy. Kinetic considerations dictate it will happen only if sufficient energy or reactive free radicals are introduced to cause reaction initiation. Thus at room temperature a flammable methane-air mixture must be ignited.

Combustion chemistry primarily involves reactions of free radicals. Free radicals have one or more unpaired electrons available for bond formation, and are very reactive. Typically hydrogen atoms (H), hydroxyl radicals (OH), oxygen atoms (O), and methyl radicals (CH_3) are the most important species. Free radical initial generation, increased production, reaction, and consumption, mark the major phases of combustion chemistry. These reaction regimes are denoted as initiation, branching, propagation and termination. The specifics are determined by the fuels involved.

Initiation:

Sufficient energy must be provided to break bonds in order to generate free radicals from stable molecules. Sparks, hot surfaces, and electric discharges are common energy sources. An existing flame provides an initiation source not only by its energy, but also due to its existing radical presence. This is an example of piloted ignition as opposed to spontaneous ignition. Methane pyrolyses generates radicals as

$$CH_4 \rightarrow CH_3 + H - 439 \text{ kJ/mole} \quad (1)$$

Thermodynamic data[3] are for 298 K.

Branching:

A branching reaction is one that produces more radicals than are consumed. In this way the initial radicals generate a sufficiently high radical concentration to allow the flame to self propagate. The reaction

$$H + O_2 \rightarrow OH + O - 70 \text{ kJ/mole} \quad (2)$$

is usually the major oxygen consumption and primary branching combustion reaction. It is key in flame propagation as one reactive radical generates two reactive radicals. The rate of reaction (2) can be given as

$$\text{Rate} = AT^n[H][O_2]\exp(-E_a/RT) \quad (3)$$

where AT^n relates to collision frequency and orientation effectiveness, [H] and $[O_2]$ are reactant concentrations, and E_a is the activation energy. The exponential operation on this last term means that for typical positive activation energy values, rates will be significant only at elevated temperatures.

On the molecular level, if the rate of reaction (2) is decreased sufficiently, the fire will be extinguished. Dilution (lowering reactant concentrations), energy removal (reducing temperature) and radical removal (chemical scavenging or catalytic reaction) all take place with chemical suppression agents.

Propagation:

Reactions that consume fuel or oxidizer without changing the total number of flame radicals are called propagation reactions. One such reaction for methane is

$$CH_4 + H \rightarrow CH_3 + H_2 - 3 \text{ kJ/mole} \quad (4)$$

Termination:

The overall reaction rate is decreased when radicals recombine to form stable molecules or react to produce much less reactive radicals. Examples are

$$H + OH + M \rightarrow H_2O + M + 499 \text{ kJ/mole} \quad (5)$$

$$H + O_2 + M \rightarrow HO_2 + M + 216 \text{ kJ/mole} \quad (6)$$

In these cases significant energy is released which is removed by a third body denoted as M. The need for an entity to stabilize the energy rich product is the interaction that allows agents to help cause extinguishment by serving as efficient third-bodies. In reaction (6), while HO_2 is a free radical, it is much less reactive than H. The combustion reaction rate thus decreases.

Halon Interaction

While a detailed understanding of chemical flame suppression remains incomplete, the most likely mechanism for Halon 1301 can be described as

$$CF_3Br + H \rightarrow CF_3 + HBr + 76 \text{ kJ/mole} \quad (7)$$

The bromine containing HBr can then enter into a cycle catalyzing recombination of hydrogen free radicals.

$$H + HBr \rightarrow H_2 + Br + 70 \text{ kJ/mole} \quad (8)$$

$$Br + H + M \rightarrow HBr + M + 372 \text{ kJ/mole} \quad (9)$$

Other reactions contribute as well. The removal of a number of hydrogen atoms for each bromine via catalytic reactions is the reason for the high suppression efficiency of halons. The fluorine containing radical also contributes to chemical suppression via formation of HF. In this case, one hydrogen free radical is scavenged per reacting fluorine.

Chemical activity:

As described above, all agents possess some degree of physical suppression mechanisms. When there are significant chemical suppression mechanisms operating as well, the agent is considered a chemical suppression agent. A method to estimate the physical suppression efficiency of chemical agents for air-liquid hydrocarbon fires[4] shows that halon 1301 efficiency is 20 per cent physical and 80 per cent chemical.

The classic Purdue University study[5] demonstrated that the effectiveness of halogenated fire suppressants increases as F < Cl < Br < I and that a molecule containing two atoms of a given halogen is usually more effective than a molecule containing only one. More recent studies have assigned relative effectiveness values for the halogens. Bromine and iodine are shown[6] to have similar high effectiveness, with the CF_3 radical also possessing significant chemical effectiveness, and chlorine much less so. A more recent study shows that while the effectiveness of physical agents is independent of concentration, the effectiveness of halon 1301 increases (per molecule) as its concentration decreases[7]. The implication is that mixtures, including at least one chemical agent, may give improved extinguishing performance, due to nonlinear effects. Further detailed experimental and associated computer modelling studies are needed to better understand these effects.

A very important, and often not adequately considered, suppression consideration is oxygen concentration. The basic combustion chemical reactions depend on oxygen. Whenever oxygen concentration is reduced, such as by fire consumption, a partially vitiated condition exists. A ventilation controlled fire will need less suppression agent to obtain extinguishment. Synthetic atmospheres and blend heptane fuel cup burner extinguishment tests performed at the US Naval Research Laboratory show that this effect is pronounced indeed. The amount of agent required for extinguishment in air (21 per cent oxygen) will be over one third greater than the concentration required in a vitiated 19 per cent oxygen environment. This amount of oxygen depletion will usually not have much noticeable effect on fire appearance. Great care must be exercised in conducting large scale fires in monitoring oxygen levels and guarding against excessive oxygen depletion. Test results to identify design concentration requirements or to compare with other tests or agents are valid only with accompanying information on oxygen levels in the vicinity of the fire during the extinguishment process.

Halon Replacement Strategies

There are several approaches to selecting candidate suppression agents that would minimize damage to the stratospheric ozone layer. Assuming replacements will be based on fluorinated hydrocarbons, the compromises involve forgoing, to various degrees, the chemical suppression efficiency of bromine and iodine.

1. Reduced ODP - Minimize the bromine, chlorine and iodine content by employing mixtures of chemical and physical agents.

2. Zero ODP - Eliminate bromine, chlorine and iodine from the agents completely.

3. Low ODP - Retain bromine, chlorine and iodine, but on molecules that will not get to the stratosphere.

The first approach reduces the ODP to the mixture weighted average. Some measure of efficient chemical suppression activity is thus retained. However, the use of ozone depleting substances is continued.
The second approach employing non-ozone depleting substances results in relying on less efficient physical mechanisms unless new clean agent type breakthroughs occur. Agent weight and volume requirements will increase, and toxic and corrosive hydrogen fluoride product may increase significantly.

The last approach relies on rapid removal in the troposphere to significantly reduce tropopause crossing. Such removal can be via photolysis, reaction, or washout. The advantage is that some measure of chemical suppression action can be retained. The tradeoff is that the tendency for increased photolysis or reaction also leads to unwanted reactions with resulting toxicity, corrosion, and material compatibility concerns. This is especially so for iodine compounds.

General guidelines on candidate replacement design include:

Molecular size	Physical effectiveness; heat capacity increases with number of atoms
Fluorine	Effectiveness (if reactive - radical scavenging), stability
Chlorine	Physical (streaming - elevated boiling point), but low chemical action
Bromine	High chemical effectiveness
Iodine	High chemical effectiveness, but increased toxicity and corrosion considerations
Hydrogen	UV absorption Atmospheric lifetime reduction, photolysis, or rain-out Reactive bonds Hydrophilic

Agent action discussion

The dominant suppression pathways are:

1. Physical, based primarily on heat capacity. This mode does not generate any additional chemical products, but is the least efficient pathway and requires much higher agent concentrations. Physical agents include nitrogen, argon, and carbon dioxide. The ratio of heat capacity to oxygen concentration, not just the oxygen concentration value itself, determines extinguishment requirements. Water mist is also a physical agent. It differs from the gases in that additional energy removal by its very high latent heat of vaporization significantly enhances effectiveness.

2. Chemical - Scavenging, based on combustion radical removal, but only a small set amount per agent molecule. While more efficient than physical means, it can generate very high product concentrations, including for the toxic and corrosive hydrogen fluoride[7, 8]. HFCs, PFCs, and HCFCs are examples of this group. While their extinguishment concentrations are only slightly less than those predicted for purely physical action, their underlying (and largely cancelling) chemical suppression and enhancement reactions mean[9]. Large scale tests document that minimum hydrogen fluoride concentrations are fire dependent, but discharge time and agent concentration independent, once beyond certain short time and high concentration values[10].

3. Chemical - Catalytic, based on bromine or iodine removing a large (situation dependent) number of combustion radicals per atom. Their high efficiency limits the involvement of chemical scavenging much less halide acid product is formed. Halon 1301 and CF_3I get their high efficiency from this mode.

As discussed previously, several modes of suppression action can typically occur simultaneously. This is true for fine solid aerosol. Fine solid aerosol shares the need for sufficient small particle size with fine water aerosol. The small size allows heating, evaporation, and decrepitation to proceed sufficiently rapidly to occur while transiting the flame front, thus extracting maximum benefit from the agent. Fine solid aerosol also has sufficiently large surface to volume ratio to allow similarly effective chemical action including decomposition and surface enhanced reactions.

Halons have been the convenient, clean, safe, agents for a vast variety of fire suppression requirements. There will not be just a single replacement. Selecting an agent (or agent mixture) for a specific need will depend on the values placed on a compromise matrix. Considerations will include ODP, fire threat, efficiency, weight, volume, toxicity, GWP, material compatibility, cost, system criticality, and life safety applications. What is technically optimum for one criteria, could be unsatisfactory for a second criteria. Societal decisions will then determine what tradeoffs are acceptable for specific cases.

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Appendix F

Guidelines for the work of the Halon Fire Extinguishing Agents Technical Options Committee

Scope

The Technology and Economic Assessment Panel and its Technical Options Committees has been established under Article 6 of the Montreal Protocol On Substances That Deplete The Ozone Layer to report on the current state of technologies that will facilitate the timely phase-out of production and consumption of substances controlled by the Montreal Protocol.

Relationship with Montreal Protocol Assessment Panels

Article 6 of the Montreal Protocol On Substances That Deplete The Ozone Layer requires that beginning in 1990, the Parties assess the control measures; i.e. production and consumption limits; on the basis of available scientific, environmental, technical and economic information. Before each assessment, the Parties convene appropriate panels of experts qualified in the fields mentioned and determine the composition and terms of reference of any such panels.

At the second meeting of the Parties to the Montreal Protocol, the Parties decided to convene members of each of the assessment panels established by the first meeting. The Panels are to review new information and to consider its inclusion in supplementary reports in time for consideration by the fourth meeting of the Parties. Three panels have been convened; Science, Environmental Effects and Technology and Economics. Six, sector specific, options committees and the Economic Options Committee will report to the Technology and Economics Panel, on current technology that could be used in lieu of substances controlled by the Protocol. The Report of the Technology and Economics Review Panel will provide an overview and summary of the findings of the seven committees and will be submitted to the Open-Ended Working Group of the Parties to the Montreal Protocol. Each committee will prepare a sector specific report intended to provide more detailed guidance to those with a particular interest in the issues discussed in the individual report.

Technical Options Committees

The Technical Options Committees have been established to provide guidance to the Parties on the uses and elimination's of Ozone Depleting Substances. The reports of the Technical Options Committees are also intended to be useful for those who regulate, own, manufacture, install, service equipment or otherwise use substances controlled by the Montreal Protocol. As well the report provides guidance to those requiring, recommending or otherwise considering appropriate measures for specific applications where controlled substances have typically been used.

Transaction of Business

Except as otherwise provided in this statement of intent, the Rules of Procedure adopted by the Parties to the Montreal Protocol shall govern the transaction of business at meetings of the Technical Options Committees.

Language

All committee meetings will be conducted in English. All committee correspondence and documents will be issued in English.

Appointment of Members

It is the intent that the Technical Options Committees represent a balanced of interests, including geo-political interests, specific to the use of substances controlled by the Montreal Protocol. A committee size of approximately 25 persons is considered as manageable and desirable. In seeking to meet this intent members are, nominated by Parties or from the Chair of the Committee.

The Chair of the Technical Options Committee shall nominate members in addition to those nominated by Parties in such cases where such a nomination is necessary for any or all of the following three reasons:

> The technical expertise of the member would contribute strongly to the committee effort
>
> The member would provide a geographical balance and provide representative advice to the committee
>
> The member would provide advice, representative of the viewpoint of an interest category that would assist the committee in achieving a balance of expertise
>
> All nominations and appointments of Members of Record shall be subject to review, at any time, by the Technology and Economic Assessment Panel.

Alternates

Any Member of Record may have one Alternate. The Alternate shall represent the Member of Record and may vote at meetings only when the Member is absent. When the Member of Record and the Alternate are both present at a meeting, the alternate may have the privilege of the floor only with the consent of the Member of Record and the Chair of the committee or subcommittee. All written comments shall be submitted by the Member of Record or by the Alternate. Where written comments are submitted by the alternate the submission shall also bear the signature of the Member of Record indicating that the comments have been reviewed by and represent the views of the Member of Record.

Appointment of Advisors

Where such an appointment serves a useful purpose the Chair of the committee or a sub-committee, may appoint a person to provide advice. An advisor may serve the committee by providing technical or other advice, and/or by liaison with other organisations that could contribute to reducing dependency on the use of substances controlled by the Montreal Protocol. Advisors do not have voting privileges.

Observers

Observers are permitted to attend meetings of the Technical Options Committee pursuant to the rules established by the Parties to the Montreal Protocol. Observers must adhere to the rules governing Publication of Committee Reports and Documents Restricted as provided herein.

Balloted Votes

Where a balloted vote is appropriate to indicate the degree of consensus achieved by the Committee the balloted vote shall be cast by the Members of Record.

Subcommittees

The Committee may create Subcommittee(s) to help carry out its work. The Subcommittee shall be appointed and discharged by the Chair. The Chair of the Subcommittee shall be a Member of Record of the Technical Options Committee. Persons serving on a sub-committee need not be Members of Record of the Technical Options Committee.

Each Subcommittee shall report only to the Technical Options Committee and shall not release any report except as the Technical Options Committee may specifically direct for the purpose of securing comments and criticisms prior to any official action. The Chair of the Technical Options Committee shall ensure that the Subcommittee is balanced in a manner necessary to achieve a balance in the report of the Subcommittee to the Technical Options Committee.

Establishing Committee Meeting Dates and Locations

Committee and Subcommittee meetings shall be co-ordinated as to time and place. Meeting dates and locations shall be established by Chair of the Technical Options Committee with due regard for compliance with the schedule of work and with cognisance of other scheduled events. Selected venue of meetings shall recognize that cost of travel and representation of geo-political interests is of importance.

Publication of Committee Reports and Documents Restricted

The Technical Options Committee shall not issue Reports or release Documents except as herein provided:

a) During the development of such material, the distribution of background material, analyses, and tentative or draft reports shall be limited to: (1) Members of Record, Alternates to Members of Record and Advisors to the Technical Options Committee (2) Members of Subcommittees (3) Others whom the Technical Committee specifically desires to receive such drafts (4) Members of the Technology and Economics Review Panel. All Draft Reports or other material generated by the committee or subcommittee(s) shall bear a date and issue reference and the warning "**Do Not Quote Or Cite**".

b) A Peer Review draft of the report shall be issued by the committee. The purpose of the peer review is to obtain comments from individuals and organisations that will enhance the technical content of the report.

c) The final Report of the Technical Options Committee shall be submitted to the Technology and Economics Review Panel. The final report shall contain a list of Members of Record of the Committee and shall include a summary of the conclusions of the members of the committee.

d) The final Report of the Technical Options Committee shall be released to the Secretariat of the Montreal Protocol On Substances That Deplete The Ozone Layer and all others by the Technology and Economics Review Panel.

Public Comment

Anyone may comment to the Chair of the Technical Options Committee concerning substantive matters related to the development, content or issuance of any draft report of the Technical Options Committee. Such comments or views should be submitted in written form, not latter than 21 days after release of the version of the draft report to which the comment applies.

The Chair of the Technical Options Committee or a designated member of the committee will make every reasonable effort to respond within 21 days of receipt of the comment.

Should the response be unsatisfactory or should the comment relate to the final report of the Technical Options Committee as submitted to the Technology and Economics Review Panel the comment should be submitted to the Chair of the Technology and Economics review panel, with a copy to the Chair of the Technical Options Committee.

Measures to Avoid Conflict of Interest

Members of the Technology and Economic Assessment Panel and the Technical Options Committees have been asked by the Parties to undertake important responsibilities. As such, a high standard of conduct is expected of members in discharging their duties. In order to assist members the following guidelines have been developed.

1. These Measures to Avoid Conflict of Interest are intended to protect Members of the Technology and Economic Assessment Panel and its' Technical Options Committees from conflicts of interest or the appearance of conflicts of interest in their participation in the Committee. Compliance with the measures detailed in these guidelines is a condition of serving as a Member of the Technology and Economic Assessment Panel and/or the Technical Options Committee.

2. The intent of these guidelines is to enhance public confidence in the integrity of Members of the while encouraging experienced and competent persons to accept Panel and/or Committee membership:

   by establishing clear rules of conduct respecting conflict of interest while and after serving on the Committee; and by minimising the possibility of conflicts arising between the private interest and public duties of Members, and by providing for the resolution of such conflicts, in the public interest, should they arise.

3. In carrying out their duties, Members shall:

perform their official duties and arrange their private affairs in such a manner that public confidence and trust in the integrity, objectivity and impartiality of the Panel and/or Committee are conserved and enhanced;

act in a manner that will bear the closest public scrutiny, an obligation that is not fully discharged by simply acting within the law of any country;

act honestly and in good faith with a view to the best interest of the Panel and its' Committees; exercise the care, diligence and skill that a reasonably prudent person would exercise in comparable circumstances;

not give preferential treatment to anyone in any official manner related to the Panel and/or Committee matters;

not solicit or accept gifts, hospitality, or other benefits from persons, groups or organisations having or likely to have, dealing with the Panel and/or Committee;

not accept transfers of economic benefit, other than incidental gifts, customary hospitality, or other benefits of nominal value, unless the transfer is pursuant to an enforceable contract or property right of the Member;

not step out of their role as a Member to assist other entities or persons in their dealings with the Panel and/or Committee, where this would result in preferential treatment to any person or group;

not knowingly take advantage of, or benefit from, information that is obtained in the course of their duties and responsibilities as a Member of the Panel and/or Committee and that is not generally available to the public; and

not act, after their term of office as a Member of the Panel and/or Committee, in such a manner as to take improper advantage of their previous office.

4. To avoid the possibility or appearance that Members of the Panel and/or Committee might receive preferential treatment, Members shall not seek preferential treatment for themselves or third parties or act as paid intermediaries for third parties in dealings with the Panel and/or Committee.

5. Members shall disclose activities which might call into question their ability to discharge their duties and responsibilities objectively.

6. The Panel and the Technical Options Committee, as individual bodies, are responsible for the application of this Code to Members and will assist in interpreting this Code as necessary.

Appendix G

Glossary

EPA	Environmental Protection Agency
UNEP	The United Nations Environment Programme
HTOC	Halons Technical Options Committee
NFPA	National Fire Protection Association (US)
FAA	Federal Aviation Administration (US)
CAA	Civil Aviation Authority (UK)
JAA	Joint Aviation Authority (Europe)
MOD	Ministry of Defence (UK)
UL	Underwriters Laboratories
BS	British Standard
ISO	International Standards Organization
ASTM	American Society for Testing and Materials
NATO	North Atlantic Treaty Organization
IE/PAC	Industry and the Environment - Programme Activity Centre
FIC	Fire Industry Council (UK)
HUNC	Halon Users National Consortium (UK)
HAG	Halon Alternatives Group (UK)
HARC	Halon Alternatives Research Corporation (US)
HRC	Halon Recycling Corporation
CEFIC	European Chemical Industry Council
CFPA	Conference of Fire Protection Associations (Europe)
DASCEM	Department of the Arts and Administration Services, Centre for Environment Management
ULC	Underwriters Laboratories of Canada
COP	Code of Practice
SATPH	Substitution and Transfer Plan of Halon (China)
DHB	Danish Halon Bank
MPS	Ministry of Public Security (China)
CTFHE	Comite Technique Francais Halon Environment (France)
CNPP	Centre National de Prevention et de Protection
EU	European Union
IST	The Bureau of Indian Standards (India)
DIFP	Defence Institution of Fire Research
ONGC	Oil and National Gas Commission
HRBSC	Halon Recycling and Banking Support Committee (Japan)
PFS	Polish Fire Service
SEA	Swedish Environmental Agency
FOEP	Federal Office of Environmental Protection (Switzerland)
HSG	Halon Sector Group (UK)
DTI	Department of Trade and Industry (UK)
DOT	Department of Transport (UK)
HO	Home Office (UK)
UKOOA	United Kingdom Offshore Operations Association
HSE	Health and Safety Executive (UK)
EC	European Community
RUG	Refridgerants Users Group
ANSI	American National Standards Institute

Glossary (continued)

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
AFFF	Aqueous Film Forming Foam
CO_2	Carbon Dioxide
Halon 1211	Bromochlorodifluoromethane
Halon 1301	Bromotrifluoromethane
Halon 2402	Dibromotetrafluoromethane
HBCFs	Hydrobromofluorocarbons
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
FCs	Fluorocarbons
CAAs	Chemical Action Agent
PAAs	Physical Action Agent
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
ALC	Approximate Lethal Concentration
ODP	Ozone Depletion Potential
GWP	Global Warming Potential
AL	Atmospheric Life
NPS	Nuclear Protection Systems
HSSD	High Sensitivity Smoke Detection

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