Montreal Protocol

Recommendations on Nominations for Essential Use Production/Consumption Exemptions and International Bank Management of Halons

Prepared by the Halons Technical Options Committee

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Report of the Recommendations of the Halons Technical Options Committee on Nominations for Essential Use Production/Consumption Exemptions and International Bank Management of Halons

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1.1 Introduction

The adjustments adopted at Copenhagen by the Fourth Meeting of the Parties to the Montreal Protocol mandated a phase out of production and consumption of halons by January 1, 1994, save to the extent that the Parties decide to permit the level of production or consumption that is necessary to satisfy uses agreed by them to be essential. Decision IV/25 of the Fourth Meeting set the criteria and the procedure for assessing an essential use and requested each Party to nominate uses it considers essential to the Secretariat, at least six months before the Fifth Meeting of the Parties to the Protocol. This decision also requested the Halons Technical Options Committee to consider and recommend on the nominations.

May 15, 1993 was fixed as the last date for nominations. The Halons Technical Options Committee and the Technology and Economic Assessment Panel drafted detailed guidelines for nominations. These were communicated to the Parties on March 29, 1993.

The following Parties responded, as indicated:

Country	Status	Production/consumption
Australia	Party	Not required
Austria	Party	
Belgium	Party	
Canada	Party	Not required
Czech Republic	Not a Party	
Denmark	Party	Not required
Egypt	Article 5	
El Salvador	Article 5	
Finland	Party	
France	Party	
Germany	Party	
Iceland	Party	Not required
Ireland	Party	
Israel	Party	
Italy	Party	
Jamaica	Article 5	
Japan	Party	
Jordan	Article 5	
Malaysia	Article 5	
Malta	Party	
Morroco	Article 5	
Norway	Party	Not required
Pakistan	Article 5	
Peoples Republic of China	Article 5	
Poland	Party	
Seychelles	Article 5	
Singapore	Party	
Slovak Republic	Party	
Spain	Party	
Sweden	Party	Not required
Thailand	Article 5	
Tunisia	Article 5	
United Kingdom	Party	
United States of America	Party	Not required

The nominations from Article 5 Parties are not required since paragraph 7 of Decision IV/25 clarified that essential use controls will not be applicable to such Parties until the phase out dates applicable to them. Therefore, these were not considered.

The criteria for “essential” use set by Decision IV/25 has two important elements. Each Party should demonstrate that:

> *It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and*
>
> *There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health; and*

Production and consumption, if any, of a controlled substance should be permitted only if:

> *All economically feasible steps have been taken to minimise the essential use and any associated emission of the controlled substance; and*
>
> *The controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances, also bearing in mind the developing countries’ need for controlled substances”.*

The Halons Technical Options Committee reviewed all of the submitted nominations for consumption/production exemption. In general it appears that for almost all of the nominations, alternative technologies now exist, particularly for new installations. As well there were no nominations that could satisfy the requirement that halons are not available in sufficient quantity and quality from existing stocks of banked or recycled halons.

1.2 Availability of halons

In its 1991 report the Halons Technical Options Committee found that if production ceases in 1995 "the bank of Halon 1301 would be adequate to supply maintenance quantities for equipment for at least 40 years after production ceases." The Committee finds that the calculations for the 1995 phase-out apply equally for the 1994 phase-out. According to the Committee's conservative estimates the world available stock of halon 1301 will be about 66,000 tonnes by the end of 1993. Of this about 5,400 tonnes will be retired from service and available for recycle world-wide in the year 1994. The total request for production and consumption exemptions for 1994 was less than 200 tonnes which represents 3.7 % of the total available.

For halon 1211 the stock at the end of 1993 will be about 69,000 tons and about 1,200 tonnes will be available for recycling in 1994. The total request for production and consumption exemptions for 1994 was about 85 tonnes which represents 7.0 % of the total available.

For halon 1211 and halon 1301, details on the calculated bank sizes will be found in Appendix Three.

The request for exemption for halon 2402 was for only 2 tonnes for 1994. It would appear that this could reasonably be provided from existing stocks.

The nominations indicate a need to improve the availability of information on managing the supply of halons where banks presently do not exist. Appendix Two (of the full report) on bank management provides guidance to help establish the necessary banking procedures in the nominating countries. UNEP IE/PAC will support transfer of information on how to access existing banks. This will assist countries with small halon banks to access halons through the free market process of other countries banking schemes.

Involvement by national governments is crucial to the effort to encourage investment in recycling facilities and the formation of national halon banks. Further, co-operation at the international level must be established to ensure that one nation does not destroy halon while another continues to produce it to meet the needs of essential uses. National regulations should facilitate imports and exports of recycled halons wherever possible.

All producers in the developed countries have either closed their manufacturing plants or have indicated their intention to do so by the end of 1993. The probable method for any halon production in 1994 and beyond, were it allowed, is likely to be by small scale production at a cost expected to be much in excess of the current price. This significantly improves the economic feasibility of alternative fire protection means and replacement chemicals. It is not known whether nominees attempted to meet their 1994 needs through the purchase of readily available, newly produced halon before the phase out date in 1993.

The Committee is very concerned that exempting those users that clearly have important halon fire protection needs will diminish efforts to establish and develop halon bank management procedures. It might also encourage continued reliance on the use of halons and impede the further development of replacement agents and the implementation of alternative fire protection strategies.

1.3 Alternative fire protection technologies

In general, the information provided with the nominations was insufficient for a detailed analysis of the fire protection options available for specific cases. It is recommended that those with the responsibility of making final fire protection determinations consult with experienced and competent fire protection engineers to achieve an acceptable degree of fire risk reduction for the specific cases nominated. This review by the Halons Technical Options Committee should not be construed as a definitive fire protection recommendation for specific fire risks.

A brief discussion of each of the nominations and the possible alternative protection technologies follows. Further information regarding alternatives to halon fire suppression systems and portable fire extinguishers is provided in Appendix One (of the full report). In many cases the need for an alternative suppression system may be eliminated by thorough application of improved facility design. Such measures include compartmentation, control of material flammability, control of ignition sources, advanced detection technologies, smoke control, emergency ventilation (for flammable vapours), etc. However the following discussion assumes that where appropriate, secure, early warning fire detection and alarm systems are provided. The potential application of these features was in general not described in the essential use nominations. Any hazard for which the use of halon is proposed should be subjected to a complete hazard assessment and design review including a complete evaluation of alternative fire hazard mitigation strategies and techniques.

It should be noted that, while the Halons Technical Options Committee believes that replacement chemicals are now commercially available for most new applications, the systems engineering necessary for new and for retrofit applications is not yet complete in all cases, and retrofit may not be feasible. In applications for which zero ODP gaseous chemical agents are available (versus non-zero ODP agents) the zero ODP agents were specified.

1.4 Conclusions

In conclusion, the Committee believes that there is no justification for granting halon production/consumption exemptions for 1994.

As there was no need to recommend production/consumption exemptions the Halons Technical Options Committee makes no specific recommendation as to the essentiality of any nominated use. The Halons Technical Options Committee further recommends that creating a list of 'essential applications' is neither appropriate nor necessary. In fact the creation of a list may be detrimental to the rapid elimination of dependency on the halons.

2 Alternatives for nominated uses

2.1 Telecommunications Facilities, Computer Rooms, and Control Rooms

A large fraction of the proposed essential uses involve facilities requiring protection of electronics equipment. For all of these applications, alternative technologies now exist for use in new facilities. Retrofit of existing halon installations with these new technologies appears feasible in many applications.

<u>Fixed Fire Suppression Systems:</u>

There are a wide range of potential alternatives to halons in electronics facilities. These include both traditional and new technologies. The optimum protection scheme for a particular facility will be driven by the details of a specific installation. The Halons Technical Options Committee believes that feasible alternatives exist for all of these applications.

The potential alternatives include:

- Automatic sprinkler systems, including the use of pre-action features, and quick response sprinkler heads.
- Zero ozone depletion, clean agent total flooding gas systems.
- Inert gas total flooding systems.
- Partial flooding gas systems including CO_2 for subfloor and cabinet protection.
- The use of water mist systems for in-cabinet protection.
- The use of very high sensitivity detection systems.
- Consideration of alternative design strategies to eliminate the need for active fire suppression systems particularly in facilities manned at all times.

Portable Fire Extinguishers:

Feasible alternatives exist for halon 1211 portable extinguishers in these applications. CO_2 or new clean agent portable extinguishers are available.

2.2 Records Storage

Several essential use nominations were received involving protection of records storage areas including medical or other vital records.

Fixed Fire Suppression Systems:

There appear to be a wide range of feasible alternatives to halons for protecting vital record storage. These include:

- Automatic sprinkler systems including the use of pre-action and/or quick response features.
- Zero ozone depletion clean agent total flooding systems.
- Inert gas total flooding systems.
- Partial flooding of modular record retrieval systems using gases including CO_2.
- Water mist systems.

Portable Fire Extinguishers:

The use of water-based portables, CO_2 portables, and extinguishers using new clean agents are considered feasible alternatives to the use of halon-based extinguishers for record storage applications.

2.3 Cultural Heritage

Fixed Fire Suppression Systems:

The protection of objects of cultural heritage can be feasibly accomplished using technologies similar to those proposed for vital records storage. The optimum protection scheme is a function of the objects or facility being protected. The Halons Technical Options Committee believes that feasible alternatives to the use of halons exist for this application. The range of alternatives includes:

- Automatic sprinkler systems including the use of pre-action and/or quick response features.

- Zero ODP clean agent total flooding systems.
- Inert gas total flooding systems.
- Partial flooding of enclosures with gases including CO_2.
- Water mist systems.
- Very high sensitivity detection systems.

Portable Fire Extinguishers:

The use of water-based, CO_2, or clean agent portable extinguishers as alternatives to halon-based extinguishers is considered feasible.

2.4 Flammable Liquid Hazards

Fixed Fire Suppression Systems:

Facilities involving the storage, handling, or processing of flammable liquids potentially involve the use of fire suppression, explosion inerting and/or explosion suppression systems. Explosion suppression systems protecting unoccupied spaces are currently being provided with dry powder, water and zero ODP gas systems. No effective alternatives have been demonstrated for explosion suppression in occupied areas. Explosion inerting alternatives involving the use of zero ODP clean gaseous agents look promising and are currently under development. However there is concern that the only feasible gaseous inerting agents from a human health standpoint may have global warming properties. Hence, it is not clear that these agents will become commercially available. This would effectively eliminate the only currently possible halon alternatives for inerting use.

There appears to be a range of feasible alternatives for fire suppression systems in these application.

These alternatives include:

- Total flooding zero ODP gases.
- Inert gas total flooding systems (assuming discharge time and evaluation of potential human health effects is acceptable).
- CO_2 total flooding systems (assuming personnel hazards can be managed and discharge time is acceptable).
- Low expansion foam sprinkler and spray systems.
- Water mist systems.
- Total flooding dry chemical systems (potentially limited to small enclosures).

Portable Fire Extinguishers:

Portable extinguisher alternatives for these facilities include CO_2, clean agent gases, dry chemical, and low expansion foam-based portables.

2.5 Shipboard Machinery Spaces

Shipboard machinery spaces are similar to flammable liquid hazard areas that are more sensitive to fire protection system space and weight requirements.

Fixed Fire Suppression Systems:

Feasible alternatives exist for new ship design and for current construction where space and weight allowances can be made.

These alternatives include:

- Total flooding zero ODP gases.
- Inert gas total flooding systems (assuming discharge time and evaluation of potential human health effects is acceptable).
- CO_2 total flooding systems (assuming personnel hazards can be managed and discharge time limits are acceptable).
- Low expansion foam spray or sprinkler systems.
- Water mist systems.
- Total flooding dry chemical systems (potentially limited to small enclosures).

Portable Fire Extinguishers:

Portable extinguisher alternatives for these applications include CO_2, clean agent chemicals, dry powder, and low expansion foam.

2.6 Military Ground Combat Vehicles

Fire Protection Systems:

Feasible alternatives exist for unmanned compartments including engine compartments.

Potential alternatives include:

- Zero ODP gases
- Total Flooding CO_2
- Total flooding dry powder

There are no demonstrated alternatives to crew compartment explosion suppression applications. Research and development efforts are being actively pursued.

Portable Fire Extinguishers:

Feasible alternatives such as dry chemical, zero ODP gases, and CO_2 exist for portable extinguishers in this application.

2.7 Aviation Applications

Fixed Fire Suppression Systems:

No alternative technologies have been demonstrated for protection of aircraft engine nacelles. Research and development is being actively pursued.

For the design of new aircraft, potential feasible alternatives for cargo, baggage and avionics compartments exist and should be used. These include zero ODP gases, water mist, and dry chemical systems.

Portable Fire Extinguishers:

Feasible alternatives exist for portable extinguisher applications on aircraft. Zero ODP gases and dry powder are the most promising.

2.8 Locomotive and Railroad Applications

Fixed Fire Suppression Systems:

In general, it appears that feasible alternatives exist for future systems. For both locomotive and vehicle/passenger carriages the use of zero ODP gases appear to be feasible alternatives. For locomotive applications alternatives also include dry chemical and CO_2 based systems.

Portable Fire Extinguishers:

Feasible alternatives exist for portable extinguishers in rail applications. Zero ODP gaseous agents, dry chemical, and CO_2 portables are acceptable alternatives to halon-based portables.

2.9 Other nominations

Insufficient information was provided with the nominations for any technical evaluation to be undertaken. However, adequate banked halons would be adequate to satisfy the needs of these applications.

3 Decision IV/26

3.1 Introduction

Decision IV/26 also requested a response from the Halons Technical Options Committee on various technical issues. The response to these queries is as follows:

In Copenhagen the Parties to the Montreal Protocol asked UNEP IE/PAC to act as a clearing house for information relevant to international recycled halon bank management. In looking at what more could be done to facilitate international bank management, the Halon Technical Options Committee concluded that UNEP IE/PAC should hold details of all known halon banking schemes and a list of those 'banks' with halon for sale. Such information will be regularly updated and provided upon request to those requiring halons.

UNEP IE/PAC should also provide on request information on how the halon 'banks', either proposed or in existence, function. Parties are encouraged to submit to UNEP IE/PAC such information which should include a contact address, telephone and fax numbers for the organisation concerned.

3.2 Standards

The Committee concludes that at this stage there are no methods to distinguish between newly manufactured and recycled material. It further considers that ISO 7201 and ASTM ES24-93 are appropriate technical standards for recycled halon. Nitrogen is usually added in order to reuse the material and therefore it is suggested that a higher level of nitrogen could often be tolerated in the recycled product. It should be noted that efforts are presently under way to develop other suitable standards for recycled material.

The Committee also noted that if detailed and reliable records of the servicing history of the material are available, these might obviate the need for quality and certification, providing the potential user had confidence in those records.

3.3 Trade

Although the Committee had commenced its investigation into legal and institutional barriers to trade in recovered and recycled material, it was not able to finish its work in time for the publication of this report. The Committee will continue to investigate this issue.

The Committee noted that in most cases Governments do not import or export halons for recycling; this trade occurs between individual companies. The Committee therefore recommends that the principle of buyer beware should apply. Purchasers of recycled halon might consider asking for a certificate of quality or an analysis from the vendor as part of the contract of sale.

The Committee had been asked to look at means to avoid the export of halons in quantities that would encourage excessive dependence by the recipient countries. This work is not yet complete but the Committee will be considering a number of possibilities including

- the application of the essential use criteria by the recipient country
- export permits
- export only to countries which have agreed not to consume newly produced material
- Prior Informed Consent (PIC)

The Committee also recognised that undue restrictions might lead to venting in one country or dependence on newly produced halon in another.

3.4 Contaminated halons

Most recycling machines can remove moisture, oil and particulate contaminants through drying and filtration. The more serious common contaminants, such as CFC 12 and mixtures of 1211 and 1301, can only be dealt with through use of a distillation tower.

Appendix One

Alternatives to halon systems and portable fire extinguishers

1.1 Introduction

Users should first introduce effective fire protection measures to reduce the likelihood of fire. These measures may include, but are not limited to: smoke and fire detection systems; fire resistive barriers; low flammability cable and wire insulation; minimise combustible load of contents, including furnishings and supplies; emergency shut-down systems and procedures; control of smoking materials and other appropriate measures for the hazard. Potential fire damage can also be minimised by backing up records and protecting electronic and other equipment as far as possible. The risk of an explosion can be minimised by avoiding air tight enclosures and by providing high rate ventilation when handling flammable liquids and vapours.

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 non-in-kind alternatives 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. The relationship between the characteristics of the fire protection system and the hazard being protected has been summarized in a simplified manner via comparison matrices which have been part of the previous two HTOC reports. These comparison matrices were modified to reflect corrections and additions and are given in Section 1.5.

Over the previous two years, there has been an explosion in the availability of clean agent replacement chemicals and new "not-in-kind" alternative technologies. The objective of this section is to summarize the status of these new developments.

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

1. Chemical Replacements[1]

    a. PFC, HFC, HCFC and HBFC compounds, C_4F_{10}, C_3F_7H, CHF_3, C_2HF_5, CHF_2Br, C_2HClF_4 (Robin (1991, 1992), Hanauska (1991), Ferreira (1992), DiNenno et al. (1992, 1993), Fernandez (1991)).

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

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[1]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 7). The nomenclature for some of the halocarbons seriously considered as halon replacement candidates agents is shown below. (Halons 1301 and 1211, which are named using the halon nomenclature rather than the halocarbon nomenclature, are given for reference).

c. Possible moderate to long 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 gas compounds (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, Baumac International, Kidde Graviner and 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 NRCC and Naval Research Laboratory. Several proprietary systems are being evaluated including Securiplex (BP) 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 by Harrison (1993)).

1.2 Clean Agent Replacement Chemicals for fixed systems

1.2.1 Halocarbon Agents

There are at least seven halon replacement chemicals which have been announced and are in the process of commercialization. These compounds include HFC, HCFC, and FC chemicals as well as blends. Inert gases and blends are discussed in Section 1.2.2. The physical and fire suppression properties of these agents are summarized in Table 1.2.1.

Table 1.2.1

Trade Name	HFC Designtion	Formula	Mfr	Molecular Weight	Boiling Point (˚C)	Cup Burner % (heptane)	Weight req. relative to 1301[3]	Storage vol req.[3]	NOAEL (% by volume)
PFC-410	FC-3-1-10	C_4F_{10}	3M	238.03	-2	5.2 - 5.9	2.7	2.7	40
FM-200	HFC-227ea	C_3F_7H	GLCC	170.03	-16.4	5.8 - 6.6 (5.8)	2.4	2.7	9.0
FE-13	HFC-23	CHF_3	DuPont	70.0	-82.1	12 - 13	1.8	4.2	50
FE-25	HFC-125	C_2HF_5	DuPont	120.02	-48.5	8.1 - 9.4	2.3	2.8	7.5
NAF S-III	HCFC Blend A	1	NAFG	--	--	>11[2]	--	--	10
FM-100	HBFC-22B1	CHF_2Br	GLCC	130.92	-15.5	3.9 - 4.4	1.2	1.0	2
Halon 1301	Halon 1301	CF_3Br	--	149	-58	3 - 3.9	1.0	1.0	5
FE-241	HFC-129	C_2HClF_4	DuPont	136.5	-11.0	8.2	2.6	2.9	1

Notes: 1 Blend includes 82% HCFC 22, 4.75% HCFC-123, 4.5% HCFC-124, and 3.75% organic.
2 Extinguishing concentration of 8% derived from full scale tests.
3 From Sheinson.

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

(1) All of these agents are <u>electrically non-conductive</u>;

(2) All of these compounds are <u>clean agents</u>; they vaporize readily and leave no residue;

(3) All are <u>liquified gases</u> 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 superpressurized halon systems);

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

(6) All are less efficient fire extinguishants than Halon 1301 in terms of storage volume and agent weight. Hence, the use of all requires increased storage capacity;

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

(8) All of these agents 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.

Toxicity

Table 4.2.1 summarizes the toxicity information available on each chemical system. The NOAEL is the No Observed Adverse Effect Level. This is the concentration at which no adverse effect level 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. If the NOAEL is listed as greater than 23%, then the concentration at which the ambient oxygen concentration is reduced below 16%, a typical threshold value, becomes critical.

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

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 four agents that meet the criteria that the design concentration (for example, 1.2 times extinguishing concentration) must be below the NOAEL (at least for heptane fires). These include the following:

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

These agents may be considered to have sufficiently low toxicity to be used in occupied spaces.

Environmental Factors

The primary environmental factors to be considered for these agents includes ODP, GWP, (and perhaps Atmospheric Lifetime). These factors will not be considered in detail since such assessments are beyond the scope of this document. The following general statements apply:

HCFC compounds: All possess some ODP and are listed under the Montreal Protocol for future phaseout.

HFC compounds: All are zero ODP chemicals. The GWP determined largely by the atmospheric lifetime of these compounds varies widely (e.g., 30 to 500 years).

FC compounds: The perfluorocarbon group has zero ODP. The GWP and atmospheric lifetime is high.

HBFC compounds: All have relatively high ODPs and will be phased out under the Montreal Protocol.

The impact of high atmospheric lifetime and related high GWP must be evaluated in the context of the use quantity and emission pattern of these chemicals when used as halon replacement fire extinguishants. There is no credible use or emission scenario which results in measurable environmental impact for any of these compounds used as fire suppressants.

1.2.2 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 concentrations of 35-50% by volume which reduces the ambient oxygen concentration to between 14% to 10% by volume respectively. It is well 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. Proposed inert gas mixtures are summarized in Table 1.2.2.

Table 1.2.2 Proposed Inert Gas Mixtures

Inert Gas Designation	Composition	Manufacturer	Storage Pressure (psi)	Use Concentration
IG-541	Nitrogen 52% ±4% Argon 40% ± 4% CO_2 8% ±1%	Ansul	2175 psi @ 70 F	35-50%
IG-55	Nitrogen 50% ±5% Argon 50% ±5%	Securiplex/Ginge Kerr	4350 psig @ 30 C (300 bar)	35-50%

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) Both systems use pressure reducing valve 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. The use of inert gases with high discharge times and resultant long time durations of vitiated atmospheres may result in increased carbon monoxide production in some cases.

Physiological Effects

The primary health concern relative to the use of these agents is the effect of reduced oxygen concentration on occupants of a space. The use of reduced oxygen environments has been extensively researched and studied. There is growing consensus that inert gases can be used in extinguishing concentrations without excessive risk to occupants. One compound, Inergen (50% N_2, 45% Ar, 5% O_2), 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 normally found in the workplace. Limited medical peer review studies have indicated that no excessive risk would be posed by these mixtures at the required use concentrations.

Environmental Factors

Inert gas systems pose no environmental risk due to ozone depletion or global warning potential.

1.3 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 depletion by steam expansion,
- wetting of surfaces, and
- flame blow-off.

Water mist systems have attracted great interest for a number of reasons. These systems are perceived to have the following potential advantages:

(1) use water, non-toxic, no environmental problems, cheap, and close to the heart of fire protection professionals;

(2) they are potentially superior to sprinklers in that

a. they can suppress flammable liquid pool and spray fires,

b. they utilize water quantities a tenth or lower than sprinklers and hence have little or collateral damage,

c. they may be made to perform functionally in some applications like total flooding gases (i.e., obstructed, enclosed fires) activated by a variety of means,

d. they may be non-electrically conductive, and

e. they may have application as inerting or explosion suppression systems.

Some of these potential perceived benefits have been demonstrated for some systems. There are currently at least eight water mist system technologies available or under development using either dual-fluid (N_2/air and water) or single-fluid high-pressure systems.

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 five water mist fire suppression systems.

Theoretical analysis of ideal water droplet suppression efficiencies has indicated that water liquid volume concentrations on the order of 0.1 L (water)/m^3 (air) or $^2/_3$ of the weight of halon needed 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 order of magnitude efficiency improvement over applicable 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 and the loss rate by deposition to surfaces and by gravitational 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 dilution has been shown to be important for suppression of enclosed 3-D flammable liquid spray fires.

The efficacy of a particular water mist system is strongly dependent on the ability to not only generate sufficiently small droplet sizes but to distribute critical concentration of droplets throughout the compartment (Mawhinney (1993), Cousins (1992), Jackman (1992)). This depends on the droplet size, velocity, distribution, the spray pattern geometry and as well as the momentum and mixing characteristics of the spray jet and the geometry and other characteristices of the protected area.

The potential efficacy of water mist fire suppression systems has been demonstrated 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), Tuomissar (1992), Soja (1990), Gamiero (1993)), shipboard accommodation spaces (Arvindson and Ryderman (1992)), and computer and electronics applications (Hill et al. (1993), Tuomissar (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 much more dependent 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 high pressure (40-200 bar) and spray nozzles which deliver drop sizes is the 10 to 100 rm diameter range. Dual systems use air, nitrous, 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. 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.

While these systems have received some acceptance from approval authorities for limited applications, there is no current widespread approval testing or standardization effort underway.

Table 1.3-1 summarizes the current manufacturers of water mist systems for fire suppression use. Some of these manufacturers are in the R&D phase with their particular hardware.

Table 1.3-1 Water Mist Hardware Manufacturers

Company	Country
Marioff Hi-fog	Finland
Securiplex	Montreal, Canada
Ginge Kerr	United Kingdom, Denmark, Norway
ADA Technologies	U.S.A.
Baumac International	U.S.A.
FSI/Kidde Graviner	United Kingdom
Kidde Fenwal	U.S.A.

Physiological Effects

Concern has been expressed by some regulatory authorities that the production of 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 of a concern relative to pure water. The ability of small drops to dissolve or adsorb products of combustion is a potential problem, but soot particulates formed in most fire scenarios are a much more efficient transport mechanism.

Environmental Factors

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

1.4 Fine 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.

The use of Combustion Generated Aerosols (CGA) also termed Pyrotechnically Generated Aerosols (PGA) originated in the 1980's in the Soviet Union (Kopylov (1988, 1993)). The systems utilize a chemical reaction to generate fine solid and liquid particulate. The resultant aerosol is, in principal, distributed through the protected volume in concentrations sufficient to cause gas phase suppression. The primary suppression mechanism appears to be gas phase cooling. The use of solid particulate as a gas phase cooling mechanism is well known.

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), and Spectrex Inc. (1992).

At the present time, at least three companies are pursuing commercialization of combustion generated aerosols. These include the following:

- Kidde Aerospace, U.S.A.;
- Kidde Graviner, United Kingdom; and
- Spectronix, Israel.

A natural extension of both CGA and water mist technology is the possibility of using fine solid particulate as a total flooding agent using more traditional dispensing systems than the CGA/PGA technology. This would permit optimization of the particulate type, size distribution, and mixing/distribution characteristics. The resultant "total flooding fine dry chemical particulate" system may have significant advantages over previously discussed particulate technologies.

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. There are potential caking problems with very fine powders. This potential difficulty may be solved with coated or encapsulated particles. There are also potential irritant, toxicity and visibility problems associated with these technoligies.

1.5 Alternatives to halon systems

The Halons Technical Options Committee has devised a method of evaluating alternative fire protection systems and portable fire extinguishers. The method is intended as a useful tool when considering fire protection options, it has some obvious limitations outlined in the full report of the Halons Technical Options Committee. It may be necessary for many of those responsible for purchasing, inspecting, approving, operating, and maintaining fire protection systems to consult with a fire protection expert to effectively undertake their respective duties. The alternative fire protection choices offered may not provide the same level of fire protection offered by the use of the present halons. In some circumstances greater fire 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 other fire protection options.

Examples of alternative, fixed fire protection systems are:

- Water sprinkler systems
- Fine water mist systems
- Carbon dioxide systems
- Foam systems
- Dry powder systems
- Inert gas systems
- Other gaseous agent 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 specialised applications, especially where flammable liquid fires could occur.

Water sprinkler systems are connected to a municipal or private water supply. 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, however the cooling effect of water sprinkler application is usually sufficient to limit structural damage.

Fine water mist systems are a relatively new type of water extinguishing system. Water is applied at a higher pressure than a conventional water sprinkler system. In general, water mist systems are capable of extinguishing fires at much lower application rates than conventional sprinkler systems and are capable of extinguishing fires involving flammable liquids. They may also be effective at cooling hot surfaces. Some water mist systems produce a fog with penetration capability that approaches that of gaseous agents.

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 vapours. 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 displacing and diluting normal air. As a result fires are extinguished primarily by thermal effects. Carbon dioxide (CO_2) systems are used to protect 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.

Inert gas mixtures are generally comprised of nitrogen and argon. In some cases, a small amount of carbon dioxide is added to the mixture to stimulate breathing by people who could be present. Use of inert gas mixtures is a relatively new concept. It is claimed that these mixtures are safer for human exposure than carbon dioxide systems. However technical issues that would allow use in normally occupied areas have not yet been resolved.

Other gaseous agent systems will utilise some of the halon replacement chemicals. Systems are available for some of these agents. Generally, these gaseous agents will not be direct replacements for the existing halons and in most cases they will not be suitable for recharge of existing halon systems. These agents are not yet proven acceptable for use in explosion suppression or inerting applications.

1.5.1 Evaluating alternative systems

The first step is to evaluate alternative systems and agents in general terms, and not in relation to any specific application. Each system is assigned a base score (higher scores indicate higher acceptability in the category) for each of the following:

- **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.

- **ability to permeate** - a measure of how effective the agent is in reaching the source of a fire in cases where obstructions could be present between the discharge nozzle and the fire. Gaseous agents score highest.

- **occupant risk** - a measure of the hazard to persons who could be present during discharge of the fire protection system. Carbon dioxide scores lowest and water sprinklers score highest.

- **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 Class A fires.

- **suitability for use on energised 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 minimised by shutting power off before application.

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

The base case evaluation of these eight characteristics in relation to eight types of fixed systems is shown below:

Fixed Fire Protection Systems - Base Case								
	Low Space/ Weight	Damage Limtg	Ability To Perm	Ocpnt Risk	Flam Liq Ext Cap	System Efficy	Energ Electrcl Equip	Instld Cost
Monitored Detection	0	5	0	10	0	5	1	5
Detection + Automatic Sprinklers	0	5	0	10	0	10	2	4
Detection + Fast Response Sprinklers (FRS)	0	7	0	10	0	10	3	4
Detection + Zero ODP Clean Agent	5	9	5	7	7	8	5	1
Detection + Inert Gas Mixture	3	9	5	5	8	8	5	1
Detection + Total Flood CO2	4	9	5	2	8	8	5	1
Detection + Total Flood Dry Powder	4	4	1	7	7	7	4	1
Detection + Water Fog	4	9	3	9	8	8	4	3

The second step is to weight these characteristics for their importance in a specific application. For instance if people could be present in the area to be protected, then occupant risk is important and will receive a high weighting. When the base case scores and the weighting factors for each system are multiplied, the relative merits of different agent systems for a specific application can be compared.

Score = Base Case X Weighting Factor

The table below shows the final weighted scores in a typical evaluation of fixed systems for a museum collection storage room. Dry powder systems were not included in this evaluation. Any fire extinguishing system and agent used in a museum collection storage room should have a short response time, cause little secondary damage as the result of agent discharge and have high efficacy. The ability to permeate inaccessible areas and low cost are also important. The weighting factors applied reflect the importance of these characteristics.

The two highest scores for this example are achieved by fast response sprinklers and water fog sprinklers. In both cases an early warning fire detection system would also be provided. A conventional sprinkler system, zero ODP clean agent system and inert gas system all in conjunction with early warning fire detection, also achieve relatively high scores. The choice of a high expansion foam system, carbon dioxide system and detection only achieve the lowest scores for this example.

Fixed Fire Protection Systems - Cultural Heritage Collection Room (Normally Occupied)									
	Low Space/ Weight	Damage Lmtg	Ability To Perm	Ocupnt Risk	Flam Liq Ext Cap	System Efficy	Energ Elec	Instald Cost	**Total**
	max 5	*max 10*	*max 5*	*max 10*	*max 10*	*max 10*	*max 5*	*max 5*	
Hazard Specific Weighting Factor	**0**	**10**	**5**	**10**	**0**	**10**	**0**	**5**	
Monitored Detection	0	50	0	100	0	50	0	25	**225**
Detection + Automatic Sprinklers	0	50	0	100	0	100	0	20	**270**
Detection + Fast Response Sprinklers (FRS)	0	70	0	100	0	100	0	20	**290**
Detection + Pre-Action Sprinklers	0	50	0	100	0	80	0	15	**245**
Detection + Zero ODP Clean Agent	0	90	25	70	0	80	0	5	**270**
Detection + Inert Gas Mixture	0	90	25	50	0	80	0	5	**250**
Detection + Total Flood CO2	0	90	25	20	0	80	0	5	**220**
Detection + High Expansion Foam	0	60	0	20	0	70	0	15	**165**
Detection + Water Fog	0	90	15	90	0	80	0	15	**290**

Score = Base Case x Weighting Factor

1.6 Alternatives to halon portable fire extinguishers

Examples of alternative, portable fire extinguisher types are:

- Straight stream water
- Water spray
- Foam
- Carbon dioxide
- Dry powder
- Zero ODP clean agents

Straight stream water are 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 live electrical circuits are present.

Water spray extinguishers are most suitable for use on fires of ordinary combustibles such as wood, paper and fabrics, although this type 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.Foam extinguishers generally use an aqueous film forming foam which may increase the effectiveness of the extinguisher on fires of ordinary combustibles such as wood, paper and fabrics and provide a 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.

Carbon dioxide extinguishers use CO_2 as a liquefied 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 chemical extinguishers are of two types. Ordinary dry chemicals and 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 live 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.

Primary streaming halon replacement candidates are shown in the following table:

Candidate	Extinguisment Concentration	ODP	LC_{50}/ALC
Halon 1211	3.2%	~4	>8% (ALC)
FC-5-1-14	4.4%	0	>30% (LC_{50})
HBFC-22B1	4.4%	~1.4	10.8% (LC_{50})
HCFC-123	7.1%	0.02	3.5% (LC_{50})
HCFC-124	8.2%	0.022	36% (LC_{50})
HCFC-227ea	6.3%	0	80% (LC_{50})

1.6.1 Evaluating alternative portable fire extinguishers

The method should be viewed as a guide. The important features of alternative, 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 Halons Technical Options Committee. The method is developed primarily as a means of structuring the thought process relative to the evaluation of the use of alternative choices of portable fire extinguishers for a particular use. It is fully expected that any application of point values may vary between countries due to local conditions.

The parameters evaluated for each agent are discussed below.

Effectiveness on Ordinary Combustibles

This parameter scores the ability of the agent to extinguish fires in ordinary solid polymer combustibles, including cellulosics. It includes consideration of deep seated burning. The lowest score is given to carbon dioxide, the highest to water based and multipurpose dry powder extinguishers.

Effectiveness on Flammable/Combustible Liquid Fires

The agents are scored on the ability to extinguish flames above liquid fuels. 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 with a score of 5, Zero ODP clean agent is next highest at 3, with straight stream water scores 0.

Electrical Conductivity

The electrical conductivity of the agent is scored in this category. The highest scores are given to Zero ODP clean agent and CO_2. Dry powder is scored at 3, water spray at 1 and all other agents at 0.

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 electronics equipment cabinet. As expected, the gaseous agents are scored 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 score is given to straight stream water extinguishers, the lowest to carbon dioxide. Zero ODP clean agent 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.

Cost

This parameter reflects the average cost of typical portable fire extinguishers. Carbon dioxide portables are expensive due to the shell costs, AFFF, and water based portables are scored just slightly lower than multipurpose dry powder. The cost of a Zero ODP agent fire extinguisher is assumed as relative to carbon dioxide however the cost of the extinguisher is obviously sensitive to differences in agent cost.

The base case evaluation of these eight characteristics in relation to seven types of portable fire extinguishers is shown below:

Portable Fire Extinguishers - Base Case								
	Ordnry Combst	Flam Liquids	Elect Non-cond	Ability To Perm	Stream Range	Effectiv /Wght	2ndry Damage	Cost
CO2	1	2	5	5	1	1	5	0
Zero ODP Clean Agent	4	3	5	5	4	5	4	0
Multipurpose Dry Powder (Chemical)	5	5	3	1	5	5	0	3
AFFF	5	2	0	0	4	3	1	2
Water Stream	5	0	0	0	5	1	2	2
Water Spray	5	1	1	0	3	2	2	2
Water Spray+C02	5	2	1	5	3	0	2	0

Use Evaluation

Each parameter evaluated (e.g., electrical conductivity, effectiveness on Class A fires) is weighted as to its importance for each application. An example for a commercial computer room is provided below.

The weighting and final score is performed in a similar manner to Fixed Fire Protection Systems, as previously described.

An example of the method used to evaluate the choice of portable fire extinguishers for an aircraft passenger cabin follows.

Portable Fire Extinguisher - Passenger Aircraft Cabin									
	Ordnry Combst	Flam Liquids	Elect Non-Cond.	Ability to Permeate	Stream Range	Effectiv\ Weight	2ndry Damage	Cost	**Total Score**
Hazard Specific Weighting Factor	(max 5) **5**	(max 5) **0**	(Max 5) **5**	(Max 5) **5**	(Max 5) **5**	(Max 5) **5**	(Max 5) **5**	(Max 3) **0**	
CO2	5	0	25	25	5	5	25	0	**90**
Zero ODP Clean Agent	20	0	25	25	15	25	20	0	**130**
Multipurpose Dry Powder	25	0	15	5	25	25	0	0	**95**
AFFF	25	0	0	0	20	15	5	0	**65**
Water Stream	25	0	0	0	25	5	10	0	**65**
Water Spray	25	0	5	0	15	10	10	0	**65**
Water Spray+C02	25	0	5	25	15	0	10	0	**80**
Water Fog	25	0	20	20	15	20	20	0	**120**

Score = Base Case x Weighting Factor

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Appendix Two

Halon bank management

2.1 Introduction

The 1992 Copenhagen amendments to the Montreal Protocol require a phase out of halon production by the end of 1993.

It is therefore prudent to plan for the recycling and reuse of halons for the following reasons:

- 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”.

Throughout this appendix "recycling" includes recovery, recycling and reclamation per decision IV/24 of the parties.

2.2 Recycled Halon Bank Management

2.2.1 Introduction

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 such programmes. In the following paragraphs a number of these are described. It is clear that each country solution is different, 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 the solution and mean that each 'bank' will be tailor made. There are, however, some similarities between approaches. Switzerland, the UK and the USA have chosen as a basis for their schemes a simple clearing house approach where the free market can be used to drive the process. The Netherlands and Malaysia describe a much more regulated structure.

All of the 'banks' set out below are in stages of relative infancy. The descriptions 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. Most of the descriptions also include lessons which those setting up the schemes have learned which are intended as further advice. Section 7.3 looks at the basic elements needed for any banking strategy. As the end of 1993 draws nearer, no doubt more 'banks' will be set up. The UNEP IE/PAC office in Paris will have further information on those.

2.3 Country Specific Existing and Proposed Civilian Recycled Halon Bank Management Programmes

2.3.1 Canada

(i) 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.

(ii) Factors which influenced the type of bank chosen

Although there is yet no formal halon bank established in Canada, the concept of a halon bank is developing on the following premise:

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

(iii) 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 look at a national inventory of halons and to monitor the transfers of halons between users.

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

a) a test for “critical” use;
b) certification requirements for recycling (product, equipment, service organisation);
c) tracking and monitoring the national inventory of halons;
d) an information clearinghouse to monitor transfers of recycled halons and to exchange information;
e) destruction technologies

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: who is to run it, how will it operate (establishment of a toll free telephone number), not for profit cost recovery basis, profit making, etc.

Different aspects of a certification program are also being developed. Underwriters’ Laboratories of Canada (ULC) should issue a final version of a standard for the certification of service companies by the fourth quarter of 1993. A standard for the certification of recycling equipment is also being developed in parallel with this effort. ULC is also looking into the establishment of a special telephone service to provide clearinghouse functions (information exchange, updating of the inventories of halons in Canada, etc.).

The following Industry Code of Practice was developed:

Industry Code of Practice
Halon Disclosure Statement

1) The ________(Supplier)____________ has advised me that the halon used in the fire equipment that I have selected is a known ozone depleting substance. The Parties to the Montreal Protocol have agreed to phase out production of halon (1211/1301) by January 1, 1994.

2) The________(Supplier)____________ has advised me that Environment Canada is obligated, by international agreement, to ensure that all practicable measures are taken to prevent releases of halon (1211/1301) into the atmosphere including :

- to recover halon (1211/1301) from equipment during servicing and maintenance as well as prior to equipment dismantling or disposal;
- to destroy unneeded halon (1211/1301) where economically feasible and environmentally appropriate to do so.

This could entail the imposition of specific requirements at some future date.

3) The ________(Supplier)____________ has advised me of other appropriate fire protection measures and choices.
The ________(Supplier)____________ has also advised me that halon (1211/1301) may not be available for future recharge and my halon facility will be redundant at that time..

4) I have carefully reviewed the following criteria to justify halon use:

"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."

_____New Installation _____ Recharge

____

Supplier Signature Name of Fire Equipment Company Date

____

Customer Signature Name of Customer Company Date

(iv) How the organisation 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.

(v) Lessons learned

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

(vii) Other developments

Issues that will be addressed include:

a) “essentiallity” - the clearinghouse will have to decide if it wishes to operate with a list of essential uses or with essential use criteria. It currently seems to lean towards the establishment of a formal mechanism to assess or set priorities for halon uses; the Industry Code of Practice will help in that respect. The annual 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 and ultimate responsibility for destruction are unknown at this time.

2.3.2 Denmark

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

The DHB 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 DHB and the DHB has established a data base on users of halons. The data base is updated monthly and provides a record of halons stored at each of the operators. At present only 1301 is covered by the DHB.

DHB 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 DHB specifying the obligations and rights if each party.
DHB pays the operators for collecting halons and the operators pay the DHB when selling the halons. DHB fixes the internal price between operators and the DHB each quarter. Based on the monthly report from the operators, the balance is settled between the operator and the DHB.

When halon users contact the DHB 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.

Up until 1992 the annual Danish import of halon 1301 was 120 tons. 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 tons. At present, the DHB has 10 to 15 tons stored at the operators and at major users.

2.3.3 France

(i) 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.

(ii) Factors which influenced the type of bank chosen

During 1990 and 1991, CTFHE tried to set up a bank management scheme as part of the voluntary agreement made between the [users and 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 1992 a more pragmatic approach was adopted.

(iii) Objectives

a) protect the ozone-layer from environmentally harmful venting,

b) find practical, simple, feasible scheme, and advice, for the users.

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".

*This list of professionals bodies will be updated regularly. It is intended that bodies on the list are equipped with adequate recycling equipment, not just recovery equipment, in order to guaranty the quality of product and service quality.

(iv) How the organisation functions

About ten companies, scattered in the country, are candidates [for the list]. 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'.

Quality control will be set up (or sub-contracted) by CTFHE to vet the companies in the following areas: adequate recycling equipment; minimal product quality (lower level than ISO 7201), training, reporting to the CTFHE. This system will be set up before the end of 1993. No user membership scheme is planned. It appears unrealistic.

There is interest in trade with banks in other countries (mainly within the EC) 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 EC.

(v) Lessons learned

The bad image of halons has made many companies reluctant to join in a sophisticated bank management scheme, but a simple system should prove to be more effective.

(vi) Other comments

CTFHE will try, in addition, to provide information for all on the status of substitutes and alternative solutions.

2.3.4 India

(i) Introduction

India is a developing country with a very small consumption of ODS, and therefore meets the criteria under Article 5.1 of the Montreal Protocol. Even before joining the Protocol, India was tackling the problem of ozone depletion caused by halons. In June 1990 the National Task Force to phase out halons was set up. The Task Force sub committee submitted its report during 1991 and updated it in April 1993. The Task Force has members from regulatory bodies, fire research institutions, fire fighting equipment manufacturers, halon manufacturers and [suppliers?/users?] consumers.

There are no measures as yet to regulate halon use. The Task Force suggested regulation through standards and codes of practice for the use of authorities such as factory inspectors, insurance companies & Fire Officers etc to restrict halon use to critical sectors. This is under consideration.

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

a) Bureau of Indian Standards, the organisation responsible for preparation of specifications and operation of ISI mark on fire fighting equipment have dropped the standard for aerosol halon extinguishers and mobile equipment of 25 to 50 kg capacity.

b) Because of dwindling supplies and increasing cost of Halon 1301, a few users are switching over to Halon 1211 for some applications and other new installations to carbon dioxide.

c) Usage of halon 1301 systems is limited to essential uses such as military, shipping, offshore platforms, computer rooms, power etc.

There is a proposal for legislation to control halon emissions during refilling, transfer, testing and training. However because of delay and uncertainties over alternative technology availability, the timing of the law will depend on the identification, adoption and take up of halon alternatives in India.

(ii) Factors which influenced the type of bank chosen

The Task Force has taken guidance from phase out strategies of other countries, but some of the unique features of India which makes it different from other developing countries have also been taken into consideration such as:

a) India is late starter in Halon use - 1985.
b) Until 1990 it was totally dependent on halon imports.

c) India has technical capability to manufacture halons. Production of 1211 began in 1991 (about 75 tonnes per annum).

d) The country's size and dispersed industrial infrastructure.

e) India's economy is in growth phase.

f) Near self dependence in defence equipment & other high fire risk industries.

g) India does not trade in halons with other countries.

h) Because of low availability and high cost, halon uses are mostly confined to essential/critical sectors.

i) Due to aggressive marketing efforts, between 1989 and 1992 halon portable extinguishers replaced many conventional extinguishers even in non-critical areas. This trend is now being reversed quickly due to environmental awareness of Montreal Protocol issues and market forces.

j) Fire fighting equipment manufacturers in India are in private sector and all of them are small scale industries. There are more than 50 companies making fire fighting equipment, about 25 of them make halon based extinguishers and systems.

k) There is no company specialising solely in halon equipment or extinguishers. They make almost all kinds of extinguishers and systems. Halon business may contribute about 5% of their total business.

l) It is mainly the manufacturer of halon and the [users/suppliers?]consumers who are concerned about the use, availability, conservation, refill, repair, maintenance, banking and phase out strategies.

According to a recent survey India's estimated consumption level for the last three years is as follows:

Year	Halon 1211 (tonnes)	Halon 1301 (tonnes)
1990	500	200
1991	500	200
1992	400	100

Production capacity for both the halons at present is 300 tonnes per annum, which is likely to go up to 700 tonnes per annum by 1996-97. According to some estimates about 700 tonnes of halon 1301 and 3000 tonnes of 1211 have been installed so far. However, there is no record of actual places of installation.

(iii) Objectives

There is no halon bank facility which can be used for re-allocation, servicing, refilling. If the halon bank scheme proposed is set up, it will serve primarily to repair, refill and maintain existing halon systems and to lesser extent for new installations after ascertaining the criticality of the application on the basis of the halon essentiallity criteria.

(iv) How the organisation functions

The Task Force on Halon has shown that there is only about 500 tonnes of 1301 and 2500 tonnes of 1211 banked in essential areas such as Military, oil, power. Halon installations are of recent origin and will last for the next few years, after which the halon will require recovery, recycling and the systems require maintenance and in some case refilling by new/recycled halon. The Task Force felt that re-allocation of this halon might not be a feasible proposal. However, they recommended that a halon bank strategy be built up for refill, repair and in certain cases for critical new facilities. A bank of about 1000 tonnes of halon 1301 and 3000 tonnes of 1211 may be necessary for the next 10 years i.e. until 2004, to meet essential requirements.

Three possible ways forward have been identified.

a) Users in critical sectors like defence, oil and power could join together and manage their own physical bank. They would arrange the necessary funds, personnel, location and methodology themselves.

b) A halon banking company could be set up for procurement, supply, recycling and keeping track of the halon. The funds could be raised through public shares and equity from the suppliers, users and other interested parties. The company would take into account environmental concerns and follow the standards for handling halon laid down by legislative bodies.

The Bank would operate as follows:

Halon manufacturer	Halon bank company for purchase, recovery, recycle, testing and banking. Incineration/Destruction of halon which is beyond recycling.	After a time if the use does not remain essential or recycling is needed the halon will be returned to the halon banking company for action
Halon supplier/user	Keep record of available halon. Sole halon supply agency on demand and on fulfilment of essential use criteria. A committee will be formed to verify essentiallity and to issue essentiallity certificate	

The cost of the original halon and recycling etc would be calculated and Halon bank company would cover all overheads including destruction costs which might become necessary at very late stage. Users and suppliers would have to register with the Halon Bank company giving their approximate annual requirement and also their available halon.

c) India could link up with developed countries halon banks, if the supplies are assured for regular consumption at reasonable cost.

2.3.5 Japan

(i) Introduction

The use of halon for fire suppression in Japan is recommended in the Fire Service Act and therefore, as the installation of fire suppression systems is compulsory for many applications, a large number of halon systems exist. In the light of 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 of Japan issued guidelines (Fire Defence Protection No 161, August 15 1991) to the effect that new halon installations should be restricted to specified areas only, and all other new installations be protected by non-halon systems.

This ordinance took effect on 1 January 1992 and allows the use of halon for electric/electronic communication facilities, on board aircraft, and for historical heritage. It prohibits their use in car parks and machine rooms where the use of halons has been particularly substantial in Japan.

A study group was organised within the Fire Extinguishing Systems Manufacturers Association to prepare a national halon bank management organisation. This study group (called Halon Bank Preparatory Committee), with the co-operation of the Fire Defence Agency, is now working on details of the structure of the bank management scheme. The aim is to complete the preparatory work by the end of May 1993 and to found the halon bank management body (tentatively named the Council for Halon Bank Management) as soon as possible before the end of June 1993.

(ii) Factors which influenced the type of bank chosen

Maintaining fire suppression systems in active service is a legal requirement when such installations are compulsory to comply with the Fire Services Act. Such 1301 installations (mostly total flooding systems) are estimated to be more than 20,000 sites, or 23,000 tonnes, nation-wide by the end of 1993. Halon 1301 cylinders that are emptied because of release on a fire or through any other cause, need to be refilled and maintained throughout the life of the relevant buildings/facilities in order to meet the legal requirements.

Modifications or demolition of existing building/facilities will create surplus halon that can be re employed to either refill existing but emptied cylinders, or for new applications that are considered essential, or be destroyed. The Fire Defence Agency, which is responsible for the enforcement of the Fire Service Act, recognises the need to regulate the balance of supply and demand by making flexible use of the national inventory of halon 1301. From this comes its instruction to form a bank management programme.
The estimated aggregate of 23,000 tonnes of halon 1301 by the end of 1993 can be divided roughly into the following usage patterns:

Application of halon 1301	**Explanation**	**Share%**
Car parks	Car repair shops, car parks (mainly high rise structures)	25.5
Electricity	Dynamo room, cable room, film depository	22.5
Communications	Communication rooms, studios etc	20.1
Hazardous Installations	Reservoir, paint handling workshop, workshops using hydraulic equipment etc	11.7
Machinery room	Machinery room, kitchens etc	4.6
Art objects	Galleries, Museums	2.5
Control room	Navigation control, process controls	0.7
Miscellaneous	Processing workroom, research labs warehouse, library stacks, valuables	12.3

(iii) Objectives

The bank management scheme has been founded in order to minimise the unnecessary release of halons. To attain this objective, the proposed Council for Halon Bank Management will be tasked to prepare and maintain the complete national list of halon 1301 cylinders. They will administer each move of such registered cylinders, whenever it occurs.

(iv) Organisation and function

Council for Halon Bank Management will be founded as an independent and non-profit organisation, and its operation will primarily be supported by dues paid by members. The membership will consist of regular members and supporting members, the former being typically represented by fire equipment manufacturers and major users/organisations of halon systems, and the latter being the individual or society who gives the approval to the intent of halon bank management.
The operating cost of the Council will be covered by the following:

a) Enrolment fee paid by regular members and supporting members
b) Annual membership fees paid by regular members and supporting members

c) Subsidy by Government

d) Commission paid by supplier/recipient

The Fire Defence Agency will not be directly involved in running the operation of the Council, but will act as the competent authority.

The major business of the Council will be as follows:

a) prepare data base of national halon bank and maintain an up to date record - Note halon bank is defined as consisting of the following:

   - Halons with cylinders actually in service;

   - Virgin halons stocked;

   - Recovered halons.

b) Administer recovery of halons

c) Administer supply of halons

d) Co-ordination with competent authority

e) Public relations

Operation procedure for halon recovery and supply

Member		Member		
Protected Facilities	Halon demand	Fire equipment manufacturer	Report on halon inventory	Council for Halon Bank Management
	Halon supply	Maintenance and service companies	Halon supply request	
	Halon recovery	Others	Halon recovery instruction	

Council for Halon Bank Management is prepared to trade with banks of other countries.

(v) Pending problems

Physical location for halons that are recovered but not immediately required? Who will pay for above ?

2.3.6 Malaysia

(i) 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 1 June 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.

(ii) Operation

The next stages of the system are 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 fifth stage would include the prioritisation 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.

2.3.7 The Netherlands

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.

For collection and recycling of halons a co-operative association with excluded liability has been set up, with the objective to provide for the halons 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 regenerated by this company meets the usual standards for aviation industries 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 realise 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 are offered -free of charge- from existing installations in the Netherlands will be taken back by he 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 sully shortages elsewhere. Such an exchange fits within international agreements.

The association (Co-operative Vereniginge Halonen, U.A.) officially was set up on April 5th 1993. The activities started in the same month with collecting halon. The recycling unit is under construction and will start-up in November 1993. In July 1993 there were 60 applications for membership from the following areas:

- aircraft manufacturing companies
- airlines
- ministry of defence
- public works
- chemical industry
- ship owners

Since the start-up of the bank 30 tons of halon 1301 was offered to the bank for free. This quantity is sufficient to meet the needs of the 60 members in the coming two years. Only small quantities of halon 1211 have been requested by members where more halon 1211 was offered to the association.

Contact address for more information:

Cooperatieve Vereniging Halonen, U.A.
attention: Mr. R.C. Basart
P.O. Box 8138
3503 RC Utrecht
The Netherlands
fax: +31 30 588 600

2.3.8 Russia

(i) Introduction

In February 1993 the State Institute of Applied Chemistry in Saint Petersburg and a group of experts from the Interagency Commission for the Protection of the Ozone Layer met and were designated as the organisations responsible for the development of a national halon bank programme. The scheme is still under development.

(ii) Objectives

The bank will:

a) control halon use;
b) control recycling and supply of halons;
c) meet essential fire protection needs.

The quantities needed to support those essential uses for the years 1994-96 were assigned as follows:

Ministry	**1994**			**1995**			**1996**		
	2402	**1301**	**1211**	**2402**	**1301**	**1211**	**2402**	**1301**	**1211**
Defence	200	10	10	200	10	10	200	10	10
Atomic Energy	10	10	nil	10	10	nil	10	10	nil
Culture	nil	5	2	nil	5	2	nil	5	2
Civil Aviation	65	3	12	65	3	12	65	3	12
Gas Industry	nil	30	nil	nil	30	nil	nil	30	nil
Sea Transport	5	nil	nil	5	nil	nil	5	nil	nil

This amounts to 10% of the total halons produced in Russia now. The applications to be protected are as follows:

- nuclear reactors
- atomic submarines
- aircraft
- crew compartments of armoured carriers

- strategic command posts
- most valuable cultural objects
- gas pumping stations.

2.3.9 Sweden

(i) Introduction

The Swedish Environmental Protection Agency is responsible for issuing regulations on handling halon. Under the Swedish ordinance on CFCs, halons etc from the 1 July 1991 all new halon installations were prohibited. The 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 1211 may not be sold, manufactured, recharged or imported. From 1 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 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 twenty 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.

(ii) Organisation of bank

There is 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.

2.3.10 Switzerland

(i) 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 extinguishers is banned - except for essential applications
  All existing fixed fire protection systems with 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, recharging existing installations is still possible. For recharging the essentiallity 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 is the fire equipment manufacturers. Being a small country, only a few halon equipment manufacturers exist in Switzerland. 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.

(ii) Factors influencing the decision

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). A centralised pool would also run the risk of ending up with a large amount of material which might be considered a hazardous waste. 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 eventual recharge of existing systems. These reasons have resulted in the decision to opt for a clearing house solution where only information is traded between the partners involved.

(iii) 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 has to be shared with the other members upon demand. The halon is then traded between the parties to this agreement.

(iv) Organisation of the Swiss Halon Banking System

All halon that has been taken out of decommissioned installations becomes part of the bank. It has to be registered with the federal authorities as "no longer used halon". Owners of recyclable halon are encouraged to store the agent on their premises for sale upon demand. They should also register the available amount with their equipment manufacturer. Equipment manufacturers will maintain a small but adequate halon supply for servicing and refilling. Until the reclaimed halon is sold to a new owner, the original owner keeps the title and therefore the legal responsibility for the halon.
This solution requires no special organisation as it is managed by the equipment manufacturers within their normal trade operations. As there are only few companies involved, the exchange of information does not pose any special problems. The organisation can therefore be run at minimal additional cost. Large halon users like banks or insurance companies will run their own bank management program. They rely on their in-house supply of halon from decommissioned systems.
The government's halon register is used as a national inventory of halon available for reclamation and recycling. It will in the future fulfil the role of a national clearing house as it can provide manufacturers with additional information on the potential availability of halon. The register will also be the source of information for an eventual international trade of recycled halon. At the moment this is not possible under Swiss law, however.

(v) Lessons learned

The co-operative effort of the Federal Office of Environmental Protection with the Fire Equipment Manufacturers Association has proven to be a very productive approach. The regulatory demands and the commercial interests and concerns could be balanced in the process. Several different solutions for the establishment of a clearing house 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.
The process 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 in finding a solution. It also required the government authorities to allow a solution to develop without interfering strongly from the beginning.

2.3.11 United Kingdom

(i) 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.

The use of halons has never been mandatory, but it has been the agent of choice in many applications since the mid 70s. 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).

Changes in UK waste law in mid 1992 meant that halon could 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.

Two major halon using organisations were already looking at how they might organise themselves to meet their needs beyond the phase out of halon production. These were the Ministry of Defence (see UK Military Banking Chapter ??) 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.

Very few UK halon users could organise in this way. 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 Halon Users' National Consortium (HUNC) - a computerised clearing house which would put those who wanted to buy halons in touch with those who wanted to sell. The organisation would own no halon of its own. It would be non-profit making funded by members' subscriptions rather than 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 the 'bank' 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 enquirers. 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.

(ii) Objectives

HUNC activities are controlled by its Constitution which effectively sets the objectives for the organisation 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/IEPAC in Paris;

f) to maintain current information on international requirements for halons.

Over and above all else HUNC is a service organisation 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.

(iii) How HUNC functions

HUNC was initially constituted as an unincorporated organisation bound by its Constitution. In order to limit the general liability of its Council the organisation will transform during 1993 into a company limited by guarantee. 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 for specific technical expertise as 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 operations and attendant administration.

Membership of HUNC is available to any company or organisation 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 organisation 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 are 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/IEPAC 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.

(iv) Lessons learned

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' organisation, 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 organisation. 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 strands will be common to all.

g) 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 who sells the idea to colleagues. The organisation with such a 'champion' often becomes a '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.

(v) Other comments

HUNC will clearly develop over time, as its members' needs change. It is hoped that the structure adopted will enable this to happen easily. It seems likely that the HSG will also move away from being a Government chaired group and become a forum for discussion between users of fire protection and those who provide that protection whether it be halon based or some other media.

2.3.12 United States of America

(i) Introduction

Controls on the production, import, transport and use of halons are governed by the U.S. Clean Air Act Amendments of 1990 (CAA), as implemented by the U.S. 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. Currently the EPA is writing regulations to implement the Copenhagen changes to the Montreal Protocol which will effectively ban the production and import of halons into the U.S. except for essential uses approved by the Parties to the Protocol. 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 maximise 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 U.S. The study report also provided suggestions and recommendations for future management of the U.S. halon bank.

(ii) Factors influencing the type of bank chosen

In the U.S., 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 U.S. halon bank is distributed over of 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 organisation 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).

(iii) Objectives

HRC is a voluntary, non-profit trade association formed to assist users of halon fire fighting chemicals to inventory and re deploy the existing bank of halon 1301. HRC will:

- Act as a broker for sales of recycled halon 1301.
- Provide guidelines and procedures for a self determination of critical halon use.
- Provide an independent review and critical halon use certification if requested.
- Provide a list of companies who will recycle halon to a recognised standard.
- Act as a clearinghouse for information on standards of recycled halon, and regulations or legislation that affects halon recycling, equipment, or technology.
- Act as the link between halon users in the U.S. and halon banks in other countries.

(iv) How HRC operates

HRC will broker Halon 1301 through a two-tier system. This system has been 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 has created a voluntary certification system for identifying potential buyers whose needs may reasonably be determined to be justifiable. Potential buyers meeting the necessary criteria will be granted one of two designations, 'Certified' or 'Registered'.

The 'Certified' label will be 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 will be paid for their services, but other members of the committee will be volunteers.

The 'Registered' label will be 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.
It is anticipated that this two-category system will stimulate the use of HRC and ensure an ample flow of halon 1301 into the market from owners who are willing to recycle their product only for truly responsible usage.

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 will maintain a database of sellers and buyers, and will provide updated listings to each group on a regular basis. HRC will operate as a non-profit organisation, funded by fees set annually by its board of directors as follows:

- i) Founding members donated funds to cover initial set up and incorporation costs.

- ii) Each seller will pay 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 will not be assessed this fee.

- iii) Each buyer will pay a 'Registered' or 'Certified' user joining/listing fee to cover processing costs.

- iv) A brokerage fee, which is a fixed cost per pound of halon transferred, will be charged to cover operating costs. Upon consummation of a deal, the buyer and seller will forward copies of the contract indicating the quantity of halon transferred. The appropriate brokerage fee will then be assessed on the buyer. Note, subsequent deals between the parties will be assessed the brokerage fee at the then prevailing rate.

HRC will encourage 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.

(v) Lessons learned

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 U.S. The voluntary application of the critical use review committee was deemed to be more acceptable.

(vi) Other comments

Depending upon the success or otherwise of the current program and future legislation, HRC could offer storage facilities in the future, particularly for the collection of small quantities of donated halon 1301.

2.4 Basic requirements for a recycled halon banking strategy

From the wide range of systems above 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 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.

2.4.1 Key players

It is interesting to note that while in some countries the fire equipment suppliers play a major role (Denmark, Switzerland, UK), in the USA they have a very minor part. This is because of the historic shape of the halon supply market. Again in Switzerland, for example, the users play an almost passive role whereas they are they prime movers in most of the other schemes.

Governments too have a widely differing function in these schemes. In some cases (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, USA) governments have left it to the participants to define the operating framework and permit market forces to prevail. However, 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, transport and wise management of recovered and recycled halons.

2.4.2 Inventory and brokerage

Some of the banking strategies are based on a detailed inventory of the halon held in a country; some are based round an inventory of the halons held by the members of the bank. As a minimum any banking strategy must have a list of the halon users who no longer require material and one of users who still require halons but who do not have a sufficient stock. There must then be a method of matching the two.

2.4.3 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 this would be a list of companies who have or have access to recycling facilities.

Those users who need halon have to be assured that it is fit for use in fire protection applications and therefore has to be some level of confidence in the material. This can be provided either by requiring material to be recycled to a certain agreed standard (ISO 7201, ASTM ES 24-93) or by knowing its provenance - a history of where it has been used, stored etc.

2.5 Additional features for halon bank management

In addition to the basic features described in section 2.4 a given bank management schemes can be tailored to meet the special requirements of its participants by the provision of one or more of the following features. They have been incorporated in some of the national bank schemes described in section 2.3.

a) 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.

b) Certification of recycled material to a given international standard. This makes material more readily transferable between applications and/or banks in other countries.

c) Standards and codes of practice for handling the material. This allows for inspections and tighter controls of potential losses from ageing systems.

d) Methods for determining 'essentiallity' 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.

e) A physical bank (central or distributed) with deposits and withdrawals. This allows tighter control of quality and supply of halons.

f) Advice or facilities for disposal 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.

g) Access to other halon banks through the international clearing house. This facilitates access to a bigger market for the sale or purchase of halons.

Appendix Three

Estimated Historic and Future Halon Supplies

3.1 Introduction

The computer program BANK was used to develop the estimates used in this section of the report.

For halon 1211 based fire equipment the following base assumptions were used in the calculations shown. 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 1211 assume that before 1988 there was no recovery. Between 1988 and 1992 the recovery rate increases to a maximum of 25%. 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 in the calculations shown. Equipment life has been estimated as 15 years. The computer program calculates that 6.7% of the additions to the bank for a year reach the end of useful life for each of 15 years thereafter. This 6.7% 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.

The calculations shown in this report assume that recycled halon, in excess of bank maintenance requirements, will be made available for new installations to protect "essential" facilities. For comparison purposes, calculations are provided for 2000, 1997 and 1995 as phase-out years.

3.2 Explanation of Individual Factors Used by the Computer Program BANK to Generate Halon Bank Estimates

C1 Year

The current year

C2 Production/Imports (Prod)

Production, in metric tonnes. 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. The estimated production figures are as follows:

C3 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, losses however are accounted for under category (C7). Losses that occur when halon 1301 is recovered and recycled during hydrostatic test of the system container are dealt with in a similar manner.

The computer program divides the quantity of halon added to the bank in a given year (C 11) by the usable life, entered by the user of the program. This equal portion of halon is then returned each year (C1) over the usable equipment life to form part of the amount available for recycle (C3) for any given year.

C4 Supply

The total supply equals Production (C2), plus Recycle (C3).

C5 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 (C 10). From industry studies conducted in the United States and Europe the following factors were derived to calculate this estimated quantity:

For Halon 1301	1.5% of the Bank at the start of the year (C 10)
For Halon 1211	2% of the Bank at the start of the year (C 10)

C6 Testing and Training (Tst/Tng)

It is recognized that awareness will be a driving force to reduce emissions attributed to these causes. Again the starting factors used were derived from industry studies. Future values are judgement estimates.

For Halon 1301

Before 1988	15% of Supply (C4)
1988	12.5% of Supply (C4)
1989	10% of Supply (C4)
1990	7.5% of Supply (C4)
1991	5% of Supply (C4)
1992	2.5% of Supply (C4)
1993 and beyond	2% of Supply (C4)

For Halon 1211

Before 1988	10% of the Bank at the start of the year (C10)
1988	7.5% of the Bank at the start of the year (C10)
1989	5% of the Bank at the start of the year (C10)
1990	2.5% of the Bank at the start of the year (C10)
1991	2% of the Bank at the start of the year (C10)
1992	1.5% of the Bank at the start of the year (C10)
1993 and beyond	1% of the Bank at the start of the year (C10)

C7 Other (Other emissions including service, leakage, false & unwanted discharges)

It is recognized that awareness will be a driving force to reduce emissions attributed to these causes. Again the starting factors used were derived from industry studies. Future values are judgement estimates.

For Halon 1301

Before 1988	2.5% of the Bank at the start of the year (C10)
1988	2.25% of the Bank at the start of the year (C10)
1989	2% of the Bank at the start of the year (C10)
1990	1.75% of the Bank at the start of the year (C10)
1991	1.5% of the Bank at the start of the year (C10)
1992	1.25% of the Bank at the start of the year (C10)
1993 and beyond	1% of the Bank at the start of the year (C10)

For Halon 1211

Before 1988	5% of the Bank at the start of the year (C10)
1988	4.75% of the Bank at the start of the year (C10)
1989	4.5% of the Bank at the start of the year (C10)
1990	4% of the Bank at the start of the year (C10)
1991	3.5% of the Bank at the start of the year (C10)
1992	3% of the Bank at the start of the year (C10)
1993 and beyond	2.5% of the Bank at the start of the year (C10)

C8 Unrecovered Halon

This factor is calculated in conjunction with the theoretical Recycle quantity. As it is recognized that it is impractical to recover the full quantity theoretically available for recycle, the quantity that is not recycled is treated as an emission. This calculation is performed as follows:

(1 - Recovery Factor) X Recycle (C3) = Unrecovered Quantity (C8)

Up until 1988 the minimum recovery factor entered by the user of the program is used to perform this calculation. After 1994 the maximum recovery factor is used to calculate this quantity. The calculations for the years 1989 to 1994 use an incremental recovery. The minimum and maximum recovery values are entered by the user of the program. The values used in the calculation are printed at the top of each spreadsheet and chart.

C9 Destruct

Should the policy decision be made to not allow use of a halon to be recycled into new equipment the excess halon that becomes available annually through recycle would be available for environmentally acceptable destruction, for all years after the year in which production/imports cease. This quantity is not treated as an emission. As a result cumulative emission quantities would be less than cumulative production quantities. If the recycle option has been selected then halon in excess of bank maintenance requirements is assigned to (C11) additions to the bank. The user of the program enters the choice of recycle or destruct. The choice selected is printed at the top of each spreadsheet and chart.

C10 Bank at the Start of the Year (Strt Bnk)

This is equal to the bank at the end of the previous year, less the quantity that becomes available for recycle; ie. (C12) for the previous year less (C3) for the current year.

C11 Bank Change (Bnk Chng)

This is the annual supply, less all annual emissions and represent the quantity that can be used for new installations of halon fire equipment. In some cases this quantity is negative, which indicates that additional halon would have to be removed from the bank to provide sufficient halon to service the remainder of the bank in the current year.

C12 Bank at the End of the Year (End Bnk)

This quantity equals the Bank at the start of the year (C10), plus the additions to the bank for the year (C11).

C13 Yearly Emissions (Yr Emis)

The total emission quantity for the current year.

C14 Cumulative Emissions

The total of all emissions to date including those of the current year.

C15 Cumulative Production

The total of all production to date including the production for the current year,

3.3 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

Computer generated calculations using the Emission Estimate method are included in this Appendix. Calculations and graphs for both halon 1301 and halon 1211, with production phase-out in the year 1994 are provided.

This calculation was performed using version 7.1 of the computer program BANK
World - Halon 1301 - Phase-Out Year is 1994 - Equip Life 15 yrs - From 1994 Recovered Halon to be Recycled.
Up to 1988 recovery is estimated as 50% increasing to 75% by 1995.
World usage equals 100% of Global Production.
Global Production is based on published CEFIC data plus estimates of other production - all quantities are expressed as tonnes.
When the Bank size decreases to less than 5% of its' maximum attained size - the calculation terminates.

C1 Year	C2 Prod	C3 Recycle	C4 Supply	C5 Fires	C6 Tst/Trng	C7 Other	C8 UnRec	C9 Destruct	C10 Strt Bnk	C11 Bnk Chng	C12 End Bnk	C13 Yr Emis	C14 Cum Emis	C15 Cum Prod
1963	10	0	10	0	-2	0	0	0	0	9	9	2	2	10
1964	20	1	21	0	-3	0	0	0	8	17	25	4	5	30
1965	30	2	32	0	-5	-1	-1	0	23	25	48	7	12	60
1966	40	3	43	-1	-7	-1	-2	0	45	33	78	10	22	100
1967	50	6	56	-1	-8	-2	-3	0	73	42	114	14	36	150
1968	60	8	68	-2	-10	-3	-4	0	106	50	156	19	54	210
1969	100	12	112	-2	-17	-4	-6	0	144	83	227	28	83	310
1970	200	17	217	-3	-33	-5	-9	0	210	168	378	50	132	510
1971	550	28	578	-5	-87	-9	-14	0	349	463	813	115	247	1060
1972	839	59	898	-11	-135	-19	-30	0	753	704	1457	195	442	1899
1973	1292	106	1398	-20	-210	-34	-53	0	1351	1081	2432	317	759	3191
1974	1461	178	1639	-34	-246	-56	-89	0	2254	1214	3468	425	1184	4652
1975	2019	259	2278	-48	-342	-80	-130	0	3209	1679	4887	600	1784	6671
1976	3172	371	3543	-68	-531	-113	-186	0	4516	2645	7162	898	2681	9843
1977	3550	548	4098	-99	-615	-165	-274	0	6614	2945	9559	1153	3834	13393
1978	4015	744	4759	-132	-714	-220	-372	0	8815	3321	12135	1438	5273	17408
1979	4718	965	5683	-168	-852	-279	-482	0	11171	3901	15072	1782	7054	22126
1980	4877	1224	6101	-208	-915	-346	-612	0	13848	4020	17868	2081	9135	27003
1981	5694	1490	7184	-246	-1078	-409	-745	0	16378	4706	21084	2478	11613	32697
1982	7565	1801	9366	-289	-1405	-482	-901	0	19283	6289	25572	3077	14690	40262
1983	7386	2218	9604	-350	-1441	-584	-1109	0	23355	6120	29475	3484	18173	47648
1984	8692	2623	11315	-403	-1697	-671	-1311	0	26852	7232	34084	4083	22256	56340
1985	9781	3099	12880	-465	-1932	-775	-1550	0	30985	8159	39144	4721	26977	66121
1986	11076	3632	14708	-533	-2206	-888	-1816	0	35512	9265	44777	5443	32420	77197
1987	11604	4219	15823	-608	-2373	-1014	-2109	0	40559	9718	50276	6105	38525	88801
1988	12551	4820	17371	-682	-2171	-1023	-2259	0	45457	11236	56692	6135	44660	101352
1989	11152	5497	16649	-768	-1665	-1024	-2405	0	51196	10787	61983	5861	50521	112504
1990	9115	6135	15250	-838	-1144	-977	-2492	0	55848	9799	65647	5451	55972	121619
1991	7326	6676	14002	-885	-700	-885	-2504	0	58970	9029	68000	4973	60945	128945
1992	4884	7102	11986	-913	-300	-1522	-2441	0	60898	6809	67707	5177	66122	133829
1993	2442	7359	9801	-905	-196	-603	-2300	0	60348	5797	66144	4005	70127	136271

This calculation was performed using version 7.1 of the computer program BANK
World - Halon 1301 - Phase-Out Year is 1994 - Equip Life 15 yrs - From 1994 Recovered Halon to be Recycled.
Up to 1988 recovery is estimated as 50% increasing to 75% by 1995.
World usage equals 100% of Global Production.
Global Production is based on published CEFIC data plus estimates of other production - all quantities are expressed as tonnes.
When the Bank size decreases to less than 5% of its' maximum attained size - the calculation terminates.

1994	0	7524	7524	-879	-150	-586	-2116	0	58620	3792	62412	3732	73859	136271
1995	0	7517	7517	-823	-150	-549	-1879	0	54895	4115	59010	3402	77261	136271
1996	0	7524	7524	-772	-150	-515	-1881	0	51487	4205	55692	3319	80579	136271
1997	0	7490	7490	-723	-150	-482	-1873	0	48201	4263	52464	3227	83807	136271
1998	0	7355	7355	-677	-147	-451	-1839	0	45109	4241	49351	3114	86920	136271
1999	0	7230	7230	-632	-145	-421	-1807	0	42121	4225	46346	3005	89925	136271
2000	0	7029	7029	-590	-141	-393	-1757	0	39316	4149	43465	2881	92806	136271
2001	0	6762	6762	-551	-135	-367	-1691	0	36703	4019	40721	2743	95549	136271
2002	0	6412	6412	-515	-128	-343	-1603	0	34309	3823	38132	2589	98138	136271
2003	0	6019	6019	-482	-120	-321	-1505	0	32113	3591	35704	2428	100566	136271
2004	0	5510	5510	-453	-110	-302	-1377	0	30195	3267	33462	2242	102808	136271
2005	0	5008	5008	-427	-100	-285	-1252	0	28454	2945	31398	2064	104872	136271
2006	0	4551	4551	-403	-91	-268	-1138	0	26847	2651	29498	1900	106772	136271
2007	0	4126	4126	-381	-83	-254	-1032	0	25372	2378	27750	1748	108520	136271
2008	0	3831	3831	-359	-77	-239	-958	0	23919	2198	26117	1632	110152	136271
2009	0	3591	3591	-338	-72	-225	-898	0	22527	2058	24585	1533	111685	136271
2010	0	3475	3475	-317	-70	-211	-869	0	21109	2009	23119	1466	113151	136271
2011	0	3335	3335	-297	-67	-198	-834	0	19784	1940	21724	1395	114546	136271
2012	0	3184	3184	-278	-64	-185	-796	0	18540	1861	20401	1323	115869	136271
2013	0	3024	3024	-261	-60	-174	-756	0	17377	1773	19150	1251	117120	136271
2014	0	2859	2859	-244	-57	-163	-715	0	16291	1680	17971	1179	118299	136271
2015	0	2689	2689	-229	-54	-153	-672	0	15281	1581	16862	1108	119407	136271
2016	0	2518	2518	-215	-50	-143	-630	0	14344	1480	15824	1039	120446	136271
2017	0	2349	2349	-202	-47	-135	-587	0	13475	1378	14853	971	121417	136271
2018	0	2186	2186	-190	-44	-127	-547	0	12667	1279	13946	907	122324	136271
2019	0	2032	2032	-179	-41	-119	-508	0	11914	1185	13099	846	123170	136271
2020	0	1893	1893	-168	-38	-112	-473	0	11206	1102	12308	791	123961	136271
2021	0	1770	1770	-158	-35	-105	-443	0	10538	1029	11567	741	124702	136271
2022	0	1662	1662	-149	-33	-99	-416	0	9904	966	10870	696	125398	136271
2023	0	1568	1568	-140	-31	-93	-392	0	9302	912	10214	656	126054	136271
2024	0	1482	1482	-131	-30	-87	-371	0	8732	864	9596	618	126672	136271
2025	0	1403	1403	-123	-28	-82	-351	0	8193	819	9012	584	127256	136271
2026	0	1323	1323	-115	-26	-77	-331	0	7689	774	8463	549	127805	136271

This calculation was performed using version 7.1 of the computer program BANK

World - Halon 1301 - Phase-Out Year is 1994 - Equip Life 15 yrs - From 1994 Recovered Halon to be Recycled.

Up to 1988 recovery is estimated as 50% increasing to 75% by 1995.

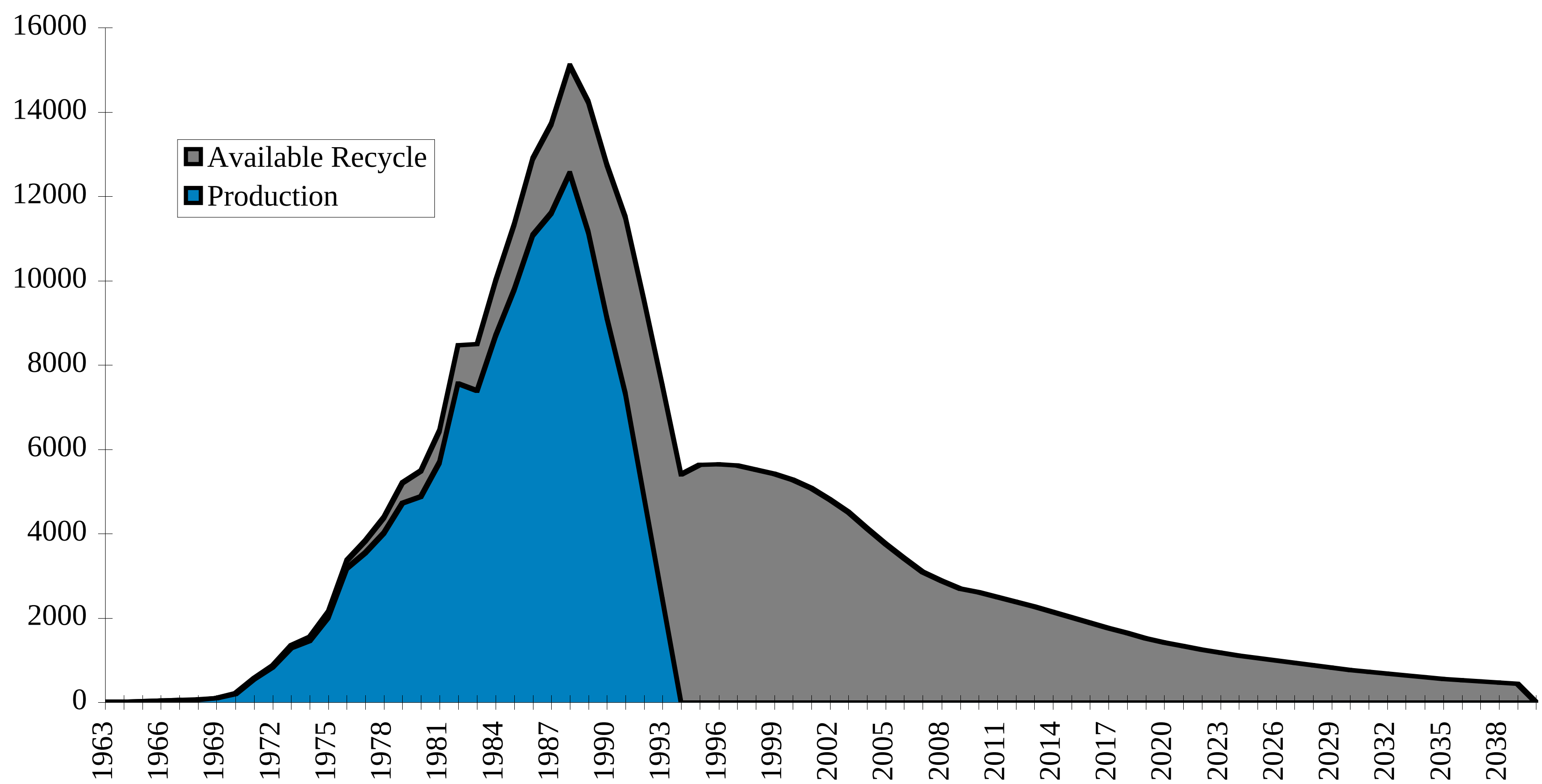
World usage equals 100% of Global Production.

Global Production is based on published CEFIC data plus estimates of other production - all quantities are expressed as tonnes.

When the Bank size decreases to less than 5% of its' maximum attained size - the calculation terminates.

2027	0	1245	1245	-108	-25	-72	-311	0	7217	729	7946	517	128322	136271
2028	0	1170	1170	-102	-23	-68	-292	0	6776	685	7461	485	128807	136271
2029	0	1097	1097	-95	-22	-64	-274	0	6363	642	7005	455	129262	136271
2030	0	1028	1028	-90	-21	-60	-257	0	5977	601	6578	427	129689	136271
2031	0	963	963	-84	-19	-56	-241	0	5615	563	6178	400	130089	136271
2032	0	902	902	-79	-18	-53	-225	0	5276	526	5803	375	130464	136271
2033	0	845	845	-74	-17	-50	-211	0	4958	493	5450	352	130816	136271
2034	0	793	793	-70	-16	-47	-198	0	4658	462	5120	330	131146	136271
2035	0	744	744	-66	-15	-44	-186	0	4376	434	4810	310	131456	136271
2036	0	700	700	-62	-14	-41	-175	0	4110	408	4518	292	131748	136271
2037	0	658	658	-58	-13	-39	-165	0	3859	384	4244	274	132022	136271
2038	0	620	620	-54	-12	-36	-155	0	3624	362	3986	258	132280	136271
2039	0	583	583	-51	-12	-34	-146	0	3403	341	3743	242	132522	136271
2040	0	3743	3743	0	0	0	-3743	0	0	0	0	3743	136265	136271

World Halon 1301 - Phaseout Year 1994 - Equipment Life 15 Years



This calculation was performed using version 7.1 of the computer program BANK
World - Halon 1211 - Phase-Out Year is 1994 - Equip Life 20 yrs - From 1994 Recovered Halon to be Recycled.
Up to 1988 recovery is estimated as 0% increasing to 25% by 1995.
World usage equals 100% of Global Production.
Global Production is based on published CEFIC data plus estimates of other production - all quantities are expressed as tonnes.
When the Bank size decreases to less than 5% of its' maximum attained size - the calculation terminates.

C1 Year	C2 Prod	C3 Recycle	C4 Supply	C5 Fires	C6 Tst/Trng	C7 Other	C8 UnRec	C9 Destruct	C10 Strt Bnk	C11 Bnk Chng	C12 End Bnk	C13 Yr Emis	C14 Cum Emis	C15 Cum Prod
1963	50	0	50	0	-5	0	0	0	0	45	45	5	5	50
1964	100	2	102	-1	-4	-2	-2	0	43	93	135	10	15	150
1965	200	7	207	-3	-13	-6	-7	0	129	178	307	29	43	350
1966	300	16	316	-6	-29	-15	-16	0	291	251	541	65	109	650
1967	500	28	528	-10	-51	-26	-28	0	513	413	926	116	224	1150
1968	700	49	749	-18	-88	-44	-49	0	877	551	1428	198	422	1850
1969	900	77	977	-27	-135	-68	-77	0	1351	670	2022	306	728	2750
1970	1260	110	1370	-38	-191	-96	-110	0	1912	935	2847	435	1163	4010
1971	1700	157	1857	-54	-269	-134	-157	0	2690	1243	3933	614	1777	5710
1972	2200	219	2419	-74	-371	-186	-219	0	3714	1569	5282	850	2628	7910
1973	2750	297	3047	-100	-499	-249	-297	0	4985	1903	6888	1145	3772	10660
1974	3300	392	3692	-130	-650	-325	-392	0	6495	2196	8691	1497	5269	13960
1975	3800	502	4302	-164	-819	-409	-502	0	8189	2408	10597	1894	7163	17760
1976	4356	623	4979	-199	-997	-499	-623	0	9974	2660	12634	2318	9482	22116
1977	5000	756	5756	-238	-1188	-594	-756	0	11879	2981	14859	2775	12257	27116
1978	5650	905	6555	-279	-1395	-698	-905	0	13955	3278	17232	3277	15534	32766
1979	6280	1069	7349	-323	-1616	-808	-1069	0	16164	3532	19696	3816	19350	39046
1980	6910	1245	8155	-369	-1845	-923	-1245	0	18451	3773	22224	4382	23732	45956
1981	6689	1434	8123	-416	-2079	-1040	-1434	0	20790	3155	23945	4968	28700	52645
1982	7485	1592	9077	-447	-2235	-1118	-1592	0	22353	3685	26038	5392	34092	60130
1983	8259	1776	10035	-485	-2426	-1213	-1776	0	24262	4134	28397	5900	39992	68389
1984	10408	1980	12388	-528	-2642	-1321	-1980	0	26416	5917	32334	6471	46463	78797
1985	12491	2272	14763	-601	-3006	-1503	-2272	0	30062	7380	37443	7382	53845	91288
1986	13731	2632	16363	-696	-3481	-1741	-2632	0	34811	7813	42624	8550	62395	105019
1987	17058	3010	20068	-792	-3961	-1981	-3010	0	39614	10324	49938	9744	72139	122077
1988	20181	3505	23686	-929	-3482	-2206	-3396	0	46433	13674	60106	10012	82151	142258
1989	16182	4161	20344	-1119	-2797	-2518	-3901	0	55945	10009	65953	10335	92486	158440
1990	14852	4628	19480	-1227	-1533	-2453	-4194	0	61325	10073	71398	9407	101893	173292

This calculation was performed using version 7.1 of the computer program BANK

World - Halon 1211 - Phase-Out Year is 1994 - Equip Life 20 yrs - From 1994 Recovered Halon to be Recycled.

Up to 1988 recovery is estimated as 0% increasing to 25% by 1995.

World usage equals 100% of Global Production.

Global Production is based on published CEFIC data plus estimates of other production - all quantities are expressed as tonnes.

When the Bank size decreases to less than 5% of its' maximum attained size - the calculation terminates.

C1 Year	C2 Prod	C3 Recycle	C4 Supply	C5 Fires	C6 Tst/Trng	C7 Other	C8 UnRec	C9 Destruct	C10 Strt Bnk	C11 Bnk Chng	C12 End Bnk	C13 Yr Emis	C14 Cum Emis	C15 Cum Prod
1991	11882	5085	16967	-1326	-1326	-2321	-4450	0	66313	7544	73857	9423	111316	185174
1992	7921	5400	13321	-1369	-1027	-2054	-4557	0	68457	4315	72772	9006	120322	193095
1993	3960	5538	9498	-1345	-67	-1681	-4499	0	67234	1906	69140	7592	127914	197055
1994	0	5538	5538	-1272	-64	-1590	-4326	0	63602	-1714	61888	7252	135166	197055
1995	0	5428	5428	-1129	-56	-1411	-4071	0	56460	-1240	55220	6668	141834	197055
1996	0	5308	5308	-998	-50	-1248	-3981	0	49912	-969	48943	6277	148111	197055
1997	0	5175	5175	-875	-44	-1094	-3881	0	43768	-720	43049	5894	154005	197055
1998	0	5026	5026	-760	-38	-951	-3769	0	38023	-493	37530	5518	159523	197055
1999	0	4862	4862	-653	-33	-817	-3646	0	32669	-287	32381	5149	164672	197055
2000	0	4685	4685	-554	-28	-692	-3514	0	27696	-103	27593	4788	169460	197055
2001	0	4496	4496	-462	-23	-577	-3372	0	23097	62	23159	4435	173895	197055
2002	0	4342	4342	-376	-19	-470	-3256	0	18817	220	19037	4122	178017	197055
2003	0	4169	4169	-297	-15	-372	-3126	0	14868	358	15226	3810	181827	197055
2004	0	3980	3980	-225	-11	-281	-2985	0	11247	478	11724	3502	185329	197055
2005	0	3708	3708	-160	-8	-200	-2781	0	8017	558	8575	3150	188479	197055
2006	0	3367	3367	-104	-5	-130	-2525	0	5208	602	5810	2765	191244	197055
2007	0	5810	5810	0	0	0	-5810	0	0	0	0	5810	197054	197055

World Halon 1211 - Phaseout Year 1994 - Equipment Life 20 years