MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

MAY 2004

PROGRESS REPORT

Montreal Protocol
On Substances that Deplete the Ozone Layer

Report of the UNEP Technology and Economic Assessment Panel

May 2004

PROGRESS REPORT

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Co-ordination:	**Technology and Economic Assessment Panel**
Composition of the report:	Lambert Kuijpers
Layout:	Dawn Lindon, Eindhoven, Netherlands Ozone Secretariat, UNEP
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UNEP
MAY 2004 REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

PROGRESS REPORT

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Executive Summary

Review of Essential Use Nominations for Metered Dose Inhalers (MDIs)

The following table summarises TEAP recommendations (R: recommend, UR: Unable to recommend) on nominations for essential use production exemptions for MDIs (requested quantities in tonnes).

	European Community	Poland	Ukraine	United States	Russian Federation
2005		4.2 UR	53.1 R		
2006	550 R	4.2 UR		1900 R	286 UR
2007		4.2 UR			243 UR
2008		4.2 UR			

This year, ATOC has recommended a number of exemptions with the suggestion to Parties that approval be conditioned on review of quantities in 2005 when requested information has been provided to ATOC by Parties.

It is worth noting that the accounting framework reports the Party's stockpile, which can be contrasted with annual use, but does not report whether individual companies hold sufficient but not excessive stockpiles. Under Decision IV/25, production and consumption of a controlled substance for an essential use should be permitted only if "*the controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances…*". Management of the Party's stockpile may be dependant on knowledge of the individual holdings by various companies. Therefore, Parties may wish to consider options to redistribute available stockpiles among users.

The potential impacts of the phase-out of CFCs in non-Article 5(1) countries on the availability of affordable inhaled therapy in Article 5(1) countries

The phase-out of CFC-containing MDIs in non-Article 5(1) countries does not have a significant impact on treatment availability in Article 5(1) countries.

For local Article 5(1) country manufacturers of CFC MDIs, there is a need for the transition to be managed actively to ensure that access to components that are required to manufacture CFC MDIs is uninterrupted.

Capital cost may be a barrier to conversion to non-CFC technologies for some local manufacturers, but not necessarily to overall transition within an Article 5(1) country.

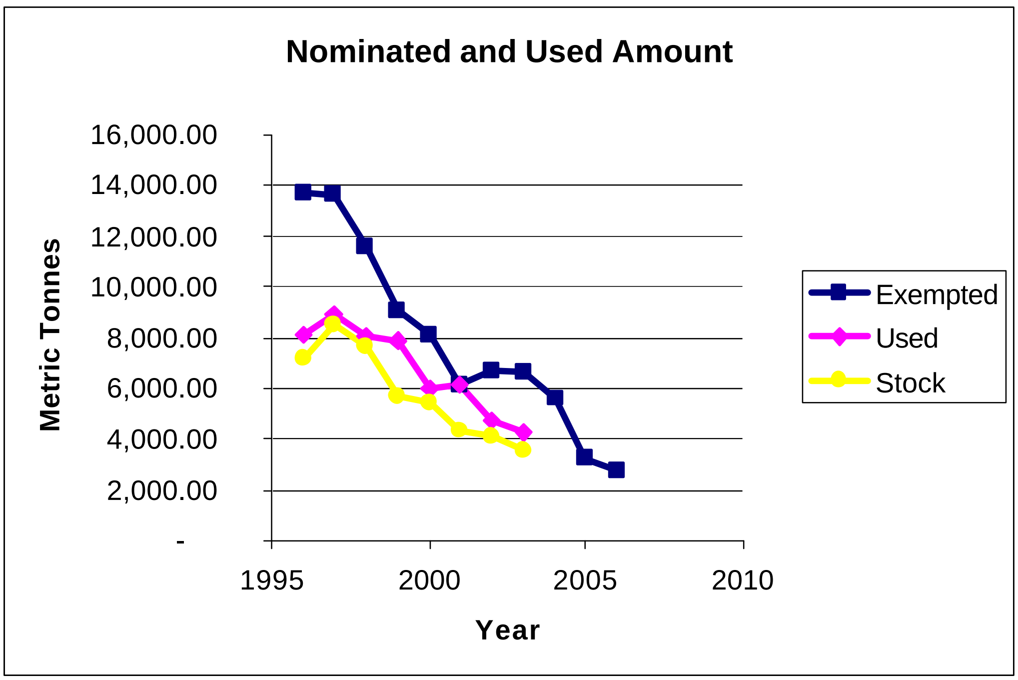
Update of the Handbook on Essential Use Nominations

Complex pharmaceutical supply chains, the difficulty to project future use and the problems associated with confidential information, were some of the reasons why ATOC considers it as not necessary to modify the Handbook of the Essential Use Nominations. The ATOC will revisit the issues at its 2005 meeting when ATOC will report back on what information may be most useful to Parties in deciding the quantities and timelines for the final phase-out of CFC based MDIs.

Progress Report

The downward trend in CFC use for MDIs continues. The figure below reflects the use of CFC for the production of MDIs for asthma and COPD in non-Article 5(1) countries, and includes amounts exempted under nominations made by the Russian Federation and Ukraine after 2002.

Relevant quantities regarding the use of CFCs for the production of MDIs



Technically satisfactory HFC alternatives to CFC MDIs are now available world-wide, particularly for salbutamol. ATOC notes that no additional countries have submitted transition strategies in the last twenty-four months. Parties are reminded of paragraph 4 of Decision XV/5 stating that "*no quantity of CFCs for essential uses shall be authorised after the commencement of the Seventeenth Meeting of the Parties if the nominating Party not operating under paragraph 1 of Article 5 has not submitted to the*

Ozone Secretariat, in time for consideration by the Parties at the twenty-fifth meeting of the Open-ended Working Group, a plan of action regarding the phase-out of the domestic use of CFC-containing metered-dose inhalers where the sole active ingredient is salbutamol". Enforcement of this Decision might affect the nominations of the Russian Federation and Ukraine.

Foams TOC Technical Progress

Among the major items covered in the foam sector update are:

- Supply shortages of HFCs are making the phase-out of HCFCs difficult in Europe, particularly for SMEs.
- Emerging technologies (e.g. exotherm management technology) are contributing to the phase-out process in challenging applications both in developed and developing countries.
- Hydrocarbons are likely to be the predominant blowing agent in the medium term.
- Banks of CFCs and HCFCs continue to be accumulated and are currently in excess of one million tons each, confirming the relevance of the end-of-life foam management issues.
- CFC phase-out continues to take place in developing countries according to Montreal Protocol schedule.

Halon TOC Technical Progress

Research and development for halon alternatives continues. International approvals of engineered water mist systems have resulted in a broader use of this alternative. An additional halon 1301 alternative clean agent has been commercialised. It appears that recent actions of several Parties and International Agencies may have resulted in significant changes to the estimated quantities and geographical distribution of halons as provided in the 2002 Assessment Report of the HTOC; this important issue will be carefully evaluated during the next HTOC assessment.

Methyl Bromide TOC Technical Progress

This section on methyl bromide (MB) gives an update of the MB production and consumption; updates information on alternatives for preharvest and postharvest uses, and for quarantine and pre-shipment (QPS) applications, and provides updated information on processes used for capture and destruction of MB from fumigations.

According to available information, MB production in 2002 was about 40,360 metric tonnes, which represents 55% of the historical peak. On the basis of

Ozone Secretariat data available in April 2004, non-QPS production was reduced to about 28,400 tonnes in 2002 while global consumption fell to about 41,240 tonnes in 2001,and to about 30,350 tonnes in 2002.

In non-Article 5(1) regions, controlled MB consumption was reduced from about 56,100 tonnes in 1991 (baseline) to about 23,490 tonnes in 2001, and about 17,500 tonnes in 2002. The preliminary estimate for 2003 indicates consumption of less than 14,800 tonnes, representing an aggregate reduction of approximately 74% since 1991.

In Article 5(1) regions, MB consumption was more than 17,750 tonnes in 2001 and fell to about 12,830 tonnes in 2002.

Most countries have met their reductions in methyl bromide targets under the Montreal Protocol by adoption of alternative fumigants in the soil sector, such as fumigant mixtures containing chloropicrin or by applying consecutive treatments with other fumigants to increase their reliability. Adoption of transition strategies that reduce the rate of MB used per unit area of soil such as by using MB/chloropicrin mixtures and/or allow reduced rates of MB application by adoption of barrier films (e.g. VIF) have also been used widely. Most applications granted Critical Use Exemptions at the EMOP use these transition strategies.

Significant progress has been made in registration of alternatives. Registration is a major constraint on availability of alternatives. In particular, emulsifiable formulations of chloropicrin have been registered recently in Italy, the USA, and Japan. In USA and elsewhere, two new emulsifiable formulations of 1,3-dichloropropene and chloropicrin products, as soil fumigants, and sulfuryl fluoride, as a fumigant for some structures and foodstuffs, have been registered. The consistency of metham sodium has been improved by new application technologies through drip irrigation or spading techniques or by combination with other fumigants (e.g. 1,3-D or Pic).

Heat treatments with steam have long been established as a method of disinfesting soils, including as an MB replacement. Recently hot water treatments have been developed as a MB replacement. Mobile machines using hot air are at an advanced stage of development. These may be applicable to both protected cultivation and small scale broadacre production systems and appear to be more energy efficient than steaming systems for the same energy input and cost.

Adoption of crops grown in substrates continues to be a strong trend in protected, intensive agriculture (e.g. for cut flowers, nursery plants, vegetables) in both Article 5(1) and non-Article 5(1) countries. Although initial investments are normally high, it has been proven that increased productivity and yield, due to higher planting densities being possible but also to better quality, pay off extra costs rapidly.

Alternatives to methyl bromide for durable commodities and structures are classified as physical methods, such as heat or irradiation treatments, or chemical methods such as fumigation with phosphine or sulfuryl fluoride. Both avenues of MB replacement are being researched, adapted and commercially adopted at varying rates the many application areas of stored product protection where MB is currently used.

Some specific non-QPS postharvest and structural applications of MB still present unsolved areas for the replacement of MB as pest control agent. These include control of some fungi in particular historical buildings and wooden artefacts, and the treatment of fresh chestnuts and high moisture fresh dates. It may be necessary to resort to occasional use of fumigation, such as with methyl bromide, for treatment of mills and food processing facilities to a level of pest control required to meet stringent food standards where IPM and heat systems have not proved adequate.

For chemical methods, lack of registration, logistical and accessibility problems, as well as the economic feasibility, still delays adoption of alternatives in some specific areas where technically feasible alternatives are available. For example, although many uses of methyl bromide for durable commodities have been replaced by phosphine, applied either as solid formulations or the more recently registered gas formulations, logistical and/or economic issues caused by longer treatment times have delayed adoption for some specific situations.

For physical methods, heat treatments continue to be identified as an effective candidate to replace methyl bromide for many structural uses to control pests of food processing facilities where rapid overall treatment times are important. Research and commercial adaptation work continues in several countries to refine techniques and test equipment to enable sufficient and even heat distribution, particularly in very large buildings. Cold areas, such as cellars, are difficult to disinfest thoroughly with heat treatments.

Development of methyl bromide alternatives for QPS applications continues to be a difficult process, often coping with diverse situations with small quantities of MB (<1 tonne annually) consumed for particular uses. A variety of technologies are potentially suitable as replacements, but their actual use is constrained by the sensitivity of the treated commodity, cost, effort and time required in gaining the required registrations and approvals, and the need for a very high level of effectiveness against target pests in the supply chain in which the measures are applied. Research progress on development of several alternatives is summarised.

Decisions VII/5(c) and XI/13(7) urge Parties to adopt recovery and recycling technology for MB QPS treatments where technically and economically feasible. Recapture of MB from small scale fumigations in freight containers or fumigation chambers, typically less than $50m^3$ capacity, are carried out in several countries with using charcoal filters to recapture MB after use. Adoption of this technology has been driven by the need to meet local air quality regulations rather than for protection of the ozone layer.

Refrigeration, AC and Heat Pumps TOC Technical Progress

HFCs remain the main alternatives to CFCs and HCFCs in most refrigeration, air conditioning and heat pump sub-sectors. Efforts are continuing to develop non-HFC, zero ODP and low GWP alternatives for the various applications.

In *domestic refrigeration*, HFC-134a and HC-600a continue as the dominant options. In more than 50% of the (approximately 1.5 billion) domestic refrigerators in service the refrigerant in the unit is still CFC-12. Service demand for this refrigerant is normally satisfied with reclaimed or stockpiled material in developed countries, with virgin CFC material in Article 5(1) countries.

In *commercial refrigeration*, HCFC-22 is still very widely used in the United States. The economic growth in China has a major impact on its HCFC-22 use in commercial refrigeration and a significant increase of HCFC-22 production is forecast for Article 5(1) countries within the next 10 years. Some global food and beverage companies are now seeking non-HFC alternative technologies or alternative refrigerants to HFCs, which include HCs and CO_2; the Stirling technology has also been thoroughly tested for refrigerating capacities between 200 and 300 W. A number of developments are underway aimed at optimising secondary loop systems that should be at least as efficient as the reference direct system.

In *large size refrigeration and food processing*, research activities have continued in the United States, Japan and Europe on CO_2 as refrigerant. New industrial designs have been developed --particularly with low charge NH_3 systems and for CO_2 systems. In 2004, new compressor designs were introduced, equipped for CO_2 at discharge pressures of 40 to 60 bar, for the defrosting of evaporators.

In *transport refrigeration*, the volume of refrigerated sea transport on reefer ships and porthole containers is decreasing. , HCFC-22 is the predominant refrigerant, also on fishing fleets world-wide. Concerning system design, new HFC systems are increasingly used for container cooling, while the current systems are usually equipped with scroll compressors.

In *unitary air conditioning*, a recently observed trend in the non-Article 5(1) countries is the conversion of R-407C products to R-410A to obtain both additional size and cost reductions. Rapid growth in air conditioner production in China (primarily ductless splits and window room air conditioners) is significantly increasing China's use of HCFC-22. In the United States, in 2001, approximately 7% of the HCFC-22 usage was replaced by HFC refrigerants; the penetration of non-HCFC technologies is expected to increase significantly between now and 2006 in the USA.

In *new Chiller products*:

7 to 100 kW scroll compressors, using HCFC-22, R-407C, and R-410A, are replacing reciprocating compressors;
140 kW to 700 kW screw compressors are displacing reciprocating compressors;
700 kW to 2275 kW screw compressors are displacing centrifugal compressors.

A 2004 assessment of *existing CFC chillers* indicates that there are 36,800 CFC chillers still in service in the U.S.A. Approximately 30,000 CFC chillers are estimated to remain in operation elsewhere, including in the Article 5(1) countries. These chillers are mainly centrifugal chillers operating with CFC-11 refrigerant. The number of CFC chillers in Article 5(1) countries has been rather stable after the phase-out in manufacturing in the mid-nineties. The installed base of CFC chillers (status 2001-2002) has been recently in all Article 5(1) countries.

Heat pumps for comfort heating have capacities up to 30 kW. Small capacity (10 -30 kW) air-to-water heat pumps are popular in China and Japan, as well as in Italy, Spain, and other southern European countries for residential and light commercial use in combination with fan-coil units. Sales of water-heating heat pumps were small around the world prior to 1995 but have increased steadily since that time. The application of heat pumps in China is increasing quickly, reaching 35,000 units in 2002. Sales increased due to nation-wide housing projects where preference is for hydronic systems.

In *mobile air conditioning (MAC)* all new vehicles with A/C have been equipped with the refrigerant HFC-134a since 1994, at least in non-Article 5(1) countries. By 2008 almost all vehicles then on the road are expected to be using HFC-134a and the global transition from CFC-12 will be complete. Due to concerns about HFC-134a global warming and emissions from MAC systems, vehicle makers and their suppliers are searching for a replacement refrigerant. Since 1998, the leading potential replacement refrigerant has been carbon dioxide (R-744), but more recently, the use of HFC-152a has been proposed and publicly demonstrated in prototype vehicle systems.

In *refrigerant conservation*, significant improvement has been shown. New stationary HFC systems can now be systematically designed and maintained in order to obtain low emission rates. Furthermore, a number of countries have started to implement regulations related to recycling at end of life, which includes recovery of refrigerant.

Some Issues Deferred for Consideration by the CTOC being Established

Annual update on the use and emissions of n-propyl bromide (decision XIII/7, paragraph 3); review of requests for consideration of specific uses against decision X/14 criteria for process agents (Decision XV/7, paragraph 3); and assessment of the development and availability of laboratory and analytical procedures that can be performed without using the controlled substances in Annex A, B and C (Group II and III substances) of the Montreal Protocol (decision XV/8, paragraph 2) will be considered by the new Chemical Technical Options Committee (CTOC) which is being constituted.

Military Uses

Another important sector to be considered is the military uses. The non-Article 5(1) Parties have made significant progress in eliminating ODS from new equipment and meeting the needs of the old equipment through banking and recycling. They have largely avoided essential use nominations for military uses so far. Considering the large quantity of military equipment depending on ODS and the huge cost of modifying the equipment for Non-ODS, future nominations can be avoided only if all the Parties devote enough resources now to meet their ODS demand through banking and recycling. Future essential use exemptions from Article 5(1) Parties can be avoided only if they make similar arrangements before 2010 through assistance from the Multilateral Fund.

Confidentiality Issues

While presenting its essential use nomination, one Party has given some information on the basis of confidentiality and TEAP made arrangements to protect the confidentiality of the information.

TEAP considered more formal arrangements for dealing with the confidentiality issue in future.

TEAP requests that the Meeting of the Parties request all Parties to specify if any part of the information given by them is confidential and to send such information through registered mail services rather then through email since there will be possibility of hacking or accidental distribution through computers.

TEAP also requests to amend the terms of reference of TEAP appropriately to

- prohibit any member from revealing any information given by a party on a confidential basis to anyone outside TEAP/TOC and encourage all members of TEAP/TOC to do their best to protect such information;

- instruct TEAP/TOC to prepare their reports in such a manner not reveal any confidential information;

If TEAP/TOC considers that they cannot prepare a report without revealing the whole or part of the confidential information, they should inform the Party of this fact. In this way the Party has the choice between:

- having TEAP prepare its report without the benefit of the confidential information, or
- relaxing confidentiality of the whole, or part of the information.

Acknowledgement

TEAP wishes to express its sincere appreciation for the many significant contributions of Gary Taylor who is retiring from TEAP. TEAP also expresses its gratitude to the expert members of the Solvents, Coatings, and Adhesives Technical Options Committee and its latest Chairs Ahmad Gaber and Mohinder Malik and to the members of the Aerosol Products Technical Options Committee who have been instrumental in the sector phaseout progress that allows TEAP to further consolidate its Technical Options Committees.

TEAP Organisation

TEAP is looking for qualified nominations for TEAP and all its TOCs. In 2004, TEAP completed the organisation of the "Chemicals Technical Options Committee" (CTOC) to integrate topics including process agents and feedstocks, destruction, laboratory and analytical uses, non-medical aerosol products, solvents, and CTC. In 2004, TEAP will continue to recruit experts on the topics of greatest importance to Parties and will continue its reorganisation to focus on sectors where technologies are still rapidly evolving.

1 Essential Uses

1.1 Essential Use Nominations for Metered Dose Inhalers (MDIs)

1.1.1 Criteria for Review of Essential Use Nominations for MDIs

Decision IV/25 of the 4th Meeting and subsequent Decisions V/18, VII/28, VIII/9, VIII/10, XII/2, XIV/5 and XV/5 have set the criteria and the process for the assessment of essential use nominations for metered dose inhalers (MDIs).

1.1.2 Review of Nominations

The review by the Aerosols, Sterilants, Miscellaneous Uses and CTC Technical Options Committee (ATOC) is conducted as follows.

Three members of the ATOC independently review each nomination, each member preparing an assessment. For nominations where some divergence of views is expressed, additional expertise or information can be sought. Further information can also be requested if nominations are found to be incomplete. The ATOC considers the assessments and prepares a consensus report.

Nominations are assessed against the guidelines for essential use contained within the Handbook on Essential Use Nominations (TEAP, 2001). In 2004, ATOC reviewed essential use nominations and made recommendations according to new criteria established in Decision XV/5.

Concurrent with the evaluation undertaken by the ATOC, copies of all nominations are provided to the Technology and Economic Assessment Panel (TEAP). The TEAP consults with other appropriate individuals or organisations to assist in the review and to prepare the TEAP recommendations for the Parties. TEAP also received submissions from the International Pharmaceutical Aerosol Consortium and the US Stakeholders Group on MDI Transition.

1.1.3 Summary of Parties' Essential Use Nominations for 2004

In 2004, the following Parties nominated essential use production exemptions for MDIs (requested quantities in tonnes).

	European Community	**Poland**	**Ukraine**	**United States**	**Russian Federation (Late submission)**
2005		4.2	53.1		
2006	550	4.2		1900	286
2007		4.2			243
2008		4.2			

1.1.4 Observations on nominations

- Decision XV/5 requests Parties to "*specify, for each nominated use, the active ingredients, the intended market for sale or distribution and the quantity of CFCs required*". One nominating Party, the USA, provided data responsive to this decision. ATOC considered general data issues in relation to Decision XV/5 and comments on these issues (see Chapter 2 of this report).
- Decision XIV/5 requests Parties to provide information by active ingredient, brand/manufacturer, and source. The EC provided this data, but it has not proved useful to ATOC in assessing nominations. For example, based on this historical information, ATOC is not able to assess the appropriateness of many different drugs exported to many different countries world-wide.
- Parties are reminded of paragraph 4 of Decision XV/5 stating that "*no quantity of CFCs for essential uses shall be authorised after the commencement of the Seventeenth Meeting of the Parties if the nominating Party not operating under paragraph 1 of Article 5 has not submitted to the Ozone Secretariat, in time for consideration by the Parties at the twenty-fifth meeting of the Open-ended Working Group, a plan of action regarding the phase-out of the domestic use of CFC-containing metered-dose inhalers where the sole active ingredient is salbutamol*".
- Decision VII/28(a) has requested TEAP to review annually the quantity of controlled substances authorised and to submit a report to the Parties in that year. In each year, the Parties when authorising essential use exemptions have chosen to include this as a condition of authorisation. For example, in 2003, Decision XV/4 authorises essential use exemptions for 2004 and 2005 subject to conditions "*established by the Meeting of the Parties in paragraph 2 of its decision VII/28*". This year, ATOC has recommended a number of exemptions with the suggestion that Parties make approval on the condition of review of quantities in 2005 when requested information has been provided by Parties.
- Technically satisfactory HFC alternatives to CFC MDIs are now available world-wide, particularly for salbutamol.
- Decision VIII/10 states "*that Parties not operating under Article 5 will request companies applying for MDI essential use exemptions to demonstrate ongoing research and development of alternatives to CFC MDIs with all due diligence and/or to collaborate with other companies with such efforts…*". One nominating Party stated that "All companies reformulating their MDIs to be CFC-free submitted information… demonstrating their on-going research and development of alternatives to CFC MDIs. Those companies that will discontinue the sale of their CFC products have indicated that they will not reformulate their MDIs".

ATOC has assumed that a lack of demonstrated research and development is not an absolute prohibition to recommending essential use volumes. Parties may therefore wish to clarify Decision VIII/10.

- The accounting frameworks provide aggregate figures for a Party's stockpile, yet individual companies may hold a substantial and, perhaps, disproportionate amount. Under Decision IV/25, production and consumption of a controlled substance for an essential use should be permitted only if "*the controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances…*". The optimal management of the stockpile within the Party may be dependant on a clear knowledge of the individual holdings by various companies. Therefore, Parties may wish to pay careful attention to the amounts of stockpiled material held by individual companies in their management of the stockpile.
- Parties are reminded that nominations and accompanying accounting frameworks must be submitted according to the timetable set out in Decisions V/18 and VIII/9. This year, a nomination was submitted long after the designated deadline, which adversely affected the evaluation and report writing processes.

1.1.5 Committee Evaluation and Recommendations for 2004 Essential Use Nominations

Quantities are expressed in metric tonnes.

European Community

ODS/Year	Nominated Quantity
2006	550 tonnes

Specific Use: MDIs for asthma and COPD
Recommendation: Recommend exemption but suggests that Parties request an ATOC review of quantities in 2005

Comments: The nomination for 2006 is approximately 30 percent lower than that requested for 2005, continuing a steady downward trend for requests from the EC. The stockpile is being reduced and represents approximately six months supply.

The EC provided a large, detailed accounting of the MDIs produced in the EC and their intended markets (domestic versus detailed identification of exports) in response to Decision XIV/5. However, the nomination did not provide data detailing for what uses the quantities for 2006 are intended nor where such products might be marketed, though there was a general statement that approximately 41 percent would be for domestic use, 33 percent for use in Article 5(1) countries and 12 percent in non-Article 5(1) countries, with 14 percent of unknown destination. The ATOC would like to request such data only for salbutamol CFC MDIs to enable a review of the appropriateness of the volumes recommended for 2006 during ATOC's deliberations in 2005.

Poland

ODS/Year	**Nominated Quantity**
2005	**4.2 tonnes**
2006	**4.2 tonnes**
2007	**4.2 tonnes**
2008	**4.2 tonnes**

Specific Usage: MDIs for asthma
Recommendation: Unable to recommend

Comments: Poland already has an approved exemption for 2005 for 230 tonnes. The nomination submitted this year requests 4.2 metric tonnes in each year of 2005, 2006, 2007 and 2008. The nomination is for one corticosteroid MDI product indicated for asthma.

ATOC is unable to recommend volumes for 2007 and 2008 at this year's meeting. The nomination for 2005 appears to be in addition to the Polish nomination made in 2003 for 2005 and for a different product and a different company. Data submitted to support the nomination for 2005 and 2006 were incomplete and the ATOC is unable to recommend the nomination. ATOC notes that Poland is due to join the European Union in May 2004, and therefore the requested volumes may be addressed within the European Union's essential use processes.

Russian Federation

ODS/Year	**Quantity**
2006	286 tonnes
2007	243 tonnes

Specific Usage: MDIs for asthma and COPD

Recommendation: TEAP: Unable to recommend because nomination was received by UNEP after the submission deadline. ATOC: Exemption recommended but suggest that Parties request an ATOC review of quantities in 2005. Unable to recommend exemption for 2007.

Comments: This nomination was received by the Ozone Secretariat on 24 March 2004, which was seven weeks after the 31 January deadline and one week after the ATOC meeting of 17-19 March 2004.

However, ATOC considered an unofficial copy of the nomination, which was hand delivered to ATOC during its meeting. The CFCs requested are only for the production of salbutamol CFC MDIs. The ATOC suggest that Parties request additional data to enable a review of the appropriateness of the volumes recommended for 2006 during ATOC's deliberations in 2005. Furthermore, ATOC has not received a transition strategy for the Russian Federation. ATOC notes that CFC usage has been increasing while nominated quantities have been declining. ATOC also notes with concern the relatively high proportion of CFCs reportedly released during manufacture. This would result in emissions of over 60 tonnes of CFCs in 2006 and technically could be reduced with improved manufacturing practice. ATOC is unable to recommend volumes for 2007 at this year's meeting. In a letter accompanying the nomination, the Russian Federation declared its intention to cease use of ODS in this sector in 2008 – 2009.

Ukraine

ODS/Year	**Quantity**
2005	53.1 tonnes

Specific Usage: MDIs for asthma/COPD

Recommendation: Recommend exemption

Comments: The nomination is for 53.1 tonnes of CFC for MDIs for asthma/COPD. This clear and comprehensive nomination is for one local manufacturer that produces seven products for treating asthma and COPD. The nomination notes that the company has made progress in reformulating products with HFC-134a. The nomination states that their main barrier to full transition is the need to invest in new manufacturing technology.

The nomination for asthma/COPD for 2005 represents an approximate 25 per cent reduction from the 2004 approved quantity and reflects the introduction of novel HFC-134a based formulations for some products.

ATOC has not received a transition strategy for Ukraine.

United States

ODS/Year	Nominated Quantity
2006	1900 tonnes

Specific Usage: MDIs for asthma and COPD

Recommendation: Recommend exemption but suggests that Parties request an ATOC review of quantities in 2005

Comments: The USA nomination consists of 1900 tonnes, which is unchanged from the nominated quantities for 2005. The USA nomination states that approximately 70 percent of this nomination is for salbutamol (albuterol) and 30 percent for other drug moieties. The nominated quantities are almost exclusively for domestic use. The USA accounting framework states that the stock on hand at the end of 2003 was 1828 tonnes. The USA has reported approximately 400 tonnes of previously unreported pre-1996 stockpiles.

The USA is currently undertaking a public consultation (rule-making) with regard to the essentiality of salbutamol CFC MDIs which is expected to be completed by March 2005. The USA nomination for 2006 does not pre-judge the outcome of this consultation (rule-making) and therefore requests ODS quantities that would allow continued supply regardless of regulatory outcome.

Currently, two technically acceptable alternative HFC MDIs for salbutamol (albuterol) have been available for more than two years in the USA. ATOC believes that there are no technical barriers, as defined under Decision IV/25, to the phase-out of CFC MDIs where salbutamol (albuterol) is the sole moiety.

However, at present, there is inadequate production capacity for salbutamol HFC MDIs to meet patient needs in the USA. One company has publicly indicated that 12-18 months are required to increase production capacity to meet or exceed its share of potential demand. Companies will require advanced notice of cessation of sales of salbutamol CFC MDIs in order to build production capacity to meet future demand for alternatives.

As a consequence of the above, it is uncertain at this time whether salbutamol CFC MDIs will qualify as essential in any or all of 2006 or subsequent years, but it is clear that an approximately three year supply of CFC will be available in 2005 if the quantities recommended here are approved at MOP XVI.

The ATOC discussed the need for the volume of CFCs requested by the USA for salbutamol MDI production in the context of possible patient impact. The nomination for CFC quantities for salbutamol was recommended by ATOC with the strong suggestion to Parties that the quantity should be reviewed by the ATOC in 2005 in light of the outcome of the USA domestic consultation (rule-making) process.

The USA could delay its nomination for 2007 until information is available on the outcome of its consultation (rule-making) and companies supplying CFC and HFC MDIs could adjust their production to complete the phaseout with no surplus CFC that would otherwise need to be destroyed or reallocated to other approved essential uses.

The ATOC also recommends approval of the portion of the nomination for non-salbutamol CFC MDIs.

1.2 Update on Essential Use Exemption for Methyl Chloroform Used in Aerospace Applications

Brief History of Methyl Chloroform Solid Rocket Motor Essential Use Exemption

At the Sixth and Seventh Meetings of the Parties (Decision VI, Nairobi, 1994 and Decision VII/28, Vienna, 1995) Parties granted an initial Essential Use Exemption (EUE) to the United States for the use of methyl chloroform for aerospace applications including the manufacture and assembly of solid rocket motors used on the Space Shuttle and Titan. One important reason that the EUE was granted is that methyl chloroform is chemically unstable and could not, at that time, be reliably stockpiled for critical uses in aerospace applications where extraordinarily high technical standards must be achieved.

At the Tenth Meeting of the Parties (Decision X/6, Cairo, 1998) Parties agreed that the remaining quantity of methyl chloroform, authorised for the United States at previous meetings, be made available for use in manufacturing solid rocket motors until such time as the allowance is depleted, or until such time as safe alternatives are implemented for remaining essential uses.

NASA/Thiokol estimates that the remaining quantity of methyl chloroform granted under the existing EUE is sufficient for anticipated Shuttle flights.

Progress on Reducing Use and Emissions

There has been significant progress in reducing and eliminating the use and emissions of methyl chloroform, but alternatives and substitutes are not yet available for some critical applications. Since 1989, methyl chloroform use has been reduced from 635 tonnes per year to approximately 16 tonnes per year in 2002 and 2003, with likely annual use at this level for the near future. Actual future use depends on the number of Shuttle flights, the inventory of rocket motors, and adjustments in manufacturing procedures to maintain safety and to upgrade technology. For example, in 2004 ATK Thiokol will use approximately 272 kilograms (210 litres) of methyl chloroform to clean production tooling surfaces and facilities between batches of the unique fuels used for Booster Separation Motors and Space Shuttle Solid Rocket Motors.

The methyl chloroform used in these applications ensures that production remains consistent and that processing variables are minimised, if not eliminated. Booster Separation Motors components are a critical and integral part of the Space Shuttle launch system, providing the Solid Rocket Booster separation capability during ascent.

Accounting Framework and Methyl Chloroform Inventory

Until recently, Thiokol/NASA used stockpiled methyl chloroform for uses not requiring the highest levels of purity and purchased small batches of freshly-manufactured methyl chloroform for the most critical applications, where absolute purity is essential. This year, Thiokol/NASA will purchase the remaining 102 tonnes of methyl chloroform granted under the EUE authorisation. This methyl chloroform will be placed in a sophisticated leak-tight storage system designed to maintain chemical purity. NASA has re-confirmed that it will destroy any methyl chloroform manufactured under terms of the EUE that is unneeded or unusable.

TEAP Recommends Continued EUE

TEAP reaffirms its recommendation for the already-granted EUE and concurs with the NASA/Thiokol technical assessment confirming the importance of the continuing use of methyl chloroform for their critical aerospace applications.

2 ATOC Response to Decision XV/5(7) and Update of the Handbook on Essential Use Nominations

2.1 Response to Decision XV/5(7): The potential impacts of the phase-out of CFCs in non-Article 5(1) countries on the availability of affordable inhaled therapy in Article 5(1) countries

2.1.1 Introduction

In Decision XV/5(7) Parties requested "*the Technology and Economic Assessment Panel to report, in time for the twenty-fourth meeting of the Open-ended Working Group, on the potential impacts of the phase-out of CFCs in Parties not operating under paragraph 1 of Article 5 on the availability of affordable inhaled therapy in Parties operating under paragraph 1 of Article 5.*"

2.1.2 CFC transition in non-Article 5(1) countries

Over the past 15 years, many of the pharmaceutical companies that manufacture metered dose inhalers in non-Article 5(1) countries for the treatment of asthma and COPD, have been reformulating these products using non-ozone depleting propellants or alternative, non-ODS technologies. This process has involved reformulating products, re-engineering the manufacturing infrastructure, and reconfiguring ingredient and component supply.

Both pharmaceutical manufacturers and their suppliers have had to manage the transition between the CFC and non-CFC-containing products carefully in order to ensure continuity of supply and thus patient safety. The components of MDIs have had to be substantially changed to accommodate HFC propellants (e.g., cans, valves, elastomers). The components need to be considered individually in these discussions.

2.1.3 MDI supply scenarios in Article 5(1) countries

In order to evaluate the potential effects and risks posed by the above developments it is helpful to understand the current supply scenarios in different Article 5(1) countries and how these may or may not be affected by transition. Every Article 5(1) country that has inhaled asthma therapies imports from multinationals, but in addition, some have local production either by local companies or multinationals. The following bullets describe the elements of the supply of MDIs in Article 5(1) countries.

- *Importation* – For the vast majority of Article 5(1) countries, respiratory treatments are imported from another country, often from Europe. These products are manufactures by multinational pharmaceutical companies: e.g., GSK, 3M, IVAX, Chiesi, Boehringer Ingelheim.

- *Local manufacture by a local company* – Also, in some Article 5(1) countries CFC MDIs are made in the country of use: e.g., India, Pakistan, Egypt, Bangladesh, Croatia, Argentina, Cuba, Brazil, South Africa, China, and Mexico.
- *Local manufacture by subsidiary of multinational* – In some Article 5(1) countries the same CFC and CFC-free products manufactured in non-Article 5(1) Parties are produced by the subsidiaries of multinational pharmaceutical companies in Article 5(1) countries: e.g., India, Pakistan, Egypt, China, and Turkey.

These are discussed in more detail below.

2.1.4 Factors Affecting Importation

The introduction of an HFC alternative product to replace a CFC-containing product is subject to the usual regulatory processes for approval of pharmaceutical products. In developing markets that do not have their own regulatory approval system importation will occur through one of the larger markets in the region which is regulatory active e.g. many Southern Africa countries will use approval in South Africa to trigger their own product availability. Similar processes occur in the Caribbean and Central America.

Increased cost of HFC MDIs has been perceived as a problem that may hinder the transition in Article 5(1) countries. In practice, however, this has not been the case in most countries – HFC products have been introduced at price parity to the CFC version. In many Article 5(1) and non-Article 5(1) countries, importation requires an import licence and products can be subject to import duties. These duties can be set high to protect local manufacturers, however, they apply equally to CFC and HFC MDIs.

In some countries, the policy is to revoke import licences for inhaled products when a local supply of a generic product containing the same drug becomes available. This would not only block further import of CFC products but also new HFC products. The transition could be facilitated if a government treats differently imported HFC products from CFC products.

2.1.5 Factors Affecting Local MDI Manufacturers

The market share of locally manufactured MDIs varies where such manufacturing occurs. For example, in China locally manufactured MDIs account for a high proportion of the total market, but in Brazil local production only accounts for a small proportion.

2.1.5.1 Ingredient and Component Supply

The MDI is a complex device. A particular inhaled drug need not change in the transition, but other MDI components, such as valves, cans, excipients and elastomers, often must be changed to successfully reformulate. Ingredients (drug substance, excipients and propellant) can often be sourced locally or from another country. Components (e.g., valves and cans) can be imported from Europe, the USA and some Article 5(1) countries. Where importation from Europe or the USA is an important source of these components, there is a possibility that a reduction in the use of cans and valves in non-Article 5(1) countries could potentially lead to a shortage or price increase of these components for some Article 5(1) countries. This would be particularly relevant for valves, which have a short shelf-life (validated for only 12 months). It will be important for manufacturers relying on imported components to manage their supply chain actively. For example, if a change in valve is required due to supply interruption, this may require the revised product to undergo testing of its performance characteristics and possibly regulatory scrutiny.

2.1.5.2 Access to Alternative Technologies

As CFC MDI use declines in non-Article 5(1) countries, patients in Article 5(1) countries will have access to a number of alternative inhalation devices. Patents for pharmaceutical technologies have been filed in many Article 5(1) countries. In countries where no patents exist for HFC technologies, intellectual property is not a barrier to local manufacture. However, even if no barriers exist, there may be constraints on access to specific components e.g. cans and valves, due to exclusive supply agreements between innovator companies and component suppliers. This may necessitate additional development work in the local market or exploration of licensing arrangements. Regardless of intellectual property/licensing agreements, the capital cost of establishing an HFC production line may be a barrier to local manufacture but not necessarily a barrier to transition.

Also, as a direct result of the phase-out of CFC MDIs, there has been a significant increase in the variety and prevalence of dry powder technologies. Capsule-based unit dose and reservoir powder products are perhaps the simplest and most established technologies. Patents do not restrict use of many of these technologies. Moreover, multiple products are available for many molecules routinely used for treating asthma and COPD.

As another option, there are a few companies whose business model is to develop and license products and/or technology. Establishing a licence with such a company for local manufacture may provide access to patented products/technologies. These agreements have a cost that will be either "one-off" milestone based or royalty based on product sales.

2.1.6 Factors affecting local subsidiaries of multinational companies

2.1.6.1 Ingredient and Component Supply

Components are often sourced on a global basis for products sold by multi-national companies. Therefore, factors that affect the global supply of these components will affect local manufacture by multinational companies, just as they affect production world-wide.

2.1.6.2 Access to Alternative Technologies

In recent years, the pharmaceutical industry has undertaken significant cost control measures in manufacturing. This has included a rationalisation and consolidation of manufacturing facilities to fewer sites. Local production by multinationals has therefore decreased in prevalence but access to alternative products will be available through importation by these same multinational companies.

2.1.7 Pricing Issues

Pricing and reimbursement of medical treatments is highly nation specific and drawing general conclusions can be difficult.

Some general observations on price may be made:

- Price parity is generally maintained when imported HFC products replace imported CFC products.
- Price parity is also generally maintained when imported products replace CFC MDIs previously produced locally by the same multinational company.
- Pricing differentials that exist between products are driven by the branded versus generic nature of the products not by their HFC or CFC designation.
- Price can be significantly increased by import duties. However, these duties do not generally discriminate between HFC and CFC products.

2.1.8 Conclusions

The phase-out of CFC-containing MDIs in non-Article 5(1) countries need not have a significant impact on treatment availability in Article 5(1) countries.

For local Article 5(1) country manufacturers of CFC MDIs, there is a need for the transition to be managed actively to ensure that access to components that are required to manufacture CFC MDIs is uninterrupted.

Capital cost may be a barrier to conversion to non-CFC technologies for some local manufacturers, but not necessarily to overall transition within an Article 5(1) country.

2.2 Update of the Handbook on Essential Use Nominations

Decision XV/5(9) requests the TEAP to "*modify the Handbook on Essential Use Nominations to reflect the present decision.*" This request intends for the TEAP to incorporate into the Handbook guidance for essential use nominations to provide the level of detail required under Decision XV/5.

In particular, Decision XV/5(2) states that Parties "*when submitting their nominations for essential use exemptions for CFCs for metered-dose inhalers, specify for each nominated use, the active ingredients, the intended markets for sale and distribution and the quantity of CFCs required.*" This level of detail, particularly regarding the intended markets for sale and distribution, represents a tremendous burden for the nominating Party to collect and may be difficult for the ATOC to analyse accurately. One Party, in its 2006 nomination, notes: "One of the difficulties in forecasting CFC quantities for 2006 is gaining an accurate understanding of the rate of transition to CFC-free MDIs in the EC's export markets, which includes both Article 5(1) and non-Article 5(1) Parties."

The complexities of the issues include the following:

- Complex pharmaceutical supply chains and distribution networks render any such data unreliable, no matter how carefully accumulated and submitted. For instance, parallel importation and internet drug sales make it very difficult for a manufacturer to report to the authorities of the nominating Party details of "*markets for sale and distribution*," due to the extent of these sales and importation that are out of the control of the manufacturer.
- The data are based on past and present patterns, but must project future use (e.g., two year's hence). As noted by the nominating Party quoted above, this presents difficulties for the reliability of such details, as they represent projections on matters for which the nominating Party may have little information (e.g., timing of expected transition in an export market).
- Providing this information to the nominating Party's authorities and then to the Ozone Secretariat as a part of the essential use nomination presents difficulties with commercial confidential information and proprietary considerations.
- While such data may be unreliable for essential use assessment purposes, they may be useful to individual Parties in constructing their nominations and managing internally their transition.

- Finally, at this time, general information on intended markets and precise volumes of domestic use versus exportation would be most useful in assessing the essential use nominations, and primarily for salbutamol.

Due to these data issues and limitations, the ATOC was unable, at this time, to implement the instructions of the Parties regarding Decision XV/5(9). The ATOC will revisit the issues at its 2005 meeting when ATOC will report back on what information may be most useful to Parties in deciding the quantities and timelines for the final phase-out of CFC based MDIs.

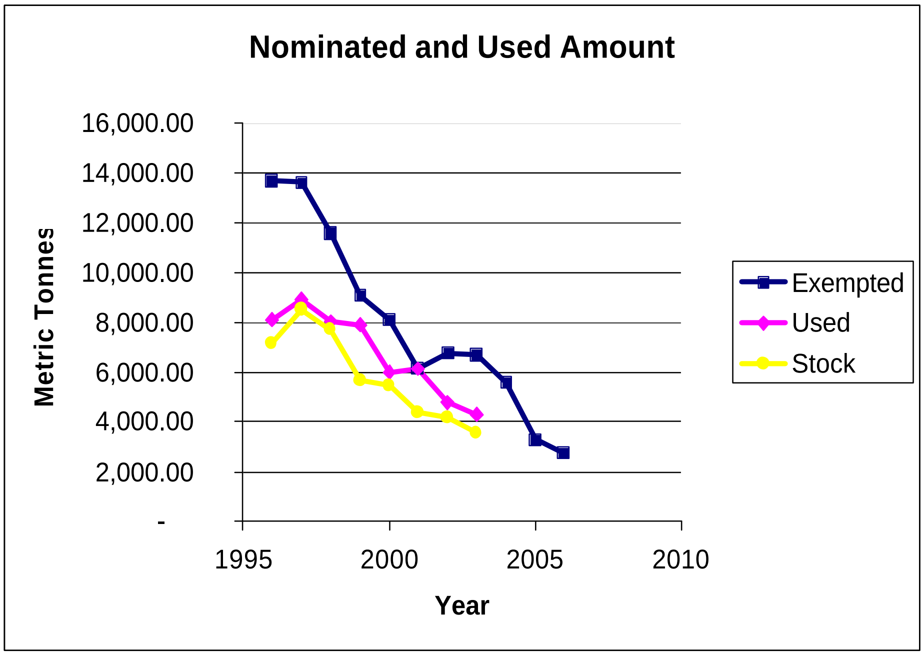
3 Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee (ATOC) Progress Report

ATOC met in 2004 in Paris --at Atofina's headquarters-- and concentrated solely on the assessment of Essential Use Nominations for MDIs and their phase-out.

3.1 Trends in CFC consumption for MDI production

The downward trend in CFC use for MDIs reported in last year's update continues. Figure 3-1 below illustrates this trend. These numbers do not reflect the use of CFC for the production of MDIs for asthma and COPD in Article 5(1) countries. Figures after 2002 include amounts exempted under nominations made by the Russian Federation and Ukraine.

Figure 3-1: Relevant quantities regarding the use of CFCs for the production of MDIs



For the year 2006 essential use amounts requested (but not yet approved) total 2,740.2 tonnes, which represents a decrease of over 80% since essential use exemptions started in 1996. In the non-Article 5(1) countries use of CFCs in 2003 to manufacture MDIs for asthma and COPD has fallen by about 500 tonnes compared to 2002. Hungary has reported that it has ceased making essential use nominations for CFCs for MDIs.

It should be noted that in some cases significant consumption of CFCs is for manufacture of MDIs for export. Phase-out of CFC MDIs for export will either occur because of multinational decisions, or because of transition policies in importing countries.

Data submitted to the ATOC in accounting frameworks continues to show reductions in stockpile quantities that parallel declines in use. Currently, the accounting frameworks provide aggregate figures for a Party's stockpile, yet individual companies may hold a substantial and, perhaps, disproportionate amount. The optimal management of the stockpile within the Party may be dependant on a clear knowledge of the individual holdings by various companies. Therefore, Parties may wish to pay careful attention to the amounts of stockpiled material held by individual companies in their management of the stockpile.

3.2 Transition to alternatives to CFC MDIs

There are more than 30 countries where there are two or more salbutamol (short acting beta-agonist) HFC MDIs marketed and the previously noted increase in the introduction and acceptance of multi-dose powder inhalers has continued. However, it is clear that the development of HFC MDIs, their registration and launch into a market cannot alone lead to a full uptake in the market without additional regulatory action.

Salbutamol CFC MDIs is now declared non-essential in twelve member states of the EU and two additional European countries. In the EU, alternative products continue to be introduced for many drugs. Notably, a novel non-propellant multi-dose delivery system has been introduced in Germany. The USA is undertaking public consultations with regard to the essentiality of salbutamol CFC MDIs that is expected to be completed in March 2005. In the USA beclomethasone and salmeterol are now only available as non-CFC products.

3.3 Transition Strategies

ATOC notes that no additional countries have submitted transition strategies in the last twenty-four months. Parties are reminded of paragraph 4 of Decision XV/5 stating that "*no quantity of CFCs for essential uses shall be authorised after the commencement of the Seventeenth Meeting of the Parties if the nominating Party not operating under paragraph 1 of Article 5 has not submitted to the Ozone Secretariat, in time for consideration by the Parties at the twenty-fifth meeting of the Open-ended Working Group, a plan of action regarding the phase-out of the domestic use of CFC-containing metered-dose inhalers where the sole active ingredient is salbutamol*". Hungary has reported progress with its phase-out and the cessation of essential use nominations for CFCs for MDIs. Canada has announced that from 2005 all MDIs sold in Canada will be CFC-free as implemented through regulation.

Pharmaceutical companies in Japan have ceased the production of CFC MDIs for the domestic market.

3.4 Article 5(1) countries and CEIT

As in much of the world, prevalence of asthma and COPD in Article 5(1) countries and CEIT continues to rise, leading to greater demand for treatment. An increasing proportion of this treatment is being met with inhaled therapy. This has resulted in a greater use of CFC MDIs.

As mentioned in last year's report, issues surrounding CFC MDIs in CEIT are complex. The ATOC does not have sufficient data for many of these countries to make a full and reasonable assessment of the state of transition, nor to make reasonable technical recommendations on how to assure an effective transition. ATOC notes that at least four CEITs are known to have been producing CFC MDIs, but it is possible that other CEIT may be locally producing. It is still true that only two of seventeen CEIT have submitted transition strategies to the Secretariat. This is expected to change as some countries join the EU in 2004 and as others respond to Decision XV/5.

4 Foams Technical Options Committee (FTOC) Progress Report

4.1 General

This update is the first foam sector review published since the 2002 Report of the Flexible and Rigid Foams Technical Options Committee, issued in May 2003. It highlights changes in technology that have occurred in the last year. The key conclusions from this update report are as follows:

- The use of HCFCs in the foam sector in Europe was phased out at the end of 2003. However, supply shortages of HFC-365mfc are making the transition in 2004 particularly difficult for SMEs.
- HCFC-141b use in foams was phased-out in Japan at the end of 2003.
- The final phase-out of HCFC-141b use in polyurethane foam in the United States is expected by year-end (2004).
- Developing countries are continuing to phase-out use of CFCs in the foam sector through the implementation of National and Sector Plans.
- Liquid CO_2 (LCD), variable pressure technologies and, to a growing extent, exotherm management technologies (EMT) are all contributing to the phase-out process in the challenging flexible slabstock sector.
- The use of HFCs in rigid insulating foam is set to be constrained almost exclusively to Europe, North America and Japan. This reflects the climatic requirements of these regions and the continued availability of HCFCs in other parts of the world.
- Hydrocarbons continue to make progress in many high volume sectors and are likely to be the predominant blowing agent (50% plus share) within the next 5-10 years.
- The sustained availability of both CFCs and HCFCs at lower overall cost than their respective substitutes continues to hinder phase-out.
- Demand for foamed products is expected to grow at 5% (or greater) per year for the foreseeable future, driven by increased insulation requirements and greater use of foams because of their thermal efficiency and longevity.
- Banks of CFCs and HCFCs in installed rigid foams are currently estimated to be in excess of one million tonnes each.

4.2 Technology Status

The following table illustrates the main substitute technologies in the polyurethane, extruded polystyrene and phenolic foam sectors.

FOAMS TOC UPDATE REPORT 2004 *MAIN* TECHNICAL OPTIONS TABLE

SECTOR	DEVELOPED COUNTRIES	DEVELOPING COUNTRIES		COMMENTS
	CURRENT/FUTURE	CURRENT	FUTURE	
POLYURETHANE RIGID				
Domestic refrigerators and freezers	HCs (cyclopentane & cyclo/iso pentane blends), HFCs	Residual CFC-11, HCFC-141b & HCs	HCFC-141b, HFCs & HCs	HFC-134a & HFC-245fa mainly in USA
Other appliances	HCs, HFCs	Residual CFC-11, HCFC-141b & HCs	HCFC-141b & HCs	
Transport & reefers	HCs, HFCs	HCFC-141b	HCFC-141b & HCs	Potentially HFCs but no known use
Boardstock	Mainly HCs, minor use of HFCs	No known production Art 5-1	NA	HFC for stringent product fire standards.
Panels – continuous	Mainly HCs, some HFCs	Residual CFC-11, HCFC-141b & HCs	HCFC-141b & HCs	HFC for stringent product fire standards
Panels discontinuous	Residual HCFC-141b, HFCs, some HC	Residual CFC-11, HCFC-141b	HCFC-141b & HFCs	HFCs, not HFCs, for SMEs
Spray	Residual HCFC-141b, HFCs, CO_2, (HC)	Residual CFC-11, HCFC-141b	HCFC-141b & HFCs	Qualification of HCs for spray foam applications is highly region-specific
Blocks	Residual HCFC-141b, HCs, HFCs,	Residual CFC-11, HCFC-141b	HCFC-141b & HFCs	HC use increasing
Pipe-in-pipe	Mainly HCs, residual HCFC-141b	Mainly HCFC-141b	HCFC-141b & HCs	Cyclopentane is main HC
One Component Foam	Mainly HCs, some HFCs	Minimal use in Art 5-1	Mainly HCs, some HFCs	HC use driven by cost
POLYURETHANE FLEXIBLE				
Slabstock & block-foam	LCD, (EMT)	Methylene chloride, (LCD)	MC, LCD, (EMT)	MC is less prefered because of perceived occupational health risks
Moulded	Mainly CO_2 (water)	Residual CFC-11 (?), mainly CO_2 (water)	Mainly CO_2 (water)	CO_2 (water) is industry standard
Integral Skin	CO_2 (water), HFCs	Residual CFC-11 (?), CO_2 (water), some HCFCs	CO_2 (water), some HCFCs	
PHENOLIC				
Board & block	Mainly HFCs, some HCs	HCFC-141b	HCs	HFCs are used to retain fire performance
EXTRUDED POLYSTYRENE				
Sheet	HCs	Mainly HCs		Some safety issues in Art 5-1 countries
Boardstock	HCFC-142b, HFC-134a, HFC-152a, CO_2, CO_2/ethanol, (HCs)	Mainly HCFC-142b	HCFC-142b, HFC-134a, CO_2	HCFC-142b use in North America until 2010. Final choice is end-product specific
POLYOLEFIN				
Sheets, planks & tubes	HCs (iso-butane & LPG)	Mainly HCs		Some safety issues in Art 5-1 countries

4.3 Regional Developments

4.3.1 Developed Countries

The phase-out of HCFC use in polyurethane rigid foam is continuing apace, with Europe completing its phase-out programme under EC 2037/2000 on time. HCFC-141b phase-out has been completed in Japan and is also expected to be complete in the United States by the end of 2004. The focus on HCFC-141b was driven by its higher ozone depletion potential and the use of HCFC-142b and HCFC-22 is likely to continue until 2010 in the US, primarily because of the challenge associated with transition in the extruded polystyrene (XPS) sector.

Countries such as Canada and Australia are conducting phase-out under the Montreal Protocol control schedule provisions. However, voluntary agreements are being struck wherever possible to encourage earlier phase-out.

The potential for continued trade in HCFC-containing PU systems remains real, since consumption is recorded within the country of origin. Some regions (e.g. the European Union) have resisted this possibility through the adoption of use bans within its legislation. This model is being actively considered by the United States under SNAP for HCFC-141b. However, other developed countries remain vulnerable to the possibility of imports from Article 5(1) countries, unless use-controls or trade measures are introduced.

The use of hydrocarbon technologies continues to grow with boardstock and appliance manufacturers continuing to favour this option, and penetration has extended to sandwich panels, blocks, pipe-in-pipe and even reefers. Work also continues on hydrocarbon-based spray foam for the North American market and some early commercialisation has taken place. However, HFC-based systems continue to predominate in the United States for appliance and spray foam applications (specifically HFC-245fa because of licensing issues). In Europe and Japan, there is very little consideration of hydrocarbon-based technologies because of safety concerns and any non-HFC interest is focused on CO_2 (water) systems, although these are less competitive because of higher densities and poorer thermal efficiency. One company in Japan is also looking at super-critical CO_2 as a spray foam option, but the economics are equally unattractive at present.

In the United States Ecomate™ has emerged as a blowing agent of interest. The product is based essentially on methyl formate but is also understood to contain some proprietary components which add to its performance. No commercial sales are yet reported, but there is considerable interest in the commercial appliance and panel sectors among others, mainly because of reduced flammability risk when compared with other hydrocarbons.

Significant uptake of HFCs has begun in both North America and Europe to coincide with HCFC phase-out. The trend also coincides with the publication of the draft EU Regulation for fluorinated gases which provides some constraints on the use of HFCs in one component foams.

4.3.2 Developing Countries

CFC phase-out in developing countries is reported to be progressing reasonably well. India, for example, reports that 75% phase-out has now been achieved. With residual uses now being targeted within National and Foam Sector Plans, it is expected that full phase-out will be achieved by 2008 in most cases.

Although hydrocarbons have been widely adopted in major appliance uses, the focus on CFC phase-out has led to the widespread uptake of HCFCs in foams destined for commercial refrigeration applications and other smaller use sectors. As indicated in the Task Force Report on HCFCs, this usage is expected to grow to 40,000-50,000 tonnes in the period to 2015, driven largely by the expected growth in China.

There is expected to be very little use of HFCs for local foam markets in developing countries for the foreseeable future. This trend is driven by the fact that the costs of HFC-based systems (even when combined with cheaper co-blowing agents) will always be less competitive than their HCFC-based counter-parts. Since these will be available through to 2040 (albeit capped from 2015), there seems little likelihood that HFC use will be significant in future unless the HCFC supply situation in developing countries changes.

On the flexible foam side, there has been a continuing challenge to find blowing agent replacements in the continuous slabstock sector, particularly for the smaller manufacturers, and in the discontinuous slabstock (box) sector for countries reluctant to adopt the use of methylene chloride. The latter continues to be a cause of concern for some on the basis of occupational health risks (see 2002 FTOC Assessment Report, Appendix 2, for full details). The two main alternative technology choices to date have been liquid CO_2 (LCD) and variable pressure technology (VPT). Although in the early stages there were high hopes for LCD, the technical challenges have proved too great in some regions, particularly in the Middle East & North Africa where specific density/hardness requirements have proved elusive. The use of LCD has also been problematic for the smaller foam manufacturers. Although VPT is potentially a viable alternative, the costs associated with such an engineered approach have been a considerable barrier. In more recent times, the emergence of exotherm management technology (EMT) has provided a possible way forward. To date, around thirty companies have trialled the technology with eight successfully commercialising it and twenty-two further companies making preparations to do so. This does not yet represent conclusive evidence of a widely applicable process, but does offer encouragement for those not wanting to use methylene chloride.

4.4 Blowing Agent Availability

4.4.1 Liquid HFC availability

As foam manufacturers have reviewed their requirements for HFCs and sought ways of reducing reliance on these blowing agents for cost and environmental reasons, the demand for liquid HFCs has steadily reduced. It is now estimated that the total demand for HFCs on foams in 2015 will reach about 75,000 tonnes. This compares with a previous estimate made at the 1999 Petten Conference of 115,000 tonnes by 2010. These figures include substantive use of HFC-134a and, to a lesser degree, HFC-152a for the XPS industry. Accordingly, the underlying demand for liquid HFCs (HFC-245fa, HFC-365mfc and HFC-227ea) is even lower.

The net effect has been to reduce demand for plant investment. Three major plants have resulted – two for HFC-245fa (one in the USA and the other in Japan) and one for HFC-365mfc (based in Europe). This has created high reliance on these plants for transition strategies – a reliance which has come under pressure in recent months.

In the United States, there has been reluctance to move towards technologies in which only one supplier exists. Although security of supply has been one consideration, the other has been the lack of a competitive component in the supply-side offer. In Europe, similar concerns have existed, but have been recently compounded by actual supply-side shortages for HFC-365mfc. It appears that the capacity limit for an important intermediate may be the prime source of the constraint and that this shortage may last through 2004. One of the problems in predicting demand for HFCs 'post-2003' was that of estimating the proportion of foam manufacturers which would be switching from HCFC usage at 31 December 2003 rather than 31 December 2002. This was partly as a consequence of the initial uncertainties surrounding the PIR definition within the EU Regulation (2037/2000). Whatever the explanation, the major impact of shortage is on those companies with limited product portfolio, most notably SMEs. The European Commission is therefore in the process of reviewing this impact to establish whether any form of relief is justified under the Management Committee provisions of EC2037/2000.

4.4.2 On-going availability of HCFCs for developing countries

This issue has been reviewed at length within the TEAP Task Force Report on HCFCs published in May 2003. The conclusions were that some mothballing of HCFC-141b plants may be appropriate in developed countries to avoid later significant capacity investment in developing countries at a later date. Although the use of HCFC-142b for XPS is growing in China, it is expected that the majority of future use will be met from existing plants; bearing in mind that co-production will continue for the manufacture of engineering polymers (PVDF).

4.5 End-of-life Issues

4.5.1 Appliances

The implementation of blowing agent recovery in Europe has continued under the provisions of Article 16 of EC 2037/2000. However, the level of compliance with these provisions is understood to vary significantly between Member States. A study is being undertaken by the European Commission to investigate the situation further. In Japan, an amendment to the Law for Recycling of Special Kinds of Home Appliances has recently been passed (effective 1st April 2004) mandating the recovery of all fluorocarbon blowing agents at end-of-life. This change formalises previous voluntary commitments by several manufacturers.

The situation in the United States is still under review. Although it has now been established that upwards of 90% of domestic refrigerators pass through commercial car shredders for metal recovery/recycling, it is still not clear precisely what this means in terms of blowing agent releases at this stage. Further co-operative research between industry and government is on going to establish the situation more accurately.

4.5.2 Buildings

With respect to buildings, the JTCCM (Japanese Technical Center for Construction Materials) Project in Japan continues. The third year report will be published shortly, including:

- Revised assessments of the banks of CFCs and HCFCs in building insulation foams;
- Estimated emissions of CFCs and HCFCs from building insulation foams
- Emission factors for each life cycle stage;
- Survey on the present status of separation, recovery and destruction of CFCs and HCFCs in building insulation foams;
- JIS draft standard on a method for determining the content of fluorocarbon in building insulation foams.

One reason for revision of the historic bank estimates in Japan results from progress in optimising the test method used to determine blowing agent retained in foams. This work is being incorporated into the draft JIS standard.

The fourth and final year of the project will focus on identifying the most technically feasible and economically viable means of recovering blowing agents from these foams. This work will feed into the latest TEAP review of End-of-Life Issues for Foams which is expected to report in April 2005.

In addition, the development of emission scenarios within the IPCC/TEAP Special Report on HFCs and alternatives has led to a considerable amount of further work in determining emissions functions, most notably in the XPS sector. Current indications are that this work will support the reduction of emissions functions for XPS foams, with the consequent effect on future emission projections. However, this will also place further focus on the historical development of CFC and HCFC banks which are already estimated to be above 1 million tonnes each using current assumptions.

5 Halons Technical Options Committee (HTOC) Progress Report

As requested by Decision XV/11 “Plan of action to modify regulatory requirements that mandate the use of halons on new airframes”, which reads

- Acknowledging that potential alternatives to the use of halons exist to provide the necessary fire protection for both engine nacelles and cargo bays of commercial aircraft,
- Concerned to note that new airframes are still being designed and certified with halons as the required fire extinguishant owing to regulatory requirements,
- Acknowledging that airframe certification agencies and airframe manufacturers will wish to participate in a joint effort to allow the certification of alternatives to halon on new airframes,

to authorise representatives of the Ozone Secretariat and the Technology and Economic Assessment Panel to engage in discussions with the relevant International Civil Aviation Organization bodies in the development of a timely plan of action to enable consideration of the possibility that modifying the regulatory requirements that mandate the use of halons on new airframes may be feasible without compromising the health and safety of airline passengers, and to report thereon to the sixteenth Meeting of the Parties.

UNEP’s Ozone Secretariat arranged a meeting with the ICAO in March 2004. The HTOC plans to assemble further background information for ICAO as requested during this meeting, and additionally plans to meet with IATA this year. An interim report to the 16th Meeting of the Parties will be provided, as requested by the Decision cited above.

Research and development for halon alternatives continues. International approvals of engineered water mist systems for the protection of spaces up to 500 m^3 have resulted in a broader use of this alternative. An additional halon 1301 alternative clean agent has been commercialised and has been included in the latest revision of the National Fire Protection Association (NFPA-USA) standard. It is anticipated that this agent will also be included in the next revision of the applicable International Standards Organization (ISO) standard.

The HTOC further reports that as a result of evaluations of the existing installed base and emissions of halons for the IPCC/TEAP Special Report on “Safeguarding the Ozone Layer and the Global Climate System, Issues related to hydrofluorcarbons and perfluorocarbons,” it appears that recent actions of several Parties and International agencies may have resulted in significant changes to the estimated quantities and geographical distribution of halons as provided in the 2002 Assessment Report of the HTOC. Mindful that existing stocks of halons are presently the sole source of supply available to meet the current and future needs of critical applications for which alternatives are not yet available, this important issue will be carefully evaluated during the next assessment by the HTOC.

6 Methyl Bromide Technical Options Committee (MBTOC) Progress Report

This section on methyl bromide (MB) gives an update of the MB production and consumption; updates information on alternatives for preharvest and postharvest uses, and for quarantine and pre-shipment (QPS) applications, and provides updated information on processes used for capture and destruction of MB from fumigations. Some additional information on alternatives is given that was published prior to the MBTOC 2002 Assessment Report where that information is useful to supplement that in the report.

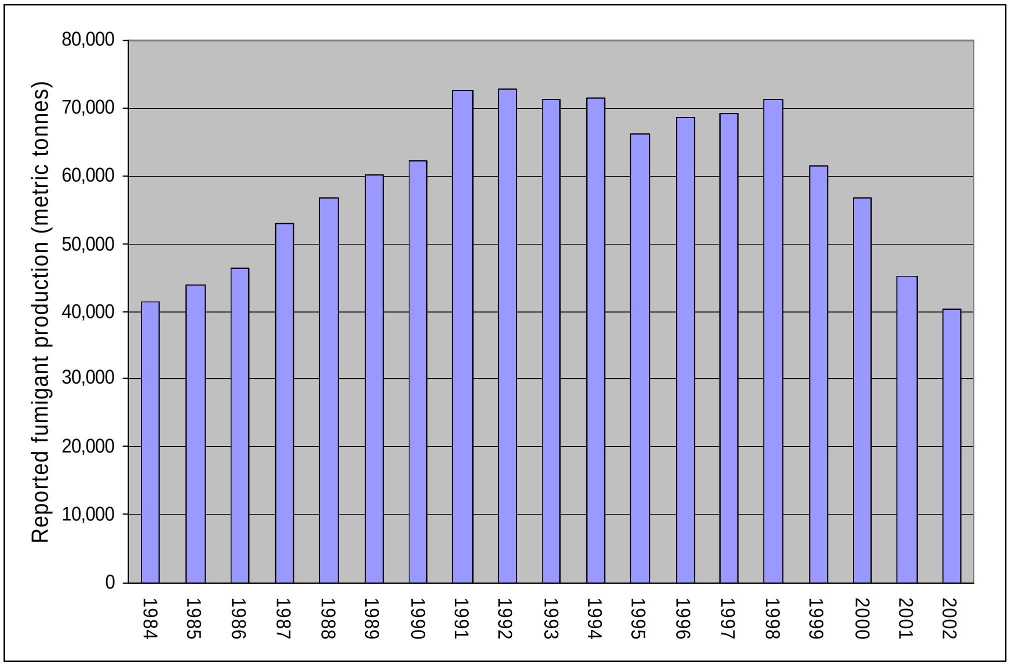
Information is also given on progress in registration of various alternatives as requested in Decision Ex. I/4(9j). This decision requests TEAP to "report annually on the status of registration of alternatives and substitutes for methyl bromide, with particular emphasis on possible regulatory actions that will increase or decrease dependence on methyl bromide" Specific comment is given in Sections 1.2.1, 1.3.1.1, 1.3.1.4, 1.3.1.6 and 1.4.1.3 below.

6.1 MB production and consumption - update

6.1.1 Production trends

Estimates of global MB production for all fumigant uses (QPS and non-QPS, excluding feedstock) are shown in Figure 6-1. According to available information, fumigant production in 2002 was about 40,360 metric tonnes, which represents 55% of the historical peak (about 73,000 tonnes).

Figure 6-1: Trends in global reported production of MB for fumigant use – QPS and non-QPS, 1984 - 2002 (metric tonnes)



Sources: 1984-1999 data MBTOC 2002 Assessment Report; 2000-02 data calculated from Ozone Secretariat dataset of April 2004.

MBTOC estimated that global production for uses controlled by the Montreal Protocol (i.e. non-QPS) was at least 62,750 tonnes in 1998. Reported non-QPS production was reduced to about 28,400 tonnes in 2002.

Non-Article 5(1) countries reduced non-QPS production from about 66,000 tonnes in 1991 (baseline) to about 32,050 tonnes in 2001 and about 27,080 tonnes in 2002, representing a reduction of 59%. Initial reports for 2003 indicate further substantial reductions. Article 5(1) countries have reduced their non-QPS production from a peak of more than 2,500 tonnes to approximately 1,300 tonnes in 2002. The Article 5(1) baseline is estimated to be 1,300-1,400 tonnes (average 1995-98).

A list of known MB production facilities was published in the MBTOC 2002 Assessment Report (in Table 3.2). MB is produced in 3 Article 5(1) countries (China, India and Romania) and 5 non-Article 5(1) countries (France, Israel, Japan, Ukraine and USA).

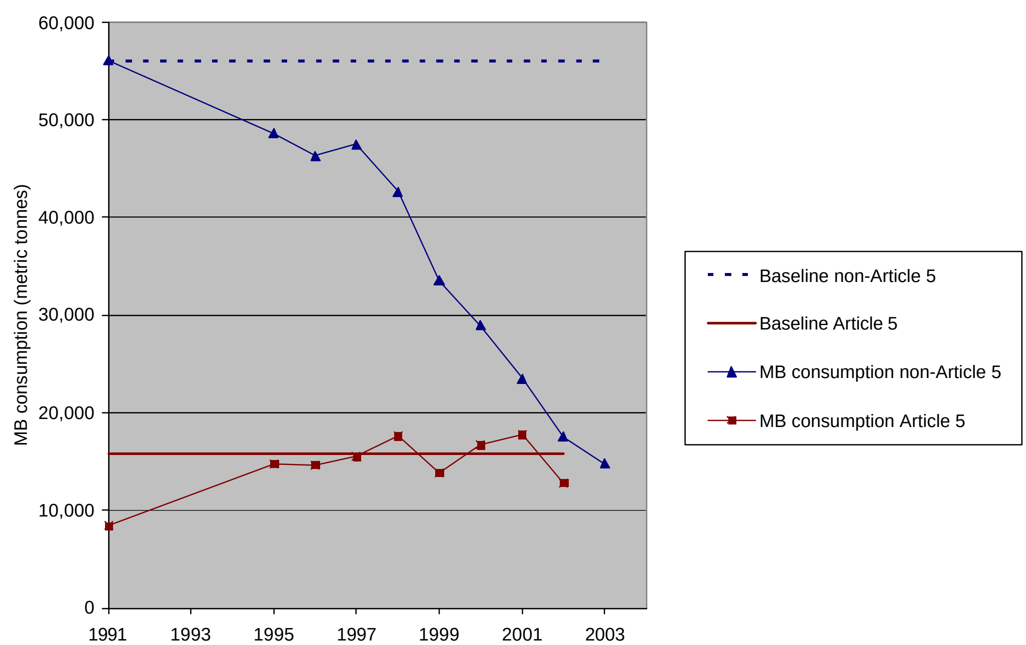
6.2 Consumption trends

Some countries have corrected their historical consumption data, so some official figures and baselines have changed since previous MBTOC reports, although the changes in general are relatively small. Under the Protocol, consumption at a national level is defined as the amount of MB produced plus the amount of MB imported minus the amount of MB used for QPS minus the amount used for feedstock, so it represents the supply of MB for uses controlled by the Protocol (i.e. non-QPS fumigant use). Global consumption of MB for controlled uses was estimated to be more than 64,460 tonnes in 1991and remained above 60,000 tonnes until 1998. On the basis of Ozone Secretariat data available in April 2004, global consumption fell to about 41,240 tonnes in 2001,and about 30,350 tonnes in 2002. Figure 6-2 shows the trends in MB consumption for Article 5(1) and non-Article 5(1) regions from 1991 to 2002.

In non-Article 5(1) regions, controlled MB consumption was reduced from about 56,100 tonnes in 1991 (baseline) to about 23,490 tonnes in 2001, and about 17,500 tonnes in 2002. The preliminary estimate for 2003 indicates consumption of less than 14,800 tonnes, representing an aggregate reduction of approximately 74% since 1991.

Article 5(1) regions, in aggregate, have also reduced MB consumption below the baseline level, following the steady increase that occurred to 1998, as shown in Figure 6-2. Calculated from Ozone Secretariat data, MB consumption was more than 17,750 tonnes in 2001 and fell to about 12,830 tonnes in 2002. This represents a reduction of 19% from the total baseline (about 15,765 tonnes) in Article 5(1) regions according to the revised Ozone Secretariat data.

Figure 6-2: Baselines and trends in reported MB consumption in non-Article 5(1) and Article 5(1) regions, 1991 – 2002 (metric tonnes)



Source: MBTOC estimates calculated from Ozone Secretariat data of April 2004

6.2.1 Quarantine and pre-shipment trends

According to Ozone Secretariat data, at least 11,410 tonnes of MB were reported to be produced for QPS purposes in 1999. More than 11,245 tonnes were reported to be produced for QPS purposes for 2002, but the data is not complete.

Many countries have noted that the use of MB for the fumigation of wooden pallets and packaging materials has increased substantially in the last couple of years because an increasing number of importing countries require some type of quarantine treatment for these items. At present, there is insufficient data to quantify this change.

Data collection is in progress to allow TEAP to respond to Decision XI/13(4b) that requested information on the volume of MB that would be replaced by the implementation of technically and economically feasible alternatives for QPS purposes.

6.3 Alternatives for soil treatment - update

Most countries have met their reductions in methyl bromide targets under the Montreal Protocol by adoption of alternative fumigants, such as fumigant mixtures containing chloropicrin (e.g. 1,3-D/Pic) or by applying consecutive treatments with other fumigants to increase their reliability e.g. 1,3-D/Pic drip applied followed by metham sodium (Trout, 2003b). Adoption of transition strategies that reduce the rate of MB used per unit area of soil such as by using MB/chloropicrin mixtures and/or allow reduced rates of MB application by adoption of barrier films (e.g. VIF) have also been used widely. Most applications granted Critical Use Exemptions at EMOP will use these transition strategies.

6.3.1 Fumigants used alone and in combination

6.3.1.1 Chloropicrin

Owing to its excellent fungicidal activity, chloropicrin continues to be developed and adopted as one of the major components of fumigant strategies to replace MB. Traditionally it has been injected into soils as a mixture with MB, but new application methods are improving its use as an MB alternative when applied alone or as mixtures with other products (e.g. 1,3-D/Pic).

Recently, an encapsulated formulation of chloropicrin has been developed in China. Much of China's current consumption of MB is applied by smallholders using simple application systems and cans of MB typically weighing about 500g. The encapsulated formulation is simple to apply without special tools. The chloropicrin formulation has been registered in China since 2002 and is in commercial use as an MB replacement.

Emulsifiable formulations of chloropicrin have been registered recently in Italy, the USA, and Japan. These formulations are proving a suitable alternative to MB in crop production systems where drip irrigation can be used to facilitate production and in soil types where the fumigant can move freely through the soil. The formulation can be applied through irrigation/fertigation drip lines, avoiding the need for injection equipment, and also allowing chloropicrin to be used as an MB replacement in some situations where injection equipment cannot be used.

6.3.1.1.1 Consecutive application of chloropicrin and fosthiazate

In Japan, soil treatment by consecutive applications of chloropicrin and of a granular formulation of fosthiazate has become popular among vegetable farmers formerly using MB. Fosthiazate (Nematorin-Ace®) is registered for the control of nematodes as a pre-plant treatment. Chloropicrin is more effective against fungi than against nematodes. Fosthiazate supplements that activity to give a broader spectrum of pest control.

In one system, fosthiazate granules are applied to the soil surface and then incorporated into the soil. The soil is then ploughed and prepared for planting of the seedlings. Next, chloropicrin is applied under plastic film with the covering left in place for at least for ten days. After removing the film, seedlings are transplanted. This can be used in either open field or protected cropping systems. It often used for protected melon cultivation.

In an alternative application method, chloropicrin is applied first under plastic. After the plastic is removed, the soil is ploughed to allow residual fumigant to degas. Fosthiazate granules are incorporated into the soil at this time. This method is usually applied in open field systems.

6.3.1.2 Cyanogen

Cyanogen, is showing promising results as an alternative fumigant to MB for soil disinfestation in trials in Australia (strawberry runners, strawberry fruit and carrots (Ren et al. 2003, Mattner et al. 2003)). Preliminary results show a broad range of efficacy against pathogens and weeds, but it has not been tested extensively against nematodes (Mattner et al. 2003). Cyanogen has a high vapour pressure and does not persist long in soils. Application technologies have not fully resolved the challenge of retaining it long enough in soils for adequate exposure times against some pests.

6.3.1.3 Dazitol

Dazitol is a nematicide/ fungicide/ insecticide formulation that contains a mixture of active plant extracts, in particular capsaicin from chilli peppers and allyl isothiocyanate from mustard seeds (Champon 1998, Slevin 2003). Although it is registered in the United States, little independent research on its efficacy has been reported. The manufacturer has reported it as an efficient soil fumigant for the control of soil-borne diseases and pests attacking tomato and turf in a number of countries (Champon 1998). The manufacturer reports commercial adoption of this fumigant in the Middle East, particularly on cucumber and melon crops in Jordan (Slevin 2003). Further data is required to determine its performance relative to MB.

6.3.1.4 1,3-dichloropropene and chloropicrin

Formulations of 1,3-D mixed with chloropicrin continue to increase in acceptance as a key alternative to MB/Pic formulations, particularly for certain crops, such as strawberries. In several countries, e.g. Australia, Spain, 1,3-D mixed with 35% chloropicrin injected into prepared beds is being used as an effective alternative to methyl bromide in the strawberry fruit industry (Miranda et al. 2003, López Aranda et al. 2003, Ajwa et al. 2003, Mattner et al. 2002).

Two new emulsifiable formulations of 1,3-dichloropropene and chloropicrin products have been registered in USA and elsewhere and are seen as viable alternatives for MB in many situations. In Line (emulsifiable 1,3-dichloropropene + chloropicrin) and Telone EC (emulsifiable 1,3-dichloropropene) when applied though buried drip lines provided excellent control against a number of soil pathogens and pests (nematodes and weeds), in melons, citrus, grapes and strawberries (Ajwa et al. 2002, Ajwa and Trout 2000, Martin 2003, Martinez et al. 2000). A limitation of the technique is that pathogens and pests are only controlled where the soil is wetted. A uniform distribution of the product is thus a necessity. About 10% of the 1,3-D in California was applied by drip irrigation (Martin 2003).

Regulatory restrictions on the use of 1,3-D alone or formulations with chloropicrin are presently restricting its uptake in several counties in California, USA (Trout 2003) and its use is prohibited in some regions (e.g. Prince Edward Island, Canada).

6.3.1.5 Metham sodium and dazomet

Use of the methyl isothiocyanante producing fumigants, metham sodium and dazomet, as alternatives to methyl bromide has been limited in the past by inconsistency of results and long plant back times compared to MB/Pic mixtures. Dazomet uptake has also been restricted by cost and limited registration in certain countries (e.g. USA) and metham sodium because of enhanced degradation in certain sandy soils with high pH (Matthiessen et al. 2003). These products, however, continue to be considered as an alternative to MB/Pic mixtures, because they have the ability to control both pathogens and weeds, and also provide an alternative that offsets the need for chloropicrin. Increased knowledge of fumigant movement, development of application methods that apply these products more consistently to soil and their use in combination with other treatments are offering more consistency of these products (Norton 2003). For instance, dazomet granules are replacing MB/Pic use for several high value industries in Australia and USA, e.g. turf in golf courses, where new equipment has improved application (Mitchell pers. comm., Park and Landschoot, (2003). The consistency of metham sodium has been improved by new application technologies through drip irrigation or spading techniques or by combination with other fumigants (e.g. 1,3-D or Pic). For example, 1,3-D/Pic EC followed by metham applied a week later is being used commercially as an alternative to MB in strawberry crops in the US (Norton 2003)).

Metham sodium has been adopted as an MB alternative in diverse regions and crops, such as Chile (greenhouse tomatoes and peppers, grape replant, stone fruit tree replant), South Africa (field bulbs, lettuce), France, Netherlands and Belgium (field grown strawberry fruit) (Carrasco et al. 2002, Barel 2003a, Koppenol pers. comm., Mutitu and Barel 2003). In Spain, metham sodium is used for about 1500 ha strawberry fruit, 1400 ha field tomato, 120 ha protected tomato, and 600 ha pepper, applied by drip irrigation or injection. In Italy, metham sodium is used on about 900 ha greenhouse vegetables, 350 ha tomato and about 180 ha cut flowers, mainly applied by drip irrigation, although injection is also used (Rabasse pers. comm., Barel 2004). Many MLF phase out projects have adopted metham sodium, often via drip irrigation, as a major MB alternative.

In the last decade, the development of rotary spading techniques in northern Europe has increased efficacy of this product significantly, and more consistent control is achieved at depths of up to 45cm in a range of soil types (Mulder 2001). This rotary spading equipment can avoid groundwater contamination and meets the stringent water protection requirements in the Netherlands (Mulder 2001). Rotary spading machines have expanded to a number of countries and crops including strawberry fruit and lettuce (open field), potatoes and carrots in Belgium; 1000 ha of crops (strawberries, carrots, fruit trees, potatoes) in The Netherlands; about 800 ha of strawberries, carrots, lettuce and other crops in France; 300 ha field grown bulbs and about 400 ha lettuce in South Africa and production of several protected crops including tomatoes and peppers in Chile (Carrasco 2003, Koppenol 2004, Peters 2004, Barel 2004).

6.3.1.6 Methyl iodide

Methyl iodide (iodomethane) continues to show similar efficacies to methyl bromide in trials (Ajwa et al. 2003). Recent studies are focusing on lowering the dosage rate and validating performance when used in combination with chloropicrin (Browne et al., 2003, Dickson et al., 2003, Elmore et al., 2003, Ren et al., 2003, Schneider et al., 2003). Research is also considering ways to reduce the potential for offsite exposures to methyl iodide resulting from postfumigation off-gassing. Registration is being sought in the US with a possible decision before the end of 2004.

6.3.1.7 Dimethyldisulphide

Over the last 3 years, dimethyldisulphide (DMDS) has been developed and evaluated in France and Italy as an alternative to MB when applied via shank injection or via drip irrigation (Charles 2003). The product has been reported to be as effective as MB at rates of 600 to 800 kg/ha for control of a range of nematodes and fungal pathogens. Further development is required to confirm its potential to replace MB

6.3.1.8 Propylene oxide

Although propylene oxide is registered for protection of some specific pests of stored products, recent trials have shown that it also has broad spectrum activity against pathogens and weeds as a soil applied fumigant (Norton 2003). Applications by shank injection to soil at approx 40-50 litres per hectare have been as effective as other fumigants used in trials in the US, but further development is required to improve consistency of treatments.

6.3.1.9 Sodium azide

Trials in the US are continuing to evaluate effective application methods and rates using sodium azide to achieve consistent control of weeds, nematodes and fungal pathogens. In tomato and green pepper trials in Alabama, rates of 112 kg/ha or greater of sodium azide delivered through drip irrigation tape gave good control of weeds and nematodes (Rodriguez-Kabana et al. 2003ab). Fusarium crown rot of tomato was better controlled by sodium azide than by methyl bromide in one trial and the root gall index on pepper plants was lower in plots treated with sodium azide at rates greater than 112 kg/ha than in methyl bromide treated plots (Rodriguez-Kabana et al. 2003ab). A multi-stage application protocol was developed in which the sodium azide is delivered in stages using water to flush the material gradually throughout the root zone in such a way that the higher rates needed for weed control are delivered to the upper soil layer where weed seeds are present, without using higher than needed rates throughout the entire root zone (Rodriguez-Kabana pers. comm.).

Evaluation of sodium azide against hybrid and common bermuda grass in Alabama demonstrated good short-term control of bermuda grass when azide was applied under plastic to clean-tilled sod fields at rates of 140 kg/ha or higher (Guertal et al. 2003). Control of nutsedge was not successful at the rates evaluated. Further turfgrass sod studies in Alabama demonstrated that azide at a rate of 112 kg/ha did not control torpedo grass, but a glyphosate pre-treatment plus azide at a rate of 224 kg/ha resulted in plots without torpedo grass, bermuda grass, and yellow nutsedge 10 days after treatment (Walker et al. 2003). Additional long term trials are needed, as sod fields require bermuda grass eradication for several years.

In three trials conducted in cut flowers in California (Gerik 2003), sodium azide applied through the drip irrigation system at a rate of 112 kg/ha. This resulted in reduced levels of mustard, knotweed, and purslane, but did not control *Malva* or clover. A methyl bromide control was not included in these trials. An additional trial in a ranunculus production system showed that sodium azide at 72 kg/ha provided control of clover, sow thistle, and *Malva* comparable to other methyl bromide alternatives (metham sodium, iodomethane/chloropicrin, chloropicrin, and 1,3-D+chloropicrin) (Elmore et al. 2003).

In perennial nursery (trees and vines) and vineyard replant trials in California, sodium azide was delivered through drip irrigation lines at a rate of 336 kg/ha. In a grapevine nursery/vineyard replant trial, citrus nematode populations in plots treated with sodium azide and followed by a water cap were lower than the untreated control at the time of planting (Schneider et al. 2001). At the end of the first and second growing seasons, rootknot nematode populations on susceptible grape varieties had increased in the azide treated plots to levels comparable to the levels found in untreated control plots and were significantly higher than in plots treated with methyl bromide (Schneider et al. 2002a, 2003a). At harvest, 20-70% of the grapevine nursery plants from azide treated plots had galled roots as compared to 75% in untreated plots and 0% in methyl bromide treated plots (Schneider et al. 2002b). In another grapevine nursery/vineyard replant trial, azide treatments reduced the citrus nematode populations at the time of planting to levels comparable to those found in the methyl bromide treated plots (Schneider et al. 2003b). Data on nematode population levels and amount of root galling at harvest are not yet available. Additional trials using a multi-stage application protocol are planned.

6.3.1.10 Sulfuryl fluoride

Experimental results in tomato, cucumber and tobacco showed that sulfuryl fluoride, 25-50 g/m^2, showed good efficacy for control of both soilborne fungal pathogens and nematodes (Cao, pers. comm.). Yield of crops after applying sulfuryl fluoride was similar to that obtained from methyl bromide treated plots. Application of sulfuryl fluoride can be more convenient than that of methyl bromide, as sulfuryl fluoride is a gas at normal ambient temperatures. Unlike MB, it can be applied in cold weather without the need for a heated vaporiser. Sulfuryl fluoride is broken down rapidly in soils so plant back is less than for MB. Further testing is required to determine if the product is stable for long enough to achieve effective control of a range of pathogens in different soil types.

6.3.2 Non-chemical alternatives

A range of non-chemical treatments continue to be considered as part of integrated pest management strategies to control pathogens and weeds to replace methyl bromide. This section lists some of the more important changes in the status of several non chemical methods as alternatives to methyl bromide, but does not cover the full list of options that are being considered or adopted to replace MB in some specific circumstances (e.g. biofumigation).

6.3.2.1 Heat treatments

Steaming has long been established as a method of disinfesting soils, including as an MB replacement. Recently hot water treatments have been developed as a MB replacement. Mobile machines using hot air are at an advanced stage of development. These may be applicable to both protected cultivation and small scale broadacre production systems and appear to be more energy efficient than steaming systems for the same energy input and cost.

6.3.2.1.1 Hot air treatment

Recently, new remote controlled soil sterilising machines (Cultivit) that operate with heated air at up to 800°C have been developed in Israel and The Netherlands. They have been reported to be as effective as methyl bromide and other fumigants for soil disinfestation (Barel pers. comm.). These machines can treat strips of soil up to 250m long in approximately one hour. Versions of the machines are under development for both broadacre and protected cultivation systems. Further development and commercial scale up of these machines is required before an accurate assessment of their potential as an MB replacement can be fully identified.

6.3.2.1.2 Hot water treatment

Hot water treatment consists in applying hot water of 80-95°C onto the field in order to raise the soil temperature to levels high enough to control pathogens. This control measure has been recently developed in Japan and is being adopted on tomatoes, melon, cucumber, watermelon, spinach, cut flowers and other crops (Nishi 2002). Hot water treatment is useful for control to fungal diseases, bacterial diseases, nematodes and weeds, but has not proven successful for controlling virus diseases (Uematsu et al. 2003a). This technique has been trialled for over 10 years and proven successful for the control of verticillium wilt of tomato (*Verticillium dahliae*) and corky root of tomato (*Pyrenochaeta lycopersici*). Successful disinfection of soilless substrates used for gerbera production has also been reported (Uematsu et al. 2003b).

Hot water equipment systems are supplied from eleven companies in Japan. Two types of systems are available: tube-watering and dragging types. In tube-watering systems, hot water is sprinkled using tubes installed on the field. In the dragging system, hot water is supplied to the soil surface using watering equipment made of metal pipes that is designed to roll smoothly on the ground when dragged. Machines cost from US$ 27,000 to 64,000 depending on the system and areas up to 300m^2 can be treated in a day (Uematsu et al. 2003a).

6.3.2.1.3 Steaming

Use of steaming or pasteurisation for soils and substrates has continued to increase as an alternative to methyl bromide, particularly for use in intensive protected cropping systems, such as flowers and vegetables. This is largely due to new and more efficient equipment being available, such as negative pressure steaming, hood steaming (for seed beds) and improved, more flexible equipment for sheet steaming (Carrasco 2003, Pacett 2003, Runia 2000, Barel 2003b). Negative pressure steaming allows treatment of much deeper soil depths than sheet steaming, and uses almost half the fuel of sheet methods (Runia 2000).

Examples of soil steaming in commercial and routine use include: South Africa (tomatoes, chrysanthemum cuttings), Kenya (chrysanthemum cuttings), Uganda (chrysanthemum cuttings), Tanzania (cut flowers and chrysanthemum cuttings), Colombia (cut flowers and cuttings), Brazil (flowers and cuttings), Italy (cut flowers, ornamentals and cuttings), Belgium (strawberry (protected), tomato, lettuce, leek and onion seedlings), the Netherlands (about 50% of cut flower production, including 900 hectares of chrysanthemum, cuttings and radish), UK (protected tomato and lettuce), Lebanon (strawberry), Guatemala (cut flowers), and in other crops and countries mentioned in MBTOC 2002 Assessment Report (Barel 2004, Solís and Calderón 2002, Haroutunian 2003, Ellis 1991, Gullino 1992, Pizano, 2003). Steam was used on about 2000 hectares in France in the year 2000 (Fritsch 2002).

Steaming is also comparable to methyl bromide for sterilising plug or seedling trays. This is mostly achieved in an enclosed box or chamber where steam is circulated inside at a specific controlled temperature. Common materials that can be sterilised by this method include trays and pots for production of seedlings of crops such as tobacco and lettuce. This system is used in many countries, including the US, Netherlands, Belgium, Chile, South Africa, Argentina and Uganda (Nesmith 1997, Hensley 2002, Pearce and Palmer 2002, INTA 2003, Melton and Broadwell 2003).

Steam has replaced the use of MB for sterilisation of substrates in a number of areas. For example, steam treatments (with negative pressure systems) in bunkers or containers have been adopted by some forest tree nurseries in Chile (Carrasco 2003, Barel 2003a). Steam has also been adopted as a MB alternative for substrates in the Netherlands, and for plant nurseries in South Africa (Jansen pers. comm., Runia 2000). Steaming of peat is very difficult using normal sheet steaming methods, but is very effective when using negative pressure methods. Negative pressure steaming is more energy-efficient than other steam methods (Barel 2003b, Runia 2000).

6.3.2.1.4 Solarisation

Commercial adoption of solarisation continues to increase in some countries where cropping and climate conditions make this technique an efficient alternative to methyl bromide. In Costa Rica for example, an estimated 20% of the melon cropping area (about 2000 ha) is now using solarisation, which has proven particularly successful when combined with metham sodium (Chaverri 2004). The same has been reported from China for the control of soilborne diseases affecting strawberry and tomato (Cao, pers. comm.).

Recently, a method known as 'high temperature soil solarisation' or 'double-tent solarisation', has been developed as a control measure for pests attacking young seedlings or transplants and containerised plants, including nursery plants (Stapleton *et al.* 1999,2000). The system has been approved by the California Department of Food and Agriculture for treatment of containerised soil. In the 'double-tent' set-up the soil reaches a minimum temperature of 70 °C, which is maintained for at least 30 continuous minutes, or a minimum of 60 °C that is maintained for at least 60 continuous minutes (Stapleton *et al.* 1999, 2000). Soil must be either in polyethylene planting bags or in piles not more than 30 cm high, placed on a layer of polyethylene film, concrete pad, or other material, which will not allow reinfestation of soil, and covered by a sheet of clear polyethylene film. An additional layer of clear polyethylene film is suspended over the first layer to create a still air chamber over the soil. Soil moisture content must be near field capacity.

6.3.2.2 Biofumigation

Biofumigation as a stand alone treatment generally does not provide the same fumigation effects as direct use of chemical disinfestants, but skilled use of biofumigant products can reduce dependence on chemical fumigation, including MB use. Biofumigation involves the use of volatile toxic substances that are released during the bio-decomposition of organic amendments or directly from roots, control diseases, nematodes, arthropods and weeds. Much research has been carried out in the past few years to understand the mechanism of the action of various products released from organic amendments and to improve biofumigation techniques. It has been found generally that any organic debris may act as a biofumigant, but their efficacy depends on the doses and methodology of application (Bello et al. 2003, Lazarovits et al. 2001, Cartia 2002, López-Aranda et al. 2002). In addition, organic matter stimulates soil microbial activity and improves soil physical and chemical properties.

The effectiveness of biofumigation can be improved with plastic soil covers or other types of insulated systems, which trap and enhance the effect of the volatiles substances and heat soils. For this reason, biofumigation combined with solarisation considerably shortens the time necessary to accomplish pest control through solarisation alone and increase efficacy. The combination has been used successfully as an alternative to soil fumigants in the production of tomatoes, cucurbits, peppers and other vegetables, cut flower, bananas, fruit and vineyard replants (Bello et al. 2003).

Potential disadvantages of biofumigation include variable efficacy, especially during the first two or three years of application in soils with a low biological activity; possible phytotoxicity effects; lack of available organic amendments, although this may resolved by the use of green manures; and a delay in the plant back time to allow for amendment decomposition and their ability to become weeds (Villeneuve and Lepaumier 2000, Bello et al. 2003).

6.3.2.3 Biological control

Trichoderma has been adopted as an adjunct to MB alternative treatments in some Article 5(1) countries. For example, cut flower producers in Kenya and forest tree nursery producers in Chile, add *Trichoderma* to soil or substrates after steam sterilisation. (Barel 2003ab, Carrasco 2003). Growers in Colombia amend the soil with *Trichoderma* after steaming, and report lower losses due to fusarium wilt of carnations (Carulla 2002). In Israel, a commercial formulation of *Trichoderma harzianum* known as Root-Pro® has been shown to provide efficient control of fusarium and rhizoctonia diseases attacking carnations and tomatoes (Mycontrol 2002).

6.3.3 Methods that avoid the need for soil disinfestation

6.3.3.1 Substrates/hydroponics

Adoption of crops grown in substrates continues to be a strong trend in protected, intensive agriculture (e.g. for cut flowers, nursery plants, vegetables) both in Article 5(1) and non-Article 5(1) countries (de Joog 2001, Kipp et al. 2000, Pizano 2003, Savas and Passam 2002, UNIDO 2003). Although initial investments are normally high, it has been proven that increased productivity and yield, due to higher planting densities being possible but also to better quality, pay off extra costs rapidly (Valderrama and La Rota 2003, Cavelier 2003, Savas and Passam 2002, Schnitzler and Gruda 2002, Maloupa et al. 1999). A study in Almería, for example, noted that soil cultivation of sweet pepper provided a yield of 105,000 kg/ha and net revenue of Euro 8000/ha, while substrates provided yields of 160,000 kg/ha and net revenue of Euro 33,000/ha (Caballero and De Miguel 2002). The Netherlands tends to use more intensive substrate systems, providing average yields of 260,000 kg/ha and net revenue of Euro 41,000/ha (KWIN 2003). An economic study that compared soil cultivation with various types of substrates systems in Greece concluded that substrates can substantially improve farmers' incomes (Grafiadellis et al. 2000).

Substrates are used on about 12,000 ha in Western Europe (Stanghellini and van Os 2004). Fritsch (2002) notes that soilless culture is increasing significantly as a replacement for MB for tomato and strawberry fruit in France. For example, by 2002 substrates had been adopted on about 950 ha tomato and substrates had replaced MB for about 350 ha strawberry production in that country (Fritsch 2002). Similar changes are occurring in Article 5(1) countries. In Kenya, for example, several cut flower producers have replaced MB with substrates (mainly pumice and coconut fibre) for roses and carnations. Substrates will be adopted on many farms assisted by the MB phase-out project (Mutitu and Barel 2003).

Substrates are also an excellent option for propagation purposes, including of woody plants such as roses, in which the "mini-plant" system allows for rooting and grafting the rootstock and scion at the same time. This system is also extremely efficient with respect to production space (e.g. number of plants produced per unit area) (Vargas and Samper 2003, World Bank 2002).

Leoni and Ledda (2004) note that in Sardinia (Italy) the forthcoming limitation on MB has stimulated scientific and technical development in the last few years, and has stimulated the growth of substrate cultivation and use of grafted plants in the region. Production using substrates was nil a decade ago and is now used for about 8% of vegetable production in Sardinia (Leoni and Ledda 2004).

Some important factors that need to be accounted for when considering substrate adoption are:

Local sourcing of substrate materials is generally essential, since imported substrates are mostly too expensive to make this alternative cost efficient (Valderrama and La Rota 2003, Cavelier 2003). Growers in many countries have gained experience with very diverse substrates such as rice hulls, coffee husks, volcanic scoria, pumice stone, coconut peat or coconut coir and many others (Calderón 2001).

Recycling systems make this alternative feasible where water supplies are limited and are important in preventing soil and groundwater contamination with nutrient solutions.

Substrates that are to be reutilised may need to be sterilised. Steaming is a feasible non-MB option (Barel 2004).

6.3.3.1.1 *Substrates and production of transplants*

Plug plants (or seedlings, transplants) offer a means of avoiding soilborne diseases and the need for fumigation with MB. The widespread adoption of tobacco plug plants (produced in floating trays) has been previously reported by MBTOC (2002). Strawberry plugs are providing a useful commercial alternative to MB in northern Europe and other areas where short production seasons suit their use. Further development is required for crops grown over longer production seasons, such as most strawberries in California and Spain. Presently plugs only support a small proportion of the transplant market in these major strawberry production regions of the world (<1%), and further development is required if they are to replace the need for in-field fumigation.

Recently, trials have been conducted in USA to find ways to improve the performance of plugs and to reduce the costs of production and transport. Plug plants can cost several times that of bare root plants, so extra benefits in establishment, yield and handling are required to offset this cost if compared to bare rooted runners grown in fumigated soils. This has been achieved in some areas where early season production can take advantage of the market windows, but further research is required to improve full season performance (Sances 2000). At present, plug plants may be grown in MB-treated soil.

Strawberry plugs, as with all transplanted crops, require strict hygiene protocols to be followed otherwise disease outbreaks can occur. In an on-going multi-year study in California, plants grown in greenhouse plantings for the 2003-2004 production period were contaminated with anthracnose disease, *Colletotrichum acutatum*, which had been spread from infected tip material from a particular commercial grower. This has affected the adoption of this alternative technology commercially, and caused plug growers to rethink their source of tip material in the future. All research material for the 2003-2004 season in California was lost to this disease event (Sances 2003).

6.3.3.2 Grafting

Grafted plants often used in combination with soilless culture, are being adopted increasingly, in most regions of the world because they offer a range of commercial benefits and can avoid the need for MB fumigation. In Japan and South Korea, for example, grafted plants are used for more than 90% of the total area of protected cucumber, watermelon, melon and eggplant and for more than 40% of the area of melon and tomato (Lee 2003). In open field production in Japan, grafted plants are used for more than 40% of the eggplant and cucumber area, and for more than 92% of the watermelon (Lee 2003).

In Sardinia, the production of grafted seedlings increased from almost nil in 1996 to about 1.7 million in 2003 (Leoni and Ledda 2004). Leoni and Ledda (2004) state that the tomato crop area in Sardinia treated with MB has been reduced from 50% in 1992 to about 4% currently, due to agronomic changes which include the adoption of grafted plants and resistant varieties.

Grafting of both perennial and of annual crops (almonds, tomato, cucurbits), alone or in association with use of various soil fumigants (e.g. metham sodium, 1,3-D, chloropicrin) is widely used in many countries as an alternative to MB. The results expressed as marketable yields, gall index or disease severity are as good as with MB (Koren 2002, Besri 2003, Browne et al. 2003, Hafez et al. 2003, Minuto et al 2003). Applicability may be limited by availability of rootstocks tolerant to local pests and diseases.

6.3.3.3 Resistant cultivars

The range of varieties with resistance to pathogens previously requiring fumigation with MB is widening, particular for tomato and melon. In many crop production systems, cultivation of resistant cultivars is widely adopted to control many soilborne pathogens (Laterrot 2002). Use of resistant cultivars and grafting, as a stand alone treatment, may not provide the grower with a means to replace MB. However, integration with other integrated pest management strategies may enable strategies to be as effective as MB fumigation (Gantz et al. 2002, Sachs 2002).

6.3.4 Article 5(1) perspective

Adoption of alternatives to methyl bromide continues to expand in Article 5(1) countries, with a substantial number of demonstration and phaseout projects funded by the Multilateral Fund. Recent progress reports have identified that:

- Steam has replaced the use of MB in a number of areas. For example, sterilisation with negative pressure steaming of substrates, such as peat and other materials for forest tree nurseries in Chile, steaming of substrates for cuttings and seedlings in countries such as South Africa, Bolivia, Kenya and Tanzania (Carrasco 2003, Pacett 2003, Runia 2000, Barel 2004). Steam has replaced the use of MB in a number of areas. For example, sterilisation with negative pressure steaming of substrates, such as peat and other materials for forest tree nurseries in Chile, steaming of substrates for vegetables such as lettuce, cabbage seedlings and trays for plant production in South Africa, Bolivia, Kenya, Netherlands and Belgium (Carrasco 2003b, Pacett 2003, Runia 2000). In this case the substrate is treated in special bunkers or containers with drain pipes and fans in the bottom which suck/distribute the steam evenly through the substrates and remove the condensate. Mostly they work with a dual system that gives a high capacity. Steaming of peat is difficult using normal sheet steaming methods, but is very effective when negative pressure methods are used;

- A study in Guatemala (cut flowers) found that steam was as effective as MB in controlling a broad spectrum of pests and cost about 14% more than MB (US$0.42 per m^2 for steaming, compared to US$0.37 for MB fumigation) (Solís and Calderón 2002);
- According to Ozone Secretariat data, dramatic reductions in the consumption of MB have occurred in China (official data is 1813 tonnes in 2002, compared to 3501 tonnes in 2000) largely due to the reduction in the tobacco sector, where floating trays have been adopted as the main alternative (Cao pers. comm.). Research in China has also identified grafting as a good alternative for protected tomato cropping (Cao pers. comm.);
- Argentina has reduced MB consumption for soil fumigation from almost 800 tonnes in peak year (1999) to about 409.5 tonnes in 2003. This reduction was largely achieved by the wide adoption of floating trays and metham sodium in tobacco seedbeds. For protected tomatoes, peppers and eggplants alternatives that have been adopted include metham sodium, solarisation, steam and biofumigation. For open field strawberry fruit and runner production the main alternative adopted has been metham sodium. For protected ornamental plants and cut flowers the most used alternatives are steam, and metham sodium. Adoption of these alternatives has been achieved through actions planned within the framework of two MLF funded projects which include: recruitment and training of extension staff, training of thousands of growers in the use of the alternatives, awareness campaigns and promotion of institutional public commitments to reduce MB use and protect the ozone layer (UNIDO 2003, Valeiro pers. comm.);
- Kenya's consumption of MB has been reduced from a peak of 390 tonnes in 1998 to 232 tonnes in 2002 (Ozone Secretariat data). The alternatives adopted include more than 40ha substrates for roses and more than 10ha steam for chrysanthemum cuttings (GTZ 2004, Barel pers. comm.).

  Uganda reported imports of 50 tonnes MB in 2002 (Ozone Secretariat). Growers are due to reduce 40 tonnes MB this year by adopting steam in 3 chrysanthemum cuttings nurseries (UNIDO 2004). New programs are commencing in roses to evaluate substrates and metham sodium.
- The largest Ecuadorian rose propagator, accounting for 62% of MB consumption in 2001 in this country, will successfully convert his entire operation to substrate production by 2005 (World Bank 2002).

6.4 Alternatives for durable commodities and structures - update

Alternatives to methyl bromide for durable commodities and structures are classified as physical methods, such as heat or irradiation treatments, or chemical methods such as fumigation with phosphine or sulfuryl fluoride. Both avenues of MB replacement are being researched, adapted and commercially adopted at varying rates the many application areas of stored product protection where MB is currently used.

Some specific non-QPS applications of MB still present unsolved areas for the replacement of MB as pest control agent. These include control of some fungi in particular historical buildings and wooden artefacts, and the treatment of fresh chestnuts and high moisture fresh dates. It may be necessary to resort to occasional use of fumigation, such as with methyl bromide, for treatment of mills and food processing facilities to a level of pest control required to meet stringent food standards where IPM and heat systems have not proved adequate.

For chemical methods, lack of registration, logistical and accessibility problems, as well as the economic feasibility, still delays adoption of alternatives in some specific areas where technically feasible alternatives are available. For example, although many uses of methyl bromide for durable commodities have been replaced by phosphine, applied either as solid formulations or the more recently registered gas formulations, logistical and/or economic issues caused by longer treatment times have delayed adoption for some specific situations. Resolving these issues is the subject of considerable present industry-government focus, and commercial adaptation research.

For physical methods, heat treatments continue to be identified as an effective candidate to replace methyl bromide for many structural uses to control pests of food processing facilities where rapid overall treatment times are important. While heat treatment is technically effective, research and commercial adaptation work continues in several countries to refine techniques and test equipment to enable sufficient and even heat distribution, particularly in very large buildings. Buildings of more than 30,000 m^3 seem to be less suitable for this technique for logistical and stability reasons. Heat stress to the machinery and structure restricts this technique from being more widely used instead of MB. Cold areas in these premises, such as cellars, are very difficult to disinfest thoroughly with heat treatments.

6.4.1 Update for specific technologies

6.4.1.1 Heat treatments

To ensure a heat treatment is effective and does not damage buildings, temperature increase and cool-down must proceed with speed, reasonable enough to complete the treatment in a weekend, but not so quickly that the structure are damaged. Typically these treatments use temperatures from 40 to 60°C. With this technique, local climatic conditions and local building methods will impact effectiveness and heat techniques required. Additionally, costs of heating mills and food processing facilities vary widely, depending on energy costs in various regions. For these reasons, commercial adaptation work is taking considerable effort. Results reported have been inconsistent and industry economic impact can be considerable. Where techniques have been found to work, the food industry (mills, food and spice processing facilities) has quickly adopted the technique.

In the UK, heat is not currently considered an option to replace the fumigation treatment of large food processing buildings because commercial adaptation research has not validated currently available technology to achieve the necessary temperature (>50°C for at least one hour) in all the harbourages where insects can hide. In addition the risks of structural shrinkage, and damage to sensitive equipment resulting from exposure to high temperatures for long periods has not yet been satisfactorily quantified. Also it has not yet been demonstrated that it is possible to achieve the level of kill necessary to meet UK Food Safety requirements using heat alone in this type of buildings. However, several UK and European food processing facilities achieve UK Food Safety requirements without using MB fumigation. For example, FritoLay International, a large international food processing company uses a cost-effective IPM system based largely on systematic cleaning programmes and inspection, and has not used MB for 6 years in its UK plant (Raynaud 2002, 2003).

In Canada, where manufacturers of heat equipment and distribution technologies have collaborated with the flour milling industry and Agriculture and Agri-Food Canada researchers, heat techniques have been adapted and found effective. For example, Quaker Oats of Canada has used sanitation programmes and heat treatments in their cereal milling and processing facility, part of which is 100 years old and constructed of timber posts, wooden floors and stone walls (Sheppard 1998, MBIGWG 1998). Pillsbury has used heat combined with IPM systems for a number of years, and the company's pest control manager has reported that heat has proven to be successful (Heaps 1998). About 30 food processors in North America (e.g. General Mills, Nestlé Purina, Keebler (bakery), Riceland (rice miller), Nabisco, Kraft and Riviana), and at least 23 mills (e.g. Lauhoff, General Mills, Quaker Oats (US), Con Agra, Seimer Milling) have also used heat treatments to control insects in their facilities (Heaps 1998, Mueller 2003, Corrigan 2002). While heat has not yet been adapted for very large structures, a number of facilities of varying sizes and constructions have used heat combined with IPM systems and as a result have not used MB for almost a decade (Stanbridge 2002, Mueller 2003, Heaps 1998).

The efficacy of heat compared with methyl bromide to control pest insects in flour mills was evaluated in a recent Canadian study (Canadian National Millers Association 2004). Two heat treatments, one using propane-fired heaters (Temp-Air), and another using portable low-pressure steam heaters (Roo-Can Manufacturing Inc.) were examined. Methyl bromide treatments were included so that the alternatives could be compared to the currently used control method. Maximum temperatures ranged between 45 and 78°C in the two mills treated with heat. Temperatures were generally higher in the mill that used propane-fired heaters and all of the insects in bioassays were killed.

In the steam-heated mill, there were 4 test cages out of 23 that had some survival at the end of the treatment. Trapping indicated pest populations dropped to 5 to 27% of what they were before the propane-heat treatments. Although populations were significantly reduced after the steam-heat treatment, inspections found live insects in the mill immediately after the heat treatment. Both the methyl bromide treatments caused populations to drop to 0 to 6% of what they were before the treatments. The heat-treated mills were shut down for 30 hours (steam heat) or 60 hours (propane heat), The mills that used methyl bromide were shut down 52 or 94.5 h. Mill personnel were satisfied by the level of insect control given by the heat treatments. There were no major equipment problems due to heat treatment. Several additional Canadian companies intend to use heat treatments to control insect infestations in the future (Fields pers. comm.).

There is still uncertainty as to he most tolerant stage of pests to heat treatment. Maloof et al. (2003) provided quantitative data about the susceptibility of each stage of the red flour beetle to heat. In a series of tests using 6 temperatures from 42 to 60°C, newly hatched larvae were shown to be the most heat-tolerant stage. 7.2 h was required to kill 99% of this stage compared to 1.8 h for other stages. They proposed that young larvae be used as a gauge of heat treatment efficacy. Studies in the UK, however, showed eggs and older larvae to be the most tolerant stages of red flour beetle at 44-47°C (Bell et al. 2004)

6.4.1.2 Irradiation

Another physical method is irradiation, suitable for some commodities, but not an alternative for structural treatment. In numerous countries, herbs, spices and vegetable seasonings are commercially irradiated in a process that controls insects and microorganisms. Treatment of other durable commodities, while often technically effective has been small scale and not widely reported. Irradiation of perishable commodities is more common than the irradiation of durable commodities.

6.4.1.3 Sulfuryl fluoride

Sulfuryl fluoride (SF) has substantial potential for the replacement of methyl bromide as a fumigant for some postharvest and structural uses, particularly where the action of phosphine, the main alternative, is too slow or corrosion risk cannot be managed reasonably. Sulfuryl fluoride may also be appropriate where heat treatments, potentially as rapid as methyl bromide, are not feasible or adequately effective. Its use has hitherto been constrained by lack of appropriate registration.

Several field tests in various countries have successfully been carried out to disinfest large structures (empty flour mills, food factories) by using SF at *ct*-products of about 1500 – 2000 ghm^{-3} and temperatures of 25 - 35°C. (e.g. Ducom et al. 2003, Drinkall et al. 2003, Schreyer et al. 2003).

In 2003 sulfuryl fluoride received its first registration (Switzerland) in the general area of foodstuffs, for use in emptied wheat flour mills. Recently a registration has been approved in Italy for fumigation of emptied flour mills and pasta mills. Additional registrations in UK, Germany and France are anticipated during 2004 and 2005. Registration is also being sought in both Australia and Canada. The registrant has indicated that registration is not being sought in all countries where it is a potential replacement for MB, because of market constraints.

In January 2004, SF, as ProFume, was granted federal registration in USA for postharvest uses for dried fruit, tree nuts and cereal grains, and for rice and flour mills and processing premises. State registrations in over 40 US states were granted by 1 May 2004 and registration in most remaining states is expected by August 2004. Commercial SF fumigations have been carried out in structures in the USA since April 2004.

Lack of registration, specifically food tolerances, of SF in Europe prevents use of SF on export tree nuts from USA. Methyl bromide is currently used for fumigation of export nuts where a rapid treatment is required. Alternatives are not at present available.

6.5 Update on methyl bromide alternatives – QPS

Development of methyl bromide alternatives for QPS applications continues to be a difficult process, often coping with diverse situations with small quantities of MB (<1 tonne annually) consumed for particular uses. A variety of technologies are potentially suitable as replacements, but their actual use is constrained by the sensitivity of the treated commodity, cost, effort and time required in gaining the required registrations and approvals, and the need for a very high level of effectiveness against target pests in the supply chain in which the measures are applied.

Research progress on development of several alternatives is given below.

6.5.1 Alternatives for QPS and their effect on product quality

Three potential chemical fumigant alternatives to MB, carbonyl sulfide (COS), methyl iodide (MI) and sulfuryl fluoride (SF), were tested on lemons against California red scale (*Aonidiella aurantii*) and MI and COS were tested on nectarines against codling moth (*Cydia pomonella*) (Aung *et al.* 2001; Aung *et al.* 2004). MI and COS intensified nectarine peel colour, delayed fruit softening, but did not alter overall fruit quality. COS at 80 g m^{-3} resulted in insufficient mortality for quarantine purposes (target: probit 9 level (99.9968%)). MI gave sufficient level of kill at 25 g m^{-3} MI gave 100% red scale mortality on lemons at $\geq$40 g m^{-3} but caused significant fruit injury. Conditioning lemons at 15°C for 3 days before MI fumigation lessened lemon phytotoxicity. Forced aeration on lemons following MI fumigation significantly reduced phytotoxicity compared to 2 h postfumigation aeration. Although SF at ≥ 40 g m^{-3} gave 100% mortality, it resulted in commodity phytotoxicity.

Hot water immersion and irradiation quarantine treatments are used to disinfest lychee (*Litchi chinensis* Sonn.) of fruit flies and other pests before export from Hawaii to the U.S. mainland, avoiding the need for MB treatment. In comparative trials, irradiation at 400 Gy was superior to hot water immersion, 48-49 °C for 20 mins, as a quarantine treatment on the basis of fruit quality (Follett and Sanxter 2003).

6.5.2 *IPM/ systems approaches in lieu of MB fumigation:*

IPM strategies were investigated (Siegel *et al.* 2004) to reduce overwintering populations of navel orangeworm in pistachio orchards, and thereby reduce the need for postharvest MB fumigation, by using insect parasitic nematode treatments in orchards after harvest. Ability of two species of nematodes, *Steinernema carpocapsae* and *Steinernema feltiae*, was investigated to control navel orangeworm, *Amyelois transitella*, in infested pistachios on the ground. *S. carpocapsae* was more effective than *S. feltiae. T*he trials demonstrated that *S. carpocapsae* could play a role in the post harvest control of navel orangeworm.

Gardenia flowers are not allowed entry into the Mainland US from Hawaii without treatment for coffee green scale which is present in Hawaii but absent from the Mainland. Research (Hollingsworth 2001, Hollingsworth and Hara 2000, Anon. 2003) has developed a systems approach for this scale with two components: (1) field certification once per year (gardenia bushes are examined, and if no green scale is found, the field passes and a compliance agreement is signed) and (2) mandatory inspection of the harvested flowers for each shipment.

6.5.3 *Irradiation treatments*

Apples, pears and stone fruit suffer from a variety of pests that are objects of quarantine in some areas. Shipments of these fruits into areas free of these pests are often fumigated with MB as a quarantine measure. The pests include apple maggot, *Rhagoletis pomonella* (Walsh), oriental fruit moth, *Grapholita molesta* (Busck) and plum curculio, *Conotrachelus nenuphar* (Herbst). Irradiation is being researched as a possible alternative quarantine treatment. Irradiation of third instar larvae of apple maggot at 50 Gy completely prevented emergence from the full pupa in apples in both ambient and hypoxic atmospheres (Hallman 2004a). There was no adult emergence from irradiated fifth instar larvae of oriental fruit moth, the most radiotolerant stage present in fruit, after irradiation at 200 Gy in air, but 5.3% emerged when irradiated under hypoxic conditions (Hallman 2004b). With the more tolerant southern strain of plum curculio, a dose of 92 Gy was recommended as a quarantine treatment. At this dose reproduction was prevented. At that dose, oviposition may still occur for up to a week and some of the eggs may hatch, but there is no development beyond the first instar (Hallman 2003).

Irradiation is an alternative to MB fumigation for quarantine control of tephritid fruit flies. Approved irradiation quarantine treatment doses for melon fly, *Bactrocera cucurbitae*, Mediterranean fruit fly, *Ceratitis capitata*, and oriental fruit fly, *Bactrocera dorsalis*, infesting fruits and vegetables for export from Hawaii to the continental U.S. are 210, 225, and 250 Gy, respectively. Irradiation studies were initiated to determine whether these doses could be reduced in order to lower treatment costs, minimise any adverse effects on quality, and support a proposed generic irradiation dose of 150 Gy for fruit flies. Melon fly is the most tolerant of the three species to irradiation. An irradiation dose of 150 Gy applied to large numbers of melon fly late third instars in papayas resulted in no survival to the adult stage, indicating that this dose is sufficient to provide quarantine security. Oriental fruit fly and Mediterranean fruit fly were controlled with irradiation doses of 125 and 100 Gy respectively. Results support a proposed generic irradiation quarantine treatment dose of 150 Gy for all tephritid fruit flies (Follett and Armstrong 2004).

Cryptophlebia illepida (Butler) and *C. ombrodelta* (Lower) (Lepidoptera: Tortricidae) are quarantine pests that attack lychee, longan, rambutan, mangoes and other fruits in Hawaii. Studies were undertaken to determine whether irradiation treatment at 250 Gy, an accepted treatment for disinfestation of fruit flies in tropical fruits from Hawaii, would also control the two *Cryptophlebia* species and avoid the need for MB treatment. It was found that the irradiation quarantine treatment with a minimum absorbed dose of 250 Gy approved for Hawaii's fruit flies will effectively disinfest fruits of any *Cryptophlebia* in addition to fruit flies (Follett 2004a).

Hawaii's sweet potato growers produce several unique varieties of sweet potatoes. They are unable to ship sweet potatoes to the U.S. mainland without a quarantine treatment because of the presence of two regulatory pests: West Indian sweetpotato weevil, *Euscepes postfasciatus* and sweetpotato vine borer, *Omphisa anastomosalis.* Recently growers have been exporting sweet potatoes to the U.S. mainland using methyl bromide fumigation. Preliminary results with adults of the two pests suggest 200-250 Gy may be sufficient to prevent their reproduction. Based in part on results from the early stages of this research, USDA-APHIS published an interim rule (Federal Register, June 26, 2003) allowing interstate movement of sweet potatoes from Hawaii with an irradiation treatment of 400 Gy. Since the rule was published, about 20 tonnes of sweet potatoes per week have been exported from Hawaii to the U.S. mainland with irradiation treatment (Follett 2003a)).

6.5.4 *Heat treatments*

A hot water immersion treatment unit has been designed and constructed to control fruit flies and *Cryptophlebia* in lychee and longan exported to the U.S. mainland. A hot water immersion treatment of 49°C for 20 min is approved for both fruit as an alternative to MB treatment. The unit sits at Kahili Farms on Kauai awaiting certification (Follett 2003b).

The pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), is a polyphagous pest recently introduced to the United States. Vapour heat treatments have been developed against life stages of *M. hirsutus*. Treatment at 47°C required 45 min to kill all *M. hirsutus*, whereas treatment at 49°C required 10 min. The egg stage was the most heat tolerant at 49°C. (Follett 2004c).

6.5.5 *Ozone fumigation*

There is a quarantine requirement for green coffee imported into Hawaii to be fumigated with 48 g m^{-3} methyl bromide for 8 h at ambient conditions to kill any infestations of coffeeberry borer, *Hypothenemus hampei* (Ferrari) and coffee leaf rust, *Hemileia vastatrix* Berk. & Br. These are two of the most destructive pests of coffee production in many regions, but are not found in Hawaii. Ozone fumigation was carried out at 10,000 ppm under -30.5 cm Hg of vacuum at 13°C for 6 h. In preliminary results of tests with coffee berry borer, apparently using these same treatment parameters, there was no survival from large numbers of mixed age test insect assays, indicating that vacuum fumigation will control this pest. (Armstrong et al. 2003).

6.5.6 *Low temperature/brine storage*

Low temperature storage in brine solutions were developed (Yokoyama and Miller 2004) as alternatives to methyl bromide to control olive fruit fly, *Bactrocera oleae* (Gmelin), in olives harvested in infested orchards and transported to areas where processing plants are located. Exposure of olives infested with olive fruit fly larvae for 2 weeks and 3 weeks reduced pupal and adult emergence to <1.0% at 0-1°C and 2-3°C respectively.

6.6 Recapture/recycling

Decisions VII/5(c) and XI/13(7) urge Parties to adopt recovery and recycling technology for MB QPS treatments where technically and economically feasible. Recapture of MB after use in fumigations has been adopted in a number of situations. This has been driven by the need to meet local air quality regulations rather than for protection of the ozone layer.

Small scale fumigations in freight containers or fumigation chambers, typically less than 50m^3 capacity, are carried out in several countries with using charcoal filters to recapture MB after use. The carbon can be reactivated chemically with sodium thiosulphate in the commercially-available Nordiko process with destruction of the methyl bromide (Nordiko 2004). Alternatively it can be disposed of in landfill sites or incinerated.

Large scale use of recapture techniques have not been adopted. In Germany, a recapture technique based on carbon filters was developed for structures of up to 40,000m³, but is no longer available in the market. Similarly, large scale zeolite-based recapture and recovery systems (MBTOC 2002) appear to no longer be available.

Though theoretically possible, recycling technology has not been commercialised. The economics of MB supply favour purchase of new stocks with destruction of recaptured MB over recovery and recycling of recaptured gas.

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7 Refrigeration, AC and Heat Pumps (RTOC) Progress Report

7.1 Domestic Refrigeration

No new alternatives to ODS have emerged which are more energy-efficiency than or cost competitive with conventional vapour-compression refrigeration technology for domestic refrigerator applications. HFC-134a and HC-600a continue as the dominant options for domestic refrigeration applications. Approximately 50% of new global domestic refrigerator production had been converted to HFC-134a by 2000. An additional approximate 25% of new global production had been converted to HC-600a by this same date. Subsequent developments (2000-2004) have maintained this trend with an apparent increase in the percentage of domestic units converting to HC-600a. Large market examples of post-2000 conversions are production in China converting to HFC-134a and HC-600a, production in India converting to either HFC-134a, HC-600a or an HC-600a/HC-190 blend; and some production in Japan converting from HFC-134a to HC-600a. Conversion is expected to continue in an orderly manner and no near-term developments have been identified which could significantly alter the available options.

Retrofit or emission reduction to lessen the service demand has been less effective. The estimated percentage of refrigerators requiring repair of the hermetic sealed system and replacement of the original refrigerant charge sometime during their service life is 10% in Article 5(1) countries and 2% in developed countries. Refrigerators are typically serviced using the refrigerant type selected by their original manufacturer. In more than one-half of the (approximately 1.5 billion) domestic refrigerators in service, the refrigerant in the unit is still CFC-12. Service demand for this refrigerant is normally satisfied with reclaimed or stockpiled material in developed countries. New production CFC-12 is still likely to be the lowest cost alternative in Article 5(1) countries. CFC-free blends have been specifically developed to satisfy service demand. The use of these blends will become significant only when CFC-12 availability is limited.

7.2 Commercial refrigeration

HCFC-22 market trends

The trends are similar to those presented in the 2002 RTOC Assessment Report, but some issues need an analysis from a new perspective.

HCFC-22 is still massively used in the commercial refrigeration sub-sector in the United States. Owing to the United States phase-down schedule for HCFC-22, possible shortages of this refrigerant for servicing needs may occur by 2008.

The high economic growth in China has had a tremendous impact on HCFC-22 use in commercial refrigeration (apart from the use in unitary A/C) and a significant increase of production is forecast for Article 5(1) countries within the next 10 years.

Owing to the current low price of the refrigerant HCFC-22, there are no real drivers for refrigerant recovery, i.e. the economic incentive for recovery and recycling does not play a significant role.

Non-HFC options

Some of the global food and beverage companies –conspicuously Coca Cola, McDonald's and Unilever-- are now seeking non-HFC alternative technologies or alternative refrigerants to HFCs. Significant development work has been undertaken by these companies for efficient and HFC-free vending machines, walk-in coolers and ice-cream freezers. The refrigerants competing for the replacement of HFCs are HCs and CO_2. In the case of some companies, the (current ASTM/ building code) HC charge limit of 150 g is taken as the threshold. New developments for small CO_2 systems are expected. The Stirling technology has been thoroughly tested for refrigeration capacities between 200 and 300 W, and it has been shown to be competitive in terms of energy efficiency compared to baseline vapour compression systems.

Indirect systems

For large capacity systems (from 25 kW up to several hundreds kW), for medium size supermarkets up to large hyper-markets, the continuing trend is to install prototype installations as secondary loop systems. For low temperature systems CO_2 used as a heat transfer fluid is considered to be a potential candidate, either in the liquid phase or in two-phase flow (liquid and vapour).

For medium temperatures, the "classical" solutions using water-glycol or other water-based heat transfer fluids are still the most widely used options.

A number of developments are underway aimed at optimising secondary loop systems that should be at least as efficient as the reference direct system.

Leak tightness and containment

Some sales companies are making progress in lowering the average emission rates (servicing needs), which are still in the range of 20 to 25% for many supermarkets and in the range of 25% for hyper-markets. The servicing needs are (still) largely covered by both HCFCs and HFCs.

7.3 Large size refrigeration (industrial, cold storage and food processing)

The current technical options have changed particularly in low temperature applications with CO_2 as heat transfer fluid. Where it concerns refrigerant developments, there has been an increase of indirect systems to reduce the charge of NH_3 systems since the publication of the 2002 Assessment report.

Several research activities have continued in the United States, Japan and Europe on CO_2 as refrigerant and on CO_2 oils. New industrial systems and concepts have been developed --particularly with low charge NH_3 systems and for CO_2 systems. In 2004, new compressor designs were introduced, equipped for CO_2 at discharge pressures of 40 to 60 bar, for the defrosting of evaporators. Some efforts have been made to develop CO_2 heat pumps for industrial customers in Japan, driven by the high energy cost.

Mainly in Europe and Japan strong efforts have been undertaken to develop standard cascade systems based on CO_2 and NH_3; the technology has been introduced to the market in 2004. Below temperatures of –35 to –45°C, depending on the system size, CO_2 has been used as refrigerant. At higher temperatures CO_2 has been used as a heat transfer fluid.

The CO_2 technology has been introduced in small and large scale systems with cooling capacities up to 5 MW in the United States, Japan and Europe. Most new CO_2 systems are appearing in The Netherlands, due to financial governmental support.

CO_2 as a refrigerant and as a heat transfer fluid has become the current state of the art in new systems in Europe.

Some systems have been retrofitted from HCFC-22 to CO_2 or to brine systems, mainly in the cold storage sub-sector. The trend towards small NH_3 charges has increased, even in industrial refrigeration systems. Some efforts have been made with HCs with limited market penetration. In a number of new systems, R-410A has been applied as the low temperature refrigerant.

7.4 Transport Refrigeration

The Transport Refrigeration sector of the RTOC 2002 Assessment Report contained the sub-sectors (a) reefer ships, (b) intermodal refrigerated containers, (c) road- and rail transport, (d) refrigeration and air-conditioning on merchant marine, and (e) air-conditioning in railcars.

In general, there has been no significant change in technical options since the 2002 Assessment (to date) in these sub-sectors.

The volume of refrigerated sea transport on reefer ships and porthole containers is decreasing, while their main refrigerant continues to be HCFC-

22; this is also the predominant refrigerant on the fishing fleets world-wide. With an increasing volume of intercontinental refrigerated transport, transport in intermodal refrigerated containers is increasing substantially. Suitable container ships have been built well beyond the replacement needs, and a shortage on the market for refrigerated containers can be observed. Concerning system design, new HFC systems are increasingly used for container cooling, while the current systems are usually equipped with scroll compressors.

Refrigerated transport by rail has been technologically upgraded in some countries, especially in the United States. Here, the existing railcar fleets are replaced by larger railcars and vapour compression refrigeration systems based on current road trailer systems. These systems typically utilise non-ODS refrigerants. Regarding the air conditioning in rail cars and trains, not much has changed compared to earlier reports. In the latter application, i.e. in new high speed European trains, both air and CO_2 are under consideration as refrigerants.

In industrialised systems new road transport refrigeration systems largely use HFCs as working fluids. Research is increasing on CO_2 systems, but it is unclear if sufficiently reliable and cost-effective solutions can be developed to allow full scale commercialisation. Alternative systems using hydrocarbon refrigerants are commercially available in Europe but use is restricted.

In general, it can be stated that chlorine containing refrigerants are increasingly substituted by HFCs in all sub-sectors of refrigerated transport.

7.5 Unitary Air Conditioning

Since the publication of the RTOC 2002 Assessment Report, only incremental change has occurred in the state of the technical options, including the continued penetration of HFC technologies into the markets of the developed countries and the significant growth in HCFC-22 usage in China.

In Japan, the air conditioning manufacturers are well advanced in the transition to non-ODP technologies in new equipment. Japanese manufacturers are almost exclusively using HFCs in their transition strategy. They are using both R-407C and R-410A to replace HCFC-22. Initially several types of products were converted from HCFC-22 to R-407C because this required minimal product redesign. A recently observed trend is the conversion of R-407C products to R-410A to obtain both additional size and cost reductions.

Rapid growth in air conditioner production in China (primarily ductless splits and window room air conditioners) is significantly increasing China’s use of HCFC-22. Approximately 34 million units were produced in 2003 (window and ductless splits).

In the United States, the shift to non-ODP technologies in unitary products has been occurring only slowly. Most US manufacturers have introduced residential (7 to 15 kW) ducted products using R-410A. In 2001, approximately 7% of the HCFC-22 usage has been replaced by HFC refrigerants. The penetration of non-HCFC technologies is expected to increase significantly between now and 2006, as manufacturers redesign their residential ducted products to meet new minimum efficiency standards, which go into effect in January 2006.

In Europe, the transition away from HCFC refrigerants is occurring at a much faster pace as a result of regulations requiring an accelerated phase-out. HCFCs have mainly been replaced by HFC technologies, with a minority by hydrocarbon technologies.

Research has continued on other non-ODP technologies and refrigerants -- particularly CO_2. At this time none of the other technologies and refrigerants have been commercialised in air conditioning products.

7.6 Chiller air conditioning (see also Task Force report)

Centrifugal chiller conversions from CFC-11 and CFC-12 to HCFC-123 and HFC-134a continue to take place (with inherent low leakage of refrigerants). Moreover, screw compressors continue to displace reciprocating compressors in new chiller products ranging in capacity from 140 kW to 700 kW. Screw compressors are also displacing centrifugal compressors in new chiller products in capacities up to about 2275 kW. The refrigerant used in new screw chillers is moving to HFC-134a although HCFC-22 chillers are still being manufactured. In the capacity range from 7 to about 100 kW, scroll compressors are being used to an increasing extent compared to reciprocating compressors. The refrigerants used are HCFC-22 and R-407C. A transition to R-410A has begun in new chillers in this capacity range.

A 2004 assessment of existing CFC chillers indicates that there are 36,800 CFC chillers still in service in the U.S.A. Approximately 30,000 CFC chillers are estimated to remain in operation elsewhere, including in the Article 5(1) countries. These chillers are mainly centrifugal chillers operating with CFC-11 refrigerant. Conversion of existing CFC chillers to use other non-CFC refrigerants has nearly stopped because almost all good candidates for conversion have been converted (less than 1% of the existing stock is still retrofitted each year in the United States). If a CFC chiller is taken out of service now, replacement by a non-CFC chiller (mostly HCFC or HFC chiller) is the common choice.

The number of CFC chillers in Article 5(1) countries has been rather stable after the phase-out in manufacturing in the mid-nineties. Most chillers have been kept in operation. Of course, since 1993-1995, non-CFC chillers are increasingly being installed in the Article 5(1) countries as well. CFC chiller replacement programs involving grants and revolving funds are getting more and more attention. The installed base of CFC chillers (status 2002-2003) has been recently estimated at 15,000 in all Article 5(1) countries; further information can be found in the Chiller Task Force report, part of the TEAP 2004 Progress Report.

Water-Heating Heat Pumps

Water-heating heat pump markets are growing, in part due to their use in low-energy buildings designed to use low-temperature heating systems (e.g., radiant floor heating). In Europe, comfort heating dominates heat-pump markets - mostly systems with hydronic distribution using outside air or the ground. In addition, use is increasing to recover heat from the exhaust air stream and use it to preheat ventilation air. Heat pumps for combined comfort heating and domestic hot water (DHW) are common in some European countries.

Heat pumps for comfort heating have capacities up to 30 kW. Supply temperatures are 35^0-45^0 C for new construction and 55^o- 65^o C for retrofit. Small capacity (10 -30 kW) air-to-water heat pumps are popular in China and Japan, as well as in Italy, Spain, and other southern European countries for residential and light commercial use in combination with fan-coil units.

In developed countries HCFC-22 still is used as one of the main refrigerants in heat pumps but manufacturers have begun to introduce HFC alternatives (HFC-134a, R-407C, R-404A) to replace their HCFC-22 models.

Sales of water-heating heat pumps were small around the world prior to 1995 but have increased steadily since that time. The installed base of ground-source heat pumps was estimated by the IEA to be 110,000 units in 1998. The Swedish Energy Agency estimates that over 300,000 heat pumps are in operation there, a small portion of which are air-air. The application of heat pumps is China is increasing quickly, reaching 35,000 units in 2002. Sales increased due to nation-wide housing projects where preference is for hydronic systems. More than half of the sales volume is for units less than 30 kW capacity.

7.7 Vehicle Air Conditioning

Vehicles (cars, trucks, and buses) built before the mid-1990's used CFC-12 as the refrigerant. Since 1994, new vehicles with A/C have been equipped with HFC-134a. As a result, HFC-134a has now replaced CFC-12 as the globally accepted mobile A/C (MAC) refrigerant and the industry is busy expanding global production to meet the increasing demand. By 2008, most vehicles built with CFC-12 air conditioning will have been retired, with almost all vehicles then on the road expected to be using HFC-134a; the transition from CFC-12 will be complete.

Due to concerns about HFC-134a global warming emissions from MAC systems, vehicle makers and their suppliers are reducing their system leakage and improving energy efficiency, and are searching for a replacement refrigerant. Since 1998, the leading potential replacement refrigerant has been carbon dioxide (R-744) for which several global vehicle manufacturers and suppliers have demonstrated prototype cars. Recently, the use of HFC-152a (with a global warming potential less than one-tenth that of HFC-134a) has been proposed and publicly demonstrated in prototype vehicle systems. It has been commercialised for large trucks, off-roads and mining equipment. Further development activities for both potential replacement refrigerants are ongoing.

On-site recycling of refrigerant at service shops has been proven to be quite effective for HFC-134a systems; a full 60% of the original charge can be recycled and reused during service. Combining this with service frequency scenarios allows an estimation of the current and future refrigerant emissions from MAC systems. Such emission estimates can be useful when calculating the cost benefit analysis of proposed changes.

7.8 Refrigerant containment

Refrigerant conservation has shown significant improvement since the last assessment. New stationary HFC systems can now be systematically designed and maintained in order to obtain low emission rates.

To reduce the direct emissions, the automotive industry started to improve the design of HFC-134a mobile A/C systems in order to reach a leak rate level below 20 g per year.

Furthermore, a number of countries have started to implement regulations related to recycling at end of life, especially for used domestic appliances and used cars, which includes recovery of refrigerant. Where it relates to recovery, via an increasing number of national policies systems are put in place to finance recovery schemes, often HFC recovery. In general, more and more governments are implementing various policies in order to make leak tightness controls mandatory and in order to certify personnel, which handles refrigerants.

8 TEAP Response to Decision XV/7: Review of New Process Agent Applications

Requests to add new Process Agent Applications have been presented to UNEP by Argentina, The Democratic People´s Republic of Korea, Israel, Romania, United Kingdom and the USA.

Due to the fact that the new CTOC is still being organised, TEAP set up a Task Force formed by Dr. Nick Campbell, Mr. J.G.W Porre, Mr. Jose Pons, Dr. Ian Rae and Dr. Masaaki Yamabe.

The work of this Task Force will be included in the September TEAP Report prior to the MOP-16.

9 Military Uses

The Special Circumstances of Military Uses

ODS will continue to be necessary for the safe and effective operation of a wide range of military systems until those systems are retired from service, possibly through the middle of the 21st century. EUEs for this purpose can be avoided only if all Parties take steps to either meet the necessary demand for ODSs through banking and recycling or modify the equipment—often at great cost—to operate without ODSs.

At the time the Montreal Protocol was signed in 1987, most military systems in developed countries and most in the developing countries relied on ODS for their manufacture, maintenance and operation. Today, the technical need for those ODS has been virtually, but not totally, eliminated for new systems. Some legacy systems continue to rely on ODSs for fire protection, air conditioning, and refrigeration. The pace and magnitude of technical changes made by global military organisations since 1987 to eliminate dependence on ODS is unprecedented. The degree of success by developed (non-Article 5(1) countries) in complying with the requirements of a global environmental treaty is also unprecedented.

The time scales for the development, production and operational life for military systems is far longer than the time provided for ODS phaseout by the Montreal Protocol. While some systems have been successfully modified during their operational lives to eliminate the need for ODS, the technical and economic hurdles to phaseout ODS use for others have so far proven insurmountable in both developed and developing countries.

Many of these systems and their ODS uses were documented at four global workshops held between 1991 and 2001 on the role of the military in implementing the Montreal Protocol: Williamsburg Virginia (September 1991), Brussels (January 1994), Herndon Virginia (November 1997) and Brussels (February 2001). The 2001 Brussels workshop involved one hundred and sixty senior military officers, environmental authorities, technical experts, and environmental NGOs from 33 countries.

Some of these military applications, such as the use of halon in aircraft applications, are identical to commercial applications. Others are unique to the military; such as the use of halon in crew compartments of ground combat vehicles. In the Halon Technical Options reports, military experts provided detailed descriptions of weapons system applications for halons that would persist beyond the 1994 phaseout, and predicted new halon production would not likely be necessary provided existing inventories of halon could be managed in a way that made them available for on-going military requirements. These estimates and predictions made by HTOC remain valid today.

The military has made great strides in eliminating CFCs from shipboard refrigeration systems. For example, as of January 2004 the United States has:

- converted 796 of its 898 CFC-12 air conditioning and refrigeration plants to HFCs, making 231 of its ships free of CFC-12
- converted 107 of a total 424 CFC-114 air conditioning plants, making 25 ships free of CFC-114.

These conversions have eliminated approximately 135 tonnes of CFC refrigerants and are estimated to result in the elimination of over 230 metric tonnes of CFCs by the time the program completes at the end of 2012. The conversions also improved the energy efficiency of the plants by about 15 per cent, reducing fossil fuel consumption and carbon emissions.

The current military situation can be summarised as follows:

1. There has been significant progress in eliminating ODSs from new military equipment.

2. In some important applications, such as aerospace and aviation, the military has made more progress than comparable commercial uses. The first aircraft produced since the Montreal Protocol with a halon replacement for engine nacelle fire protection was a military aircraft.

3. There has been continuous progress in developing alternatives and replacements to military uses of ODS in existing equipment and maintenance, and many of the alternatives currently used commercially in the areas of solvents, halons and refrigeration were developed and validated through co-operative efforts between military organisations and commercial partners.

4. Military organisations have made significant investments in converting systems where possible to use ODS alternatives. This is particularly true in shipboard refrigeration plants, which were designed to use CFC-114 and are being converted to HFC or HCFC replacement refrigerants.

5. Most developed countries have strategies in place to re-deploy the recovered and recycled ODSs to the service of equipment not yet retrofit, and to ultimately halt use altogether. Some developed countries have created halon banks and other stockpiles to assure the continuing supply of ODSs for mission-critical uses.

6. Some technically feasible non-halon fire protection systems for aircraft are heavier than the halon systems they replace, with implications for greater fuel use, increased greenhouse gas emissions, and decreased air quality.

7. Developing countries have many of the same uses of ODSs, but few have reported phaseout efforts beyond gradual elimination as equipment dependent on ODSs is upgraded or scrapped. Parties can anticipate applications to the MLF as the Article 5(1) country phaseout continues and investment criteria (cost per ODP kg eliminated) are increased to address the most difficult applications. The MLF can help in reducing the A5 Parties demand for ODSs for military use by transferring technical information on alternative technology from the appropriate non-A5 countries.

8. It is possible that military organisations in non-Article 5(1) countries, CEIT, and Article 5(1) countries will come to depend on Emergency and Essential Use Nominations in cases of both unanticipated and un-financed needs.

10 TEAP/TOC Organisation and Reorganisation

10.1 TEAP Operation – New TOC Created

TEAP wishes to express its sincere appreciation for the many significant contributions of Gary Taylor who is retiring from TEAP. Gary Taylor is a founding member of TEAP and the Halon Technical Options Committee and was Co-Chair of the TEAP Process Agent Task Force. He earned the 1990 U.S. EPA Stratospheric Ozone Protection Award, the 1995 UNEP Global Ozone Award, the 1997 U.S. EPA Best-of-the-Best Stratospheric Protection Award, and the 2003 David Ball Award for Fire and the Environment.

TEAP also expresses its gratitude to the expert members of the Solvents, Coatings, and Adhesives Technical Options Committee and its latest Chairs Ahmad Gaber and Mohinder Malik and to members of the Aerosol Products Technical Options Committee who have been instrumental in the sector phaseout progress that allows TEAP to further consolidate its Technical Options Committees. It is a badge of honour for these sector experts to be first to complete the TOC work in assessing and verifying the technically and economically feasible alternatives that are available. Smaller teams of experts from these sectors will be consolidated in the new CTOC in order to update information.

In 2004, TEAP completed the organisation of the "Chemicals Technical Options Committee" (CTOC) to integrate topics including process agents and feedstocks, destruction, laboratory and analytical uses, non-medical aerosol products, solvents, and CTC. TEAP member Dr. Masaaki Yamabe (Japan) will be one of three Co-Chairs. Other Co-Chairs will be selected from those experts who will be integrated into the CTOC from the current Solvents and Aerosol Product TOCs and the latest Process Agents and Destruction Task Forces and from new nominations recruited or nominated by Parties.

TEAP is looking for qualified nominations for TEAP and all its TOCs. There is a particularly urgent need for agricultural pest control practitioners and agricultural economists for the Methyl Bromide Technical Options Committee and for chemist and/or chemical engineers and laboratory and analytical experts for the new CTOC. There are many openings for qualified experts including openings for Co-Chairs of the CTOC and HTOC. Nominations of experts from Article 5(1) countries are particularly welcome.

TEAP has endorsed the HTOC selection of Dr. Daniel Verdonik and David Catchpole as interim Co-Chairs of the Halons Technical Options Committee to replace Gary Taylor who is resigning from TEAP in 2004, Dr. Walter Brunner who resigned from TEAP at the end of 2003, and Dr. Barbara Kucnerowicz-Polak who stepped down from Co-Chair to HTOC member in

2002. Permanent Co-Chairs are sought from within the existing HTOC and from new nominations.

Dr. Jonathan Banks is retiring at the end of 2004 from TEAP and the position of Co-Chair of MBTOC but will remain a member of MBTOC. Interim replacements for Dr Banks are under consideration. An ad-hoc committee of the Parties, including 12 representatives each from Article 5(1) and non-Article 5(1) Parties, will assist TEAP in these MBTOC reorganisation efforts.

In 2004, TEAP will continue to recruit experts on the topics of greatest importance to Parties and will continue its reorganisation to focus on sectors where technologies are still rapidly evolving. The Methyl Bromide Technical Options Committee will be strengthened further for consideration of nominations for Critical Use Exemptions with particular emphasis on assessing the development, demonstration, registration and deployment of technical options and the economics of implementation. The Foams and Refrigeration/AC Technical Options Committees will be strengthened in preparation for assessing the rapid introduction of alternatives to HCFCs for the Assessment Report in 2006.

11 Confidential Business Information

Paragraph 2 of Decision XV/5 requests that non-Article 5 Parties identify in their nominations for essential use exemptions for chlorofluorocarbons (CFCs) for metered-dose inhalers "for each nominated use, the active ingredients, the intended market for sale or distribution and the quantity of CFCs required." Paragraph 3 requests that the Technology and Economic Assessment Panel (TEAP) and its Technical Options Committee on aerosols (ATOC) make recommendations on nominations with reference to the information identified above.

With the exception of salbutamol (albuterol), which is available either as a branded or as a generic product, most of the active ingredients involved in nominations are associated with specific brand-name products made by individual companies. For this reason among others, some pharmaceutical companies requested that identified information related to Decision XV/5 be considered as "confidential business information" that will be available to appropriate members of the Ozone Secretariat and TEAP with the understanding that it will not be made public.

Therefore, TEAP agreed to treat such information as commercially sensitive, to allow access to the information by TEAP and ATOC members on a need-to-know basis and to endeavour to ensure that the information is used only for purposes of evaluating essential use nominations and not further distributed without permission of the nominating Party. Published reports of TEAP and ATOC make reference only to aggregate salbutamol/albuterol and non-salbutamol/albuterol requests (that is, non-company specific data) in communicating with the Parties and the general public in presentations, correspondence, recommendations, reports, or other formats.

Because this commercially sensitive information was not needed in 2004 to assess the essential use nominations for the production of MDIs, only TEAP and ATOC Co-Chairs reviewed the data.

TEAP requests that the Meeting of the Parties instruct Parties to only submit such information via registered mail services and not by Internet, where accidental distribution is more likely.

TEAP requests that Parties revise TEAP's Terms of Reference appropriately to:

Prohibit any TEAP/TOC member from revealing outside the TEAP/TOCs any information given by a Party on the basis of confidentiality and to encourage the members to protect the confidentiality to the best of their ability.

Instruct TEAP/TOCs to prepare their reports in a manner not to reveal any information given to them on the basis of confidentiality.

If TEAP/TOC considers that they cannot prepare a report without revealing the whole or part of the confidential information, they should inform the Party of this fact. In this way the Party has the choice between:

- having TEAP prepare its report without the benefit of the confidential information, or
- relaxing confidentiality of the whole, or part of the information.

12 TEAP and TOC Membership Information

12.1 TEAP Member Biographies

The following contains the background information for all TEAP members as at May 2004.

Dr. Radhey S. Agarwal
(Refrigeration TOC Co-chair)
Professor of Mechanical Engineering
Mechanical Engineering Department
Indian Institute of Technology, Delhi
India- New Delhi - 110016
Telephone: 91 11 2659 1120 (O), 2658 2160 (R)
Fax: 91 11 2652 6645
E-Mail: rsarwal@mech.iitd.ernet.in

Radhey S. Agarwal, Co-chair of the Refrigeration, Air-conditioning, and Heat Pumps Technical Options Committee, is the Professor of Mechanical Engineering at the Indian Institute of Technology (IIT Delhi), Delhi, India. IIT Delhi makes in-kind contribution for wages. Costs of travel, communication, and other expenses related to participation in the TEAP and its Refrigeration TOC are paid by UNEP's Ozone Secretariat.

Dr. Stephen O. Andersen
(Panel Co-chair)
Director of Strategic Climate Projects
Atmospheric Pollution Prevention Partnerships Division
United States Environmental Protection Agency
Ariel Rios Building
Mail Code 6201J
1200 Pennsylvania Avenue, NW
Washington, DC 20460
U.S.A.
Telephone: 1 202 343 9069
Fax: 1 202 343 2203
E-Mail: andersen.stephen@epa.gov

Stephen O. Andersen, Co-chair of the Technology and Economic Assessment Panel, is Director of Strategic Climate Projects in the Climate Protection Partnerships Division of the U.S. Environmental Protection Agency, Washington, D.C., USA. The U.S. EPA makes in-kind contributions of wages, travel, communication, and other expenses. With approval of its government ethics officer, EPA allows expenses to be paid by other governments and organisations such as the United Nations Environment Programme (UNEP).

Mr. Paul Ashford
(Foams TOC Co-chair)
Principal Consultant
Caleb Management Services Ltd.
Grovelands House
Woodlands Green, Woodlands Lane
Almondsbury, Bristol BS32 4JT
United Kingdom
Telephone: 44 1454 610 220
Fax: 44 1454 610 240
Mobile: 44 7774 110 814
E-Mail: Paul@Calebgroup.net

Paul Ashford, Co-chair of the Rigid and Flexible Foams Technical Options Committee is the principal consultant of Caleb Management Services. He has over 20 years direct experience of foam related technical issues and is active in several studies informing future policy development for the foam sector. His funding for TEAP activities, which includes professional fees, is provided under contract by the Department of Trade and Industry in the UK. Other related non-TEAP work is covered under separate contracts from relevant commissioning organisations including international agencies (e.g. UNEP DTIE), governments and trade associations.

Dr Jonathan Banks
(Methyl Bromide TOC Co-chair)
Grainsmith Pty Ltd
10 Beltana Rd
Pialligo ACT 2609
Australia
Telephone: 61 2 6248 9228
Fax: 61 2 6248 9228
E-Mail: apples3@bigpond.com

Jonathan Banks, Co-chair of the Methyl Bromide Technical Options Committee, is a private consultant. He serves on some national committees concerned with ODS and their control; he receives contracts from UN agencies and other institutions related to methyl bromide alternatives and grain storage technology, including fumigation technology. His funding for TEAP and MBTOC activities is through grants from the Department of Environment and Heritage, Australia and from UNEP.

Dr. Lambert Kuijpers
(Panel Co-chair, Refrigeration TOC Co-chair)
Technical University Pav A58
P.O. Box 513
NL – 5600 MB Eindhoven
The Netherlands
Telephone: 31 49 247 6371 / 31 40 247 4463
Home: 31 77 354 6742
Fax: 31 40 246 6627
E-Mail: lambermp@wxs.nl, lambermp@planet.nl

Lambert Kuijpers, Co-chair of the Technology and Economic Assessment Panel and Co-chair of the Refrigeration, Air-conditioning and Heat Pumps Technical Options Committee, is based in Eindhoven, The Netherlands. He is supported (through the UNEP Ozone Secretariat) by the European Commission and The Netherlands government; this has been continued for the years 2003/2004. It applies to all his activities related to the TEAP and the TOC Refrigeration (including the IPCC/TEAP Special Report); it concerns in-kind contributions for wages and travel expenses. UNEP also funds administrative costs on an annual budget basis. In addition to activities at the Department "Technology for Sustainable Development" at the Technical University Eindhoven, other activities include consultancy to governmental and non-governmental organisations, such as the World Bank, UNEP DTIE and the French Ecoles des Mines, for activities related to estimating inventories and emissions of ODS and alternatives. Dr. Kuijpers is also an advisor to the Re/genT Company, Netherlands (R&D of components and equipment for refrigeration, air-conditioning and heating).

Mr. Tamás Lotz
(Senior Expert Member)
National Directorate of Environment, Nature and Water
Aga utca 4
1113 Budapest
Hungary
Telephone: 36 1 457 3563
Fax: 36 1 201 3056
E-Mail: lotz@mail.kvvm.hu

Tamas Lotz, Senior Expert Member, is a consultant on air pollution abatement in the National Directorate of Environment, Nature and Water in Budapest, Hungary. He was one of the authors of the Hungarian Country Programme for the phase-out of ODS. Travel and per diem costs are covered by UNEP, and communication costs are an in-kind contribution by the National Directorate of Environment, Nature and Water.

Prof. Nahum Marban-Mendoza
(Methyl Bromide TOC Co-chair)
Coordinator, Crop Protection Graduate Programme
Professor
Dept de Parasitologia Agricola
Universidad Autonoma Chapingo
Chapingo, CP 56230, Edo de Mexico
Mexico
Telephone: 52 595 954 1646
Fax: 52 595 954 1608
Home: 52 55 56 56 2067
E-Mail: nahumm@correo.chapingo.mx

Nahum Marban-Mendoza, Co-chair of the Methyl Bromide Technical Options Committee, is a full-time professor of Integrated Pest Management and Plant Nematology at the Universidad Autonoma Chapingo in the graduate programme of crop protection. He has over 25 years experience in the research and development of non-chemical alternatives to control plant parasitic nematodes associated with different crops in Central America and Mexico. Prof. Marban-Mendoza has been funded by both private and government funds; occasionally he receives funds for wages and travel. The communication costs related to MBTOC activities and the costs of travel and other expenses related to participation in TEAP and TOC meetings are paid by the UNEP Ozone Secretariat.

Mr. E. Thomas Morehouse
(Senior Expert Member)
Institute for Defense Analyses
4850, Mark Center Drive
Alexandria, VA 22311
U.S.A.
Telephone: 1 703 750 6840
Fax: 1 703 750 6835
E-Mail: tom.morehouse@verizon.net

Thomas Morehouse, Senior Expert Member for Military Issues, is a Researcher Adjunct at the Institute for Defense Analysis (IDA), Washington D.C., USA. IDA makes in-kind contributions of communications and miscellaneous expenses. Funding for wages and travel is provided by grants from the Department of Defense and the Environmental Protection Agency. IDA is a not-for-profit corporation that undertakes work exclusively for the US Department of Defense. He also occasionally consults to associations and corporate clients.

Mr. Jose Pons Pons
(Panel Co-chair, Aerosol Products TOC Co-chair)
Spray Quimica C.A.
Urb.Ind.Soco
Calle Sur #14
La Victoria 2121, Edo Aragua
Venezuela
Telephone: 58 244 3223297 or 3214079 or 3223891
Fax: 58 244 3220192
E-Mail: joseipons@telcel.net.ve

Jose Pons Pons, Panel Co-chair and Co-chair Aerosol Products Technical Options Committee, is President, Spray Quimica, La Victoria, Venezuela. Spray Quimica is an aerosol filler who produces its own brand products as well as does contract filling for third parties. Spray Quimica makes in-kind contributions of wage and miscellaneous and communication expenses. Costs of Mr. Pons' travel are paid by the Ozone Secretariat.

Prof. Miguel W. Quintero
(Foams TOC Co-chair)
Professor of Chemical Engineering
Universidad de Los Andes
Carrera 1a, no 18A-70
Bogota
Colombia
Telephone: 57 1 339 4949, Ext. 3888
Fax: 57 1 332 4334
E-Mail: miquinte@uniandes.edu.co

Miguel W. Quintero, Co-chair of the Foams Technical Options Committee, is professor at the Chemical Engineering Department at Universidad de los Andes in Bogota, Colombia, in the areas of polymer processing and transport phenomena. Mr. Quintero worked 21 years for Dow Chemical at the R&D and TS&D departments in the area of rigid polyurethane foam. His time in dealing with TEAP and TOC issues is covered by Universidad de los Andes and costs of travel and other expenses related to participation in TEAP and TOC meetings are paid by the Ozone Secretariat.

Mr. K. Madhava Sarma
(Senior Expert Member)
AB50, Anna Nagar,
Chennai 600 040
India
Telephone: 91 44 2626 8924
Fax: 91 44 5217 0932
E-mail: sarmam@vsnl.net

K. Madhava Sarma retired in 2000, after nine years as Executive Secretary, Ozone Secretariat, UNEP. Earlier, he was a senior official in the Ministry of Environment and Forests (MOEF), Government of India and held various senior positions in a state government in India. He works occasionally as a consultant to UNEP and is an unpaid member of the Technical and Finance Committee, MOEF, Government of India. The Ozone Secretariat pays the costs in connection with his travels for the TEAP.

Mr. Gary M. Taylor (Resigns from TEAP as of 30 June 2004)
(Halons TOC Co-chair)
Taylor/Wagner Inc.
3072 5th Line
Innisfil, Ontario L9S 4P7
Canada
Telephone: 1 705 458 8508
Fax: 1 705 458 8510
E-Mail: Gtaylor@taylorwagner.com

Gary Taylor, Co-chair of the Halon Technical Options Committee (HTOC), member of the TEAP and Co-chair of the PATF is a principal in the consulting firm Taylor/Wagner Inc. Funding for participation by Mr. Taylor on the HTOC is provided by the Halon Alternatives Research Corporation (HARC). HARC is a not-for-profit corporation established under the United States Co-operative Research and Development Act.

Dr. Helen Tope
(Aerosol Products TOC Co-chair)
Atmosphere and Energy Unit
EPA Victoria
GPO Box 4395QQ
Melbourne, Victoria 3001
Australia
Telephone: 61 3 9695 2637
Fax: 61 3 9695 2578
E-Mail: helen.tope@epa.vic.gov.au

Helen Tope, Co-chair Aerosol Products Technical Options Committee, is a senior policy officer, EPA Victoria, Australia. EPA Victoria makes in-kind contributions of wage and miscellaneous expenses. The Ozone Secretariat provides a grant for travel, communication, and other expenses of the Aerosols Products Technical Options Committee out of funds given to the Secretariat unconditionally by the International Pharmaceutical Aerosol Consortium (IPAC). IPAC is a non-profit corporation.

Prof. Ashley Woodcock
(Aerosol Products TOC Co-chair)
North West Lung Centre
South Manchester University Hospital Trust
Manchester M23 9LT
United Kingdom
Telephone: 44 161 291 2398
Fax: 44 161 291 5020
E-Mail: Ashley.A.Woodcock@man.ac.uk

Ashley Woodcock, Co-chair Aerosol Products Technical Options Committee, is a Consultant Respiratory Physician at the NorthWest Lung Centre, Wythenshawe Hospital, Manchester, UK. Prof. Woodcock is a full-time practising physician and Professor of Respiratory Medicine at the University of Manchester. The NorthWest Lung Centre carries out drug trials of CFC-free MDIs and DPIs for pharmaceutical companies (for which Prof. Woodcock is the principal investigator). Prof. Woodcock has received support for his travel to educational meetings and occasionally consults for several pharmaceutical companies. Wythenshawe Hospital makes in-kind contributions of wages and communication and the UK Department of Environment, Food and Rural Affairs sponsors travel expenses in relation to Prof. Woodcock's Montreal Protocol activities.

Mr. Masaaki Yamabe
(Senior Expert Member)
National Institute of Advanced Industrial Science and Technology (AIST)
1-1-1 Umezono, Tsukuba
Ibaraki 305-8568
Japan
Telephone: 81 29 862 6031
Fax: 81 29 862 6048
E-Mail: m-yamabe@aist.go.jp

Masaaki Yamabe is research coordinator (Environment and Energy) at the AIST. He was a member of the Solvents TOC during 1990-1996. AIST pays wages, travelling and other expenses.

Prof. Shiqiu Zhang
(Senior Expert Member)
Centre for Environmental Sciences
Peking University
Beijing 100871
The People's Republic of China
Telephone: 86 10-627-64974
Fax: 86 10-627-51927
Email: zhangshq@ces.pku.edu.cn

Ms. Shiqiu Zhang, Senior Expert Member for economic issues of the TEAP, is a Professor at the Centre for Environmental Sciences of Peking University. UNEP's Ozone Secretariat pays travel costs and daily subsistence allowances, communication and other expenses.

12.2 TEAP-TOC Membership Lists

2004 Technology and Economic Assessment Panel (TEAP)

Co-chairs	Affiliation	Country
Stephen O. Andersen	Environmental Protection Agency	US
Lambert Kuijpers	Technical University Eindhoven	Netherlands
Jose Pons Pons	Spray Quimica CA	Venezuela

Senior Expert Members	Affiliation	Country
Tamás Lotz	Consultant to the Ministry for Environment and Water	Hungary
Thomas Morehouse	Institute for Defense Analyses	US
K. Madhava Sarma	Consultant	India
Masaaki Yamabe	National Institute of Advanced Industrial Science and Technology	Japan
Shiqiu Zhang	Peking University	China

TOC Chairs	Affiliation	Country
Radhey S. Agarwal	Indian Institute of Technology Delhi	India
Paul Ashford	Caleb Management Services	UK
Jonathan Banks	Consultant	Australia
Nahum Marban Mendoza	Universidad Autonaoma Chapingo	Mexico
Miguel Quintero	Universidad de los Andes	Colombia
Gary Taylor	Taylor/Wagner Inc.	Canada
Helen Tope	EPA, Victoria	Australia
Ashley Woodcock	University Hospital of South Manchester	UK

TEAP Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee (ATOC)

Co-chairs	Affiliation	Country
Jose Pons Pons	Spray Quimica CA	Venezuela
Helen Tope	EPA Victoria	Australia
Ashley Woodcock	University Hospital of South Manchester	UK

Members	Affiliation	Country
D. D. Arora	Tata Energy Research Institute	India
Paul Atkins	Oriel Therapeutics	USA
Olga Blinova	Russian Scientific Center “Applied Chemistry”	Russia
Nick Campbell	Atofina SA	France
Hisbello Campos	Centro de Referencia Prof. Helio Fraga, Ministry of Health	Brazil
Christer Carling	AstraZeneca	Sweden
Francis M. Cuss	Bristol-Myers Squibb	USA
Mike Devoy	GlaxoSmithKline	UK
Chandra Effendy	p.t. Candi Swadaya Sentosa	Indonesia
Charles Hancock	Charles O. Hancock Associates	USA
Eamonn Hoxey	Johnson & Johnson	UK
Javaid Khan	The Aga Khan University	Pakistan
P. Kumarasamy	Aerosol Manufacturing Sdn Bhd (KP Quality Products)	Malaysia
Robert Layet	Ensign Laboratories	Australia
Robert Meyer	Food and Drug Administration	USA
Hideo Mori	Otsuka Pharmaceutical Company	Japan
Robert F. Morrissey	Johnson & Johnson	USA
Geno Nardini	Instituto Internacional del Aerosol	Mexico
Dick Nusbaum	Penna Engineering	USA
Tunde Otulana	Aradigm Corporation	USA
Fernando Peregrin	AMSCO/FINN-AQUA	Spain
Jacek Rozmiarek	GlaxoSmithKline Pharmaceuticals SA	Poland
Abe Rubinfeld	Royal Melbourne Hospital	Australia
Albert L. Sheffer	Brigham and Women`s Hospital	USA
Greg Simpson	CSIRO, Molecular Science	Australia
Roland Stechert	Boehringer Ingelheim (Schweiz) GmbH	Switzerland
Robert Suber	RJR-Nabisco	USA
Adam Wanner	University of Miami	USA
You Yizhong	Journal of Aerosol Communication	China

TEAP Flexible and Rigid Foams Technical Options Committee (FTOC)

Co-chairs	Affiliation	Country
Paul Ashford	Caleb Management Services	UK
Miguel Quintero	Universidad de los Andes	Colombia

Members	Affiliation	Country
Volker Brünighaus	Hennecke	Germany
Michael J. Cartmell	Huntsman Polyurethanes	US
Antonio Cristodero	Independent Consultant	Argentina
Tony Griffiths	Gellsoft Ltd	Cyprus
Kiyoshi Hara	JICOP	Japan
Jeffrey Haworth	Maytag Grp	US
Mike Jeffs	ISOPA	Belgium
Ta Kao Kadota	Dow	Japan
Anhar Karimjee	Environmental Protection Agency	US
Pranot Kotchabhakdi	Sunprene (Thailand) Co. Ltd.	Thailand
Candido Lomba	ABRIPUR	Brazil
Yehia Lotfi	Technocom	Egypt
Risto Ojala	Independent Consultant	Finland
Lorraine Ross	Intech Consulting	US
Robert Russell	Independent Consultant	US
Patrick Rynd	Owens Corning	US
Mudumbai. Sarangapani	Polyurethane Countil of India	India
Ulrich Schmidt	Haltermann/Dow	Germany
Haruo |Tomita	Kaneka	Japan
Bert Veenendaal	RAPPA	US
Mark Weick	Dow	US
Dave Williams	Honeywell	US
Jinghuan Wu	Atofina	US
Alberto Zarantonello	Cannon	Italy
Lothar Zipfel	Solvay	Germany

TEAP Halons Technical Options Committee (HTOC)

Co-chairs	**Affiliation**	**Country**
Gary Taylor	Taylor/Wagner Inc. (resigns as of 30 June 2004)	Canada

Members	**Affiliation**	**Country**
David Catchpole	Petrotechnical Resources Alaska	US
Jeffery Cohen	US EPA	US
Michelle Collins	NASA	US
Philip DiNenno	Hughes Associates	US
Zhu Hailin	Ansul	China
Matsuo Ishiyama	Halon Recycling & Support Committee	Japan
H.S. Kaprwan	Defence Institute of Fire Research	India
Nikolai P. Kopylov	All Russian Research Institute for Fire Protection	Russia
Barbara Kucnerowicz-Polak	State Fire Services Headquarters	Poland
Dirk Legatis	GTZ Proklima	Germany
David Liddy	Ministry of Defence	UK
Guillermo Lozano	G.L. & Associados	Venezuela
John O'Sullivan, MBE	British Airways	UK
Erik Pedersen	World Bank	
Reva Rubenstein	Consultant	US
Donald Thomson	MOPIA	Canada

Consulting Experts	**Affiliation**	**Country**
Tom Cortina	HARC	US
Steve McCormick	United States Army	US
Joseph Senecal	Kidde-Fenwal Inc.	US
Ronald S. Sheinson	Naval Research Laboratory - Department of the Navy	US
Ronald Sibley	Defence General Supply Agency	US
Malcolm Stamp	Great Lakes Chemicals (Europe) Limited	UK
Daniel Verdonik	Hughes Associates	US
Robert Wickham	Consultant	US

TEAP Methyl Bromide Technical Options Committee (MBTOC)

Co-chairs	Affiliation	Country
Jonathan Banks	Consultant	Australia
Nahum Marban Mendoza	Universidad Autonoma Chapingo	Mexico

Members	Affiliation	Country
Alessandrio Amadio	UNIDO	Italy
Marten Barel	Consultant	Netherlands
Chris Bell	Central Science Laboratory	UK
Antonio Bello	Centro de Ciencias Medioambientales	Spain
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco
Cao Aocheng	Chinese Academy of Agricultural Sciences	China
Fabio Chevarri	IRET-Universidad Nacional	Costa Rica
Ricardo Deang	Consultant	Philippines
Patrick Ducom	Ministère de l'Agriculture	France
Hodayah Finman	US EPA	US
Volkmar Hasse	GTZ	Germany
Saad Hafez	University of Idaho	US
Rick Keigwin	US Environmental Protection Agency	US
George Lazarovits	Agriculture & Agr-food Canada	Canada
Michelle Marcotte	Marcotte Consulting Inc.	Canada
Cecilia Mercado	UNEP DTIE	France
Melanie Miller	Consultant	Belgium
Andrea Minuto	Agroinnova Universita Torino	Italy
Mitsusuda Mizubuchi	MAFF	Japan
Mokhtarud-Din Bin Husain	Department of Agriculture	Malaysia
Kazufumi Nishi	Nat Institute of Vegetables and Tea Science	Japan
David Okioga	Ministry of Environment and Natural Resources	Kenya
Marta Pizano de Marquez	Hortitecnia Ltda	Colombia
Ian Porter	Institute for Horticultural Development	Australia
Christoph Reichmuth	BBAGermany	Germany
John Sansone	SCC Products	US
Jim Schaub	US Department of Agriculture	US
Sally Schneider	US Department of Agriculture	US
Don Smith	Industrial Research Limited	New Zealand
JL Staphorst	Plant Protection Research Institute	South Africa
Akio Tateya	Japan Fumigation Technology Association	Japan
Robert Taylor	Natural Resources Institute	UK
Alejandro Valerio	Department of Agriculture	Argentina
Ken Vick	United States Department of Agriculture	US
Nick Vink	University of Stellenbosch	South Africa
Chris Watson	IGROX Ltd	UK
Jim Wells	Novigen Sciences, Inc., International	US

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

Co-chair	Affiliation	Country
Radhey S. Agarwal	Indian Institute of Technology Delhi	India
Lambert Kuijpers	Technical University Eindhoven	Netherlands

Members	Affiliation	Country
Ward Atkinson	Sun Test Engineering	US
James A. Baker	Delphi Automotive Systems	US
Julius Banks	Environmental Protection Agency	US
Marc Barreau	Atofina	France
Steve Bernhardt	Honeywell International	US
Dariusz Butrymowicz	Institute of Fluid Flow Machinery	Poland
James M. Calm	Engineering Consultant	US
Denis Clodic	Ecole des Mines	France
Daniel Colbourne	Calor Gas	UK
Jim Crawford	Trane /American Standard	US
Sukumar Devotta	National Env. Eng. Research Institute (NEERI)	India
László Gaal	Hungarian Refrigeration and AC Association	Hungary
Kenneth E. Hickman	York – Consultant	US
Martien Janssen	Re/gent	Netherlands
Makoto Kaibara	Matsushita Electric Industrial Corporation	Japan
Ftouh Kallel	Sofrifac SA	Tunisia
Michael Kauffeld	Fachhochschule Karlsruhe	Germany
Fred Keller	Carrier Corporation	US
Jürgen Köhler	University of Braunschweig	Germany
Holger König	Axima	Germany
Horst Kruse	FKW Hannover	Germany
Edward J. McInerney	General Electric	US
Mark Menzer	Air Conditioning and Refrigeration Institute	US
Petter Nekså	SINTEF Energy Research	Norway
Haruo Ohnishi	Daikin Industries	Japan
Hezekiah B. Okeyo	Ministry of Industrial Development	Kenya
Roberto de A. Peixoto	IMT	Brazil
Frederique Sauer	Dehon Service	France
Adam M. Sebbit	Makerere University	Uganda
Stephan Sicars	Siccon Consultancy	Germany
Arnon Simakulthorn	Thai Compressor Manufacturing	Thailand
Aryadi Suwono	Thermodynamic Research Lab Bandung University	Indonesia
Peter Tomlein	Slovak Refrigeration Association	Slovakia
Pham Van Tho	Ministry of Fisheries	Vietnam
Vassily Tselikov	ICP "Ozone"	Russia
Paulo Vodianitskaia	Multibras SA Electrodomesticos	Brazil

TEAP Solvents, Coatings and Adhesives Technical Options Committee (STOC)

Co-chair	Affiliation	Country
Members	**Affiliation**	**Country**
Brian Ellis	Protonique	Switzerland
Srinivas K. Bagepalli	General Electric	US
Mike Clark	Mike Clark Associates	UK
Bruno Costes	Aerospatiale	France
Joe Felty	Raytheon TI Systems	US
Yuichi Fujimoto	Japan Industrial Conference for Ozone Layer Protection	Japan
Ahmad H. Gaber	Cairo University / Chemonics Consultancy	Egypt
Jianxin Hu	Center of Environmental Sciences, Beijing University	China
William Kenyon	Global Centre for Process Change	US
A.A. Khan	Indian Institute of Chemical Technology	India
Stephen Lai	Singapore Inst. of Standards and Industrial Research	Singapore
Seok Woo Lee	National Institute of Technology and Quality	Korea
Abid Merchant	DuPont	US
James Mertens	Dow Chemical	USA
Andre Orban	European Chlorinated Solvents Association	Belgium
Patrice Rollet	Promosol	France
Shuniti Samejima	Asahi Glass	Japan
Hussein Shafa'amri	Ministry of Planning	Jordan
John Stemniski	Consultant	US
Peter Verge	Boeing Manufacturing	US
John Wilkinson	Vulcan Materials	US