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EUROPEAN ECONOMIC COMMUNITY

Aspects of Effecting Further Reductions in Chlorofluorocarbon Usage in the EEC

FINAL REPORT

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ABSTRACT

Comparative statistics are presented and analysed for the production and use of chlorofluorocarbons F-11 and F-12, and for aerosol fillings in the EEC, the USA and the rest of the world, principally over the period 1976 to 1979.

The current technical situation regarding the substitution of CFC by non-CFC propellants and solvents in aerosols is reviewed, and possible measures are discussed for effecting a reduction in F-11/F-12 usage in aerosols substantially beyond the minimum of 30% relative to 1976, required by the Council Decision of 26 March 1980.

Estimates are given of the losses of added value and job opportunity which might ensue from a major reduction in sales of F-11 and F-12 in the EEC, and the socio-economic impact of further CFC usage reduction measures on the aerosol industry is considered in the light of a survey of aerosol filling locations, representing the majority of EEC filling capacity.

Technical and economic possibilities are examined for reducing CFC usage and emissions to atmosphere in connection with the principal non-aerosol uses of CFCs: refrigeration and air conditioning, foam plastics manufacture and solvent applications.

CONCLUSIONS

A. Chlorofluorocarbon Production and Use: EEC, World, and USA Statistics.

A.1. In 1976, the reference year for the Council Decision to reduce F-11/F-12 usage for aerosols in the EEC by at least 30%, world production of these CFCs reached a secondary peak of 800 thousand tons but progressively declined thereafter to 702 thousand tons in 1979, a fall of 12.2%. Over the same period EEC output declined by 6.8%, from 326 to 304 thousand tons, the greater external decline being attributable to the United States ban on CFC propellants in most aerosols, which became fully effective in 1979.

A.2. From 1976 to 1979, F-11/F-12 sales for aerosols in the EEC fell by 22.8% and if this rate of decrease is maintained the 30% minimum reduction target will be exceeded in 1981. Outside the EEC, sales for aerosols in the same period by CMA reporting companies declined by 53.8%, again reflecting the U.S. ban. For areas outside the EEC and the USA, the reduction was only 5.1%. In 1979, the EEC accounted for 54% of world sales for aerosols of 254.6 thousand tons.

A.3. The F-11/F-12 usage pattern in the EEC is in marked contrast to that outside. Sales for aerosols in the EEC in 1979 accounted for 62.2% of sales compared with 27.6% outside the Community, whereas use for refrigeration was only 9.2% in the EEC compared with 40% outside.

A.4. For the non-aerosol applications of F-11 and F-12, world sales rose substantially in all categories and by 34% overall in the period 1976 to 1979. In the EEC, sales for non-aerosol uses rose by 23.7%, mainly due to an increase for foam plastics, whereas sales for refrigeration remained virtually unchanged.

A.5. The net reduction in total F-11/F-12 sales by EEC producers from 1976 to 1979 was 8.1%, the decrease of 22.8% in sales for aerosols having been substantially offset by the rise in sales for foams and other uses.

A.6. The EEC accounted for 34% of world sales totalling 646.6 thousand tons of F-11/F-12 by CMA reporting companies in 1979, and nearly two thirds of these EEC sales were for aerosols. It follows that if the EEC wishes to make another significant contribution to restricting world usage of F-11/F-12, this would necessitate a further substantial reduction in use for aerosols. If the reduction from the 1976 level of use in aerosols were to be raised to 60%, this would reduce total world sales by 10% of the 1979 levels. A reduction of 30% in 1979 EEC sales for non-aerosol applications would reduce the 1979 level of world sales by less than 4%.

A.7. World production of the other principal fully halogenated CFCs, F-113 and F-114, is estimated to have risen from 88,000 tons in 1977 to 109,000 tons in 1979, when it represented 12% of world production of F-11, 12,113 and 114. Corresponding EEC production figures for 1977, the latest year for which data is available, were 24,000 tons and 7%. There is a case for the collection of world and EEC annual statistics for all CFCs produced in significant quantities.

B. Aerosols

B.1. The EEC aerosol fillings total of 1,868 million units in 1979 was only marginally below the 1976 total of 1,873 million, and represented 30% of the world total. The fall of 22.8% in F-11/F-12 propellant usage in the EEC over this period is due to several factors, including CFC substitution and changes in sales category patterns, but the respective contributions cannot be quantified.

B.2. Fillings in Greece of 29m units in 1979 are equivalent to 1.5% of total EEC fillings in that year. USA fillings were slightly higher in 1979 than in 1978, despite the ban on CFCs in most aerosols. Outside Western Europe and the USA, the 1979 fillings total of 1837m. units was 37.6% above that for 1976.

B.3. No alternative fluorocarbon propellants to F-11 and F-12 have emerged which satisfy the technical economic, environmental, biological and other criteria for large scale application and none is in prospect. Pump sprays and other devices are not making significant in-roads into the market for self-pressurised packaging based on liquefied gas propellants.

B.4. Except for fragrances and a few minor product sectors, liquefied hydrocarbon gas propellants are now the established alternatives to CFCs, despite the disadvantages attaching to their high flammability and poor solvent properties, often necessitating the use of auxiliary solvents and diluents such as alcohols and methylene chloride which are also subject to regulatory restrictions.

B.5. Dimethylether ('DME'), although flammable, could become a valuable alternative to hydrocarbon propellants because of better solvent properties, miscibility with water and compatibility with fragrances. Wider acceptance depends upon the results of a toxicity testing programme, and the availability of more than one primary supplier in the EEC.

B.6. For effecting reductions in F-11/F-12 usage in filling aerosols substantially beyond the minimum of 30% relative to 1976 levels of use, as required by the Council Decision of 26 March 1981, a number of direct and indirect regulatory measures can be considered as well as the government - industry convention concept.

B.7. Direct regulatory measures available include a total ban with special exemptions; major product sector bans - e.g. on CFC usage in hairsprays; and CFC concentration limits. Lack of sectoral usage statistics makes it difficult to quantify the outcome of the second course and the third would be complicated to devise and expensive to police. Extension of Article 1 of the March 1980 Decision to the chlorofluoroethanes would only marginally increase CFC propellant usage reduction but might restrict non-aerosol applications, especially in solvent cleaning.

B.8. Restrictions leading to elimination of F-11/F-12 usage in aerosols in 1984, could reduce EEC output by about 138,000 tons compared with 1976. The consequent loss of added value at 1980 prices due to lower sales of CFCs and co-products, allowing for reduced raw material imports, is estimated at ECU 228,220,000 with an associated job opportunity loss of 8,620. There would be some off-set - possibly as much as 30% - due to increased usage in aerosols of hydrocarbon propellants, alcohols, chlorinated hydrocarbons and other materials.

B.9. At a given sales volume, the socio-economic impact of further CFC restrictions on the aerosol filling sector, aside from development expenditure, is essentially related to the costs and problems of conversion to flammable propellants. The basic capital costs of conversion could typically range from ECU 56,000 for a facility producing up to 1 million units/year on an existing site, to ECU 1,160,000, for conversion and re-location of a two-line 20m. unit/year capacity installation.

B.10. Information on 200 filling locations obtained by postal survey, and on more than 140 others by indirect means indicates that there are up to 400 active fillers in the EEC, with about 70 accounting for 80% of all fillings. Half the locations surveyed are not equipped for flammable propellants and nearly 80% of these were reported unsuitable for conversion, but almost all fillers producing over 10m units/year are able or planning to be able to use flammable propellants.

B.11. Further CFC restrictions and the need for more conversion would result in consolidation of filling operations on fewer sites. Personnel engaged for more than 50% of their time on aerosol manufacture in the EEC may total about 10,000; re-structuring of the industry might put up to 2000 job opportunities at risk.

B.12. The effect of further CFC restrictions on aerosol sales volumes would depend on many factors and is particularly difficult to predict under present economic circumstances; while some depression is likely, this could be minimised if enough time is available for re-formulation to be achieved in a series of graduated steps.

C.1. Refrigeration

C.1.1. Vapour compression using CFC refrigerants is the predominant system in the manufacture and use of refrigeration and air conditioning equipment in the EEC, and because of its advantages in terms of economics, efficiency, safety and versatility it is most unlikely that the development of absorption and other systems will make a significant impact on this situation in the next decade. It follows that practical measures to reduce CFC emissions in this application field must be concentrated on the reduction of preventable losses at all stages from initial manufacture and installation, to the ultimate disposal of equipment.

C.1.2. The principal CFC refrigerants used in the EEC are F-12,F-22 and F-502. Sales for F-12 for refrigeration have remained virtually constant at about 20,000 tons annually, over the period 1976 to 1979; statistics for F-22 and F-502 are not available.

C.1.3. There is scope for reducing emissions by equipment design improvement, the earlier detection and cure of leaks and by following less wasteful procedures in charging and servicing, but there is little economic incentive for conservation and it is likely to prove difficult to change long established working practices and attitudes.

C.1.4. Potentiality also exists for the recovery or destruction of refrigerant currently vented to atmosphere on account of contamination or other reason preventing re-use. Technology for these measures is not yet established, and they are likely to prove costly and complicated to implement.

C.1.5. Before evolving a strategy for reducing CFC refrigerant emissions in the EEC it will be essential to have data on the distribution of losses by source and equipment, and it is suggested that in consultation with industry a survey procedure should be devised to obtain this. Practical steps that could be taken meanwhile are the development of equipment design codes, and research on refrigerant recovery and disposal.

C.2. Foam Plastics

C.2.1. CFC blowing agents are used in the production of a number of foam plastics, but mainly for flexible (open cell) and rigid (closed cell) polyurethane. Reliable statistics on CFC usage for the various foams are not available, but much of the increase in CFC usage for this application, from 42,000 tons in 1976 to 56,000 tons in 1979, is attributable to rigid polyurethane - the production of which in Western Europe is reported to be growing at a rate of nearly 9% annually. CFC usage for flexible polyurethane slabstock in the EEC has fallen by about 25% since 1976 and no growth is anticipated over the next 5 years.

C.2.2. The CFC content of closed cell polyurethane foam is an essential factor in the low thermal conductivity of this material, which has a unique combination of advantages for thermal insulation; no alternative non-CFC blowing agents are available for rigid polyurethane when it is used for this purpose, which is the major application. Reductions in CFC emissions might be made by minimising losses during foam production and conversion, and possibly by measures to prevent release during disposal, but these are only marginal prospects.

C.2.3. In open cell flexible polyurethane foams, CFCs are used as secondary blowing agents for producing the softer, lower density grades. CFC escapes from the foam during production and the possibility of recovery from the process ventilation air by adsorption on active carbon is being explored in a pilot plant project in England. Methylene chloride is an alternative blowing agent but toxicity problems dictate a cautious approach to substitution. Softer high density grades of foam can now be made using recently introduced polyols, and some reduction in CFC usage is likely to follow from this development. Vacuum blowing is a possibility on which research has been recommenced. There is a case for a co-ordinated research programme in Europe on the various medium and long term prospects for reducing CFC release in open cell foam manufacture.

C.3. Solvent Cleaning Applications

C.3.1. The growing use of fully halogenated CFCs, especially of F-113 for solvent cleaning makes this an application area which deserves further attention. More information is needed to quantify the sources of emission, and it would be useful to discuss equipment design standards operating practice and solvent disposal procedures with the industry sectors concerned.

1. INTRODUCTION

1.1. Study Objectives

To investigate and report upon:

a) Options for effecting further reductions in chlorofluorocarbon usage in filling aerosols in the EEC and the socio-economic implications of implementing such reductions and,

b) technical and economic possibilities for chlorofluorocarbon substitution and usage reduction in non-aerosol applications, particularly in the manufacture of foam plastics, and in refrigeration and air conditioning.

1.2. Background

The study relates to the possibility that the continuing release of large tonnages of chlorofluorocarbons ('CFCs') into the atmosphere may deplete the earth's stratospheric ozone layer, with harmful consequences for health and the environment.

The EEC is implementing precautionary measures in accordance with Council Decision 80/372/EEC of 26 March 1980, /1/, and in this connection the present study was undertaken to provide the Commission with the technical and socio-economic information and advice needed to complement the reviews of the latest scientific evidence on the chlorofluorocarbon-ozone depletion issue, and on the effect of ultra-violet radiation on health.

Two previous studies on aspects of reducing CFC usage in the Community have been carried out by Metra for the Commission, and were the subject of reports issued in October 1978 and June 1980, /2/, /3/. The first study examined the socio-economic implications of three scenarios for regulating the use of fully halogenated CFCs in aerosols, and the problems of reducing CFC usage in the principal non-aerosol applications. The second was concerned with technical aspects and alternative means of implementing the Council Decision of 26 March 1980. In the following text the reports on those studies are cited respectively as Metra 1978, and Metra 1980.

Some of the material presented in the Metra 1978 and 1980 reports has been incorporated in the present report to make it substantially self-contained, but references to the previous reports are given in instances where readers may wish to consult them for additional detail.

1.3. Period of Study

The investigatory part of the study was conducted between 1st August and 31st December 1980. Where practicable, additional information received between 1st January and 20th February 1981 has been taken into account in compiling this report.

1.4. Acknowledgement

Information, data and views were contributed by numerous private and public sector organisations, including nearly 200 companies which participated in a survey of aerosol fillers, and trade associations representing the principal industries involved. Metra gratefully acknowledges the extensive co-operation and assistance given by these organisations and by the individual executives concerned.

1.5. Note on Fluorocarbon Numbering System

The various fluorocarbon compounds mentioned in this report are designated by a number in accordance with the internationally accepted system.

Reading from right to left the first digit represents the number of fluorine atoms in the molecule; the second is one more than the number of hydrogen atoms; and the third is one less than the number of carbon atoms and is omitted when zero.

For the chlorofluoroalkanes the number of chlorine atoms in the molecule is the difference between the total of the numbers of hydrogen and fluorine atoms present and the total number of hydrogen or halogen atoms needed for saturation, i.e. 4 in the chlorofluoromethanes and 6 in the chlorofluoroethanes.

Other rules, not detailed here, have been devised to cover isomers, azeotropes, cyclic and unsaturated compounds, and the presence of halogens other than chlorine or fluorine.

In this report the prefix 'F', standing for fluorocarbon, is placed before the number. This prefix is used because it is that employed in the Council Decision of March 1980, and in the previous Metra reports. Other prefixes frequently used are 'FC', also standing for fluorocarbons, and 'CFC', standing for chlorofluorocarbon. The disadvantage of the CFC prefix is that it is inappropriate for compounds which do not contain chlorine, whereas F or FC are applicable to all compounds of carbon and fluorine.

The prefix F and the present universally used numbering system were originally adopted by Du Pont for their range of fluorocarbon products marketed under the tradename "FREON'. However, some other companies subsequently adopted tradenames begining with F for these compounds, and used the same numbering system and prefix. Nowadays, the prefix F does not signify the product of any particular company.

The chlorofluorocarbons most frequently mentioned in the present report are as follows:

Fluorocarbon No.	Chemical Formula	Chemical Name
F-11	CCl_3F	Trichlorofluoromethane
F-12	CCl_2F_2	Dichlorodifluoromethane
F-22	$CHClF_2$	Monochlorodifluoromethane
F-113	$C_2Cl_3F_3$	Trichlorotrifluoroethane
F-114	$C_2Cl_2F_4$	Dichlorotetrafluoroethane

1.6. References

1. Official Journal of the European Communities No. L 90/45, 3 April 1980.

2. Metra: 'Social and Economic Implications of Controlling the Use of Chlorofluorocarbons in the EEC', October 1978. (EEC Study Contract).

3. Metra : 'Aspects of Implementing a Reduction in Chlorofluorocarbon Usage in Aerosols', June 1980. (EEC Study Contract).

2. CHLOROFLUOROCARBON PRODUCTION AND USE: EEC, WORLD AND USA STATISTICS

2.1. Importance of the Statistical Perspective

CFC release anywhere in the world may contribute to the accumulation of these compounds in the stratosphere, and emission control must therefore be considered both in global and regional terms.

Adequate statistics must be available if quantitative assessments are to be made of the absolute and relative significance of emissions associated with particular applications and areas, and of the potential effect on the global release situation of a set of regionally applied control measures.

From the outset of this series of studies, great importance has been attached to obtaining data on CFC production and use in the EEC, and to presenting comparative analyses of EEC and world patterns and trends so that technical and socio-economic aspects of possible action to reduce CFC usage and release in the Community can be viewed in a full perspective.

The following data analysis concentrates on F-11 and F-12, which are the only CFCs for which annual production and use statistics are being regularly collected, although substantial tonnages of some other CFCs are produced - particularly of F-22, F-113 and F-114.

The Council Decision of March 1980 specifically relates to F-11 and F-12, but the present study is not confined to these compounds and the point will be developed later in this section that it would be desirable to have data on all CFCs which are manufactured in significant quantities.

2.2. Data Sources

2.2.1. EEC Statistics

For each of the four years 1976 to 1979, aggregate data is available for production and sales of F-11 and F-12 by the nine chlorofluorocarbon producer-marketers in the EEC.

The data has been provided by the EFCTC - the European Fluorocarbon Producers Technical Committee of CEFIC, under an arrangement whereby individual producers submit data in confidence to an independent firm of UK accountants (Peat,Marwick,Mitchell & Co) who collate the figures.

This exercise was first carried out for the years 1976 and 1977 in conjunction with the first Metra study, and repeated for the years 1978 and 1979 for the second study. It is the present intention of the producers that the provision of comparable annual statistics should be continued for so long as the Council Decision of March 1980 remains in force. The insistence on providing data for the EEC as a whole rather than for individual Member States is associated with a desire to maintain commercial confidentiality, there being no more than two producers in any EEC country.

Production totals include any importation by the producers from outside the Community. We have been assured by the EFCTC that with plants running well below capacity such importation is currently negligible, and that they are not aware of any significant importation by non-producers.

Sales are first analysed into home market sales (mainly sales within the country of production), other EEC sales, and export sales to countries outside the EEC. Sales within the EEC are further analysed into four application categories: aerosols; refrigeration (including air conditioning); foam plastics; and solvent and other uses.

Discrepancies between production and sales totals have not exceeded 2% in any year, and are attributable to stock changes and reporting errors.

For the years 1976 and 1977, the home market sales were also broken down into sales for flexible polyurethane foams, rigid polyurethane foams and non-urethane foams. The EFCTC subsequently advised that this additional analysis could not be given with confidence, mainly because some sales outlets use or market CFC blowing agents for more than one type of foam.

The accession of Greece to the EEC could complicate the provision of comparative statistics for 1981 and thereafter. There is one F-11/12 producer in Greece, and if confidentiality is to be maintained the production and use data should be aggregated with that for the rest of the EEC. This would mean that EEC totals after 1980 could not be compared with those for previous years, but if aggregates including Greece were now to be provided for those years the Greek figures would be immediately calculable by difference.

This problem needs to be resolved before the time comes for compilation of the 1981 statistics.

2.2.2. World Statistics

Under a scheme administered by the CMA (the USA Chemical Manufacturers Association) 19 companies, including all the EEC producers, report their annual F-11 and F-12 production and sales figures to an independent firm of U.S. accountants which prepares aggregate tabulations.

On the basis of the reporting company data, supplementary information and estimates in respect of other producers, and procedures for computing annual and cumulative figures for world production and release, the CMA Fluorocarbon Technical Panel provides the following tabulations of expanded data in respect of F-11 and F-12:

- annual and cumulative production, sales and releases in respect of reporting companies only

- annual production and release for Communist Countries (excluding China), Argentina and India

- annual and cumulative world production and releases.

The expanded data for sales is given in four categories: refrigeration-hermetically sealed; refrigeration-non hermetic; blowing agents - closed cell foam; open cell foam and aerosols and all other production. These categories do not correspond with those available for EEC sales, but the accountants' collations separate the open cell foam, aerosol and other use categories, so that by combining the two refrigeration sub-divisions and the two foam sub-divisions we obtain a set of four groups which can be directly compared with the EEC data, viz. aerosols, refrigeration, foams and other uses.

The world data presented in this report is taken from CMA papers issued in May 1980, /1/, /2/.

2.2.3. USA Statistics

Although F-11/12 sales in the USA dropped following the regulatory action on CFC usage in aerosols they still accounted for about 25% of world sales in 1979, and it is of interest to include US figures in some of the comparisons.

The CMA provided us with aggregated statistics for the six US reporting companies in 1976 and 1977, and the figure for 1979 is taken from the Draft OECD Report on Chlorofluorocarbons of October 1980, /3/.

2.3. Data Presentation

The following presentation up-dates the Metra 1980 report by including world and USA data for 1979. In most of the tabulations and diagrams, data for 1976 is compared with that for 1979 because this gives a more readily comprehensible picture and data for the intermediate years are available in the previous reports. For the same reason, most of the data relates to total F-11 and F-12 rather than to the individual compounds; the Council Decision of March 1980 also relates to aggregate totals.

Figure 2.1. graphs world production of F-11 and F-12 over the years 1969-1979 and EEC production from 1976 to 1979.

Table 2.1. gives EEC production and sales of F-11/-12 for the years 1976 and 1979, the home territory and other EEC sales data in the tabulations supplied by the independent accountants through the EFCTC having been consolidated to give total EEC sales by category. Sales by category are also expressed as percentages of all sales in the EEC and of total EEC and export sales and Figure 2.2. illustrates this data diagrammatically.

Table 2.2. compares the sales category distribution of the individual CFCs, F-11 and F-12, for sales in the EEC in 1979, and the contrast is depicted in Figure 2.3.

FIGURE 2.1 CHLOROFLUOROCARBONS F-11 AND F-12 WORLD AND EEC PRODUCTION : 1969-79

Sources: CMA and EFCTC

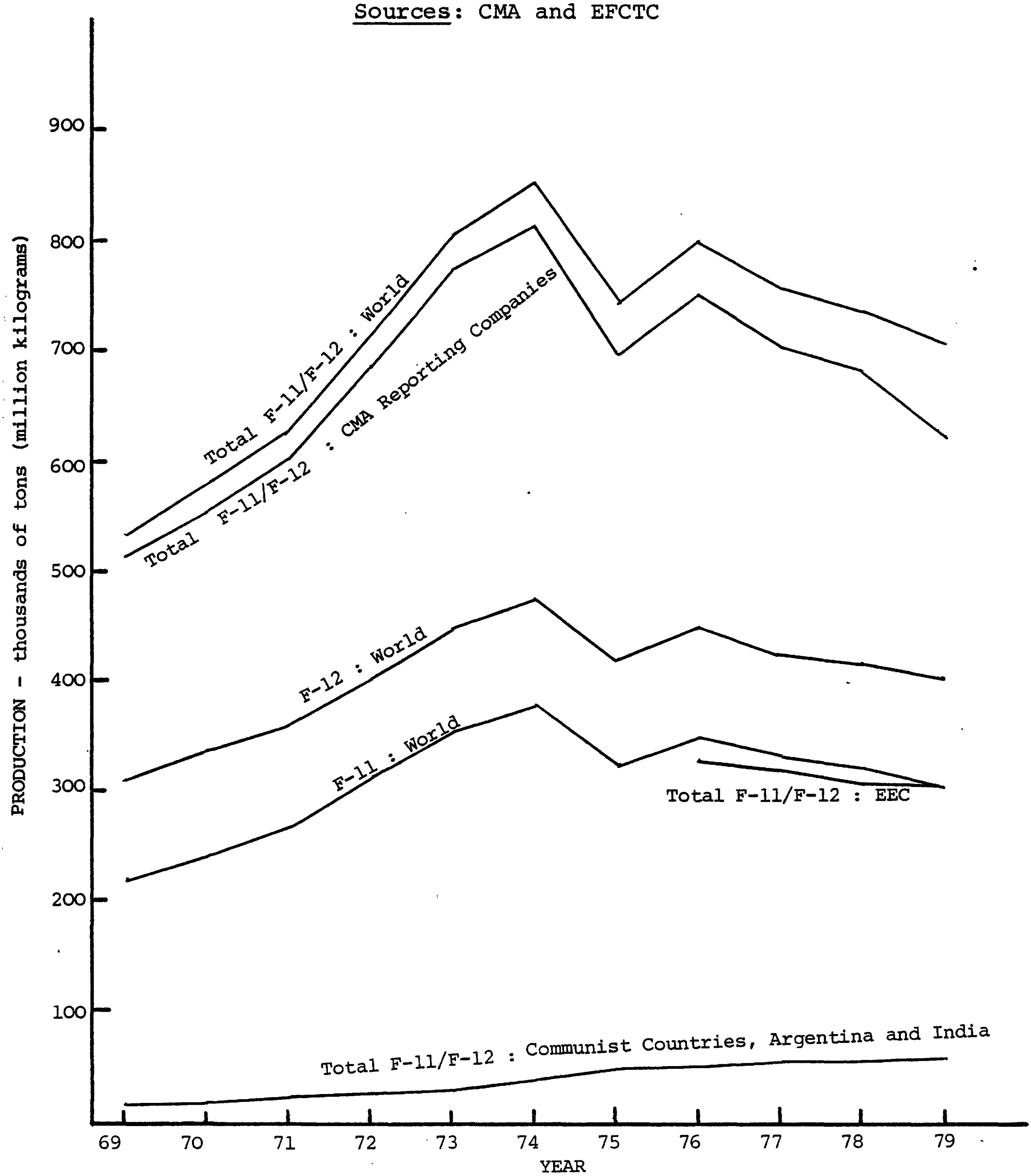


TABLE 2.1.

F-11/F-12 PRODUCTION AND SALES BY EEC PRODUCERS: 1976 AND 1979

Tons F-11/F-12

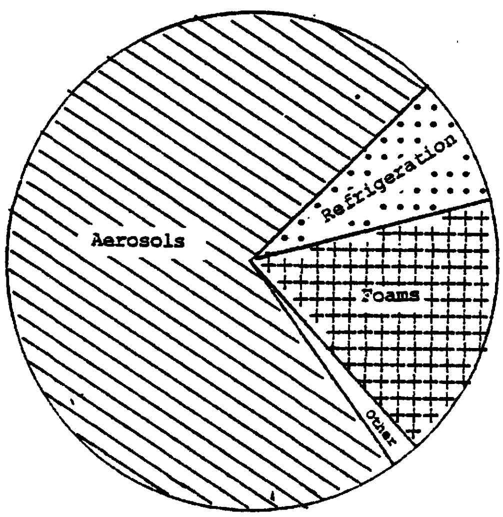
	1976	1979	Change : 1976 to 1979	
			tons	%
PRODUCTION (including imports from outside the EEC)	326,433	304,238	- 22,195	-6.8
SALES IN EEC MARKETS (excluding sales to co-producers)				
Aerosols - Tons	176,914	136,552	- 40,362	-22.8
% All Sales in EEC	72.5	62.2		
% EEC and Export Sales	54.0	45.3		
Refrigeration - Tons	20,773	20,300	- 473	- 2.3
% All Sales in EEC	8.5	9.2		
% EEC and Export Sales	6.3	6.7		
Foam Plastics - Tons	42,154	55,788	+ 13,634	+32.3
% All Sales in EEC	17.3	25.4		
% EEC and Export Sales	12.9	18.5		
Other Uses - Tons	4,178	6,921	+ 2,743	+65.7
% All Sales in EEC	1.7	3.2		
% EEC and Export Sales	1.3	2.3		
Total: Non-aerosol Uses - Tons	67,105	83,009	+ 15,904	+23.7
% All Sales in EEC	27.5	37.8		
% EEC and Export Sales	20.5	27.6		
TOTAL EEC SALES - Tons	244,019	219,561	- 24,458	-10.0
% EEC and Export Sales	74.5	72.9		
TOTAL EXPORTS OUTSIDE EEC-Tons	83,578	81,636	- 1,942	- 2.3
% EEC and Export Sales	25.5	27.1		
TOTAL EEC AND EXPORT SALES - Tons	327,597	301,197	- 26,400	- 8.1

Source: EFCTC

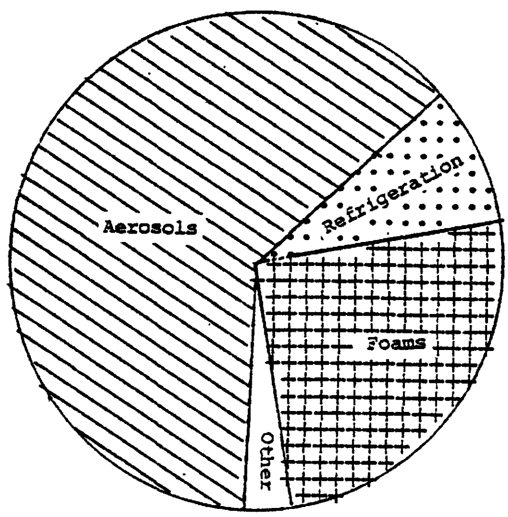
FIGURE:2.2. DISTRIBUTION OF EEC AND TOTAL SALES OF F-11/F-12 BY EEC PRODUCERS : 1976 AND 1979

EEC SALES

1976

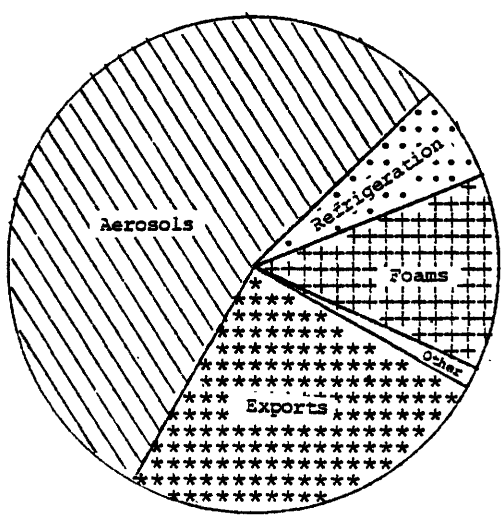


1979



ALL SALES

1976



1979

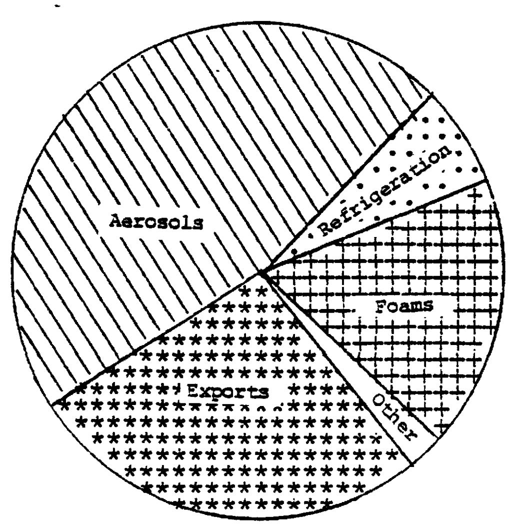


TABLE 2.2

EEC PRODUCER SALES OF F-11 AND F-12 COMPARED FOR YEAR 1979

SALES IN 1979	F-11		F-12	
SALES IN EEC	Tons	%	Tons	%
Aerosols	62,344	51.6	74,208	75.2
Refrigeration	2,253	1.9	18,047	18.3
Foam Plastics	49,598	41.0	6,190	6.3
Other Uses	6,639	5.5	282	0.3
TOTAL EEC SALES	120,834	100.0	98,727	100.0
EXPORT SALES	37,767		43,869	
TOTAL EEC AND EXPORT SALES	158,601		142,596	
EXPORT SALES AS PERCENTAGE OF TOTAL SALES		23.8%		30.8%

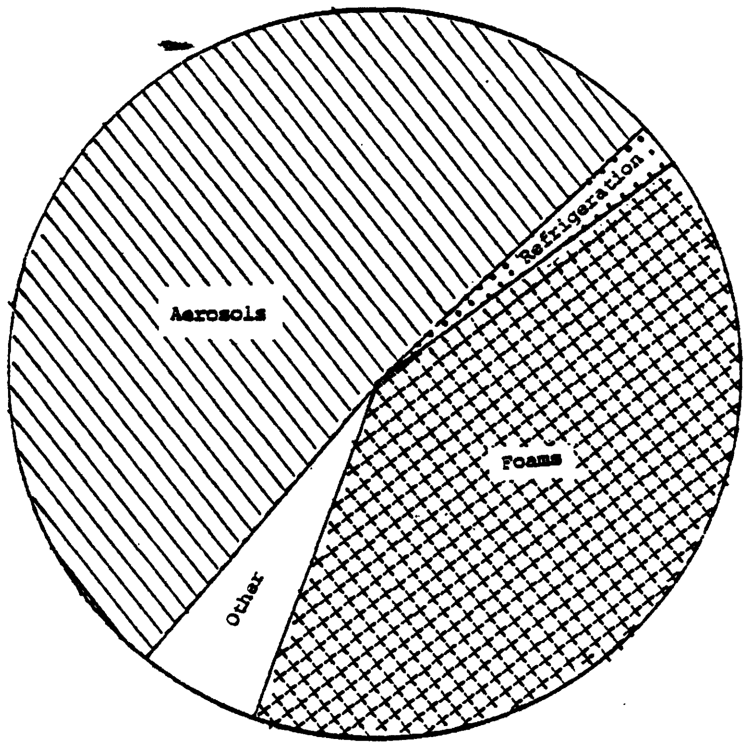
Source: EFCTC

TABLE 2.3 F-11/F-12 SALES BY CATEGORY AND TERRITORY FOR CMA REPORTING COMPANIES : 1976 AND 1979

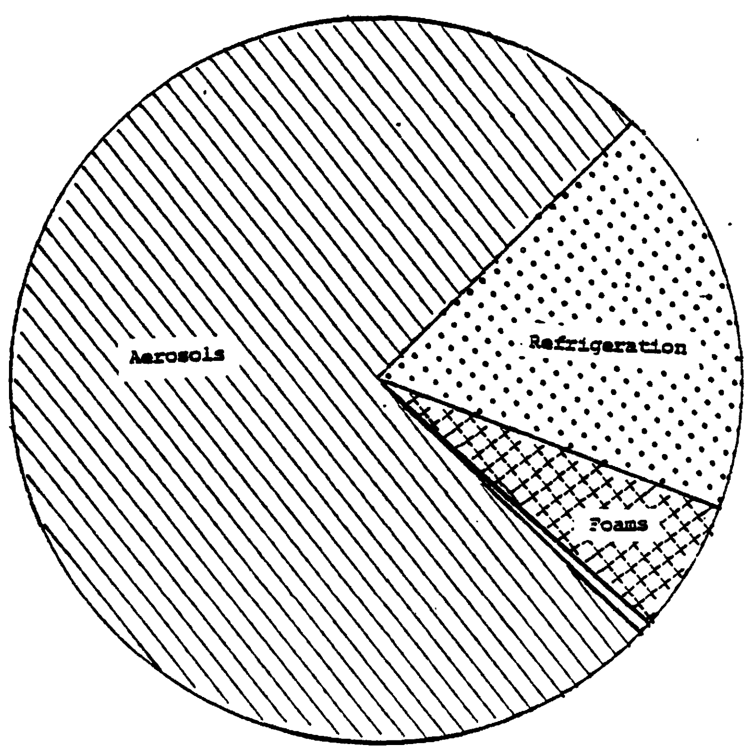
Sales Category	Year	World 'ooo tons	EEC 'ooo tons	EEC % world	World Excluding EEC 'ooo tons	USA 'ooo tons	World Excluding EEC & USA 'ooo tons
Aerosols	1976	432.3	176.9	40.9	255.4	138.0	117.4
	1979	254.6	136.6	53.7	118.0	6.6	111.4
	% Change	- 41.1	- 22.8		- 53.8	- 95.2	- 5.1
Refrigeration	1976	152.3	20.8	13.7	131.5	88.0	43.5
	1979	191.1	20.3	10.6	170.8	89.0	81.8
	% Change	+ 25.5	- 2.3		+ 29.9	+ 1.1	+ 88.0
Foam Plastics	1976	110.4	42.1	38.1	68.3	44.4	23.9
	1979	152.4	55.8	36.6	96.6	36.3	60.3
	% Change	+ 38.0	+ 32.2		+ 41.1	- 18.2	+152.3
Other Uses	1976	29.8	4.2	14.1	25.6	18.6	7.0
	1979	48.5	6.9	14.2	41.6	33.0	8.6
	% Change	+ 62.8	+ 65.7		+ 62.5	+ 77.4	+ 22.9
Totals : Non-aerosol categories	1976	292.5	67.1	22.9	225.4	151.0	74.4
	1979	392.5	83.0	21.1	309.0	158.3	150.7
	% Change	+ 34.0	+ 23.7		+ 37.1	+ 4.8	+ 76.3
Totals : All Categories	1976	724.8	244.0	33.7	480.8	289.0	191.8
	1979	646.6	219.6	34.0	427.0	164.9	262.1
	% Change	- 10.8	- 10.0		- 11.2	- 42.9	+ 36.7

Note : 'World' = Total CMA Reporting Company sales for stated category.
(CMA Reporting Companies include all the EEC CFC producers)
EEC and USA figures are for sales within these territories

FIGURE.2.3 DISTRIBUTION OF F-11 AND F-12 SALES IN EEC : COMPARISON FOR YEAR 1979



F-11



F-12

<u>Figure 2.4.</u> charts progress towards the end of 1981 minimum reduction target of 30% relative to the 1976 level of use of F-11 and F-12 in filling aerosols in the EEC.

<u>Table 2.3</u> categorises world sales by all CMA reporting companies in 1976 and 1979 and the percentage changes between these years, with corresponding data for the EEC and the USA, and for sales outside the EEC including and excluding sales in the USA.

<u>Figure 2.5</u> represents the trends of F-11/F-12 sales in the EEC and the world for the main application categories over the period 1976 to 1979.

<u>Table 2.4</u> compares the percentage distribution of sales of F-11/F-12 by CMA reporting companies in the EEC, non-EEC countries and the world for 1976 and 1979.

<u>Table 2.5</u> expresses F-11/F-12 sales in the EEC by category as percentages of world sales by CMA reporting companies in each category, and as percentages of combined world sales for all categories.

<u>Figure 2.6.</u> depicts the 1979 distribution by category of world sales of F-11/F-12 by CMA reporting companies, and the proportions represented by sales in the EEC.

FIGURE 2.4. F-11/F-12 USAGE IN EEC : PROGRESS TOWARDS MINIMUM 30% REDUCTION TARGET

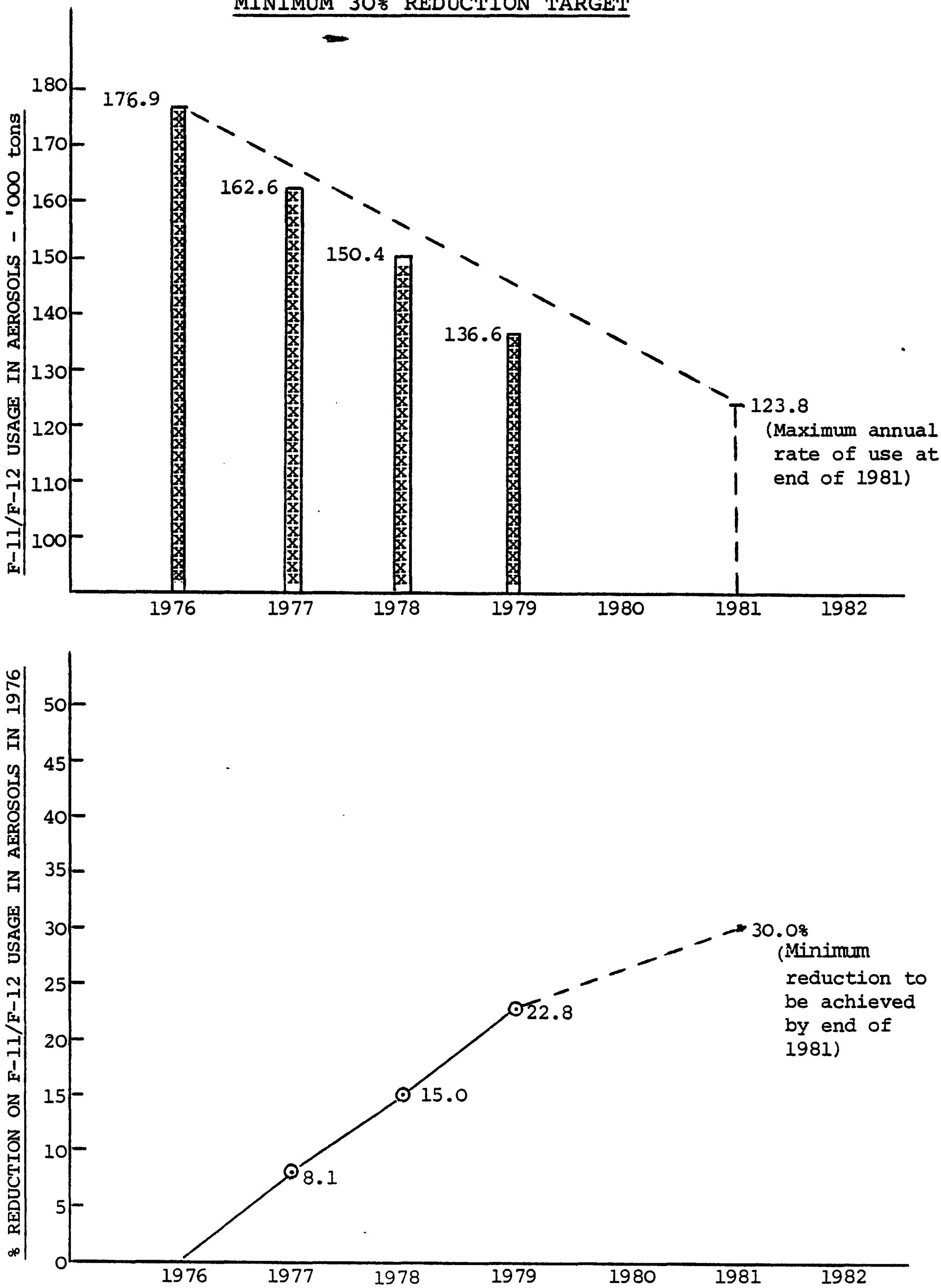


TABLE 2.4

PERCENTAGE DISTRIBUTION OF CMA REPORTING COMPANY SALES OF F-11/F-12 BY CATEGORY AND TERRITORY: 1976 and 1979

	% TOTAL F-11/F-12 SALES BY CMA REPORTING COMPANIES					
	1976			1979		
TERRITORY:	EEC	Non-EEC	World	EEC	Non-EEC	World
Aerosols	72.5	53.1	59.6	62.2	27.6	39.4
Refrigeration	8.5	27.4	21.0	9.2	40.0	29.5
Foam Plastics	17.3	14.2	15.2	25.4	22.6	23.6
Other Uses	1.7	5.3	4.1	3.2	9.7	7.5
Non-aerosol uses	27.5	46.9	40.4	37.8	72.4	60.6
	100.0	100.0	100.0	100.0	100.0	100.0

Source: CMA and EFCTC statistics

Note: EEC sales distribution relates to sales within the EEC. Non-EEC distribution relates to differences between world sales by all CMA reporting companies and EEC sales.

TABLE 2.5.

F-11/F-12 SALES IN EEC BY CATEGORY AS PERCENTAGE OF WORLD SALES BY CMA REPORTING COMPANIES: 1976 and 1979

	Sales in EEC as % World Sales for Stated Category		Sales in EEC as % Total World Sales for all categories	
	1976	1979	1976	1979
	%	%	%	%
Aerosols	40.9	53.7	24.4	21.1
Refrigeration	13.7	10.6	2.9	3.1
Foam Plastics	38.1	36.6	5.8	8.6
Other Uses	14.1	14.2	0.6	1.1
All non-aerosol uses	22.9	21.1	9.3	12.8
All Categories	33.7	34.0	33.7	34.0

Source: CMA and EFCTC statistics

FIGURE 2.5

F-11/F-12 SALES BY CATEGORY IN EEC AND WORLD BY CMA REPORTING COMPANIES : 1976 TO 1979

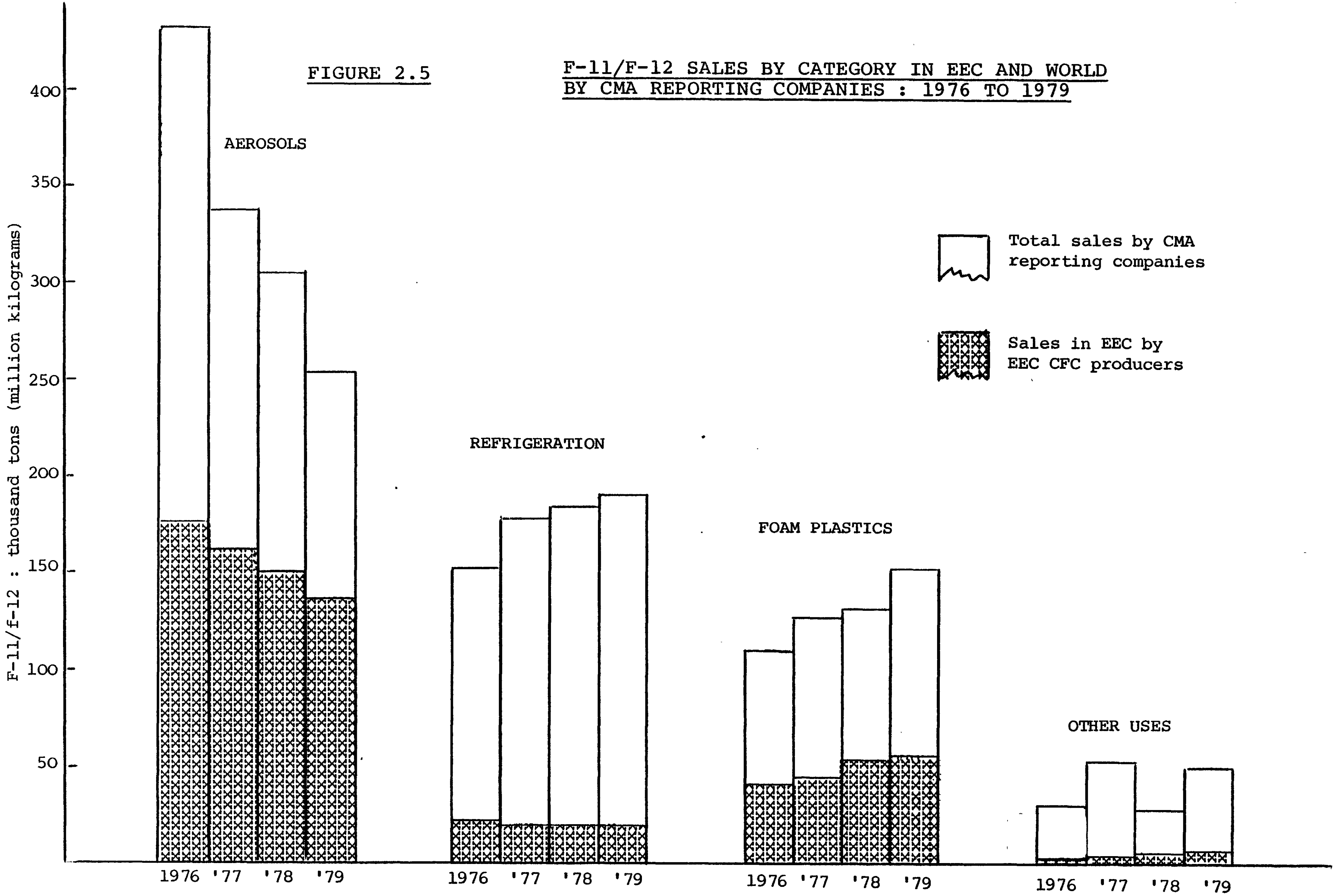


Table 2.6. shows the impact which reductions in the 1979 levels of sales of F-11/F12 in the EEC would have on the total 1979 world sales level.

Table 2.7. gives F-113 and F-114 statistics for production and sales by EEC producers in 1977. Figures for later years are not currently available for these two compounds.

Citation of Sources: The sources cited at the foot of each table are the original data sources consulted. In all instances the original data has been further processed by Metra for presentation in this report. The figures have been constructed from the original and derived data tabulations.

2.4. Commentary on CFC Statistics

2.4.1. F-11/F-12 Production Trends

As shown by Fig.2.1., world production of both F-11 and F-12 has progressively declined from the secondary peaks of 1976. The combined F-11/F-12 total of 799.7 thousand tons in 1976 fell to 702.3 thousand tons in 1979, a drop of 12.2%, and over the same period EEC production fell from 326.4 to 304.2 thousand tons, a reduction of 6.8%. Due to the differential rate of decline, EEC output as a proportion of the world total rose from 40.8% in 1976 to 43.3% in 1979.

With only marginal increases in production recorded or estimated for the communist countries, Argentina and India, the net world production decrease is linked with falling sales of the CMA reporting companies,

TABLE 2.6.

IMPACT OF REDUCTIONS IN F-11/F-12 SALES IN EEC ON CMA REPORTING COMPANY WORLD SALES IN 1979

Table A. Impact of Further Reductions in Sales in EEC for Aerosols on Total CMA Reporting Company Sales at 1979 Level.

Reduction in 1976 Sales of F-11/F-12 for Aerosols in EEC (176,914 tons)		Reduction in 1979 Sales for Aerosols in EEC (136,552 tons)	1979 World Sales less reduction in 1979 sales for aerosols in EEC	Reduction in 1979 level of Total World Sales
%	'000 tons	'000 tons	'000 tons	%
22.8*	40.4*	0.0	646.6	0.0
30 +	53.1 +	12.7	633.9	2.0
40	70.8	30.4	616.2	4.7
50	88.5	48.1	598.5	7.4
60	106.1	65.8	580.8	10.2
70	123.8	83.5	563.1	12.9
80	141.5	101.2	545.4	15.7
90	159.2	118.9	527.7	18.4
100	176.9	136.6	510.0	21.1

* Actual reduction in 1979

\+ Minimum reduction required by Council Decision of March 1980. (Further reductions are hypothetical).

Table B. Impact of 30% Reduction in Sales in EEC for non-Aerosol Applications on CMA Reporting Company Sales at 1979 Levels

Sales Category	Actual 1979 Sales in EEC tons	1979 World Sales for All Uses less 30% EEC Sales for Stated Category '000 tons	Reduction in 1979 World Sales for All Uses %
Refrigeration	20,300	640.5	0.94
Foam Plastics	55,788	629.9	2.6
Other Uses	6,921	644.5	0.32
All non-Aerosol Uses	83,009	621.7	3.9

Source: Metra, from CMA and EFCTC statistics

TABLE 2.7. F-113 AND F-114. PRODUCTION AND SALES BY EEC PRODUCERS IN 1977

		F-113	F-114	TOTAL F-113 + F-114
PRODUCTION (including any imports from outside EEC)	- tons	16,463	7,416	23,879
SALES IN EEC				
Aerosols	- tons	120	5,141	5,261
% All Sales in EEC		0.87	92.3	27.2
% EEC + Export Sales		0.67	72.2	21.1
Refrigeration	- tons	132	91	223
% All Sales in EEC		0.96	1.6	1.2
% EEC + Export Sales		0.74	1.3	0.89
Foam Plastics	- tons	655	337	992
% All Sales in EEC		4.8	6.1	5.1
% EEC + Export Sales		3.7	4.7	4.0
Solvent & Other Uses	- tons	12,831	-	12,831
% All Sales in EEC		93.4	-	66.5
% EEC + Export Sales		71.9	-	51.4
TOTAL EEC SALES	- tons	13,738	5,569	19,307
% EEC + Export Sales		77.0	78.2	77.3
TOTAL EXPORTS OUTSIDE EEC	- tons	4,100	1,556	5,656
% EEC + Export Sales		23.0	21.8	22.7
TOTAL EEC + EXPORT SALES	- tons	17,838	7,125	24,963

Source: EFCTC

for which the main cause has been declining sales for aerosols (Table 2.4.), especially in the United States where the ban on CFC usage in most aerosol products became fully effective in 1979. However, if the strong growth over the period 1976 to 1979 of sales in the non-aerosol sectors continues unchecked, world production decline will eventually be reversed, although the upturn could be delayed by further action outside the USA against usage in aerosols.

2.4.2. F-11/F-12 Sales by EEC Producers: 1976-79

The following important features may be noted in the statistics presented in Tables 2.1 and 2.2, and in Figures 2.2, 2.3. and 2.4.

- Sales for aerosols fell from 176,914 tons in 1976 to 136,522 tons in 1979, a reduction of 22.8%. However, this continued to be the largest sales category, accounting for 62.2% of sales within the EEC, and 45.3% of total (EEC + export) sales in 1979.

- Progress towards the minimum 30% reduction target in sales for aerosols compared with 1976 was ahead of that corresponding to a steady linear rate of decrease, and if the average annual reduction of 7.6% achieved over the three years continues through 1980 and 1981, the target will be exceeded. (Fig.2.4)

- Sales for Refrigeration have not been changed significantly since 1976, and at 20,300 tons in 1979, accounted for only 9.2% of EEC sales.

- <u>Sales for Foam Plastics</u> registered substantial growth, and at 55,788 tons in 1979 were 32.3% above the 1976 level.

- <u>Other Uses</u> in 1979 accounted for the relatively small fraction of 3.2% of EEC sales, although at 6,921 tons the volume was 65.7% above that in 1976.

- <u>Export Sales</u> declined slightly, from 83,578 tons in 1976 to 81,636 tons in 1979, but in relation to total sales the proportion rose from 25.5% to 27.1%.

- <u>The net reduction</u> in annual sales over the period was 26,400 tons, or 8.1% of the 1976 total, the reduction in sales for aerosols having been substantially offset by increased sales for foam plastics and miscellaneous uses.

- <u>The differing F-11 and F-12 sales patterns</u> are brought out in Table 2.2. and Fig.2.3. For F-11 the main non-aerosol use is as a blowing agent in the manufacture of foam plastics whereas for F-12 it is as a refrigerant.

2.4.3. EEC Sales of F-11/F-12 in Relation to World Sales

The following comments refer to sales by CMA reporting companies, which include all EEC producers.

2.4.3.1 Trends: 1976 to 1979 (Table 2.3 and Fig.2.5)

Sales for aerosols outside the EEC declined by 53.8% over the period as compared with 22.8% within the Community. The disparity is attributable to the fall of 95.2% in the USA due to ban on CFC usage in 'non-essential' aerosols, since in the rest of the world the decline in the aerosol sector was only 5.1%.

World sales in the non-aerosol sectors rose by 34.0% overall, with the non-EEC countries registering increased sales in each non-aerosol sector, despite static situations in sales for refrigeration in the EEC and USA, and a reduction in USA sales for foam plastics.

The net outcome of the various sectoral changes was that falls of 10 to 11% occurred in total EEC, non-EEC and world sales, and a massive reduction of 43% in sales in the USA. For areas outside the EEC and the USA, however, a rise of 36.7% occurred in total sales, the slight fall in sales for aerosols being outweighed by a doubling of the non-aerosol sector sales.

2.4.3.2 Sales Distribution Patterns (Tables 2.4 and 2.5; Fig.2.6)

The sales patterns within and outside the EEC are in sharp contrast, the divergence having increased since 1976. In the EEC in 1979, 62.2% of sales were for aerosols and only 9.2% for refrigeration whereas outside the EEC the proportions were 27.6% and 40.0% respectively.

The proportions for foam plastics were similar (EEC: 25.4%; non-EEC: 22.6%) but solvent and other uses accounted for 9.7% outside the EEC, compared with 3.2% in the Community.

2.4.3.3 Sales Volume Comparison (Tables 2.5 and 2.8; Fig.2.6)

As shown in Table 2.8 below, the fall in USA sales between 1976 and 1979 virtually reversed the proportions of the world total held by the USA and the rest of the world excluding the EEC, but the proportion accounted for by the EEC has remained at just over one third of the world total.

TABLE 2.8.
TERRITORIAL DISTRIBUTION OF F-11/F-12 SALES: 1976 and 1979

	1976		1979	
	'000 tons	%	'000 tons	%
EEC	244.0	33.7	219.6	34.0
USA	289.0	39.9	164.9	25.5
Rest of World	191.8	26.5	262.1	40.5
Total	724.8	100.0	646.6	100.0

Taking the individual sales categories (Table 2.5) it is noteworthy that in 1979 the EEC accounted for 54% of world sales by the reporting companies for aerosols, but only 11% of those for refrigeration. A more significant perspective is provided by the ratios of EEC sales by category to total world sales, which in 1979 were aerosols: 21%, refrigeration: 3%, foam plastics: 9%, and other uses: 1%.

2.4.4. Impact on World Sales of Reduction in Use in EEC

Table 2.6A shows the impact on 1979 world sales of progressively reducing EEC usage in aerosols from the level of usage in 1979 to zero, the 1979 level being already 22.8% below that of 1976. It will be seen that to reduce 1979 world sales by 10%, the EEC reduction would have to be 60% of the 1976 level.

Turning to the non-aerosol applications, Table 2.6B shows that even if the EEC were able to reduce sales in all of these by 30%, the reduction in world sales at the 1979 level would be only 3.9%.

The foregoing analysis relates to a static situation, and in the current economic recession it is difficult to gauge future growth rates. If sales for non-aerosol uses are assumed to continue to grow at the same average linear rates as obtained from 1976 to 1979 the following results ensue:

a) In the EEC, the minimum reduction of 53,000 tons in the 1976 level of use in aerosols required by the 1980 Council Decision would be neutralised over the course of 10 years by the average rise of 5,300 tons annually in the non-aerosol sales, i.e. by the end of 1986.

b) Worldwide, the reduction in use in aerosols in the period 1976-81 achieved by action in the EEC and the USA will amount to about 184,000 annual tons. This would be neutralised in approximately 5.5 years by the 1976-79 average annual increase of 33,300 tons in non-aerosol sector sales, i.e. in the latter half of 1981. (This calculation ignores changes in sales for aerosols in countries outside the EEC and USA, which fell by an average of only 1700 tons annually from 1976 to 1979).

Hence, if the EEC wishes to make a significant contribution to retarding world sales growth after 1981, the statistics lead to the conclusion that this would entail additional material reductions in F-11/F-12 usage in aerosols, because the potentiality in the non-aerosol sales sectors is insufficient.

Outside the EEC and the USA, sales for aerosols in 1979 amounted to 111.4 thousand tons, compared with 136.6 thousand tons within the EEC, and the gap is likely to have narrowed further by the end of 1981. Thus there is a strong case for the proposition that any measures to secure additional reductions in usage for aerosols in the EEC after 1981 should be accompanied by equivalent measures in those countries outside the Community which have not yet acted in this direction.

2.4.5. Inter-Community Trading in F-11 and F-12

The extent of inter-Community trading is indicated by the proportion of producer sales outside their home markets to their total sales in the EEC. The proportions for the years 1976 to 1979 are shown in Table 2.10. below, which has been constructed from the original EFCTC data. It should be noted that trading between the producers themselves and between customers of the producers is excluded from these figures.

A downward trend might be expected in a contracting market situation, but there has been only a marginal decrease from 25.0% in 1976, to 23.6% in 1979.

TABLE 2.9 F-11/F12 SALES OUTSIDE EEC PRODUCERS HOME MARKETS AS PERCENTAGES OF TOTAL EEC SALES.

Year	Sales in Home Markets	Sales in Other EEC Markets	Total Sales in EEC	Other EEC Sales as % Total EEC Sales
1976	183.0	61.0	244.0	25.0
1977	173.4	59.6	233.0	25.6
1978	176.2	55.2	231.4	23.9
1979	167.8	51.8	219.6	23.6

2.4.6. Need for Data on Other Chlorofluorocarbons

Besides F-11 and F-12, two other fully halogenated CFCs are produced and marketed in substantial tonnages in the EEC. These are the chlorofluoroethanes F-113, used mainly in solvent cleaning systems, and F-114, used principally as an aerosol propellant in perfumes, colognes and shave foams.

For the Metra 1978 study the EFCTC provided production and use data for F-113 and F-114 for the years 1976 and 1977, and an analysis of the latter set is presented in Table 2.7.

The EFCTC has not continued collecting data for F-113 and F-114, and the March 1980 Council Decision referred only to F-11 and F-12.

Features of the 1977 EEC figures are:

- the sharp differentiation of function, some 93% of EEC sales of each compound being used in their principal applications

- the preponderance of F-113 sales, totalling 17,838 tons, compared with 7,125 tons of F-114.

- the substantial amount of export business, which at 22.7% of total sales was slightly lower than the proportion of F-11/F-12 exports in the same year: 25.8%

The combined F-113/F-114 sales tonnage of nearly 25,000 tons in 1977 represents 7.4% of total sales of F-11,12,113 and 114 in that year. Since that year, F-11/F-12 sales by EEC producers have fallen, F-114 sales have possibly remained fairly static, but the demand for F-113 is believed to have been rising by as much as 8% annually. If these trends continue then F-113 and F-114 could soon comprise 10% or more of the total sales of these four CFCs.

The CMA does not collect world statistics for F-113 and F-114, but the OECD report of October 1980 quoted the following total production figures supplied by Du Pont. (Table 2.10).

TABLE 2.10 F-113 and F-114. WORLD PRODUCTION: 1977-79

'000 Tons

	F-113	F-114	Total F-113 + F-114
1977	70	18	88
1978	79	21	100
1979	91	18	109

Source: OECD (from Du Pont)

The average F-113: F-114 ratio of 4.2 is much higher than for the EEC, where it was 2.2 in 1977, and the annual combined growth rate over the two years averages nearly 12%, which is also believed to be higher than that of EEC production.

The total of 109 thousand tons of F-113/F-114 in 1979 represents 13% of the estimated world total production of the four fully halogenated CFCs: F-11,12,113 and 114.

The other principal commercial CFC is F-22, $CHClF_2$, which is mainly used as a refrigerant, and because it is not fully halogenated and therefore more liable to degradation in the troposphere, it is regarded as a very much smaller threat to stratospheric ozone.

No statistics are available for EEC production and use of F-22, but the OECD - again citing Du Pont as the source - gives the production in the three years 1977-79 as 102,000; 114,000 and 131,000 tons respectively. These figures exclude the use of F-22 as a chemical intermediate, e.g. for the manufacture of the fluorocarbon plastic PTFE (polytetrafluoro-ethylene), because that production is not eventually released to atmosphere.

If a similar ratio of total F-22 production to total world sales by CMA reporting companies of F-11/F-12 for refrigeration applies in the EEC, then F-22 production in the EEC in 1979 would have been about 14,000 tons.

The combined world production tonnage of F-113,114 and 22 in 1979 of 240,000 tons represents over 25% of the aggregate world production of these compounds plus F-11 and F-12.

This substantial percentage reinforces our view that there is a case for the regular collection of annual statistics on all CFCs which are produced in significant quantities, both in the world and the EEC, for so long as there is concern about the effect of releases of CFCs on the ozone layer.

A possible arrangement in the EEC for CFCs other than F-11 and F-12 might be for each producer to submit an annual return to independent accountants in respect of any other CFC compound of which production (including importation from outside the EEC) had exceeded, say, 1000 tons. The accountants would summate the data, but to maintain commercial confidentiality would only provide notification to the effect that production of a given compound (or group of compounds) lay in one of three ranges, e.g. 1000 to 10,000 tons; 10,000 to 20,000 tons; and above 20,000 tons. For production exceeding 20,000 tons there would be a prime facie case for considering whether actual tonnage figures should be provided, in the same way as for the current arrangement applying to F-11 and F-12.

2.5. Conclusions

2.5.1 In 1976. the reference year for the Council Decision to reduce F-11/F-12 usage for aerosols in the EEC by at least 30%, world production of these CFCs reached a secondary peak of 800 thousand tons but progressively declined thereafter to 702 thousand tons in 1979, a fall of 12.2%. Over the same period EEC output declined by 6.8%, from 326 to 304 thousand tons, the greater external decline being attributable to the United States ban on CFC propellants in most aerosols, which became fully effective in 1979.

2.5.2. From 1976 to 1979, F-11/F-12 sales for aerosols in the EEC fell by 22.8% and if this rate of decrease is maintained the 30% minimum reduction target will be exceeded in 1981. Outside the EEC, sales for aerosols in the same period by CMA reporting companies declined by 53.8%, again reflecting the U.S. ban. For areas outside the EEC and the USA, the reduction was only 5.1%. In 1979, the EEC accounted for 54% of world sales for aerosols of 254.6 thousand tons.

2.5.3. The F-11/F-12 usage pattern in the EEC is in marked contrast to that outside. Sales for aerosols in the EEC in 1979 accounted for 62.2% of sales compared with 27.6% outside the Community, whereas use for refrigeration was only 9.2% in the EEC compared with 40% outside.

2.5.4. For the non-aerosol applications of F-11 and F-12, world sales rose substantially in all categories and by 34% overall in the period 1976 to 1979. In the EEC, sales for non-aerosol uses rose by 23.7%, mainly due to an increase for foam plastics, whereas sales for refrigeration remained virtually unchanged.

2.5.5. The net reduction in total F-11/F-12 sales by EEC producers from 1976 to 1979 was 8.1%, the decrease of 22.8% in sales for aerosols having been substantially offset by the rise in sales for foams and other uses.

2.5.6. The EEC accounted for 34% of world sales totalling 646.6 thousand tons of F-11/F-12 by CMA reporting companies in 1979, and nearly two thirds of these EEC sales were for aerosols. It follows that if the EEC wishes to make another significant contribution to restricting world usage of F-11/F-12, this would necessitate a further substantial reduction in use for aerosols. If the reduction from the 1976 level of use in aerosols were to be raised to 60%, this would reduce total world sales by 10% of the 1979 levels. A reduction of 30% in 1979 EEC sales for non-aerosol applications would reduce the 1979 level of world sales by less than 4%.

2.5.7. World production of the other principal fully halogenated CFCs, F-113 and F-114, is estimated to have risen from 88,000 tons in 1977 to 109,000 tons in 1979, when it represented 12% of world production of F-11,12,113 and 114. Corresponding EEC production figures for 1977, the latest year for which data is available, were 24,000 tons and 7%. There is a case for the collection of world and EEC annual statistics for all CFCs produced in significant quantities.

2.6. References

1. U.S. Chemical Manufacturers Association 1979 World Production and Sales of Fluorocarbons FC-11 and FC-12. May 12 1980.

2. U.S. Chemical Manufacturers Association - Fluorocarbon Project Panel. World Production and Release of Chlorofluorocarbons 11 and 12 through 1979. May 23, 1980.

3. OECD Draft Report of Chlorofluorocarbons, ENV(80)32, 30 October 1980.

3. AEROSOLS

Before considering possible means of further reducing CFC usage in aerosols it is helpful to review trends in production and the current techno-commercial situation in respect of CFC propellant substitution. In sections 3.1 and 3.2 the corresponding reviews in the Metra 1980 report are up-dated.

3.1. Aerosol Production Trends

Overall trends in manufacture over the decade 1970 to 1979 are shown graphically in Figure 3.1. in terms of total aerosol units filled in Western Europe, the EEC, the USA and the rest of the world.

Table 3.1 lists total fillings in each of the four years 1976 to 1979 for the individual EEC Member States and other West European countries, the USA and the rest of the world. Figure 3.2 provides a visual contrast of fillings in 1976 and 1979 for 7 EEC countries and the rest of Western Europe including Greece.

Table 3.2 compares fillings in 1976 and 1979 in the 5 principal aerosol manufacturing countries of the EEC, analysed into 7 sales categories.

National filling statistics include an element of estimation in that they are based on a combination of returns provided by member companies of aerosol trade associations, and assessments of the outputs of non-reporting companies including those in countries where there are no aerosol associations. These

FIGURE 3.1 WORLD AEROSOL FILLINGS : 1970-1979

Source: Metal Box

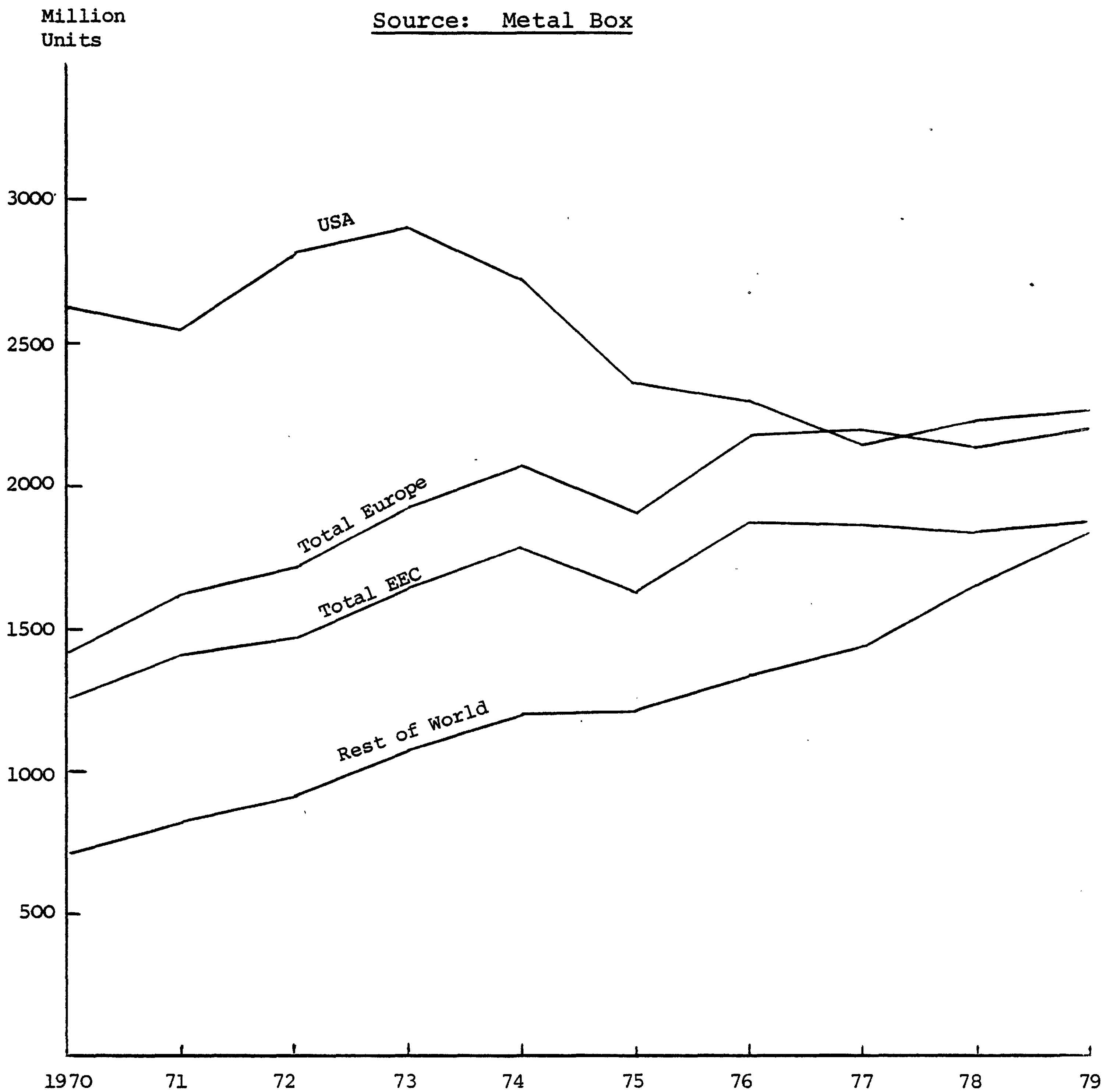


TABLE 3.1. EEC AND WORLD AEROSOL FILLINGS: 1976 - 1979

Millions of Units

	1976	1977	1978	1979	1979 Percentage Distributions		% Change 1976 to '79
					% EEC Total	% World Total	
Belgium	51	54	52	61	3.3		+ 19.6
Denmark	13	11	9	11	0.6		+ 18.2
France	454	466	412	419	22.4		- 7.7
F. R. Germany	457	454	450	467	25.0		+ 2.2
Ireland (nominal estimate)	(5)	(5)	(5)	(2)	0.1		- 60.0
Italy	253	192	207	227	12.2		- 10.3
Netherlands	145	143	139	159	8.5		+ 9.7
United Kingdom	495	532	563	522	27.9		+ 5.5
TOTAL : EEC	1,873	1,857	1,837	1,868	100.0	29.6	- 0.3
Austria	35	38	37	36			+ 2.9
Finland	21	15	14	18			- 14.2
Greece	26	28	30	29			+ 11.5
Norway	14	15	12	11			+ 21.4
Portugal	17	31	24	26			+ 52.9
Spain	120	146	130	156			+ 30.0
Sweden	18	13	12	12			- 33.3
Switzerland	50	53	44	50			0.0
TOTAL : REST OF W. EUROPE	301	359	303	338		5.4	+ 12.3
TOTAL WESTERN EUROPE	2,174	2,216	2,140	2,206		35.0	+ 1.5
USA	2,295	2,150	2,231	2,258		35.8	- 1.6
REST OF WORLD (estd.)	1,335	1,427	1,656	1,837		29.2	+ 37.6
TOTAL WORLD	5,804	5,793	6,027	6,301		100.0	+ 8.6

Source: Metal Box

FIGURE 3.2 WESTERN EUROPE AEROSOL FILLINGS : 1976 AND 1979

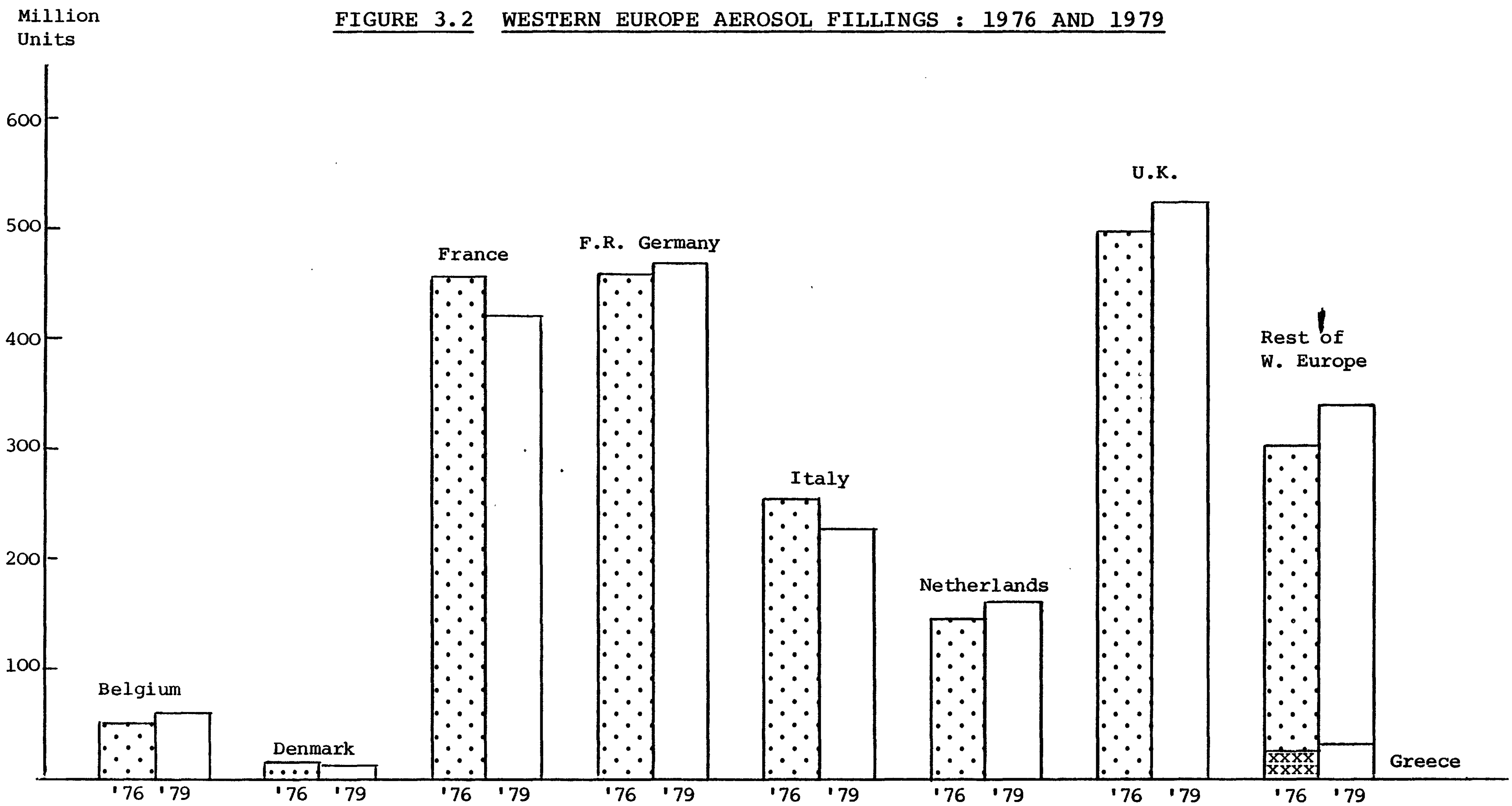


TABLE 3.2 AEROSOL FILLINGS BY PRODUCT SECTOR IN 5 EEC COUNTRIES : 1976 AND 1979

	United Kingdom		F.R. Germany		France		Italy		Netherlands		Totals (5 Countries)		Change 1976 to 1979	
Fillings - million units	1976	1979	1976	1979	1976	1979	1976	1979	1976	1979	1976	1979	No	%
Hairsprays	139	104	133	120	105	86	56	50	18	10	451	370	-81	-18.0
Deodorants and Antiperspirants	66	52	140	123	46	33	46	38	12	2	310	248	-62	-20.0
Other Personal Products	81	91	34	35	155	158	22	24	6	4	298	312	+14	+ 4.7
Household Products	96	102	54	67	54	43	32	33	68	85	304	330	+26	+ 8.6
Insecticides	47	60	27	27	26	16	55	48	25	40	180	191	+11	+ 6.1
Paint	16	29	23	31	3	6	3	6	16	18	261	343	+82	+31.4
Miscellaneous	50	84	46	64	65	77	39	28						
TOTAL	495	522	457	467	454	419	253	227	145	159	1804	1794	-10	-0.6
Percentage Distribution														
Hairsprays	28.0	19.8	29.1	25.7	23.1	20.4	22.1	21.9	12.4	6.0	25.0	20.6		
Deodorants and Antiperspirants	13.3	10.1	30.6	26.3	10.1	8.0	18.2	16.8	8.3	1.1	17.2	13.8		
Other Personal Products	16.4	17.4	7.4	7.5	34.1	37.6	8.7	10.5	4.1	2.5	16.5	17.4		
Household Products	19.4	19.4	11.8	14.3	11.9	10.4	12.6	14.6	46.9	53.3	16.9	18.4		
Insecticides	9.5	11.6	5.9	5.8	5.7	3.8	21.7	21.1	17.2	25.4	10.0	10.6		
Paint	3.2	5.5	5.0	6.6	0.7	1.4	1.2	2.9	11.0	11.6	14.5	19.1		
Miscellaneous	10.1	16.2	10.1	13.7	14.3	18.4	15.4	12.3						
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Metal Box. Note: These 5 countries accounted for over 95% of EEC fillings in 1976 and 1979.

assessments are generally made by panels of industry experts, on which are represented major suppliers of cans, valves, propellants etc. to the filling sector. For consistency, the statistics presented here are based on collations compiled by one organisation, the Metal Box Company.

The following features merit comment:

a) The EEC fillings total for 1979 is only marginally below that for 1976, hence the fall of 22.8% in F-11/F-12 usage in aerosols over that period (Section 2, Table 2.1) must be attributable to other factors, mainly changes in formulation and sales category patterns, and perhaps also to variations in the average unit fill volumes. These factors cannot easily be quantified, but the reductions of 18% in hairspray fillings and of 20% in anti-perspirants and deoderants in the five principal filling countries suggest that sales pattern changes played a significant role, since these two sectors account for the major proportion of CFC usage in aerosols.

b) In 1979, EEC fillings represented 85% of the Western Europe total and about 30% of the world total. In the non-EEC countries of Western Europe, Spain accounted for 46% of 1979 fillings and Greece for 8.6%. If the 29 million fillings in Greece are added to the EEC total of 1868m. they represent only 1.5%.

c) In the USA, fillings climbed to a peak of 2902m in 1973, and slumped to 2150m in 1977 following adverse public reaction associated with the ozone depletion issue. Table 6 shows that fillings are now rising again, despite the ban on CFCs in most aerosol products.

d) Strong growth is registered in countries outside the USA and Western Europe, where fillings rose from 1335m. in 1976 to an estimated 1837m. in 1979, an increase of 37.6%

3.2. CFC Propellant Substitution: Techno-Commercial Situation

3.2.1. Range of Alternatives

The commercially available options for CFC propellant substitution were reviewed in our report of June 1980. As no significant developments have been reported in the interim a summary of the present situation is given here, and the reader is referred to Metra 1978 and Metra 1980 for more detail.

It is important to remember that the CFCs used in aerosols do not act only as propellants: they also have essential functions as solvents and diluents. If the CFC content of a formulation is to be reduced or eliminated then it must be replaced by substances which will also perform these ancillary functions.

In theory, it would be possible to replace the currently used CFC propellants with other fluorocarbon compounds having appropriate physico-chemical properties but which would not threaten the ozone layer. At present, however, no such compounds are available in commercial quantities which fully satisfy the technical, environmental and toxicological criteria.

One fluorocarbon, F-152a ($CH_3 . CHF_2$), which contains no chlorine, is considered by Du Pont to be acceptable as an aerosol propellant for a number of product categories, but it is not being made in Europe and on account of the high production cost is unlikely ever to become a commercial proposition in the main aerosol market sectors.

F-22, ($CHClF_2$), extensively used in refrigeration, is still a potential candidate, but it is more expensive than F-11/F-12, has not yet been fully cleared in respect of toxicological safety, and is not yet regarded as entirely innocuous to the ozone layer if released in large tonnages.

In the absence of an acceptable fluorocarbon alternative, the possibilities are as follows:

- non-fluorocarbon liquefied gas propellants, viz. hydrocarbon (propane/butane) mixtures and dimethylether

- compressed and dissolved gases: carbon dioxide, nitrous oxide, nitrogen and air

- devices employing stored mechanical energy e.g. in the form of a spring-loaded piston or elastomeric bag

- manually operated dispensers such as 'finger pumps'. (These may give similar practical results but do not conform to the industry definition of an aerosol dispenser as an internally pressurised non-reusable pack, or the EEC definition which relates to internally pressurised packs employing a propellant gas).

The present status of these alternatives is summarised below.

3.2.2. Hydrocarbons

Hydrocarbon propellants in the form of propane/butane mixtures are currently the predominant substitute for CFCs, and are now being used in most of the high volume product sectors in the EEC, the principal exception being perfumes and colognes. They are relatively cheap - typically around 20% of the cost of CFC propellants on a volume for volume basis - and have the technical advantages associated with liquefied gases.

Availability in the Community has been, and to some extent still is restricted by production capacity and distribution facilities, and there have been variations in quality - especially in respect of odours associated with trace impurities. These limitations are rapidly being eliminated and, in most areas of the Community, availability is seldom likely to be a determining factor in decisions to instal hydrocarbon filling facilities.

New suppliers have entered the market and are providing technical support facilities for customers, and it appears probable that supply will soon be geared to meet any likely rate of increase in demand.

The outstanding disadvantage of hydrocarbon propellants is their high flammability, and any filler wishing to use them must incur substantial costs to meet safety requirements such as minimum separation distances between storage and filling areas, the isolation of filling from other operations, and the provision of gas detection equipment, extra ventilation systems and various safety devices. In many cases an existing factory cannot be converted for using hydrocarbon propellants because it cannot be adapted to meet the safety requirements or is located in an area where storage of the hydrocarbons would not be permitted.

Hydrocarbons also present formulation problems. They are poor solvents for some active ingredients, and there may be difficulties, sometimes insuperable, in devising a commercial formulation which does not contain more than 45% of flammable components and which must then be labelled accordingly. The flammability aspect also introduces problems in respect of transport, and storage in warehouses and shops.

An economic incentive to use hydrocarbons is provided by the lower cost relative to that of CFCs, but some fillers have found that in certain formulations the estimated savings have been offset by lower unit sales associated with longer product life. This is due to the need to restrict the discharge rate when using flammable propellants, so as to limit the flame extension if the aerosol is discharged across an ignition source.

In the EEC, hydrocarbon propellants have been extensively used for many years in the household products sector where aqueous formulations are often employed and the problems mentioned above do not arise.

For the high sales volume sectors it is with personal products - especially hairsprays, antiperspirants and deodorants - that the main problems are encountered, and many fillers who have decided to use hydrocarbons in these products are doing so in admixture with CFCs. By using HC/CFC mixtures, material costs are reduced, the flammables content can generally be kept within the 45% limit, beyond which the flammability labelling and other restrictions apply, and technical reformulation problems minimised.

3.2.3. Dimethylether

Dimethylether - 'DME' - is the only commercially available non-CFC liquefied gas type propellant which affords an alternative to hydrocarbons. An aerosol grade is produced by Union Rheinische Braunkohlen Kraftstoff AG at Wesseling, Köln, and distributed under the tradename 'Aeropur' by Aerofako of Apeldoorn. It is intermediate in price between F-11/F-12 and hydrocarbon propellants, and the distributors draw attention to a number of advantages over hydrocarbons including:

- lower flammability
- partial miscibility with water and complete miscibility on addition of 6% ethanol
- better compatibility with perfumes and fragrances, (comparable with CFCs)
- better solvent characteristics for resins, insecticides etc, and a cheaper alternative to alcohols when the latter are subject to excise duty

Although used in Belgium and the Netherlands for some years, fillers in the EEC generally have been reluctant to adopt DME, partly because there is only one supplier and also because of doubts about safety aspects relating to chemical stability and toxicity. An extensive testing programme supported by the Netherlands Government appears to have resolved most of these questions, although long term toxicity trials have yet to be completed.

In Japan, where there are several suppliers, DME is extensively used in insecticides, paints and other non-personal aerosol products but, although interest has been expressed, DME propellant is not being produced in the USA.

In the previous study the manufacturing situation at URBK Wesseling was examined and it was found that output could be expanded to meet any foreseeable demand in the Community. Duplication of plant facilities is such as to give a high degree of assurance of continuity of production, although no petrochemical complex is altogether free from risks.

Metra understands that pilot manufacturing trials with DME are being undertaken by one or two of the larger European filler-marketers and these may presage more widespread acceptance. There is no doubt, however, that emergence of a second supplier would do much to encourage potential users.

3.2.4. Dissolved Gases: Carbon Dioxide and Nitrous Oxide

These gases, which dissolve under pressure in water, alcohols, and other solvents used in aerosols still find only minor application as propellants. Probably the largest use is that of carbon dioxide in windscreen de-icers where it has an advantage over liquefied gas propellants in better maintenance of pressure at low temperatures. Nitrous oxide us used to a small extent in perfumes and some food products.

Although very safe as propellants, there are fundamental technical limitations mainly associated with their relatively low solubility which makes it difficult to maintain satisfactory pressure characteristics over the life of the unit. There is also the question of what solvent to use to replace the volume which might otherwise be occupied by liquefied gas propellants.

Ingenious devices have been developed to overcome the falling pressure drawback, such as the intermittent regeneration of CO_2 by reacting a carbonate with a mild acid, but these are likely to be limited to relatively small product categories.

In Germany, carbon dioxide began to find application in personal products in conjunction with CFCs, thus enabling CFC concentrations to be reduced, but the current preference is understood to be for CFC-hydrocarbon mixtures.

On present evidence it appears most improbable that these gases will ever significantly replace liquefied gas propellants in the principal product sectors.

3.2.5. Compressed Gases

Compressed gases such as air and nitrogen, although the cheapest and most innocuous of propellants, have even greater technical limitations than dissolved gases. Their use is largely restricted to products which are dispensed without change of state such as creams and pastes and which therefore need a relatively small amount of compressed gas in the container.

So-called 'refillable aerosols', such as paint sprays which are periodically re-charged from an air compressor or compressed gas reservoir, are excluded from the industry definition of an aerosol as a non-reusable pressurised pack.

3.2.6. Pump Sprays

Manually operated sprays, such as atomisers which can be activated by repeatedly depressing a piston with the finger, although not defined as aerosols, are designed to imitate their action. While designs have been considerably improved in recent years, pump sprays do not appear to be making any significant inroads into the aerosol market. Their main application is in fragrances and other packs where very small amounts of material are dispensed at a time. Where a sustained spray is required there seems to be a clear customer preference for the self-pressurised aerosol.

3.2.7. Other Devices

Numerous designs have been developed and patented which utilise stored mechanical energy in springs and elastomeric materials. There is also a class of system in which the propellant gas is separated by a membrane or piston from the material to be dispensed, thus minimising the amount of propellant required.

Such devices are generally unsuited to producing finely atomised sprays, and there is no indication that they are making any headway in the main product sectors.

3.2.8. Solvent Problems

The point must be reiterated that CFC substitution raises problems of replacing their solvent and diluent functions. This particularly applies in respect of F-11 which acts as a solvent, diluent and vapour pressure modifier but which, with a boiling point of + 23.8 C, is not in fact a propellant on its own.

The use of alcohols is restricted by flammability considerations, and the high cost associated with the taxes and duties in many Member States constitute an unequally applying impediment to re-formulation. This point was dealt with in some detail in Metra 1980.

The principal non-flammable non-CFC solvents available are methylene chloride and 1:1:1 trichloroethane, but their technical, organoleptic and toxicological characteristics are generally less satisfactory than those of F-11, and in the EEC they may not be used in concentrations above 35% in cosmetic products.

The use of DME would overcome solvent problems in many cases, and in some formulations it would reduce but not eliminate the flammability problem.

3.2.9. <u>Main Trends in Substitution</u>

Further enquiries have served only to confirm the conclusion stated in our June 1980 report to the effect that the main trend in CFC propellant substitution is towards hydrocarbon propellants.

Particularly in the personal products sectors, this trend is coupled with a widespread preference to use mixtures of CFC and HC propellants because, as mentioned in Section 3.2.2., this reduces problems linked with solvent replacement and flammability. Another aspect is that a stage-wise replacement of CFC propellants avoids sharp changes in product characteristics which might affect market acceptability, while providing more time for research on ways of overcoming or mitigating the difficulties of maintaining product quality as complete CFC substitution is approached.

It is too early to say whether a trend will develop towards DME as an alternative or complementary propellant to hydrocarbons. We believe that many fillers are attracted by the technical advantages of DME but are reluctant to rely on a single supplier, and perhaps still holding reservations on safety aspects.

3.3. Alternative Measures for Further Reducing CFC Usage in Filling Aerosols in the EEC

3.3.1. Reduction Resulting from Council Decision of March 1980

It is of interest to consider how the reduction required by the 1980 Council Decision is actually being achieved because it is known that many fillers have taken no positive steps to reduce their usage of CFC propellants, and have no plans to that effect. The answer must lie in a combination of action by some fillers and marketers, especially the larger ones, partially or completely to substitute CFCs by other propellants - principally hydrocarbons, together with the influence of largely uncontrolled market forces which have changed the volume of demand in some of the main CFC consuming sectors. These factors cannot be quantified, and it is impossible to assess the extent to which the minimum reduction requirement might be exceeded at the end of 1981. As an opinion, we think it might reach 35% for the EEC as a whole.

In the event of an upturn in the aerosol market it would be necessary for the industry to undertake additional CFC substitution simply to maintain the minimum reduction requirement, and in a progressively rising market it would become increasingly difficult for fillers taking such action to compensate for those who did not convert to non-CFC propellants.

3.3.2 Extent of Further Reduction to be Considered

For three reasons it is not believed to be sensible or practical to think in terms of additional measures to raise the present minimum reduction level by a relatively small percentage.

a) It is not thought possible to devise acceptable measures which would achieve a fine degree of adjustment in CFC propellant usage.

b) The play of unpredictable factors such as those associated with changes in consumer purchasing decisions in each country could outweigh any action designed to effect a small further decrease in CFC usage.

c) As demonstrated in Section 2.4.4. and Table 2.6. the impact of increasing the reduction in use in aerosols in the EEC from say, 30% to 40%, could affect world sales levels of F-11/F-12 by well under 3%, and it must be questionable as to whether such a small step is worth taking at all.

Accordingly, measures have been considered which could be used to effect a substantial further reduction and, in talking with industry, reductions of up to 70% of the 1976 level of use have been postulated.

It does not follow, of course, that such a large further reduction would have to be achieved quickly and, for a number of reasons including the importance of the safety factor in converting to flammable propellants, a period of several years might be allowed for the inevitable structural changes in the industry to be made as smoothly as possible.

3.3.3. CFCs to be Considered in Further Reduction Measures

The 1980 Decision applies only to F-11 and F-12, whereas existing regulation outside the EEC relates either to all fully halogenated CFCs, or to all fully halogenated chlorofluoroalkanes - thus embracing F-114, which is mainly used in conjunction with F-12 as a propellant in fragrance sprays and in shave foams.

It may be feared that any further measures to restrict F-11/F-12 usage in the EEC might encourage fillers to move towards the chlorofluoroethane propellants and solvents, unless these are included in the restrictions. On account of the much higher cost of these alternatives however, it is most unlikely that such a change would occur, except perhaps in some low volume high value product sectors.

Providing the usage of F-113 and F-114 is monitored as suggested in section 2.4.6., further regulation could be restricted initially to F-11 and F-12. This would minimise difficulties in the fragrance sector which has a high unit output but consumes a relatively low tonnage of propellants because of the small average container size.

3.3.4. Existing and Proposed Regulation in Countries Within and Outside the EEC

A summary of the current situation on CFC aerosol propellant regulation is given below. The only change from the position reported in detail in Metra 1980 is that Canada has implemented the regulations promulgated in March 1979.

Netherlands

A requirement that all aerosols containing CFCs must be labelled with a warning of possible effects on health and the environment came into effect in April 1979.

The Netherlands is the only EEC country to date to have adopted a regulatory measure.

Norway

The manufacture and importation of aerosols employing fully halogenated CFCs as propellants is prohibited after 1 July 1981. Certain medical products are exempt, and there are provisions for granting other exemptions.

Sweden

The manufacture and importation of aerosols containing fully halogenated chlorofluoroalkanes was banned as from 30 June 1979, with provisions for exempting medical and other products.

Canada

From 1 May 1980, the use of fully halogenated chlorofluoroalkanes in manufactured or imported aerosols was prohibited in three product sectors: hairsprays, deodorants and antiperspirants.

United States

The use of fully halogenated chlorofluoroalkanes as propellants in non-essential aerosols was banned from 15 December 1978, and the introduction of products containing these propellants into interstate commerce was prohibited from 15 April 1979. Exemptions granted on grounds of essential purpose and absence of technically feasible alternatives include certain medical products, some industrial products such as diamond grit sprays and solvent cleaners for electronic equipment, articles needed for the safe maintenance and operation of aircraft, and military applications.

3.3.5. Options for the EEC

3.3.5.1 Types of Action Available

Measures which the EEC could consider for securing further reductions in CFC propellant usage fall into three categories:

- Conventions with industry: the extension to greater degrees of reduction of the government-industry agreements now concluded or under negotiation.
- Direct regulatory action: bans or limitations on CFC usage in aerosols, on a positive or negative list basis.
- Indirect action: economic incentives; warning label requirements and other adverse publicity.

In the following paragraphs the basic alternatives in these categories are outlined and discussed.

3.3.5.2. Conventions with Industry

This is the course which Member States have been following for implementing the 1980 Council Decision, with agreements being negotiated between governments and the aerosol industries as represented by national aerosol associations.

In particular circumstances it may be possible for a minimum reduction well above 30% to be negotiated, for instance in a country where the aerosol filling industry has contracted, as may occur if a major multi-national filler decides to concentrate its operations among a smaller number of locations.

At the present time, however, it is unlikely to be practicable to use the convention approach to secure reductions much beyond 30% throughout the EEC for the following reasons:

- the aerosol industry has indicated that it is firmly opposed to further reduction on the grounds that it is not warranted by the present scientific evidence.

- the industry is not structured and organised in such a way as to be able to enter into such undertakings. The present reduction target is being achieved through action being taken by a comparatively small number of larger fillers, which outweighs the lack of action by others. Further reduction would require action by a larger number of fillers, but the trade associations have no powers to commit or compel their members to any action and many fillers do not belong to trade associations.

3.3.5.3 Direct Regulatory Action

a) Prohibitions on Use

Two approaches are possible under this heading:

- To ban the use of specified CFCs in all aerosol manufacture and importation, with a system for granting exemptions on grounds of public interest and social necessity

- to ban CFC usage in designated product sectors

The first approach is that adopted by Norway, Sweden and the United States, while the second is being employed by Canada.

Designated product sector bans on the Canadian pattern could be used to secure a substantially increased reduction in CFC usage while leaving a wide range of products unaffected. It is a course which would allow many of the smaller fillers to continue in business in the lower volume and more specialised sectors, and who would otherwise have to cease operation because of inability to convert to flammable propellants.

b) Concentration Limits

Maximum CFC concentration limits could be set for designated product sectors, and adjusted periodically after monitoring the overall reduction achieved in relation to that required.

To obtain the same extent of reduction as in a product sector ban, concentration limits would have to be applied to a larger number of sectors. There would be difficulties in deciding on sectors and limits, and problems in maintaining fair competition throughout the Community.

It is much more costly and time consuming to ascertain the CFC concentration in an aerosol than simply to check whether CFCs are present, so the task of policing would be greater than in the prohibitory types of regulation.

c) <u>Extension of 1980 Council Decision to Chlorofluoroethanes</u>

In 1976, 104 tons of F-113 and 5,094 tons of F-114 were used in filling aerosols in the EEC (Metra 1978), and 30% of these amounts is less than 1% of the total usage of F-11,12,113 and 114 in aerosols in that year. Extension of the second part of Article 1 of the 1980 Council Decision would therefore achieve very little.

As explained in Section 2.4.6., the preponderance of chlorofluoroethane production and sales is of F-113 which is used mainly in solvent cleaning. Application of the first part of Article 1 of the 1980 Decision to limit the production capacity for chlorofluoroethanes would thus impose a major restriction on a non-aerosol use, whereas this is not the case in respect of the non-aerosol uses of F-11 and F-12 because of the substantial margin of excess production capacity for these CFCs. Such a measure could be construed as being inequitably directed against a CFC application of considerable industrial importance.

3.3.5.3 Indirect Action

a) Taxation

A tax or excise duty which artificially raised the price of CFC propellants differentially with respect to non-CFC substitutes would make it more economic for fillers to convert, and the operation of market forces would inevitably lead to further reduction in CFC propellant usage - especially in the large volume sectors such as hairsprays. By levying the duty at the initial point of sale, i.e. on leaving the CFC producers' works, the administration involved would be minimised.

There are a number of obvious objections to this concept, including:

- the difficulty of assessing the level of duty needed to achieve a desired degree of CFC usage reduction
- if levied at the first point of sale, some EEC countries would collect duty revenue and others would not
- the duty would have to be levied on imports from outside the EEC, increasing the administration involved and creating opportunities for evasion
- problems of harmonising duty levels among Member States

- unless levied on all F-11/12 sales irrespective of final use the volume of administration and policing would be greatly increased.

Notwithstanding these problems, it should be remembered that the limit on production capacity is also an economic measure in the long term, because when demand catches up the price mechanism will operate in the same way as a tax, although it will not attract administrative costs. In the medium term, therefore, taxation is a logical measure in theory, although there are likely to be formidable difficulties in implementation.

b) Other Economic Incentives

The converse of imposing financial penalties on CFC usage would be a system of grants or tax relief measures designed to reduce the financial burden of conversion to non-CFC propellants.

Here again there would be problems in devising and administering equitable arrangements, and it would be difficult to estimate the extent of conversion which would result unless the economic incentives were to be allied with direct regulatory restrictions on CFC usage.

A major objection might be the setting of an awkward precedent in providing financial assistance in connection with environmental protection measures, which would be contrary to the 'polluter pays' concept.

c) Labelling Regulations

A labelling measure on the lines adopted in the Netherlands (Section 3.3.4) would almost certainly reduce CFC usage and would not be difficult or costly to enforce. As with taxation, it is an indirect measure and the impact is difficult to predict: probably it would vary from country to country depending on the variable climate of public opinion, and the extent to which the measure was accompanied by supporting publicity.

Apart from imprecision, the chief objections to the measure are that it might be intepreted as an official condemnation of aerosols per se, and that it abrogates governmental responsibility by asking members of the public to make a decision on a complex issue on which even expert opinion is divided.

3.3.6. Selection of Options

In respect of CFC usage in aerosols the Community now has three alternative courses:

(i) To take no further restrictive measures at this stage but to continue monitoring all aspects of the situation

(ii) to take measures which may have little impact on world CFC release but which demonstrate a continuing positive policy towards control

(iii) to implement measures which will certainly make a significant contribution towards restricting the growth of CFC release

The case for and against each alternative involves scientific and policy considerations which it is outside our remit to discuss, but comment can be made on the possibilities for action.

Thus, under (ii) would fall labelling regulation or extension of Article 1 (2) of the existing Decision to make it applicable to chlorofluoroethanes.

A taxation measure could be adapted for either (ii) or (iii) but might be too complex and controversial a step for early introduction.

CFC concentration limits could in theory be adapted for (ii) or (iii), but in practice this approach is likely to prove too expensive and complicated to devise and administer.

Despite industry opposition to the convention concept as a means of obtaining further CFC usage reduction, it might be employed to secure a marginal increase over the 30% minimum, i.e. to achieve course (ii).

To implement course (iii), however, we believe that it would be necessary either to introduce a complete ban with limited exemptions as in the USA, Norway and Sweden, or to ban CFCs in certain major CFC using product sectors as in Canada, where the use of fully halogenated CFCs is banned in manufactured or imported hairspray, antiperspirant and deodorant aerosols. Data is not available which would enable an accurate prediction to be made of the CFC usage reduction this would achieve in the EEC but we believe it would exceed 70% of the 1976 level.

3.4. Socio-Economic Implications of Further Reductions in CFC Usage in Aerosols.

3.4.1 General Approach

There are three principal ways in which further CFC propellant usage reduction could have important socio-economic implications for the aerosol and related industries:

a) Added value loss due to lower CFC sales

The CFC production and associated industries would be materially affected by any major reduction in CFC propellant usage because of the large tonnages involved. In the macro-economic context there would be some offset due to growth in the sales of alternative propellants and solvents but, because of the lower values of the substitutes, the net effect would be loss of added value with a reduction in employment opportunity.

b) Structural change in the aerosol filling industry

Many fillers, especially the smaller ones, would not be able or willing to convert to flammable propellants. The outcome would be that some companies would contract or cease their filling operations, while others would pick up some of this business and expand.

c) <u>Added value loss due to lower aerosol sales</u>

Any reduction in aerosol sales would affect the filling and marketing sectors of the industry, and all other industries significantly involved in the chains supplying goods and services to fillers and marketers.

For the CFC industry, estimates have been made of the loss of added value and jobs at risk in respect of a given reduction in F-11/F-12 output, (Section 3.4.2).

A special survey was made of the EEC aerosol filling industry to establish its structure and obtain information from which inferences may be drawn about the impact of CFC reduction measures . (Section 3.4.3).

In respect of possible aerosol sales depression associated with CFC substitution, we do not think it is possible in the present economic situation to go beyond a qualitative discussion, because of the numerous imponderable factors involved (Section 3.4.4).

3.4.2. Added Value and Job Opportunity Losses Linked with F-11/F-12 Production Cutback

3.4.2.1 Estimation Procedure

At Metra's invitation, the EFCTC made estimates of the loss of added value and associated job opportunity loss resulting from a major cutback in F-11 and F-12 production, making due allowances for the value of co-products and of imported raw materials. The EFCTC set up the exercise on the basis of an initial set of questions from Metra, and made the calculations using data provided by the independent accounting firm of Peat, Marwick, Mitchell and Co., from the collation of details of materials, quantities and values supplied in confidence by all the EEC producers.

3.4.2.2 Materials and Processes

F-11 and F-12 are produced by reacting hydrogen fluoride with carbon tetrachloride. The process is described in Metra 1978, and it is only necessary here to list the main materials in the production sequence.

Primary Raw Materials

Fluorspar (Calcium fluoride)
Salt (Sodium chloride)
Sulphur
Methane (from natural gas) or Naphtha (from crude oil)

Intermediates

Chlorine (from electrolysis of sodium chloride)
Sulphuric acid (from sulphur)
Propylene (from naphtha)

Precursors

Hydrogen fluoride (from fluorspar and sulphuric acid)
Carbon Tetrachloride (from chlorination of methane or propylene)

Products

F-11 (CCl_3F) and F-12 (CCl_2F_2)

Principal Co-products

Caustic soda (sodium hydroxide)
Hydrochloric acid
Hydrogen
Sodium hypochlorite

Calculation is complicated by the widely differing degrees to which the individual CFC producers are integrated with the production of precursors and intermediates, and in the utilisation of co-products.

One producer may start with primary raw materials, another may purchase one of the two precursors and manufacture the other. It will also be appreciated that only fractions of the total production of the various intermediates and precursors are used in conjunction with F-11 and F-12 production, although this probably accounts for the great majority of carbon tetrachloride consumption.

To make the calculation a number of simplifications and assumptions had to be made, and the more important of these are mentioned below.

3.4.2.3 Basis of Calculation

a) Extent of production cutback. The calculation relates to a hypothetical situation in 1984, it being assumed that sales in that year would be 138,000 tons below those in 1976. This is on the basis that EEC sales for aerosols in 1984 would be virtually nil, while sales for other uses would have grown since 1976 at a compound rate of about 5%, the reasoning being that even if further regulation fell short of an almost total ban on usage in aerosols, the outcome would be a complete swing to non-CFC propellants, with fillers unable to convert having to cease operation.

b) Values relate to average European levels in 1980, expressed in ECU.

c) <u>Turnover</u> relates to the average European selling price of 50:50 F-11/F-12 mixtures, while <u>net-back</u> represents the average naked ex-works value of sales, i.e. excluding transport, packaging, insurance etc.

d) <u>Co-products</u>. The amounts of caustic soda, hydrochloric acid (32% aqueous solution), sodium hypochlorite and hydrogen are on the basis of production in a typical integrated process starting with primary raw materials. Hydrogen is taken at fuel value, the other co-products at average European prices. Derivatives of caustic soda such as silicates, phosphates and other sodium salts have been excluded from the calculation, as have smaller tonnage hydrocarbon chlorination co-products such as perchloroethylene and methylene chloride.

e) <u>Imports</u> Some fluorspar is imported into the EEC and a level of 10% of usage has been taken. It is assumed that all the sulphuric acid used is made from imported sulphur, and although this is not entirely the case the difference is relatively small.

f) <u>Labour Costs</u> are assumed to be the same for all sectors whereas in fluorspar mining they may be below the European average, hence job loss opportunity may be somewhat under-estimated.

g) Total added value is assumed 80% labour related, directly or indirectly. The balance of 20% represents financial support, profit etc.

h) Job opportunity loss is calculated as being:

$$\frac{0.8 \times \text{Total Loss of Added Value}}{\text{Average European Labour Cost}}$$

i) Lost capital assets relate to the 1980 replacement value only of the plant for producing F-11/F-12 from carbon tetrachloride.

It will be noted from the above that a conservative approach has been adopted in value level assumptions and in deciding which materials to take into account.

The calculation is essentially of short term application, but although the chemical industry would be likely to take steps to make up shortfalls of co-products such as caustic soda and hydrochloric acid, this would entail capital expenditure which might reduce scope for investment in other projects.

3.4.2.4 Calculated Losses of Added Value and Job Opportunity in 1984

Note: Material quantities relate to changes relative to year 1976; values relate to averages for 1980.

F-11/F-12

Loss of sales volume	tons	138, 000
Total loss of turnover	ECU x 10^3	101, 000
Total loss of net-back income	ECU x 10^3	92, 600

Co-Product Losses	ECU x 10^3
Caustic soda: 3.4 t/t 11/12 @ 154 ECU/t (NaOH)	72, 250
Hydrochloric acid: 6.4 t/t11/12 @ 60 ECU/t (HCl)	53, 000
Sodium hypochlorite: 0.63t/t 11/12 @ 75 ECU/ t (NaOCl)	6, 500
Hydrogen (H_2): 1020M^3/t 11/12 @ 62ECU/M^3	8, 700
	140, 450
Total Losses: F-11/12 and Co-products	233, 050
Less: value of imports	
Sulphur: 0267 t/t 11/12 @ 130ECU/t	(3,785)
Fluorspar: 0.63t/t 11/12 @ 120 ECU/t	(1,043)
	(4,830)
TOTAL LOSS OF ADDED VALUE: ECU x 10^3	228, 220

TOTAL LOSS OF EMPLOYMENT OPPORTUNITY		8,620 Jobs
Replacement Value of F-11/12 Plant	ECU	96 million

3.4.2.5 Comment on Results

Although the calculation relates to a specific loss of sales volume, it is likely to be valid on a pro rata basis for tonnages lying not too far from the reference level, and the following factors would then apply:

Loss of added value per ton F-11/12 - ECU 1654
Loss of job opportunity " " " " - 0.0625

It is important to appreciate that a calculation of this kind gives no indication of the distribution of employment losses as between the numerous industry sectors involved or in terms of geographical location, and that it cannot be used to make predictions about the re-structuring of the CFC and associated industries in terms of specific plant and mine closures.

3.4.2.6 Compensating Effects of Increased Sales of Non-CFC Materials

The aerosol industry will try to maintain and increase its sales despite any cutback in CFC usage, and this must lead to increasing sales of alternative propellants and solvents, including hydrocarbons, DME, alcohols and chlorinated solvents such as methylene chloride, the distribution depending on a combination of technical and economic factors, and trends in aerosol product sector sales.

To calculate this off-set would involve too many assumptions for the result to be accorded any confidence. Given the some aerosol sales volumes and patterns applying in the reference year, 1976, the sales of non-CFC substitutes might reduce the added value loss calculated in 3.4.2.4. by perhaps 30%.

3.4.3. Survey of Aerosol Fillers

3.4.3.1 Method of Survey

A survey of aerosol fillers in the EEC was conducted by postal questionnaire accompanied by a covering letter explaining the purpose of the study and giving an assurance of confidentiality. The forms and letters were in the national languages of the Community.

Companies were asked to nominate an executive who could be contacted in the event of queries, and the questions asked related to:

Plant locations

Nature of filling business (self and/or contract filler)

Total fillings in 1979 (Under 10,10 to 30, or more than 30 million units)

Aerosol product categories

Whether factory equipped for flammable propellants and, if not, suitability of site for such propellants.

Propellants in current use

Plans for conversion to flammable propellants and probable action in event of further restrictions on CFC propellants

Likely effect of further CFC restrictions on volume of business

Number of employees spending more than 50% of their time on aerosol manufacture, and possible changes.

A space for additional information and comment was also provided.

The FEA and the national aerosol associations decided not to be directly involved in the survey because of their view that further restrictions on CFCs should not be considered at the present time. They helped in a number of ways however, including the identification of non-member fillers.

Initially, questionnaires were despatched to national association members. Despatches to non-members followed as soon as these were identified, but some of that advice became available too late in the study for action. For West Germany, questionnaires were sent to a sample of 30 of the 98 firms mentioned to us.

For the earlier despatches, where no return was received, the firm was telephoned and this significantly increased the response rate.

3.4.3.2 Response

Some firms approached proved not to be fillers but marketers, and a number of the non-returns logged may not in fact represent valid approaches. Exclusive of the despatches known to be invalid, 175 member firms of national aerosol associations and 100 non-members were approached and, to date, 183 returns in respect of more than 200 factories have been received, a response of 66.5%. These returns have been supplemented by more limited information from indirect sources on 144 other fillers (mostly small volume ones) who did not respond to the survey or were not approached.

Returns are still being received and the results reported here represent the position at the end of January 1981, the initial despatches having been made mid-October 1980.

3.4.3.3 Results

Table 3.3 gives figures by country in respect of numbers of companies and sites, type and volume of business. The EEC aerosol industry is characterised by having a large number of small firms and it has now been established that a high proportion of those filling less than 10 million units annually is in fact at the lower end of this range, with many filling less than

500,000 units. Some of these small operators who are not trade association members have yet to be identified but the total number of fillers in the Community is probably less than 400. It seems likely that some 70 companies account for 80% or so of all fillings, and almost all these are represented in the survey.

Table 3.4 shows propellant usage distribution by country, propellant identity and number of locations in which used, for fillers responding to the survey. It will be noted that CFC propellants are used in nearly 95% of locations, and hydrocarbon propellants in 46%.

Information in respect of propellant usage by the other 144 fillers identified is incomplete, but only 14 of them are known to use hydrocarbon propellants.

Ireland is not included in the data tabulations because the number of fillers is very small, and data could not be given without breaching the confidentiality undertaking.

The numbers of locations at which each main product category is filled is shown by country in Table 3.5., which has been compiled from questionnaire returns only.

TABLE 3.3. EEC AEROSOL INDUSTRY STRUCTURE BY TYPE AND SIZE OF BUSINESS

Country	No. Of Firms	No. of Filling Locations	Self Filler	Contract Filler	Self and Contract Filler	Fillings in 1979 (Millions of Units)		
						<10	10-30	>30
Companies Supplying Information on Survey								
Belgium	12	12	4	-	8	9	3	-
Denmark	5	5	2	2	1	5	-	-
France	18	24	10	4	10	19	4	1
F.R. Germany	46	48	21	8	19	31	14	3
Italy	32	34	12	7	15	26	7	1
Netherlands	10	10	2	1	7	7	2	1
U.K.	60	69	36	11	22	49	16	3
TOTALS	183	202	87	33	82	147	46	9
Companies on which Information Obtained Indirectly								
Denmark	2	2	2	-	-	2	-	-
France	5	5	4	-	1	4	1	-
F.R. Germany	51	51	45	5	1	48	3	-
Italy	14	14	14	-	-	14	-	-
Netherlands	4	4	-	2	2	1	2	1
U.K.	68	68	36	16	16	68	-	-
TOTALS	144	144	101	23	20	137	6	1
TOTALS : ALL FIRMS	327	346	188	56	102	284	52	10
% Distribution (based on number of filling locations)	-	100.0	54.3	16.2	29.5	82.1	15.0	2.9

TABLE 3.4. : AEROSOL PROPELLANT USAGE DISTRIBUTION

PROPELLANTS IN REGULAR USE	NUMBER OF FILLING LOCATIONS							TOTALS	
	Be	Dk	Fr	FRG	It	Nl	UK	No.	%
CFC 11/12 (inc. 12/114)	12	5	23	46	33	9	63	191	94.8
CFC 114	6	3	16	24	17	7	41	114	56.0
Propane/Butane	5	2	9	32	15	8	22	93	45.0
Dimethylether	1	1	1	4	-	3	-	10	4.2
Carbon Dioxide	4	1	2	20	3	2	14	46	23.0
Nitrogen/air	1	1	9	10	2	-	4	27	13.6
Nitrous Oxide	2	1	3	1	1	-	-	8	4.2
CFC 152a	-	-	-	1	-	-	-	1	0.5
CFC 22	-	1	-	-	-	-	-	1	0.5
No. of Locations in Survey	12	5	24	48	34	10	69	202	(= 100 %)

TABLE 3.5 PRODUCT CATEGORY REPRESENTATION

(Results from completed questionnaires)

PRODUCT CATEGORY	NUMBERS OF FILLING LOCATIONS							TOTAL
	Be	Dk	Fr	FRG	It	Nl	UK	
Hairsprays	11	3	9	20	18	6	21	88
Antiperspirants/ Deodorants	8	4	13	22	16	6	23	92
Colognes/ Perfumes	8	2	15	12	12	4	22	75
Other Personal	6	3	13	19	9	2	17	69
Medicinals/ Pharmaceuticals	1		5	10	5	2	16	40
Household	6	3	7	27	15	5	25	88
Insecticides	7	2	11	23	16	4	22	85
Paints & Lacquers (inc Automotive)	4	2	3	18	12	3	14	56
Other Automotive	7	3	5	22	13	7	22	79
Industrial	6	3	6	21	16	5	21	78
Others	4	3	4	23	11	2	14	61

Source: Metra Survey

Table 3.6. shows the numbers of locations equipped and not equipped to use flammable propellants, and the size ranges of their filling operations, together with the numbers of locations reported to be unsuitable for conversion, and those planning to convert.

Table 3.7. lists alternative actions which could be taken in the event of further restrictions being imposed on the use of CFC propellants, and the numbers of locations for which respondents indicated they would probably take the stated action.

There were some anomalies in the answers to questions on the use of flammable propellants, with some respondents stating that a location is unsuitable for conversion but also stating that they would convert in the event of further CFC restrictions.

The effects which fillers believe further CFC restrictions would have on the volume of their aerosol business are indicated in Table 3.8.

Table 3.9 summarises the information obtained on employment. Although fillers were asked to state the numbers of employees engaged for more than 50% of their time on aerosol manufacture, it appears that this question was intepreted in different ways.

3.4.3.4. Costs of Flammable Propellant Filling Facilities

To supplement the aerosol filler survey with information on the economics of conversion to flammable propellants, some budget estimates were obtained from a major European supplier of aerosol production equipment, Aerofil Ltd, England., and these are summarised in Table. 3.10.

TABLE 3.6 FACILITY TO USE FLAMMABLE PROPELLANTS

	No and (%) of Locations			
	Total	Fillings in 1979 million units		
		<10	10-30	>30
Locations for which direct information available	199 (100.0)	150 (75.4.)	41 (20.6)	8 (4.0)
Locations equipped to use flammable propellants	98 (100.0)	57 (58.2)	33 (33.7)	8 (8.1)
Locations not equipped for flammable propellants of which:	101 (100.0)	93 (92.1)	8 (7.9)	- -
No. reported unsuitable for conversion	80 (79.2)	78	2	-
No. planning to convert to flammable propellants in 1981 or later	17 (16.8)	11	6	-

TABLE 3.7 PROBABLE REACTIONS OF FILLERS NOT EQUIPPED FOR FLAMMABLE PROPELLANTS TO FURTHER CFC RESTRICTIONS

Reaction to further restrictions on use of CFC propellants	Locations on which stated action would probably be taken	
	No.	%
Conversion of present factory for use of flammable propellants	21	24.1
Move filling operation to new site suitable for flammable propellants	17	19.5
Transfer some or all of filling operations to contract filler	30	34.5
Cease manufacture of some or all of aerosol product lines	19	21.8
No. of responses to question	87	100.0.

TABLE 3.8. EXPECTED EFFECT OF FURTHER CFC RESTRICTIONS AEROSOL BUSINESS

Expected Effect	Fillers Reporting	
	No.	%
Expansion	20	10.0
Decline	91	45.7
No Change	66	33.2
Cessation	22	11.1

* With one exception, all fillers predicting expansion were equipped or planning to be equipped for using flammable propellants.

TABLE 3.9. EMPLOYMENT IN AEROSOL MANUFACTURE

(Nos of regular employees engaged for more than 50% of their time on aerosol manufacture).

	Total	Fillings in 1979: million units		
		< 10	10.-30	> 30
No. of locations reporting	180	130	43	7
Range of employees numbers		0-100	10-250	12-1500
Total employees	7607	2895	2493	2219
Average no. per location		22.3	58.0	317

Much of the conversion cost is associated with the various safety precautions which are obligatory for the storage and use of hydrocarbon propellants or DME . These include the provision of a storage compound with fire extinguishing equipment and with minimum separation distances from other buildings: typically 6 metres for cylinder storage, and 15 metres for bulk storage tanks. Filling machines must be situated in ventilated enclosures, and the facility must be equipped with gas detection and other safety devices. Provision must also be made for the specialised design work and advice likely to be needed to ensure conformity with local regulations, and for the re-training of personnel.

Costs would be higher if conversion had to be accompanied by re-location of the facility at a new site. Aerofil estimate that the costs for hydrocarbon storage, filling house with machinery and safety systems, and for the re-location of existing equipment would amount to about ECU 870,000 for a single line 10m unit facility, and ECU 1,160,000 for two lines.

Conversion from CFC to hydrocarbon propellants may be an economic investment because the latter are much cheaper; actual prices vary with locality and quantity but for bulk deliveries a typical F-11/F-12: hydrocarbon cost ratio would be 5:1 on a volume for volume basis. There are offsetting factors, however:

TABLE 3.10 BUDGET COSTS FOR HYDROCARBON FILLING FACILITY AT EXISTING PLANT

ECUs thousands

Cost Item (Note 1)	Installation and Capacity: million units/year			
	1 filling machines; up to 1m	1 line, 5m	1 line, 10m	2 x 10 m lines
Hydrocarbon gas storage (Note 2)	19	103	151	151
Filling House and Equipment	19	87	107	214
Safety Systems	10	12	48	96
Design, Consultancy, Operator Training	8	19	29	29
TOTAL: ECU x 10^3	56	221	335	490

Source: Aerofill Limited

Note (1) January 1981 prices applying in UK

Note (2) Cylinder storage up to 1m capacity, bulk tank storage for higher capacities re-formulation usually entails replacing some or all of the CFC content with a combination of hydrocarbons and more expensive materials such as alcohols and methylene chloride, and unit sales may fall because of the lower discharge rate adopted for safety reasons. The overall economics can therefore vary widely with local circumstances.

3.4.3.5 Implications of the Survey Findings

The indications from Table 3.6 are that the great majority of the larger fillers - 95% of those surveyed and filling more than 10 million units in 1979 - are already equipped or have plans to be equipped to use flammable propellants. Nearly two thirds of the smaller fillers surveyed are not able to use flammable propellants and as the survey is weighted towards the larger capacity ranges due to the late identification of the very small firms, the actual proportion may be higher. Although the responses summarised in Table 3.7 indicate that 78% of fillers without flammable propellant facilities would either convert or transfer manufacture to contract fillers in the event of further CFC restrictions, the bias in the survey representation makes it likely that the actual proportion would be lower, although it might not be very different in terms of capacity. However, there can be no doubt that the necessity to convert would alter the structure of the filling industry in Europe, contraction of the small filler sector being accompanied by expansion of the larger firms -

particularly those undertaking contract filling, and among the larger companies there is already a tendency to concentrate operations on fewer sites.

One possible development would be expansion of contract fillers geared to undertake relatively short production runs, and therefore able to take over filling from small operators unable to convert.

Employment in the industry is difficult to define because there is a good deal of part-time and seasonal working, and switching of personnel between aerosol manufacture and other operations. The survey total of 7600 employees spending more than 50% of their time on aerosol production needs to be supplemented by the numbers in the firms on which information is not available and these fall mainly in the low end of the capacity range, mostly below 1m. units/year. Taking the '50% + of working time' criteria, it appears that employment in aerosol production may amount to approximately 10,000.

Some of the job loss occurring if a proportion of the smaller firms cease operation will be compensated by additional employment elsewhere. The net effect cannot be closely estimated but at the 1979 level of output the number of jobs at risk in the event of consolidation seems unlikely to be more than 2000.

3.4.4. Sales Volume Changes Due to CFC Substitution

The effect of further major CFC restrictions on aerosol sales volumes would depend on the type of measure employed, the time allowed for implementation and any compensatory action such as easement of restrictions on alcohols.

Factors tending to depress sales could include:

- public reaction against aerosols generally, engendered by labelling regulations, if applied, and any bad publicity associated with increased usage of flammable propellants

- perceived lowering of product quality

- longer unit life due to lower discharge rates

- reduction in availability and range of choice at the retail end, due to reduction in variety of products and brands, and restrictions in stocking associated with flammability

The EEC aerosol industry contends that the recovery registered in the USA following the slump to the low point of 1977 cannot be taken as indicative of what might happen in Europe because conditions are entirely different: the U.S. industry is differently structured with fewer small fillers, regulations affecting non-CFC solvents are less onerous, and consumers accept quality standards lower than those prevailing in the Community, especially in the personal product sector. Against this it may be argued that the EEC industry has already gained time for research on re-formulation, and experience in the gradual substitution of CFCs, so that product characterisics have been changing less perceptibly, and that with a further allowance of time there could be a smooth transition. The aerosol industry is inventive and resourceful, and with the benefit of hindsight should avoid marketing errors which contributed to the slump in USA sales.

No specific regulatory scenario has been put forward for evaluation and it is not proposed to hypothecate one. On balance, it must be supposed that further CFC restrictions would be likely to depress aerosol sales, but not to a catastrophic extent.

3.5. Conclusions

3.5.1 The EEC aerosol fillings total of 1,868 million units in 1979 was only marginally below the 1976 total of 1,873 million, and represented 30% of the world total. The fall of 22.8% in F-11/F-12 propellant usage in the EEC over this period is due to several factors, including CFC substitution and changes in sales category patterns, but the respective contributions cannot be quantified.

3.5.2 Fillings in Greece of 29m units in 1979 are equivalent to 1.5% of total EEC fillings in that year. USA fillings were slightly higher in 1979 than in 1978, despite the ban on CFCs in most aerosols. Outside Western Europe and the USA, the 1979 fillings total of 1837m. units was 37.6% above that for 1976.

3.5.3 No alternative fluorocarbon propellants to F-11 and F-12 have emerged which satisfy the technical, economic, environmental, biological and other criteria for large scale application, and none is in prospect. Pump sprays and other devices are not making significant in-roads into the market for self-pressurised packaging based on liquefied gas propellants .

3.5.4. Except for fragrances and a few minor product sectors, liquefied hydrocarbon gas propellants are now the established alternatives to CFCs, despite the disadvantages attaching to their high flammability and poor solvent properties, often necessitating the use of auxiliary solvents and diluents such as alcohols and methylene chloride which are also subject to regulatory restrictions.

3.5.5 Dimethylether ('DME'), although flammable, could become a valuable alternative to hydrocarbon propellants because of better solvent properties, miscibility with water and compatibility with fragrances. Wider acceptance depends upon the results of a toxicity testing programme, and the availability of more than one primary supplier in the EEC.

3.5.6 For effecting reductions in F-11/F-12 usage in filling aerosols substantially beyond the minimum of 30% relative to 1976 levels of use, as required by the Council Decision of 26 March 1981, a number of direct and indirect regulatory measures can be considered as well as the government - industry convention concept.

3.5.7 Direct regulatory measures available include a total ban with special exemptions; major product sector bans - e.g. on CFC usage in hairsprays; and CFC concentration limits. Lack of sectoral usage statistics makes it difficult to quantify the outcome of the second course and the third would be complicated to devise and expensive to police. Extension of Article 1 of the March 1980 Decision to the chlorofluoroethanes would only marginally increase CFC propellant usage reduction but might restrict non-aerosol applications, especially in solvent cleaning.

3.5.8 Restrictions which virtually eliminated F-11/F-12 usage in aerosols in 1984, could reduce EEC output by about 138,000 tons compared with 1976. The consequent loss of added value at 1980 prices due to lower sales of CFCs and co-products, allowing for reduced raw material imports, is estimated at ECU 228,220,000 with an associated job opportunity loss of 8,620. There would be some off-set - possibly as much as 30% - due to increased usage in aerosols of hydrocarbon propellants, alcohols, chlorinated hydrocarbons and other materials.

3.5.9. At a given sales volume, the socio-economic impact of further CFC restrictions on the aerosol filling sector, aside from development expenditure, is essentially related to the costs and problems of conversion to flammable propellants. The basic capital costs of conversion could typically range from ECU 56,000 for a facility producing up to 1 million units/year on an existing site, to ECU 1,160,000 for conversion and re-location of a two-line 20m. unit/year capacity installation.

3.5.10 Information on 200 filling locations obtained by postal survey, and on more than 140 others by indirect means indicates that there are up to 400 active fillers in the EEC, with about 70 accounting for 80% of all fillings. Half the locations surveyed are not equipped for flammable propellants and nearly 80% of these were reported unsuitable for conversion, but almost all fillers producing over 10m units/year are able or planning to be able to use flammable propellants.

3.5.11. Further CFC restrictions and the need for more conversion would result in consolidation of filling operations on fewer sites. Personnel engaged for more than 50% of their time on aerosol manufacture in the EEC may total about 10,000; re-structuring of the industry might put up to 2000 job opportunities at risk.

3.5.12. The effect of further CFC restrictions on aerosol sales volumes would depend on many factors and is particularly difficult to predict under present economic circumstances; while some depression is likely, this could be minimised if enough time is available for re-formulation to be achieved in a series of graduated steps.

4.0. NON-AEROSOL APPLICATIONS OF CHLOROFLUOROCARBONS

4.1. Refrigeration and Air Conditioning

4.1.1. Dominance of CFC Refrigerants

Chlorofluorocarbons now account for a very high proportion of all refrigerants used in closed cycle vapour compression systems, which in turn constitute by far the largest part of all current manufacture and installed capacity for refrigeration and air conditioning throughout the world.

Simply stated, the principle of the vapour compression cycle is that a low boiling point liquid - the refrigerant - is allowed to evaporate, and in so doing it extracts heat from and thus reduces the temperature of its surroundings. The vapour passes to another part of the system, remote or insulated from the evaporation section, where it is re-liquefied by mechanical compression followed by cooling with air or water, and then re-cycled to the evaporator.

Refrigeration is a much older industry than those linked with the other main applications of CFCs, and its development has recently been reviewed by Thevenot, /1/. Before the advent of fluorocarbons the refrigerants used included ammonia, carbon dioxide, methyl chloride and butane, all of which had one or more serious drawbacks: poor technical efficiency, high toxicity, flammability or chemical reactivity. The development of fluorocarbon refrigerants characterised by excellent thermodynamic properties, low toxicity, non-flammability and high chemical stability contributed to the rapid development of refrigeration from the 1930's onwards, and of the non-fluorocarbon refrigerants only ammonia is still used to any significant extent.

The present situation is that there are no early or even medium term prospects of any substantial replacement of vapour compression by systems based on other principles, or of reversion to non-fluorocarbon refrigerants. The dominant fluorocarbon refrigerants are chlorofluorocarbons, mainly F-12 and F-22, and the problem of reducing usage and release of CFCs in this area of application is essentially one of minimising preventable escape to atmosphere in the manufacture, testing, installation, operation, maintenance and disposal of equipment.

In the EEC, as shown in Section 2, refrigeration and air conditioning account for a much smaller amount of F-11/F-12 sales than in the rest of the world, 20,300 tons in 1979 as compared with 170,800 tons, and the annual sales have remained virtually constant in the EEC since 1976, although rising in the rest of the world by nearly 30%. Part of this difference is due to the much more widespread use of air conditioning in the USA and other countries outside Europe.

4.1.2. The EEC Refrigeration Industry

4.1.2.1. Application Categories

The available European statistics generally relate to three application areas:

- domestic refrigeration and freezers

- commercial and industrial refrigeration, including retail store refrigeration and cold stores, and often grouped under the term 'refrigeration machinery'.

- air conditioning

Similar categories were used by Rand Corporation in a major study of U.S. non-aerosol CFC emissions for the USEPA, /2/.

Mobile air conditioning for cars and trucks is still a very minor application in the EEC and need not be further considered here, although it is a major source of refrigerant loss elsewhere.

Heat pumps, which also employ the vapour compression principle, are a developing application and about 100,000 units are now being installed annually in the Community. They are still a relatively small source of CFC loss and need not be considered separately from refrigeration equipment.

TABLE 4.1 : REAL PRODUCTION TRENDS : DOMESTIC REFRIGERATORS AND FREEZERS : 1979 = 100

	1976	1977	1978	1979
Denmark	102.2	111.9	100.0	n/a
Federal Republic of Germany	127.5	130.6	102.9	100.0
Italy *	n/a	n/a	n/a	n/a
U.K. (Estimate)	125.3	121.8	111.5	100.0

* Italian production of domestic refrigerators fell from 4.9 million units in 1977 to 4.5 million units in 1979; and of freezers from 2.3 million in 1977 to 1.9 million units in 1979.

TABLE 4.2 : REAL PRODUCTION TRENDS : REFRIGERATION MACHINERY : 1979 = 100

	1976	1977	1978	1979
Denmark	109.9	100.0	100.0	n/a
Federal Republic of Germany	102.8	109.7	100.0	100.0
Italy	n/a	90.9	93.1	100.0
U.K. (Estimate)	102.3	107.5	100.0	100.0

TABLE 4.3 : REAL PRODUCTION TRENDS : AIR CONDITIONING EQUIPMENT : 1979 =100

	1976	1977	1978	1979
Denmark	96.6	93.1	100.0	n/a
Federal Republic of Germany	105.0	110.2	104.7	100.0
Italy *	n/a	87.3	89.2	100.0
U.K. (Estimate)	86.0	93.0	97.4	100.0

* Does not include domestic units, whose value is of the same order as these figures, and whose production fell from 206,000 units in 1977 to 160,000 in 1979.

TABLE 4.4 : PRODUCTION LEVELS IN 1979*

Millions of ECU

	Domestic Refrigerators and Freezers	Refrigeration Machinery	Air Conditioners
Denmark (1978)	19.2	144	29.1
Federal Republic of Germany	887	299	128
Italy	n/a	195	86**
U.K. (Estimate)	135	269	176

* Denmark data is 1978

** Does not include domestic air conditioners

In the next sections statistics are presented for production, trade and employment in the EEC refrigeration industry over the period 1976 to 1979. They are taken from published government sources, and have been checked, where possible, with industry and trade association figures. Data is generally only available for the manufacturing sectors and not for installation and servicing.

4.1.2.2. Manufacture in the EEC

The national figures for the production of refrigeration equipment in the nine members of the Community of December 1980 are not all available to the same degree of detail, and are not all comparable with each other. For four of the Community's largest producers, it is possible to develop reasonably reliable figures for three categories of product, which cover virtually all manufacture in the industry. Production trends of these categories are outlined in Tables 4.1., 4.2., and 4.3., based on 1979 prices; Table 4.4. shows comparative production levels in European Currency Units at 1979 exchange rates.

The French industry is large, but data in the same detail is not available. 1978 production of equipment for heating, cooling and ventilating, not including domestic products, was ECU 768 million based on 1979 prices and exchange rates. According to the French industry association, Uniclima, the refrigeration part of the industry grew 44% between 1976 and 1979; air conditioning and ventilating has only grown 24% in the same period, which is approximately equivalent to no growth in real terms.

The Dutch industry is also significant. The manufacture of air conditioning and ventilating machinery, and of refrigerators, totalled ECU 281 million in 1977, based on 1979 prices and exchange rates.

The six countries detailed, Denmark, Federal Republic of Germany, Italy, United Kingdom, France and the Netherlands appear to account for more than 90% of the Community's production of refrigeration equipment. Data for other countries is not listed here.

Some production trends are clear; in domestic refrigerators and freezers, U.K. production has fallen every year (and in this category imports are three times larger than exports). In this sector, German and probably Italian producers are dominant.

For refrigeration machinery, the situation is fairly stable though Italian production is growing, German and possibly French manufacturers are strongest in this sector. In air conditioning, which is generally a growth sector, British and possibly French producers are largest.

4.1.2.3. Trade in Refrigeration Equipment by EEC Member Countries

Data on the international flows of refrigeration industry equipment is quite comprehensive, comparable and up-to-date. The results, presented in Table 4.5., are converted to European Currency Units at 1979 exchange rates. They show that the Italian industry is a strong exporter, in all categories; the Federal Republic of Germany is also an overall exporter, while Denmark is a strong exporter of refrigeration machinery. The other countries are net importers, primarily of domestic refrigerators and freezers.

4.1.2.4. Employment

The figures available for employment in the refrigeration industry are generally unsatisfactory, usually because they are not available in sufficient detail to distinguish the refrigeration industry from other industries. Only the Italian figures are in detail:

	1977	1978	1979
Refrigeration equipment	10,900	11,200	11,300
Air conditioning equipment	2,650	2,800	2,850

Domestic refrigerators, freezers and air conditioning units employ about another 20,000 people, unchanged during this period.

TABLE 4.5: EEC TRADE IN REFRIGERATION INDUSTRY EQUIPMENT: 1979

Millions of ECUs

Country		Domestic Machinery	Refrigeration Machinery	Air Conditioning
Belgium and Luxembourg	Imports Exports	36.5 8.9	59.6 12.2	19.2 14.4
Denmark	Imports Exports	15.0 12.0	20.2 117.0	2.6 3.8
Federal Republic of Germany	Imports Exports	94.7 119.0	151.0 171.0	36.5 72.4
France	Imports Exports	138.0 43.6	148.0 131.0	17.8 36.9
Ireland	Imports Exports	6.5 0.2	19.0 32.3	4.9 1.3
Italy	Imports Exports	11.2 312.0	18.3 355.0	5.8 55.6
Netherlands	Imports Exports	45.7 9.8	62.3 32.4	20.6 9.3
U.K.	Imports Exports	102.0 30.2	154.0 123.0	122.0 127.0

In the Netherlands, the manufacture of air conditioning and ventilation machinery and of refrigerators employed 7700 people in 1977, up from 7400 in 1976. In France the manufacture of refrigeration, air conditioning and ventilation equipment employed about 17,800 people in 1979.

There seems to be little useful employment data for the other main producing countries, but it is likely that employment in the EEC in manufacturing refrigeration and air conditioning equipment is approximately 100,000 people.

The omission of both the installation and servicing sectors from the available figures gives a large under-estimate of the size of the industry: the employment figures would be greatly increased if these sectors could be included, but the trade figures would be only slightly affected.

4.1.2.5. Marine Refrigeration

This is an important division of the refrigeration machinery sector. Information has been supplied to Metra by Lloyd's Register of Shipping, and is based on the Register which is generally estimated to cover more than 80% of the Free World's fleet. Lloyd's publish a specification for refrigeration equipment, and regularly inspect refrigeration installations to ensure that they are kept up to standard. The research for this data was carried out for a paper which is to be published in November 1981, and may not be reproduced in Metra reports beforehand, but the broad picture is as follows:

In 1940, the large majority of marine installations were based on carbon dioxide, with most of the other systems using ammonia. The introduction of F-12 has caused the use of carbon dioxide to drop nearly to zero. The use of F-12 has peaked in favour of F-22, now the most popular marine refrigerant. Ammonia systems are still used by a small proportion of refrigerated ships.

The cost of refrigerant is not a major part of the cost of running a refrigerated ship, and the refrigerant would be vented to atmosphere if it was expedient. Generally, ships carry a spare charge or part charge of refrigerant, dependant on the construction of the refrigerant system. A charge for a marine application is of the order of one or two tons, and a ship can be expected to last about 25-35 years.

4.1.3. Refrigerants

a) Nomenclature

In this section, the physical properties of various refrigerants are presented, and then discussed in the light of the requirements of the refrigeration industry. Within the industry, the R notation is used to denote chemicals used as refrigerants; thus F-12 when used as a refrigerant is referred to as R-12, but in this report the F notation is used for all fluorocarbons. Some physical properties of a few leading refrigerants are given in Table 4.6.

The numerical classification system for fluorocarbons is extended in the case of refrigeration to include azeotropes in the 500 series, miscellaneous organic compounds in the 600 series and inorganic compounds in the 700 series. Within the organic 700 series, the molecular weights of the compounds have been added to 700 to arrive at the identifying refrigerant number. The additional suffix B followed by a number indicates the number of bromine atoms present.

b) <u>Properties of Refrigerants</u>

In a vapour compression system the refrigerant must always be in the liquid and vapour phases. Of the refrigerants in Table 4.6., F-113 has the highest freezing point, and in certain applications this could be a limiting factor. On the other hand F-13, F-503 and F-14 have comparatively low critical temperatures, above which they cannot be liquefied, and they are generally used in a two stage system. The size of a refrigeration unit for a given duty depends partly on the charge of refrigerant necessary

TABLE 4.6 : PROPERTIES OF REFRIGERANTS

Refrigerant	Formula	Boiling Point °C at 1 Atmosphere	Freezing Point °C	Critical Temperature °C	Latent Heat of Vapourisation Kj/kg	Use as Refrigerant
F -113	$CCl_2F-CClF_2$	47.6	- 35	214.1	147	Small use for air conditioning
F -11	CCl_3F	23.8	-111	198	182	Centrifugal refrigeration machines
F -114	$CClF_2-CClF_2$	3.6	- 94	145.7	137	Limited use for air conditioners
F -12	CCl_2F_2	- 29.8	-158	112	165	All uses in refrigeration and air conditioning
F -500	CCl_2F_2/CH_3CHF_2	- 33.3	-158.9	105	206	Occasional use as a capacity improvement on R-12
R -717	NH_3 (ammonia)	- 33.4	- 77.7	133	1399	Commercial refrigeration and cold storage
F -22	$CHClF_2$	- 40.8	-160	96	234	Widely used in refrigeration and air conditioning
F -502	$CHClF_2/CClF_2-CF_3$	- 45.6	-	90.1	178	Increasingly used as a substitute for R-22
F -13B1	$CBrF_3$	- 57.8	-168	67	119	Used for specialised commercial applications
F -13	$CClF_3$	- 81.4	-181	28.9	148	Low temperature applications, used in a two stage system
F -503	$CHF_3/CClF_3$	- 88.6	-	19.5	173	Used to improve capacity on R-13 systems: also must be used in two stage systems
F -14	CF_4	-127.9	-183.9	- 45.7	136	Specialised use for very low temperatures, must be used in three stage system.

Sources: ICI /3/ and Du Pont /4/

to provide adequate performance, and partly on the volume occupied by the charge. The charge of refrigerant depends largely on the latent heat of vaporisation of the refrigerant used: this is very similar for most chlorofluorocarbon refrigerants, with the exception of F-22, which is rather better than the others. R-717, ammonia, has a latent heat of vaporisation which is much better (i.e. higher) than that of CFC refrigerants. However, this advantage is rather off-set by the fact that ammonia vapour and ammonia liquid have much lower densities than those of a chlorofluorocarbon refrigerant; there is little difference between various chlorofluorocarbon refrigerants in respect of this variable. The greater latent heat of F-22, combined with the fact that its density is similar to that of other CFC refrigerants, gives it an advantage that is particularly useful when space is at a premium, such as in retail food stores.

The advantage of having a small charge confined in a small space is that it reduces the size of all the components of a refrigerating system, with corresponding decreases in capital costs. Chlorofluorocarbon refrigerants are well suited to this task because they have relatively low boiling points and relatively high densities.

Fluorocarbon refrigerants have relatively low toxicity, and are rated highly for safety in this respect, e.g. by the USA Underwriters Laboratory, /4/.

Although ammonia is cheap and has good thermodynamic properties, it has lost favour on account of its toxicity and because it can form explosive mixtures with air, /5/. It still has its proponents, however, who argue that the toxicity danger is exaggerated because ammonia is intolerably offensive at concentrations far below the lethal level, and hence readily detectable, and that with proper precautions it is a safe refrigerant to use for many commercial and industrial applications. There seems little possibility of ammonia regaining much of the ground it has lost to fluorocarbons, however, and no other non-fluorocarbon refrigerants are available which do not have serious technical or safety disadvantages.

4.1.4. Alternative Refrigeration Systems

Vapour compression using fluorocarbon refrigerants has become the most popular system because it generally offers the optimum combination in terms of initial cost, energy efficiency, size and safety, and is highly versatile in application.

The main current alternative to vapour compression is the absorption system in which refrigerant vapour from the evaporator passes to an absorber instead of a compressor, and dissolves in another medium - usually a liquid. The refrigerant is then driven out of solution by the application of heat, re-liquefied in an air or water cooled condenser, and re-cycled to the evaporator. The most common of these systems employs ammonia as the refrigerant and water as the solvent, with hydrogen gas present to improve the flow characteristics; the second uses water as refrigerant and lithium bromide solution as absorbent /7/. Other systems have been developed using solid absorbents, but none has found continuing commercial application. Absorption is less energy efficient than vapour compression, but does not require electric power, can utilise waste and solar heat, is noiseless in operation, and involves no moving parts other than valves. It is likely to have further potential for these reasons, but has technical disadvantages which tend to limit its applicability to small scale installations.

Air cycle refrigeration is very safe, but low energy efficiency restricts its use to a few areas, such as aircraft air conditioning.

Thermo-electric refrigeration based on the Peltier effect and employing modern semi-conductor materials is feasible and is used in very specialised applications, but is a long way from being a major commercial proposition.

In short, with available technology, the development of alternative refrigeration systems is not seen as a means of significantly reducing CFC usage in vapour compression systems over the next decade.

4.1.5. Fluorocarbon Refrigerant Losses

Refrigerants are regarded as lost and released to atmosphere when they escape or are deliberately vented from their container or refrigerating system, because recovery after that point is impracticable. The quantities of refrigerant that are lost each year within the EEC are substantial, but not easy to quantify.

It is accepted that while a proportion of refrigerant sales is for the initial charge in new equipment, the greater part is for replacement and other purposes. It can also be contended that the great majority of all refrigerant sold is ultimately released to atmosphere although a proportion may be destroyed by equipment malfunction and disposal. To a large extent, therefore, refrigerant sales are an indicator of refrigerant losses.

In the EEC, sales statistics for the years 1976 to 1979 are available for refrigerant F-12 but not for F-22 and F-502, which are the other principal refrigerants used in the Community.

Based on data from an industrial source, an approximate breakdown has been prepared for the UK refrigerant market in 1980, and this is shown in Table 4.7.

TABLE 4.7. : UK SALES OF REFRIGERANT : 1980 ESTIMATE

	Tonnes	%
F-11	600	7
F-12	4100	49
F-22	3050	37
F-502	600	7
TOTAL	8350	100%

Note: these four refrigerants generally account for at least 98% of U.K. refrigerant sales.

Source: Metra estimate, based on information from industry sources.

Within the U.K., it seems that the consumption of F-12 is stable while there is some growth in the other refrigerants, where use may be rising at the rate of a few percent per year. Bearing in mind the production data detailed in Section 4.1.2., which showed that the U.K. is relatively weak in the production of domestic refrigeration equipment and relatively strong in the production of air conditioning equipment; and furthermore that domestic refrigeration equipment only uses F-12, whereas air conditioning equipment generally uses F-22 and F-502, one may conclude that sales of F-22 and F-502 within the Community are somewhat smaller than might be indicated from the proportions sold in the U.K.

Probably the most useful classification of the sources of loss is into those losses that could have been prevented by a change in the design of the product, and those that could have been avoided by changes in the operating, servicing or disposal procedure. EEC industry sources estimate that the effective implementation of improved procedures could reduce the loss of refrigerant in installing, servicing and disposing of large central installations by at least half, and this is in agreement with the findings of the Rand Study and the OECD in respect of the USA, although the situations are not strictly comparable.

The lack of detailed statistics on the sources of loss of each refrigerant in the Community discourages the forming of detailed conclusions on refrigerant loss and it would take a considerable amount of research to accurately define the amount of refrigerant lost and the amount 'banked'.

4.1.6. Approaches to Reducing CFC Refrigerant Emissions

Three approaches are considered for reducing CFC release to atmosphere:

- equipment design changes
- changes in procedures
- use of fluorocarbon refrigerants other than CFCs

TABLE 4.8 : SOURCES OF REFRIGERANT EMISSIONS : USA - 1976

	% Distribution		
	Domestic Refrigerators and Freezers	Refrigeration Machinery	Air Conditioning
Manufacture, Shipping and Installation	7	6	2
Leakage	3	46	31
Servicing	26	11	61
Disposal	64	37	5

Source: OECD /8/

4.1.6.1. Design Changes

The refrigeration industry is a competitive one, and so manufacturers are under continual pressure to reduce costs. However, there is little evidence that this promotes the use of designs which are less effective in reducing refrigerant loss; the competitiveness of the industry ensures that reliability, as well as cost, is a very important selling point, and reliability is enhanced by lower leakage rates.

a) Industrial Systems

For the larger systems, both in refrigeration and air conditioning, there are a number of points within the system which are known to be the most frequent source of refrigerant loss. Some of these are amenable to better product design. Several EEC sources have referred to leakages caused by malfunctioning gland seals, and one source went so far as to say that leakages from gland seals and from valve spindles account for 99% of emissions arising from component failure.

There appears to be a case here for design development and the evolution and implementation of a design code.

b) Domestic Systems

The situation for domestic refrigerators and freezers is rather different because the systems, being small, require relatively small charges of refrigerant at each location. Furthermore, the large majority of these systems are hermetically sealed and so the leakage rate is very much smaller. A hermetically sealed unit is one where the motor which drives the compressor is sealed in the refrigerant atmosphere. It should be noted that hermetically sealed units are subject to one type of failure which is not found in other units: on the rare occasions where the electric motor burns out, the refrigerant is converted into a rather unpleasant mixture containing hydrochloric and hydrofluoric acids. This mixture is generally vented to atmosphere, and the system scrapped. When the system is to be re-used, it will be flushed with refrigerant which will then be vented to atmosphere before re-charging the system. In spite of this, the losses from hermetic units are much lower than those from other types. Leakage from domestic refrigeration appliances in the U.S.A. has been estimated at less than 1% of the initial charge of the system per annum.

Overall, the domestic sector in the EEC is not seen as one for which design improvement would yield a worthwhile reduction in refrigerant losses.

4.1.6.2. Procedural Changes

There is considerable scope for reducing the loss of refrigerant by changing the procedures used during maintenance and disposal and, to a lesser extent, during manufacture and installation. There are two aspects of this problem: on the one hand, refrigerant loss can be caused by working practices which are contrary to recommended procedures, and on the other, the economic imperatives on the industry render many refrigerant-saving procedures uneconomic

a) Laissez Faire Work Practices

Refrigerant losses due to errors by personnel have not been subjected to detailed analysis either in Europe or the U.S.A. However, one industry source in the U.K. reckoned that carelessness was a major source of refrigerant loss. In part, this stems from the fact that refrigerants are fairly cheap when compared to the cost of labour, and furthermore, during many servicing operations, the maintenance company will charge the owner of the plant for any refrigerant used so there is no incentive for the maintenance company to conserve refrigerant. Within the industry, the ozone depletion issue does not appear to have encouraged the development of a refrigerant-conserving attitude among its personnel.

The casual attitude towards the loss of refrigerant is further enhanced by the same characteristics of chlorofluorocarbon refrigerants that have promoted their use over the past fifty years: being colourless, odourless, non-toxic, non-explosive and volatile, venting a chlorofluorocarbon refrigerant to atmosphere is a very convenient and apparently harmless way of disposing of it. In this regard, it has been suggested that a stenching agent be added to these refrigerants in order to discourage their casual venting, but technical and other objections to this include the chemical reactivity and toxicity of such substances.

b) Economic Pressures to Discard Refrigerants

The economic aspects of the procedures are at least as important as any other. For a new system, the cost of the refrigerant is only a few percent of its total cost. The cost of refrigerant used during servicing is only a tiny proportion of the running costs of the supermarket, office or cold store in which the system is applied. Any economic comparison between the cost of refrigerant loss and the labour and other costs involved in conserving the refrigerant often favours the venting of the refrigerant, particularly in smaller systems. Larger systems are generally provided with built in containers for storing refrigerant during servicing, but it is not clear to what extent they are used on every occasion that refrigerant re-use is possible.

c) Recovery and Disposal

The recovery of used refrigerants presents a number of problems and hazards:

- the recovered refrigerant would often be contaminated and would have to be purified before re-use. This is not the type of process which the industry is well qualified to undertake, and it would be very costly to arrange for the collection of numerous small amounts of various refrigerants and their transportation to central installations

- inadvertent mixing of refrigerants could result in unusable azeotropes

- a major hazard is created if a container is overfilled.

Du Pont is reported to have a purification unit under development which would be suitable for use by the refrigeration industry and it will be of interest to monitor progress.

The alternative to recovery is the destruction of used refrigerants, which is complicated by their chemical stability. Incineration results in the formation of toxic and corrosive acids, for which safe means of extraction from the effluent gases and subsequent disposal must be provided, and this again requires special equipment and careful supervision.

The recovery of refrigerant lost during servicing and disposal offers the prospect of the largest practicable reduction in refrigerant emissions, yet it is one of the most difficult to achieve. The scepticism and indifference of the industry's personnel towards ozone depletion, when coupled with the strong economic disincentives to conserve refrigerant, combine to create formidable barriers to ensuring compliance with less profligate procedures, whether that compliance be insured by enforcement or inducement. Enforcing new procedures on the many thousands of personnel at sites distributed throughout the Community would be very difficult indeed. One industry source in the U.K. noted that servicing personnel are as casual in their attitude towards conserving F-502 as they are towards F-12; yet F-502 is at least two and a half times more expensive than F-12. If this holds true for attitudes throughout the EEC, it may take some considerable while to bring about any radical changes.

d) Leak Detection

The early detection and elimination of leakage is an area in which the user of commercial and industrial equipment can play an important role, either by in-house monitoring or by arranging for regular inspection by a servicing organisation.

It is one thing to ascertain that leakage is occurring and another to pinpoint the source. One approach has been to incorporate a dye in the refrigerant which gives a visual indication of leakage and location, but this has not met with universal acceptance and there is still scope for development in leak detection technology.

4.1.6.3. Alternative Fluorocarbon Refrigerants

Environmental danger from CFC refrigerant release may be lessened or eliminated by using CFCs which are not fully halogenated, or fluorocarbons which do not contain chlorine or bromine.

The principal prospects here are F-22, $CHClF_2$, and F-502 which is an azeotropic mixture of F-22 (48.8%) and F-115 (51.2%). F-115 (C_2ClF_5) is fully halogenated but F-22 is not. Both these refrigerants are widely used, and F-502 is finding increased application in the larger retail food storage sector, where centralised refrigeration units are used as distinct from individual cabinet units.

While the possibility exists of encouraging a move towards these alternative refrigerants there is a large volume of installed capacity which it would be uneconomic to convert or replace in the short term; and they are not the optimum refrigerants for every application. There is also an unresolved question about mutagenicity associated with exposure to F-22 which cannot be entirely disregarded when considering the possibility of more widespread adoption.

4.1.7. Possibilities for Early Action on Refrigerant Loss Reduction

As observed in Section 4.1.5., there is no reliable quantitative information as to the actual amounts of refrigerant associated with the various sources of loss in the EEC. It is therefore difficult to attempt any assessment of what it might be practicable to achieve by any of the approaches reviewed in Section 4.1.6.

Annual sales of fully halogenated refrigerants in the EEC amounts only to about 21,000 tons, and unless the outcome of any particular course of action to reduce emissions can be at least approximately quantified, a considerable amount of effort might be expended for very little result.

The primary need is for more information on the distribution of refrigerant sales by function and by type and size of equipment. It would then be possible to decide where loss prevention measures would be worthwhile. As a first step, therefore, it is suggested that discussions should be held with the appropriate sectors of the industry with the objective of devising a sampling and survey procedure which would provide the data required.

Practical measures which could usefully be taken in the interim are

- the development of equipment and component design codes aimed at reducing losses from the known major sources

- collaborative research on means of refrigerant recovery and disposal

4.1.8. Conclusions

1. Vapour compression using CFC refrigerants is the predominant system in the manufacture and use of refrigeration and air conditioning equipment in the EEC, and because of its advantages in terms of economics, efficiency, safety and versatility it is most unlikely that the development of absorption and other systems will make a significant impact on this situation in the next decade. It follows that practical measures to reduce CFC emissions in this application field must be concentrated on the reduction of preventable losses at all stages from initial manufacture and installation, to the ultimate disposal of equipment.

2. The principal CFC refrigerants used in the EEC are F-12, F-22 and F-502. Sales of F-12 for refrigeration have remained virtually constant at about 20,000 tons annually, over the period 1976 to 1979; statistics for F-22 and F-502 are not available.

3. There is scope for reducing emissions by equipment design improvement, the earlier detection and cure of leaks and by following less wasteful procedures in charging and servicing, but there is little economic incentive for conservation and it is likely to prove difficult to change long established working practices and attitudes.

4. Potentiality also exists for the recovery or destruction of refrigerant currently vented to atmosphere on account of contamination or other reason preventing re-use. Technology for these measures is not yet established, and they are likely to prove costly and complicated to implement.

5. Before evolving a strategy for reducing CFC refrigerant emissions in the EEC it will be essential to have data on the distribution of losses by source and equipment, and it is suggested that in consultation with industry a survey procedure should be devised to obtain this. Practical steps that could be taken meanwhile are the development of equipment design codes, and research on refrigerant recovery and disposal.

4.1.9. Refrigeration References

/1/ THEVENOT, R. A History of Refrigeration throughout the world, International Institute of Refrigeration Paris, 1979.

/2/ PALMER, A.R., MOOZ, W.E., QUINN, T.H., WOLF, K.A., Economic Implications of Regulating Chlorofluorocarbon Emissions from Non-Aerosol Applications, Rand, Santa Monica, 1980 ('The Rand Report')

/3/ HODSON, R.J., Properties and Applications of Refrigerants Heating, Air Conditioning and Refrigeration, May 1979.

/4/ Du Pont, Freon Product Information Bulletin B-2E, Geneva.

/5/ MEACOCK, H.M., Refrigeration Processes, Pergamon Press, London 1979

/6/ FLUOROCARBON COMMITTEE, The Fluorocarbon/Ozone Controversy and its Relationship to Refrigeration and Air Conditioning (Draft), Air Conditioning and Refrigeration Institute, Arlington, Virginia, 1980.

/7/ ALTHOUSE, A.D., TURNQUIST, C.H., BRACCIANO, A.F., Modern Refrigeration and Air Conditioning, Goodheart-Willcox, South Holland, Illinois 1975

/8/ OECD Draft Report of Chlorofluorocarbons, Paris, 1980.

4.2. Foam Plastics

4.2.1. Use of CFCs as Blowing Agents

CFCs - mainly - F-11 - are used as blowing agents in the manufacture of a variety of foam plastics including flexible and rigid polyurethanes, polyolefins, polystyrene, polyvinyl chloride and phenolic resins.

The total tonnage sold for this application in the EEC grew from 42,000 tons in 1976 to nearly 56,000 in 1979. Polyurethane foams are the principal consumption categories and although no reliable data is available on the present distribution, information obtained in the 1978 study indicated the distribution in 1977 to be:

	% of CFC blowing agent sales
Rigid polyurethane	48.5
Flexible polyurethane	41.4
Other foam plastics	10.1
	100.0

It is believed that the proportion used for rigid polyurethane is now higher because sales of that material are known to have been rising at a rate of about 9% annually in the EEC, whereas sales of flexible polyurethane have stagnated.

In respect of CFC release, foam plastics can be broadly classified as having open or closed cell structures. From the former, the CFC blowing agent rapidly diffuses into the atmosphere, whereas closed cells with impermeable walls can retain most of their initial CFC content for many years. Flexible and rigid polyurethane foams are the principal examples of open and closed cell types respectively, and the present study was confined to these materials. Manufacturing technology, applications and industry structure were extensively reviewed in Metra 1978, and in this section we concentrate on the present situation concerning possibilities for reducing CFC blowing agent usage and release.

4.2.2. Rigid Polyurethane ('PUR/PIR') Foams

4.2.2.1. Current Commercial Situation

The predominate application of closed cell polyurethane foams is for insulation and they are widely used for this purpose in transportation, building construction, technical insulation (pipes, tanks, etc) and in domestic appliances - especially refrigeration and freezers. In addition to a remarkably low thermal conductivity, much lower than that of any other commercial insulating material and about half that of the next lowest, it has other important advantages including adhesion to surfaces, facility to be poured into complex cavities, good thermal resistance and long term retention of physical properties. It may be used to form composite materials combining high strength with good insulation, and in some applications such as refrigerator construction it is now regarded as indispensable. Because of these virtues it is playing a significant role in energy conservation.

It is the low thermal conductivity of the F-11 trapped in the closed cells which confers the exceptionally good insulating properties. In other words, F-11 is an essential component of the material when used for insulation purposes and not simply an agent used for creating the cell structure. Apart from other CFCs, there are no other gases with properties which would enable them to be used instead of F-11 in this application.

An industry source estimated EEC consumption of low density rigid PU foam for all applications to have been 195,000 tons in 1979, and forecast a rise to 311,000 tons in 1985. CFC consumption for this use may be expected to rise pro rata.

4.2.2.2. CFC Emissions from Rigid PU Foam

CFC emissions can occur during the initial formation of the foam and in any subsequent cutting and machining operations; during the life of the foam - however slow this process may be; and during eventual disposal.

Although we have been told that losses in manufacture are probably no more than 5% of the CFC used, consideration of the limited available data on CFC usage, PU foam production, and on typical formulations suggests to us that the manufacturing losses may be higher than is supposed.

The rate of loss during the working life of the foam will depend on a number of factors such as operating temperature, ratio of surface to thickness, and whether or not the foam is clad with an impermeable material such as metal sheet.

Emissions on disposal will depend upon the method, and whether any CFC remains in the foam at this stage. Incineration is likely to decompose any residual CFC, but retention might be almost indefinite if the material is buried.

The magnitude of these emissions is uncertain but it must be recognised that there is a rapidly increasing 'bank' of this trapped CFC, and that much of it may eventually be released.

4.2.2.3. Prospects for Reducing the CFC Release Associated with Rigid PU Foam

Because of its superior thermal insulation properties the substitution of CFC blown rigid polyurethane foam by other materials would entail energy penalties.

In certain applications, however, there are alternative materials being used such as phenolic resins and other foam plastics in building construction. That aspect apart, however, there are no apparent prospects, even in the long term, for making substantial reductions in CFC usage in this application - the indications being that usage is likely to continue to increase.

Marginal possibilities which might be explored include

a) A study to determine the extent and possibilities for reduction of losses during manufacture and conversion.

b) An investigation of disposal procedures with a view to devising and codifying methods which will prevent release of residual CFC.

4.2.3. Flexible (Open Cell) Polyurethanes

4.2.3.1. Aspects of Production and Use

Flexible polyurethane foam is used mainly in furniture and automotive upholstery, bedding, packaging, textiles, thermal and acoustic insulation. A large proportion is made by a continuous production process in the form of slabstock which is subsequently cut into the required shapes, and the balance by in situ foaming and batch moulding. EEC slabstock production in 1973 is estimated at 415,000 tons.

Flexible PU foam is made in grades of different density, mostly in the range 16 to 35 Kg/m^3, by varying the amount of blowing agent used. The higher density grades are blown with carbon dioxide which is generated by reaction between water and some of the organic isocyanate (usually toluene di-isocyanate or 'TDI") in the polyol/isocyanate mixture from which the polyurethane is produced. This reaction is highly exothermic, and there is a limit to the amount of carbon dioxide which can be generated in this way beyond which the temperature rises to levels at which the foam is damaged and a fire risk ensues. For the softer, lower density foams it is therefore necessary to use a secondary blowing agent, and this is the role played by CFCs, mainly F-11, in the production process, on which more detail is given in Metra 1978.

EUROPUR, the federation of the European national trade associations of flexible polyurethane slabstock producers, has provided the following figures for the total amounts of CFCs used by manufacturers representing a large proportion (ca. 80%) of the slabstock produced in the EEC in the years 1976 to 1979, and forecasts for the period 1980 to 1986 in respect of the same manufacturers.

TABLE 4.9 CFC BLOWING AGENT USAGE FOR FLEXIBLE POLYURETHANE SLABSTOCK MANUFACTURE IN EEC.

		CFC - tons
	1976	10,540
	1977	7,885
	1978	8,219
	1979	8,030
Forecast	1980	7,552
	1982	7,385
	1984	7,146
	1986	7,141

The figures reflect the current recession in the principal low density foam using industries, and indicate a 'no growth' scenario for the next 5 years for CFC consumption in this application.

4.2.3.2. Possibilities for Reducing CFC Usage and Release in Flexible Polyurethane Foam Production

a) Recovery

Virtually all the CFC blowing agent escapes from the foam after its formation, much of it into the ventilating system of the production line, good ventilation being essential because of the high toxicity of toluene di-isocyanate vapour, some of which also escapes during the foam formation reactions.

The possibility exists of recovering some of the CFC from plant ventilation air by means of an adsorbent such as active carbon, but there are some major practical difficulties in achieving this. The CFC is present at a very low concentration, so a large and expensive installation is needed to handle the air volume involved. Also, traces of TDI and other substances in the air stream will also be adsorbed, creating technical problems in the treatment of the spent adsorbent.

Research on CFC and TDI extraction from air streams by active carbon is being undertaken in a pilot plant at the High Wycombe, England, plant of Dunlop Ltd. This is a joint project between the International Isocyanate Institute and the British Rubber Manufacturers Association Flexible Foam Group.

b) <u>Alternative Blowing Agents: Methylene Chloride</u>

After exploration of all known possibilities the only alternative blowing agent found offering acceptable although not entirely satisfactory technical characteristics is methylene chloride. Some plants in the USA and at least one in Europe use methylene chloride, but many foam producers are reluctant to use it because of its toxicity and the problems attaching to maintaining its concentration in air below the TLV value of 200 throughout the plant. Considerable opposition by operating personnel to the use of methylene chloride has been reported, and because of uncertainty about the effects of long term exposure there is a possibility of the TLV being reduced to 100 or less.

Methylene chloride is cheaper than CFC blowing agents and it is an economic proposition to use it in a new specially designed plant, but adaptation of existing plants is difficult and costly, and may be impossible in some locations.

One or two companies are understood to be actively exploring the use of methylene chloride in new foam plants, but the majority of the producers in Europur consider that this alternative to CFCs must be approached with great caution.

c) Vacuum Blowing

The use of reduced pressure to eliminate the need for secondary blowing agents is a possibility which has been considered for many years but has never reached the production stage. Europur advises that research on this prospect has now been re-started in Europe.

d) Use of 'Soft Polyols'

Modified polyols have been developed which enable the requisite degree of softness to be obtained at higher densities than was previously possible, hence reducing the secondary blowing agent consumption. Commercial production of these polyols is commencing and their use will reduce but by no means eliminate CFC blowing agents, and the extent of the potential reduction is not yet quantifiable.

4.2.3.3. Need for Co-ordinated Development Programme

The possibilities reviewed above are all medium to long term prospects requiring considerable research and development.

There appears to be a good case for a co-ordinated programme which would avoid duplication of effort and resources, and while co-operation on a world-wide basis is desirable, it may be more practicable to organise it regionally. It is suggested, therefore, that the concept of a collaborative European programme should be explored.

4.2.4. Conclusions

1. CFC blowing agents are used in the production of a number of foam plastics, but mainly for flexible (open cell) and rigid (closed cell) polyurethane. Reliable statistics on CFC usage for the various foams are not available, but much of the increase in CFC usage for this application, from 42,000 tons in 1976 to 56,000 tons in 1979, is attributable to rigid polyurethane - the production of which in Western Europe is reported to be growing at a rate of nearly 9% annually. CFC usage for flexible polyurethane slabstock in the EEC has fallen by about 25% since 1976 and no growth is anticipated over the next 5 years.

2. The CFC content of closed cell polyurethane foam is an essential factor in the low thermal conductivity of this material, which has a unique combination of advantages for thermal insulation: no alternative non-CFC blowing agents are available for rigid polyurethane when it is used for this purpose, which is the major application. Reductions in CFC emissions might be made by minimising losses during foam production and conversion, and possibly by measures to prevent release during disposal, but these are only marginal prospects.

3. In open cell flexible polyurethane foams, CFCs are used as secondary blowing agents for producing the softer, lower density grades. CFC escapes from the foam during production and the possibility of recovery from the process ventilation air by adsorption on active carbon is being explored in a pilot plant project in England. Methylene chloride is an alternative blowing agent but toxicity problems dictate a cautious approach to substitution. Softer high density grades of foam can now be made using recently introduced polyols, and some reduction in CFC usage is likely to follow from this development. Vacuum blowing is a possibility on which research has been recommenced. There is a case for a co-ordinated research programme in Europe on the various medium and long term prospects for reducing CFC release in open cell foam manufacture.

4.3. Solvent Cleaning Applications

4.3.1. Development Trends

Although 'solvent and other uses' accounted for less than 7000 tons of F-11/F-12 EEC sales in 1979, (3.2% of all EEC sales), a substantial tonnage of F-113 is used in solvent cleaning - nearly 13,000 tons in 1977, and this application is believed to be growing in the EEC at a rate which may be as high as 8% annually.

Solvent cleaning was reviewed in the 1978 Metra study but was not given special attention in the present assignment, and no new information of significance has been obtained.

F-113 has an attractive combination of properties for vapour/liquid solvent cleaning applications but, because of its relatively high cost compared to other solvents and cleaning agents, such as chlorinated hydrocarbons, its use was largely confined initially to specialised applications, such as flux removal from printed circuits and the cleaning of high precision engineering equipment, for which no adequate alternative cleaning systems were available. Because of its technical advantages and low toxicity, however, it is now making some inroad into the market for the traditional solvents such as perchloroethylene and is being used for dry cleaning as well as industrial applications. This is another area for which detailed statistical information is lacking.

Equipment as well as application development has continued, and a recent innovation has been the incorporation of a heat pump which eliminates the need for cooling water in the condenser section of a vapour rinse unit.

4.3.2. Emission Prevention

Aside from the use of alternative systems, based on non-CFC cleaning agents, possible ways of reducing CFC emissions in this application include

- equipment design standards which minimise escape to atmosphere by diffusion
- attention to operating procedures, e.g. to minimise excessive drag-out losses
- avoidance of release to atmosphere in the disposal of discarded solvent.

4.3.3. Conclusion

The growing use of fully halogenated CFCs, especially of F-113, for solvent cleaning makes this an application area which deserves further attention. More information is needed to quantify the sources of emission, and it would be useful to discuss equipment design standards, operating practice and solvent disposal procedures with the industry sectors concerned.