

COSTS OF CONTROLLING METHYL CHLOROFORM IN THE U.S.

REVIEW DRAFT

OCTOBER 5, 1989

**DIVISION OF GLOBAL CHANGE
OFFICE OF AIR AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY**

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EXECUTIVE SUMMARY

Because of its high production volume, methyl chloroform (MCF) currently represents a significant source of chlorine (about 15 percent) to the stratosphere. The short atmospheric lifetime of MCF relative to the fully halogenated CFCs allows its contribution to stratospheric ozone to be reduced significantly faster than the contribution from any of the CFCs. Because of these factors, significant short term reductions in stratospheric chlorine concentrations can be achieved by controlling MCF use. This analysis focuses on the technical feasibility and costs of limiting MCF use in the United States.

The report examines the growth prospects for MCF demand in the U.S. and the costs associated with a potential freeze of MCF production at 1986 levels and a phase-out of MCF production by the year 2000. Overall, demand for MCF is projected to grow from 1989 to 2000 at average annual rates ranging from 2.2 to 4.7 percent. These growth rate estimates consider alternative assumptions on the reductions in MCF use achievable by conservation and recycling practices and allow for potential increased demand in the near-term due to restrictions on CFC-113 and other regulated solvents. The largest end uses for MCF are metal vapor degreasing and cold cleaning; however, most of the growth in market demand for MCF will be due to increased use in smaller end uses (aerosols, coatings and inks, adhesives, and electronics cleaning). This is due to the rapid growth in the markets for these products and the fact that industry is switching from increasingly regulated solvents (e.g., perchloroethylene, methylene chloride, VOCs, and CFC-113) to MCF.

Technically feasible technologies that reduce or eliminate the use of MCF are available for all end-uses of MCF.¹ For vapor degreasing and cold cleaning these alternative technologies include primarily aqueous and terpene cleaning, but also alternative cleaning solvents of low ozone depleting potential and engineering controls. For aerosols, adhesives, and coatings and inks, water-based technology offers effective substitutes for MCF-based systems in most applications. In addition, reformulation to petroleum distillates and use of alternative delivery systems currently available can significantly reduce the use of aerosols containing MCF in consumer and occupational uses. The expanded use of hot melt adhesives and solvent recovery systems can achieve further reductions of MCF use in adhesives. High-solid and powder coatings are innovative technologies that are currently available to users of coatings.

This analysis estimates the costs of a freeze of MCF production at 1986 levels and a phase-out by the year 2000. The social costs associated with a phase-out by the year 2000 are estimated to be between \$1.3 and \$2.7 billion during the period 1989-2000 depending on the baseline growth rate assumed for MCF. Over longer periods of time, the present value of social costs grows significantly -- to about \$58 billion by the year 2075. The estimates of social costs are reduced by about 10 percent or less if the phase-out is initiated with MCF production assumed to be frozen at 1988 instead of 1986 levels.

¹ MCF is also used as an intermediate for the production of fluorocarbons and fluoropolymers. However, this end use is assumed to remain uncontrolled and has negligible emissions.

1. INTRODUCTION

The United States as a party to the Montreal Protocol on Substances that Deplete the Ozone Layer has committed to reducing the use of specified fully halogenated chlorofluorocarbons (CFCs) and halons. These chemicals contain chlorine and bromine, which migrate to the stratosphere and have been shown to deplete the ozone layer. EPA promulgated final regulations implementing the Protocol on August 12, 1988 (53 FR 30566). The conditions for the Protocol's entry-into-force were satisfied in December 1988, and the Protocol and the EPA's rule went into effect January 1, 1989.

On the same day that the Agency issued its final rule implementing the Montreal Protocol, it also published an Advanced Notice of Proposed Rulemaking (ANPRM) on possible further efforts to protect stratospheric ozone (53 FR 30604, August 12, 1988). Currently, the Montreal Protocol and the EPA regulation require a 50 percent phased-in reduction in the production and consumption of specified fully-halogenated CFCs by 1998, and a freeze at 1986 levels of specified halons beginning in 1992. In the August ANPRM however, EPA described new scientific information which suggests that additional reductions in CFCs, halons and possibly other ozone depleting chemicals may be necessary. This new scientific information suggests that ozone is depleting at a faster rate than the scientific community and the Parties to the Protocol had originally anticipated. Future chlorine and bromine concentrations in the upper atmosphere will depend primarily on future emissions of CFCs, halons, and other ozone depleting substances.

In August 1988, the U.S. EPA issued a study entitled "Future Concentrations of Stratospheric Chlorine and Bromine,"¹ which looked at chlorine and bromine levels after the implementation of the restrictions in the Montreal Protocol. The U.S. EPA estimated that concentration of chlorine in the stratosphere would increase from the current level of 2.7 to 8 parts per billion (ppb) by 2075, even with the reductions in CFC production called for in the Protocol. This increase would be caused not only by the allowed use of CFCs and halons under the Protocol, but also by CFC use in countries that are not members of the Protocol and by the growth in the production and use of the non-regulated chemicals such as methyl chloroform² and carbon tetrachloride. Specifically, the study predicted that approximately 45 percent of the total increase in chlorine and bromine would be caused by emissions from the remaining CFCs and halons. An additional 35 percent of the increase in chlorine would occur as the result of methyl chloroform emissions. The role of MCF in contributing chlorine to the stratosphere is discussed in more detail in Chapter 2 of this report.

Because methyl chloroform currently contributes significant quantities of chlorine to the stratosphere on April 17, 1989, EPA issued an ANPRM (Advance Notice of Proposed Rulemaking) (54 FR 15230, April 17, 1989) stating that it would be discussed as part of efforts to strengthen the Montreal Protocol and requesting that industry provide information on the availability

¹ Clx Report, U.S. EPA Office of Air and Radiation, 400/1-88/005, August 1988.

² Methyl chloroform is also referred to as 1,1,1-trichloroethane, TCA, and CH₃CCl₃.

of substitutes for methyl chloroform. This analysis incorporates the comments received by EPA, which are discussed in the individual sections describing substitute technologies for the various end uses of methyl chloroform.

In addition, this report presents estimates of the costs that society would incur if the use of methyl chloroform is reduced according to two alternative reduction scenarios:

- a freeze at 1986 levels, and
- a phase-out by the year 2000.

Chapter 2 discusses methyl chloroform's contribution to stratospheric chlorine concentrations. Chapter 3 describes the potential increase in demand for methyl chloroform over the next twelve years (i.e., from 1989 through the year 2000) given the current market and regulatory environment in the end-use industries. This chapter describes the reasons for the use of methyl chloroform in each end-use and projects the growth in methyl chloroform demand assuming that no restrictions were imposed. For modelling purposes, this chapter also presents long term growth projections for the period 2000 to 2050, and after 2050. Chapter 4 describes control technologies that reduce the use of methyl chloroform in each end-use. Public comments on the availability and feasibility of substitutes are addressed in this chapter. Chapter 5 describes the approach used to estimate the costs of the two alternative reduction scenarios for methyl chloroform (freeze and phase-out). Chapter 6 presents the results of this cost analysis for the two reduction scenarios including the social costs and transfer payments associated with the reduction of methyl chloroform use in the various user industries.

2. METHYL CHLOROFORM'S CONTRIBUTION TO STRATOSPHERIC CHLORINE CONCENTRATIONS

Because methyl chloroform currently is a significant source of chlorine to the stratosphere, it is being considered for possible regulation under the Montreal Protocol. This chapter seeks to assess the role of past and current methyl chloroform emissions in increasing stratospheric chlorine levels, the potential role of future emissions, and the magnitude and timing of decreases in chlorine concentrations that would result from including this chemical in the Montreal Protocol.

2.1 Current Chlorine Contributions

Methyl Chloroform differs from the fully halogenated CFCs in that it has a substantially shorter atmospheric lifetime. For example, the lifetime of methyl chloroform has been calculated to be on the order of 6-7 years compared to lifetimes of 60 and 120 years for CFC-11 and CFC-12, respectively. The importance of a chemical's atmospheric lifetime is that the longer its lifetime, the higher the percentage of the compound that will survive to be transported to the stratosphere where its chlorine will be released and begin the process of destroying ozone. However, the lifetime alone does not determine the risks from that chemical to the ozone layer. The total amount of stratospheric chlorine contributed from a particular chemical will be determined not only by its atmospheric lifetime, but also by the quantity of its emissions, and the amount of chlorine it contains. Because methyl chloroform is currently produced and used in large quantities (e.g., roughly equivalent to the total of all the CFCs combined) and because it contains three chlorine atoms, its contribution to current stratospheric chlorine levels has been significant.

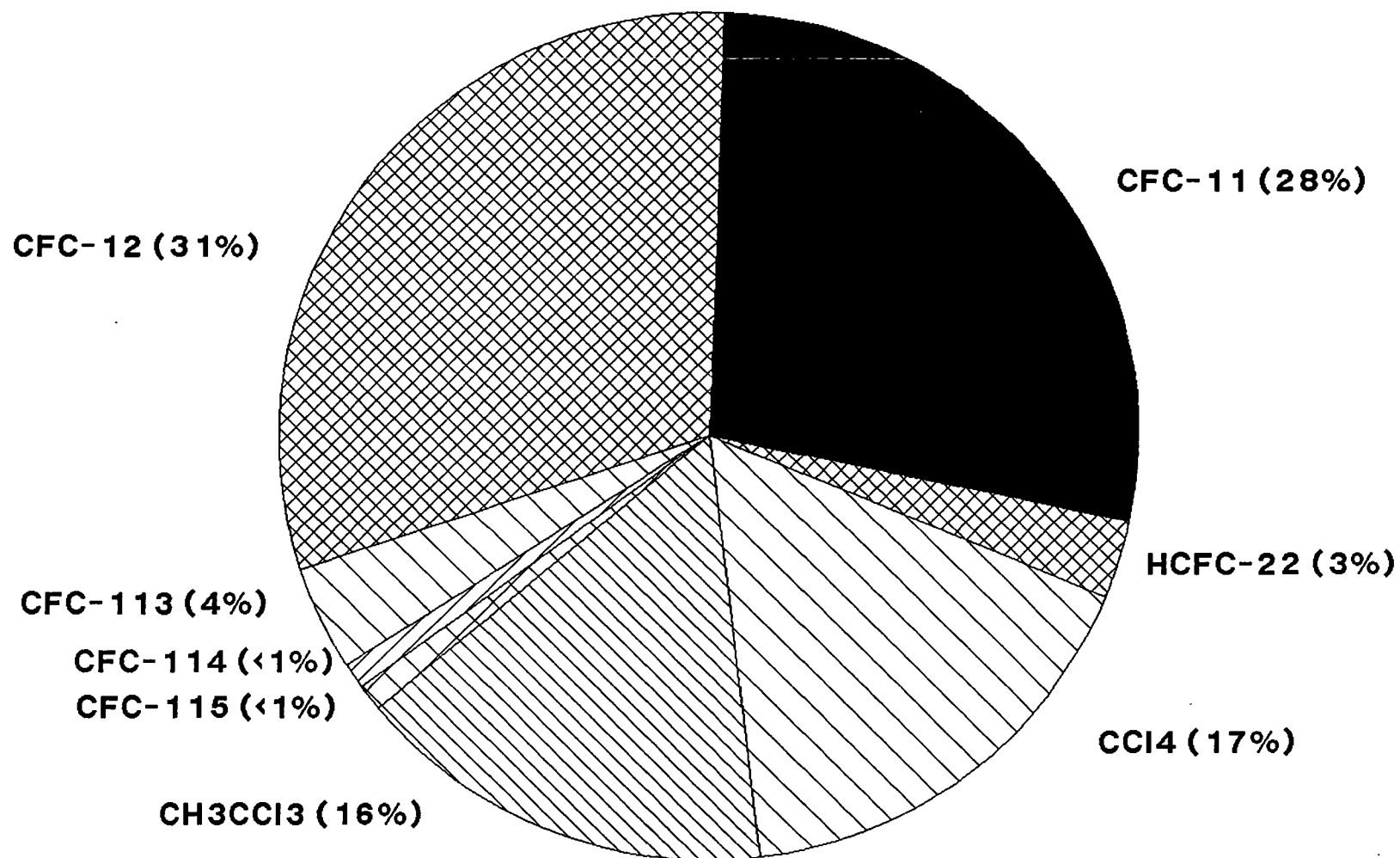
Exhibit 1 shows the current contribution to chlorine concentrations from the fully halogenated CFCs, methyl chloroform, carbon tetrachloride and HCFC-22. Despite its short atmospheric lifetime, MCF contributes 16 percent of the chlorine in the atmosphere. This is about 4 times more than the contribution from CFC-113 and 5 times more than HCFC-22.

2.2 Impact of Atmospheric Lifetimes

The relatively short atmospheric lifetime of methyl chloroform is one characteristic that makes this chemical similar to many of the HCFC substitutes currently being developed. This same characteristic also means that chlorine in the stratosphere from methyl chloroform will be reduced at a much faster rate once emissions are reduced. Exhibit 2 illustrates this point. It shows changes in chlorine contributions over time from a one-time flux of an equal quantity of emissions (i.e., 300 million kilograms) of CFC-11 and 12 and methyl chloroform. The graph demonstrates that methyl chloroform's short atmospheric lifetime (relative to the fully halogenated CFCs) allows its contribution to stratospheric chlorine concentrations to be reduced significantly faster than the contribution from any of the CFCs. It shows that chlorine from methyl chloroform is almost entirely cleansed from the atmosphere in 15 to 20 years, whereas significant quantities of chlorine from the CFCs remain for well over 100 years. Thus, controls on methyl chloroform emissions will reduce stratospheric chlorine levels more rapidly than controls on any of the CFCs.

Exhibit 3 makes the same point but shows the reductions in chlorine based on each chemical's actual 1986 contribution to stratospheric chlorine

EXHIBIT 1
CONTRIBUTIONS TO 1985 ANTHROPOGENIC
CHLORINE CONCENTRATIONS

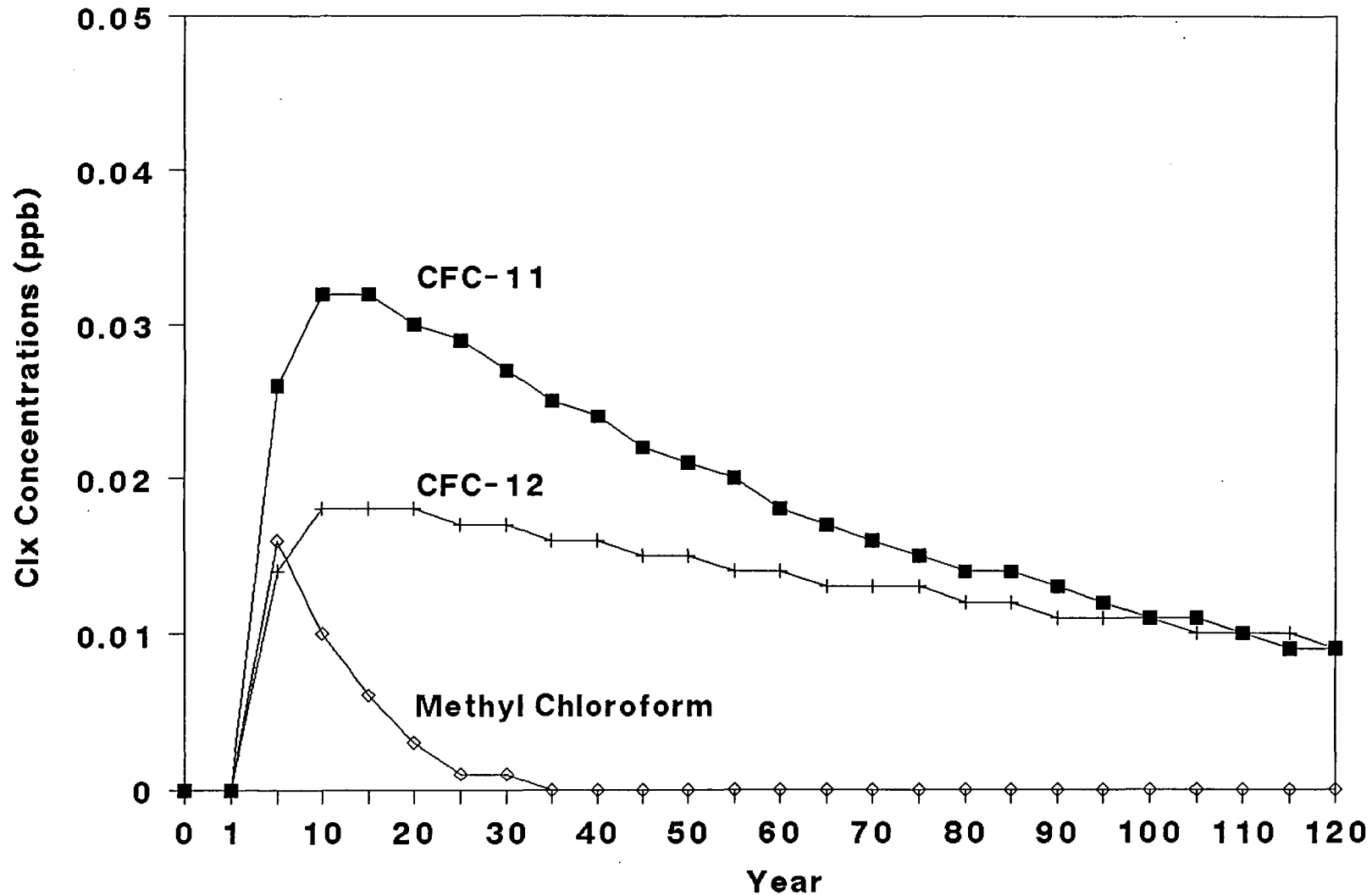


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EXHIBIT 2

SIMULATED CHLORINE CONCENTRATIONS FROM CFC- 11, CFC- 12 AND METHYL CHLOROFORM FROM HYPOTHETICAL ONE YEAR EMISSIONS OF 300 MILLION KILOGRAMS



- 7 -

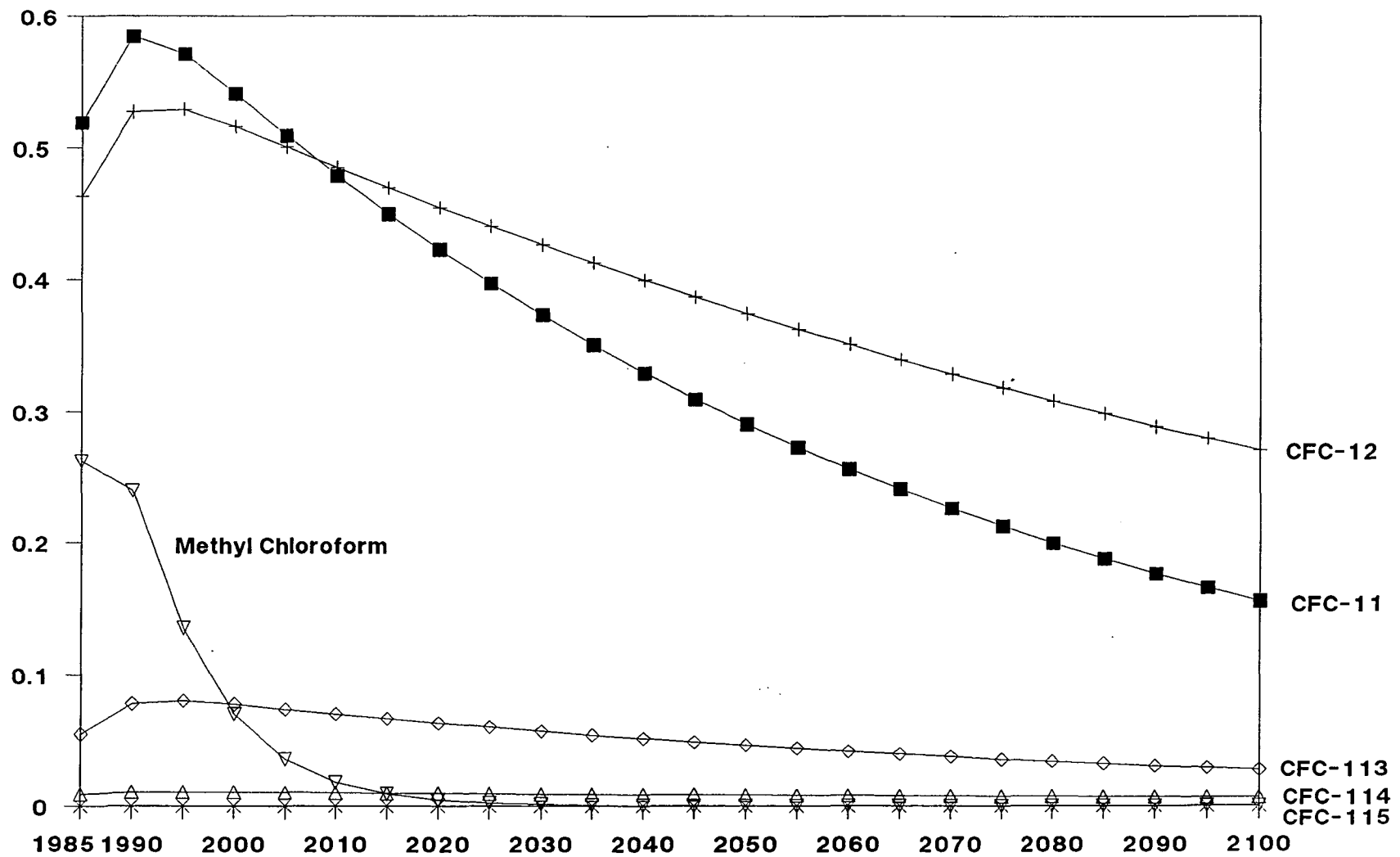
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EXHIBIT 3

SIMULATED STRATOSPHERIC CHLORINE CONCENTRATIONS FROM

FULLY HALOGENATED CFCS AND METHYL CHLOROFORM

FROM HISTORIC EMISSIONS THROUGH 1985



concentrations. By assuming arbitrarily that emissions of each chemical were completely eliminated in 1986, it shows the path of reductions in chlorine over time for each chemical. Again, the graph underscores the dominant role played by a phase-out of methyl chloroform in achieving near-term reductions in stratospheric chlorine. It shows that chlorine from methyl chloroform is essentially eliminated within several decades following a phase-out, whereas significant quantities of chlorine from CFCs continue to remain in the stratosphere for well over a 100 years.

2.3 Impacts on Total Chlorine Concentrations

The Montreal Protocol's Scientific Assessment focussed on two aspects of efforts to minimize damage from ozone depletion. One involved limiting the magnitude of increases in total chlorine levels. To put this in context, natural concentrations of stratospheric chlorine are approximately 0.7 ppb. Current concentrations are about 3.0 ppb. Future increases in chlorine concentration appear inevitable for several reasons: chlorinated compounds already in the troposphere will eventually add to stratospheric concentrations; chlorinated compounds trapped in products will slowly be released over time; and CFCs and related compounds will continue to be used over the next decade or longer (in developing countries) until substitutes are developed and fully employed.

The second consideration in limiting damage from ozone depletion involves reducing stratospheric chlorine concentrations back to levels that existed prior to the onset of the Antarctic ozone hole -- approximately 1.5-2.0 ppb.

Exhibit 4 shows the effect on both of these goals (i.e., maximum chlorine concentrations and timing of reaching pre-ozone hole concentrations) of different levels of controls on methyl chloroform. A phase-out of methyl chloroform would reduce maximum chlorine levels from 4.0 ppb to 3.7 ppb which would result from a freeze on this chemical at 1986 levels (assuming the CFCs and carbon tetrachloride are phased out in 2000 and no substitution occurs). Thus, whether MCF is frozen or phased out will significantly affect the increased risks of greater ozone depletion from higher chlorine concentration. The difference between a phaseout of MCF (3.7 ppb) and a freeze (4.0 ppb) represents a 40 percent increase in risks from today's level (3.0 ppb).

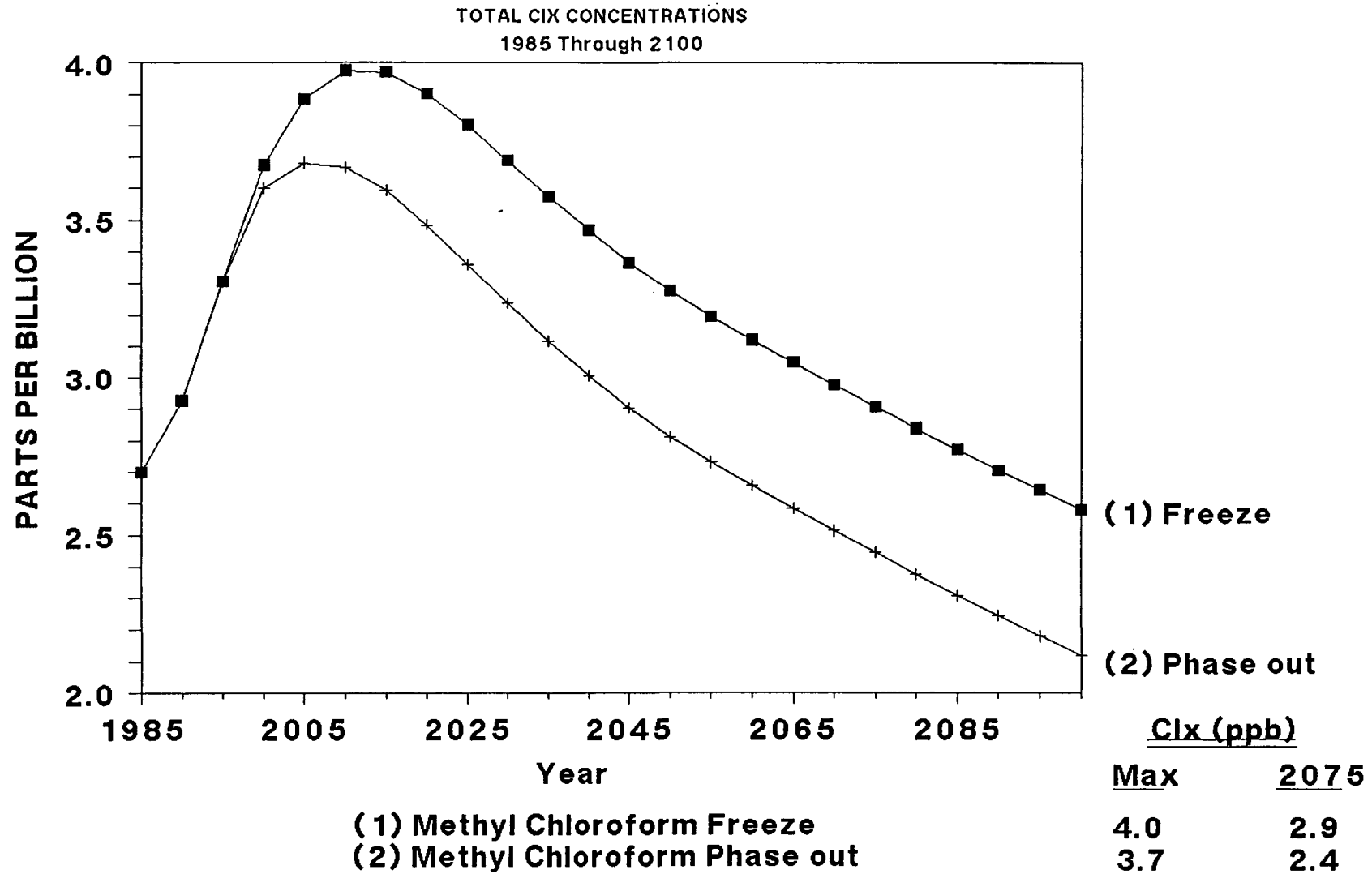
Further, a phase out of methyl chloroform would allow stratospheric chlorine to return to current concentrations by about 2060, or 35 years earlier than if methyl chloroform emissions were simply frozen. It is important to note that this graph compares the difference between a freeze and a phase-out of methyl chloroform and therefore assumes no growth in future emissions.

2.4 Reducing Near-term Chlorine Concentrations

The analysis clearly indicates that a phase-out of methyl chloroform would be the single most important source for near-term reductions in stratospheric chlorine levels. The significant role played by this chemical can be attributed to two factors: it is already a significant contributor of chlorine to the stratosphere and because it has a relatively short atmospheric lifetime, its chlorine contribution can be eliminated relatively rapidly following a phase out.

EXHIBIT 4

EFFECT OF METHYL CHLOROFORM PHASE OUT



Assumptions:

- o 2000 Phase out of Fully Halogenated CFCs and Carbon Tetrachloride
- o 100% Global Participation
- o No HCFC Substitution for Foregone CFCs

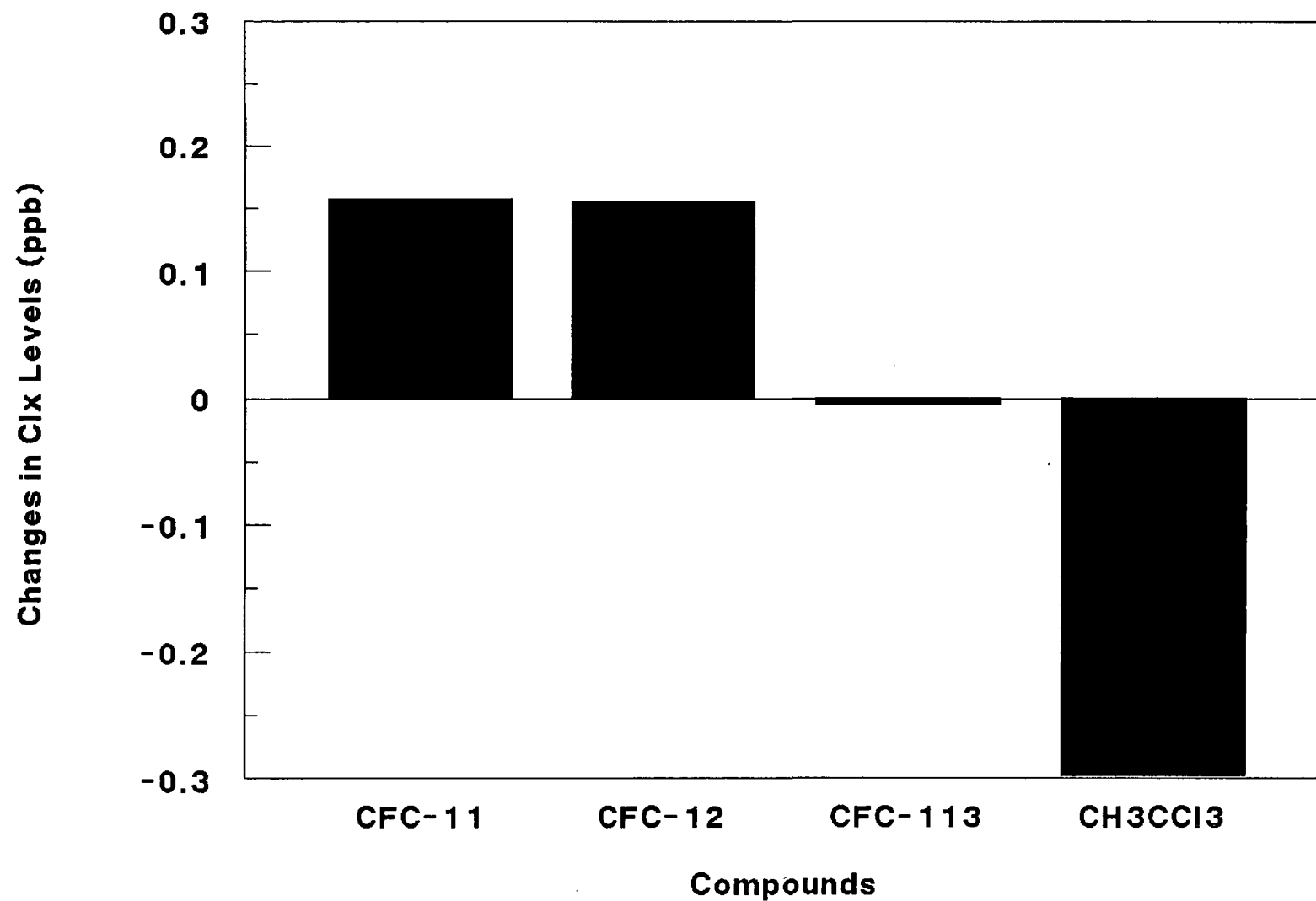
Exhibit 5 demonstrates this point. It shows the same phase-out scenario presented in the previous figure (i.e., a phase-out of CFCs, carbon tetrachloride and methyl chloroform). However, it depicts the changes in chlorine concentrations separately for each chemical for the period from 2005 to 2035. It shows that a phase-out in 2000 of the CFCs and carbon tetrachloride will not have significant short-term results in reducing stratospheric chlorine concentrations, though they will be critical for achieving long-term reductions. In sharp contrast, the 2000 phase-out of methyl chloroform will result in its full impact being experienced during this near-term period and will yield a net reduction of 0.3 ppb.

2.5 Conclusions

This chapter examined the role of methyl chloroform in contributing to stratospheric chlorine concentrations. It focussed on the unique characteristics surrounding methyl chloroform, specifically its large contribution to current stratospheric chlorine concentrations (e.g., roughly equal to CFC-11, -12 and carbon tetrachloride) and its relatively short atmospheric lifetime. Taken together, these factors suggest that a phase-out of methyl chloroform is the most effective means of limiting increases in peak chlorine concentrations and in achieving significant near-term reductions in stratospheric chlorine concentrations.

EXHIBIT 5

CHANGES IN CIX LEVELS FROM A PHASE OUT: 2000 TO 2035



Assumptions:

- o 2000 Phase out of Fully Halogenated CFCs, Carbon Tetrachloride and Methyl Chloroform
- o 100% Global Participation
- o No HCFC Substitution for Foregone CFCs

3. DEMAND FOR METHYL CHLOROFORM IN MAJOR END-USES

This chapter discusses projections of the growth in methyl chloroform demand in the U.S. Section 3.1 discusses the changes in MCF production and trade over the past 10 years and addresses public comments regarding the future trends in MCF demand. Section 3.2 discusses the factors driving methyl chloroform demand in the future and section 3.3 summarizes the demand growth rate projections for three alternate scenarios for the period of 1989 to 2000. Section 3.4 elaborates on the factors affecting methyl chloroform demand in specific end-uses and presents the resulting demand growth rate estimates for these end-uses. Section 3.5 discusses long-term projections in methyl chloroform demand (i.e., from 2001 to 2075) which are necessary to model the long-term economic impacts associated with potential reductions in methyl chloroform use.

3.1 MCF Production and Trade Over the Past 10 Years.

Exhibit 6 shows the production figures for MCF reported by the U.S. International Trade Commission sources, exports reported by the U.S. Bureau of Census, and imports estimated by an independent market research firm for the period of 1978-1989. Various comments to the MCF ANPRM (54 FR 15230, April 17, 1989) indicate that MCF is a commodity chemical that is approaching maturity, i.e., MCF demand will remain essentially the same over the next few years. The figures reported in Exhibit 6 show production changes over time. It shows that production had decreased in the early 1980's during the worldwide economic recession. More recently, however, production levels appear to be increasing with growth in 4 of the last 5 years. While it is difficult to make definitive conclusions from this data on MCF production, the

Exhibit 6. U.S. Production and Trade of Methyl Chloroform: 1978 - 1988
(Thousands of pounds)

Year	Production (a)	Annual Growth Rate (b)	Exports (c)	Annual Growth Rate (d)	Imports (e)	U.S. Demand (f)=(a)-(c)+(e)
1978	644,475		N/A		N/A	N/A
1979	716,336	11.2%	59,557	N/A	N/A	N/A
1980	692,269	-3.4%	61,279	2.9%	N/A	N/A
1981	613,993	-11.3%	56,003	-8.6%	N/A	N/A
1982	595,186	-3.1%	63,743	13.8%	10,000	541,443
1983	586,400	-1.5%	56,785	-10.9%	12,000	541,615
1984	674,540	15.0%	46,533	-18.1%	15,000	643,007
1985	868,776	28.8%	39,796	-14.5%	20,000	848,980
1986	652,109	-24.9%	87,279	119.3%	N/A	N/A
1987	694,274	6.5%	110,547	26.7%	N/A	N/A
1988	723,656	4.2%p	94,808	-14.2%	71,152 (g)	700,000
Average Growth ('79-88):		1.2%(h)				

Notes:

N/A: Not available.

p: preliminary USITC estimate.

Sources:

- (a) U.S. International Trade Commission - Synthetic Organic Chemicals (various years)
- (b) Percent change in production with respect to previous year.
- (c) Exports: U.S. Census Bureau (publication FT446).
- (d) Percent change in exports with respect to previous year.
- (e) The U.S. Bureau of Census does not report imports for MCF separately. The above estimates are from a market research firm: Chemical Products Synopsis - Mannsville Chemical Products Corp. (June 1985).
- (f) Demand = Production - Exports + Imports. Lack of import data prevents the calculation of demand for all years.
- (g) Computed imports: Based on CMR (1989) estimate of demand of 700 million pounds in 1988 and reported exports.
- (h) Compounded growth rate from 1978 to 1988 production levels.

data does show that the average annual percentage change in MCF production over the past 10 years has been a positive 1.2 percent¹.

The demand for MCF (i.e., domestic consumption) is the difference between the sum of MCF production and imports and MCF exports. Export data for MCF are available from the Bureau of Census; however, imports are reported for a generic category of "chlorinated hydrocarbons" and not separately for MCF. Current estimates of MCF demand place total MCF demand in the U.S. at 700 million pounds (CMR 1989); this is lower than the estimated demand for 1985 but higher than demand in 1982 through 1984. Incomplete data, therefore, make it difficult to assess any trends in MCF consumption.

In conclusion, the change in production over the past ten years has been on average a positive 1.2 percent annually. Lack of adequate trade data prevent reliable projections of future MCF demand based on historical demand. However, the analysis of major factors driving MCF demand in each sector in the subsequent sections lead to the conclusion that MCF has a significant growth potential.

3.2 Major Factors Driving Future MCF Demand in the U.S.

Three factors will determine the growth in methyl chloroform demand over the next 12 years (from 1989 to 2000): (1) increased use of conservation practices² which reduce the use of methyl chloroform, (2) market growth in

¹ This average is calculated as the average compounded growth from 1978 to 1988 production levels reported in Exhibit 6 (column b); however, it should be noted that growth over the past ten years has not been steady.

² Conservation practices include the use of recycling technologies and improved operating measures that result in a reduction in MCF use. The term "conservation" is used in the rest of the report to describe these type of controls.

industries that use methyl chloroform, and (3) regulatory restrictions on other chlorinated solvents (trichloroethylene, perchloroethylene, and methylene chloride), CFC-113, and materials classified as Volatile Organic Compounds (VOCs)³.

3.2.1 Decrease in MCF Demand due to Increased Conservation Practices.

Conservation practices in the cold cleaning and vapor degreasing end-uses have in the past and will continue in the future to reduce the use of MCF as users attempt to minimize the costs associated with solvent losses and waste disposal. Based on current consumption, these measures may lead to reductions ranging from 20 to 60 percent of current MCF consumption in these end-uses by the year 2000⁴. The specific conservation practices that can be implemented to reduce MCF use in metal cleaning include improved operating practices, the use of recycling technologies (including carbon adsorption systems), avoiding the use (or frequency of use) of a solvent where necessary, and emissions control technologies such as refrigerated freeboard chillers, and automatic covers and hoists. In the electronics industry, similar control technologies may lead to significant reductions in the amount of solvent needed to deflux printed circuit boards, and for preparation of wafers for integrated circuits and degreasing of semiconductors.

³ Methyl chloroform is not classified as a Volatile Organic Compound (VOC). VOCs include most hydrocarbons which are capable of becoming gases under atmospheric pressure and that upon contact with solar radiation produce ground level ozone (smog). Restrictions on the use of VOCs may result in a switch to methyl chloroform.

⁴ This is consistent with various industry comments to the April 14 ANPRM indicating that users can implement technically available, low-cost controls which will lead to significant reductions in MCF use.

3.2.2 Increase in MCF Demand due to Growth in MCF-Using Industries.

The market growth, i.e., the increase (or decrease) in the output or number of units produced in the industries that use MCF will lead to increased (or decreased) demand for methyl chloroform. This analysis is based on historical market growth rates reported in government and industry sources (primarily the U.S. Department of Commerce Industrial Outlook and trade journals). Exhibit 7 presents the specific industry growth rates used for the five major end-uses of methyl chloroform.

The growth rate estimate for the metal vapor degreasing and cold cleaning end-uses is an average of the growth rates in seven major metal working or metal using industries (i.e., fabricated metal products, primary metal industries, machinery, furniture and fixtures, transportation equipment, and instruments and related products) which are classified as 2-digit SIC codes (Standard Industrial Classification). The growth rates for each of these industries are averages because the data reported in the U.S. Department of Commerce 1989 Industrial Outlook only reports growth rates for 4-digit SIC codes (e.g., sub-sectors within the fabricated metal products). A similar procedure was used to compute the average growth rate for the electronics industry. A detailed presentation of the methodology and data used to compute these values is presented in Appendix A.

The adhesives and coatings industries are reported by 4-digit SIC codes and, therefore, the industry growth rates of 5 and 1 percent, respectively, are quoted directly from the reported data. The market growth rate for the aerosols industry of 6 percent is the weighted average output growth for

EXHIBIT 7

MARKET GROWTH IN END-USES FOR METHYL CHLOROFORM

MCF End-Use	Industry Annual Growth Rate ^a	SIC CODES
Metal Vapor Degreasing and Cold Cleaning	2.1%	25, 33, 34, 35, 37, 38, 39
Aerosols	6.0% ^b	N/A ^c
Adhesives	5.0%	2891
Electronics	8.7%	36
Coatings and Inks	1.0%	2851

Sources: Based on U.S. Industrial Outlook 1989. U.S. Department of Commerce.

N/A: Not available.

^a Except where noted otherwise, the annual average growth rates are averages for the 1984-89 period as reported. Because the averages for 2-digit SIC codes are not reported, the rates shown are the weighted average growth rates of all corresponding 4-digit SIC codes reported. The calculation of these average growth rates is presented in Appendix A.

^b Based on Aerosol Age 1989. Weighted average output growth of household products, automotive and industrial products, and aerosol pesticides from 1983 to 1988. The estimated shares of MCF consumption in these aerosol product categories (ICF 1989a) are used as the weights for computing the average.

^c Statistics for the aerosols industry are not reported in the U.S. Industrial Outlook 1989.

household products, automotive and industrial products, and aerosol pesticides from 1983 to 1988 (Aerosol Age 1989⁵). As discussed in Section 2.3.2, these represent the product categories where most of the MCF is used. The estimated shares of MCF consumption in these aerosol product categories (analyzed in ICF 1989a) are used as the weights for computing this average.

3.2.3 Increase in MCF Demand due to Regulatory Restrictions on Other Solvents

Demand for methyl chloroform may also grow due to increased regulatory restrictions on the use of CFC-113, other chlorinated solvents (e.g., perchloroethylene, trichloroethylene, and methylene chloride), and Volatile Organic Compound (VOC) solvents (particularly in California). It is estimated that current restrictions imposed on CFC-113 use under the Montreal Protocol, will encourage some users of CFC-113 at least in the near-term, to switch to methyl chloroform. In addition, early this year OSHA enacted a final rule lowering the exposure limits for perchloroethylene and trichloroethylene (methylene chloride's exposure limit is currently under review and is expected to undergo similar reductions) (54 FR 2944, January 19, 1989). The increased stringency of these exposure limits may lead some chlorinated solvent users to switch to methyl chloroform instead of trying to control exposure. Compliance with VOC emissions limits, particularly in the coatings and inks and adhesives industries, may also cause a switch to MCF-based products, which is exempt from VOC rules.

⁵ This source reports the number of aerosol units produced in various product categories and is based on the Chemical Specialties Manufacturers Association's pressurized products survey for 1988. The U.S. Industrial Outlook does not report statistics for the aerosols industry.

Each of the three factors discussed above (i.e., increased conservation, market growth, and regulatory restrictions on other solvents) will affect the level of demand for methyl chloroform in each end-use depending on specific characteristics of the end-use in question. For example, conservation practices in the metal cleaning industry are projected to offset to a large extent the combined effect of market growth and switch from other solvents to methyl chloroform resulting in a slow to no growth in methyl chloroform demand in this sector. In contrast, the high market growth in the aerosols industry and the increased use of methyl chloroform as a replacement for methylene chloride and perchloroethylene leads to a net increase in methyl chloroform consumption in aerosols. Hence, some end-uses contribute to large increases in methyl chloroform demand whereas other end-uses will stabilize methyl chloroform demand. For this reason, the distribution of methyl chloroform consumption by end-use is important for projecting total methyl chloroform demand.

Two alternative distributions of current demand for methyl chloroform by end-use are used in the projections discussed below: the Halogenated Solvents Industry Alliance's (HSIA) distribution and the Chemical Marketing Reporter's distribution (CMR) published in January of 1989⁶:

⁶ Various comments to the methyl chloroform's ANPRM quote this distribution of consumption by end-uses reported in CMR, including comments by MCF producers and others.

End Use	CMR ^a Use Shares	HSIA Use Shares
Metal Vapor Degreasing	40	44
Metal Cold Cleaning	14	20
Aerosols	12	11
Adhesives	9	9
Electronics	5	6
Fluorocarbons/ Fluoropolymer Intermediates	8	4
Coatings and Inks	6	3
Miscellaneous	6	3
Total	100	100

^a Values adjusted to exclude exports.

Source: CMR 1989.
HSIA 1987.

As shown above, CMR attributes more consumption to non-traditional methyl chloroform end-uses (i.e., aerosols, adhesives, and inks and coatings). The differences in the shares allocated for each end-use affect the projections of total demand because of the significant difference in their market growth rates (as shown in Exhibit 7). Thus, the alternative share distributions are used as a tool for sensitivity analysis.

3.3 Summary of Demand Scenarios

Demand for methyl chloroform totalled 700 million pounds in 1988 (CMR 1989). Exhibit 8 shows demand projections for methyl chloroform considering three scenarios: "low conservation-high chlorinated solvent switch", "high conservation-low chlorinated solvent switch", and "no solvent switch".

3.3.1 Scenario 1: Low Conservation-High Chlorinated Solvent Switch

For this scenario the following assumptions were used:

- 25 percent of the chlorinated solvents consumption in metal vapor degreasing, cold cleaning, and electronics switches to MCF;

EXHIBIT 8. SUMMARY OF DEMAND SCENARIOS FOR METHYL CHLOROFORM

Scenario	(million pounds)		Annual Growth
	1988 Demand	2000 Demand	
1. LOW CONSERVATION -- HIGH CHLORINATED SOLVENT SWITCH ^a			
HSIA Use Shares ^b	700	1,129	+4.1%
CMR Use Shares ^b	700	1,215	+4.7%
2. HIGH CONSERVATION -- LOW CHLORINATED SOLVENT SWITCH ^c			
HSIA Use Shares	700	816	+1.3%
CMR Use Shares	700	936	+2.4%
3. LOW CONSERVATION -- NO SOLVENT SWITCH ^d			
HSIA Use Shares	700	901	+2.1%
CMR Use Shares	700	904	+2.2%

^a The assumptions for scenario 1 are as follows:

- 25 percent of the chlorinated solvents used in metal vapor degreasing, cold cleaning, and electronics switches to MCF;
- MCF captures 25 percent of the volume of CFC-113 used in metal vapor degreasing, cold cleaning, and electronics in 1986;
- conservation practices in vapor degreasing, cold cleaning, and electronics reduce current MCF consumption in these end-uses by 20 percent by the year 2000; and
- the growth rates of the industries using MCF will be the same as their past five-year growth rates.

^b The HSIA and CMR use shares are shown in page 22.

^c The assumptions for scenario 2 are the same as those of scenario 1 except for the following:

- 10 percent of the chlorinated solvents used in metal vapor degreasing, cold cleaning, and electronics switches to methyl chloroform; and
- conservation practices in vapor degreasing, cold cleaning, and electronics reduce current MCF consumption immediately by 60 percent by the year 2000.

^d This scenario uses the same assumptions as scenario 1 except that no VOC, chlorinated solvents, and CFC-113 consumption is assumed to be captured by MCF.

- conservation practices in vapor degreasing, cold cleaning, and electronics reduce current MCF consumption in these end-uses by 20 percent by the year 2000;
- the volume of CFC-113 used in metal vapor degreasing, cold cleaning, and electronics is reduced to 50 percent of 1986 levels. That is, if 100 units of CFC-113 were used in 1986 then only 50 units are used in 1998. Of these 50 units, 50 percent switches to MCF, i.e., 25 units of use switch to MCF⁷;
- demand growth (or decline) in the industries that use methyl chloroform results from the combination of their market growth rates shown Exhibit 7 (i.e., their growth rates over the last five years) and the conservation measures and/or solvent switch assumptions described above.

Under this scenario, the annual growth in methyl chloroform demand could range from range from 4.1 percent to 4.7 percent resulting in total consumption of between 1,129 and 1,215 million pounds by the year 2000. This range of projected growth rates is based on the HSIA and CMR end use distributions.

3.3.2 Scenario 2: High Conservation-Low Chlorinated Solvent Switch

The assumptions for the second scenario, "high conservation-low solvent switch" are:

- 10 percent of the chlorinated solvents consumption in metal vapor degreasing, cold cleaning, and electronics switches to methyl chloroform;
- the volume of CFC-113 used in metal vapor degreasing, cold cleaning, and electronics is reduced to 50 percent of 1986 levels. That is, if 100 units of CFC-113 were used in 1986 then only 50 units are used in 1998. Of these 50 units, 50 percent switches to MCF, i.e., 25 units of use switch to MCF;

o ⁷ Alternatively, if CFC-113 use is phased-out by 2000, it is assumed that MCF would account for 25 percent of the CFC-113 market in 1986. Thus, the amount of MCF that results from CFC-113 substitution in either case (a 50 percent reduction or a phaseout of CFC-113) is assumed to be the same.

- conservation practices in vapor degreasing, cold cleaning, and electronics reduce current methyl chloroform consumption immediately by 60 percent by the year 2000⁸;
- demand for methyl chloroform in coatings and inks grows at 13 percent annually⁹; and,
- demand growth (or decline) in the other industries that use methyl chloroform results from the combination of their market growth rates shown Exhibit 7 (i.e., their growth rates over the last five years) and the conservation measures and/or solvent switch assumptions described above.

This scenario indicates that growth in methyl chloroform demand could range from 1.3 percent to 2.4 percent resulting in total consumption of between 816 and 936 million pounds by 2000. Again, the low and high growth rate estimates correspond to HSIA and CMR end use distributions, respectively.

3.3.3 Scenario 3: Low Conservation-No Solvent Switch

As discussed in section 2.1 three factors will determine the growth in methyl chloroform demand through the year 2000: (1) increased use of conservation practices, (2) the market growth in industries that use methyl chloroform, and (3) regulatory restrictions on other solvents (other chlorinated solvents, CFC-113, and VOCs) and the resultant switch by users to methyl chloroform. This scenario is developed assuming that the growth in MCF demand is driven by only the first two factors described above, i.e., increased conservation practices and market growth, and no increase in MCF demand occurs as a result of solvent substitution. Thus the assumptions for this scenario are:

⁸ The percentage reduction associated with conservation practices is not applied to the amount of MCF implied in the previous bullet.

⁹ Based on industry projections of the growth of MCF demand in this end-use discussed below in section 3.4.5 (CMR 1987, Chemical Engineering 1987).

- conservation practices in vapor degreasing, cold cleaning, and electronics reduce current MCF consumption in these end-uses by 20 percent by the year 2000;
- demand for methyl chloroform in coatings and inks grows at 1 percent annually;
- demand growth (or decline) in the other industries that use methyl chloroform results from the combination of their market growth rates shown Exhibit 7 (i.e., their growth rates over the last five years) and the conservation measures described above; and,
- users do not switch from regulated solvents (i.e., CFC-113, other chlorinated solvents, and VOCs) to MCF.

Although this is an extremely conservative scenario, it is intended to show the residual demand for MCF in the event that users decided to continue using the current solvents when feasible or to replace them with alternatives other than MCF (e.g., aqueous cleaning, water-based adhesives and coatings, etc.). The results of this scenario indicate that MCF demand would still grow at 2.1 to 2.2 percent annually and reach 901 to 904 million pounds, based on HSIA and CMR use shares, respectively.

As shown in Exhibit 8, demand for methyl chloroform is expected to grow even in the most conservative scenario primarily because of the high market growth in the aerosols, adhesives, coatings and inks, and electronics end-uses. The demand for methyl chloroform in vapor degreasing and cold cleaning end-uses, which account for the largest proportion of use at present, are expected to have slow growth or even decline because increased use of conservation practices will offset increases in demand resulting from the substitution of chlorinated solvents and CFC-113.

3.4 Discussion of Demand in Specific End-Uses

Exhibit 9 shows a summary of the demand growth rates for MCF in its seven end-uses. These rates result from applying the conservation, market growth, and solvent substitution assumptions discussed under the three projection scenarios. The following sections review the use of methyl chloroform in each end-use and discuss in detail the demand growth rates presented in Exhibit 9.

3.4.1 Vapor Degreasing and Cold Cleaning in The Metal Cleaning Industry

Vapor degreasing and cold cleaning account for the largest use of methyl chloroform. High solvency, low heat of vaporization, non-flammability, and low toxicity make methyl chloroform a good solvent for removing organic compounds, such as grease and oil from the surface of metals or metal manufactured parts. Solvent cleaning is usually an essential part of the production process as it prepares parts for next operations, such as assembly, painting, coating, electroplating, machining, fabrication, packaging, and inspection. Solvent cleaning may be divided into two types: cold cleaning and vapor degreasing. Cold cleaning is usually accomplished by immersing, soaking, or spraying the metal parts with solvent that is at room temperature. Vapor degreasing is a process that uses hot solvent vapor to remove contaminants. The advantage of using vapor degreasing over cold cleaning is that in vapor degreasing the metal parts are always cleaned with pure solvent because it is in the vapor state, as opposed to cold cleaning where the parts are being cleaned with solvent that has been contaminated with organics removed from the metal parts.

EXHIBIT 9

GROWTH IN METHYL CHLOROFORM IN ITS SIX MAJOR END-USES

MCF End-Use	Demand Scenarios					
	Scenario 1 ^a		Scenario 2 ^b		Scenario 3 ^c	
	HSIA	CMR	HSIA	CMR	HSIA	CMR
	Use Shares:					
Metal Vapor Degreasing	1.3%	1.4%	-4.2%	-4.1%	0.3%	0.3%
Metal Cold Cleaning	0.8%	1.0%	-4.8%	-4.7%	0.3%	0.3%
Aerosols	9.5%	9.5%	9.5%	9.5%	6.0%	6.0%
Adhesives	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Electronics	9.4%	9.9%	4.8%	5.4%	6.9%	6.9%
Coatings and Inks ^d	13.0%	13.0%	13.0%	13.0%	1.0%	1.0%
Miscellaneous	3.2%	3.6%	-0.6%	0.4%	1.7%	1.7%

Source: ICF estimates.

^a Scenario 1: Low Conservation-High Chlorinated Solvent Switch

^b Scenario 2: High Conservation-Low Chlorinated Solvent Switch

^c Scenario 3: Low Conservation-No Solvent Switch

^d The growth rate estimates for coatings and inks are discussed in detail in section 3.4.5.

The future demand for methyl chloroform in this end-use will depend on three factors: (1) the extent of conservation measures that will be practiced by industry to reduce the use of methyl chloroform, (2) the market expansion (contraction) of these end-uses which will result in an increased (decreased) use of methyl chloroform, and (3) the increase in demand due to the substitution away from chlorinated solvents such as perchloroethylene, trichloroethylene, and methylene chloride and CFC-113. It is estimated that current regulatory actions on chlorinated solvents which impose stricter exposure limits may lead some chlorinated solvent users to switch to methyl chloroform instead of trying to control exposure. In addition, it is assumed that current restrictions imposed on CFC-113 use under the Montreal Protocol, will encourage some users of CFC-113 to switch to methyl chloroform. This is particularly true in the near-term in cases where current equipment allows for substitution among chlorinated solvents and would result in use of a lower ozone-depleting compound.

To determine the future growth in methyl chloroform demand three scenarios are used: "low conservation-high chlorinated solvent switch", "high conservation-low chlorinated solvent switch", and a conservative scenario of "low conservation-no solvent switch". In the first scenario it is assumed that 25 percent of the current use of chlorinated solvents (i.e., perchloroethylene, trichloroethylene, and methylene chloride¹⁰) in vapor degreasing and cold cleaning in the metal cleaning end use will be substituted

¹⁰ OSHA is in the process of promulgating a proposed rule that would considerably lower the permissible exposure level (500 ppm) for methylene chloride.

by methyl chloroform. This is based on the assumption that some users will switch to methyl chloroform instead of adopting better control measures to reduce exposures, whereas, other users would continue to use chlorinated solvents because MCF has the desired properties for a specific application or because equipment has been adapted to use MCF. It is estimated that 25 percent of the CFC-113 use, based on 1986 levels, will be substituted by methyl chloroform¹¹. In addition, it is estimated that conservation practices will reduce methyl chloroform use by 20 percent by the year 2000 and that the market will grow at an estimated annual growth rate of 2.1 percent, respectively (see Exhibit 7). This results in an annual growth rate of 1.3 percent and 0.8 percent for the vapor degreasing and cold cleaning end uses under the HSIA end use distribution, and a 1.4 percent and 1.0 percent annual growth rate under the CMR end use distribution.

The second scenario, "high conservation-low chlorinated solvent switch" is similar to the first scenario except that: (1) increased conservation practices reduce methyl chloroform consumption by 60 percent by 2000, (2) 10 percent of the current use of chlorinated solvents is substituted by methyl chloroform, and (3) 10 percent of the CFC-113 use, based on 1986 estimate, is substituted by methyl chloroform. As shown in Exhibit 9, this results in an annual growth rate of -4.2 percent and -4.8 percent for the vapor degreasing and cold cleaning end uses under the HSIA end use share estimates, and a -4.1

¹¹ As stated in an earlier footnote, this is based on the estimate that CFC-113 consumption in this end use will be reduced by 50 percent due to the Montreal Protocol, and 50 percent of this reduction will be accomplished by substitution to methyl chloroform. Alternatively, if CFC-113 use is phased-out by 2000, this would represent a 25 percent substitution of MCF for CFC-113 in this use.

percent and -4.7 percent annual growth rate under the CMR end use share assumptions. Finally, under the "low conservation-no solvent switch" scenario is similar to the scenario 1 except that MCF is not used to substitute other chlorinated solvents or CFC-113. It is implicitly assumed that users continue using the same solvents or switch to alternatives other than MCF. This scenario results in an annual growth rate of 0.3 percent for both, the vapor degreasing and cold cleaning end uses under both the HSIA and CMR end use share estimates. (Only one growth rate value results because market growth rate and conservation assumptions are the same for both end-uses).

3.4.2 Aerosols

Methyl chloroform is used in aerosol formulations as either an active ingredient or as a solvent of other active ingredients. Its main advantages with respect to other solvents are its non-flammability, the acceptability of its toxicity profile, and good solvency power. In automotive and industrial products, which include various aerosol automotive cleaners and degreasers, methyl chloroform acts as the active ingredient because it is the degreasing or cleaning agent of the formulation. In aerosol pesticides, methyl chloroform is used to dissolve the active ingredients (i.e., the insect toxicant) and to allow rapid evaporation of the product. In household products, methyl chloroform may act as a solvent of resin-based active ingredients (e.g., in spray shoe polishes and water repellents), or as the active ingredient of cleaning products (e.g., aerosol spot removers and leather/suede cleaners).

It is estimated that demand for methyl chloroform in the aerosols industry will increase at an annual rate of 10 percent over the next 12 years

(ICF 1989a, Aerosol Age 1989). Two factors contribute to this increased use of methyl chloroform: (1) the rapid market expansion of specific product categories where methyl chloroform is used, and (2) the switch from regulated chlorinated solvents (methylene chloride and perchloroethylene) to methyl chloroform given their similar non-flammability and solvency power. The aerosol industry's output has seen healthy growth since 1983. In particular, the combined output growth of household products, automotive and industrial products, and aerosol pesticides, which account for most of the methyl chloroform used in aerosols, has averaged 6 percent per year over the past 5 years (Aerosol Age 1989). In addition, increased regulatory restrictions due to health concerns on the use of perchloroethylene and methylene chloride in aerosols are likely to cause a switch from these solvents to methyl chloroform. Because of this substitution effect, it is estimated that consumption of methyl chloroform in aerosols will increase at an annual rate of 3.5 percent over the next 12 years¹².

Thus, the combined effect of these two factors -- market expansion and switch from other chlorinated solvents -- is estimated to result in a 9.5 percent annual growth of methyl chloroform demand in this use sector.

3.4.3 Adhesives

The main physical properties that make methyl chloroform a suitable solvent for adhesive applications are its non-flammability, good

¹² This growth rate is based on a calculated base-case consumption of 41 million kilograms and a projected consumption of 62 million kilograms in 12 years. The projection to 62 million kilograms is based on the assumption that methyl chloroform will substitute for methylene chloride and perchloroethylene in aerosol formulations to the maximum extent feasible (see Appendix B).

solvency power, and high evaporation rate. Methyl chloroform is used to formulate styrene butadiene rubber adhesives, neoprene contact adhesives, and natural rubber and urethane-based adhesives, among others. These adhesives are used in various construction and packaging applications, such as recreation turf installation, hardboard panelling, glued plywood floors, assembly of metal doors, installation of thermal sandwich panels, manufacture of pressure-sensitive tapes and labels, and consumer contact cements.

Various sources project substantial growth in the adhesives market over the next decade with estimates ranging from 5 to about 8 percent (Chemical Week 1988, Chemical Week 1987, C&EN 1989). As shown in Exhibit 7, the U.S. Department of Commerce projects the adhesive market to grow at 5 percent (U.S. Industrial Outlook 1989). In addition, growth in methyl chloroform use in the adhesives industry is fueled by the replacement of VOC solvents in applications such as laminating adhesives. Although the switch away from VOC solvents in certain sectors is leading to increase MCF demand, there is no basis for quantifying this increase. Considering the average growth prospects of the major market segments where methyl chloroform-based adhesives are used (i.e., 5 percent for construction and packaging markets (Chemical Week 1987)) and consistent with U.S. Department of Commerce estimates of overall market growth, it is estimated that methyl chloroform use will grow at an annual rate of 5 percent.

3.4.4 Electronics

Methyl chloroform is used in the electronics industry to remove solder flux from printed circuit assemblies, in the oxidation step during the fabrication of silicon wafers, in the dry photo resists process, and in the

degreasing step to clean silicon wafers in the initial wafer fabrication process. It is estimated that the demand for methyl chloroform in the electronics end-use will depend on the same three factors discussed in Section 2.1 (i.e., the extent of conservation, the switch from chlorinated solvents and CFC-113, and the market growth). The growth in methyl chloroform in this end use is estimated for the three scenarios discussed earlier. Except for an estimated 8.7 percent market growth (U.S. Industrial Outlook, 1989, see Exhibit 7), the assumptions used for electronics (e.g., concerning conservation and solvent switch) are similar to those for vapor degreasing and cold cleaning because of the similarity of MCF use in these end-uses.

This results in an annual growth rate in MCF demand of 9.4 percent and 9.9 percent for the low conservation-high chlorinated solvent switch scenario, and 4.8 percent and 5.4 percent annual growth rate for the high conservation-low chlorinated solvent switch scenario under the HSIA and CMR end use share estimates, respectively. Under the low conservation-no solvent switch scenario demand for MCF in the electronics industry grows at 6.9 percent annually.

3.4.5 Coatings and Inks

Methyl chloroform is used by manufacturers, printers, and users of protective and decorative coatings and inks. In coatings, methyl chloroform is used alone or combined with other solvents to solubilize the binding substance composed of resin systems such as, alkyd, acrylic, vinyl, polyurethane, silicone, and nitrocellulose resin. In addition to its non-VOC status and good solvency power, methyl chloroform is also used because of its

non-flammability and fast evaporation rate. These properties also make methyl chloroform a suitable thinner¹³ for spray coating applications. Inks are used to print items ranging from wallpaper to dog food bags to beverage bottles and cartons. Many of these applications involve the application of colored ink to a film (or laminate) in the flexible packaging industry. As for coatings, methyl chloroform is a desirable solvent for ink applications because of its non-VOC status, non-flammability, and fast evaporation rate.

Although the overall market for coatings and inks is projected to have a relatively slow growth (approximately 1 percent according to U.S. Industrial Outlook 1989), the current trends to replace VOC solvents from current formulations is estimated to result in a significant increase in methyl chloroform demand. According to CMR (1987), Dow Chemical has indicated that "1,1,1-trichloroethane [methyl chloroform] use in coatings and inks end uses has risen from 8 to 9 million pounds in 1983 to 45 million today (1987)". In addition, Chemical Engineering (1987) quotes a Dow Chemical representative indicating that continued growth is expected to reach "120 million pounds by 1990". This represents an average annual growth of 51 percent from 1983 to 1987 and a 39 percent increase from 1987 to 1990. Because this sudden growth is likely to level off over the next 12 years, it is assumed that one-third of the latter estimate or 13 percent will be the average growth in methyl chloroform use over the next 12 years. This 13 percent growth rate is used for the first two demand scenarios and the "low conservation-no solvent switch" scenario assumes that MCF demand in this end use grows at the industry

¹³ A thinner is used to reduce the viscosity of high-solid coatings.

growth rate of 1 percent (U.S. Industrial Outlook 1989), i.e., for the purposes of constructing an extremely conservative demand scenario it is assumed that no switch occurs from VOCs to MCF.

3.4.6 Fluorocarbon/Fluoropolymer Intermediates

Methyl chloroform serves as raw material for the manufacture of polyvinylidene fluoride fluoropolymer. It is also used as the precursor chemical for HCFC-141b and HCFC-142b. Because these captive uses result in little or no emissions of methyl chloroform, they are assumed to remain unrestricted and thus, they are not further discussed in this analysis.

3.4.7 Miscellaneous Uses

Methyl chloroform is used in relatively small quantities in a variety of industries including the dry cleaning (primarily for the formulation of spot removers and leather and suede cleaners), fabric protection, film cleaning, and extraction industries. The common practice in the dry cleaning industry is the use of perchloroethylene; however, it is conceivable that stricter worker exposure limits on perchloroethylene may induce users to either invest in tightening up perchloroethylene machines or to switch to methyl chloroform machines. A comparison of the cost of MCF dry cleaning machines with new perchloroethylene machines that comply with the new OSHA standards indicates that there is little incentive to switch to MCF because MCF machines cost 10 percent more than the new perchloroethylene equipment. In addition, the price of MCF (dry cleaning grade) is 86 percent higher than the price of the standard perchloroethylene used in dry cleaning (Dickowitz 1989). Hence, little to no-growth in MCF demand is expected in the dry cleaning industry.

In addition, Dow has indicated in its comments to the ANPRM that MCF may be used in the future to replace CFC-11 as an auxiliary blowing agent for flexible polyurethane foam until the industry develops a solventless process (Dow 1989). In most cases, methylene chloride is the only short-term option considered for this industry; however, regulations in several states limit its use (Dow 1989). The use of MCF in lieu of methylene chloride was successfully tested in June, 1989, by Dow Chemical's polyurethane flexible foam technology group. Dow indicates that "the use of 1,1,1 [MCF] as a temporary substitute for CFC-11 as an auxiliary blowing agent could lead to a slight temporary increase in 1,1,1 demand" (Dow 1989). In the most extreme case, i.e., a pound-for-pound substitution of MCF for 100% of the CFC-11 used -- the introduction of MCF as a blowing agent would only raise its demand by approximately 4.8 million pounds, or less than 1% of current U.S. demand.

Although limited information is available on the other miscellaneous uses, methyl chloroform use is likely to grow particularly in areas of the country where VOC limits are restrictive. For the purposes of this analysis, it is estimated that miscellaneous uses will grow at the average rate of the specified end-uses of methyl chloroform, i.e., at 3.2 to 3.6 percent¹⁴ every year for HSIA and CMR use shares, respectively.

3.5 Long Term Projections of Methyl Chloroform Demand

Demand projections for the period 2000 to 2075 are necessary for modelling the economic and environmental effect of potential controls on MCF.

¹⁴ Based on demand scenario 1. See Exhibit 4 for demand growth rates under the other two scenarios.

Demand for MCF from 2000 to 2050 is estimated to grow at 2.2 percent annually based on projected worldwide growth in overall economic activity. After 2050 MCF production is assumed to remain constant.

4. CONTROL OPTIONS BY END-USE

Exhibit 10 summarizes the specific control technologies used to model MCF reductions in the seven end-uses considered. This chapter describes the controls considered for each end-use and addresses public comments received in response to the ANPRM on MCF (54 FR 15230, April 17, 1989).

4.1 Vapor Degreasing and Cold Cleaning in the Metal Cleaning and Electronics Industries

4.1.1 Aqueous and Terpene Cleaning

Aqueous cleaning processes can be used to replace MCF based cleaning in the metal cleaning and electronics industries. Aqueous cleaning may be broadly defined as a cleaning process that uses water either alone or with chemical additives to clean parts in manufacturing and maintenance applications. In this definition, the word "parts" applies to any manufactured or partially manufactured object, from a screw to a fully assembled piece of complicated electronic machinery. Aqueous cleaning chemicals have a wide variety of formulations, but all of them are used with water as a cleaning medium. These chemicals are designed to clean inorganic and organic contaminants. Generally the cleaners consists of some type of alkaline salt, surfactant, and cleaning additives such as chelating and sequestering agents. Aqueous cleaning processes generally combine the cleaning action of a water-based cleaning solution with some type of mechanical or thermal cleaning action. The aqueous cleaning process consists of four major steps that include (1) cleaning, (2) rinsing, (3) drying, and (4) disposal (see Exhibit 11). Each of these steps is an important and integral part of an aqueous cleaning system.

EXHIBIT 10. Summary of Control Options for Methyl Chloroform

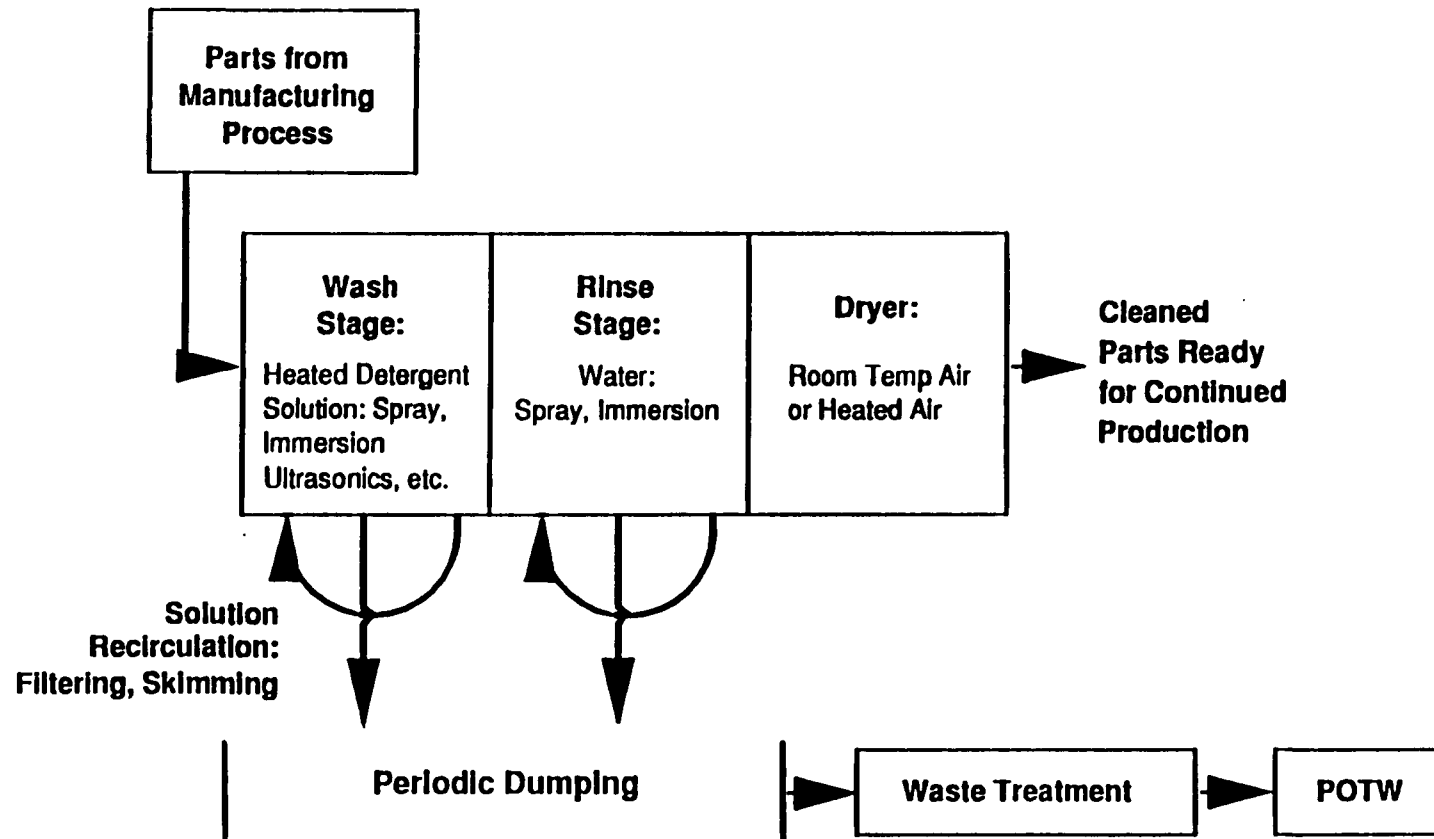
End Use	Control Option
Open Top and Conveyorized Vapor Degreasing	Aqueous and Terpene Cleaning* Engineering Controls and Recovery Practices** Alternative Chemical 1*** Alternative Chemical 2***
Cold Cleaning	Aqueous and Terpene Cleaning* Engineering Controls and Recovery Practices** Alternative Chemical 1*** Alternative Chemical 2***
Electronics	Aqueous and Terpene Cleaning* Engineering Controls and Recovery Practices** Alternative Chemical 1*** Alternative Chemical 2***
Aerosols	Reformulation to: Petroleum Distillates Water-based Systems Alternative Methods for: Consumer Uses Occupational Uses
Adhesives	Water-based systems Hot Melts Solvent Recovery Other Solvents
Coatings and Inks	Water-based Systems Solvent Recovery
Miscellaneous	Alternative Solvents

* Terpene cleaning is also a technically feasible option to reduce MCF use. Research on the costs of this option is underway by OAR.

** Includes housekeeping controls, solvent reclamation, carbon adsorption and drying tunnel, automatic covers, and other emission-reducing measures.

*** Alternative Chemical 1 and 2 represent future blends of organic chemicals (possibly HCFCs of low ODP or alcohols) for these end uses.

EXHIBIT 11
AQUEOUS CLEANING PROCESS



The cleaning process is defined by both the type of cleaning equipment and chemical cleaner used to carry out a cleaning job. Aqueous cleaning equipment may be grouped into two major categories: spray equipment and immersion equipment. In spray cleaning the parts are washed with a cleaning solution that is sprayed on to the parts at high pressure. In immersion cleaning, parts are immersed in the cleaning solution and the contaminants removed by some form of agitation. The wash stage in the aqueous cleaning process is based on a recycling design. The wash stage generally consists of a wash tank where the wash solution is stored. In an immersion type cleaner the parts are immersed in the wash tank and are cleaned by some form of agitation. After cleaning the parts are removed from the wash tank and soiled parts are immersed. In the case of spray washers the parts are placed in the wash tank and through the use of pumps the water in the wash tanks is sprayed onto the parts. The wash water is used for weeks and sometimes for months before being discharged. The amount of time the wash water can be repeatedly used depends on the cleaning process and the level of contaminants being removed. In metal cleaning applications, the wash tank is generally equipped with an oil skimmer that removes free floating oils. In addition, the wash water is filtered to remove suspended particles (e.g., metal chips) before being pumped to the spray nozzles. This cleaning step increases the lifetime of the wash water. In electronics cleaning the standards of cleanliness are high and therefore the wash water has to be discharged frequently¹.

¹ For the electronics industry, there are systems available which use filters to clean the wash water before returning the water to the cleaner. These systems are discussed below.

The rinsing step involves the washing of the cleaned parts with either clean water or water in which additives like rust preventive agents or brighteners have been added. The rinse step is performed either to remove any remaining contaminants or as a final finishing step. The equipment design for rinsing equipment is also similar to the wash stage (i.e., the rinse water is used for a certain period of time before being recycled or discharged). In the electronics industry, closed loop "zero discharge" recycling systems have been developed where the rinse and the wash water can continuously be recirculated without being discharged. Exhibit 12 shows a typical closed loop "zero-discharge" recycling system². The system continuously filters the rinse and the wash water to remove contaminants, thereby allowing continuous use of the water. In essence the system acts as a source of deionized water which further aids the cleaning process.

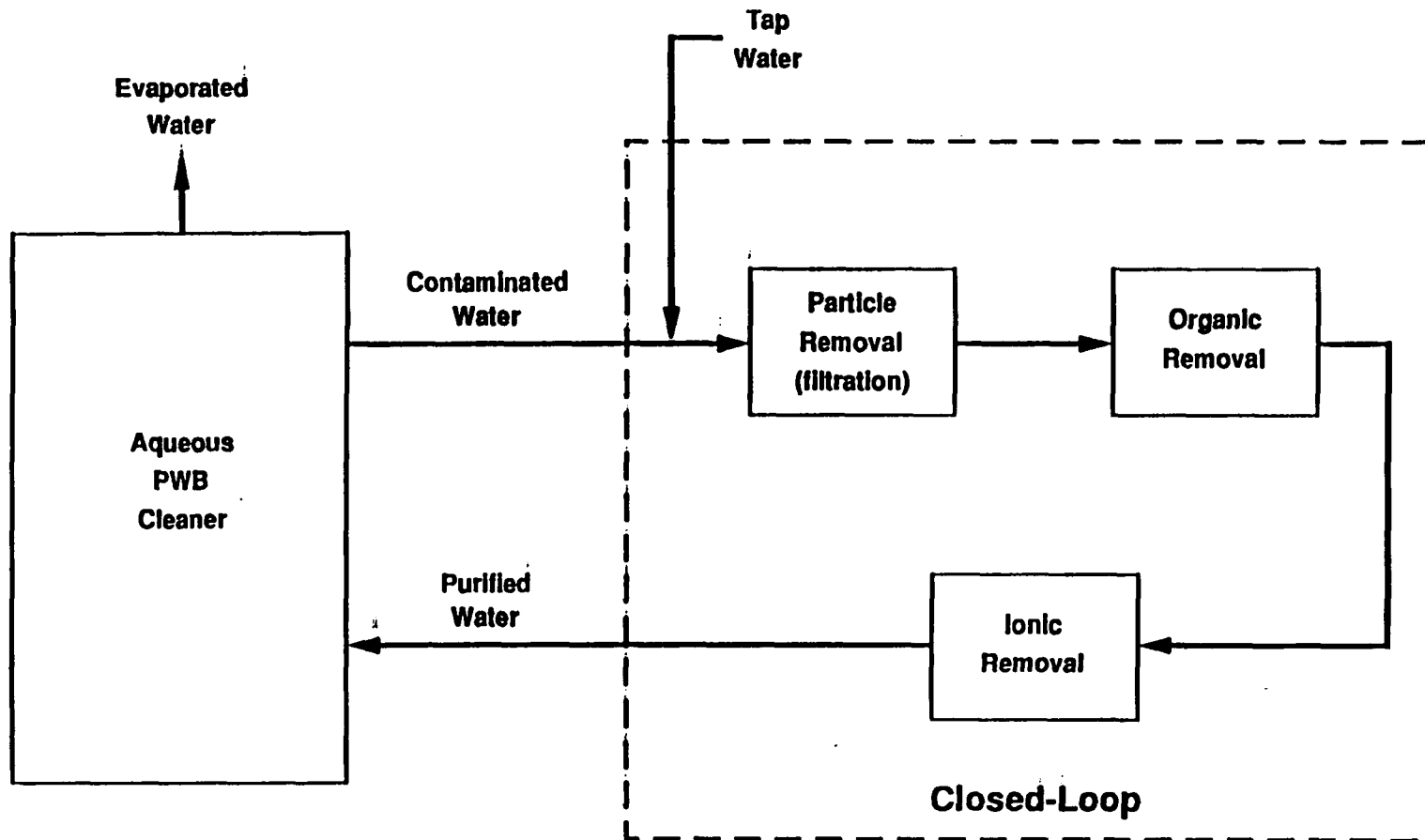
The drying step is performed after the rinsing step and its purpose is to dry the cleaned parts before the next manufacturing process step. Drying is carried out using a drying oven or an air knife. An air knife blows air at high pressure onto the parts. The air can be heated or at room temperature.

Proper disposal is important to the environmental acceptability of aqueous cleaning. The wastewater generated from aqueous cleaning processes

² The commercially available "zero-discharge" closed loop recycling system can only be used currently for aqueous processes used to remove water soluble fluxes in the electronics industry. These systems are not suitable to treat wastewater being discharged from rosin based soldering processes because the rosin material would use up the activated carbon and the ion-exchange resin at a high rate and thus the process would increase costs substantially. Research is underway to develop systems that can be used to treat wastewater from rosin based processes. Alternatively, expanded use of water-soluble rosins which are now commercially available, might reduce the need of wastewater treatment.

EXHIBIT 12

**ZERO DISCHARGE WATER RECYCLING SYSTEM
FOR THE ELECTRONICS INDUSTRY**



can contain pollutants like oil, grease, dissolved and suspended metals, organic, and is highly alkaline. Depending on the type and level of pollutants the wastewater may require treatment prior to disposal³. Exhibit 13 presents a conceptual design of a wastewater treatment process for treating wastewater generated in the metal cleaning industry. As discussed above systems are commercially available that can be used to treat wastewater discharged from aqueous processes in the electronics industry (see Exhibit 11). This might include pretreatment prior to discharge to the sewer or the hauling away of the wastewater by an authorized contractor.

Aqueous cleaning technology is commercially available and has successfully replaced the use of solvents in various operations, which include some of General Dynamics' vapor degreasing processes, the U.S. Air Force base (Vandenburg) metal parts cleaners (OAQPS 1989), and printed circuit board cleanup operations at GE (Waynesboro, VA), AT&T (Montgomery, IL) and Bose Corporation (Westborough, MA). Aqueous cleaning has been tested in various electronics applications and has proved effective for different soil types.

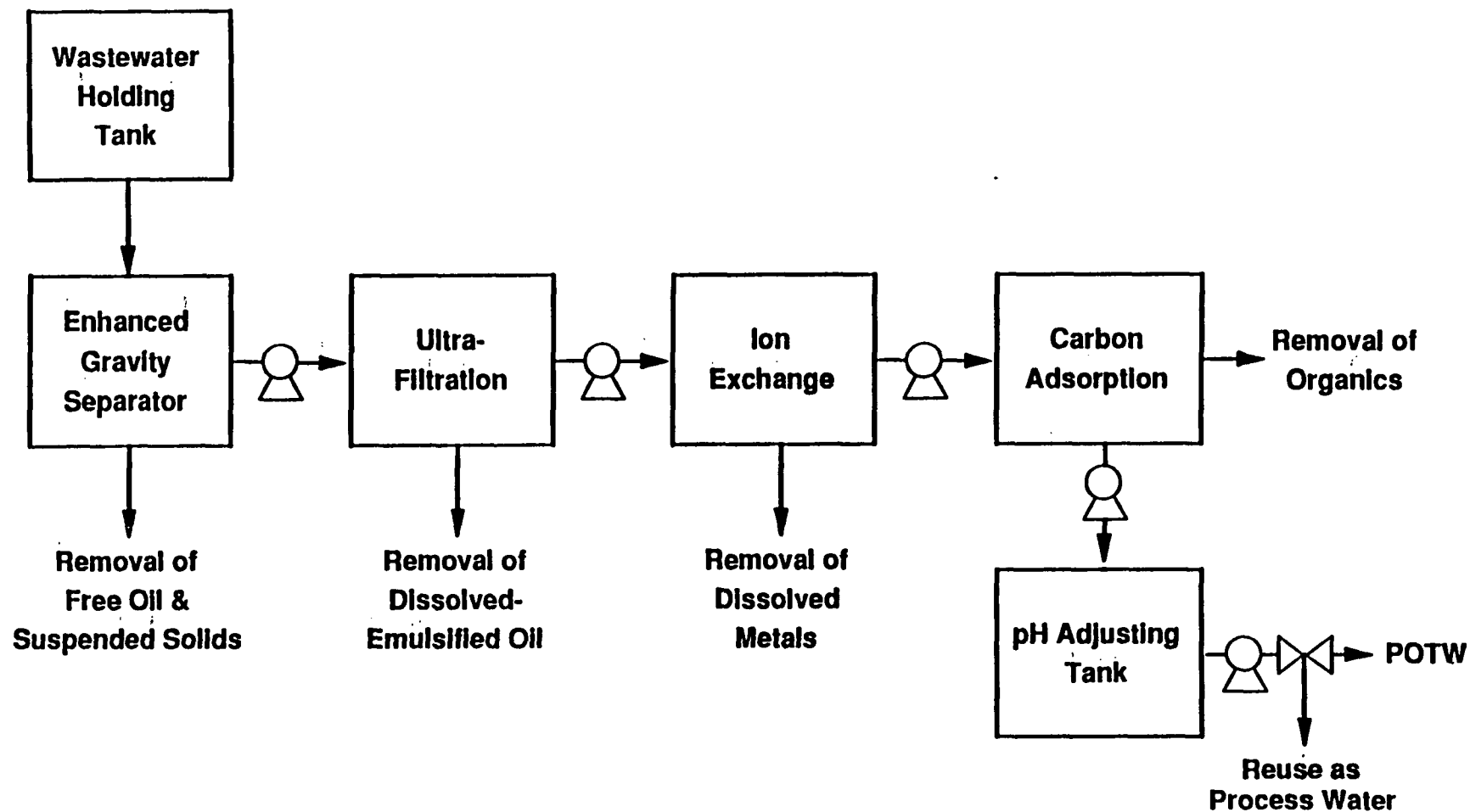
Terpenes are considered feasible alternatives to replace MCF use in the electronics and metal cleaning industries⁴. Terpenes are hydrocarbon based

³The pollutants that are present in aqueous cleaning wastewater are the contaminants present on the parts prior to being cleaned and the organic matter present in the cleaner formulation (e.g., surfactants). These contaminants might include grease/oil, metal fines, polishing and buffing compounds removed from parts in the metal cleaning industry or organic matter such as flux and metal fines from solder removed from printed circuit boards in the electronics industry.

⁴ This analysis presents a discussion of the technical feasibility of terpenes and subsequent revisions of this draft will include the costs associated with this control technology.

EXHIBIT 13

Semi-Continuous Wastewater Treatment Process for the Metal Cleaning Industry



solvents derived from natural sources. Natural solvent terpenes are found in nature and occur in nearly all living plants. The two most abundant sources of terpenes are turpentine and other essential oils. Terpenes are generally regarded as derivatives of isoprene (2-methyl-1,3-butadiene). Terpene cleaning is similar to aqueous based cleaning processes in that it is also a four step cleaning process: (1) washing, (2) rinsing, (3) drying, and (4) waste disposal. The wash stage consists of washing the components/parts with a terpene solution. The terpene solution used in the wash stage is generally used either in concentrated form (50 to 100 percent concentration) or in very diluted form (5 to 10 percent concentration). The concentrated form is used for cleaning purposes in the electronics industry and the diluted form is generally used in the metal cleaning industry. The rinse stage involves the rinsing of the components/parts with water. Both the wash and rinse stage used in terpene cleaning process are similar to those used in the aqueous process. Terpene cleaning machines under development are likely to be completely enclosed machines which will minimize worker exposure by reducing terpene emissions. Research is underway to develop equipment that can be used to recycle and treat waste generated from terpene cleaning processes.

Most commercially available terpenes have a flash point of between 100°F and 200°F, i.e., they are combustible. This concern is especially important when the a concentrated terpene solution is used. Equipment is currently available with an inert gas blanket to reduce the combustibility risk of using terpenes. At the present time inadequate data is available to fully examine issues regarding the toxicity and aquatic effects of terpene. Tests are being conducted to quantify the human health and ecotoxicity issues related to the

use of terpenes.

4.1.2 Engineering Controls

Engineering controls include a number of emission control devices or practices that may substantially reduce the use of methyl chloroform. Add-on engineering controls for vapor degreasers used in the electronics and metal cleaning industry include the use of automatic covers and hoists, increased freeboard ratio, freeboard refrigeration devices, and carbon adsorption systems and drying tunnels. For cold cleaning, the use of a cover, increased freeboard height, and proper drainage all contribute to the reduction of solvents emissions. Improved housekeeping can also eliminate waste and reduce overall solvent use. All of the above are established technologies and practices that can be implemented immediately.

4.1.3 Alternative Organic Solvents

Several alternative solvents are available and others are under development which can substitute for methyl chloroform. Some of the candidate substitutes include HCFC blends with weighted ODP ranging from 0.03 to 0.08 (e.g., HCFC-123 and HCFC-141b) and hydrocarbons such as 5-pentafluoro propanol (5FP), which is an alcohol that has had its hydrogen replaced with fluorine. In this analysis two substitute proprietary chemicals are considered. Alternative solvent 1 is assumed only to be used in new equipment. Alternative solvent 2 is assumed to be used in existing, as well as, new vapor degreasing and cold cleaning units. None of these solvents are currently available, but are likely to become available within the next 2 to 10 years. It is further assumed that the amount of alternative solvents 1 and 2 used in

new equipment would be one-half of the methyl chloroform use⁵ and that the amount of alternative solvent 2 used in existing equipment would be the same as the amount used for MCF.

4.1.4 Response to Public Comments

The majority of the public comments received on the substitutes for MCF in metal cleaning and electronics cleaning focused on aqueous cleaning in the following specific areas:

- aqueous cleaning equipment requires much more energy than solvent cleaning;
- aqueous cleaning consumes large amounts of water, and generates large volumes of wastewater which is expensive to treat;
- aqueous cleaning equipment requires increased floor space as compared to solvent systems;
- aqueous cleaning causes corrosion and leaves residues; and
- aqueous cleaning cannot be used to remove contaminants like buffing compounds and carbon black.

Energy consumption of aqueous cleaning system varies from being less than solvent cleaning to four times that of a solvent based systems. The energy consumption of an aqueous cleaning process depends upon: (1) the state of technology used, (2) the number of cleaning stages used, and (3) the type of equipment configuration used. Newer equipment, both batch and in-line, being installed today is more energy efficient than solvent cleaning equipment (Gengler 1989). In particular, this applies to aqueous cleaning systems that are based on the closed loop recycling principle. The continuous filtering

⁵ This is based on communications with industry sources indicating that these solvents require one half of the amount of CFC-113 used in these applications (Ruckriegel 1989). This analysis assumes that MCF and CFC-113 are used in the same amounts.

and reusing of the wastewater generated from the wash and rinse stage, reduces the amount of energy needed to heat the water used in these cleaning steps compared to a once-through system. In a once-through system the rinse and wash water after use is discharged and fresh water is then heated to the operating temperature. By avoiding the heat required to raise the temperature of the water from room temperature to the process operating temperature the energy consumption of the aqueous cleaning system is reduced significantly.

The number of cleaning stages depends on the cleaning requirement. For example, for low degree of cleanliness (maintenance applications) most systems generally consists only of one stage - the wash stage, whereas, for high degree of cleanliness, systems generally consists of a wash and a rinse stage. The addition of a drying stage is required when the part being cleaned is to be worked on in the subsequent process step immediately and is required to be dry. Thus for cleaning applications (e.g., maintenance cleaning) where only a wash stage is required energy consumption is generally equivalent to solvent based processes, whereas, for cleaning processes that require all three stages (i.e., wash, rinse, and drying) energy consumption can be greater than solvent based processes.

In addition, the cleaning process also depends upon the type of equipment configuration used. Aqueous cleaning equipment generally consists of (1) batch, (2) semi-batch, and in-line cleaners. Batch and semi-batch are used for low volume cleaning and maintenance applications, whereas, in-line cleaners are used for high volume cleaning (e.g., in large manufacturing facilities). Generally in-line cleaners consume more energy than batch and semi-batch cleaners because of the high volume of water used and the number of

cleaning stages.

Aqueous cleaning equipment with water recycling capabilities is currently available on the market and is typically used in the metal cleaning industry. The wash and rinse water from the aqueous cleaner is stored in holding tanks within the aqueous cleaning unit. Filters and oil skimmers are attached to the holding tanks to remove particulate matter and free floating oil. The use of these filters allows water to be reused, thus increasing the lifetime of the wash and rinse water. In most applications the wash and rinse water of an aqueous cleaner equipped with recycling capabilities are used for a period varying from one week to 6 months depending on the cleaning process. After the end of such period the wash and rinse water is pretreated and discharged to the sewer, or shipped off-site for treatment.

Aqueous cleaning equipment available for use in the electronics industry can have a closed loop "zero-discharge system" attached to the aqueous cleaning process. The addition of the closed loop recycle system filters (treats) the wastewater discharged from the wash and the rinse stage and recycles it to the equipment. Thus, no wastewater is generated from closed loop aqueous processes used in the electronics industry.

The floor space used by an aqueous cleaning system depends upon the equipment configuration used. Batch systems generally take up the same amount of space as solvent machines. On the other hand, in-line aqueous cleaning machines generally take up the same amount to more space than solvent based machines. This is because of the increased number of stages used (i.e., wash, rinse, and drying stages). A large communications company has recently brought on line an aqueous cleaning in-line system where the wastewater is

recycled after filtration. The space requirements are similar to solvent cleaning in-line systems.

Parts cleaned via aqueous cleaning are prevented from rusting by (1) the application of rust preventive agents during the rinsing steps, especially if the parts are not going to be dried, or (2) by drying the parts after cleaning thus removing any excess water that might cause rusting.

Aqueous cleaning processes with the proper choice of equipment configuration and cleaner type can be used to remove all types of contaminants that solvent based cleaning removes. For example, the use of ultrasonics, the use of increased number of wash and rinse stages, and the use of spray systems instead of immersion type systems can be used to effectively remove a wide variety of contaminants.

Public comments on the use of terpenes centered on the following points:

- terpenes are flammable;
- terpenes have raised toxicity concerns; and
- terpenes evaporate slowly and leave residue on parts.

Terpenes are flammable when used in concentrated form. However, in most applications in the metal cleaning industry terpene cleaners are used in a diluted form (e.g., 5-10 percent terpene solution in water), thus reducing the flammability concern. In the electronics industry where terpenes are used in a concentrated form (50-100 percent solution in water), specially designed equipment is available that uses an inert atmosphere blanket to prevent the presence of air or oxygen, thus reducing the flammability concern. Additional toxicity tests are underway to further quantify the health and environmental effects of using terpenes. Equipment currently being designed and tested for

terpene cleaning is completely closed, thereby minimizing worker exposure by eliminating terpene emissions. Research is currently being conducted to develop equipment that can be used to recycle and treat waste generated from terpene cleaning processes.

Terpenes evaporate slowly and that is why the terpene cleaning processes use a rinse and a drying step after the wash stage. The terpene residues are removed by rinsing the parts with water and then drying the parts to remove excess amounts of water and any terpene that is left over after the rinse step.

4.2 Adhesives

An adhesive is any substance, inorganic or organic, natural or synthetic, that is capable of bonding by surface attachment. Adhesives are used to bind similar and dissimilar materials, such as glass, plastic, rubber, wood, or metal. Adhesives are used in various industries, such as construction, transportation, and packaging; the range of final products that use adhesives includes structures for home construction, automobiles, aircraft, furniture, labels, tapes, and paper bags. In many manufacturing processes, adhesives are applied using spraying technology, brushes or rollers. Methyl chloroform is used in adhesive applications because it dissolves many resins (the binding substance used in adhesives) and is non-flammable. Recently, demand for MCF in adhesives has increased in certain areas of the country (e.g., particularly California) because it is exempt from VOC regulations that limit the use of the traditional solvents used in the adhesives industry (e.g., toluene, hexane, MEK); thus, MCF has been used to replace VOC solvents.

Among the binding substances (resins) that use MCF are styrene-butadiene rubber, neoprene, natural rubber, and rubber cement. The end-use applications include construction, packaging, consumer, and automobile adhesives. The use of MCF may be reduced or eliminated by the use of alternatives such as water-based and hot melt adhesives, and by the use of solvent recovery systems.

4.2.1 Water-based Adhesives

Water-based adhesives use water, in lieu of organic solvents, as the primary solvent. A water-based adhesive can be a solution, a latex, or an emulsion. Solutions are made from materials that are soluble in water alone or in alkaline water. Most natural adhesives are water solutions. Latexes are stable dispersions of solid polymeric material in an essentially aqueous medium. An emulsion is a stable dispersion of immiscible liquids. Emulsions usually appear milky white liquid and dry to a clear film. Latex adhesives are more likely to replace solvent-based adhesives than solution adhesives because their synthetic binders provide more versatility and higher performance (ICF 1989a). However, latexes require more extensive formulation because they are produced from polymers that were not designed for use as adhesives. For instance, most rubbers are used to manufacture durable products like tires.

The binding substances that are candidates for water-borne adhesives are natural binding substances including natural rubber; synthetic elastomers such as SBR, neoprene, and isoprene; vinyl resins like polyvinyl acetate (PVAc) and polyvinyl chloride (PVC); acrylics; and epoxies (ICF 1989a). Some of these binding substances require additional formulation and additives such as emulsifiers, surfactants, or additional resins. Water-based adhesives are

commercially available and are used in various applications, such as the manufacture of automobiles, and tapes and labels.

Water-based adhesives may prove to be cheaper than solvent-based systems primarily because (1) no major equipment changes are required to use these new adhesives, and (2) water-based adhesives are cheaper per pound of dry adhesive pound.

4.2.2 Hot-melt Adhesives

A hot melt adhesive is applied in a molten state and forms a bond upon cooling to a solid state. Hot melts are primarily 100 percent solids thermoplastic bonding materials which achieve a solid state and resultant strength upon cooling. The major applications of hot melt adhesives are bookbinding, packaging, textiles, and product assembly including construction glazing and automotive door panel and carpet installation. The binding substances that provide the foundation for hot melt adhesives are (ICF 1989a): ethylene vinyl acetate and other polyolefin resins; polyamide (or nylon) and polyester resins; polyester/amide resin alloys; and thermoplastic elastomers.

Hot melts have several advantages. Because no solvents are used in hot melts, they reduce air pollution. The hot melt equipment saves space and energy (ICF 1989a). Using hot melt technology allows automation, lowering manufacturing costs and increasing productivity. With hot melts, the 100 percent solids shipments eliminates the excess freight costs involved in storing and shipping either water- or solvent-based adhesives. Hot melts can be applied faster and more efficiently than water or solvent-borne adhesives because there is no delay for evaporation. Hot melts are inherently water resistant. Hot melt pressure sensitive adhesives require far less energy to

process than any other adhesive types and some of these adhesives now compete with water-based acrylics in outdoor applications. They have been used on paper labels for indoor applications since 1978. Hot melt acrylic pressure sensitive adhesives require relatively low capital investment since no oven capacity is needed (ICF 1989a).

Hot melt adhesives have certain characteristics that may limit their performance in certain use conditions. They have poor specific adhesion to a number of substrates. In particular, performance problems with hot melt adhesives include material creep under load over time and at high temperatures, limited strength, and limited heat resistance. Hot melt adhesives offer lower operating costs (lower energy and space requirements) for new facilities that can install the relatively inexpensive hot melt application equipment.

4.2.3 Solvent Recovery

Add-on controls can be used to reduce MCF emissions from manufacturing plants using MCF-based adhesives (e.g., to produce packaging and tapes). These existing facilities can also reduce methyl chloroform use by installing solvent recovery systems such as carbon adsorption systems. In a carbon adsorption system exhaust air flows through a carbon bed where the solvent is separated from the effluent and adsorbed onto a surface of carbon particles. The carbon bed is regenerated for reuse by flushing it with steam. Smaller units can use replaceable carbon beds which can be regenerated offsite. The steam and the solvent are then condensed and separated in liquid form. The water may require additional stripping of residual solvent. The residual solvent can be reclaimed.

4.2.4 Response to Public Comments

Public comments on the use of MCF in adhesives were in the following areas:

- MCF is the only VOC compliant solvent left to industry primarily in California's South Coast Air Quality Management District (SCAQMD).
- MCF is used for adhesive consumer application because of its non-flammability.
- wood flooring adhesives requires the use of MCF because water-based adhesives cause wood to warp.

California's SCAQMD proposed Rule 1168 early this year to control VOC emissions from adhesive applications and included a number of control technologies to reduce VOC emissions including the use exempt solvents, such as MCF. There is also a range of solventless options proposed that may be used including hot melt adhesives, reactive liquids (two non-solvent liquids reacting upon contact and forming an uniform bond), anaerobic adhesives (solventless liquids curing by the exclusion of oxygen), oxygen-cured adhesives (cured by oxidation), and "UV" cured adhesives (cured by a crosslinking reaction initiated by UV light). Where solvent use is preferred because of key performance reasons, high solids alternatives or solvent recovery devices can significantly reduce emissions. Although the feasibility of these technologies should be evaluated on a case-by-case basis, it is believed that the range of options is wide and should permit the elimination or minimization of MCF use in the short to mid-term.

Methyl chloroform's non-flammability is a desirable property for consumer adhesive applications (e.g., contact cement); however, flammable consumer products do exist for similar end uses (e.g., sealants, aerosol

coatings, etc.) and for many other uses (e.g., paint thinners, cosmetic products, etc). The fire hazard can be mitigated with adequate product labeling as required by the Consumer Product Safety Commission.

Water-based adhesives have satisfactory performance for wood parquet bonding if the wood parquet uses a synthetic backing. The synthetic backing prevents water from getting in contact with the wood and thus minimizes wood expansion. Wood parquet with synthetic backing is available, it may however be more expensive than standard parquet.

4.3 Aerosols

Aerosol packaging is a popular method for storing and dispensing consumer and industrial products ranging from insecticides to hair sprays. Approximately 84,000 different brand names of aerosol products are estimated to exist in the U.S. marketplace (ICF 1989a). A total production volume of 2.9 billion units is estimated for 1988 (Aerosol Age 1989).

In an aerosol package, the contents are stored under pressure in a metal container and dispensed in a controlled manner by the activation of a valve. Once expelled from the can, a combination of the propellant used, orifice shape, and composition of the product determines the form in which the product is delivered. This can range from a fine mist (the most common) to a liquid stream to a foamy lather. In general, the ingredients of an aerosol are the active ingredient, the solvent or carrier, and the propellant. The active ingredient is responsible for the effectiveness of the product, e.g., the compound that allows a cleaner to clean; the solvent or carrier solubilizes all ingredients in the formulation; and, the propellant expels the contents from the can. Generally, methyl chloroform functions as either an active

ingredient or as a solvent in aerosol formulations.

Methyl chloroform functions as the active ingredient as well as the carrier in various aerosol products, e.g., degreasers and cleaners. It is generally difficult to substitute this solvent in these applications because few non-chlorinated solvents have the desired properties. In comparison with non-chlorinated solvents, for example, methyl chloroform's higher solvency and its non-flammability make it an excellent solvent for aerosol applications. Methyl chloroform's high density adds to container weight while its high stability translates to a long shelf life. Other properties that make methyl chloroform especially well-suited for aerosol applications are its high evaporation rate and its ability to generate a spray of small particle size. Quick evaporation allows methyl chloroform to deliver the active ingredient efficiently and small particle size results in a good spray pattern.

Two groups of control technologies considered for the reduction of MCF use in aerosol products: (1) the reformulation of aerosols to petroleum distillates or to water-based systems and (2) a switch to alternative methods that eliminate the need for the aerosol delivery system.

4.3.1 Reformulation to Petroleum Distillates

Reformulation from methyl chloroform to petroleum distillates can be done in various automotive products such as, tire cleaners, lubricants, spray undercoatings, and in household products such as, water repellents/shoe waterproofers, glass frostings, and insecticides.

4.3.2 Reformulation to Water-based Systems

Reformulation from methyl chloroform to water-based systems can be performed in certain shoe polishes and foggers (partial or total release

insecticides used to control infested rooms).

4.3.3 Alternative Delivery Systems

Methyl chloroform use in aerosols can also be reduced if alternative methods that eliminate the use of the aerosol delivery system in occupational and consumer uses are adopted. Two examples of these alternative methods include the substitution of aerosol brake cleaners used in repair shops with a manual "wet-brush" (recirculating liquid) systems, and the substitution of aerosol spot removers with increased use of professional dry cleaning services. Although more examples of alternative non-aerosol methods can be found for the other aerosol products that currently use MCF, the cost data presented in the Chapter 5 uses these two applications as examples.

4.3.4 Response to Public Comments

Most comments on the use of MCF in aerosols concentrated on the following areas:

- MCF's fast evaporation in wasp and hornet sprays has a knockdown effect.
- MCF is non-flammable and its use provides an extra margin for consumer safety. The fire hazard is more significant for products designed to clean electric motors and appliances.
- In air insecticides and room foggers, MCF helps penetration of insects' exoskeleton while water-based formulae bead up and choice of active ingredients is limited.

The knockdown effect of aerosol insecticides is really a chilling effect that results from the fast evaporation of the solvent. If MCF is replaced with a solvent of relatively low boiling (or similar to MCF's boiling point) the same knockdown effect will be obtained. If MCF is replaced with water-based systems, chemical additives in the toxicant blend known as synergists or

knockdown-agent (e.g., pyrethrin) can be added to the formulation to achieve similar effects (Aerosol Age 1987). McLaughlin Gormley King, a leading supplier of insecticide active ingredients indicates that although the knockdown effect obtained with these insecticide synergists is not as quick as that obtained with solvent-based formulae, the results are satisfactory for homeowner purposes (Aerosol Age 1987).

Consumer safety has been a major concern of the aerosol industry ever since non essential uses of fully halogenated chlorofluorocarbons (CFCs) were replaced with flammable hydrocarbon propellants. The industry reformulated the vast majority of aerosol products resulting in most cases in flammable aerosol products. For example, aerosol hair sprays contain more than 95 percent flammable materials (ethanol and isobutane) and many spray paints contain more than 90 percent flammable solvents and propellants. These products have warning labels with the precautionary measures that should be taken for safe use. Flammable consumer products are already available and the fire risk associated with the reformulation from MCF to flammable materials can be mitigated if product labels and consumer education programs are implemented. In addition, the use of MCF in an aerosol formulation does not necessarily mean that the product will be non-flammable because the typical propellants used are flammable (e.g., propane and isobutane).

Industry sources confirmed that an organic solvent is needed in insecticides to aid the penetration of the waxy insect exoskeleton; however, MCF is not the only solvent that can be used (Rogosheske 1989). Mineral spirits and petroleum distillates are also effective for this use in either solvent-based or water-based systems. (These solvents may be emulsified in

water-based systems). A wider range of active ingredients for water-based systems has recently become available (Rogosheske 1989). An increased number of active ingredients can now be dissolved using emulsifiers and low concentration of organic solvents.

4.4 Coatings and Inks

According to CMR (1987), 48 percent of the U.S. coatings market in 1986 was based on solvent-based formulations. Alternate technologies include waterborne coatings with 12 percent, high solids with 11.5 percent, two part-systems with 12 percent, emulsions with 10 percent, powder coatings 6 percent, and radiation cured coatings with 1.5 percent of the market, respectively. In addition, there are solvent recovery and alternative low-emissions coating application methods to the use of spray coating, such as dipping, flow, and curtain coating.

4.4.1 Water-based Coatings and Inks

Water-borne coatings contain water in lieu of conventional solvents. They are applied using methods similar to those used for high-solid coatings. Recent advances in technology have improved the dry-time, durability, stability, adhesion, and application of water-borne coatings (Fitzwater 1986). Primary uses of these coatings include furniture, electronics in automobiles, aluminum siding, hardboard, metal containers, appliances, structured steel, and heavy equipment. In some water-borne coatings, standard solvents are added to aid application, but even these contain much less solvent than conventional coatings, since the primary solvent is water (Johnson 1987).

Water-based inks for flexographic and rotogravure laminations have

been successfully developed that overcome technical hurdles such as substrate wetting, adhesion, color stability, and productivity. Solvent borne inks have good wetting properties because of the low surface tension of solvents. The high surface tension of water requires the use of co-solvents to lower the surface tension to enable the wetting of treated surfaces. 80 parts by volume of water can be combined with 20 parts by volume of alcohol and ethyl acetate to achieve an effective surface tension. The ability of the water-based ink to adhere to the film can be enhanced by treating the film through accepted methods such as use of primers or heat (Podhany 1988). It is estimated that 55 percent of the flexographic inks and 15 percent the gravure inks used in the U.S. in 1987 were water-based. Continued growth of aqueous inks has been projected by various industry sources (Weiss 1988, Argent 1985).

4.4.2 High-solid Coatings

High-solid coatings resemble conventional solvent coatings in appearance and use; however, high-solid coatings contain less solvent and a greater percentage of resin. Many methods are used to apply high-solid coatings, including dipping, flow coating, conventional air and airless atomizing, air and airless electrostatic spraying, rotating disks and bells, rolling, continuous coating, centrifugal coating, and tumbling. High-solid coatings are currently used for appliances, metal furniture, and farm and road construction equipment. Because of the refinement of application technology and the addition of flow control agents and thinners, high-solid coatings offer superior finish quality, yet require much less solvent than standard coatings (Clark 1987).

4.4.3 Powder Coatings

Powder coatings contain only the resin in powder form, and thus have no solvent. They are applied using fluidized beds, electrostatic spray, and electrostatic fluidized beds. Typically, the object coated is heated above the powder's melting point, so that the resin fuses into a continuous film. The resin then hardens, either at the heated temperature or as the object cools, to form a finish with superior durability and corrosion resistance (Jarosh 1985). While powder coatings were first used only for electrical transformer covers, they have expanded in use to include underground pipes, electrical components, concrete reinforcing bars, appliances, automobiles, farm and lawn equipment, lighting fixtures, aluminum extrusions, steel shelving, and some furniture. (Farrell 1987).

4.4.4 Solvent Recovery

Goods are printed or coated with solvent-based coatings and inks in a continuous process. Once the coating or ink has been applied, the product is passed through a drying step where the solvent is eliminated by evaporation. Solvent recovery systems such as carbon adsorption systems can be used to capture these solvent emissions.

4.4.5 Response to Public Comments

Most of the public comments received on the use of MCF in coatings and inks centered in the following areas:

- poor performance of water-based coatings, particularly under changing weather conditions for road striping/marketing applications;
- MCF is needed to meet VOC limits; water-based alternatives are corrosive and other alternatives requiring curing cannot be used due to the sensitivity of aluminum structures;

- MCF is the last compliant solvent available to industry in the SCAQMD; change to water-based or other alternatives will be expensive (equipment changes).

Although waterborne traffic paints work well in many states, they have caused problems in certain areas of the country (e.g., two California counties), because poor adhesion and durability in cold, wet weather. In such climates, where waterborne coatings are rendered impractical, there are other, low-VOC alternatives that should be considered, most notably thermoplastics. Thermoplastics are solids that typically contain a resin, pigments, calcium carbonate filler, and glass beads. They are melted and sprayed at about 450°F. Thermoplastics provide superior wet/dry night visibility and durability, yet emit virtually zero VOCs (EPA 1988). During wet weather, the substrate upon which the coatings are applied must be artificially dried with heated air. This is a relatively inexpensive process, according to the California Department of Transportation (Warnes 1989). Once applied, the durability is satisfactory even under severe weather conditions.

Since application requires special support equipment, the initial capital costs for thermoplastic painting are 25 percent higher than for solvent borne painting. However, thermoplastic markings last four to nine times longer than solvent borne markings. Thus, the same amount of road maintenance would require fewer hours worked, fewer salaried employees, fewer hours of traffic control and clogged highways. The annual operating savings, which would amount to 43 percent, would pay for the cost of new equipment within ten years (EPA 1988). Thermoplastics do have the disadvantages of (1) a slower, more complicated application process, and (2) reduced durability on portland cement concrete. These problems must be weighed against the cost

effectiveness and high performance of thermoplastics.

Further public comments indicate that, in the aerospace industry, heat-cured coatings (e.g., powder coatings) may be impossible to apply without damaging the aircraft parts, and that other alternative coatings (e.g., high-solid and water-borne coatings) will not meet military specifications for durability or adhesion. Heat cured processes cannot be used to coat an assembled aircraft, but can be used to coat all detailed parts, which account for 75 percent of total painting (Toepke 1989). Several alternatives to MCF-based coatings now meet military specifications. For the primer used on all painted surfaces, water-borne coatings meet military specs for all military aircraft, except the SR-71 and some F-15s, which account for less than 10 percent of total military aircraft produced. For these two models, and for the topcoats used on exterior surfaces, high-solid coatings exist that meet military specifications. Furthermore, with the present research underway, water-borne and high-solid coatings may soon be able to meet radar evasion requirements for stealth aircraft (Toepke 1989).

Some concerns have been voiced that control options for MCF in this area may not be financially feasible. In the case of water-borne, high-solid, and powder coatings, capital costs may be 20-27 percent lower than for solvent-based coatings (see Exhibit 22 in Chapter 5) (PCI 1989). Moreover, these control options may provide savings of up to 40% in annual operating costs (PCI 1989).

4.5 Miscellaneous Uses

Methyl chloroform is used in miscellaneous industries such as dry cleaning, fabric protection, and film cleaning. The possibility of increased

use of MCF in dry cleaning resulting from increased limits on the use perchloroethylene use was analyzed. In January 1989 the Occupational Safety and Health Administration (OSHA) published a final rule amending its existing Air Contaminants standard (54 FR 2332). In the final rule, the permissible exposure limit (PEL) of perchloroethylene is reduced to 25 ppm. Perchloroethylene is also a VOC and emission restrictions may lead some users to consider alternative dry cleaning solvents. Currently methyl chloroform is used extensively as a dry cleaning solvent in both Europe and Japan with limited usage in the United States. Some industry sources indicate in their comments to the ANPRM that MCF is used primarily to clean suede and leather. A study by the International Fabricare Institute (1988), however, indicates that MCF's properties are similar to perchloroethylene's and that MCF can be readily used in all application areas. MCF dry cleaning equipment requires the use of stainless steel and costs 10 percent more than new perchloroethylene equipment capable of meeting the 25 ppm exposure level⁶ (Dickowitz 1989). In addition, MCF (dry cleaning grade) is 86 percent more expensive than perchloroethylene. This cost disadvantage and the availability of cheaper perchloroethylene machines that meet the new exposure levels is likely to limit the growth of MCF demand in the dry cleaning industry. This is supported by industry sources who believe that the dry cleaning industry, which in the past resisted change from petroleum-based solvents to perchloroethylene (Collins 1989, Dickowitz 1989), would opt to continue using

⁶ Based on the costs of two comparable machines: \$53,250 for the MCF machine and \$48,250 for the perchloroethylene machines (Dickowitz 1989). The costs of the solvents were quoted at \$7.90 (MCF) and \$4.25 (perchloroethylene) per gallon (Collins 1989).

perchloroethylene instead of the more expensive and less familiar MCF.

Other public comments on miscellaneous uses of MCF included:

- use of MCF in specialized lubricants used in mold releases and because of non-flammability, volatility, and compatibility with other ingredients, non-VOC; water has low volatility and solvency.
- non-aerosol consumer products (stainless steel cleaners, spot removers, general purpose degreasing products).

Methyl chloroform is used as a diluent in specialized lubricants.

Specialized lubricants containing methyl chloroform are used in mold release agents (Kidd 1989). An industry source, reported that methylene chloride is the predominant solvent used in mold release agents at their company (Van der Graf 1989). Research and testing is currently underway on water-based mold release agents and it is likely that a water-based mold release agent will be available in the near future (Zasachy 1989).

The use of MCF in non-aerosol certain consumer products may be reduced if alternative solvents are used. In many cases, these solvent will be flammable; however, adequate labelling and consumer education programs could be used to reduce fire risks. Consumer currently use extremely flammable materials such paint thinners and aerosol products containing flammable solvents and propellants; thus, the same precautions already taken for these products could be taken for the products mentioned above. For some products, the flammability risk may be too high, e.g., spot removers usually applied to fabrics. In such cases, professional services (perchloroethylene based-dry cleaning in this case) are available which will achieve the same results. The costs of professional services may substantially higher than the costs of the products sold directly to consumers.

5. APPROACH FOR ESTIMATING COSTS OF CONTROLLING MCF PRODUCTION

This chapter describes the analytical methods used to estimate the costs to society due to restrictions on MCF production. The economic rationale underlying this analysis is based on the framework described in EPA's Regulatory Impact Analysis (EPA 1988) that assessed the costs associated with regulating the production of CFCs. Because potential regulation of MCF will restrict its supply and possibly increase its price, an important step in estimating social costs is assessing the costs borne by affected industries. The costs associated with various controls determine potential industry responses to regulations on MCF. A detailed description of the underlying economic framework is not discussed here,¹ but essentially consists of estimating social costs based on the changes in consumer and producer surplus caused by proposed regulations on MCF production. Thus, a major component of this approach is characterizing the markets that use MCF and, in particular, estimating the demand schedules for MCF, i.e., the amount of MCF that would be demanded by each industry (or end-use) at higher prices. The costs of the options that firms adopt in response to increased MCF prices define the derived demand schedules for MCF. A model (referred to as the "MCF Cost Model" in the remainder of this chapter) was developed to estimate the timing and costs of MCF reductions. The remainder of this chapter is divided into three sections. Section 5.1 discusses the methodology used to evaluate the adoption of controls over time and describes the input data for the model.

¹ For a detailed discussion of this subject see Appendix I: Framework and Method for Estimating Costs of Reducing the Use of Ozone-Depleting Compounds in the U.S., Regulatory Impact Analysis: Protection of Stratospheric Ozone, Volume II, Part 1, OAR, EPA. August 1, 1988.

Section 5.2 describes the operation of the model and Section 5.3 describes the interpretation of the results (social costs and transfer payments). Section 5.4 presents a detailed discussion of the costs of individual controls potentially available for implementation in each end-use. A more detailed presentation of the data is contained in an earlier document (ICF 1989a).

5.1 Methodology Used to Evaluate the Adoption of Controls

This section describes the methodology used to simulate the adoption of controls over time and the total costs of controlling MCF production in the U.S. Section 5.1.1 describes the input data used in the MCF Cost Model. Section 5.1.2 provides step-by-step description of the manner in which these input data are used in the model.

5.1.1 Input Data

The operation of the MCF Cost Model requires a set of input data that includes:

- baseline MCF demand, i.e., the estimated consumption of MCF from 1989 to the year 2000 assuming that no controls are imposed,
- the reduction schedule, i.e., the timing of MCF reductions over time,
- distribution of MCF consumption by end-use,
- market penetration and use-reduction potential of each control option, and
- costs of each control option,

The baseline MCF demand is a projection of the amount of MCF (in kilograms) that would be used in the U.S. from 1989 to the year 2000 if no controls are imposed. Two important considerations are incorporated into the calculation of baseline MCF production. First, the baseline excludes eight

percent of the total MCF demand because this amount is used as a chemical intermediate and is assumed to remain uncontrolled over time. Second, a base year is established to define a reference amount of MCF that can be used as the basis to calculate reduction percentages for each future year. This analysis uses two alternative base years, 1986 and 1988; thus, two baseline demand schedules are used to estimate costs.

The reduction schedule defines the target percent reduction of MCF production with respect to the base year over the period of analysis. The reduction schedules modeled include a freeze at 1986 (or 1988) production levels, and a phase-out by the year 2000. In the freeze scenario production remains constant at 1986 (or 1988) production after 1989. In the phase-out scenario production is frozen to 1986 (or 1988) levels from 1989 to 1994, reduced by fifty percent of 1986 (or 1988) levels from 1995 to 1999, and phased out in the year 2000.

The distribution of MCF by end use is important because it defines the level of reduction that can be achieved by the various industries using MCF. The distribution by end-use proposed by CMR (1989) and presented in Chapter 2 is used in the model. Because the MCF used as a chemical intermediate is not included in this analysis, the distribution by end use is normalized to exclude this eight percent of total demand.

The market penetration and use reduction potential for each control option are key inputs because they determine the level of MCF reductions that can be achieved in a given year. The market penetration rate is defined for each end use separately and takes into account the following factors:

- starting date: the year in which a control is first available for adoption;
- penetration time: the amount of time for a control option to be evaluated by industry and adopted by firms for whom it would be cost-effective;
- use reduction: the amount of MCF that can be reduced by the implementation of a control;
- applicability to new and/or existing equipment: defines whether a control option can be applied to both new and existing equipment or only to new equipment;
- market penetration: the portion of the market that is captured by a control option in a given year.

Exhibit 14 presents the data corresponding to the first four factors for each of the control options considered. For example, "Alternative Solvent 2" is simulated to become available in 1992, takes 6 years to reach its maximum penetration of 80 percent², and is applicable to new and existing equipment. Exhibit 14 also shows the use reduction, i.e., the amount of MCF that can be reduced by the implementation of any given control relative to the amount used in the base case situation for each end use. For example, "Alternative Solvent 2" mentioned earlier eliminates completely the use of MCF and thus, the use reduction rate is 100 percent. Recovery and recycling options reduce between 40 to 55 percent of MCF use.

The market penetration for each control option varies over the simulation period. Initially, engineering controls and other conservation and recycling technologies are readily available and take a large proportion of the market; subsequently, alternative chemicals replace these technologies as

² The market here refers to the market for particular end-uses (e.g., cold cleaning, vapor degreasing, etc.).

Exhibit 14. MCF Controls and Data Used to Estimate Their Implementation

End-Use	Control	Start Year	Years to Reach Maximum Penetration	Use Reduction	Applicable to New (N) or to New and Existing (N/E) Equipment
Conveyorized Vapor Degreasing	Aqueous Cleaning	1989	3	100.0%	N
	Alternative Solvent 1	1992	3	100.0%	N
	Alternative Solvent 2	1992	6	100.0%	N/E
	Engineering Controls	1989	1	55.0%	N/E
Open Top Vapor Degreasing	Aqueous Cleaning	1989	3	100.0%	N
	Alternative Solvent 1	1992	3	100.0%	N
	Alternative Solvent 2	1992	6	100.0%	N/E
	Engineering Controls	1989	1	53.0%	N/E
Cold Cleaning	Aqueous Cleaning	1989	3	100.0%	N
	Alternative Solvent 1	1992	3	100.0%	N
	Alternative Solvent 2	1992	6	100.0%	N/E
	Engineering Controls	1989	1	51.0%	N/E
Aerosols	Petroleum Distillates	1989	2	100.0%	N/E
	Water-based Systems	1989	3	100.0%	N/E
	Alternative Delivery Systems				
	- Occupational Uses	1990	5	100.0%	N
	- Consumer Uses	1989	1	100.0%	N
Adhesives	Water-based	1990	2	100.0%	N/E
	Hot Melts	1990	3	100.0%	N/E
	Solvent Recovery	1989	2	40.0%	N/E
Coatings & Inks	Water-based Ink	1990	2	100.0%	N/E
	Water-based Coating	1989	1	100.0%	N/E
	High-solids	1989	2	100.0%	N/E
	Powder coating	1989	2	100.0%	N
	Solvent Recovery	1989	2	40.0%	N/E
Miscellaneous	Other Solvents	1989	2	100.0%	N/E

Note: For illustrative purposes, the controls shown in this Exhibit have been regrouped into 7 controls in Exhibit 15.
The controls in Exhibit 15 were grouped as follows:

- (a) considering aqueous cleaning systems for conveyorized vapor degreasing, open top vapor degreasing and cold cleaning as a single control,
- (b) grouping together Alternative Solvents 1 and 2 in the above end uses (which represent HCFCs and alcohol-based cleaning solvents),
- (c) grouping together engineering controls and all other conservation or recycling technologies,
- (d) specifying that petroleum distillates for aerosols and "other solvents" for miscellaneous uses refer to non-chlorinated solvents,
- (e) grouping together water-based systems for aerosols, adhesives, and coatings and inks,
- (f) grouping alternative delivery systems for occupational and consumer aerosols,
- (g) grouping high solids and powder coatings, and hot melt adhesives as "Other Technologies".

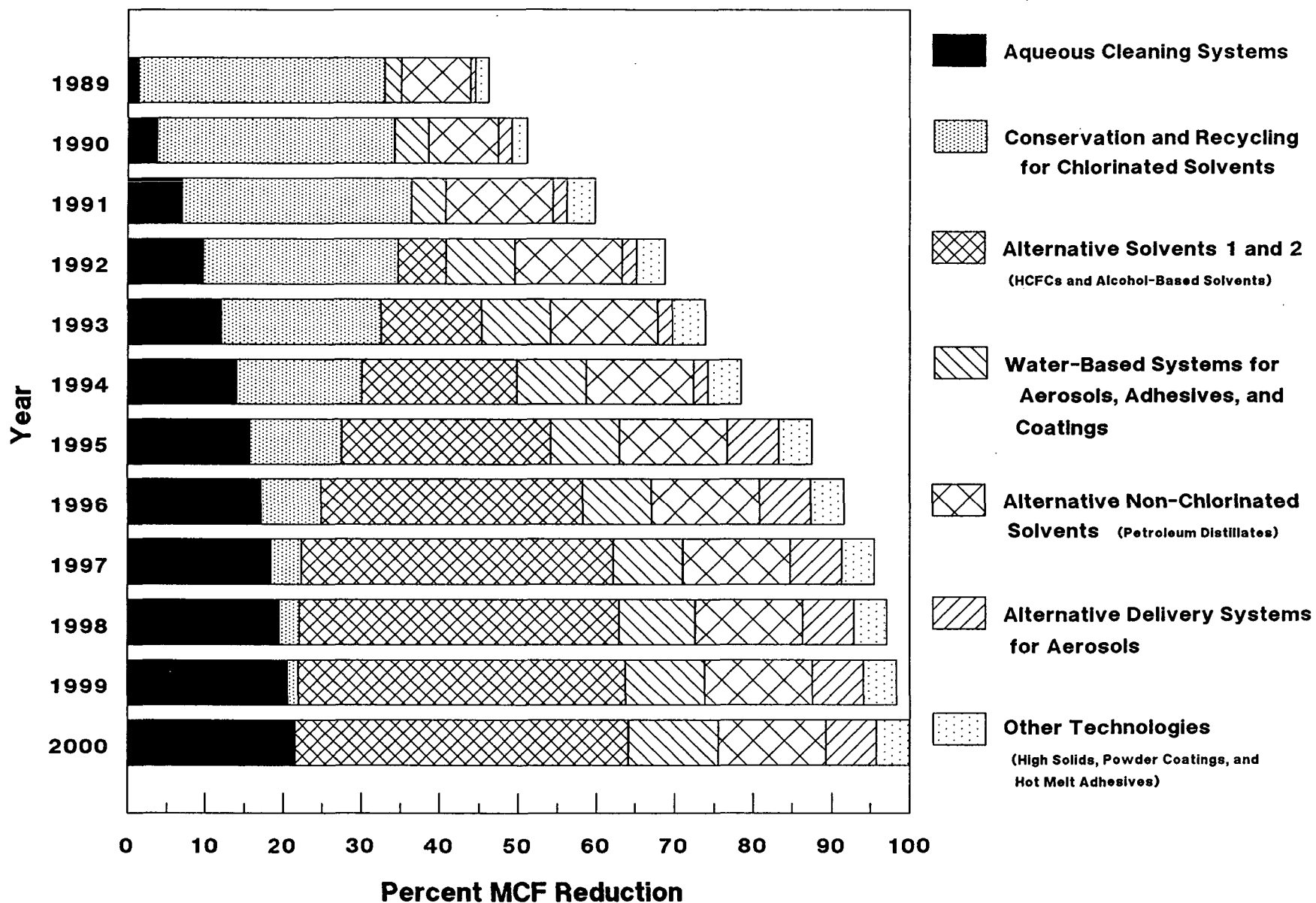
greater reductions are required. To calculate market penetration, a distinction is made in the model between control options that cannot be applied to existing MCF manufacturing equipment and control options that can be used in existing MCF equipment. For example, in the baseline there is an existing stock of vapor degreasing and cold cleaning equipment and this stock grows as new MCF equipment is purchased every year. Some controls such as aqueous cleaning and "Alternative Solvent 1" require new equipment specifically designed for these substitutes and, thus, these options can only compete in the "replacement" market. A firm that has used a vapor degreasing machine for its estimated useful life is likely to replace the unit with a new machine using an alternative cleaning solvent (or an aqueous cleaner) if the costs of MCF and/or MCF-using equipment are higher. The market penetration for aqueous cleaning and "Alternative Solvent 1" are therefore limited by the number of new machines added every year.³ For this reason the market shares for aqueous cleaning and Alternative Solvent 1 grow gradually.

The market penetration rates and the use reduction rates are converted to percentage reduction of total methyl chloroform use that can be achieved by each control option annually from 1989 to 2000. Exhibit 15 shows the maximum penetration possible of the controls in terms of reductions of MCF use that can be achieved by their implementation⁴. Exhibit 15 also shows the gradual introduction of water-based adhesives, coatings & inks, and aerosols.

³ For other end-uses this is not applicable. For example, it is assumed that aerosol products manufacturing equipment can be directed to the production of other non-MCF containing aerosols.

⁴ The actual controls selected in any given year depend on the phaseout/freeze schedule selected.

Exhibit 15. Maximum MCF Reduction Possible Due to Controls*



* Note: The actual controls selected in any year depend on the phase-out/freeze schedule specified. This exhibit does not show the actual controls selected, instead it shows the maximum MCF reduction if all available controls are used.

Social and private annualized costs of the control options were estimated from the capital and operating costs data discussed in section 5.4. The social costs are evaluated using pre-tax costs discounted at a social discount rate of two percent. Private costs are evaluated using after-tax costs using a private after tax discount rate of six percent. The costs are expressed in terms of dollars per kilogram of MCF avoided and are computed by dividing the annualized cost estimate for any control by the amount of MCF that is avoided by implementing the same control. The specific cost data for the controls in each end-use are discussed in section 5.4.

In summary, input data for the model that computes the costs of reducing MCF costs consists of: (a) baseline MCF demand (in million kg) for the years 1989 to 2000, (b) a series of control options to reduce MCF use (c) the level of total reduction achievable by each control option from 1989 to the year 2000, and (d) the social and private costs per kilogram of MCF reduced by each control option.

5.1.2 Model Operation

The input data described above is used to compute total social costs and transfer payments⁵ associated with the reductions imposed by a freeze or a phase-out of MCF production. To compute these costs, the model performs the following steps:

1. **Compute target production and associated reductions:** based on the baseline demand and reduction schedule compute the desired level of use (in million kilograms) and reductions (in percent relative to the baseline) for each year (1989-2000).

⁵ The significance of social costs and transfer payments is discussed in detail in section 5.3.

2. **Generate the derived demand curve for MCF:** sort the control options and associated annual use reductions by ascending private costs. This establishes the order in which controls will be selected in step 4.
3. **Compute cumulative reductions:** add use-reductions for each control moving down in the ordered list to show the total reductions that would be achieved at each price level.
4. **Select the set of controls that meet the target consumption:** for each year compare the target reduction with the cumulative reductions achievable by a set of controls; consider the next control if the target is not met or stop if the target is achieved.
5. **Compute social costs and transfer payments:** for each year multiply the absolute value of reductions (in kilograms) by the social and private cost per kilogram for the last control option in the selected set (i.e., the option with the highest private cost per kg of MCF reduced).
6. **Discount the stream of social costs and transfer payments:** use two percent for social costs and six percent for private costs and discount costs over a 10 year period.

5.2 Significance of Social Costs and Transfer Payments

The results of this analysis are presented in terms of social costs and transfer payments. Each type of action undertaken by industry to reduce methyl chloroform use may increase the resources required to produce or consume the same amount of goods and services. A product switch may increase the resources required because consumers might pay more for a different product than they were paying previously for the methyl chloroform-based product. A switch in production methods or the use of a substitute chemical similarly may increase the resources required to produce the same product. The manufacturer will, of course, pass as much of these increased production costs as possible to consumers depending on market conditions.

For this analysis, the increase in resources necessary to produce the

same amount of goods and services is termed a social cost. Other analyses often use the equivalent term "real resource cost". Social costs measure the extent to which society as a whole is poorer due to regulation.

Social costs can take different forms: capital costs (including costs of purchasing new capital to replace capital retired due to a phase out), one-time costs (e.g., product reformulations or industry retooling), operating costs, and energy costs. For example, electronics firms cleaning printed circuit boards may experience increased capital costs if they must purchase aqueous cleaning equipment to replace solvent cleaners that use MCF. Energy costs could increase if less energy efficient cleaning processes were adopted as a result of a phase-out. Finally, operating costs could increase if more expensive chemicals were substituted for methyl chloroform. If less expensive materials are substituted, costs could decline.

The costs of a potential regulation on a commodity are not all resource or social costs. For example, if a tax increases the price of the commodity, consumers pay more for the commodity, but more resources are not required to produce the product.⁶ The tax only transfers money from consumers to the government. Similarly, if the supply of a commodity is restricted by government regulation or by a monopolist, consumers will have to pay more for the commodity but again no additional resources (machinery, labor, raw materials, etc.) will be needed to manufacture the commodity. If the price rises, it provides extra profit -- that is, money is transferred from consumers to producers, but no additional resources are used.

⁶ For simplicity, this discussion assumes that the tax does not decrease the amount of this commodity purchased by consumers.

Economists distinguish such transfer payments from real resource or social costs. The distinction is important because if a regulation increases the social costs of production, society as a whole is worse off. However, a regulation that induces transfer payments but not resource costs makes some parties in society worse off, but other parties better off by an equal amount. Therefore, society as a whole is neither worse off or better off.

To calculate the social costs and transfer payments associated with a freeze and phase-out of methyl chloroform use, the potential set of control actions is sorted from lowest to highest private cost per kilogram of reduction to determine the order in which each action would be taken. Given any required level of total methyl chloroform reduction, the list defines the increase in methyl chloroform price (the "trigger price") necessary to initiate a given control. Implicitly, MCF users are assumed to compare the trigger prices of the controls and the current price for methyl chloroform as restrictions on the supply of this chemical are imposed. If the trigger price for a control is less than the methyl chloroform price increase in a given year, then the control is assumed to be implemented. If two or more control options for a given end use had costs below the trigger price, then the options that meet the target emissions reduction are implemented. If two control options have equal private costs, the option with lower social costs is assumed to be implemented first.

In the phase out scenario, the price per kilogram of methyl chloroform reduced is undefined in the year 2000 because methyl chloroform is no longer available. At this juncture, it is assumed that firms using methyl chloroform will choose the controls that minimize cost while meeting the requirements of

the phase out. In this analysis, firms are assumed to select controls that completely phase out methyl chloroform and have the lowest cost per kilogram of reduction. These controls must also meet all the interim methyl chloroform reductions mandated prior to the complete phase out. Social costs and transfer payments are then estimated based on the cost per kilogram of methyl chloroform reduction associated with the selected control options. It is important to remember that the cost per kilogram of methyl chloroform reduction is estimated on an annual basis. As a result, this price may vary each year depending on the timing of the implementation of different controls selected.

5.3 Costs for Individual Controls in each End-Use

5.3.1 Methodology for Vapor Degreasing and Cold Cleaning

The approach used in this analysis to develop the costs of reducing the use of MCF in vapor degreasing and cold cleaning is based on a comparison of total costs for a base case and for the control options. This approach shows the current actual costs of MCF use in vapor degreasing and cold cleaning and permits a direct comparison of actual costs across options. A general description of the elements used to develop the cost data follows.

Definition of Base Case Costs. The base case costs are defined as the current average costs of using MCF according to the operating characteristics of average or "model" vapor degreasing and cold cleaning units. The definition of these average units is based on a detailed analysis of the types of equipment available and the amount of solvent consumed (ICF 1988b). In addition, it is assumed that these average units currently operate with no additional controls except those provided with the standard equipment. The

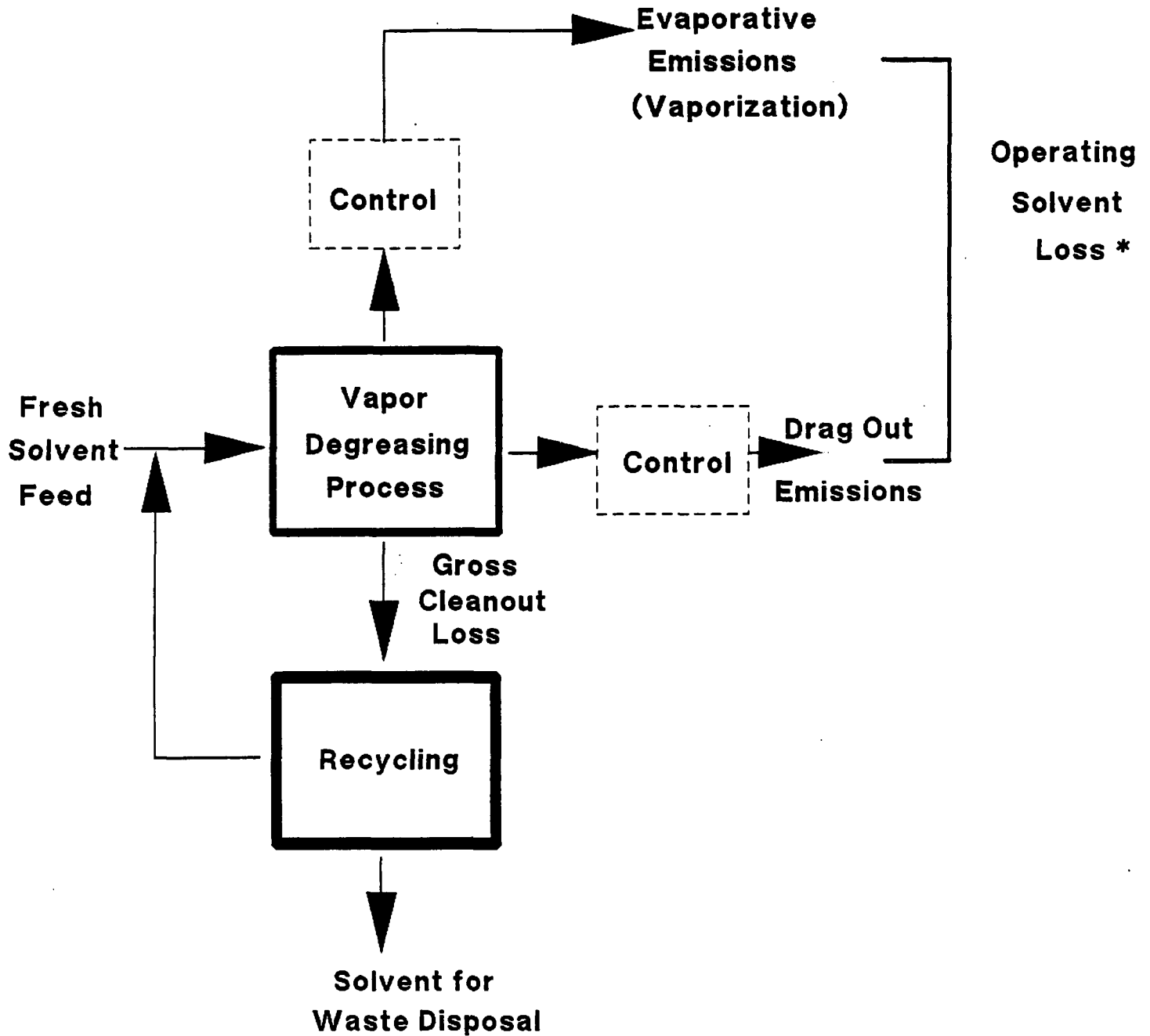
base case thus defines the costs associated with the current practice which include the capital and operating costs. Operating costs include the costs of solvent, electricity, and waste disposal. Labor costs are not included in the operating costs because they are estimated to remain unchanged across control options.

An important parameter in estimating the amount of solvent consumed in the base case vapor degreasing and cold cleaning units is based on the amount of solvent consumed and/or lost during the operation of these units. This amount is determined by performing a mass balance on the vapor degreasing and cold cleaning units. Exhibit 16 shows a schematic of the solvent material balance in a vapor degreasing unit⁷. As depicted in the schematic, the major losses from an uncontrolled vapor degreaser result from evaporative emissions, drag out emissions, clean out losses, and downtime losses. Evaporative emissions result from the vaporization of solvent during the operation of the vapor degreaser; drag out emissions result from the solvent being carried over by the parts that are being cleaned; clean out losses occur when the contents (i.e., the solvent contaminated with metal fines, grease, and other contaminants removed from the cleaned parts) of the vapor degreasing unit are drained out and distilled (recycled) to purify the solvent. The bottoms from the still that remain after distillation (recycling) represent the clean out losses; and downtime losses resulting from emissions when the unit is not in operation. Each of these emissions and/or losses are determined for the base

⁷The solvent material balance schematic for a conveyORIZED vapor degreasing, open top vapor degreasing, and cold cleaning unit is identical to this one.

EXHIBIT 16

SOLVENT MATERIALS BALANCE IN VAPOR DEGREASING



* This excludes downtime solvent loss which is assumed to be two percent of the other losses (i.e. operating and cleanout losses).

case and are in turn used to quantify the amount of solvent used. The solvent consumption in a solvent cleaning machine thus consists of virgin solvent and recycled solvent. The virgin solvent is assumed to replace the solvent losses due to evaporation, down time, drag out, and waste disposal.

In this analysis it is assumed that the gross clean out losses from a solvent cleaning machine are recycled. The recycling can be carried out in-house or off-site. If the solvent were recycled in-house then the analysis would have to consider the capital investment for the still and the operating costs associated with the use of the still. However, in this analysis the recycling is carried out off-site. Thus, in order to compensate for the estimated capital and operating costs of carrying out in-house recycling the costs of off-site recycled solvent is assumed to be 20 percent less than the costs of virgin solvent (i.e., \$0.71 per Kg for recycled solvent versus \$0.89 per kg) (Ruckriegel 1989).

Incremental Costs of Controls. The costs of the control options are developed to estimate the total costs associated with the use of the control technology. Capital costs include the costs of new equipment needed for the implementation of the control option. Annual operating costs include raw material costs (solvent for MCF and detergent for aqueous cleaning), water, electricity, and waste treatment or disposal costs. As stated earlier, labor costs are not included because they are estimated to remain unchanged across control options.

5.3.2 Cost Data for ConveyORIZED Vapor Degreasing

Base Case Costs. As shown in Exhibit 17, it is estimated that the average conveyORIZED vapor degreaser assumed for this analysis consumes raw

EXHIBIT 17 COSTS OF CONTROLS FOR METHYL CHLOROFORM IN CONVEYORIZED VAPOR DEGREASING

	(1) Capital Cost	Annual Operating Costs				(6) Total Operating Costs
		(2) Raw Material (Detergent/Solvent)	(3) Water	(4) Electricity	(5) Waste Treatment or Disposal	
Base Case: MCF	93,555	69,814 (a)	Napp (a1)	6,078 (b)	3,135	79,027
Control Option		Incremental Costs (Savings) (c)				
Aqueous Cleaning (d)	6,408 (e)	(68,613)(f)	2 (g)	6,759 (h)	2,865 (i)	(58,987)
Engineering Controls (j)	54,000	(33,535)(k)	2,020 (l)	447 (m)	0	(31,068)
Alternative Solvent 1 (n)	23,388 (o)	62,154 (p)	Napp	0 (q)	(1,567)(r)	60,587
Alternative Solvent 2 (s)	20,000 (t)	194,123 (u)	Napp	0 (q)	0 (v)	194,123

Notes:

- (1) Cost of new equipment as estimated by industry sources. All costs reflect 1988 dollars.
- (2) For the Base Case, raw material costs refer to the cost of solvent (virgin and recycled). For aqueous cleaning, raw material costs include the costs of detergent (ICF 1988b).
- (3) Assumes the cost of water is \$0.0006 per gallon (ICF 1989a).
- (4) Electricity costs are computed multiplying the number of kilowatt-hr consumed times the costs of a kilowatt-hour. Annual costs are based on 2000 hrs and electricity costs of \$0.0487/kwh.
- (5) Costs of disposal of MCF and alternative solvents are estimated at \$0.84 per kg. For aqueous cleaning disposal costs are based on contract hauling costs of \$3/gallon.
- (6) = (2) + (3) + (4) + (5)

Sources:

- (a) An average conveyORIZED vapor degreaser consumes 66,534 Kg of virgin solvent and 14,928 Kg of recycled solvent in a year (ICF 1988b). It is assumed that the price of virgin solvent is \$0.89 and that of recycled solvent is \$0.71/Kg. Recycling is carried out off-site and the cost of recycling off-site is comparable to the cost of in-house recycling. In-house recycling would require capital investment for a still and operating costs associated with operating the still. The virgin solvent is used to replace the operating solvent loss (i.e., evaporative loss, drag out loss, down time loss, and waste disposal loss).
- (a1) It is assumed that water costs are negligible (ICF 1988b)
- (b) Based on electricity costs for heating the solvent, the work load, and compensation for heat loss due to radiation (ICF 1988b).
- (c) Incremental costs (savings) indicate the difference in costs between the control options and the base case.
- (d) Aqueous cleaning costs are based on the the assumption that a typical conveyORIZED spray washers would be needed to replace a typical conveyORIZED vapor degreaser (ICF 1989a).
- (e) The capital costs include the costs of aqueous cleaning equipment (i.e., wash tanks, rinse tanks, air knife and dryer) and installation costs (ICF 1989a).
- (f) Raw materials costs are based on the costs of detergent (ICF 1989a).
- (g) Water costs are based on an annual water consumption of 2000 gallons at a cost of \$0.0006 per gallon (ICF 1989a).
- (h) Electricity costs are based on a consumption of 132 kwh. This is based on energy consumption of the aqueous cleaning and drying equipment (ICF 1989a).
- (i) Waste disposal costs are based on an annual waste disposal of 2000 gallons at a cost of \$3 per gallon (ICF 1989a).
- (j) Based on a combination of improved housekeeping practices and carbon adsorption control technologies.
- (k) It is assumed that the engineering control reduces solvent loss by 60 percent (i.e., drag out, downtime, and evaporative losses) (OAQPS 1989).
- (l) Represents the cost of steam used to regenerate the activated carbon (OAQPS, 1989).
- (m) Assumes that a 6 hp fan is used for the activated carbon system (OAQPS 1989).
- (n) Represents an HCFC blend used in new equipment (Ruckriegel 1989).
- (o) It is assumed that the new solvent equipment is 25 percent more expensive than the base case. (Ruckriegel 1989).
- (p) It is assumed that compared to the old machines the new machines consumes one-half the amount of solvent. It is further assumed that the solvent (virgin & recycled) cost 20 percent more than CFC-113 (\$2.70/Kg) (i.e., \$3.24 per Kg) (Ruckriegel 1989)
- (q) It is assumed that the energy requirements are similar (Ruckriegel 1989)
- (r) Based on the assumption that the new equipment uses one-half the amount of solvent used in the base case.
- (s) Alternative solvent 2 is assumed to be similar to alternative solvent 1.
- (t) To use alternative solvent 2 the existing equipment has to be retrofitted.
- (u) It is assumed the amount of alternative solvent 2 consumed in existing equipment is similar to the base case, and that the price of alternative solvent 2 is the same as alternative solvent 1 (i.e., \$3.24/Kg).
- (v) Disposal cost similar because same amount of solvent used as in the base case.

materials worth \$69,814 per year. Electricity is used to heat the solvent and the work load, and to compensate for heat loss due to radiation (ICF 1988b). Electricity costs are estimated at \$6,078. The waste solvent in this model vapor degreaser is assumed to be disposed of at a cost of \$0.84 per kilogram or \$3,135 per year. Total annual operating costs (solvent, electricity and waste disposal) amount to \$79,027 and are the base costs of MCF use in a typical vapor degreaser. The capital cost is estimated at \$93,555.

Aqueous Cleaning. Aqueous cleaning costs are based on the assumption that a typical conveyORIZED spray washers would be needed to replace the conveyORIZED vapor degreaser depicted in the base case⁸. The throughput of the systems was used to determine the number of aqueous cleaning conveyORIZED spray washers required to provide the same cleaning load as a conveyORIZED vapor degreaser (ICF 1989a)⁹. The incremental capital costs of this unit is estimated at \$6,408 which includes installation costs (ICF 1989a). Annual operating savings with respect to the base case costs are estimated at \$58,987 which include raw material savings of \$68,613 (i.e., the difference between the detergent costs and the costs of the solvent replaced), water costs of \$2, electricity costs of \$6,759, and waste disposal costs of \$2,865.

Engineering Controls. Engineering controls are based on a combination of improved housekeeping practices and carbon adsorption control technologies. It is estimated that engineering controls reduce solvent loss by 60 percent

⁸It is assumed that the aqueous cleaning process used will be the most current technology available.

⁹ Floor space comparisons and the associated costs are not included in this analysis.

(i.e., evaporative emissions, drag out emissions, and downtime losses -- see Exhibit 16). Note that engineering controls do not reduce the amount of solvent that is disposed of because this only depends on the gross cleanout losses. Gross cleanout losses depend on the level of solvent contamination and, therefore, are not affected by the use of engineering controls. Hence, waste disposal costs relative to the base remain unchanged.

Annual operating savings associated with engineering controls amount to \$31,068 which include solvent savings of \$33,535, water costs of \$2020, and electricity costs of \$447. The capital cost of engineering controls is estimated at \$54,000.

Alternative Solvents. Alternative solvents are considered possible replacements for MCF. In this analysis two solvents are evaluated. Alternative solvent 1 is assumed only to be used in new equipment costing \$23,388 more than the MCF base equipment. Alternative solvent 2 is assumed to be used in existing, as well as, new conveyORIZED vapor degreaser units. It is assumed that the amount of alternative solvent 1 used in new equipment is 50 percent of the base case MCF use (Ruckriegel 1989). It is also estimated that alternative solvent 1 will cost 20 percent more than CFC-113. In this analysis it is estimated that CFC-113 costs \$2.70 per Kg, and therefore, the price of alternative solvent 1 is \$3.24 per Kg. The lower boiling point of alternative solvent 1 compared to MCF, and the high energy requirement of the new equipment results in an overall energy consumption equivalent to the base case machine. The use of alternative solvent 1 results in costs of \$60,587 per year. In this analysis, it is assumed that the use of alternative solvent 2 in existing equipment require retrofitting of the existing equipment worth

\$20,000. It is assumed that the amount of alternative solvent 2 consumed in existing equipment is similar to the base case, and that the price of alternative solvent 1 is the same as alternative solvent 2. The use of alternative solvent 2 results in annual operating costs of \$194,123.

5.3.3 Cost Data for Open Top Vapor Degreasing

Base Case Costs. As shown in Exhibit 18, it is estimated that the raw material costs in the average open top vapor degreaser is \$9,770 per year. Electricity costs are estimated at \$2,600 (ICF 1988b). The waste solvent in this model open top vapor degreaser is assumed to be disposed for a cost of \$0.84 per kilogram or \$888 per year. Total base case annual operating costs in a typical open top vapor degreaser amount to \$13,258. The capital cost is estimated at \$10,896.

Aqueous Cleaning. Aqueous cleaning costs are based on the assumption that two typical batch immersion washers would be needed to replace the base case open top vapor degreaser. The incremental capital costs of these units with respect to the base case are estimated at \$77,893 and include installation costs (ICF 1989a). Annual operating costs with respect to the base case costs are estimated at \$2,875 including raw material savings of \$2,545, water costs of \$2, electricity costs of \$2,742, and waste disposal costs of \$2,676.

Engineering Controls. Engineering controls are based on a combination of improved housekeeping practices, increased freeboard, refrigerated freeboard chillers, and automatic cover and hoists control technologies. It is estimated that engineering controls reduce solvent loss by 60 percent (i.e., evaporative, drag out, and downtime losses). Annual operating savings

	(1) Capital Cost	Annual Operating Costs				(6) Total Operating Costs
		(2) Raw Material (Detergent/Solvent)	(3) Water	(4) Electricity	(5) Waste Treatment or Disposal	
Base Case: MCF	10,896 (a)	9,770	Napp (a1)	2,600 (b)	888	13,258
Control Option	Incremental Costs (Savings) (c)					
Aqueous Cleaning (d)	77,893 (e)	(2,545)(f)	2 (g)	2,742 (h)	2,676 (i)	2,875
Engineering Controls (j)	11,000	(3,497)(k)	Napp	112 (l)	0	(3,385)
Alternative Solvents 1 (m)	2,724 (n)	9,399 (o)	Napp	0 (p)	(710)(q)	8,689
Alternative Solvents 2 (r)	10,000 (s)	28,568 (t)	Napp	0 (p)	0 (u)	28,568

Notes:

- (1) Cost of new equipment as estimated by industry sources. All costs reflect 1988 dollars.
- (2) For the Base Case, raw material costs refer to the cost of solvent (virgin and recycled). For aqueous cleaning, raw material costs include the costs of detergent (ICF 1988b).
- (3) Assumes the cost of water is \$0.0006 per gallon (ICF 1989a).
- (4) Electricity costs are computed multiplying the number of kilowatt-hr consumed times the costs of a kilowatt-hour. Annual costs are based on 2000 hrs and electricity costs of \$0.0487/kwh.
- (5) Costs of disposal of MCF and alternative solvents are estimated at \$0.84 per kg. For aqueous cleaning disposal costs are based on contract hauling costs of \$3/gallon.
- (6) = (2) + (3) + (4) + (5)

Sources:

- (a) An average open top vapor degreaser consumes 7,606 Kg of virgin solvent and 4,227 Kg of recycled solvent in a year. It is assumed that the price of virgin solvent is \$0.89 and that of recycled solvent is \$1.32 per Kg. Recycling is carried out off-site and the cost of recycling off-site is comparable to the cost of in-house recycling. In-house recycling would require capital investment for a still and operating costs associated with operating the still. The virgin solvent is used to replace the operating solvent loss (i.e., evaporative loss, drag out loss, down time loss, and waste disposal loss) (ICF 1988b).
- (a1) It is assumed that water costs are negligible (ICF 1988b).
- (b) Based on electricity costs for heating the solvent, the work load, and compensation for heat loss due to radiation (ICF 1988b).
- (c) Incremental costs (savings) indicate the difference in costs between the control options and the base case.
- (d) Aqueous cleaning costs are based on the the assumption that a two typical batch immersion washers would be needed to replace a typical open top vapor degreaser (ICF 1989a).
- (e) The capital costs include the costs of aqueous cleaning equipment (i.e., wash tanks, rinse tanks, and air knife) and installation costs (ICF 1989a).
- (f) Raw materials costs are based on the costs of detergent (ICF 1989a).
- (g) Water costs are based on an annual water consumption of 1188 gallons at a cost of \$0.0006 per gallon (ICF 1989a).
- (h) Electricity costs are based on a consumption of 55 kwh. This is based on energy consumption of the aqueous cleaning and drying equipment (ICF 1989a).
- (i) Waste disposal costs are based on an annual waste disposal of 1188 gallons at a cost of \$3 per gallon (ICF 1989a).
- (j) Based on a combination of improved housekeeping practices, refrigerated freeboard chiller, increased free board height, and automatic hoist.
- (k) It is assumed that the engineering control reduces solvent loss by 60 percent (i.e., drag out, downtime, and evaporative losses) (OAQPS 1989).
- (l) Based on the electricity consumption of a refrigerated chiller (OAQPS 1989).
- (m) Represents an HCFC blend used in new equipment (Ruckriegel 1989).
- (n) It is assumed that the new solvent equipment is 25 percent more expensive than the base case. (Ruckriegel 1989).
- (o) It is assumed that compared to the old machines the new machines consumes one-half the amount of solvent. It is further assumed that the solvent (virgin & recycled) cost 20 percent more than CFC-113 (\$2.70/Kg) (i.e., \$3.24 per Kg) (Ruckriegel 1989).
- (p) It is assumed that the energy requirements are similar (Ruckriegel 1989).
- (q) Based on the assumption that the new equipment uses one-half the amount of solvent used in the base case.
- (r) Alternative solvent 2 is assumed to be similar to alternative solvent 1.
- (s) To use alternative solvent 2 the existing equipment has to be retrofitted.
- (t) It is assumed the amount of alternative solvent 2 consumed in existing equipment is similar to the base case, and that the price of alternative solvent 2 is the same as alternative solvent 1 (i.e., \$3.24/Kg).
- (u) Disposal cost similar because same amount of solvent used as in the base case.

are \$3,385 which include solvent savings of \$3,497, and electricity costs of \$112. The capital cost of engineering controls is estimated at \$11,000.

Alternative Solvents. As for conveyorized vapor degreasing two alternative solvents are considered possible replacements for MCF. Alternative solvent 1 is assumed only to be used in new equipment. Alternative solvent 2 is assumed to be used in existing, as well as, new vapor degreaser units. It is assumed that the amount of alternative solvent 1 used in new equipment is 50 percent of the base case MCF use (Ruckriegel 1989). It is also estimated that alternative solvent 1 will cost 20 percent more than CFC-113. CFC-113 costs \$2.70 per Kg, and therefore, the price of alternative solvent 1 is \$3.24 per Kg. The lower boiling point of alternative solvent 1 compared to MCF, and the high energy requirement of the new equipment results in an overall energy consumption equivalent to the base case machine. Based on this, the use of alternative solvent 1 results in costs of \$8,689 per year. Alternative solvent 2 is assumed to be used in existing units with retrofitment costs estimated at \$10,000. This includes estimates for retrofitment costs on existing units. The price and energy consumption of alternative solvent 2 are similar to alternative solvent 1. In addition, the amount of alternative solvent 2 used is the same as the amount of MCF used in the base case. Total operating costs for alternative solvent 2 amount to \$28,568.

5.3.4 Cost Data for Cold Cleaning

Base Case Costs. As shown in Exhibit 19, it is estimated that the operating cost of a cold cleaning unit is \$3,850. This includes raw material costs of \$3,467 per year and waste disposal costs of \$383 (at \$0.84 per kilogram). Electricity and water costs are negligible. The capital cost is

EXHIBIT 19

COSTS OF CONTROLS FOR METHYL CHLOROFORM IN COLD CLEANING

Control Options	(1) Capital Cost	Annual Operating Costs				(6) Total Operating Costs
		(2) Raw Material (Detergent/Solvent)	(3) Water	(4) Electricity	(5) Waste Treatment or Disposal	
Base Case: MCF	1,447 (a)	3,467	Napp	Napp (b)	383	3,850
Control Option	Incremental Costs (Savings) (c)					
Aqueous Cleaning (d)	9,187 (e)	(3,233)(f)	1 (g)	284 (h)	967 (i)	(1,981)
Engineering Controls (j)	405	(897)(k)	Napp	Napp (b)	0	(897)
Alternative Solvents 1 (l)	362 (m)	4,181 (n)	Napp	Napp (b)	(315)(o)	3,866
Alternative Solvents 2 (p)	1,000 (q)	11,829 (r)	Napp	Napp (b)	0 (s)	11,829

Notes:

- (1) Cost of new equipment as estimated by industry sources. All costs reflect 1988 dollars.
- (2) For the Base Case, raw material costs refer to the cost of solvent (virgin and recycled). For aqueous cleaning, raw material costs include the costs of detergent (ICF 1988b).
- (3) Assumes the cost of water is \$0.0006 per gallon (ICF 1989a).
- (4) Electricity costs are computed multiplying the number of kilowatt-hr consumed times the costs of a kilowatt-hour. Annual costs are based on 2000 hrs and electricity costs of \$0.0487/kwh.
- (5) Costs of disposal of MCF and alternative solvents are estimated at \$0.84 per kg. For aqueous cleaning disposal costs are based on contract hauling costs of \$3/gallon.
- (6) = (2) + (3) + (4) + (5)

Sources:

- (a) An average cold cleaner consumes 2,898 Kg of virgin solvent and 1,823 Kg of recycled solvent in a year. It is assumed that the price of virgin solvent is \$0.89 and that of recycled solvent is \$1.32 per Kg. Recycling is carried out off-site and the cost of recycling off-site is comparable to the cost of in-house recycling. In-House recycling would require capital investment for a still and operating costs associated with operating the still. The virgin solvent is used to replace the operating solvent loss (i.e., evaporative loss, drag out loss, down time loss, and waste disposal loss) (ICF 1988b).
- (b) Based on electricity costs for heating the solvent, the work load, and compensation for heat loss due to radiation (ICF 1988b).
- (c) Incremental costs (savings) indicate the difference in costs between the control options and the base case.
- (d) Aqueous cleaning costs are based on the the assumption that a typical bench top ultrasonic washers would be needed to replace a typical cold cleaner (ICF 1989a).
- (e) The capital costs include the costs of aqueous cleaning equipment (i.e., wash tanks, rinse tanks, and air knife) and installation costs (ICF 1989a).
- (f) Raw materials costs are based on the costs of detergent (ICF 1989a).
- (g) Water costs are based on an annual water consumption of 450 gallons at a cost of \$0.0006 per gallon (ICF 1989a).
- (h) Electricity costs are based on a consumption of 3 kwh. This is based on energy consumption of the aqueous cleaning and drying equipment (ICF 1989a).
- (i) Waste disposal costs are based on an annual waste disposal of 450 gallons at a cost of \$3 per gallon (ICF 1989a).
- (j) Based on a combination of improved housekeeping practices, increased free board height, and water covers.
- (k) It is assumed that the engineering control reduces solvent loss by 60 percent (i.e., drag out, downtime, and evaporative losses) (OAQPS 1989).
- (l) Represents an HCFC blend used in new equipment (Ruckriegel 1989).
- (m) It is assumed that the new solvent equipment is 25 percent more expensive than the base case. (Ruckriegel 1989).
- (n) It is assumed that compared to the old machines the new machines consumes one-half the amount of solvent. It is further assumed that the solvent (virgin & recycled) cost 20 percent more than CFC-113 (\$2.70/Kg) (i.e., \$3.24 per Kg) (Ruckriegel 1989).
- (o) Based on the assumption that the new equipment uses one-half the amount of solvent used in the base case.
- (p) Alternative solvent 2 is assumed to be similar to alternative solvent 1.
- (q) To use alternative solvent 2 the existing equipment has to be retrofitted.
- (r) It is assumed the amount of alternative solvent 2 consumed in existing equipment is similar to the base case, and that the price of alternative solvent 2 is the same as alternative solvent 1 (i.e., \$3.24/Kg).
- (s) Disposal cost similar because same amount of solvent used as in the base case.

estimated at \$1,447.

Aqueous Cleaning. The average cold cleaner defined in the base case can be substituted by a typical bench top ultrasonic washer. The incremental capital cost of this unit is estimated at \$9,187 (including installation costs) (ICF 1989a). Annual operating savings for this aqueous cleaning configuration with respect to the base case costs are estimated at \$1,981 which include raw material savings of \$3,233 (i.e., the difference between the detergent costs and the costs of the solvent replaced), water costs of \$1, electricity costs of \$284, and waste disposal savings of \$967.

Engineering Controls. Engineering controls reduce solvent operating losses by 60 percent (i.e., evaporative emissions, drag out emissions, and down time losses). This results in an annual operating savings of \$897 which is solely due to solvent savings. The capital costs of engineering controls are \$405.

Alternative Solvents. Alternative solvents can also replace MCF in cold cleaning. Based on identical assumptions as for conveyORIZED vapor degreasing and open top vapor degreasing, the annual operating costs of a cold cleaner using alternate solvent 1 and alternative solvent 2 are \$3,866 and \$11,829, respectively. Capital costs for the two solvent are estimated at \$362 and \$1,000, respectively.

5.3.5 Aerosols.

Exhibit 20 presents the costs for the two groups of control technologies considered for the reduction of MCF use in aerosol products: (1) the reformulation of aerosol formulations, and (2) a switch to alternative methods that eliminate the need for the aerosol delivery system. The

Exhibit 20. Costs of Controls for Methyl Chloroform in Aerosols

	<u>Incremental Costs^a (thousand dollars)</u>			
Control Option	Capital	R&D and Marketing ^b	Total Annualized Costs ^c	Dollars per Kg of MCF Replaced ^d
Reformulation to:				
Petroleum Distillates	--	5,594	622.7	0.16
Water-based Systems	92.3	2,244	260.2	0.17
Alternate Delivery Systems				
Occupational Uses	170,700 ^e	--	19,000.0	3.84
Consumer Uses	--	--	--	20.00 ^f

Source: ICF 1989a.

^a Raw material costs are not considered in this analysis primarily because the replacement chemicals in both, the reformulated products and the alternate delivery systems are as expensive as MCF.

^b Includes R&D and marketing costs associated with the reformulation of various automotive and industrial products, household products, and aerosol pesticides currently using methyl chloroform.

^c Costs are discounted at the social rate of discount (2 percent) over the equipment lifetime (10 years).

^d For the reformulation control options, the consumption of MCF in model plants is used to compute the costs per kilogram of MCF replaced. For the costs of alternative systems, the total consumption of methyl chloroform in brake cleaners and spot removers was used to model a representative product category where a switch to non-aerosol (and non-MCF) technologies is feasible.

^e These costs represent the capital investment required if all users of MCF-based brake cleaners purchased alternative equipment.

^f Based on a comparison between the costs of professional dry cleaning services and the costs of an aerosol spot remover (ICF 1989b).

methodology used to estimate the costs associated with the reformulation of aerosol products currently using MCF is based on a previous ICF analysis (ICF 1988c) and includes the estimation of reformulation costs per plant (i.e., R&D, marketing, and capital costs), the number of aerosol plants that would incur these costs (based on the production volume of an average "model" plant), the calculation of total annualized costs and, finally, the computation of total costs per kilogram of MCF replaced.

The costs considered for a switch to alternative delivery systems in consumer and occupational uses include the costs incurred by the current users of aerosol products (e.g., brake shop owners and consumers) and do not include costs to the aerosol industry. In the event that MCF-aerosol were no longer marketable, it is estimated that aerosol manufacturing facilities could either reformulate these products or produce other aerosol products without incurring major economic losses. An example of an alternative consumer use of MCF-based aerosol is the aerosol spot remover that can be replaced with the use of professional services¹⁰.

Aerosol spot removers are designed to reduce dry-cleaning costs to consumers by providing an easy way to remove specific spots from dry-cleanable garments. No substitute formulations are available for the use of chlorinated solvents in aerosol spot removers (ICF 1988b). In the event that aerosol spot removers became no longer available, consumers would resort to additional dry cleaning services. ICF estimated these costs based on the increased number of times that consumers will have garments cleaned to get spots removed from

¹⁰ Professional dry cleaners use perchloroethylene and not MCF.

their garments which they could have treated with aerosol spot removers (ICF 1989b). The data used in this analysis includes experimental data on the number cleaning events obtained from aerosol spot removers, the period of time likely to be involved between dry cleaning events, the size of the spot remover market, and current dry cleaning fees. Spot removers used 1.1 million kilograms of MCF in 1987. The results of this analysis indicate that additional dry cleaning costs to consumers are approximately \$20 per kilogram of MCF used. These are upper bound costs because a portion of current aerosol spot remover users might decide to "live with the spot" and avoid the additional dry cleaning expense. Even in this case it is believed the level of costs remains in the tenths of dollars per kilogram of MCF replaced primarily due to the high cost of professional dry cleaning as compared to aerosol spot removers.

Aerosol brake cleaners are used by brake mechanics to remove the excess dust accumulated inside brake housings. Various systems have been developed for this application that could replace the use of the aerosol can including vacuum enclosures, recirculating liquid systems, and wet-brush systems. The liquid usually recommended for these systems is water containing a surfactant (PEI 1987). The wet-brush is the option of lowest cost and is used to show the level of costs involved. According to PEI (1987), there are 297,416 brake repair shops that employ aerosol brake cleaners and the cost of the substitute wet-brush system is \$574. The investment for all shops would amount to \$170.7 million. Operating costs are assumed to be approximately the same as the current costs of aerosol brake cleaners; thus, the cost of the equipment are believed to be indicative of the additional costs incurred. Using 10 year and

2 percent, annual costs amount to approximately \$19 million. Aerosol brake cleaners employed 4.95 million kilograms of MCF in 1987; therefore, the costs can be expressed as \$3.84 per kilogram of MCF (see Exhibit 20).

5.3.5 Adhesives.

Exhibit 21 presents the costs of the control options considered in this analysis and include the costs of replacement of MCF-based adhesives with water-based, hot melt, and non-MCF solvent-based adhesives. When MCF-based adhesives are applied as part of a manufacturing process (e.g., packaging, tape manufacturing), solvent recovery is also considered as a control option. The available cost data permits the comparison of the costs associated with a switch from a typical MCF-based adhesive (a pressure sensitive adhesive) to the alternatives mentioned above. Raw material costs represent more than 92 percent of the total costs associated with the use of water-based and hot melt adhesives¹¹; thus, raw material costs are used to establish the differences in costs associated with these options.

5.3.6 Coatings and Inks

Exhibit 22 compares the costs associated with MCF-based coatings and inks with various control options. Capital costs represent the cost of new equipment needed to set up a typical process line for each control option. Although water-based inks are more expensive on a per pound basis, the concentration of solids is higher and, therefore, 30 to 40 percent more area

¹¹Energy and labor costs are reported to be approximately the same for solvent-based adhesives and water-based and hot melt adhesives. The equipment conversion costs associated with the use of water-based and hot melt adhesives represent approximately 1 percent of total costs; thus, only raw material costs are significant and are used as indicative of relative costs.

Exhibit 21. Costs of Controls for Methyl Chloroform in Adhesives

Control Option	Incremental Costs			Total Annualized Costs ^b	Dollars per Kg of MCF Replaced ^c
	Raw Materials per Kg of Dry Adhesive ^{a/} Recovered Solvent	Capital	Energy		
Water-based	-\$2.79	0 ^d	0 ^e	--	-\$0.93
Hot-melt	-\$2.37	0 ^d	0	--	-\$0.79
Solvent-borne	-\$1.85	0	0	--	-\$0.62
Solvent Recovery	(\$52,040) ^f	500,000	34,368	37,978	\$0.65

Source: ICF 1989a.

^a The costs of a MCF-based adhesive is \$4.63 per kilogram of dry adhesive.

^b Annualized costs for water-based, hot-melt, and alternate solvent-borne adhesives are not shown because the comparison with MCF-based adhesives is made with respect to raw material costs on a per kilogram of dry adhesive used. Costs are annualized over 10 years using a 2 percent discount rate.

^c For water-based, hot-melt, and solventborne adhesives, the comparison is done by dividing the incremental costs per Kg. of dry adhesive by 3. Each kilogram of dry adhesive requires 3 kilograms of MCF. The use of a typical recovery system saves 58,473 Kgs of MCF.

^d Equipment conversion costs are insignificant compared to raw material costs given the large volume of adhesive handled in typical operations.

^e Energy costs associated with water-based adhesives do not increase because the volume of air handled in the drying equipment can be lowered significantly with respect to the volume handled with solvent-based adhesives.

^f Solvent recovery systems recover 96 percent of the total solvent used and 67 percent of this amount can be reused after recycling. This recovered solvent results in raw materials savings of \$52,040 for the model operation assumed.

EXHIBIT 22. COST OF CONTROLS FOR METHYL CHLOROFORM IN COATINGS AND INKS

	(a) Capital Costs	(b) Annualized Capital Costs	(c) Annual Operating Costs	(d) Total Annual Costs	(e) Social Cost per Kg of MCF Reduced
Inks:					
MCF-based	0 (f)	0	550,000 (g)	550,000	--
Water-borne	0 (f)	0	733,000 (g)	733,000	2.29
Coatings:					
MCF-based	150,000	16,699	750,644	767,343	--
Water-borne	110,000	12,246	666,364	678,610	(0.59)
High Solids	110,000	12,246	518,500	530,746	(1.56)
Powder	120,000	13,359	443,600	456,959	(2.05)
Solvent Recovery	500,000	55,663	(17,672)(h)	37,991	0.65

Notes:

- (a) Cost of new capital equipment.
- (b) Annual capital costs, discounted at 2 percent annual interest rate over 10 years.
- (c) Includes annual costs for: raw materials, labor & clean-up, maintenance, energy, and sludge disposal.
- (d) = (b) + (c)
- (e) Cost difference with respect to MCF base case divided by the amount of MCF replaced; 151,423 Kg for coatings and 80,000 Kgs for inks.
- (f) Capital costs for handling water-based inks are negligible.
- (g) The water-based ink used in this analysis costs \$7.33 per Kg. The cost of a MCF-based ink is estimated at \$5.50 per Kg. The concentration of MCF is 80 percent by weight (Capristo 1989). It is assumed that the model printing line uses 100,000 Kgs of ink in a year.
- (h) Includes energy costs of \$34,368 and savings of \$52,040 for the 58,473 Kgs of MCF recovered (ICF 1989a).

Source:

Bocchi, Gregory J., "Powder Coating Today," in Products Finishing Directory 1986, reprinted for Powder Coatings Institute, 1987.

can be coated. In addition, incremental equipment costs associated with water-based inks are estimated to be negligible. For coatings, this equipment includes: two waterwash booths (or powder spray booths, in the case of powder coating); a dry filter booth (not needed for powder spray); four automatic electrostatic guns; two manual electrostatic guns (just one needed for powder coating); two reciprocators (not needed for high-solid coating); heating equipment (not needed for water-borne or powder coating); recovery systems (not needed for water-borne or high-solids coating); and safety interlocks and standoffs (for water-borne coating only) (PCI 1987).

Examining the equipment needs of each type of coating, MCF-based solvents prove to be the most expensive in terms of capital costs. Switching to powder coating will save \$30,000 (20 percent) in capital costs. Switching to water-borne or high solid coatings will save even more: \$40,000 (27 percent) in capital costs (PCI 1987)¹².

Annual operating costs include the costs of raw materials, labor and cleanup, maintenance, energy, and sludge disposal. Compared with MCF-based coatings, water-borne coatings show slightly higher energy costs, but substantially lower material and disposal costs. Overall, the annual operating savings associated with water-borne coatings are \$84,280. High-solid coatings had lower material, disposal, and energy costs. Overall, the annual operating savings are \$232,000. Powder coatings cost considerably less

¹² The capital costs indicated in Exhibit 22 may be lower if existing coating lines using MCF are converted to the new technologies. Because the possibility of equipment conversion is dependent on the type of equipment and the control technology in question (e.g., it is easier to convert from solvent-based to water-borne technology than to powder technology) it is conservatively assumed that the full costs shown in Exhibit 22 are incurred.

in all 5 areas of annual operating costs, with annual savings of \$307,000 (PCI 1987).

To calculate the social cost per kilogram of MCF reduced, the difference between the total annual costs of the control option and of MCF is calculated. This difference is divided by 151,423 kilograms, the amount of MCF used in the base case model process line. For inks, substituting water-borne coatings would cost \$2.29 per kg of MCF reduced. This is based on a comparison of raw material costs only; no other operating cost data are available for inks. For coatings, substituting water-borne, high-solid, or powder coatings would save \$0.59, \$1.56, or \$2.05, respectively, per kg of MCF reduced (PCI 1987; see Exhibit 22).

The solvent recovery system presented in Exhibit 22 is similar to that used for adhesives because the characteristics of printing and coating equipment are comparable.

5.3.7 Miscellaneous Uses.

No data are available on the solvents or technologies that could be used as a replacement for methyl chloroform in miscellaneous uses. The weighted average costs of the control options for the other end-uses are used as indicative of the costs of the controls that could be used in the miscellaneous sectors. Miscellaneous uses account for 6 percent of total methyl chloroform; thus, the impact the potential inaccuracy of this assumption is small.

6. COST ESTIMATES FOR PHASE-OUT AND FREEZE SCENARIOS

This chapter presents estimates of the social costs and transfer payments associated with a phase-out and freeze of methyl chloroform production. Exhibit 23 shows the estimates of social costs for these scenarios.¹ In all cases, the results are consistent with expectations. The costs of achieving a phase-out are higher if the phase-out schedule is based on 1986 rather than 1988 production quantities. The same is true for freezing production of methyl chloroform. The costs for the freeze are higher if the production is frozen at 1986 levels instead of 1988 levels. Furthermore, the costs are higher for higher growth rates in the baseline in the period 1989-2000.² The costs of the phase-out and the freeze for Scenario 1 (corresponding to the "low conservation-high chlorinated solvent switch") are higher than those for Scenario 2 (corresponding to the "high conservation-low chlorinated solvent switch"), and the costs for Scenario 2 in turn are higher than those for Scenario 3 (corresponding to the "low conservation-no solvent switch") as the baseline growth rates for the three scenarios are 4.7, 2.4, and 2.2 percent, respectively.

The total social costs associated with a phase-out under Scenario 1 are about \$2.7 billion (if the base year is assumed to be 1986) or about \$2.4 billion (if the base year is assumed to be 1988) during the period 1989-2000. Over longer periods of time, the present value of social costs grow significantly -- to about \$58 billion by the year 2075. The costs of the

¹ The present value of social costs are calculated using a social discount rate of two percent.

² It is assumed that the baseline growth in methyl chloroform production is 2.2 percent per year for the period 2001-2050 and zero after the year 2050.

EXHIBIT 23

ESTIMATES OF SOCIAL COSTS FOR PHASE-OUT AND FREEZE SCENARIOS^a (billions of 1985 dollars)

Scenario	Short Term (1989-2000)	Long Term (1989-2075)
A. PHASE-OUT OF MCF PRODUCTION		
1. Growth Rate for Production (1989-2000) = 4.7% ^b		
Base Year: 1986 (Exhibit 25)	2.657	58.215
Base Year: 1988 (Exhibit 26)	2.365	55.558
2. Growth Rate for Production (1989-2000) = 2.4% ^c		
Base Year: 1986 (Exhibit 27)	1.384	43.942
Base Year: 1988 (Exhibit 28)	1.323	43.881
3. Growth Rate for Production (1989-2000) = 2.2% ^d		
Base Year: 1986 (Exhibit 29)	1.357	42.928
Base Year: 1988 (Exhibit 30)	1.233	42.804
B. FREEZE OF MCF PRODUCTION^e		
1. Growth Rate for Production (1989-2000) = 4.7% ^b		
Base Year: 1986 (Exhibit 31)	0.247	8.455
Base Year: 1988 (Exhibit 32)	0.143	7.004
2. Growth Rate for Production (1989-2000) = 2.4% ^c		
Base Year: 1986 (Exhibit 33)	0.011	0.484
Base Year: 1988 (Exhibit 34)	0.000	0.000
3. Growth Rate for Production (1989-2000) = 2.2% ^d		
Base Year: 1986 (Exhibit 35)	0.009	0.471
Base Year: 1988 (Exhibit 36)	0.000	0.000

^a Costs are discounted at 2 percent. It is assumed that the baseline growth in MCF production is 2.2 percent per year for the period 2001-2050 and zero after the year 2050.

^b Corresponds to the "low conservation-high chlorinated solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^c Corresponds to the "high conservation-low chlorinated solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^d Corresponds to the "low conservation-no solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^e It is assumed that the production freeze will continue to be met after 2000 with the set of controls selected in 2000.

phase-out in the short term (1989 to 2000) for Scenario 2 and Scenario 3 are about 45-50 percent lower than those for Scenario 1, and about 25 percent lower in the long term (1989 to 2075). The costs in the long term for Scenarios 2 and 3 are closer to those for Scenario 1, largely because the controls used in the post-2000 period are similar, the growth rate is the same across all scenarios, and because the post-2000 period is large. The differences still exist because the production quantity in the year 2000 is still different across the three scenarios.

The total social costs associated with a freeze are much lower in the short and long term relative to the phase-out. During the period 1989-2000, the costs are about \$0.25 billion for Scenario 1, if the freeze is assumed to be at 1986 levels, or about \$0.14 billion if the freeze is assumed to be at 1988 levels.

Exhibit 24 shows the estimates of transfer payments for the same scenarios.³ The transfer payments associated with the phase-out in the period 1989-2000 are in the range \$0.8-0.9 billion for all the scenarios. The values do not change after 2000 because methyl chloroform is no longer produced. The transfer payments associated with a freeze are lower than those for the phase-out -- about \$0.6-0.7 billion for Scenario 1, and about \$0.1 billion for Scenarios 2 and 3 in the short term. In the post-2000 period, unlike the phase-out, transfer payments exist for the freeze on production because methyl chloroform continues to be produced. The payments are about \$3 billion for

³ The present value of transfer payments are calculated using a private discount rate of six percent.

EXHIBIT 24

ESTIMATES OF TRANSFER PAYMENTS FOR PHASE-OUT AND FREEZE SCENARIOS^a (billions of 1985 dollars)

Scenario	Short Term (1989-2000)	Long Term (1989-2075)
A. PHASE-OUT OF MCF PRODUCTION		
1. Growth Rate for Production (1989-2000) = 4.7% ^b		
Base Year: 1986 (Exhibit 25)	0.852	0.852
Base Year: 1988 (Exhibit 26)	0.895	0.895
2. Growth Rate for Production (1989-2000) = 2.4% ^c		
Base Year: 1986 (Exhibit 27)	0.869	0.869
Base Year: 1988 (Exhibit 28)	0.818	0.818
3. Growth Rate for Production (1989-2000) = 2.2% ^d		
Base Year: 1986 (Exhibit 29)	0.854	0.854
Base Year: 1988 (Exhibit 30)	0.793	0.793
B. FREEZE OF MCF PRODUCTION^e		
1. Growth Rate for Production (1989-2000) = 4.7% ^b		
Base Year: 1986 (Exhibit 31)	0.727	3.165
Base Year: 1988 (Exhibit 32)	0.578	2.846
2. Growth Rate for Production (1989-2000) = 2.4% ^c		
Base Year: 1986 (Exhibit 33)	0.083	0.416
Base Year: 1988 (Exhibit 34)	0.000	0.000
3. Growth Rate for Production (1989-2000) = 2.2% ^d		
Base Year: 1986 (Exhibit 35)	0.082	0.408
Base Year: 1988 (Exhibit 36)	0.000	0.000

^a Payments are discounted at 6 percent. It is assumed that the baseline growth in MCF production is 2.2 percent per year for the period 2001-2050 and zero after the year 2050.

^b Corresponds to the "low conservation-high chlorinated solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^c Corresponds to the "high conservation-low chlorinated solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^d Corresponds to the "low conservation-no solvent switch" scenario presented in the September 19 MCF Draft Report for the CMR end use distribution.

^e It is assumed that the production freeze will continue to be met after 2000 with the set of controls selected in 2000.

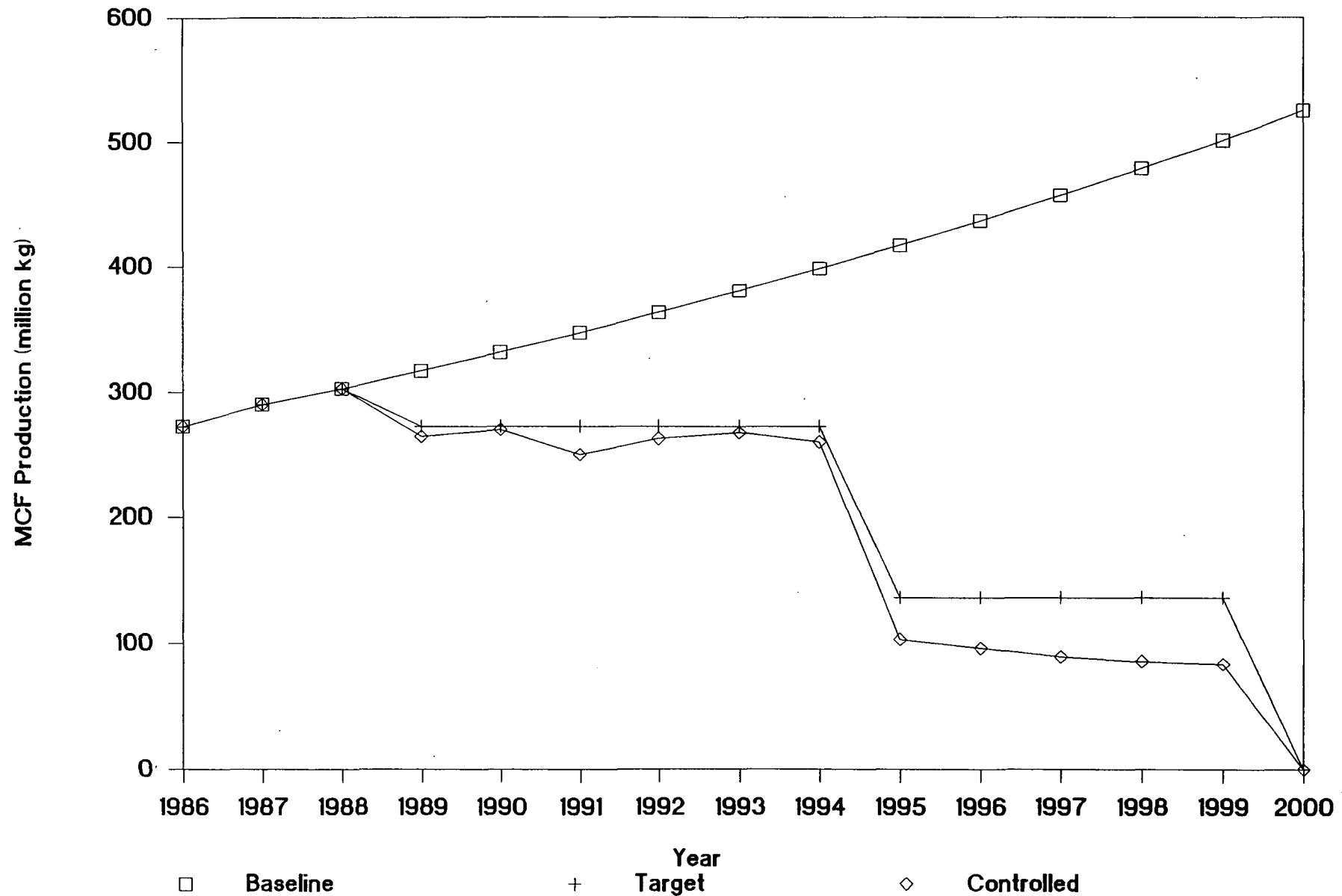
Scenario 1 in the period 1989 to 2075, and about \$0.4 billion for Scenarios 2 and 3.

In general, the estimates of transfer payments are lower if the base year is assumed to be 1988 instead of 1986. However, as the estimate of transfer payments in any year is the product of the amount of methyl chloroform produced and the increase in the price of methyl chloroform, this need not be true always (as is borne out by the entries for Scenario 1 under a phase-down in Exhibit 24). What will always be true is that if the base year is assumed to be 1986 rather than 1988, the amount of methyl chloroform produced in any given year will be always lower and the increase in the price of methyl chloroform will always be higher (or the same).

Exhibits 25 through 36 show the baseline production, the production target, and the actual production under controls for each year in the period 1989 to 2000 for all scenarios.

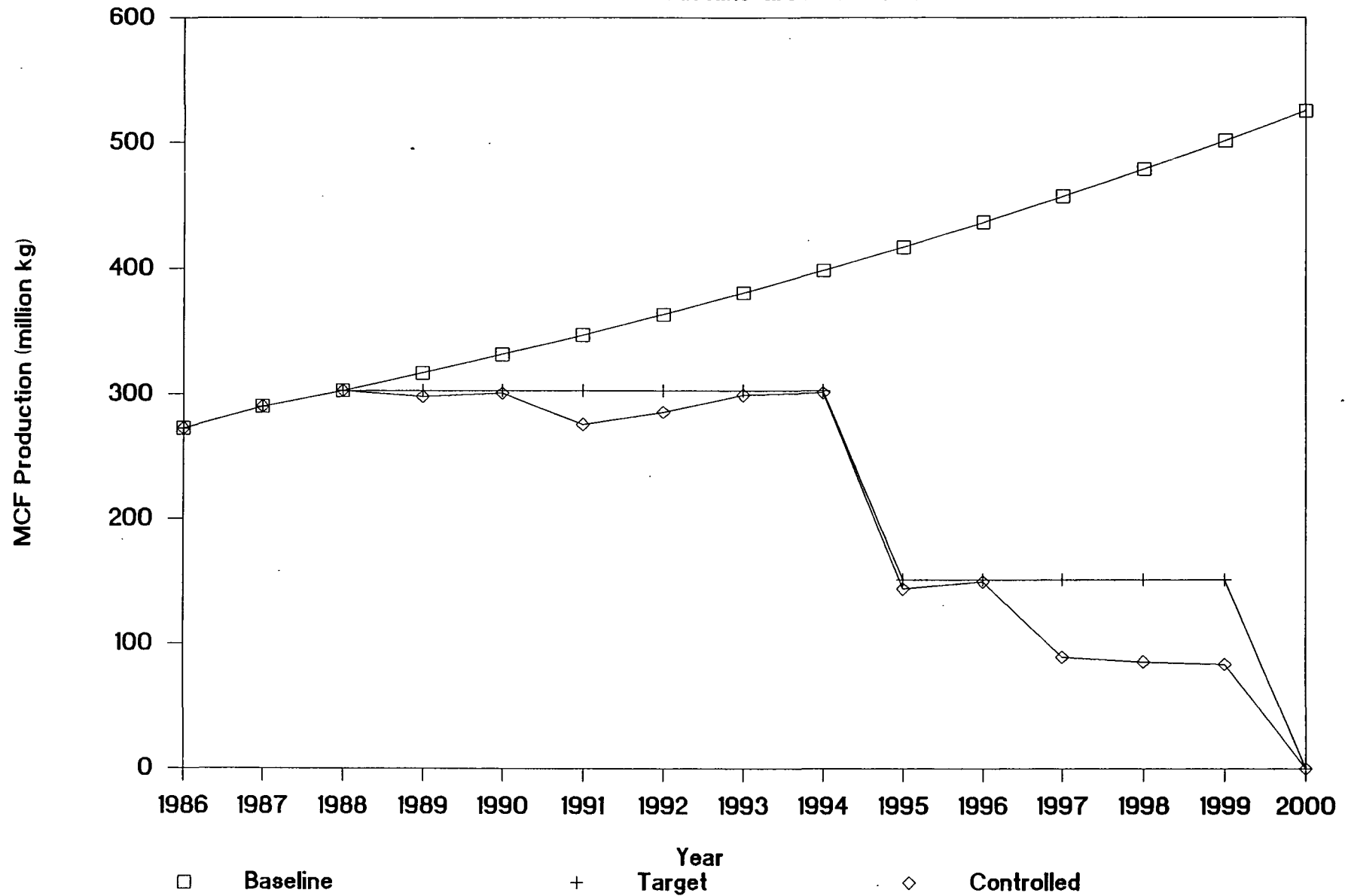
PHASE-OUT OF MCF PRODUCTION

Base Year: 1986: Baseline Growth = 4.7%



PHASE-OUT OF MCF PRODUCTION

Base Year: 1988: Baseline Growth = 4.7%



PHASE-OUT OF MCF PRODUCTION

Base Year: 1986; Baseline Growth = 2.4%

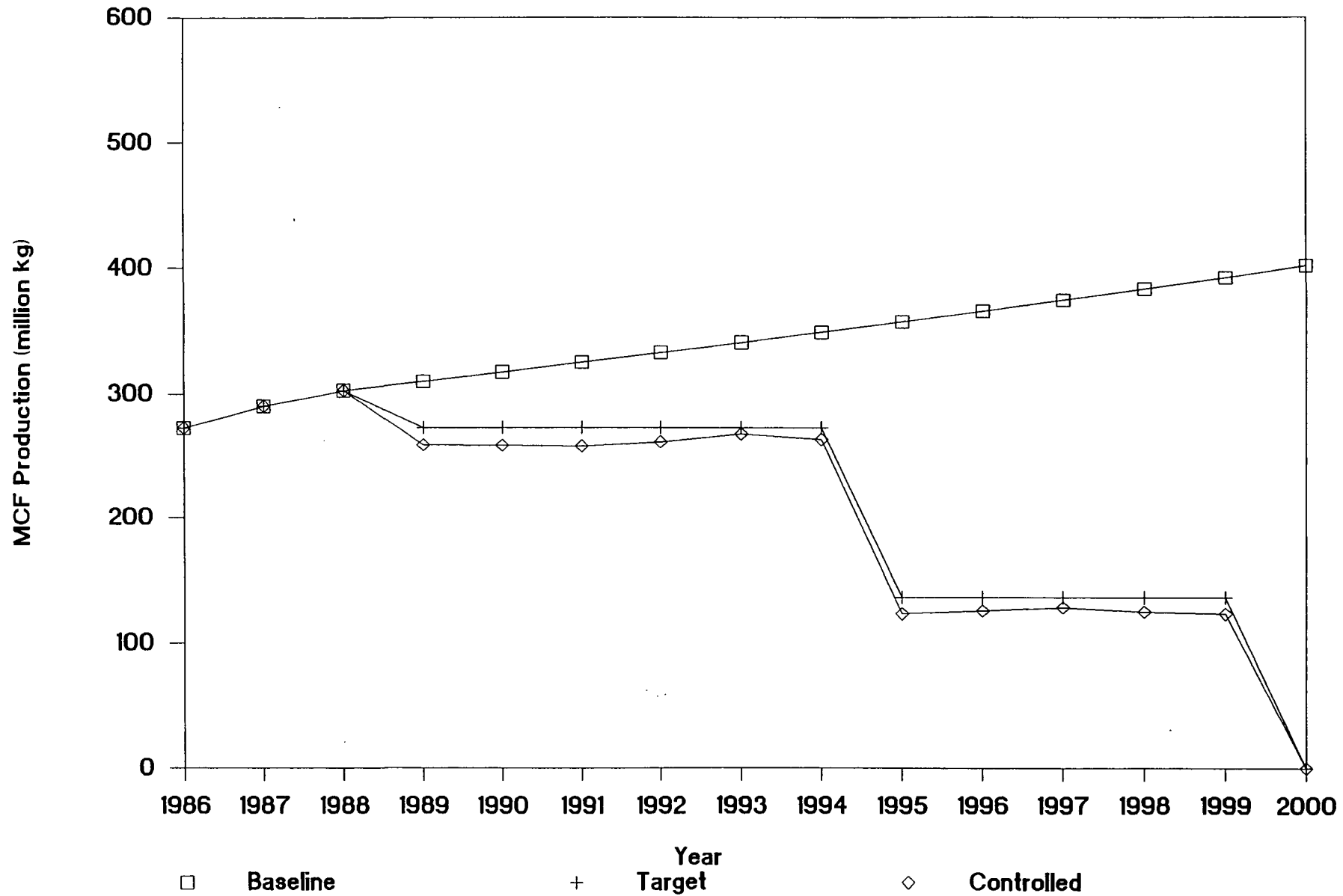
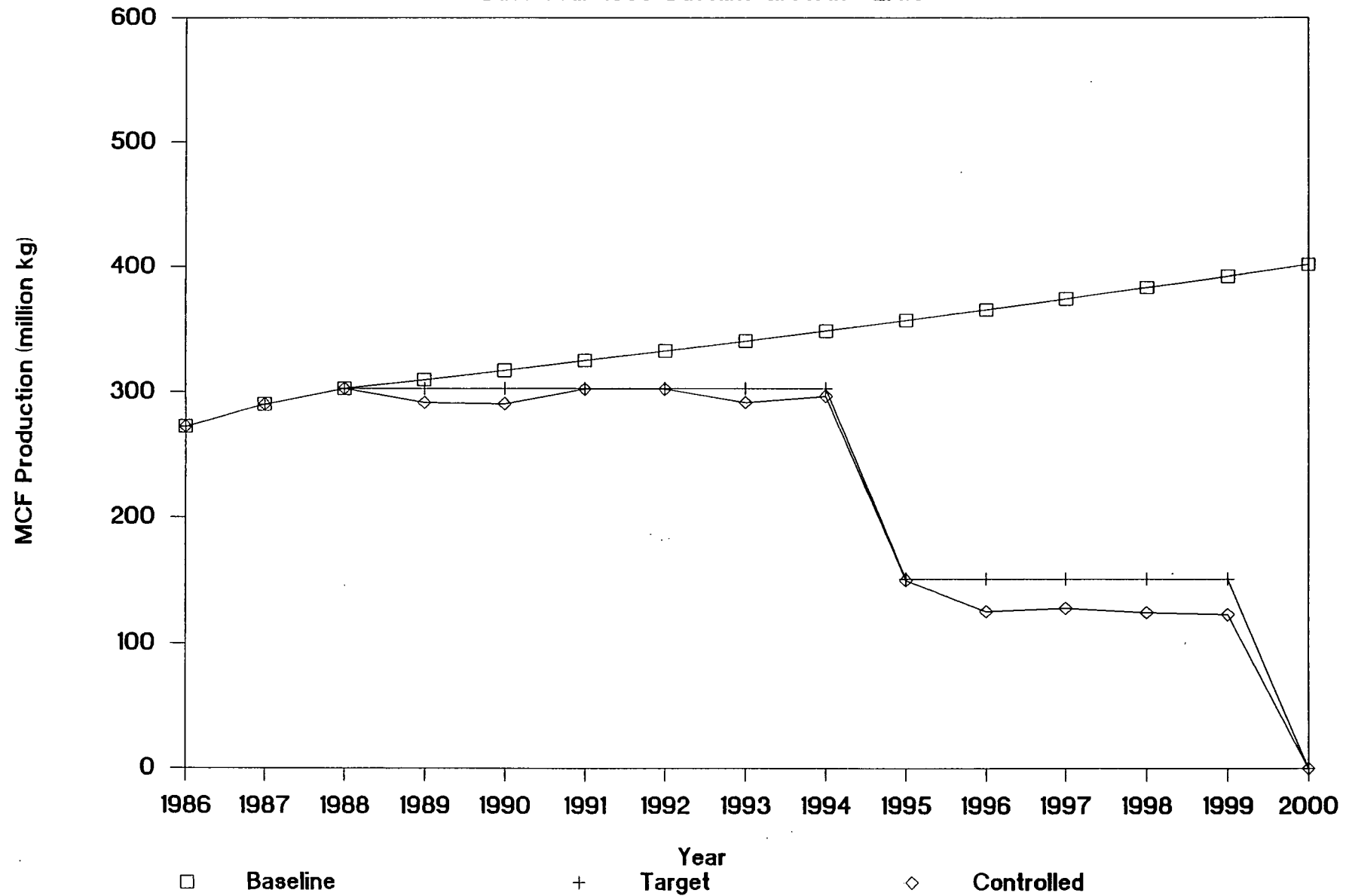


EXHIBIT 28

PHASE-OUT OF MCF PRODUCTION

Base Year: 1988: Baseline Growth = 2.4%



PHASE-OUT OF MCF PRODUCTION

Base Year: 1986: Baseline Growth = 2.2%

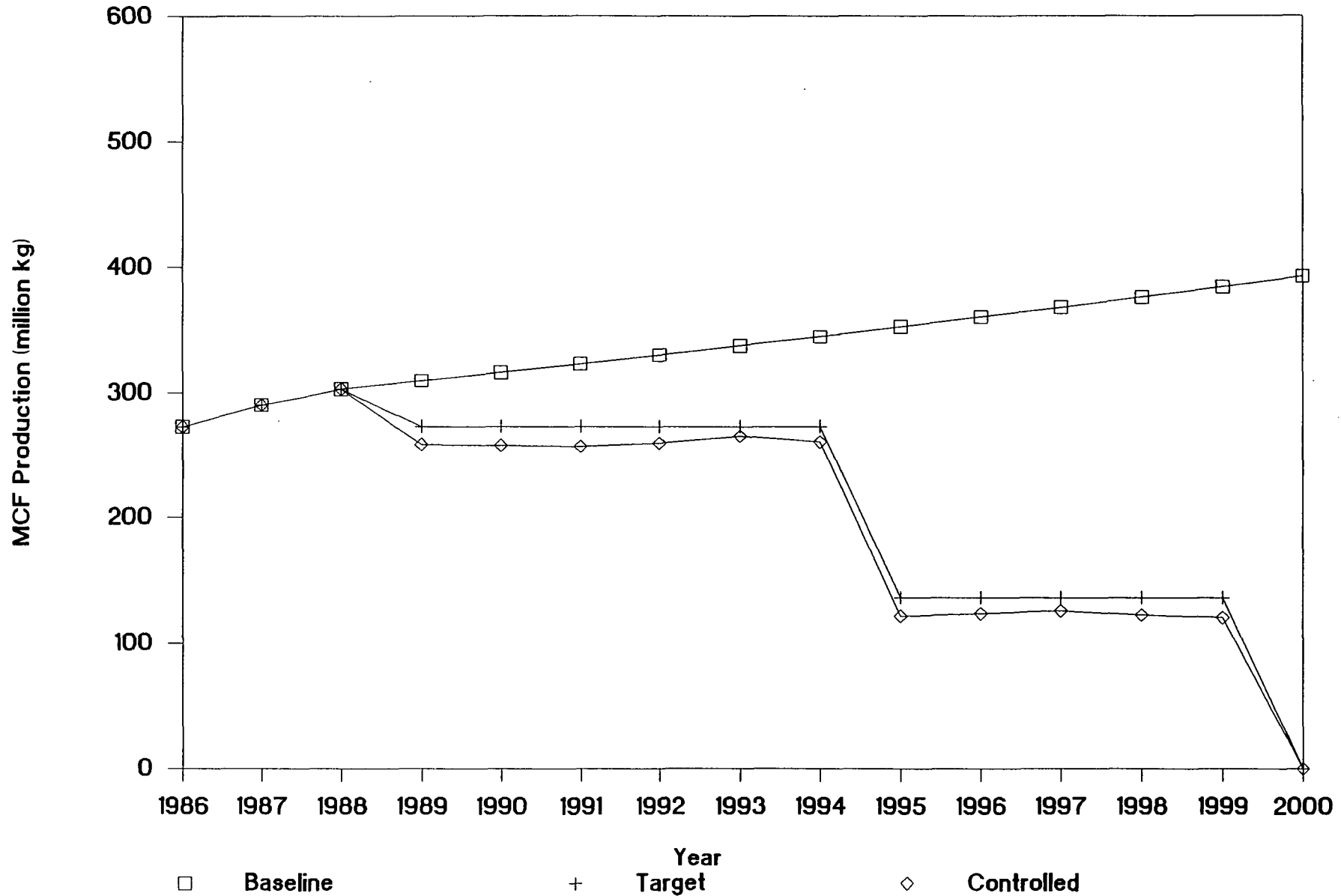


EXHIBIT 30

PHASE-OUT OF MCF PRODUCTION

Base Year: 1988; Baseline Growth = 2.2%

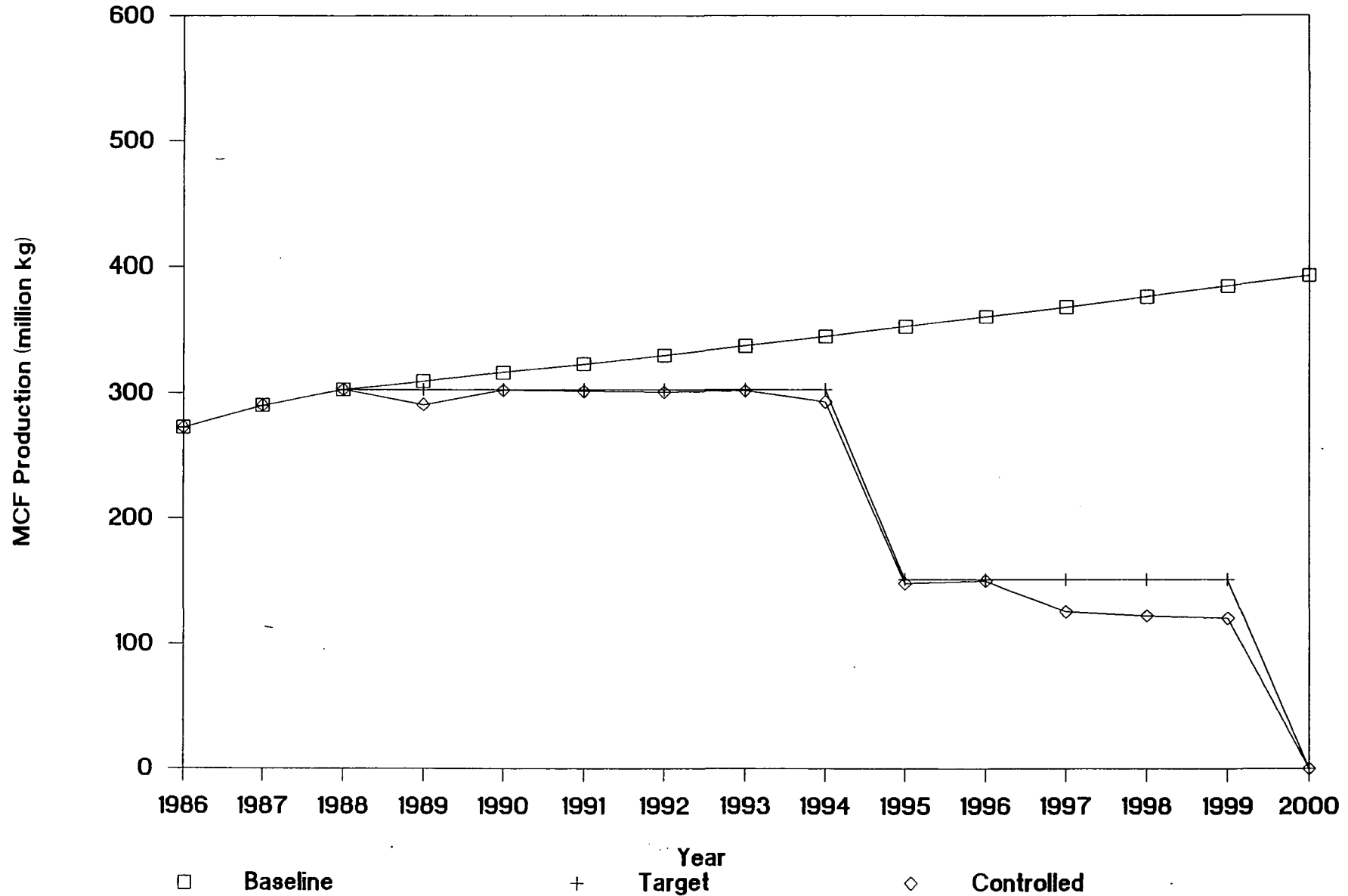
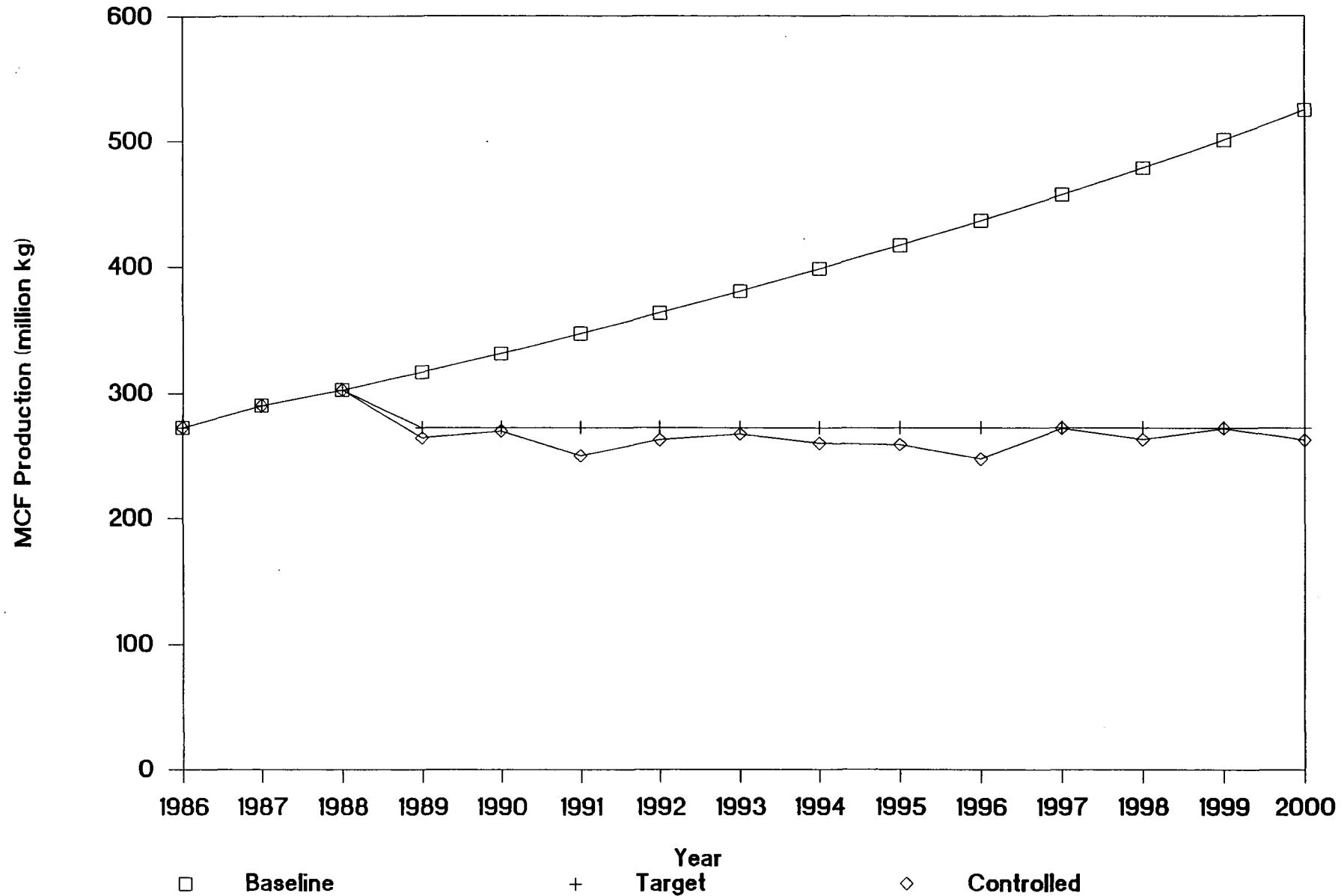


EXHIBIT 31

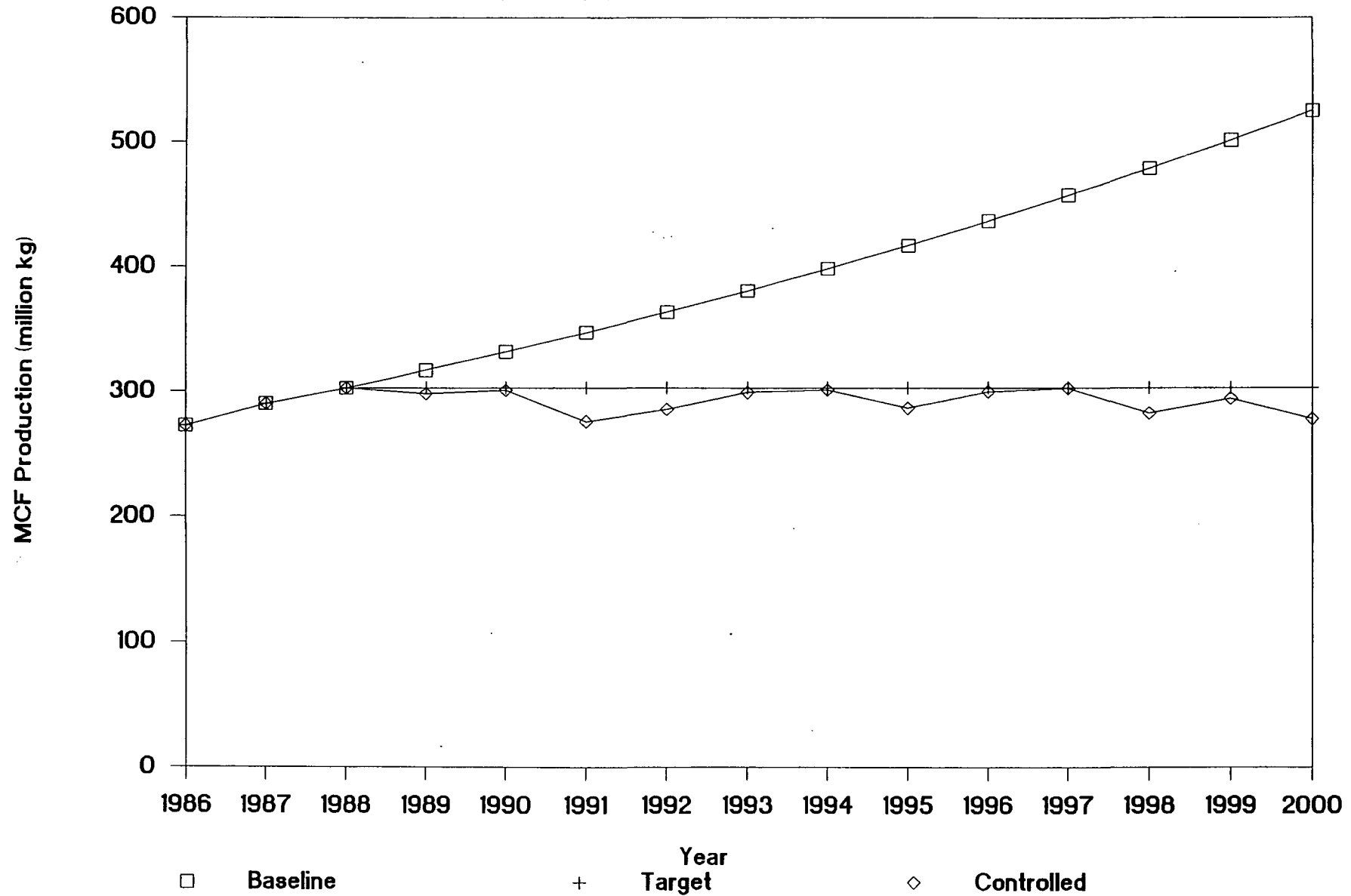
FREEZE OF MCF PRODUCTION

Base Year: 1986: Baseline Growth = 4.7%



FREEZE OF MCF PRODUCTION

Base Year: 1988: Baseline Growth = 4.7%



FREEZE OF MCF PRODUCTION

Base Year: 1986: Baseline Growth = 2.4%

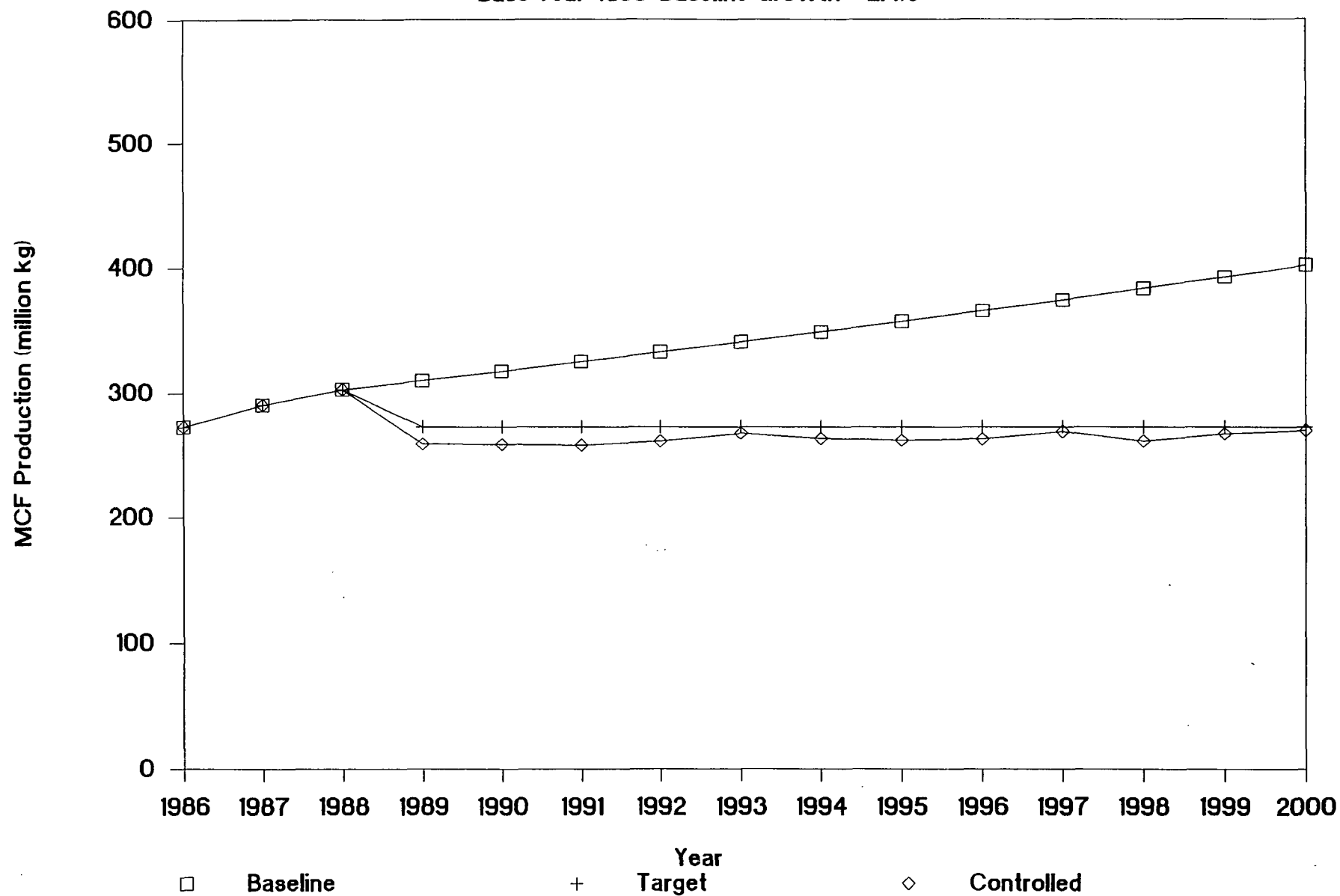
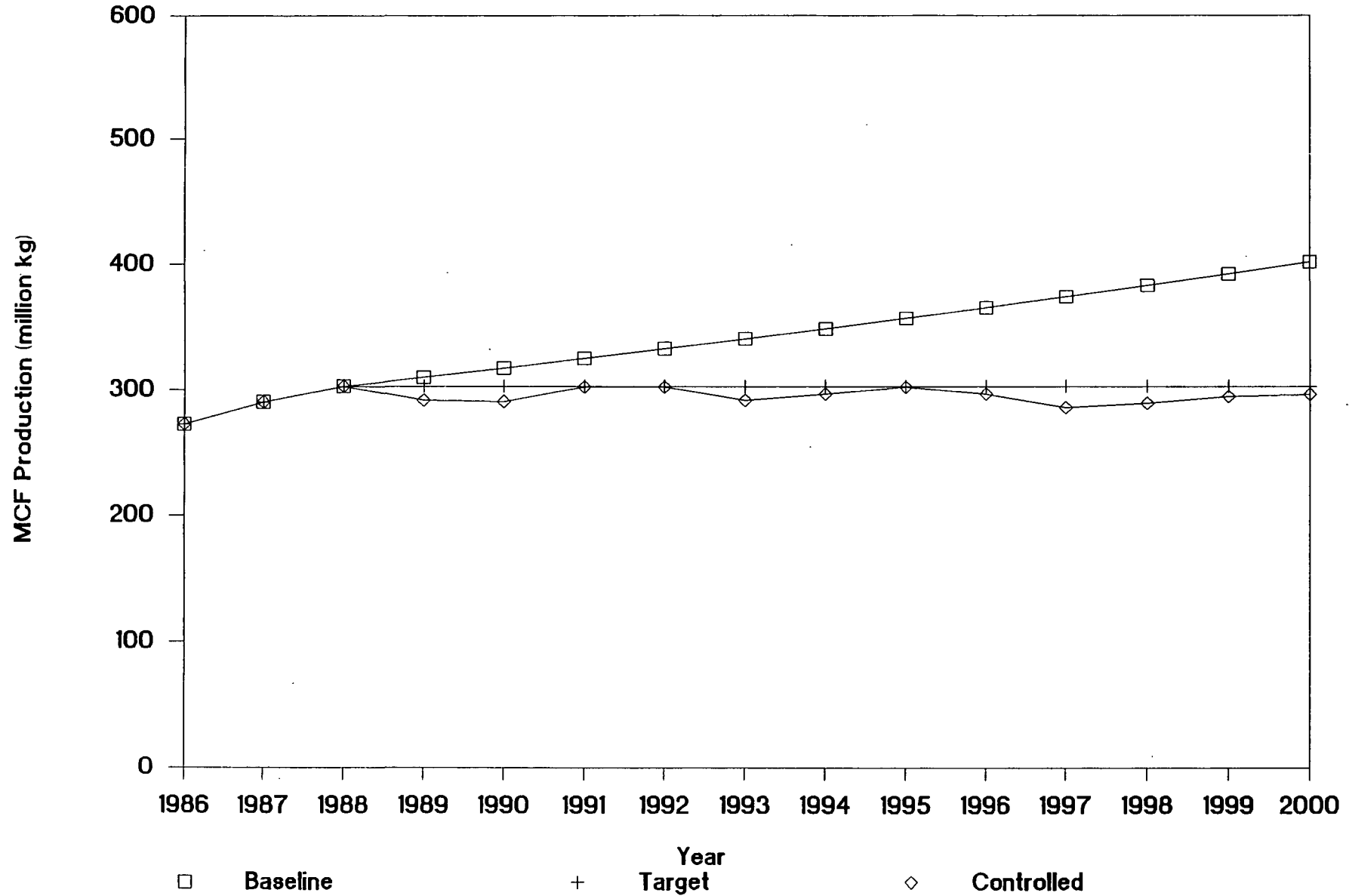


EXHIBIT 34

FREEZE OF MCF PRODUCTION

Base Year: 1988: Baseline Growth = 2.4%



FREEZE OF MCF PRODUCTION

Base Year: 1986: Baseline Growth = 2.2%

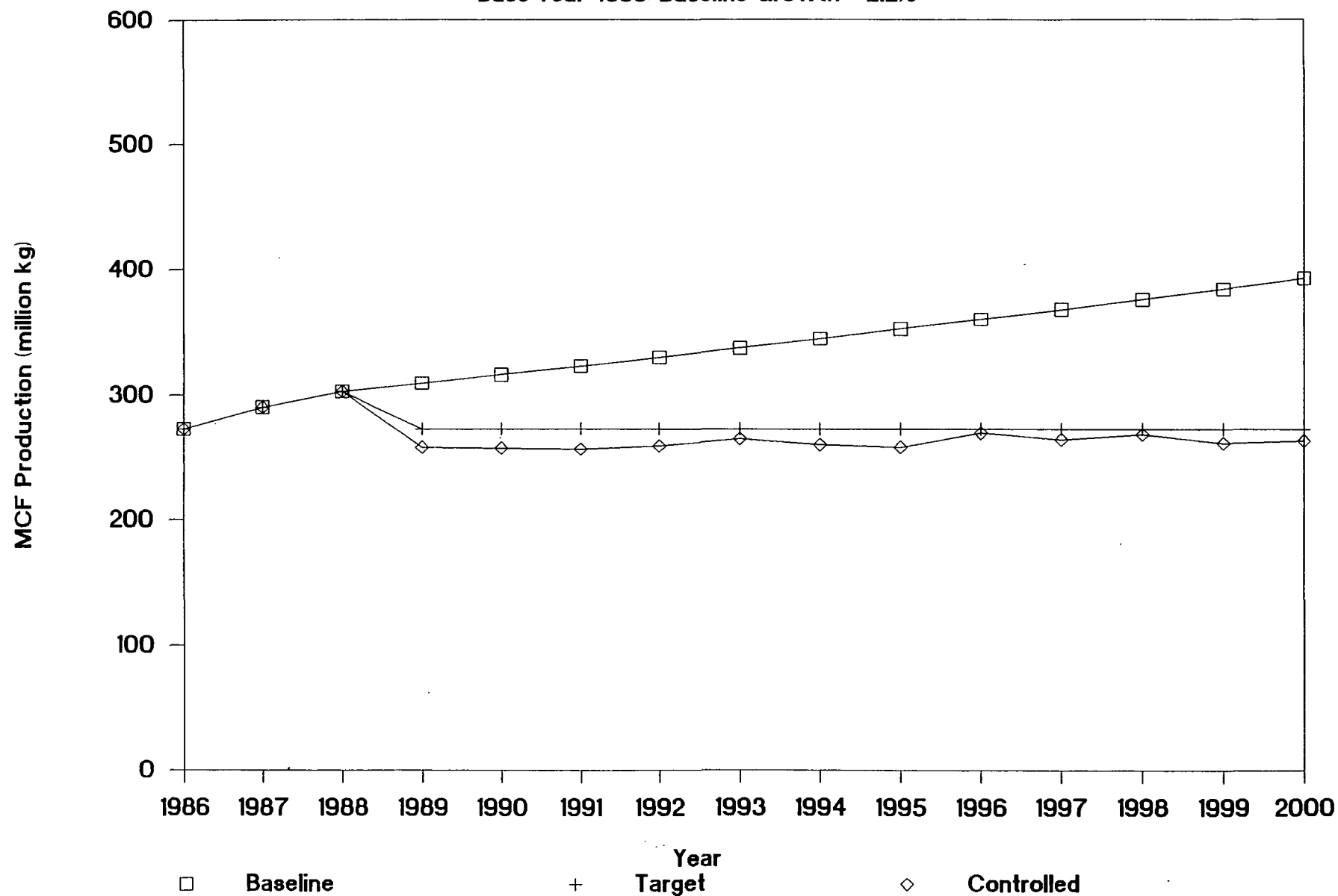
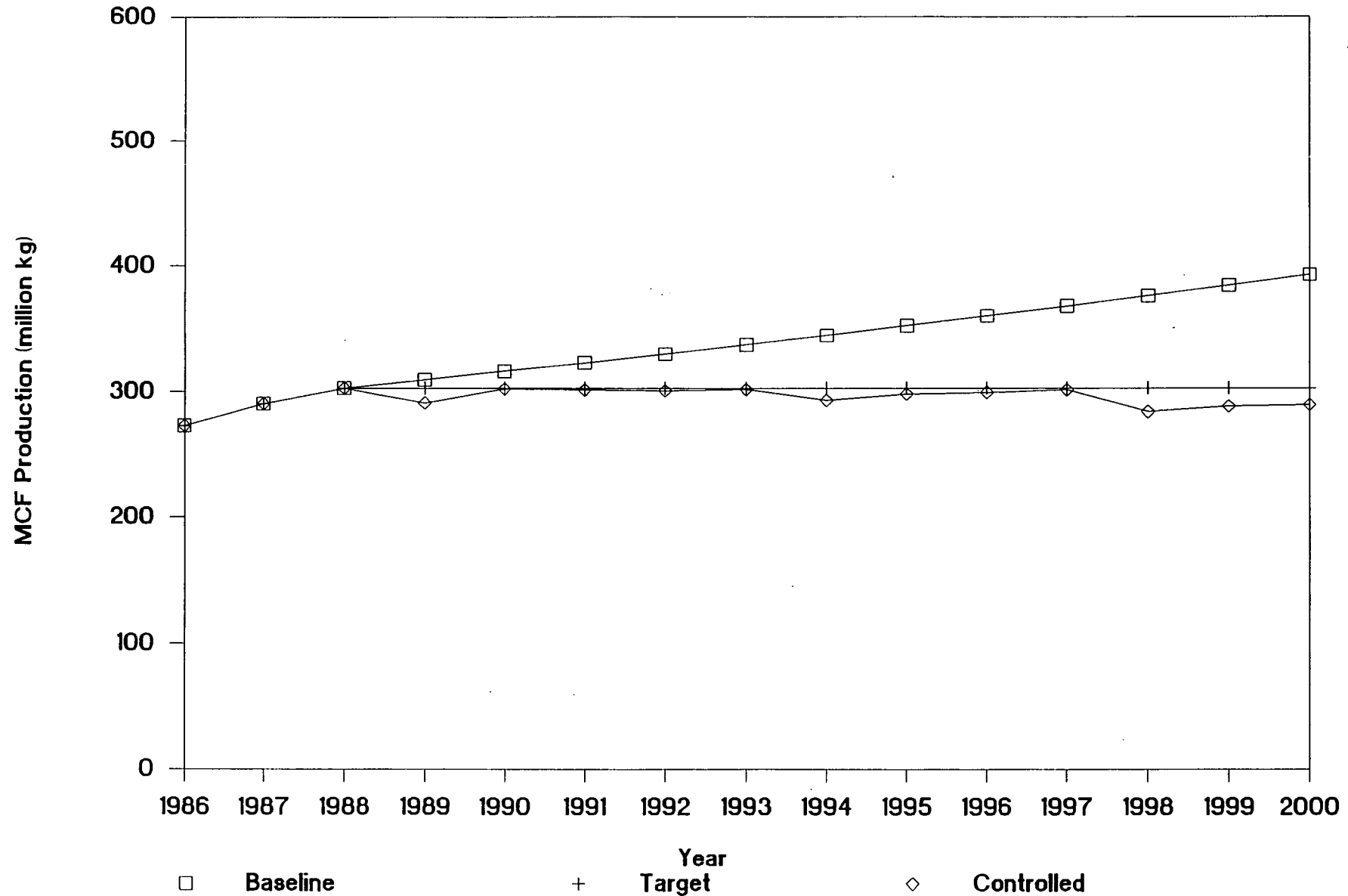


EXHIBIT 36

FREEZE OF MCF PRODUCTION

Base Year: 1988: Baseline Growth = 2.2%



APPENDIX A: CALCULATION OF INDUSTRY GROWTH RATES FOR METAL CLEANING AND ELECTRONICS

MCF demand will grow or decline as production in the industries using this solvent grows or contracts. To estimate the growth in the metal cleaning and the electronics industries (i.e., the vapor degreasing and cold cleaning end uses of MCF), this analysis uses historical growth rates reported in the "1989 U.S. Industrial Outlook" published by the Department of Commerce. The growth rate estimates presented below correspond to industries classified as 2-digit SIC codes which use methyl chloroform: seven SIC codes for metal cleaning industries and one SIC code for the electronics industry. These SIC codes account for most of the MCF consumption in these two end-uses¹:

			('82MM\$)
			1989 Industry
<u>SIC Code</u>	<u>Industry</u>	<u>Growth Rates</u>	<u>Shipments</u>
<u>Metal Cleaning:</u>			
25	Furniture & Fixtures	+1.9%	15.3
33	Primary Metal Industries	-0.8%	65.2
34	Fabricated Metal Products	+1.1%	54.0
35	Machinery, except Electrical	-0.2%	72.9
37	Transportation Equipment	+3.0%	286.2
38	Instruments and Related Products	+4.8%	67.6
39	Misc. Manufacturing Industries	+1.1%	14.3
	Weighted Average Growth Rate:	+2.1%	575.5
<u>Electronics:</u>			
36	Electric & Electronic Equipment	+8.7%	233.8

The U.S. Industrial Outlook (1989) reports average annual growth rates for the period 1984-1989 for 4-digit SIC codes; thus, an aggregation of these figures is needed to arrive at estimates for 2-digit SIC codes presented above. Exhibit A-1 shows the calculation of the weighted average annual growth rates including all of the 4-digit SIC codes corresponding to a 2-digit SIC code. The 4-digit averages are weighted using 1989 industry shipments in constant (1982) dollars².

¹ MCF may also be used for degreasing applications in SIC 75, Automobile Repair, Services & Parking; however, the U.S. Industrial Outlook does not report growth rates for this industry.

² A more rigorous approach would be to weight these growth rates by solvent consumption in each SIC code; however, based on previous research this methodology has proved difficult to implement because of the lack of information on solvent use by SIC code.

EXHIBIT A - 1. WEIGHTED AVERAGE GROWTH RATES FOR METAL CLEANING AND ELECTRONICS.

SIC	Industry Title	1989 INDUSTRY SHIPMENTS (BILL. \$2\$)	COMPOUND ANNUAL GROWTH 89/84	WEIGHTED GROWTH RATE
		(1)	(2)	(1)*(2)/ (1)
2511	Wood Household Furniture	6.615	1.8	
2512	Upholstered Household Furniture	4.875	3.1	
2514	Metal Household Furniture	1.865	0.8	
2515	Mattresses and Bedsprings	1.942	0.5	
25	Furniture and Fixtures	15.297		1.927 =====
331A	Steel Mill Products \a	46.946	-0.6	
332	Iron and Steel Foundries	9.845	-1.7	
3331	Primary Copper	2.800	-1.2	
336	Nonferrous Foundries	5.645	-0.6	
33	Primary Metals	65.236		-0.792 =====
3411	Metal Cans	11.567	0.8	
3441	Fabricated Structural Metal	7.746	-1.1	
3448	Prefabricated Metal Buildings	3.020	4.7	
3451	Screw Machine Products	3.300	3.0	
3452	Bolts, Nuts, Rivets, and Washers	5.090	2.5	
3465	Automotive Stampings	14.500	1.4	
3494	Valves and Pipe Fittings	8.740	0.1	
34	Fabricated Metal	53.963		1.088 =====
3523	Farm Machinery and Equipment	6.835	-6.0	
3524	Lawn and Garden Equipment	3.273	2.2	
3531	Construction Machinery	13.350	2.0	
3532	Mining Machinery	1.593	0.3	
3533	Oilfield Machinery	3.779	-8.8	
3541	Metal-Cutting Machine Tools	2.657	-2.9	
3542	Metal-Forming Machine Tools	1.911	8.6	
3546	Power Driven Handtools	2.080	1.2	
3551	Food Products Machinery	2.238	0.4	
3552	Textile Machinery	1.118	1.9	
3554	Paper Industries Machinery	1.944	10.7	
3555	Printing Trades Machinery	2.655	1.7	
3561	Pumps and Pumping Equipment	5.883	0.8	
3562	Ball and Roller Bearings	3.792	0.7	
3563	Air and Gas Compressors	3.041	-0.2	
3585	Refrigeration and Heating Equipment	14.332	-0.9	
3592	Carburators, Pistons, and Rings, Etc.	2.464	-3.4	
35	Machinery, Electric	72.945		-0.204 =====

(CONTINUED)

EXHIBIT A - 1. WEIGHTED AVERAGE GROWTH RATES FOR METAL CLEANING AND ELECTRONICS.

SIC	Industry Title	1989 INDUSTRY SHIPMENTS (BILL. \$)	COMPOUND ANNUAL GROWTH 89/84	WEIGHTED GROWTH RATE
		(1)	(2)	(1)*(2)/ (1)
3612	Transformers	2.997	-0.3	
3613	Switchgear and Switchboard Apparatus	4.809	-2.2	
3621	Motors and Generators	6.196	0.2	
3622	Industrial Controls	5.241	1.3	
3631	Household Cooking Equipment	2.730	-3.5	
3632	Household Refrigerators and Freezers	3.327	2.8	
3633	Household Laundry Equipment	3.410	5.4	
3634	Electric Housewares and Fans	2.685	-2.7	
3635	Household Vacuum Cleaners	1.410	2.1	
3636	Sewing Machines	0.175	1.2	
3639	Household Appliances, n.e.c.	2.200	1.8	
364A	Lighting Fixtures \b	5.209	2.5	
3643	Current-carrying Wiring Devices	2.997	-1.1	
3644	Noncurrent-carrying Wiring Devices	2.036	-1.4	
3647	Vehicular Lighting Equipment	1.650	3.9	
3651	Radio and Television Receiving Sets	12.843	8.3	
3661	Telephone and Telegraph Apparatus	14.796	-0.5	
3662	Radio and TV Communication Equipment	51.465	6.6	
367	Electronic Components and Accessories \c	93.120	16.6	
3691	Storage Batteries	2.991	-1.3	
3693	X-ray and Electromedical Apparatus	5.903	3.9	
3694	Engine Electrical Equipment	5.586	-0.6	
36	Electric/Electronic Equipment	233.776		8.661 =====
3711	Motor Vehicles and Car Bodies	108.470	-0.8	
3713	Truck and Bus Bodies	3.761	3.8	
3714	Motor Vehicle Parts and Accessories	56.444	1.8	
3715	Truck Trailers	3.083	-0.6	
3716	Motor Homes	2.013	0.2	
3721	Aircraft	35.450	7.3	
3724	Aircraft Engines and Engine Parts	19.400	8.9	
3728	Aircraft Equipment, n.e.c.	19.920	5.4	
3731	Ship Building and Repairing	7.000	-4.8	
3751	Motorcycles, Bicycles, and Parts	1.025	-1.4	
3761	Guided Missiles and Space Vehicles	23.900	14.1	
3764	Space Propulsion Units and Parts	3.520	5.9	
3769	Space Vehicle Equipment, n.e.c.	2.240	-8.0	
37	Transportation Equipment	286.226		3.045 =====

(CONTINUED)

EXHIBIT A - 1. WEIGHTED AVERAGE GROWTH RATES FOR METAL CLEANING AND ELECTRONICS.

SIC	Industry Title	1989 INDUSTRY SHIPMENTS (BILL. \$2\$)	COMPOUND ANNUAL GROWTH 89/84	WEIGHTED GROWTH RATE
		(1)	(2)	(1)*(2)/ (1)
3811	Engineering and Scientific Instrument	4.871	8.9	
3822	Environmental Controls	1.881	0.7	
3823	Process Control Instruments	4.125	2.8	
3824	Fluid Meters and Counting Devices	1.022	6.4	
3825	Instruments to Measure Electricity	7.765	1.3	
3829	Measuring and Controlling Devices	3.057	7.7	
3832	Optical Instruments and Lenses	7.511	7.8	
3841	Surgical and Medical Instruments	6.682	9.1	
3842	Surgical Appliances and Supplies	9.034	6.7	
3843	Dental Equipment and Supplies	1.451	5.1	
3861	Photographic Equipment and Supplies	20.211	2.1	
38	Instruments	67.610		4.824 =====
3911	Jewelry and Precious Metals	3.455	2.2	
3914	Silverware and Plated Ware	0.473	-2.4	
3931	Musical Instruments	0.713	-1.5	
3942,44	Dolls, Games and Toys \d	3.338	-7.9	
3949	Sporting & Athletic Goods	5.292	7.2	
3961	Costume Jewelry	1.063	-1.1	
39	Misc. Manufacturing Industries	14.334		1.113 =====
	TOTAL FOR ALL INDUSTRIES	809.387		

\a 331A includes SIC 3312, 15, 16, 17

\b 364A includes SIC 3645, 46, 48

\c 367 includes SIC 3671-2, 3674-9

Annual growth rate calculated for 89/85

\d SIC's 3942, 44 - Annual growth rate for 86/81

Source: U.S. Industrial Outlook, 1989

APPENDIX B: DESCRIPTION OF METHOD USED TO PROJECT SOLVENT SUBSTITUTION IN THE AEROSOLS INDUSTRY

With the increased regulatory attention to methylene chloride and perchloroethylene, the use of methyl chloroform might increase as producers using other chlorinated solvents search for alternatives. The consumption of chlorinated solvents in various aerosol product categories has been estimated in a previous analysis (ICF 1989a) by means of the following calculation:

Pounds of chlorinated solvent = (weight concentration of the solvent in formulation X) * (weight of average can) * (market share of formulation) * (number of cans filled in category)

Using this formula and data for the market size, aerosol formulations, and can sizes available in 1987, the methyl chloroform consumption is estimated at 41 million pounds in the base case (ICF 1989a). Assuming regulatory restrictions are imposed on the use of methylene chloride and perchloroethylene, the choices currently available to producers include:

- switch to an existing formulation that uses only methyl chloroform as the primary solvent if available;
- reformulate to a new formulation that uses methyl chloroform as the primary solvent; and
- switch to a non-chlorinated alternative.

The consumption of MCF is projected assuming that manufacturers will reformulate aerosol products eliminating methylene chloride and perchloroethylene and switching to MCF. If non-chlorinated alternatives exist, the methyl chloroform formulation will share the market with these formulations in amounts proportional to their 1987 market shares, excluding the portion of the market occupied by the regulated formulations¹. This methodology is applied to all aerosol product categories resulting in a projected MCF consumption of 62 million pounds. Assuming that this increased MCF demand occurred in 12 years, the annual increase is 3.5 percent².

¹For example, assume that the methylene chloride formulation has a market share of 40 percent, the MCF formulation accounts for 20 percent and the non-chlorinated formulation accounts for 40 percent of the 1987 market. As substitution occurs, the MCF formulation will take one third (20/60) of 40 percent and the non-chlorinated formulation will take the remaining two thirds of 40 percent.

² $(62/41)^{(1/12)} = 1.035$, or 3.5 percent.

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