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UNITED NATIONS ENVIRONMENT PROGRAMME
INDUSTRY AND ENVIRONMENT

Technologies for Protecting the Ozone Layer

Catalogue

Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride

SOURCE BOOK

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The reviewers listed in this document have reviewed one or more interim drafts of this document, but have not reviewed this final version. These reviewers are not responsible for any errors which may be present in this document or for any effects which may result from such errors.

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Foreword

Mounting scientific research has implicated chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs) and methyl bromide in the depletion of the stratospheric ozone layer, that segment of the earth's atmosphere which protects animal and plant life from the damaging effects of ultraviolet radiation. In September 1987, nations concerned about this crisis signed the Montreal Protocol, a landmark agreement that identified the major ozone-depleting substances (ODSs) and established a timetable for the reduction and eventual elimination of their use. Under the Protocol and its amendments, ODS production and consumption of the controlled substances are to be reduced and eliminated through the development of chemical substitutes and alternative manufacturing processes. Information exchange is crucial in order to realize this global phaseout.

As an Implementing Agency of the Multilateral Fund for the Implementation of the Montreal Protocol (MF), one role of the United Nations Environment Programme (UNEP) is to provide Article 5 (i.e., developing) countries with the latest technical information to assist their expeditious phaseout of controlled ODS. Through various regular feedback mechanisms with the concerned countries, UNEP's Industry and Environment Programme Activity Centre (UNEP IE/PAC) has perceived the broad information needs of Article 5 countries to be:

- *what are the technical options that currently exist to eliminate ODS;*
- *who are the suppliers of the technologies, equipment and products required for each technical option; and*
- *how can a company assess, select, and implement an alternative technology.*

In response to each of these demonstrated needs, UNEP IE/PAC's OzonAction programme under the Multilateral Fund is producing a series of technical reference publications and guidelines that will assist industry in developing countries to make the transition from ODS to non-ODS alternatives, including the development of ODS phase-out projects. As part of the series of sector-specific *Catalogues of Technologies for Protecting the Ozone Layer,* this publication is intended to assist industry and governments in Article 5 countries with:

- identifying alternative technologies in the aerosols, sterilants, carbon tetrachloride, and miscellaneous uses sectors; and
- initiating related ODS phase-out projects.

Assistance Available to Article 5 Countries from UNEP IE/PAC

Technical Options

To address the need to understand the available technical options, UNEP IE/PAC has produced a series of easy-to-read brochures that provide an overview of the options available to companies and organizations seeking to eliminate their ODS use. The *Protecting the Ozone Layer* technical brochure series is based on the UNEP Technical Options Committee reports, which are also available to developing countries through UNEP IE/PAC.

The brochures are designed for decision-makers in government and industry, and make an excellent introduction to the alternatives in the aerosols, foams, halons, solvents, and refrigeration sectors.

Technology Suppliers

Once the technical options are understood, the next step a developing country must face is to select an appropriate option and then identify the wordwide suppliers of the alternative technologies and equipment. In response to this need, UNEP IE/PAC is producing a series of *Catalogues of Technologies for Protecting the Ozone Layer* for the major ODS use sectros (aerosols, foams, solvents, and refrigeration). These technical references provide descriptions of the current ODS uses in the sector, an overview of what ODS alternatives currently exist, and contacts for the suppliers of the alternative technologies. These catalogues are being developed with the cooperation of the UNEP Technical Option Committees, and one has been co-produced with USEPA and industry associations such as ICOLP.

These sector-specific catalogues are targeted at plant engineers and managers responsible for identifying, evaluating, and implementing these alternatives. It is also expected that the governments ODS officers in the national ozone units in developing countries will use them as they work with their industry, Implementing Agencies, and others to develop ODS phase-out projects.

Assessment and Implementation

The next step a company or government must take after the technology is selected and the suppliers are identified is to successfully implement the chosen technology. UNEP IE/PAC is assisting the process through two publications:

- *Practical Guide to Policy Guidelines for Industry on Management of Phase-out of ODS.* The guide is a practical document whose objective is to help industry in developing countries, specifically small and medium-sized enterprises (SMEs), to better manage and accelerate their phase-out of ozone depleting substances controlled under the Montreal Protocol. It is intended to be a "management guideline" document for business managers.

- *Elements for Establishing Policies, Strategies and Institutional Framework for Ozone Layer Protection.* This manual will provide governments in developing countries with guidelines for establishing an ODS phase-out policy and strategy, including the supporting actions, in particular the establishment of an "ozone office" in developing countries.

Acknowledgements

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UNEP IE/PAC wishes to thank all of the above contributors and their employers for helping to make this catalogue possible.

Getting Started

The following is a step-by-step guide to using this document. Taking these steps will ensure that the reader makes the best possible use of the catalogue.

Step 1: Read the "Introduction" section

Read the brief introduction at the beginning of the catalogue. It provides a summary of the problem of ozone-depletion, the relevant international regulations driving the phaseout of ozone-depleting substances, and the content of the catalogue.

Step 2: Read relevant portions of the User's Guide

All readers should carefully read the first four pages of the User's Guide which describe the complete set of criteria that should be considered in the evaluation of alternative technologies. Those sections of the User's Guide which apply to the relevant use of ozone-depleting substances -- aerosol products, sterilants, tobacco expansion, or carbon tetrachloride uses -- should be read next. Each section summarizes the information presented in detail in the datasheets.

Step 3: Read the "Disclaimer"

The disclaimer provides important information about the nature of the information presented in the catalogue.

Step 4: Identify and read relevant datasheets

Use the Table of Contents to identify relevant datasheets and then read all of the relevant datasheets. Identify those alternatives about which additional information is needed.

Step 5: Gather additional information on potential alternatives

Readers may wish to use the list of vendors provided at the end of each datasheet to gather additional information on alternatives of interest. Trade publications, industry experts, conferences, and in-house staff may also be good sources of information. Additional information may also be available from UNEP IE/PAC's OzonAction database.

Introduction

The Montreal Protocol and the Multilateral Fund

In 1974, Sherwood Rowland and Mario Molina of the University of California claimed that the man-made chemicals known as chlorofluorocarbons (CFCs) were damaging the stratospheric ozone layer. Subsequent research supported the theory, and it is now established that the stratospheric ozone layer -- which protects the earth from dangerously high levels of ultraviolet radiation from the sun -- is being destroyed by human activity. Ozone depleting substances (ODSs) including CFCs and carbon tetrachloride are used in the manufacture and operation of thousands of products, including aerosol products, sterilants, solvent applications, and miscellaneous uses.

The Montreal Protocol on Substances that Deplete the Ozone Layer was drawn up under the guidance of the United Nations Environment Programme (UNEP) in September 1987. The Protocol identified the main ODSs, and set specific limits on their production and consumption levels in the future. As of March 1994, 133 countries had ratified the agreement, with universal ratification quite probable in the near future.

London Amendments to the Montreal Protocol

It is intended that the Protocol be continually updated as necessary to reflect the changing scientific evidence and technological developments. In June 1990, the Parties to the Protocol met in London to consider the implications of new scientific evidence that showed that the ozone layer was being depleted even faster than originally thought. The London meeting agreed to phase out the consumption and production of CFCs and halons by the year 2000, and to control other chemicals, namely carbon tetrachloride and 1,1,1-Trichloroethane.

The London Amendments acknowledged the financial and technical assistance that developing countries would need, and to meet this need the Parties established the Multilateral Fund (MF) as part of financial mechanism. The MF serves all countries that operate under paragraph 1 of Article 5 of the Protocol (known as "Article 5 countries"). UNEP, the United Nations Development Programme (UNDP), and the World Bank were chosen to be the Fund's original implementing agencies, with the United Nations Industrial Development Organization (UNIDO) being added after. UNEP's responsibility as an implementing agency is to conduct research, gather data, and to provide a clearinghouse function.

Copenhagen Amendments to the Montreal Protocol

At their fourth meeting in Copenhagen, Denmark (November 1992), the Parties took decisions that advanced the phase-out schedules in non-Article 5 (i.e., developed) countries for several ODSs, included methyl bromide and HCFCs as new controlled substances, and continued the financial mechanism to assist Article 5 countries.

The London and Copenhagen Amendments were ratified by the required number of parties, and both amendments have entered into force.

Bangkok Meeting of the Parties

At their fifth meeting in Bangkok, Thailand (November 1993), the Parties approved a budget of US$ 510 million for the MF for the 1994-96 period. In light of the availability of banked halons and the efficiency of technical alternatives to halons; the Parties decided that in 1994 no exemptions for production of halon for essential uses were necessary for developed countries. The Parties also agreed, inter alia, that information on HCFC and methyl bromide alternatives and substitutes be updated annually.

Signatories to the Protocol have agreed to reduce and eliminate the use of the controlled ODSs even though substitutes and alternatives technologies were not yet fully developed. Industries and manufacturers are starting to replace the controlled ODSs with less damaging substances, but a major obstacle in the conversion process is a lack of up-to-date, accurate information on issues relating to ODS substitutes and ODS-free technologies. UNEP is meeting this challenge through its OzonAction programme (see Annex A).

Purpose of the Catalogue

This catalogue is intended to help industry in developing countries make a transition from ozone depleting substances to alternatives that do not threaten the ozone layer. It is targeted primarily at plant engineers and managers responsible for identifying, evaluating, and implementing these alternatives. It is expected that government policy makers in developing countries will also find it useful as they work with industry, bilateral agencies and agencies of the Multilateral Fund responsible for implementation of the Montreal Protocol.

While ODSs are used in a wide range of applications, this document focuses on four key industry sectors, including:[1]

- Aerosols where ODSs are used as propellants and/or solvents,
- Sterilants where CFCs are used as a carrier gas,
- Cleaning applications where carbon tetrachloride (CTC) is used as a solvent,[2] and
- Tobacco expansion where CFCs are used to restore the volume of tobacco leaves during the production process.

This document consists of two principal components: a Users' Guide for selecting non-ODS alternatives and series of datasheets.

Users' Guide

The first section of the document is intended to guide the reader through the process of identifying, evaluating, and implementing alternatives to ODSs. Key considerations in this process are presented and include organizational issues, regulatory constraints, cost and economic factors, environmental impacts, health issues, safety concerns, and technical matters.

[1] *Materials distributed by the United Nations Environment Programme address use of ODSs in other applications.*

[2] *Only uses of CTC as a solvent are addressed in this document, reflecting the findings of the 1991 UNEP Technical Options Committee that "use of CTC in developing countries is small and is principally for cleaning applications."*

The Users' Guide places some emphasis on technical matters by first briefly characterizing available technologies and then reviewing key performance characteristics that are crucial to the choice of an appropriate alternative. In addition, emerging technologies not yet available on a widespread basis are briefly reviewed so as to offer readers a perspective on technologies that may be available in the future. Because these technical issues are specific to the industry sector under consideration, the section of the Users' Guide related to technical matters is divided into three subsections: aerosols, sterilants, and CTC solvent cleaning. The Users' Guide does not contain a separate section on the technical issues associated with implementing CFC substitutes in the tobacco expansion sector because all of the relevant material is presented later in the document in single datasheet.

Datasheets

The second section of the document presents a series of 17 datasheets on specific technical alternatives. One datasheet, for example, addresses use of hydrocarbons as aerosol propellants while another focuses on use of steam sterilization in lieu of a process using CFCs. Datasheets have been prepared only for those technologies that are commercially available. As a result, the datasheets represent a "catalogue" from which industry in developing countries may be able to select an appropriate alternative technology.

The purpose of the datasheets is to present detailed and specific information on a particular alternative so as to facilitate evaluation and implementation of the alternative in the field. A key feature of the datasheets is the inclusion of a list of vendors around the world who offer the technology and bibliographic references that direct the reader to additional sources of information. In addition, the datasheets provide the following types of information:

- Summary Headline
- Industry Sector
- ODS Reduction Method
- Composition of Alternative
- Toxicity
- VOC Classification
- Ozone Depletion Potential
- Global Warming Potential
- Phaseout Schedule (if any)
- Performance Characteristics
- Substitute Production Method and Materials
- Health and Safety Considerations
- Environmental Considerations
- Associated Costs
- Current Use
- Availability

It is important to note that the information in the datasheets is of necessity summarized in a general format. The immense variety of industrial applications throughout the developing world makes it impossible to capture all of the relevant material in a single summary document. In addition, the set of available alternatives is not static. Because vendors are working hard to develop and offer new technologies, the information contained herein may become somewhat dated over time. As more information becomes available, UNEP IE/PAC will make updates of the catalogue and distribute to the focal points in the Article 5 countries.

Request for Information

The catalogues are "**living**" documents that will be updated on a regular basis to reflect technological advancements, new products, and changing control measures.

Information is welcome both on alternatives to uses covered in the catalogue as well as on alternatives not discussed.

If your technology or equipment should be included in the next version, please use the form in Annex E to supply this information to:

United Nations Environment Programme
Industry and Environment Programme Activity Centre
39-43 Quai André Citroën
75739 Paris Cedex 15
France
Fax: (33) 1 44 37 14 74

Users of ODSs are advised to use this document as a starting point in their search for alternatives. The search is also likely to include review of available technical literature, consultations with several vendors and trade associations, testing and evaluation of multiple alternatives, and careful review and consideration by in-house engineers and managers. Such an approach can maximize the opportunity for a successful and cost-effective transition away from use of ozone depleting substances.

1. User's Guide for Selecting Non-ODS Alternatives

1. User's Guide for Selecting Non-ODS Alternatives

1.1 Introduction

Plant managers should consider a variety of criteria when selecting an alternative technology to replace CFCs in aerosol, sterilant, carbon tetrachloride, and miscellaneous use sector applications. These criteria may be categorized as follows:

- Organizational
- Regulatory
- Economic
- Environmental, Health, and Safety
- Technical

This section discusses the various criteria that fall into each of these five groups. Because organizational, regulatory, economic, environmental, health, and safety criteria are generally applicable to each end use, these considerations are discussed first. Certain technical criteria, however, are only specific to one of the end uses discussed in this catalogue. For example, product dispersion characteristics are typically only of interest to those selecting an alternative aerosol propellant. Technical factors are therefore discussed by each end use in turn.

Organizational Considerations

When undertaking efforts to phase out ozone-depleting substances (ODS), company decision-makers and plant managers must carefully consider the relation between the organization's phaseout efforts and its other activities and priorities. Clearly, a company's phaseout of ODS is greatly facilitated if its management is fully committed to achieving such a goal. Other important organizational factors that may have a bearing on the choice of non-ODS technology include:

- ***Compatibility with corporate environmental policy.*** Some non-ODS alternatives generate other forms of emissions, effluents, or other wastes that are subject to the company's own environmental policies. In addition, if the company is a subsidiary of a foreign-owned corporation, the parent company's environmental policies may restrict the use of certain alternatives.

- ***Compatibility with other corporate objectives.*** Corporate policies may pose obstacles to implementing certain non-ODS technologies. In all cases, conflicts between such policies and the need to phase out ODS must be reconciled, with priority being given either to the old directive or to the demands of a phaseout. For example, a company may eliminate certain alternative technologies based on concern over product quality or performance, or it may decide that the change in quality or performance is acceptable given the impact of the new technology on its consumption of ODS.

- ***Feasibility given existing organizational structure.*** Any requirements of conversion projects must be compatible with the organizational structure of the firm. For example, if converting to a non-ODS technology requires that a plant be shut down temporarily while retrofits or full conversions are made (e.g., converting from a nonflammable propellant to a flammable one may require revamping the electrical system), the firm must have the ability to either accept the temporary loss of production capacity (e.g., by building up and then depleting product stocks) or match the loss in productive capacity at one plant with increases in production at other plants, or at the facility of a contract filler.

- ***Availability of capital.*** Perhaps the single greatest factor that impacts the ability of a plant to implement non-ODS technologies is the willingness of company management to devote the necessary capital resources. Again, the costs of converting to alternative technologies must be reconciled with competing demands for capital within the firm, and finally, they must be reconciled with the amount that management decides it is willing to spend on conversion projects. The availability of financing from the Montreal Protocol Multilateral Fund to cover the incremental costs of conversion projects in Article 5 (Developing) countries is intended to eliminate this impediment.

Regulatory Considerations

Plant managers must evaluate potential alternative chemicals or processes as to their compliance with a variety of government regulations. Alternatives should conform to the specific regulations that apply in the country where the alternative will be implemented. This may include both national and local regulations. In the United States, for example, alternatives must be evaluated vis-a-vis relevant sections of the 1990 Clean Air Act Amendments, as well as against state and local regulations that may deal with environmental aspects of alternatives such as emissions of volatile organic compounds (VOCs) or effluents from process wastewater. In Europe, "best available technology" (BAT) guidelines have been developed to control VOC emissions from certain types of ODS using processes. Exporters must be aware of relevant regulations in the countries to which they are exporting.

Economic Considerations

Process economics is a key factor in the selection of alternative technologies. Initial costs associated with an alternative process include capital cost of equipment, possible costs associated waste treatment/handling equipment, and costs for permit changes for new construction or new operating procedures. In addition, operating cost calculations incorporate costs for material, labor, maintenance, and utilities. Cost estimates for an alternative process can be developed through preliminary process design. One simple approach is to calculate the net present value (NPV) based on the discount rate and period of investment used by the company. The NPV is calculated as follows where (n) is the number of years, and (i) is the discount rate.

$$NPV = Cost_0 + Cost_1/(1+i) + Cost_2/(1+i)^2 + ... + Cost_n/(1+i)^n$$

While traditional economic considerations such as rate of return and payback period are important, the ODS reduction program may be justified on the basis of environmental protection and on the reliability of ODS supply. It is important to recognize that the price of ODS will rise rapidly as supplies dwindle. If cost savings that result from reduced ODS consumption are taken into consideration, then some alternative processes or substitute chemicals are likely to be significantly cheaper than the processes currently being used.

Environment, Health, and Safety Considerations

Unfortunately, there are no perfect substitutes for ODS use. Plant managers may often have to make tradeoffs on environmental, health, and safety issues. Such issues must be considered by plant managers as they choose between often imperfect ODS substitutes. In particular, they should consider the following:

- ***Ozone depletion and global warming.*** Each alternative must be evaluated for its contribution to ozone depletion as well as global warming. In some cases, it might be considered unacceptable to replace a high ozone depletor with a non-ozone-depleting substance that has a high global warming potential (GWP). The focus during the phaseout of ozone-depleting substances should be on finding substitutes which do not contribute significantly to other environmental problems.

- ***Volatile organic compounds (VOCs).*** Alternative chemicals that are classified as VOCs are photochemically reactive, and thus contribute to the formation of tropospheric ozone (smog). Chemicals that are VOCs may have national and/or local regulations concerning their use.

- ***Energy efficiency.*** The energy efficiency of an alternative cleaning process will have direct impacts on both the cost of maintaining a process as well as on the environment (e.g., global warming concerns).

- ***Toxicity and worker safety.*** Alternatives should minimize occupational exposure to hazardous chemicals. Personal Exposure Limits (PELs) such as those determined by the Occupational Health Safety Administration (OSHA) in the U.S. should be considered before selecting alternatives. Personal protective equipment, such as gloves, safety glasses, and shop aprons, should be reviewed for compatibility with alternatives. Work procedures and practices should be reviewed and modified to accommodate the properties of the alternative.

- ***Flammability.*** Fire and explosion hazards are very important considerations. In some instances, changes in a material or process will require the review of fire protection engineers and insurance carriers . Flammability should be evaluated and adequate fire control measures should be implemented before switching to an alternative that involves potentially flammable substances. In some cases, relocation of a plant may be necessary.

- ***Recyclability of solvent.*** It is economically and environmentally beneficial to find alternative solvents whose waste product can be recaptured and reused. For example, spent solvent can often be treated and returned to the facility for reuse.

- ***Ground water pollution.*** In order to avoid potentially expensive cleanup procedures in the future, plants should plan for the proper disposal of leftover solvent. If possible, solvent should be handled on a well-lined concrete floor. If spillage occurs, the solvent should be recovered immediately to the maximum extent possible.

Technical Considerations

The technical feasibility of an alternative process or chemical substitute must be evaluated on a case-by-case basis, and depends on a number of important considerations. While such considerations will vary from facility to facility, depending on plant location and product function, a number of them can be used to evaluate the technical alternatives available to ODS users within a particular end use. Important criteria to consider when making technical comparisons among non-ODS alternatives will be addressed for each of the main sectors included in this catalogue, i.e., aerosols, sterilants, and carbon tetrachloride.

1.2 Aerosols

An aerosol is technically defined as "a suspension of fine solid, or liquid particles in air or gas" or "a substance dispensed from a pressurized container as an aerosol." The common use of the word aerosol, however, refers to any sealed container pressurized with liquified or compressed gases such that the product is self-dispensing. This includes products which are dispensed as gases, in mist, in streams, or as foams.

CFCs have been used in aerosol products since 1942 in the United States and since 1951 in Europe. Their primary uses in aerosols fall into two categories: propellants and solvents. The CFCs used as propellants include CFC-12 and CFC-114; those used as solvents include CFC-11 and CFC-113. Another ozone-depleting substance, methyl chloroform (MCF), is also used as a solvent.

The high volatility, nonflammability, and nontoxicity of CFC-12 and CFC-114 make them ideal propellants in a variety of products. CFC-11 is used to dissolve active ingredients in aerosol products. Because CFC-11 evaporates quickly, it is used primarily as a diluent and vapor pressure depressant and seldom as an active ingredient in solvent applications. CFC-11 is used in precision and general mold release agents. CFC-113 is used as a solvent. It evaporates less rapidly than CFC-11 but more rapidly than MCF. CFC-113 can serve as a diluent for the active ingredient or by itself as an active ingredient in aerosol products. It is used as a cleaning agent in electronics solvent cleaners, and as a solvent and diluent in mold release agents and lubricants.

MCF functions similarly to CFC-113 in aerosols and is widely used to depress flammability. In some cases, MCF cannot replace CFC-113 because it can decompose in the presence of water to form hydrogen chloride, a corrosive acid. It is also a much stronger solvent and may attack components being cleaned in electronic applications such as plastics. MCF is used as a diluent in applications such as water and oil repellents, lubricants, spray undercoats, tire shiners, and mold release agents. It is used as a solvent in products such as electric motor cleaners, spot removers, brake cleaners, insecticide, and electronics solvent cleaners. MCF can serve as both a diluent and solvent in some applications such as insecticides.

Due to the reduction of CFC consumption in industrialized countries that are Parties to the Montreal Protocol, the use of CFC propellants has decreased significantly while remaining high in many developing countries. In many countries, CFC consumption is now limited to uses considered "essential." "Nonessential" applications now use non-ozone-depleting or lower ozone-depleting alternative technologies. This catalogue discusses such technologies, including alternative propellants, alternative delivery systems, and alternative solvents.

The propellants that will be covered in this catalogue include:

- hydrocarbons (HCs)
- dimethyl ether (DME)
- compressed gases (CO_2, N_2O, N_2)
- HFC-152a and HFC-134a
- HCFC-22

Alternative delivery systems, which eliminate the need for a propellant altogether, that will be discussed include:

- pump sprayers (finger-pump and trigger-pump)
- dry powder inhalers

Other types of not-in-kind substitutes such as barrier packs, two-components systems, roll-ons, and mechanical pressure dispensers are not discussed in this document.

In addition to propellants and not-in-kind propellant substitutes, alternative solvents can be chosen to reduce the ozone-depleting potential of aerosol products. Alternative solvents that will be presented include:

- HCFC-141b
- perchloroethylene

The following discussion provides a brief summary of each of these alternatives. Following the descriptions is a presentation of the technical criteria that may be used to evaluate each alternative. Part II of this catalogue presents technical datasheets for each alternative.

Non-ODS Alternatives in the Aerosols Sector

Hydrocarbons (HCs) such as propane, n-butane, and isobutane can be used as alternative propellants in most aerosol applications. While HCs are VOCs, they have low photochemical reactivity. Therefore, their contribution to the formation of smog is fairly low. They currently account for 96% of worldwide substitutions and 86% of aerosol uses in the United States. The advantages of HCs include their availability, low cost, low toxicity, and good dispersion characteristics. Because these HCs are liquified gases, they provide a fairly uniform pressure inside the aerosol can throughout the life of the product. One drawback is their nonpolarity, which renders them immiscible with many polar solvents, including water. The main drawback of HCs is their high flammability. They should not be used in aerosol applications in which flammability is a concern, unless the risk of flammability can be mitigated. The conversion from CFCs to HCs may require several changes throughout the plant and in plant operations to accommodate the flammability hazard. Separate gassing facilities must be built and a number of fire safety protection measures should be taken to ensure the safety of workers. Also, great care must be taken during the handling, storage, transportation and filling of HCs. Because the highly flammable properties of HCs are internationally recognized, several countries have established rules, regulations, and recommended practices for their handling.

Dimethyl Ether (DME) has advantages which include high solvency and easy reformulation to water-based products. Its strong solvent properties make it ideal for the formulation of viscous and adhesive aerosols. However, DME's strong solvency also dissolves plastic parts, o-rings, seals, and can linings, and causes deterioration of certain can and valve gasket materials. Special care should be taken in the selection of these materials. Like hydrocarbons, DME is flammable. While DME's lower explosive limit is higher than that of most HCs, retrofits or redesign of filling lines and storage facilities are still required, and fire safety precautions must be taken during its handling, storing, transport, and during aerosol filling. In the U.S., plants that are already in compliance with fire regulations for HCs may still have to undergo retrofits to be in compliance with electrical system regulations for DME. DME is used in some European and Japanese aerosol formulations. Its popularity stems from its low cost -- its price is currently comparable to the price of hydrocarbons in these regions. DME is less widely used in the United States because of its cost relative to other propellant alternatives. The price of DME in the United States is approximately twice that of hydrocarbons.

Compressed Gases are high-pressure propellants that are typically injected into containers in the gaseous form instead of as liquids under pressure. The most commonly used compressed gases include carbon dioxide (CO_2), nitrous oxide (N_2O), and nitrogen (N_2). A major concern with aerosol products propelled by compressed gases is the pressure drop inside the container that occurs during use. This causes the spray to become weaker as the product is consumed. Compressed gases usually cannot serve as drop-in replacements for CFCs or HCFCs. Alternative dispensing mechanisms and stronger containers may be needed because these gases are under higher pressures. Containers holding compressed gases must be able to withstand pressure between 6.9-7.9 bar at 21.1°C, approximately double that of conventional aerosols at this temperature. The use of compressed gases is also limited by the coarse size of the particles dispersed and the corrosion problems associated with aqueous systems. On the positive side, compressed gases are nonflammable, and therefore useful for applications that require nonflammability. However, because so little propellant is used, the flammability, environmental and other characteristics of the aerosol product will likely be determined by the properties of the solvent or diluent chosen. Compressed gases are inexpensive and are readily available worldwide from distributors of industrial gases.

HFC-152a and HFC-134a have zero ozone-depleting potential. HFC-152a has been used to a limited extent in certain developed countries for over 10 years. Because it is a negligibly reactive volatile organic compound (VOC), and because it is both less flammable and easier to substitute than DME, HFC-152a is a desirable alternative propellant. However, due to its high cost and unavailability (currently, DuPont is the only manufacturer) its use is limited to certain established areas within the aerosol market. HFC-134a is a more recently developed nonflammable chemical that is gaining popularity as a substitute in various refrigeration, air conditioning, and in a limited number of foam blowing applications. In the U.S., it is being used as a duster and in several applications in the electronics industry. It is also being tested as a propellant in medical inhalers by pharmaceutical companies worldwide. Although HFC-134a has the many characteristics of an ideal alternative propellant, it is not expected to be widely used in aerosol applications due to its limited availability in the aerosols market, prohibitively high cost, and very high global warming potential.

HCFC-22 is a widely available nonflammable liquified propellant. It is being used as a substitute propellant in aerosol products that require nonflammability, such as solvent cleaning sprays, lubricants, mold release agents, aircraft maintenance products, pesticides, and medical products. HCFC-22 is generally not a drop-in substitute because of its high pressure relative to CFCs. Often, a pressure-depressing solvent or low-pressure propellant such as HCFC-142b is added to the formulation. If HCFC-22 propellant blends are used, or if the aerosol solvent has properties that reduce vapor pressure, there is a possibility that equipment modifications are unnecessary. Otherwise, tanks and valves on filling equipment should be modified, and stronger aerosol valves and cans should be selected, to accommodate the higher pressure. Because of their ozone-depleting potential, HCFCs are scheduled for phaseout under the Montreal Protocol. In the U.S., the Clean Air Act prohibits the use of HCFCs in aerosol products after 1 January 1994. Their use should only be transitional and limited to instances where propellant nonflammability is crucial.

Pump Sprayers are the single largest not-in-kind competitor to aerosol-propelled products. Two common pump sprayers include the finger-pump sprayer and trigger-pump sprayer. Finger-pump sprayers are the most widely used pump-action dispensers. They are used in numerous personal and household products that are based on water, hydro-alcoholic, and alcoholic formulations. While finger-pump valves can be crimped into aerosol cans and can be made to look like aerosols, they have a greater flexibility in design than do aerosols. Trigger-pump sprayers are used less in personal products and more in utilitarian products, particularly in household cleaning applications. The trigger mechanism dispenses larger quantities per actuation than does the finger-pump mechanism because the trigger pump has a larger dispensing chamber and piston. Both finger-pump and trigger-pump sprayers have single-stage filling operations. This differs from aerosol filling operations, which require both a filling and gassing stage.

Dry Powder Inhalers (DPIs) can be used as an alternative to metered dose inhalers (MDIs) in a majority of cases. Specifically, pulmonary medications that can be satisfactorily formulated as microfine powders can be delivered as dry powders with DPIs, altogether eliminating the use of a chemical propellant. The active delivery system is replaced by a passive one, in which the medication is dispersed into the airstream by the force of the patient's inhalation. Because DPIs rely on the patient's ability to inhale the medication, they may not be appropriate for all patients. Because DPIs are not-in-kind substitutes, pharmaceutical firms must reformulate the medication into powder form. The powder is held in a gelatin capsule, blistered disk, or as a bulk powder and placed within a special delivery tube. Dry powder inhalers are used fairly widely in Europe.

HCFC-141b is currently the most viable alternative to CFC-113 in aerosol precision- cleaning operations. It is the only solvent alternative that is nonconductive, nonflammable, nontoxic, nonhygroscopic, and fast evaporating. It is unlikely that HCFC-141b will be a substitute for methyl chloroform because the two compounds have similar ozone-depleting potentials. The transition from CFCs to HCFC-141b for defluxing is relatively easy. Straight HCFC-141b may be substituted directly for CFC-113 in aerosol cans for contact cleaning operations. However, HCFC-141b cannot serve as a drop-in replacement for all solvent uses of CFC-11 and CFC-113. The high volatility and high solvency of HCFC cleaning solutions may require special equipment design criteria. Because HCFC-141b has an ozone-depleting potential and is scheduled for phaseout under the Montreal Protocol, it is only be used as a transitional solvent in essential applications. In fact, the use of HCFC-141b in aerosol formulations will be prohibited in the U.S. after 1 January 1994, with limited exemptions for critical uses only.

Perchloroethylene can be an effective substitute for CFC-11, CFC-113, and methyl chloroform in some aerosol solvent applications. However, there are many worker exposure and environmental issues associated with the use of perchloroethylene. Extensive toxicity testing has shown perchloroethylene to be carcinogenic to animals and possibly carcinogenic to humans. In addition, perchloroethylene is classified as a VOC and/or hazardous air pollutant in some countries. National and local regulations regarding the use of perchloroethylene should be consulted before considering it as an alternative solvent.

There are a number of other nonozone-depleting alternative technologies that may not yet be commercially available or are currently not widely used. Petroleum distillates (hydrocarbons fractionated from the distillation of petroleum) can be potential alternatives to ozone-depleting aerosol solvents. However, petroleum distillates are VOCs and highly flammable, and are not acceptable alternatives in applications which require nonflammable formulations. Furthermore, petroleum distillates are relatively weak solvents as compared to chlorinated solvents. Another potential class of solvent alternatives is oxygenated hydrocarbons. Oxygenated hydrocarbons include alcohols, ketones, ethers, and esters. These compounds are also VOCs and are flammable, making them unsuitable for some aerosol applications. Oxygenated hydrocarbons are relatively inexpensive and readily available from chemical distributors worldwide.

Some aerosol products can also be reformulated as water-based systems. These reformulated products usually contain active ingredients that are water soluble and can be emulsified. Most water-based products are nonflammable and can be used in the place of products containing ODSs as solvents in aerosol applications where potential ignition sources exist. However, they cannot be used around sources of electricity since they may cause electrical shorts in equipment.

Technical Comparison of Aerosol Propellants

As mentioned earlier, CFCs have been popular as propellants and solvents in aerosols because they possess a unique combination of important characteristics: they are nonflammable and fast evaporating, they provide a uniform internal pressure throughout the life of the product, they can produce a large range of spray particle sizes, they have reasonable solvency and solubility levels, and they pose little threat to worker health and safety when handled correctly. Currently, no non-ozone-depleting chemicals share all the same characteristics. Because of the lack of such ideal replacements, the criteria that are vital to the performance of a propellant or solvent must be determined for each individual aerosol application. A non-ozone-depleting alternative can then be selected based on its ability to meet the established criteria or the availability of a means to accommodate its shortcomings. Cost will also be a major consideration, primarily when choosing between two or more feasible alternatives.

Technical criteria that should be used to evaluate an alternative propellant include the following:

- vapor pressure
- change in internal pressure during life of aerosol product
- spray particle size
- solubility/solvency
- flammability level
- environmental impact
- effect on worker health and safety

Vapor Pressure

The internal pressure of an aerosol container is determined by the vapor pressure of a propellant. Aerosol pressures typically range from 3.1 to 7.9 bar at 21.1°C. If the propellant pressure does not fall within this range, then adjustments to either the aerosol can and valve or to the propellant formulation must be made. In the former case, a container capable of withstanding higher pressures must be selected. For example, the highly pressurized container may require a higher gauge of steel or aluminum and/or a pressure relief device (which is only available on the steel can), or the can may require crimping through a different process. Another way to make use of a high pressure propellant is to blend it with another, lower pressure propellant. By doing this, the pressure of a propellant can be reduced to normal aerosol levels.

The pressure range of commercially available hydrocarbon blends varies significantly from one country to another. Commercially available hydrocarbon aerosol propellant blends are made from propane, isobutane, and n-butane, whose vapor pressures are approximately 8.5 bar, 3.1 bar, and 2.2 bar at 21.1°C, respectively. Since aerosol cans can be specified to withstand pressures up to 19.6 bar, the pressures of many HC blends are well within the range for aerosol use. Because there are numerous grades of hydrocarbons available, it is important that aerosol grade hydrocarbons be used in aerosol applications.

The vapor pressure of DME is 5.4 bar at 21.1°C, making DME suitable for propellant use.

Compressed gas propellants can operate at significantly higher pressures and require alternative dispensing mechanisms, pressure relieving devices, and/or stronger containers. In other cases, compressed gas formulations are limited to a small amount of gas that can be dissolved into the solvent/diluent, resulting in normal aerosol pressures.

The vapor pressure of HFC-152a is moderately high. Propellant blends can be used to reduce the vapor pressure in the can. Examples of blends include HFC-152a/isobutane, HFC-152a/n-pentane or isopentane, and HFC-152a/ethanol/H_2O. The higher vapor pressure and nonflammability of HFC-134a make it a potentially attractive substitute for CFC-12, but not a drop-in replacement.

HCFC-22 has a relatively high vapor pressure of 9.5 bar at 21.1°C. Although it can be used without any propellant blends with special cans and valves, it is generally paired with a pressure-depressing solvent or low-pressure propellant. A typical aerosol blend is 60% HCFC-142b and 40% HCFC-22. Ethanol and DME are also effective pressure suppressants. Products in which the propellant is the sole ingredient (dusters, freezants, etc.) must use a stronger disposable or recyclable steel container with a pressure relief device in lieu of the conventional tin plate can. In addition, existing valves may have to be replaced with high-pressure valves.

Change in Internal Pressure

Either liquified gas or compressed gas propellants provide pressure to expel product from the container. Liquified gas propellants act as gas reservoirs to maintain the pressure in the headspace of a can, even as the headspace volume increases. Compressed gases, on the other hand, merely expand to fill the empty headspace. As they expand, the internal pressure of the can falls. While it is ideal to maintain uniform internal pressure throughout the life of a product, it may not be necessary. When selecting an alternative aerosol propellant, it may be useful to gauge the importance of this criterion to the aerosol application.

Hydrocarbons, DME, HFC-152a, HFC-134a, and HCFC-22 are all liquified gas propellants. Therefore, they provide a fairly uniform internal pressure within the can throughout the life of the aerosol product. HCFC-142b is also classified as a liquefied gas. While it can be used alone as a propellant, this is rarely done because of cost considerations. Instead it is often used in blends with HCFC-22 to reduce in-can pressure.

As mentioned above, a major concern with compressed gas propellants involves the pressure drop within an aerosol can as the product is dispensed. This problem is most noticeable with cans that are limited to about 3% or less of propellant. Aerosols that contain compressed gases can be rendered useless by inadvertent consumer misuse. If the valve is depressed when the can is held at an angle such that the dip tube protrudes into the gaseous phase, a significant amount of the total pressurized gas charge can escape. A sufficiently depressurized container cannot produce a satisfactory spray or delivery rate. or may stop spraying completely. When using a 360 degree valve, the ball may stick in a viscous product when the can is tilted, also causing the expulsion of only propellant. If the can is turned to a horizontal position, the ball may not fully close either the liquid or gas chamber and a mixture of liquid and gas may result.

Spray Particle Size

Spray particle size is often selected to optimize the effectiveness of an aerosol. Aerosol particles can range in size from very fine to very coarse. Fine sprays sometimes contain particles with diameters less than 30 microns, which allow an aerosol product to linger in the air for hours. This characteristic is useful for products which rely on sustained exposure, such as insecticides for flying insects. Coarse sprays, with particle diameters above 50 microns, may take merely seconds to strike the ground. An aerosol product with a coarse particle spray can be used to minimize user inhalation or to create a more target-oriented surface spray.

Propellants are capable of producing sprays with different particle size distributions. Some are so high in pressure, and must thus be present in such limited amounts, that the spray will be generally coarse -- the degree of coarseness being largely a function of valve choice. The relatively low pressure propellants, added to the can as liquids under pressure, offer more flexibility since a wide variety of percentages can be utilized. The ability to achieve a particle size distribution appropriate for consumer acceptance of the product should be a criterion for selecting an alternative aerosol propellant. Optimization of spray characteristics is achieved by selecting the appropriate level of propellant in the formula and matching this to use of a valve that will provide the desired degree of break-up, the ideal cone angle, and the correct delivery rate. In the case of the high pressure compressed gases, spray coarseness can be decreased somewhat by using solvents in which these gases are more soluble, along with valves that offer the greatest opportunity for mechanical break-up. Reducing delivery rates can often ameliorate the consumer conception of "wetness." The problem of slowly diminishing delivery rates during product use can be minimized by using larger initial head space percentage volumes, higher initial pressures, and if necessary, by the use of a standard valve that is fitted with a special, diaphragm-controlled, variable orifice actuator. In this actuator, the rate-controlling terminal orifice size is enlarged as internal gas pressure drops, thus ensuring a constant delivery rate.

Hydrocarbons, HFCs, HCFCs, and DME are generally flexible, in that they allow a range of spray particle sizes and may be used satisfactorily with vapor tap valves. When comparing hydrocarbon and DME particulate distribution characteristics, DME performs almost as well as hydrocarbons. Both propellants have good dispersion characteristics when used in solvent-based applications (e.g., hairspray). DME, however, demonstrates superior dispersion characteristics in water-based applications due to its high solubility in water. If water-based aerosol products propelled by hydrocarbons are not agitated immediately prior to use, they may produce a more coarse spray.

Aerosols products using compressed gas propellants tend to result in a more coarse spray. The sprays become more coarse as the container is gradually emptied and the internal pressure decreases. This problem can be alleviated by elevating the gas pressure and filling the cans only about 60% full of product. As mentioned above, selecting the right kind of valve can also help to ensure satisfactory delivery of the product.

Finger-pump spray particles and trigger-pump sprays are also very coarse and will strike the floor within five seconds from the time of discharge. Furthermore, at the beginning and end of each actuation, finger sprays may produce a 10 to 20 mg dribble.

<u>Solubility/Solvency</u>

The solubility of a propellant determines whether the overall contents are homogeneous (uniformly blended) or heterogeneous (exist in separate phases). In some cases, if the propellant is insoluble with the aerosol solvent, a cosolvent may be used to produce a single-phase blend. Surface-active agents can also be added to provide stability to the blend. Heterogeneous aerosols often require shaking before use to generate a temporary emulsion or dispersion that becomes a spray or foam on discharge. The solubility or solvency of a propellant may be used as a criteria for selecting an alternative propellant if a homogeneous or heterogeneous aerosol blend is desired.

HCs are nonpolar, which renders them immiscible with some polar solvents, including water. This may pose problems in formulations for products such as aerosol paints and hair sprays. These problems are often avoidable through the addition of co-solvents.

DME has high solubility characteristics. It is soluble in water up to 35%. Its high solubility makes it suitable for use in a number of products, including water-based paints. DME also has strong solvent properties. While its solvency makes it beneficial for use in certain applications, it also causes some material compatibility problems. DME can blister and partly solubilize can linings, which may lead to can corrosion from water. Appropriate chemical corrosion inhibitors are usually necessary. In general, can linings are not recommended for DME formulations in tinplate or aluminum cans.

Flammability Level

The flammability level of a propellant can be one of the most important criteria in the selection of an alternative. A flammable alternative propellant should be chosen only if safety hazards associated with using a flammable propellant in the aerosol application are minimal or can be minimized. The conversion of an aerosol plant from filling with a nonflammable propellant to filling with a flammable one usually requires the use of special ventilation, explosion proof equipment, flammable gas sensing devices, and fire protection systems. Employee training is also very important. In addition, a separate gassing facility and warehouse designed to hold hazardous commodities may have to be built to prevent widespread plant damage if a fire or explosion were to occur during filling or storage. If the space is not available, fillers may have to relocate to less congested areas. Modifications may also be required in operational procedures to accommodate flammable materials. For example, many countries have guidelines for the storage, handling, and transport of certain flammable materials. If a flammable alternative propellant is selected, a plant should have the resources to build and retrofit proper facilities and to follow existing guidelines for safe handling of flammable materials.

Three of the alternatives presented, compressed gases, HFC-134a, and HCFC-22 are nonflammable. The remainder of the alternative propellants have very high to moderate flammability levels. Hydrocarbons and DME are the most flammable. Their use necessitates extreme caution regarding fire and explosion safety. The use of hydrocarbons and especially DME also require strict adherence to electrical compliance codes. Although HFC-152a may be less flammable than hydrocarbons, the same fire-safety and explosion-prevention precautions should be taken.

Environmental Impact

While the alternatives have little to no ozone-depleting potential compared to CFCs, many of them have other environmental drawbacks. The alternative chemicals may be regulated volatile organic compounds (VOCs), greenhouse gases, hazardous air pollutants, or have other environmental risks. It is important to be aware of all of the environmental impacts an alternative has and to know whether there are any pertinent national or regional regulations. If the substitute chemical is subject to regulations, or will be in the future, it is important to find out whether the supply or use of this material will limited.

One environmental concern associated with hydrocarbons is their role as volatile organic compounds (VOCs). Their contribution to tropospheric ozone formation is small, however, compared to other emission sources. VOCs are believed to contribute to the formation of tropospheric ozone (smog) and therefore to global warming. DME is also a VOC. Depending on its end use, however, its effects may be slightly alleviated since its high solubility in water allows less solvent or diluent to be used, thereby reducing the overall VOC content of the product.

Compressed gases, HFCs, and HCFCs are non-VOCs. However, are all greenhouse gases, and thus may contribute to global warming. The 100-year time horizon global warming potentials (GWPs) of HFC-152a and

HFC-134a are 150 and 1,200 times that of CO_2. The GWP of HCFC-22 is also extremely high, at 1,600 times that of CO_2. Because the GWPs of HFC-134a and HCFC-22 are high, their use in aerosol products should be limited.

Effects on Worker Health and Safety

Aside from being flammable, some alternatives may be more toxic than the chemicals they are replacing. It is very important to know whether any exposure limits exist for these materials. Several organizations and groups in the U.S. and elsewhere publish toxicological assessment data and recommended exposure levels. If exposure limits exist, provisions must be made to ensure minimal worker exposure.

Hydrocarbon propellants (propane and butane) are essentially nontoxic. The chief concern regarding worker health and safety during handling of hydrocarbons is the high flammability of the material. Since aerosol grade hydrocarbons are odorless gases, some countries require that they be stenched to increase safety during shipping and handling. This stench must be removed prior to aerosol filling.

The only toxicity concerns associated with the use of compressed gases is the potential for respiratory distress caused by prolonged exposure to these gases. There are no toxicity concerns regarding the use of DME in aerosol applications. Toxicity is also a negligible concern for both HFC-152a and HFC-134a. Toxicity testing indicates low order acute and chronic inhalation toxicity, low order of skin and eye irradiation/sensitization, and no hazard regarding carcinogenicity, mutagenicity, and teratogenicity. Toxicity is also a negligible concern for HCFC-22.

Technical Comparison of Solvents

Many of the same criteria used to evaluate propellants can be used to evaluate aerosol solvents as well. As with alternative propellants, cost will be a primary factor in the selection of an alternative solvent. Technical criteria that are relevant to the evaluation of alternative solvents include:

- suitability for aerosol application
- compatibility with propellant

Suitability for Aerosol Application

There are a number of purposes that a solvent may serve in aerosol applications. The solvent can be used as a diluent or it can be the active ingredient in the aerosol. Because there are such a wide variety of roles that the solvent can play, there are no steadfast rules in selecting an alternative. The criteria are application-dependent. Characteristics that are most frequently used in the evaluation of a solvent include:

- solvency -- this characteristic is important in most applications. For example, in cleaning applications, it must be able to solubilize the contaminants.
- vapor pressure -- used to determine evaporation rate. Also important in many applications.
- effect on materials -- the product should not adversely affect the material upon which it is sprayed.

- flammability
- environmental impact (ODP, GWP, VOC classification, etc.)
- effect on worker and user health and safety

HCFC-141b has aggressive solvent properties. It attacks polystyrene based plastics, which are sometimes used to make pump-spray containers, causing them to break down. It may also attack some plastic components in electronic equipment, although to a lesser extent than MCF. HCFC-141b is also fast evaporating, making it useful for some cleaning applications. In small quantities, it can evaporate completely and without residue in less than 15 seconds. HCFC-141b is flammable. However, its lower explosive limit is high enough such that it is often considered nonflammable. HCFC-141b has two major environmental drawbacks. First, it is an ozone-depleting substance. Therefore, it is slated for phaseout in the future. Second, it has a fairly high global warming potential. Toxicity testing for HCFC-141b is still underway. However, acute and sub-chronic testing has shown HCFC-141b to have negligible toxicity concerns.

Perchloroethylene is a strong solvent. It is able to dissolve compounds which are difficult to dissolve in other solvents. Unfortunately, there are many worker health and safety issues associated with the chemical. While the solvent is slow drying and nonflammable, it is a regulated VOC in some countries and regions. It is also classified as a hazardous air pollutant in some areas. Extensive testing has shown perchloroethylene to be carcinogenic to animals, and possibly carcinogenic to humans. Health concerns may limit the amount of perchloroethylene that can be used. Great care should be taken to ensure the safety of workers before using perchloroethylene in aerosol applications.

In some applications, such as electronics cleaning, strong solvency can be a drawback. CFC-113 was traditionally used in electronics cleaning because it had sufficient solvency to remove solder flux residues and other contaminants, while not damaging the board material and components. Alternatives for products to be used on electronics must consider solvency and the effect of the solvent on board materials and components.

Compatibility with Propellant

When selecting a new solvent and/or propellant, it is important to be sure that the propellant is compatible with the solvent. Compatibility issues may include the solvent and propellant's combined flammability, health and safety aspects, and environmental impact. For example, if a solvent is flammable, it is desirable to find a propellant which can reduce the flammability hazard. HCFC-22, a nonflammable propellant, has the ability to suppress the flash point of the flammable solvent when it is present in the necessary volume in a formulation. In comparison, carbon dioxide, which is also a nonflammable propellant, does not have this ability. In fact, due to its high pressure characteristics, carbon dioxide often will exacerbate flammability conditions through the high pressure aerosolization of solvent particles. Therefore, when carbon dioxide is used with flammable solvents around sources of high heat or electrically energized equipment, the results can be disastrous. Combinations of solvent and propellant should also be chosen such that their combined health, safety, and environmental hazards are mitigated, rather than exacerbated.

1.3 Sterilants

Sterilization technology exposes microorganisms to certain chemical, thermal, and/or physical conditions, which must be extreme enough to cause total microbial death on items being sterilized. Hospitals, private practitioners, contract sterilizers, and manufacturers of medical products sterilize items that penetrate sterile body tissues and cavities or that come into contact with blood or sterile body cavities without penetrating the skin. Such items include 1) all sharps -- surgical instruments, hypodermics, catheters; 2) disposables -- usually single-use surgical gloves and other devices -- which are sterilized by the manufacturer and sold as sterile instruments; and 3) dental instruments, because they come in contact with blood.

Steam has historically been one of the most commonly used means of sterilization. Many items found in a hospital which require sterilization are compatible with steam sterilization processes. However, the construction of much of today's medical equipment relies on plastics and synthetic components, which are often damaged by the high heat and humidity of steam sterilization. One of the consequences of the medical industry's reliance on plastics is the need for vapor-phase sterilization, not only by hospitals, but by contractors and equipment manufacturers as well. Ethylene oxide (EtO) is an effective and proven sterilant, and it is most commonly used in mixture with CFC-12, an inert gas that significantly diminishes EtO's flammability and explosiveness. The most commonly used mixture of EtO and CFC-12 contains 12% EtO and 88% CFC-12 by volume and is called 12/88. With the global phaseout of CFCs, alternative sterilants are being developed or are available to replace EtO/CFC mixtures.

The alternatives presented include those techniques that are currently in use and are likely to be viable in developing countries. Technical data sheets are presented for each of these technologies in Part II of this catalogue.

Non-ODS Alternatives in the Sterilization Sector

100% Ethylene Oxide is a replacement for 12/88 in small sterilization units in hospitals and in larger units in commercial/industrial applications. Sterilization using pure EtO requires lower pressures than does the use of 12/88. Therefore, it can replace 12/88 in existing equipment by allowing the use of the same sterilization chamber. But, since pure EtO is not diluted with an inert gas, it poses greater flammability and explosivity concerns than does 12/88. Each of these problems must be addressed by the adoption of proper handling and storage procedures, the installation of adequate ventilation, and the adoption of explosion proof equipment, remote facilities, and other engineering precautions. All told, converting from 12/88 to pure EtO may require extensive engineering changes and may be prohibitively expensive.

Ethylene Oxide/Carbon Dioxide mixtures can serve as a replacement for 12/88 in hospitals to sterilize heat and moisture-sensitive equipment. Addition of an inert gas, in this case 85% to 92% CO_2 by weight, eliminates some of the flammability concerns associated with pure EtO. In a typical EtO/CO_2 cylinder, the initial discharges may contain excessive quantities of EtO and may therefore exhibit flammable characteristics. EtO/CO_2 mixtures operate at higher pressures than does pure EtO. Therefore, they cannot serve as drop in replacements for 12/88. Industry sources estimate that only about 30 percent of existing 12/88 equipment is capable of being retrofitted to withstand the higher operating pressures required for EtO/CO_2 mixtures.

EtO/CO_2 mixtures also tend to separate in their cylinders, resulting in uneven distribution of sterilant to carrier: too much EtO poses a fire hazard; too little EtO poses a sterility hazard. This separation also results in substantial waste because the final 40 percent of the mixture in a cylinder is unable to sterilize adequately. Finally, the CO_2 in EtO/CO_2 mixtures tends to form a weakly acidic environment, which may damage some equipment.

Steam sterilization operates at temperatures exceeding 121°C, and it is widely used on equipment that is not particularly heat or moisture sensitive. It is an unlikely candidate to replace EtO mixtures as a sterilant for sensitive medical devices such as catheters, pacemaker, and optical equipment.

Radiation sterilization employs either gamma radiation or electron beams. It is used only by medical device manufacturers or large contract sterilization facilities, usually to sterilize single-use medical products. Radiation technology is not easily adapted to hospital needs. As with any type of sterilization, use of radiation demands a prior determination of whether equipment or packaging materials will be harmed during the sterilization procedure. The percentage of medical products currently being sterilized by 12/88 that could be reformulated to be compatible with radiation is believed to be small. The substitution of radiation for 12/88, therefore, has limited applicability.

Formaldehyde is used in combination with steam to sterilize heat-sensitive medical devices. The process, known as low-temperature steam formaldehyde (LTS/F) sterilization operates at temperatures between 65°C and 80°C. The process can replace 12/88 only where the objects being sterilized are compatible with formaldehyde and can withstand high humidity and temperatures up to 80-85°C. The LTS/F process has been demonstrated for the disinfection and sterilization of urinary endoscopes, but it can not be used to replace 12/88 in sterilizing such relatively sensitive medical devices as catheters and pacemakers, which cannot withstand temperatures above 55°C.

A number of emerging alternatives to the use of 12/88 are currently being developed or undergoing testing and are expected to become commercially available in the next few years. Vapor phase hydrogen peroxide (VPHP) is currently being tested as a sterilant in small applications and is not likely to be available for several years. Gas plasma sterilization uses clouds of highly ionized gas, consisting of free electrons and positive ions and created by the addition of heat, electricity, or microwaves to gas, to sterilize equipment. Ozone sterilization is a process similar to VPHP which kills pathogens by oxidation. Microwave sterilization kills pathogens through the use of low-pressure steam and microwave energy. Dry heat sterilization is a method with limited uses which uses high temperatures to sterilize equipment over a period of two or more hours. Finally, HCFC and HFC blends with EtO have been formulated to act as drop-in replacements for 12/88. An HCFC blend is scheduled to begin production in late 1993, with commercial availability in the U.S. in mid-1994.

Technical Comparison of Sterilant

hoosing among these sterilant alternatives requires consideration of a number of factors. As with aerosol propellants, cost is an important factor to consider when selecting between two or more technically feasible alternatives. In order of importance, technical considerations include:

- the range of materials with which they are compatible
- flammability
- other health and safety issues
- equipment retrofit considerations

These considerations are analyzed for each of the available alternatives in the discussion that follows.

Materials Compatibility

As discussed earlier, sterilization technology exposes microorganisms to certain chemical, thermal, and/or physical conditions, which must be extreme enough to cause total microbial death on the material being sterilized. Such conditions may also adversely affect the item that is being sterilized. Therefore, it is essential to determine whether the operating characteristics of the sterilization technology to be used do not damage material being sterilized while still achieving sterilization.

100% EtO is a reliable commercial process and can readily replace 12/88 to sterilize sensitive medical devices. It operates at low temperatures -- usually 55°C, but as low as 25°C -- that will not melt or otherwise damage plastics and rubbers. It achieves excellent penetration of materials.

EtO/CO_2 has a reliable commercial process, and it too can replace 12/88 because its low operating temperatures will not damage plastic or rubber in sensitive medical devices. It achieves good penetration of tubing. The presence of CO_2 in the sterilant mixture, however, introduces a mildly acidic environment, that can corrode items being sterilized or the sterilizer unit itself if they are not made specifically for use with EtO/CO_2 mixtures. Finally, the presence of CO_2 in the sterilant mixture increases the rate at which EtO forms a sticky, oily, or solid polymer that can remain as a residue in the sterilizer unit, but not on the products being sterilized.

Steam sterilization operates at high temperatures (121°C or higher) and high humidity. Thus, steam cannot replace 12/88 to sterilize sensitive medical equipment containing plastics or rubber. Even some metal handles and blades can weaken or dull with repeated exposure to high-temperature steam.

Radiation can replace EtO to sterilize some sensitive medical equipment made of plastics and rubbers. Thermoplastic elastomers (TPEs) stand up well to radiation, and acrylonitrile butadiene styrene (ABS) and styrene acrylonitrile (SAN) do well with either EtO or gamma sterilization. Radiation-resistant grades of polypropylene (PP) for bottles, syringes, and other devices have been developed, as have radiation resistant PP nonwovens.

Formaldehyde/Steam mixtures operate at high humidity and temperatures of 65-80°C, which makes it unsuitable for use with some equipment that can be sterilized with 12/88. It demonstrates poor penetration capabilities, especially of tubing and certain wrappings, and provides no visual indication of successful cycle. There have been a number of variations in LTS/F process, and some of the cycles are unreliable because condensation may occur on surfaces, which can prevent adequate sterilization. Formaldehyde also tends to polymerize during sterilization processes, leaving a film of white paraformaldehyde powder on equipment surfaces.

Flammability

The flammability of sterilants can be one of the most important criteria in the selection of an alternative because of the hazards they can pose in enclosed work spaces, especially in hospitals where there is a high population density of both workers and patients. In industrial applications, flammability is also a high-level concern if industrial plants are located in congested areas. In either case the use of flammable and/or explosive sterilants must comply with relevant local and national regulations, and established industry standards for transport, handling, and use. Selection of equipment and plant engineering and design must also comply with relevant fire and building codes and standards. Such requirements may include special ventilation, blowout sections of buildings, the possible relocation of facilities in remote areas, explosion proof electrical and process equipment, flammable gas sensing devices, and fire-protection systems. Sterilants that pose flammability and explosivity hazards should be selected only if such safety precautions are already in place or if the often expensive retrofits associated with converting to flammable substitutes can be implemented. If employees are not accustomed to working with flammable sterilants, training also becomes very important.

100% EtO is highly flammable and explosive and retrofits to address those concerns are necessary. EtO/Co_2 poses no flammability risks if single dose canisters are used. If multiple-dose canisters are used, flammability and explosion risks are heightened because EtO and CO_2 tend to separate in the canister, allowing improper proportions of each gas to be delivered. If single dose canisters are not employed, extensive fire and explosion precautions should be implemented. Because of this tendency to separate, the United States Department of Transportation in 1991 classified as flammable any EtO/CO_2 mixture that contains EtO in concentrations above 6%.

Formaldehyde gas is flammable and forms an explosive mixture in air at concentrations of 7 to 72% by volume in air at ambient temperature. The concentration of formaldehyde gas used in vapor sterilization is well below the explosive concentration range and is nonflammable.

Steam and radiation sterilization pose no flammability risks.

Other Health and Safety Issues

Converting to other sterilants can introduce a number of health and safety concerns other than flammability. Primary among these are human exposure to chemicals, e.g. toxicity, carcinogenicity, and allergic and irritating reactions. To address these concerns, chemical manufacturers, industry organizations, and government and other public agencies publish toxicological assessment data and recommended exposure levels. If exposure limits exist, provisions must be made to ensure safe levels of worker exposure.

EtO (either 100% of mixed with CO_2) is highly toxic and irritating, and it is suspected to be carcinogenic. Equipment that is sterilized with it must be aerated for a prolonged period to ensure that EtO residues diffuse off of equipment and out of packaging before either are handled. To prevent injury from possible EtO leaks, rooms where it is used should be well ventilated. The toxicity of EtO is addressed in hospitals, where there is a high population density of workers and patients, by limiting its use to small doses of around 100g. In industrial uses larger amounts are used, but toxicity is less of a concern due to comprehensive engineering and administrative controls.

Formaldehyde has a pungent odor and is toxic and extremely irritating to the eyes, nose, and throat. It is mutagenic and a suspected carcinogen. Rooms where it is used should be well ventilated. Leaks are easily detected by smell. Aeration time is unnecessary following equipment sterilization.

Equipment Retrofit Considerations

Conversions to alternate sterilants entail the implementation of use of new chemicals or new processes. In many cases some portion of the old equipment can be used for the new process with certain adjustments or retrofits. Retrofits can be as simple as replacing valves and gaskets to accommodate different pressures of alternate chemical formulations. In other cases, retrofits may allow continued use of much of the same process equipment, but still be both extensive and expensive, requiring changes in plant engineering and building design to address flammability or toxicity concerns. Finally, retrofits may require the purchase of totally new process equipment, if a substitute process is not at all similar to the original one.

100% EtO operates below atmospheric pressure, so using it does not increase the risk of leaks. 100% EtO, however, is far more flammable and explosive than mixtures of EtO combined with an inert gas. Accordingly, extensive modifications must be implemented to use 100% EtO and prevent explosion and limit damage if it occurs. Facilities should implement explosion proof equipment and engineering; provide adequate venting; and, if necessary, relocate equipment to remote sites. If EtO emissions are regulated locally, it may be necessary to implement emission-control technologies.

EtO/CO_2 operates at higher pressures than does 12/88, so equipment valves and piping may have to be modified to accommodate higher pressures; these modifications may be extensive since EtO/CO_2 mixes operate at pressures four to five times higher than those of 12/88. If single charge canisters are used, EtO/CO_2 mixtures should not present explosion and flammability concerns. If multiple-charge canisters are used, allowing for uneven concentrations of EtO and CO_2 to be released, then extensive fire and explosion precautions similar to those taken for 100% EtO should be taken. Using EtO/CO_2 becomes increasingly impractical as the size of the application increases. As units become bigger and larger charges are needed, the weight of canisters becomes a prohibitive. Because of the CO_2 in the mixture, canister pressures can reach 70 bar. Canisters must, therefore, be extremely heavy since they must be able to withstand such high pressures. If single charges are being used to avoid fire and explosion hazards, then frequent canister changeout is necessary. Since cylinders are so heavy, it has proven prohibitively cumbersome to use EtO/CO_2 mixtures in anything but small hospital applications. If EtO emissions are regulated by local regulations, it may be necessary to implement emission-control technologies.

Steam sterilization can replace 12/88 only for equipment that is not sensitive to high heat or humidity. Radiation can replace 12/88 in only half or less of its applications, most likely to sterilize radiation-compatible plastics. 12/88 process equipment cannot be retrofitted to accommodate either steam or radiation, so new equipment would have to be purchased, which may prove to be prohibitively expensive, especially in the case of radiation.

Formaldehyde/Steam sterilization can replace EtO for equipment that can withstand temperatures up to 80°C and high humidity. Certain 12/88 sterilizers can be modified to incorporate an LTS/F cycle.

1.4 Carbon Tetrachloride

Carbon tetrachloride (CTC) is used most widely in industrialized countries primarily as a feedstock in the production of CFC-11 and CFC-12. In these processes, the CTC is destroyed by the reaction and is therefore not emitted to the atmosphere. In developing countries, CTC is sometimes used in industrial cleaning applications as a hand-wipe cleaner or as the active ingredient in an aerosol solvent. In addition, it is also occasionally used as a bulk cleaning solvent in vapor degreasing and dip tank applications in developing countries. Unlike use as a feedstock, these applications are emissive.

In some developing countries, CTC may be used as an inert solvent in chlorination reactions to produce a variety of chlorinated rubbers.[3] While the best method for chlorinating natural rubbers is in an inert solvent such as CTC[4], the extent to which this practice is used is not known. It is believed that CTC is not used in this application in developed countries, and that the use in developing countries is rather limited. Further research will be undertaken to determine the extent of this use. If deemed useful, a datasheet addressing this use will be included in updates to this catalogue.

A number of options are available, the most common of which are chlorinated and organic solvents, to phase out the hand-wipe and aerosol use of CTC as a cleaning solvent. Due to health concerns associated with worker exposure, chlorinated solvents are not recommended as an alternative to CTC as a hand-wipe solvent. However, many organic solvents can replace CTC as a hand-wipe solvent or as an active ingredient in aerosols. Chlorinated solvents to replace CTC as the active ingredient in aerosol applications are:

- perchloroethylene (PERC)
- trichloroethylene (TCE)
- methylene chloride (METH)

Organic solvents which may replace CTC as hand-wipe solvents or as active ingredients in aerosols include:

- alcohols
- ketones
- esters
- isoparaffinic hydrocarbons
- glycol ethers
- acetates

For the purposes of this guide, four chemicals have been selected as representative of the organic solvents. They are: isopropyl alcohol (IPA), acetone, methyl ethyl ketone (MEK), and propylene glycol methyl ether acetate (PMA).

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[3] *Powers, Paul O. Synthetic Resins and Rubbers. John Wiley & Sons, Inc., New York, NY, USA, 1943.*

[4] *Morton, Maurice. Rubber Technology. Van Nostrand Reinhold Company, New York, NY, USA, 1973.*

The following discussion provides a brief summary of each of these alternatives. Following the descriptions is a presentation of the technical criteria that may be used to evaluate each alternative. Part II of this catalogue presents technical datasheets for each alternative.

Non-ODS Alternatives in the Carbon Tetrachloride Sector

Chlorinated Solvents which do not contribute to ozone-depletion include perchloroethylene, trichloroethylene, and methylene chloride. These chemicals were widely used as solvent cleaners prior to the introduction of CFC-113 and methyl chloroform. As CTC, CFC-113, and methyl chloroform are being phased out, some users are choosing to return to using PERC, TCE, and METH in selected applications. Their major benefits are that they perform comparably to CTC in most degreasing and cleaning applications and that they are nonflammable. The factor which has greatly limited the application of these chlorinated solvents is their toxicity and associated health risk for workers. All three have low worker exposure limits in the U.S. and other developed countries. It should be noted however, that CTC is considered a "probable carcinogen" and has worker exposure limits lower than those for PERC, TCE, and METH. While the number of aerosol formulations using these chlorinated solvents as active ingredients is not large, they are nonetheless a viable alternative in some applications. When PERC, TCE, and METH are used in aerosol formulations, they must be used in well-ventilated areas and should not be sprayed in confined spaces. In the case of hand-wipe applications, the use of PERC, TCE, and METH is not recommended due to their low worker exposure limits and the long periods of time in which workers will be exposed to the chemicals while manually applying the solvent.

Where carbon tetrachloride is used in bulk cleaning applications, PERC, TCE, and METH can be substituted provided that the degreaser or dip-tank is well equipped to strictly limit the emissions of the solvent. In many cases, this will require retrofitting existing equipment or purchasing new low-emissions vapor degreasers.

Organic Solvents such as IPA, acetone, MEK, and PMA are widely available and can readily replace CTC in hand-wipe and aerosol cleaning applications. MEK, acetone, and PMA are generally used to remove oil, grease, and dirt from metal surfaces. IPA is most often used to remove flux residues after soldering in the manufacture or repair of printed circuit board assemblies and in the cleaning of sensitive non-metallic surfaces such as graphite-epoxy composites, elastomers, and thermoplastic polymers.

Two of these solvents, acetone and MEK, are believed to pose potential health risks because of possible toxicity. While PMA is not believed to pose any toxicity risks, several other glycol ethers (these fall in the category of ethylene glycol ethers rather than propylene glycol ethers) have been shown to be toxic. Care must be taken when using organic solvents because many are extremely flammable, even at room temperature. Therefore, they must be used only in well-ventilated areas in which there are no potential ignition sources. In general, there are no bulk solvent disposal issues associated with the use of organic solvents in hand-wipe or aerosol applications. One exception, however, are processes in which a cloth or other medium is dipped into a bowl of solvent. Eventually, the solvent remaining in the bowl will become too dirty to use and disposal will be required. In addition, cloths, swabs, and other media used in hand-wipe cleaning must be properly disposed of since they will contain spent solvent and contaminants from the part or surface being cleaned.

Organic solvents can be substituted for carbon tetrachloride in bulk cleaning applications. In these instances, it is important to ensure that the cleaning tank and surrounding area are equipped with sufficient fire protection equipment.

In a few locations, manufacturers in developing countries still make use of carbon tetrachloride as a vapor degreasing or dip-tank solvent in bulk cleaning operations. In addition to chlorinated and organic solvents, several additional alternative cleaning processes are available to replace carbon tetrachloride in these applications. Aqueous cleaning and semi-aqueous cleaning are the most popular of these additional alternatives. Due to the relatively small use of carbon tetrachloride in bulk cleaning applications, this use is discussed only briefly in this document.

Technical Comparison of Solvents

Plant managers should evaluate these alternatives based on a number of important criteria, including:[5]

- chemical cleaning ability
- substrate material, equipment, and subsequent process compatibility
- flammability
- toxicity and other exposure effects
- equipment requirements

As with aerosol propellants and sterilants, cost will be a consideration when selecting between two or more feasible alternatives.

Chemical Cleaning Ability

The degree of cleanliness required from a cleaning operation varies from industry to industry and from process to process. In some metal cleaning applications, cleanliness requirements are less stringent in terms of measurable residue, while in industries where critical components are being cleaned, requirements may be more stringent. The removal of contamination from a surface is not a single property of a solvent, but a combined relationship of several characteristics of the solvent, the substrate being cleaned, and the contaminants being removed. Some of the solvent characteristics include surface tension (which affects wetting ability of the cleaner), soil dissolution, emulsification, detergency, and rinsability. Substrate characteristics include quantity of contamination and surface features (blind holes or other hard to reach areas). Finally, it is important to consider the types of contaminants being removed in the cleaning process. Factors such as the makeup of the contaminant, its age, and the method by which it was deposited on the surface will affect the ability of a given alternative to clean the surface.

[5] *Waste disposal is not a concern in aerosol applications and in most hand-wipe applications. However, in bulk cleaning processes, disposal of waste solvent should be considered in the evaluation of alternatives.*

Substrate Materials, Equipment, and Subsequent Process Compatibility

In the selection of an alternative process, several compatibility issues must be considered. First is the compatibility of the cleaner with the substrate being cleaned. Factors to be considered in this evaluation include the possibility of corrosion and compatibility of the solvent with various materials, such as metals, plastics, elastomers, and composites. Second is the overall compatibility of an alternative cleaner with the equipment in which it will be used. Factors which might warrant consideration in evaluating this issue include emissions control capabilities, fire protection capabilities, and compatibility of the material of which the equipment is manufactured (steel, aluminum, etc.) with the cleaner. Finally, the effect of an alternative cleaner on subsequent operations must be considered. For example, if cleaning is being performed as a precursor to a visual inspection of parts for small cracks, it is important that the cleaning process leave no residue which might cover such cracks.

Flammability

Fire and explosion hazards are very important considerations in the evaluation of alternative cleaners, especially organic solvents. In addition to ensuring that cleaning equipment is capable of safely handling flammable solvents, a survey of the work area should be performed in order to identify and address possible ignition sources. In some instances, changes in a solvent cleaning process will require the review of fire protection engineers and insurance carriers. Flammability should be evaluated and adequate fire control measures should be implemented before switching to an alternative that involves flammable substances. In some cases, significant modifications to the existing plant and operating procedures may be necessary.

Isopropyl alcohol, acetone, MEK, and PMA are all flammable and all but PMA have flash points below 100 degrees F. They are, therefore, usually used at room temperature. If they are heated, strict fire safety precautions must be taken.

PERC, TCE, and METH are all nonflammable.

Toxicity and Other Exposure Effects

When using alternatives to CTC, occupational exposure to hazardous chemicals should be minimized. Personal Exposure Limits (PELs) such as those determined by the Occupational Health Safety Administration (OSHA) in the U.S. should be considered in the evaluation of alternatives. Personal protective equipment, such as gloves, safety glasses, and shop aprons, should be reviewed for compatibility with alternatives. Work procedures and practices should be reviewed and modified to accommodate the properties of the alternative.

PERC, TCE, and METH are of concern to many regulatory agencies in a number of countries because they are suspected carcinogens. Of the four representative organic solvents discussed in the accompanying datasheet, both acetone and MEK pose health risks to workers as a result of toxicity. In addition, acetone, MEK, and PMA have strong odors, which may cause discomfort to workers. Nonetheless, these solvents are widely used in both industrialized and developing countries.

Equipment Requirements

Eliminating CTC in solvent cleaning involves the use of new chemicals or the implementation of new processes (such as substituting aqueous cleaning for CTC in bulk cleaning applications). In the case of hand-wipe cleaning and where chlorinated or organic solvents are used as the active ingredient in aerosols, there are no changes of equipment needed for the cleaner to function properly. However, depending on the alternative being used, its physical properties, and the method of application, new or different personal protective equipment may be required for workers. In addition, additional ventilation will be required where it does not already exist.

In instances where an alternative is replacing CTC in a bulk cleaning application, portions of the old equipment can often be used for the new process with certain adjustments or retrofits. Depending on the age and overall quality of the equipment in use, retrofits can be relatively simple or they may be extensive. In some cases however, existing equipment will not be able to be retrofitted to adequately contain emissions. In these instances, it will be necessary to purchase new cleaning equipment. In addition, changes may be required in plant engineering and building design to address flammability and/or toxicity concerns.

2. Aerosols Alternative Technologies Datasheets

2. Aerosols Alternative Technologies Datasheets

2.1 Hydrocarbon Aerosol Propellants (HAPs)

Headline:

Hydrocarbons (HCs) are the most commonly used substitutes for CFCs in aerosol propellants. They currently account for 96% of worldwide conversions from CFCs and 86% of current aerosol propellant uses in the United States. Advantages of hydrocarbons include their widespread availability, low cost, low toxicity, and good dispersion characteristics. The main drawbacks of hydrocarbons are their high flammability and the difficulty of obtaining low-odor blends of the desired pressure in many developing nations. They are also volatile organic compounds (VOCs) and their use may be restricted or prohibited in some areas.

ODS Use Sector:

Aerosols, sterilants, miscellaneous uses, and carbon tetrachloride.

Industry Sector:

Most aerosol applications in which flammability is not a concern or in which the risk of flammability can be mitigated through other means.

ODS Reduction/Elimination Method:

CFC use is eliminated by using a substitute chemical and making equipment and operational procedure modifications.

Composition of Alternative:

The three hydrocarbons which are most frequently used as propellants in aerosols are propane, n-butane, and isobutane. The following chart presents some relevant properties of each:

	PROPANE	N-BUTANE	ISOBUTANE
Formula	C_3H_8	C_4H_{10}	$(CH_3)_3CH$
Boiling Point	-42.0°C	-0.5°C	-11.7°C
Vapor Pressure @21°C	8.55 bar	2.18 bar	3.16 bar
Density @15.6°C	0.51 g/cm³	0.58 g/cm³	0.56 g/cm³
HC/Air Weight Ratio	1.5:1	2.8:1	2.0:1
Flammable Limits in Air (vol %)	2.1 - 9.5%	1.8 - 8.4%	1.8 - 8.5%
Flash Point (closed cup)	-104°C	-74°C	-83°C
Kauri-Butanol Value	15.2	19.5	17.5

Sources: UNEP, 1991
CSMA, 1979

Flammability:

HC propellants are flammable in air when they are present in concentrations greater than those listed above. Because their flash points are below room temperature, any fire or energetic spark can ignite HCs at ambient temperatures. In order to prevent fire or explosion, the concentration of HCs in the air must be below the Lower Explosive Limit (LEL) and possible sources of ignition must be eliminated.

Because HC aerosol propellants are highly flammable and have no detectable odor, extreme care must be taken during transport, handling, and storage of the materials. The precautions that must be taken when using HCs in aerosol applications are discussed in greater detail below under "Health and Safety." While there are obvious drawbacks to using a flammable propellant, there may be benefits depending on the application. The flammability of HCs enhances the effectiveness of products that should be, by design, flammable. Examples of these products include engine starters, carburetor cleaners, charcoal starters, etc. (Nardini, 1992).

Toxicity:

Most hydrocarbons exhibit low toxicity, making them suitable for use in a variety of personal care and household products. For reference purposes, in the U.S. the Occupational Health and Safety Administration (OSHA) has set a permissible exposure limit (PEL) of 800 ppm for butane (USEPA, 1993).

VOC Classification[6]: VOC

Ozone Depleting Potential (ODP): 0

Global Warming Potential (GWP): Negligible

Phaseout Schedule: None

Propellant Characteristics:

Hydrocarbons, like CFCs, provide a fairly uniform pressure inside the aerosol container throughout the life of the product. This is possible because the propellant acts as a "reservoir" of gas to maintain the pressure in the headspace, even as the headspace volume increases (Radian, 1991). Because of their lower density, HCs float on the surface of water-based products. If the aerosol container is not agitated prior to use, the spray may be coarse, but the entire content of the container will still be used. Some heterogeneous aerosols (aerosols whose

[6] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

contents exist in separate phases) require shaking before use to generate a temporary emulsion that becomes a spray or foam on discharge.

HCs are nonpolar, which renders them immiscible with many polar solvents, including water. They are less effective solvents than CFCs. This may pose problems in formulations for products such as aerosol paints and hair sprays. In some cases, co-solvents such as ethanol can be used to provide single-phase blends of hydrocarbons, alcohol, and water (Radian, 1991).

Substitute Production Method and Materials:

Material Requirements

Hydrocarbons are derived from liquified petroleum gases (LPGs) which come from the ground as a constituent of wet natural gas or crude oil, or which are produced as a by-product of petroleum refining (Radian, 1991). Some LPGs contain high levels of unsaturated hydrocarbons such as ethylene, acetylene, and butadiene, and sulfur compounds such as hydrogen sulfide, methylthiol, and ethylthiol. Typically, only gas streams with less than 200 ppm sulfur are used since the cost of purifying HCs becomes too great as the level of impurity increases (UNEP, undated). HCs are purified to various grades: pure grade, aerosol grade, technical grade, commercial grade, fuel grade, and so forth. Each differs in terms of purity and odor. The aerosol grade HCs, which are used in propellant applications, are typically 95 mol-% pure. They may also contain up to 1.0 ppm sulfur compounds, 100 ppm unsaturated hydrocarbons, less than 10 ppm water, and small quantities of other impurities (UNEP, undated).

When HCs are purified, they undergo moisture removal, removal of sulfur compounds, and removal of unsaturated compounds. The most common method of hydrocarbon propellant purification is the solid adsorption process. This process involves using materials such as silica gel, activated aluminas, or molecular sieve adsorbents for dehydration and sulfur removal. Activated carbon or molecular sieves may also be used to remove unsaturated compounds. A disadvantage of using the solid adsorption purification process is the need to periodically replace or regenerate the adsorbent. If the adsorbent becomes saturated, the impurities will no longer be removed and contaminated propellant will enter the system (Radian, 1991). If unsaturated compounds cannot be satisfactorily removed by molecular sieve adsorption, they may require removal through a more expensive process like hydrogenation. Also, the use of molecular sieves may be of limited utility unless very large quantities of relatively pure material are to be processed (UNEP, undated).

Aerosol grade HCs must also fall within the proper pressure range. Two typical pressures for HC propellants at 21°C are 4.18 bar and 5.84 bar. Unfortunately, some countries produce or import HCs in pressure ranges unsuitable for aerosol use. For example, the HCs currently commercially available in Honduras have pressures at 21°C between 9.97 bar and 11.35 bar. Such a range is too high for use in aerosols. In addition, manufacturers in other countries often offer blends which may vary up to 20 percent in pressure from week to week. This variance is dependent on the well from which the gas is recovered.

Filling Processes

The equipment used in HC propellant filling is predominantly the same as that used in CFC propellant filling. When retrofitting a plant for HC filling, all equipment must be made explosion proof if it is not already. During the filling of aerosol cans, HCs inevitably leak into open air. Ventilation is necessary to prevent HC concentration levels from reaching LELs. Also, various safety features should be added to prevent or mitigate the effects of fire or explosion. Plants with indoor hydrocarbon filling facilities should contain:

- filling rooms with high resistance walls
- blow out walls or ceiling
- two speed or duplicate floor-sweeping air exhaust systems
- infra red gas detection systems
- automatic solenoid shut-off valves for propellant lines
- alarm systems

In warm climates, open air filling of hydrocarbons may be a viable option depending on local regulations. Open air filling relies on natural ventilation to dissipate HCs released during the filling operation. It is ideal for developing countries because it is inexpensive, safer than indoor filling, and requires less rigorous education on safety and operational procedures. Because open air filling uses wind, which may not always be high, to provide ventilation, it is most suitable for slow to medium speed pressure filling operations. The following is a list of design criteria which should be met when constructing an open air filling room.

- There should be considerable space for natural ventilation. If sufficient open space is not available, open air filling should not be used when designing or retrofitting a plant.

- The gassing room should have only one solid wall. A minimum of one meter should separate the gassing room wall from the wall of the main plant. The other three walls should be made of large mesh wire or open-design concrete block. The ceiling can be a plastic sheet that extends far enough outside the room to prevent rain from entering or being blown in. No equipment, tanks, etc. should break up the natural movement of air.

- No sources of fire or sparks should exist nearby. There should be no driveways, parking lots, material handling areas, electrical installations, pumps, compressors, or boiler rooms in the area of the gassing room. When retrofitting an existing plant, the above requirements may be considered restrictive. In some cases, it may be preferable to relocate several areas within the plant than to use indoor filling.

- If possible, gassing facilities should use pneumatic equipment, which minimizes maintenance and inspection to remain safe. If it is not possible to use pneumatic equipment, explosion proof electrical equipment must be used. When using explosion proof equipment, plant personnel must conduct frequent inspections to ensure the integrity of the system after maintenance and use. If production requirements permit, natural daylight should be used for illumination.

- The gassing machine, wire mesh walls, doors, conveyors, etc. should be grounded to avoid static charges that cause sparks. The floor should be made of anti-spark material or treated with an anti-spark resin. Workers should wear soft soled shoes and only cotton clothing. Any tools used in the gassing room during operation must be made of anti-spark material.

- If flammable concentrates are also used in aerosol products, the concentrate preparation room should not be near the gassing room. In addition, the solvent storage area should not be near the gassing room or hydrocarbon tanks.

- Both the HC tanks and gassing room should be protected by properly installed lightning rods to draw lightning away from these areas.

Health and Safety Considerations:

Since HAPs are odorless gases, there may be some locations in which governments require that a stenching agent be added to HAPs prior to ground transport. However, many countries, including the United States, Canada, and Mexico, do not require such processes. In areas where this requirement exists, one option for fillers is to purchase tanks of aerosol grade HCs from the United States, Europe, Japan, Egypt, or Australia and arrange to have the material stenched with 10-20 ppm ethylthiol. The material can be stenched by the supplier or at the port of entry. A modest size molecular sieve column can remove the low concentration of ethylthiol after the shipment arrives at the filling plant.

Flammability is a major concern when using hydrocarbons. Because the highly flammable properties of HCs are internationally recognized, nearly all countries have established rules, regulations, and recommended practices for ground and air transport. In the United States, the National Fire Protection Association (NFPA) issues guidelines concerning the storage and handling of hydrocarbons and other flammable materials. NFPA Code #30B is of interest to warehouse operators where aerosols are stored, while both Codes #30B and #58 are of interest to aerosol fillers. Copies of these Codes can be obtained by writing to the following address:

National Fire Protection Association
Attn: Robert Bernadetti
P.O. Box 9101
1 Batterymarch Park
Quincy, MA 02269-9101
USA

The flammable hazard is greater with HCs than many other gases because of the heavier weight of the HCs and the very low concentration that is required for ignition. The HCs are also odorless, colorless, and have a high level of expansion when passing from a liquid state to gaseous state (UNEP, undated). Extreme care must be taken in filling plants and storage facilities. If the plant is located in a developed area, the amounts of flammable materials that can be stored may be limited. The storage facilities must be equipped with emergency facilities (fire detection, sprinklers, shut-off valves, etc.) in case of fire. The aerosol gassing station should be located in an explosion-tolerant gassing house, preferably located outside the main plant building and fitted with a blow-out wall, grounded equipment, and explosion-proof electrical systems. Additional requirements depend on local regulations and should include standard and emergency ventilation at floor level, gas-detection equipment, explosion suppression systems, and electroprotective interlock systems that will react to emergency situations. For plants located in suitably warm climates, gassing of propellants outdoors as described earlier may be appropriate where local regulations permit such activities.

Facilities must ensure that normal ventilation is sufficient to accommodate a hydrocarbon propellant. Local exhaust should be used when large amounts of hydrocarbon are to be released. If this release is to take place in a low area, additional mechanical ventilation will be needed. In addition, a number of additional precautions should be taken since hydrocarbon vapors are heavier than air. These precautions include:

- No smoking in or around hydrocarbon storage or filling areas.
- Permits issued for all work requiring excessive heat or the use of flames or sparks.
- Plan for controlling and extinguishing spill fires.
- Grounding of trucks and turning off engines prior to loading or unloading.

Environmental Considerations:

Hydrocarbons are VOCs and, therefore, are believed to contribute to the formation of tropospheric ozone (smog). Their use may be regulated in different countries or regions within countries.

Associated Costs:

Hydrocarbons are the least costly aerosol propellant currently available. They cost approximately US$0.50 per kilogram in North America. In those countries which permit importation of odor-free LPGs, HCs can be delivered by ship in bulk ISO-containers at dockside costs of up to US$1.50 per kilogram. Import duties may apply.

The cost of new, explosion-proof filling equipment varies extensively depending on its speed. A hand-operated gassing machine purchased in the United States which fills 10-15 cans/min may cost from approximately US$12,000 (for a through-the-valve type piston filler) to US$30,000 (for an under-the-cap type vacuum crimper and piston filler combination), while a rotary gassing machine capable of filling 60 cans/min may cost more than US$100,000.

Current Use:

Virtually all industrialized countries use HAPs. Developing countries in which companies are currently using hydrocarbon propellants in aerosol applications include Argentina, Brazil, Columbia, Guatemala, Indonesia, Malaysia, Mexico, and the People's Republic of China.

Availability:

Though hydrocarbons are available in virtually all industrialized countries and in many developing countries, they may not be readily available for use in the aerosols industry. As mentioned, there may be some locations in which the government requires that odorant be added to LPGs to ensure safety during ground transport. If too much odor is added, the cost of purifying HCs to aerosol grade may be extremely high. However, most countries require the addition of no more than 10 ppm ethylthiol or 20 ppm butylthiol as an odorant. As mentioned earlier however, this amount can be readily removed using a modest size molecular sieve column. In addition, improper transport practices can irrevocably contaminate otherwise usable raw material. The availability of hydrocarbons may also be limited in certain countries because the government exercises control over petrochemical use. Since the quantity of petrochemicals used in aerosol filling is typically far less (0.03 to 0.10 percent) than the quantity used as fuel, governments may not make the material available to aerosol producers. Finally, the potential supply of hydrocarbons may be limited by the unsuitability of the pressure ranges of the available substances.

Vendors of Alternative Equipment

Aerosol Filling Equipment Suppliers

Advam Packaging Systems
91 Darley Street
Mona Valve, NSW 2103
Australia
Tel: (61) 2 997 5533
Fax: (61) 2 997 7996

Aerofill Limited
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

Aerojet Quimica Industrial Ltda
Av. Beira Mar, 200
Salas 801/803 Costelo
RJ
Brazil
Tel: (55) 21 262 8181
Fax: (55) 21 776 1904

Aerosol Laboratory Equipment
R.D. 1, Box 75
Route 10
Walton, NY 13856
USA
Tel: (1) 607 865 7173
Fax: (1) 607 865 7175

Akron Polymer Container
540 South Main Street
Akron, OH 44311
USA
Tel: (1) 216 253 6500
Fax: (1) 216 253 8009

Autoprod Inc.
5355 115th Avenue North
Clearwater, FL 34620
USA
Tel: (1) 813 572 7753
Fax: (1) 813 573 0367

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali SpA
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 290 06075
Fax: (39) 2 290 06700

Cozzoli Machine Company
401 E. 3rd Street
Plainfield, NJ 07060
USA
Tel: (1) 908 757 2040
Fax: (1) 908 757 7386

Daellenbach Maschinenbau
Bachstrasse 25
CH-8912 Obfelden
Zurich
Switzerland
Tel: (41) 1 761 71 25
Fax: Not available

Doje Corporation
Yougdong
P.O. Box 1211
Seoul 135
Republic of Korea
Tel: (82) 2 553 4994
Fax: (82) 2 554 0451

Druk Pak AG
CH-8132 Egg
Zurich
Switzerland
Tel: (41) 1 984 2720
Fax: (41) 1 984 0715

Gem Shine Trading Co.
Shin Chiang Chung Ind. Co. Ltd.
No 23, Lane 84, Jing-Yin Street
Shu-Lin Town, Taipei Hsien
Taiwan
Tel: (886) 2 682 5549
Fax: (886) 2 685 1769

JG Machine Works, Inc.
75 Spring Street
Paterson, NJ 07501
USA
Tel: (1) 201 881 7000
Fax: (1) 201 881 0563

Jose F. Olivieri & Assoc.
Suite 906-B
623 Ponce De Leon Ave.
Hato Rey 00919
Puerto Rico
Tel: (1) 809 766 0006
Fax: (1) 809 756 5930

KP Aerofill
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

KP Aerofill
807 W. Kimberly Road
P.O. Box 3848
Davenport, IA 52808
USA
Tel: (1) 319 391 1100
Fax: (1) 319 391 4951

Laboratories Rety De Colombia
Zona Franca B-10
Apartado Aereo 29594
Barranquilla
Colombia
Tel: (57) 58 2360641
Fax: (57) 58 413472

Nalbach Engineering Co, Inc.
6139 W. Ogden Avenue
Cicero, IL 60650
USA
Tel: (1) 708 652 8900
Fax: (1) 708 652 8920

Nimmo Packaging Systems
1 Home Villa, Farley Heath
Albury, Surrey GU5 9ER
United Kingdom
Tel: (44) 483 20 3609
Fax: (44) 483 20 3625

Pamasol
Driesbuelstrasse 2
CH-8808 Pfaffikon SZ
Switzerland
Tel: (41) 55 4824 31
Fax: (41) 55 4852 15

P & P Machinery
P.O. Box 1712
Glen Vista 2058
South Africa
Tel: (27) 11 432 2188
Fax: (27) 11 682 2142

Precision Valve (India) Pvt. Ltd.
228 Pragati Ind Estate
N.M. Joshi Marg
Bombay 400 011
India
Tel: (91) 22 309 7422
Fax: (91) 22 307 0618

Precision Valve Singapore Pte. Ltd.
10/12/Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 264 0461

Reed Enterprises Inc.
52645 Thorne Drive
Elkhart, IN 46514
USA
Tel: (1) 219 264 9900
Fax: (1) 219 264 7733

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Spider Engineering, Inc.
700 South Plumosa Street
Merritt Island, FL 32952
USA
Tel: (1) 407 452 3922
Fax: (1) 407 453 8338

Super Pak S.A.
Heraclito 327 P.A.
Col. Polanco C.P. 11560
Mexico
Tel: (52) 5 545 2127
Fax: (52) 5 251 8144

Tecnomac S.p.A.
Via Garofalo, 19
20133 Milano
Italy
Tel: (39) 2 27 80 44
Fax: Not available

Terco, Inc.
496 Lunt Ave.
Schaumberg, IL 60193
USA
Tel: (1) 708 894 8828
Fax: (1) 708 894 8846

Valve Suppliers

Aboukir Engineering Industries
Aboukir-Alexandria
Egypt
Tel: (20) 3 560 1538
Fax: (20) 3 560 3392

Aerocan Ltd.
P.O. Box 4519
Nicosia
Cyprus
Tel: (357) 2 350 550
Fax: (357) 2 350 559

Aerosol Research & Development, Ltd.
Fitzherbert Road
Farlington, Portsmouth
Hants PO6 1RU
United Kingdom
Tel: (44) 705 387 782
Fax: (44) 705 380 825

Aerosol-Technique Lindal (UK)
Cherrycourt Way, Stanbridge Road
Leighton Buzzard
Bed. LU7 8UH
United Kingdom
Tel: (44) 525 381 186
Fax: (44) 525 383 304

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Avery Denison Ltd.
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 0922 614 631
Fax: (44) 0922 613 043

BLM Associates/Lablabo
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Walter C. Beard, Inc.
P.O. Box B
Middlebury, CT 06762
USA
Tel: (1) 203 758 2194
Fax: Not available

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Carnaud-Metalbox
20 A Street
Derry, NH 03038
USA
Tel: (1) 603 434 7741
Fax: (1) 603 437 5703

Carnaud-Metalbox Packaging
Nigeria Ltd.
3-7 Metal Box Road
Ogba Ind. Est
PMB 21588 Ikeja, Lagos
Nigeria
Tel: Not available
Fax: (234) 1 964 443

Carnaud-Metalbox Packaging
Singapore Ltd.
Marsiling P.O. Box 0356
1120 Woodlands Road 9173
Singapore
Tel: (65) 269 6111
Fax: (65) 367 0912

Clayton Corporation
866 Horan Drive
Fenton, MO 63026
USA
Tel: (1) 314 349 5333
Fax: (1) 314 349 5335

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 2900 6075
Fax: (39) 2 2900 6700

Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
Germany
Tel: (49) 911 324 350
Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190-801200

EP Spray System
60 Williams Parkway, Suite J
East Hanover, NJ 07936
USA
Tel: (1) 201 515 8535
Fax: Not available

EP Spray System
30 Rue de Plan
CH 2002 Neuchatel
Switzerland
Tel: (41) 38 25 02 22
Fax: (41) 38 24 49 07

Engineered Controls International
Rego Products
100 Rego Drive
Elon College, NC 27244
USA
Tel: (1) 919 449 7707
Fax: (1) 919 449 6594

Kum Suk Chemical Co.
301-3F Ara Bldg.
705-9 Banpo-1 Dong
Seocho-Ku, Seoul
Republic of Korea
Tel: (82) 2 516 8411
Fax: (82) 2 516 8414

Kumar Aerosols (p) Ltd.
3/13-B, ASAF Ali Rd.
New Delhi 110002
India
Tel: (91) 327 9044
Fax: (91) 326 9761

Lindal Italiana S.R.L.
Via Piave, 7
22049 Valmadrera-Como
Italy
Tel: (39) 341 551 433
Fax: (39) 341 551 293

Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
Leighton Buzzard
Bedfordshire LU7 8UH
United Kingdom
Tel: (44) 525 381 155
Fax: (44) 525 383 304

Lindal Ventil GmbH
Industriestrasse 13
D-2060 Bad Oldesloe
Germany
Tel: (49) 4531 86001
Fax: (49) 4531 87664

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43-1
08014 Barcelona
Spain
Tel: (34) 3 314 9111
Fax: (34) 3 314 6081

Nampak Group
P.O. Box 247
Howard Place
South Africa
Tel: (27) 21 547 111
Fax: (27) 21 547 126

Newman-Green, Inc.
57 Interstate Road
Addison, IL 60101
USA
Tel: (1) 708 543 6500
Fax: (1) 708 543 8523

Novospray S.A.
Place Cornavin 18
CH 1201 Geneva
Switzerland
Tel: (41) 22 738 22 11
Fax: (41) 22 738 21 38

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Perfect-Valois Ventil GmbH
Hildebrandstrasse 20, Post. 130340
4600 Dortmund 13 (Wickede)
Germany
Tel: (49) 231 218 0211
Fax: (49) 231 21 17 52

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416 683 0120
Fax: (1) 416 427 1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, Florida 33315
USA
Tel: (1) 305 359 1425
Fax: (1) 305 359 0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel: (39) 2 944 9256
Fax: (39) 2 944 9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484 444851
Fax: (81) 484 446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22 3097732/3097422/3097794
Fax: (91) 22 3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111, Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapoe PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/(65) 264-0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442 (plant)
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Safeworld International
7352 Adams Road
Talent, OR 97540
USA
Tel: (1) 503 535 7661
Fax: (1) 503 535 3204

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Valve Company
1160 N. Silver Lake Road
Cary, IL 60013
USA
Tel: (1) 708 639 2124
Fax: (1) 708 639 1179

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Summitt Packaging Europe
Grot Mijdrecht 9F
3641 RV Mijdrecht
Netherlands
Tel: (31) 2979 88661
Fax: (31) 2979 87289

Summit Packaging Systems
P.O. Box 5304
Manchester, NH 03108
USA
Tel: (1) 603 669 5410
Fax: (1) 603 645 1047

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvole Aerosol Research Italiana
Via Del Pino 10
22057 Olginate (Como)
Italy
Tel: (39) 341 680 325
Fax: (39) 341 680 501

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds.
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo 60230
Brazil
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

Hydrocarbon Propellant Suppliers

Aerojet Quimica Industrial Ltda.
Rua Jura Sem. No. Quadra 538
25000 D. Caxias (RJ)
Brazil
Tel: (55) 21 776 1841
Fax: (55) 21 776 1904

Aeropres Corporation
1324 N. Hearne
Suite 200
P.O.Box 78588
Shreveport, LA 71137-8588
USA
Tel: (1) 318 221 6282
Fax: (1) 318 429 6739

Aeropres, S.A.
Circuito Ingenieros #13-102
Naucalpan de Juarez,
Edo. de Mexico C.P. 53100
Mexico
Tel: (52) 5 572 5126
Fax: (52) 5 393 0878

Color Gas Ltd.
Appleton Park
Slough, Berkshire SL3 9JG
United Kingdom
Tel: (44) 753 40 000
Fax: (44) 753 48 121

Copia Associates, Inc.
9837 Neesonwood Dr.
Shreveport, LA 71106
USA
Tel: (1) 318 797 8372
Fax: (1) 318 797 0101

DeMert & Dougherty
5 Westbrook Corp. Center
Suite 900
Westchester, IL 60154
USA
Tel: (1) 708 409 9000
Fax: (1) 708 409 9033

Diversified CPC International, Inc.
Santa Fe Industrial District
Durkee Road
Channahon, IL 60410
USA
Tel: (1) 815 423 5995
Fax: (1) 815 423 5627

Elf Atochem
4 Cours Michelet
La Defense 10
Cedex 42-92091
Paris
France
Tel: (33) 1 49 00 80 46
Fax: (33) 1 49 00 70 21

Esso Nederland
P.O. Box 1
4803 AA Breda
Netherlands
Tel: (31) 76 291 104
Fax: (31) 76 203 242

Exxon Company USA
P.O. Box 3272
Houston, TX 77253
USA
Tel: (1) 713 870 6000
Fax: (1) 713 870 6661

Klockner CPC Intl. GmbH
Hentrichstasse 65
D-4150 Krefeld
Germany
Tel: (49) 2151 52 19 17
Fax: (49) 2151 52 19 22

Petrolane Transport
P.O. Box 851
Long Beach, CA 90801
USA
Tel: (1) 213 595 7595
Fax: Not available

Puregas (Pty) Limited
P.O. Box 3884
Alrode 1451
South Africa
Tel: (27) 11 908 1618
Fax: (27) 11 908 5862

Rety de Colombia Ltda.
Bodega 10
P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Ross and Associates, D.B.
P.O. Box 423
Markham, Ontario L3P 3R1
Canada
Tel: (1) 416 479 0712
Fax: (1) 416 479 0712

Technical Propellants, Inc.
6233 North Pulaski Road
Chicago, IL 60646
USA
Tel: (1) 312 463 5555
Fax: (1) 312 463 8061

Shell Gas
Western Dock, Immingham
South Humberside DN40 1AA
United Kingdom
Tel: (44) 469 571 166
Fax: (44) 469 571 376

LPG Purification Equipment

Alcoa Separations Technology, Inc.
333 North Belt
Suite 650
Houston, TX 77060
USA
Tel: (1) 713 999 6050
Fax: (1) 713 999 5403

LaRoche Chemicals, Inc.
Airline Highway
P.O. Box 1031
Baton Rouge, LA 70821
USA
Tel: (1) 504 356 8423
Fax: (1) 504 358 2820

Davison Chemical Division
W.R. Grace & Co.
P.O. Box 2117
Baltimore, MD 21203
USA
Tel: (1) 410 659 9292
Fax: (1) 410 659 9213

Sources of Additional Information about this Technology:

1. Chemical Specialties Manufacturers' Association (CSMA). "Hydrocarbon, Dimethyl Ether, and other Propellants: Considerations for Effective Handling in the Aerosol Plant and Laboratory." Washington, D.C., USA, 1979.

2. Johnsen, Montfort A. The Aerosol Handbook 2nd Edition. Mendham, NJ, USA: Wayne Dorland Company, 1982.

3. Nardini, Geno. "Open Air Filling of Hydrocarbon Propellants:" Presented at World Conference on CFC's, Baltimore, MD, USA, 26-29 November 1990.

4. Radian Corporation for USEPA. "Manual for Non-CFC Aerosol Packaging: Conversion from CFC to Hydrocarbon Propellants." Washington, D.C., USA, September 1991.

5. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

6. UNEP Training Manual. "For the Conversion from Chlorofluorocarbon (CFC) Propellants to Alternatives, including Hydrocarbon Gases."

7. USEPA. "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substitutes: Aerosols." March 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.2 Dimethyl Ether Aerosol Propellants

Headline:

Dimethyl ether (DME) is a liquefied gas propellant. It is used in some European, Japanese, and U.S. aerosol formulations. The advantages of DME include high solvency and ease of reformulation to water-based products. Environmental, health, and safety disadvantages include its flammability, which requires the retrofit or redesign of filling lines and storage facilities, and the fact that it is a volatile organic compound (VOC). DME corrodes tinplate and aluminum cans if water is also present and therefore requires the addition of special corrosion inhibitors. In addition, DME may dissolve can linings. Finally, the use of DME as a propellant requires the use of butyl rubber or neoprene valve gaskets.

Industry Sector:

Water-based paints, hair sprays, aerosol deodorants, colognes, and perfumes.

ODS Reduction/Elimination Method:

CFC use is eliminated by switching to DME as a propellant in aerosol formulations.

Composition of Alternative:

Characteristic	$(CH_3)_2O$
Vapor Volume, mL vapor/g liquid at 21.1°C	523
Vapor Volume, mL vapor/mL liquid at 21.1°C	345
Vapor Pressure @21.1°C	5.36 bar
Vapor Specific Gravity @15.6°C and 1 bar (Air = 1)	1.64
Kauri-Butanol Value	91

Toxicity:

DME has a very low toxicity and is metabolized rapidly in the body. It has a low order of acute, subacute, and subchronic inhalation toxicology. It has no mutagenic or teratogenic effects, at least up to 28,000 ppm, the tested limit in the United States. The USEPA has estimated a short-term emergency guidance level (EGL) for DME at 500 ppm (USEPA, 1993). Overexposure may cause non-specific discomfort, nausea, headache, or weakness. Skin contact may cause freezing and possible frostbite. The aquatic toxicity of DME is unknown.

Flammability:

Flammable Limits in Air (vol %)	3.4 - 18.2%
Flash Point (closed cup)	-41.1°C
Auto Ignition Temperature	350°C

Because DME and hydrocarbons are similar in that they are highly flammable non-ODS alternative propellants, the properties of the two are often compared. DME has a lower BTU content than hydrocarbons. While DME propellant formulations may present a lower potential for fire hazards to workers and fire fighters than do hydrocarbon formulations, the flammability of the total aerosol product must be considered. Therefore, the same fire safety and explosion prevention precautions should be taken in DME filling and storing operations as with hydrocarbon aerosol propellants. In addition, retrofitting or redesign of filling lines and storage facilities will be necessary.

VOC Classification[7]: VOC

Ozone Depleting Potential (ODP): 0

Global Warming Potential (GWP):

As a VOC, DME contributes to the formation of tropospheric ozone (smog). While tropospheric ozone is considered to be a greenhouse gas, most scientists agree that its contribution to global warming is very small.

Phaseout Schedule: None

Propellant Characteristics:

DME is soluble in water up to 34.3 percent. However, if 7 percent ethanol is also present, DME is soluble in water in all proportions. DME's strong solvent properties make it beneficial in the formulation of viscous and adhesive aerosols since water and many polymeric ingredients remain soluble even at high concentrations of DME. Its high solubility also makes it suitable for use in water-based paints, and it is being investigated as a means of facilitating the introduction of water into such products as single-phase air fresheners and hair sprays. In Europe, DME is already widely used as a propellant in bathroom air freshener sprays, hair sprays, and insecticides.

[7] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

In the formulation of polyurethane aerosols, the introduction of very minor amounts of DME serves to tie up trace moisture that would otherwise adversely affect the long-term stability of the urethane pre-polymer. For example, without 2% or 3% concentrations of DME, many formulas in unactuated dispensers will turn viscous or even harden in 6 to 12 months of ambient storage. With the addition of DME, these same formulations have remained in good condition even after being stored for 30 months.

DME has strong solvent properties and can corrode tinplate containers in the presence of water. Corrosion may cause discoloration, bad odors, particulates and may cause container perforation in tinplate cans or valve cups. DME may blister or partly solubilize can linings, causing products to become hazy. In some cases, the addition of hydrocarbons or ethanol to DME/water formulas will exacerbate the corrosion process.

Because of DME's strong solvent properties, special care must be taken in the selection of valve gaskets and crimping specifications. Neoprene and butyl rubber stem gaskets are recommended, depending on the concentration of DME in the formulation. Viton fluorinated polymers are not recommended for use as stem gaskets as they decompose in the presence of DME. Neoprene cut, butyl cut, polyethylene sleeve, polyethylene laminate, and polypropylene laminate mounting cup gaskets are recommended. Before finally choosing stem and cup gaskets, extensive product weight loss studies should always be run, preferably using stem and cup gasket combinations suggested by the valve companies for the formulation type under consideration.

Substitute Production Method and Materials:

When converting the propellant, it is important to consider possible impacts on the valve and can components. Modifications of the formulation, valve, and can may be necessary to achieve the desired product delivery.

The use of DME requires the installation of equipment and adoption of safe operating practices that address its flammability. These are discussed further below in the section on health and safety considerations.

Health and Safety Considerations:

Normal ventilation is generally adequate when using DME-propelled aerosol cans. When releasing large amounts of DME from aerosol cans, however, local exhaust should be used. When releasing large amounts from aerosol cans in low places, mechanical ventilation should be used. All equipment and cylinders should be grounded. Explosion-proof electrical equipment should be used.

Because DME vapors are heavier than air, they pose safety problems similar to the light hydrocarbon aerosol propellants. Typical precautions for filling plants and storage warehouses are:

- Smoking permitted only in designated and well ventilated areas
- Issuance of permits for all for all work requiring welding and burning at the plant
- Proper contingency plan for spill fires
- Loading and unloading of products only after proper grounding of trucks and after engines have been turned off.

Environmental Considerations:

DME is a VOC and can produce smog effects. The smog problems that DME poses may be alleviated however by its high solubility in water. Since a relatively high concentration of water can be solubilized in DME-propelled products, local VOC requirements may be met because a lower percentage of VOC ingredients is present in the total formulation.

Associated Costs:

In the United States, DME costs two times as much as aerosol grade hydrocarbons (Spray Technology and Marketing, February 1993). In Europe and Japan, DME is equal or slightly higher in price than aerosol grade hydrocarbons (UNEP, 1992). The average price for DME in the United States is approximately US$0.95/kg in bulk.

Current Use:

DME has achieved some penetration of aerosols markets in certain European countries and in Japan. In 1980, it accounted for roughly 5% and 18% of all European and Japanese aerosols, respectively. DME accounted for 20% of aerosol unit production in Belgium and 17% in the Netherlands. DME is used less widely in the United States because it is more expensive relative to other propellant alternatives. Ethanol and isopropanol are taxed and very expensive in Europe, prompting Europeans' greater use of cheaper DME: using more propellant reduces the amount of alcohol required. In the United States, ethanol costs a small fraction of what it costs in Europe, and DME is about twice as expensive. Use of DME in the U.S. has therefore been limited for economic reasons. But, with prices for DME having dropped by nearly a quarter in the United States since 1988, the use of DME as an aerosol propellant has been increasing and is likely to continue doing so. Its application in personal care and medical formulations, in particular, is on the increase.

Availability:

The availability of DME outside of Europe, Japan, and the United States is limited. However, it is expected to be available in Australia and New Zealand in 1994, and the People's Republic of China expects to complete construction of a DME plant by early 1995.

Vendors of Alternative Equipment:

Aerosol Filling Equipment Suppliers

Advam Packaging Systems
91 Darley Street
Mona Valve, NSW 2103
Australia
Tel: (61) 2 997 5533
Fax: (61) 2 997 7996

Aerofill Limited
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

Aerojet Quimica Industrial Ltda
Av. Beira Mar, 200
Salas 801/803 Costelo
RJ
Brazil
Tel: (55) 21 262 8181
Fax: (55) 21 776 1904

Aerosol Laboratory Equipment
R.D. 1, Box 75
Route 10
Walton, NY 13856
USA
Tel: (1) 607 865 7173
Fax: (1) 607 865 7175

Akron Polymer Container
540 South Main Street
Akron, OH 44311
USA
Tel: (1) 216 253 6500
Fax: (1) 216 253 8009

Autoprod Inc.
5355 115th Avenue North
Clearwater, FL 34620
USA
Tel: (1) 813 572 7753
Fax: (1) 813 573 0367

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali SpA
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 290 06075
Fax: (39) 2 290 06700

Cozzoli Machine Company
401 E. 3rd Street
Plainfield, NJ 07060
USA
Tel: (1) 908 757 2040
Fax: (1) 908 757 7386

Daellenbach Maschinenbau
Bachstrasse 25
CH-8912 Obfelden
Zurich
Switzerland
Tel: (41) 1 761 71 25
Fax: Not available

Doje Corporation
Yougdong
P.O. Box 1211
Seoul 135
Republic of Korea
Tel: (82) 2 553 4994
Fax: (82) 2 554 0451

Druk Pak AG
CH-8132 Egg
Zurich
Switzerland
Tel: (41) 1 984 2720
Fax: (41) 1 984 0715

Gem Shine Trading Co.
Shin Chiang Chung Ind. Co. Ltd.
No 23, Lane 84, Jing-Yin Street
Shu-Lin Town, Taipei Hsien
Taiwan
Tel: (886) 2 682 5549
Fax: (886) 2 685 1769

JG Machine Works, Inc.
75 Spring Street
Paterson, NJ 07501
USA
Tel: (1) 201 881 7000
Fax: (1) 201 881 0563

Jose F. Olivieri & Assoc.
Suite 906-B
623 Ponce De Leon Ave.
Hato Rey 00919
Puerto Rico
Tel: (1) 809 766 0006
Fax: (1) 809 756 5930

KP Aerofill
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

KP Aerofill
807 W. Kimberly Road
P.O. Box 3848
Davenport, IA 52808
USA
Tel: (1) 319 391 1100
Fax: (1) 319 391 4951

Laboratories Rety De Colombia
Zona Franca B-10
Apartado Aereo 29594
Barranquilla
Colombia
Tel: (57) 58 2360641
Fax: (57) 58 413472

Nalbach Engineering Co, Inc.
6139 W. Ogden Avenue
Cicero, IL 60650
USA
Tel: (1) 708 652 8900
Fax: (1) 708 652 8920

Nimmo Packaging Systems
1 Home Villa, Farley Heath
Albury, Surrey GU5 9ER
United Kingdom
Tel: (44) 483 20 3609
Fax: (44) 483 20 3625

Pamasol
Driesbuelstrasse 2
CH-8808 Pfaffikon SZ
Switzerland
Tel: (41) 55 4824 31
Fax: (41) 55 4852 15

P & P Machinery
P.O. Box 1712
Glen Vista 2058
South Africa
Tel: (27) 11 432 2188
Fax: (27) 11 682 2142

Precision Valve (India) Pvt. Ltd.
228 Pragati Ind Estate
N.M. Joshi Marg
Bombay 400 011
India
Tel: (91) 22 309 7422
Fax: (91) 22 307 0618

Precision Valve Singapore Pte. Ltd.
10/12/Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 264 0461

Reed Enterprises Inc.
52645 Thorne Drive
Elkhart, IN 46514
USA
Tel: (1) 219 264 9900
Fax: (1) 219 264 7733

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Spider Engineering, Inc.
700 South Plumosa Street
Merritt Island, FL 32952
USA
Tel: (1) 407 452 3922
Fax: (1) 407 453 8338

Super Pak S.A.
Heraclito 327 P.A.
Col. Polanco C.P. 11560
Mexico
Tel: (52) 5 545 2127
Fax: (52) 5 251 8144

Tecnomac S.p.A.
Via Garofalo, 19
20133 Milano
Italy
Tel: (39) 2 27 80 44
Fax: Not available

Terco, Inc.
496 Lunt Ave.
Schaumberg, IL 60193
USA
Tel: (1) 708 894 8828
Fax: (1) 708 894 8846

Valve Suppliers

Aboukir Engineering Industries
Aboukir-Alexandria
Egypt
Tel: (20) 3 560 1538
Fax: (20) 3 560 3392

Aerocan Ltd.
P.O. Box 4519
Nicosia
Cyprus
Tel: (357) 2 350 550
Fax: (357) 2 350 559

Aerosol Research & Development, Ltd.
Fitzherbert Road
Farlington, Portsmouth
Hants PO6 1RU
United Kingdom
Tel: (44) 705 387 782
Fax: (44) 705 380 825

Aerosol-Technique Lindal (UK)
Cherrycourt Way, Stanbridge Road
Leighton Buzzard
Bed. LU7 8UH
United Kingdom
Tel: (44) 525 381 186
Fax: (44) 525 383 304

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Avery Denison Ltd.
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 0922 614 631
Fax: (44) 0922 613 043

BLM Associates/Lablabo
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Walter C. Beard, Inc.
P.O. Box B
Middlebury, CT 06762
USA
Tel: (1) 203 758 2194
Fax: Not available

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Carnaud-Metalbox
20 A Street
Derry, NH 03038
USA
Tel: (1) 603 434 7741
Fax: (1) 603 437 5703

Carnaud-Metalbox Packaging
Nigeria Ltd.
3-7 Metal Box Road
Ogba Ind. Est
PMB 21588 Ikeja, Lagos
Nigeria
Tel: Not available
Fax: (234) 1 964 443

Carnaud-Metalbox Packaging
Singapore Ltd.
Marsiling P.O. Box 0356
1120 Woodlands Road 9173
Singapore
Tel: (65) 269 6111
Fax: (65) 367 0912

Clayton Corporation
866 Horan Drive
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Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
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Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190 801200

EP Spray System
60 Williams Parkway, Suite J
East Hanover, NJ 07936
USA
Tel: (1) 201 515 8535
Fax: Not available

EP Spray System
30 Rue de Plan
CH-2002 Neuchatel
Switzerland
Tel: (41) 38 25 02 22
Fax: (41) 38 24 49 07

Engineered Controls International
Rego Products
100 Rego Drive
Elon College, NC 27244
USA
Tel: (1) 919 449 7707
Fax: (1) 919 449 6594

Kum Suk Chemical Co.
301-3F Ara Bldg.
705-9 Banpo-1 Dong
Seocho-Ku, Seoul
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Tel: (82) 2 516 8411
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Kumar Aerosols (p) Ltd.
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Fax: (91) 011 326 9761

Lindal Italiana S.R.L.
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22049 Valmadrera-Como
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Tel: (39) 341 551 433
Fax: (39) 341 551 293

Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
Leighton Buzzard
Bedfordshire LU7 8UH
United Kingdom
Tel: (44) 525 381 155
Fax: (44) 525 383 304

Lindal Ventil GmbH
Industriestrasse 13
D-2060 Bad Oldesloe
Germany
Tel: (49) 4531 86001
Fax: (49) 4531 87664

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43-1
08014 Barcelona
Spain
Tel: (34) 3 314 9111
Fax: (34) 3 314 6081

Nampak Group
P.O. Box 247
Howard Place
South Africa
Tel: (27) 21 547 111
Fax: (27) 21 547 126

Newman-Green, Inc.
57 Interstate Road
Addison, IL 60101
USA
Tel: (1) 708 543 6500
Fax: (1) 708 543 8523

Novospray S.A.
Place Cornavin 18
CH 1201 Geneva
Switzerland
Tel: (41) 22 738 22 11
Fax: (41) 22 738 21 38

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Perfect-Valois Ventil GmbH
Hildebrandstrasse 20, Post. 130340
4600 Dortmund 13 (Wickede)
Germany
Tel: (49) 231 218 0211
Fax: (49) 231 21 17 52

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416-683-0120
Fax: (1) 416-427-1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, FL 33315
USA
Tel: (1) 305-359-1425
Fax: (1) 305-359-0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel: (39) 2-944-9256
Fax: (39) 2-944-9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484-444851
Fax: (81) 484-446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22-3097732/3097422/3097794
Fax: (91) 22-3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111, Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapoe PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/(65) 264-0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442 (plant)
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Safeworld International
7352 Adams Road
Talent, OR 97540
USA
Tel: (1) 503 535 7661
Fax: (1) 503 535 3204

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Valve Company
1160 N. Silver Lake Road
Cary, IL 60013
USA
Tel: (1) 708 639 2124
Fax: (1) 708 639 1179

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Summitt Packaging Europe
Grot Mijdrecht 9F
3641 RV Mijdrecht
Netherlands
Tel: (31) 2979 88661
Fax: (31) 2979 87289

Summit Packaging Systems
P.O. Box 5304
Manchester, NH 03108
USA
Tel: (1) 603 669 5410
Fax: (1) 603 645 1047

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvole Aerosol Research Italiana
Via Del Pino 10
22057 Olginate (Como)
Italy
Tel: (39) 341 680 325
Fax: (39) 341 680 501

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds,
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo 60230
Brazil
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

Dimethyl Ether Propellant Suppliers

Aerofako B.V.
Rotterdam, Netherlands
Tel: (31) 33 64 39 11
Fax: Not available

Aeropres Corporation
1324 N. Hearne
Suite 200
Shreveport, LA 71137
USA
Tel: (1) 318 221 6282
Fax: (1) 318 429 6739

Akzo Chemicals BV
P.O. Box 975
3800 AA Amersfoort
Netherlands
Tel: (31) 33 676 362
Fax: (31) 33 676 139

Akzo Chemicals Ltd.
1-5 Queens Road, Hersham
Walton-on-Thomas, Surrey KT12 5NL
United Kingdom
Tel: (44) 932 247 891
Fax: (44) 932 231 204

C.G. Smith Chemicals
72 Ballantrae Road
Merebank, Durban, 4052
South Africa
Tel: (27) 31 42 5341
Fax: (27) 31 42 9114

Consul Chemistry Industry
P.O. 1803
Taipei
Taiwan
Tel: (886) 2 362 8032
Fax: (886) 2 366 0806

Copia Associates, Inc.
9837 Neesonwood Dr.
Shreveport, LA 71106
USA
Tel: (1) 318 797 8372
Fax: (1) 318 797 0101

CSR Limited, Distil. Gp.
P.O. Box 13
Pyrmont NSW 2009
Australia
Tel: (61) 2 692 7631
Fax: (61) 2 552 1510

Diversified CPC International, Inc.
24338 W. Durkee Road
Channahon, IL 60410
USA
Tel: (1) 815 423 5991
Fax: (1) 815 423 5627

DuPont Argentina S.A.
Casilla Correo 1888
1000 Correo Central
Buenos Aires
Argentina
Tel: (54) 1 311 8167
Fax: (54) 1 311 1329

DuPont Canada Inc.
P.O. Box 2200
Streetsville
Mississauga, Ontario L5M 2H3
Canada
Tel: (1) 416 821 3300
Fax: (1) 416 821 5057

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel: (1) 302 633 1501
Fax: (1) 302 892 1705

DuPont-Mitsui Fluorochemicals Co., Ltd.
2-3, 1-Chome Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan
Tel: (81) 3 3216 8468
Fax: (81) 3 3215 0064

DuPont UK Limited
Wedgewood Way
Stevenage
Herts SG1 4QN
United Kingdom
Tel: (44) 438 734 000
Fax: (44) 438 734 621

Kortman Intradal B.V.
P.O. Box 69
3800 AB Amersfoort
Netherlands
Tel: (31) 33 605 120
Fax: (31) 33 621 1033

Technical Propellants Inc.
6233 N. Pulaski Road
Chicago, IL 60646
USA
Tel: (1) 312 463 5555
Fax: (1) 312 463 8061

Sources of Additional Information about this Technology:

1. Chemical Specialties Manufacturers Association. Hydrocarbon, Dimethyl Ether, and other Propellants: Considerations for Effective Handling in the Aerosol Plant and Laboratory. Washington, D.C., USA, 1979.

2. Johnsen, Montfort A. The Aerosol Handbook 2nd Edition. Mendham, NJ, USA: Wayne Dorland Company, 1982.

3. Johnsen, Montfort A. Propellants II: Advanced Lecture on Aerosol Propellants. Danville, IL, USA.

4. Spray Technology and Marketing. February 1993.

5. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

6. UNEP Training Manual. "For the Conversion from Chlorofluorocarbon (CFC) Propellants to Alternatives, including Hydrocarbon Gases."

7. USEPA, Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Aerosols, 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.3 Compressed Gas Aerosol Propellants

Headline:

In the aerosol industry, the term "compressed gas" is used to mean a high-pressure propellant that must be injected into containers in the gaseous form instead of as a liquid under pressure. Compressed gases are low molecular weight gases that can be used as propellants in aerosol products. They include carbon dioxide (CO_2), nitrous oxide (N_2O), and nitrogen (N_2). Theoretically, options include ethane, argon, helium, and compressed air. However, these latter gases do not have any commercial aerosol applications in their pure form and are therefore not usually discussed. Of the compressed gases, CO_2 is used most widely. Advantages of compressed gases include their nonflammability and relatively cheap cost. A major concern with products propelled by compressed gases is the pressure drop inside the container that occurs during use.

Industry Sector:

CO_2: engine starting fluids, crawling insect insecticides, stain repellents, disinfectant/deodorants, engine cleaners, windshield de-icers

N_2O: whipped cream, specialty foam products

N_2: wasp and hornet sprays, miscellaneous medicinal products, internal engine cleaners

ODS Reduction/Elimination Method:

CFC use is eliminated by filling aerosol dispensers with compressed gas instead of CFC propellants.

Composition of Alternatives:

The following table presents some relevant characteristics of CO_2, N_2O, and N_2:

	CO_2	N_2O	N_2
Vapor Pressure @21.1°C	58.2 bar	52.4 bar	N/A
Boiling Point	-78.44°C	-88.47°C	-195.8°C
Density @0°C, 1 bar (g/l)	1.9768	1.977	1.258
Flash Point	none	none	none
Flammable Limits in Air (vol %)	none	none	none
Solubility in Water (ml/100 ml water @21.1°C)	85.4	69.62	1.51

Toxicity:

CO_2, N_2O, and N_2 are all simple asphyxiants and excessive exposure to these gases in sufficiently high concentrations may result in respiratory distress.

Flammability:

Compressed gases are nonflammable. In general, when compressed gases are used, the flammability of the aerosol is a reflection of the flammability of the concentrate or liquid portion.

VOC Classification[8]:

Non-VOC

Ozone Depleting Potential (ODP):

None

Global Warming Potential (GWP):

CO_2: 1
N_2O: 270
N_2: 0

Phaseout Schedule:

None

Propellant Characteristics:

A major concern with CO_2 and N_2O products involves pressure drops during use as propellant escapes from solution into the expanding head space. This has the effect of gradually weakening the dispersion as the product is used up. The problem is most noticeable with cans that are limited to about 3 percent or less of propellant, such as water-based formulas that are pressurized with either CO_2 or N_2O.

N_2O produces heavy sprays that become more coarse as the container is gradually emptied and internal pressure decreases. This problem can be alleviated by elevating the can's pressure (e.g., to 7.2 bar at 20°C, equivalent to the maximum legal pressure in the United States of 12.4 bars at 54.4°C) and filling cans only about 60 percent full of the product.

When in water, CO_2 serves as a mild acid. It can, therefore, cause aerosol solutions that contain water to become corrosive. This can be controlled by strongly reducing entrapped oxygen in the aerosol can, using a combination of purging and vacuum crimping, or by adding sodium nitrite or other corrosion inhibitors.

Aerosols that contain CO_2, N_2O, or N_2 can be rendered useless by inadvertent consumer misuse. If the valve is depressed when the can is at an angle such that the dip tube protrudes into the gaseous phase, a significant amount of the total pressurized gas charge can escape. The partially depressurized can will no longer produce a satisfactory spray or delivery rate, and probably will not empty. This problem is most serious with nitrogen, since nitrogen is only about 10 percent as soluble in liquids as CO_2 and N_2O.

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[8] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

Substitute Production Method and Materials:

Methods of introducing compressed gases into aerosol products include use of gasser-shakers, pre-saturation gassing, through-the-valve (T-t-V) instantaneous impact gassing, or under-the-cap (U-t-C) instantaneous impact gassing.

Compressed gases typically cannot serve as drop-in replacements for CFCs. Alternative dispensing mechanisms and stronger containers may be needed because these gases are under higher pressures. Containers holding compressed gases should be able to withstand pressures between 10.7 and 13.4 bars at 54°C, approximately 50 percent higher than that of conventional aerosols. Furthermore, the low molecular weights of these chemicals make them inadequate as replacements for CFCs in products requiring dense gas propellants, such as surface lubricants and weld inspection developers. In addition, compressed gases, because of their higher pressures, dispel material faster during delivery, which can contribute to wasted product. This can be partly corrected by using valves with 0.0254 cm or 0.0305 cm metering orifices to reduce delivery rates. When switching to compressed gases, it is important to select valves with mechanical break-up actuators so as to help improve spray patterns.

Health and Safety Considerations:

N_2O is a highly endothermic compound that can easily catalytically decompose into nitrogen and oxygen under certain conditions, especially when warm, under high pressure, or in the presence of oils, greases, or other oxidizable substances. Significant amounts of heat are released during decomposition, which, if it occurs rapidly enough can cause steel pipes to melt. Several plant accidents have occurred when supply pipes have been over heated and burst. A sweet smelling gas, N_2O can also cause a feeling of euphoria if the concentrated vapors are breathed for a short while.

Nearly 600,000 clinical and hospital personnel and over 100,000 dental personnel were working with the gas in the United States alone in the early 1980s. Those numbers have grown over the last decade, and personnel working with the gas during many days each year have suffered no ill effects. N_2O exposures at aerosol filling plants should be far less, and the consuming public would have minimal exposure.

CO_2 is present in normal air at about 372 ppm and is obviously compatible with life forms. It acts as a regulator of the breathing function, and increases in concentration will accelerate the rate of breathing. At atmospheric levels of 1,000 to 10,000 ppm, there is a slight increase in breathing rates, while at 20,000 ppm, there is a 50% increase, and at 30,000, a 100% increase. At 50,000 the increase rises to 300%, and breathing becomes laborious. Humans can only withstand a level of 100,000 ppm CO_2 for a few minutes. The U.S. Occupational Safety and Health Administration (OSHA) has set a long-term permissible exposure limit (PEL) at 10,000 ppm and a short-term exposure limit (STEL) at 30,000 ppm for carbon dioxide (USEPA, 1993).

N_2 exists as 79 percent of the ambient air. It has no toxicological constraints other than the obvious but unlikely possibility of asphyxiation in a grossly misengineered and mismanaged production situation.

Environmental Considerations:

As mentioned earlier, CO_2 and N_2O are considered to be greenhouse gases. Use of compressed gases for aerosol propellants is not likely to have an impact on global warming, however, because the gases are obtained as by-products from production of other substances. CO_2 is emitted from smokestacks or fermentation towers. Therefore, when it is purified, tanked, and sprayed out of aerosols at a later time, there is no net change in CO_2 emissions due to the aerosol use.

Associated Costs:

All of the candidate compre
ssed gases are inexpensive. In the United States, cylinders of N_2O cost approximately US$2.20 or more per kilogram depending on the grade purchased.

Current Use:

Compressed gases have found use in industrialized countries in applications where product dispersion characteristics are not critical. Their use in developing countries, however, has been rare.

Availability:

Compressed gases are readily available from chemical distributors and industrial gas suppliers in most countries.

Vendors of Alternative Equipment:

Aerosol Filling Equipment Suppliers

Advam Packaging Systems
91 Darley Street
Mona Valve, NSW 2103
Australia
Tel: (61) 2 997 5533
Fax: (61) 2 997 7996

Aerofill Limited
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

Aerojet Quimica Industrial Ltda
Av. Beira Mar, 200
Salas 801/803 Costelo
RJ
Brazil
Tel: (55) 21 262 8181
Fax: (55) 21 776 1904

Aerosol Laboratory Equipment
R.D. 1, Box 75
Route 10
Walton, NY 13856
USA
Tel: (1) 607 865 7173
Fax: (1) 607 865 7175

Akron Polymer Container
540 South Main Street
Akron, OH 44311
USA
Tel: (1) 216 253 6500
Fax: (1) 216 253 8009

Autoprod Inc.
5355 115th Avenue North
Clearwater, FL 34620
USA
Tel: (1) 813 572 7753
Fax: (1) 813 573 0367

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali SpA
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 290 06075
Fax: (39) 2 290 06700

Cozzoli Machine Company
401 E. 3rd Street
Plainfield, NJ 07060
USA
Tel: (1) 908 757 2040
Fax: (1) 908 757 7386

Daellenbach Maschinenbau
Bachstrasse 25
CH-8912 Obfelden
Zurich
Switzerland
Tel: (41) 1 761 71 25
Fax: Not available

Doje Corporation
Yougdong
P.O. Box 1211
Seoul 135
Republic of Korea
Tel: (82) 2 553 4994
Fax: (82) 2 554 0451

Druk Pak AG
CH-8132 Egg
Zurich
Switzerland
Tel: (41) 1 984 2720
Fax: (41) 1 984 0715

Gem Shine Trading Co.
Shin Chiang Chung Ind. Co. Ltd.
No 23, Lane 84, Jing-Yin Street
Shu-Lin Town, Taipei Hsien
Taiwan
Tel: (886) 2 682 5549
Fax: (886) 2 685 1769

JG Machine Works, Inc.
75 Spring Street
Paterson, NJ 07501
USA
Tel: (1) 201 881 7000
Fax: (1) 201 881 0563

Jose F. Olivieri & Assoc.
Suite 906-B
623 Ponce De Leon Ave.
Hato Rey 00919
Puerto Rico
Tel: (1) 809 766 0006
Fax: (1) 809 756 5930

KP Aerofill
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

KP Aerofill
807 W. Kimberly Road
P.O. Box 3848
Davenport, IA 52808
USA
Tel: (1) 319 391 1100
Fax: (1) 319 391 4951

Laboratories Rety De Colombia
Zona Franca B-10
Apartado Aereo 29594
Barranquilla
Colombia
Tel: (57) 58 2360641
Fax: (57) 58 413472

Nalbach Engineering Co, Inc.
6139 W. Ogden Avenue
Cicero, IL 60650
USA
Tel: (1) 708 652 8900
Fax: (1) 708 652 8920

Nimmo Packaging Systems
1 Home Villa, Farley Heath
Albury, Surrey GU5 9ER
United Kingdom
Tel: (44) 483 20 3609
Fax: (44) 483 20 3625

Pamasol
Driesbuelstrasse 2
CH-8808 Pfaffikon SZ
Switzerland
Tel: (41) 55 4824 31
Fax: (41) 55 4852 15

P & P Machinery
P.O. Box 1712
Glen Vista 2058
South Africa
Tel: (27) 11 432 2188
Fax: (27) 11 682 2142

Precision Valve (India) Pvt. Ltd.
228 Pragati Ind Estate
N.M. Joshi Marg
Bombay 400 011
India
Tel: (91) 22 309 7422
Fax: (91) 22 307 0618

Precision Valve Singapore Pte. Ltd.
10/12/Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 264 0461

Reed Enterprises Inc.
52645 Thorne Drive
Elkhart, IN 46514
USA
Tel: (1) 219 264 9900
Fax: (1) 219 264 7733

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Spider Engineering, Inc.
700 South Plumosa Street
Merritt Island, FL 32952
USA
Tel: (1) 407 452 3922
Fax: (1) 407 453 8338

Super Pak S.A.
Heraclito 327 P.A.
Col. Polanco C.P. 11560
Mexico
Tel: (52) 5 545 2127
Fax: (52) 5 251 8144

Tecnomac S.p.A.
Via Garofalo, 19
20133 Milano
Italy
Tel: (39) 2 27 80 44
Fax: Not available

Terco, Inc.
496 Lunt Ave.
Schaumberg, IL 60193
USA
Tel: (1) 708 894 8828
Fax: (1) 708 894 8846

Valve Suppliers

Aboukir Engineering Industries
Aboukir-Alexandria
Egypt
Tel: (20) 3 560 1538
Fax: (20) 3 560 3392

Aerocan Ltd.
P.O. Box 4519
Nicosia
Cyprus
Tel: (357) 2 350 550
Fax: (357) 2 350 559

Aerosol Research & Development, Ltd.
Fitzherbert Road
Farlington, Portsmouth
Hants PO6 1RU
United Kingdom
Tel: (44) 705 387 782
Fax: (44) 705 380 825

Aerosol-Technique Lindal (UK)
Cherrycourt Way, Stanbridge Road
Leighton Buzzard
Bed. LU7 8UH
United Kingdom
Tel: (44) 525 381 186
Fax: (44) 525 383 304

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Avery Denison Ltd.
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 0922 614 631
Fax: (44) 0922 613 043

BLM Associates/Lablabo
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Walter C. Beard, Inc.
P.O. Box B
Middlebury, CT 06762
USA
Tel: (1) 203 758 2194
Fax: Not available

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Carnaud-Metalbox
20 A Street
Derry, NH 03038
USA
Tel: (1) 603 434 7741
Fax: (1) 603 437 5703

Carnaud-Metalbox Packaging
Nigeria Ltd.
3-7 Metal Box Road
Ogba Ind. Est
PMB 21588 Ikeja, Lagos
Nigeria
Tel: Not available
Fax: (234) 1 964 443

Carnaud-Metalbox Packaging
Singapore Ltd.
Marsiling P.O. Box 0356
1120 Woodlands Road 9173
Singapore
Tel: (65) 269 6111
Fax: (65) 367 0912

Clayton Corporation
866 Horan Drive
Fenton, MO 63026
USA
Tel: (1) 314 349 5333
Fax: (1) 314 349 5335

Coster Aerosols Ltd.
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20154 Milan
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Fax: (39) 2 2900 6700

Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
Germany
Tel: (49) 911 324 350
Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190 801200

EP Spray System
60 Williams Parkway, Suite J
East Hanover, NJ 07936
USA
Tel: (1) 201 515 8535
Fax: Not available

EP Spray System
30 Rue de Plan
CH-2002 Neuchatel
Switzerland
Tel: (41) 38 25 02 22
Fax: (41) 38 24 49 07

Engineered Controls International
Rego Products
100 Rego Drive
Elon College, NC 27244
USA
Tel: (1) 919 449 7707
Fax: (1) 919 449 6594

Kum Suk Chemical Co.
301-3F Ara Bldg.
705-9 Banpo-1 Dong
Seocho-Ku, Seoul
Republic of Korea
Tel: (82) 2 516 8411
Fax: (82) 2 516 8414

Kumar Aerosols (p) Ltd.
3/13-B, ASAF Ali Rd.
New Delhi 110002
India
Tel: (91) 011 327 9044
Fax: (91) 011 326 9761

Lindal Italiana S.R.L.
Via Piave, 7
22049 Valmadrera-Como
Italy
Tel: (39) 341 551 433
Fax: (39) 341 551 293

Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
Leighton Buzzard
Bedfordshire LU7 8UH
United Kingdom
Tel: (44) 525 381 155
Fax: (44) 525 383 304

Lindal Ventil GmbH
Industriestrasse 13
D-2060 Bad Oldesloe
Germany
Tel: (49) 4531 86001
Fax: (49) 4531 87664

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43-1
08014 Barcelona
Spain
Tel: (34) 3 314 9111
Fax: (34) 3 314 6081

Nampak Group
P.O. Box 247
Howard Place
South Africa
Tel: (27) 21 547 111
Fax: (27) 21 547 126

Newman-Green, Inc.
57 Interstate Road
Addison, IL 60101
USA
Tel: (1) 708 543 6500
Fax: (1) 708 543 8523

Novospray S.A.
Place Cornavin 18
CH 1201 Geneva
Switzerland
Tel: (41) 22 738 22 11
Fax: (41) 22 738 21 38

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Perfect-Valois Ventil GmbH
Hildebrandstrasse 20, Post. 130340
4600 Dortmund 13 (Wickede)
Germany
Tel: (49) 231 218 0211
Fax: (49) 231 21 17 52

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416 683 0120
Fax: (1) 416 427 1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, FL 33315
USA
Tel: (1) 305 359 1425
Fax: (1) 305 359 0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel: (39) 2 944 9256
Fax: (39) 2 944 9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484 444851
Fax: (81) 484 446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22 3097732/3097422/3097794
Fax: (91) 22 3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111; Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapoe PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/(65) 264 0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442 (plant)
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Safeworld International
7352 Adams Road
Talent, OR 97540
USA
Tel: (1) 503 535 7661
Fax: (1) 503 535 3204

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Valve Company
1160 N. Silver Lake Road
Cary, IL 60013
USA
Tel: (1) 708 639 2124
Fax: (1) 708 639 1179

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Summitt Packaging Europe
Grot Mijdrecht 9F
3641 RV Mijdrecht
Netherlands
Tel: (31) 2979 88661
Fax: (31) 2979 87289

Summit Packaging Systems
P.O. Box 5304
Manchester, NH 03108
USA
Tel: (1) 603 669 5410
Fax: (1) 603 645 1047

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvole Aerosol Research Italiana
Via Del Pino 10
22057 Olginate (Como)
Italy
Tel: (39) 341 680 325
Fax: (39) 341 680 501

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds.
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo 60230
Brazil
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

Compressed Gas Propellant Suppliers

Aerofako B.V.
Rotterdam, Netherlands
Tel: (31) 33 64 39 11
Fax: Not available

Aeropres Corporation
1324 N. Hearne
Suite 200
Shreveport, LA 71137
USA
Tel: (1) 318 221 6282
Fax: (1) 318 429 6739

Akzo Chemicals BV
P.O. Box 975
3800 AA Amersfoort
Netherlands
Tel: (31) 33 676 362
Fax: (31) 33 676 139

Akzo Chemicals Ltd.
1-5 Queens Road, Hersham
Walton-on-Thomas, Surrey KT12 5NL
United Kingdom
Tel: (44) 932 247 891
Fax: (44) 932 231 204

C.G. Smith Chemicals
72 Ballantrae Road
Merebank, Durban, 4052
South Africa
Tel: (27) 31 42 5341
Fax: (27) 31 42 9114

Consul Chemistry Industry
P.O. 1803
Taipei
Taiwan
Tel: (886) 2 362 8032
Fax: (886) 2 366 0806

Copia Associates, Inc.
9837 Neesonwood Dr.
Shreveport, LA 71106
USA
Tel: (1) 318 797 8372
Fax: (1) 318 797 0101

CSR Limited, Distil. Gp.
P.O. Box 13
Pyrmont NSW 2009
Australia
Tel: (61) 2 692 7631
Fax: (61) 2 552 1510

Diversified CPC International, Inc.
24338 W. Durkee Road
Channahon, IL 60410
USA
Tel: (1) 815 423 5991
Fax: (1) 815 423 5627

DuPont Argentina S.A.
Casilla Correo 1888
1000 Correo Central
Buenos Aires
Argentina
Tel: (54) 1 311 8167
Fax: (54) 1 311 1329

DuPont Canada Inc.
P.O. Box 2200
Streetsville
Mississauga, Ontario L5M 2H3
Canada
Tel: (1) 416 821 3300
Fax: (1) 416 821 5057

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel: (1) 302 633 1501
Fax: (1) 302 892 1705

DuPont-Mitsui Fluorochemicals Co., Ltd.
2-3, 1-Chome Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan
Tel: (81) 3 3216 8468
Fax: (81) 3 3215 0064

DuPont UK Limited
Wedgewood Way
Stevenage
Herts SG1 4QN
United Kingdom
Tel: (44) 438 734 000
Fax: (44) 438 734 621

Kortman Intradal B.V.
P.O. Box 69
3800 AB Amersfoort
Netherlands
Tel: (31) 33 605 120
Fax: (31) 33 621 1033

Technical Propellants Inc.
6233 N. Pulaski Road
Chicago, IL 60646
USA
Tel: (1) 312 463 5555
Fax: (1) 312 463 8061

Sources of Additional Information about this Technology:

1. Johnsen, Montfort A. The Aerosol Handbook. Mendham, NJ, USA: Wayne Dorland Company, 1982.

2. Johnsen, Montfort, A. "Nitrous Oxide: the Mysterious Aerosol Propellant." Spray Technology and Marketing. September, 1991

3. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

4. UNEP Training Manual. "For the Conversion from Chlorofluorocarbon (CFC) Propellants to Alternatives, including Hydrocarbon Gases."

5. USEPA, "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substitutes: Aerosols," 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.4 HFC-152a and HFC-134a Aerosol Propellants

Headline:

HFC-152a has been used to a limited extent in certain industrialized countries for over 10 years. Because it is substantially more costly than hydrocarbons (HCs), its use is often reserved only for special purposes. HFC-134a is a more recently developed chemical that is gaining popularity as a substitute in various refrigeration, air conditioning, and in a limited number of foam blowing applications. HFC-134a is not expected to be widely used in aerosol applications for some time because of its relative unavailability in this sector, its high cost, and its high Global Warming Potential.

Industry Sector:

HFC-152a is currently used in a variety of aerosol products. Some of these products include:

- colognes
- dry air fresheners
- starch and fabric finishes
- freezants
- aerosol foams
- total release insect foggers (TRIF)
- mousses
- electronic dusters
- hair spray

HFC-134a is still being tested for suitability as a propellant in medical inhalers by pharmaceutical companies worldwide.

ODS Reduction/Elimination Method:

CFCs are eliminated by using substitute chemicals and making equipment and operational procedure modifications.

Composition of Alternative:

	HFC-152a	HFC-134a
Formula	CH_3-CHF_2	CH_2F-CF_3
Boiling Point	-24°C	-26.5°C
Vapor Pressure @21.1°C	4.3 bar	4.9 bar
Density @21.1°C	0.91 g/cc	1.22 g/cc
Solubility in Water @21.1°C (wt %)	0.28	0.15
Flammability Limits in Air (vol %)	3.9-16.9	nonflammable
Flash Point	-17.8°C	none
Kauri-Butanol Value	11.0	very low

Source: UNEP, undated

Toxicity:

Both HFC-152a and HFC-134a exhibit very low toxicity. The USEPA estimates the long-term exposure workplace guidance level (WGL) at 1,000 ppm for both chemicals (USEPA, 1993).

The combustion of HFC-152a and HFC-134a presents some toxicological hazards, since their reaction with oxygen produces hydrogen fluoride (hydrofluoric acid), which is a strong irritant and corrosive substance. The maximum air concentration of hydrogen fluoride is 1-3 ppm. Fire fighters should take necessary precautions to prevent toxic fume inhalation in the event of a warehouse fire.

Flammability:

HFC-152a is flammable. As shown in the table above, the lower explosive limit (LEL) of HFC-152a is 3.9%, approximately twice the limit of hydrocarbons (HCs). The minimum spark ignition energy is 22.0 milliJoules, more than 100 times higher than the 0.20 milliJoule minimum spark ignition energy of HCs. Because the flammability limit of HFC-152a in air is higher and spark ignition energy is lower compared to HCs, the probability of ignition in a HFC-152a gassing plant is lower than the probability in a HC gassing plant. However, the same fire safety and explosion prevention precautions should be taken in HFC-152a gassing operations as with hydrocarbon aerosol propellants.

HFC-134a is nonflammable.

VOC Classification[9]:

Non-VOCs

Ozone Depleting Potential (ODP):

HFC-152a: 0
HFC-134a: 0

Global Warming Potential (GWP):

HFC-152a:	0.021	(as compared to CFC-12)
	150	(compared to CO_2 - 100-year basis)
HFC-134a:	0.169	(as compared to CFC-12)
	1,200	(compared to CO_2 - 100-year basis)

Phaseout Schedule:

None

[9] VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.

Propellant Characteristics:

Because HFC-152a and HFC-134a are both liquified gas propellants, they provide a fairly uniform pressure inside the aerosol container throughout the life of the product. Both chemicals have the capability to dispense fine particle sprays. However, HFC-134a has a lower solubility than HFC-152a, which limits its usefulness in some aerosol formulations.

Substitute Production Method and Materials:

Because the vapor pressure of HFC-152a is high, aerosol cans that use 100% HFC-152a should be vacuum crimped at a maximum setting. This minimizes the build up of in-can pressure that may raise the overall container pressure to unacceptable levels. Propellant blends can also be used to reduce the vapor pressure in the can. One examples of a propellant blend is:

- 85-90% HFC-152a, 10-15% n-pentane or isopentane

HFC-152a does not cause tinplate can corrosion, gasket swelling, or extraction of can lining ingredients. It causes minimal swelling of neoprenes (nitriles) by 2%, Buna-N by 1%, and natural rubber by 2%.

HFC-134a is still undergoing testing for its suitability in aerosol applications. As such, modifications to production methods and materials are still being investigated.

For both propellants, it is important to consider possible impacts on the valve and can components. Further modifications of the formulation, valve, and can may be necessary to achieve the desired product delivery. For example, due to the high vapor pressure of HFC-134a, it is recommended that aerosol cans using 100 percent HFC-134a be vacuum crimped at a maximum setting.

Health and Safety Considerations:

The same fire safety and explosion prevention measures taken in hydrocarbon filling plants should be taken in HFC-152a gassing plants.

Environmental Considerations:

HFC-134a has a high global warming potential, so its use as an aerosol propellant is likely to be limited.

Associated Costs:

In the United States, the bulk price of HFC-152a is currently US$4.10/kg, which is almost nine times higher than the cost of hydrocarbons. The bulk price of HFC-134a is US$10.00/kg.

Current Use:

HFC-152a has been used in aerosol applications in the United States and Europe since the late 1970s. HFC-152a is very popular because it is a negligibly reactive VOC. Its use mitigates air quality concerns in many areas. Currently, the majority of HFC-152a produced is used in the low-VOC aerosols market and in various consumer products. Compared with the consumer sector, fewer industrial products use HFC-152a, primarily because of its relatively high cost.

There are few known current commercial aerosol uses for HFC-134a, as it is still being tested for suitability. Exceptions, however, include: electronics defluxing sprays, electronics thermal testing sprays, and aerosol "duster" applications.

Availability:

At present, because of the limited supply of HFC-152a, demand for the chemical far exceeds supply.

There is little support for the use of HFC-134a in aerosol applications from chemical suppliers, because they are directing their products towards other markets such as refrigeration and air conditioning. At present, the principle use for HFC-134a will probably be to replace CFC-12 in refrigeration, air-conditioning, and food freezant systems. Also, it is doubtful that HFC-134a will be widely used in aerosols (a dispersive application) due to its high GWP.

Vendors of Alternative Chemicals:

Aerosol Filling Equipment Suppliers

Advam Packaging Systems
91 Darley Street
Mona Valve, NSW 2103
Australia
Tel: (61) 2 997 5533
Fax: (61) 2 997 7996

Aerofill Limited
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

Aerojet Quimica Industrial Ltda
Av. Beira Mar, 200
Salas 801/803 Costelo
RJ
Brazil
Tel: (55) 21 262 8181
Fax: (55) 21 776 1904

Aerosol Laboratory Equipment
R.D. 1, Box 75
Route 10
Walton, NY 13856
USA
Tel: (1) 607 865 7173
Fax: (1) 607 865 7175

Akron Polymer Container
540 South Main Street
Akron, OH 44311
USA
Tel: (1) 216 253 6500
Fax: (1) 216 253 8009

Autoprod Inc.
5355 115th Avenue North
Clearwater, FL 34620
USA
Tel: (1) 813 572 7753
Fax: (1) 813 573 0367

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali SpA
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 290 06075
Fax: (39) 2 290 06700

Cozzoli Machine Company
401 E. 3rd Street
Plainfield, NJ 07060
USA
Tel: (1) 908 757 2040
Fax: (1) 908 757 7386

Daellenbach Maschinenbau
Bachstrasse 25
CH-8912 Obfelden
Zurich
Switzerland
Tel: (41) 1 761 71 25
Fax: Not available

Doje Corporation
Yougdong
P.O. Box 1211
Seoul 135
Republic of Korea
Tel: (82) 2 553 4994
Fax: (82) 2 554 0451

Druk Pak AG
CH-8132 Egg
Zurich
Switzerland
Tel: (41) 1 984 2720
Fax: (41) 1 984 0715

Gem Shine Trading Co.
Shin Chiang Chung Ind. Co. Ltd.
No 23, Lane 84, Jing-Yin Street
Shu-Lin Town, Taipei Hsien
Taiwan
Tel: (886) 2 682 5549
Fax: (886) 2 685 1769

JG Machine Works, Inc.
75 Spring Street
Paterson, NJ 07501
USA
Tel: (1) 201 881 7000
Fax: (1) 201 881 0563

Jose F. Olivieri & Assoc.
Suite 906-B
623 Ponce De Leon Ave.
Hato Rey 00919
Puerto Rico
Tel: (1) 809 766 0006
Fax: (1) 809 756 5930

KP Aerofill
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

KP Aerofill
807 W. Kimberly Road
P.O. Box 3848
Davenport, IA 52808
USA
Tel: (1) 319 391 1100
Fax: (1) 319 391 4951

Laboratories Rety De Colombia
Zona Franca B-10
Apartado Aereo 29594
Barranquilla
Colombia
Tel: (57) 58 2360641
Fax: (57) 58 413472

Nalbach Engineering Co, Inc.
6139 W. Ogden Avenue
Cicero, IL 60650
USA
Tel: (1) 708 652 8900
Fax: (1) 708 652 8920

Nimmo Packaging Systems
1 Home Villa, Farley Heath
Albury, Surrey GU5 9ER
United Kingdom
Tel: (44) 483 20 3609
Fax: (44) 483 20 3625

Pamasol
Driesbuelstrasse 2
CH-8808 Pfaffikon SZ
Switzerland
Tel: (41) 55 4824 31
Fax: (41) 55 4852 15

P & P Machinery
P.O. Box 1712
Glen Vista 2058
South Africa
Tel: (27) 11 432 2188
Fax: (27) 11 682 2142

Precision Valve (India) Pvt. Ltd.
228 Pragati Ind Estate
N.M. Joshi Marg
Bombay 400 011
India
Tel: (91) 22 309 7422
Fax: (91) 22 307 0618

Precision Valve Singapore Pte. Ltd.
10/12/Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 264 0461

Reed Enterprises Inc.
52645 Thorne Drive
Elkhart, IN 46514
USA
Tel: (1) 219 264 9900
Fax: (1) 219 264 7733

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Spider Engineering, Inc.
700 South Plumosa Street
Merritt Island, FL 32952
USA
Tel: (1) 407 452 3922
Fax: (1) 407 453 8338

Super Pak S.A.
Heraclito 327 P.A.
Col. Polanco C.P. 11560
Mexico
Tel: (52) 5 545 2127
Fax: (52) 5 251 8144

Tecnomac S.p.A.
Via Garofalo, 19
20133 Milano
Italy
Tel: (39) 2 27 80 44
Fax: Not available

Terco, Inc.
496 Lunt Ave.
Schaumberg, IL 60193
USA
Tel: (1) 708 894 8828
Fax: (1) 708 894 8846

Valve Suppliers

Aboukir Engineering Industries
Aboukir-Alexandria
Egypt
Tel: (20) 3 560 1538
Fax: (20) 3 560 3392

Aerocan Ltd.
P.O. Box 4519
Nicosia
Cyprus
Tel: (357) 2 350 550
Fax: (357) 2 350 559

Aerosol Research & Development, Ltd.
Fitzherbert Road
Farlington, Portsmouth
Hants PO6 1RU
United Kingdom
Tel: (44) 705 387 782
Fax: (44) 705 380 825

Aerosol-Technique Lindal (UK)
Cherrycourt Way, Stanbridge Road
Leighton Buzzard
Bed. LU7 8UH
United Kingdom
Tel: (44) 525 381 186
Fax: (44) 525 383 304

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Avery Denison Ltd.
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 0922 614 631
Fax: (44) 0922 613 043

BLM Associates/Lablabo
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Walter C. Beard, Inc.
P.O. Box B
Middlebury, CT 06762
USA
Tel: (1) 203 758 2194
Fax: Not available

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Carnaud-Metalbox
20 A Street
Derry, NH 03038
USA
Tel: (1) 603 434 7741
Fax: (1) 603 437 5703

Carnaud-Metalbox Packaging
Nigeria Ltd.
3-7 Metal Box Road
Ogba Ind. Est
PMB 21588 Ikeja, Lagos
Nigeria
Tel: Not available
Fax: (234) 1 964 443

Carnaud-Metalbox Packaging
Singapore Ltd.
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1120 Woodlands Road 9173
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Tel: (65) 269 6111
Fax: (65) 367 0912

Clayton Corporation
866 Horan Drive
Fenton, MO 63026
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Fax: (39) 2 2900 6700

Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
Germany
Tel: (49) 911 324 350
Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190 801200

EP Spray System
60 Williams Parkway, Suite J
East Hanover, NJ 07936
USA
Tel: (1) 201 515 8535
Fax: Not available

EP Spray System
30 Rue de Plan
CH-2002 Neuchatel
Switzerland
Tel: (41) 38 25 02 22
Fax: (41) 38 24 49 07

Engineered Controls International
Rego Products
100 Rego Drive
Elon College, NC 27244
USA
Tel: (1) 919 449 7707
Fax: (1) 919 449 6594

Kum Suk Chemical Co.
301-3F Ara Bldg.
705-9 Banpo-1 Dong
Seocho-Ku, Seoul
Republic of Korea
Tel: (82) 2 516 8411
Fax: (82) 2 516 8414

Kumar Aerosols (p) Ltd.
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Lindal Italiana S.R.L.
Via Piave, 7
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Tel: (39) 341 551 433
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Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
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Fax: (44) 525 383 304

Lindal Ventil GmbH
Industriestrasse 13
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Tel: (49) 4531 86001
Fax: (49) 4531 87664

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43-1
08014 Barcelona
Spain
Tel: (34) 3 314 9111
Fax: (34) 3 314 6081

Nampak Group
P.O. Box 247
Howard Place
South Africa
Tel: (27) 21 547 111
Fax: (27) 21 547 126

Newman-Green, Inc.
57 Interstate Road
Addison, IL 60101
USA
Tel: (1) 708 543 6500
Fax: (1) 708 543 8523

Novospray S.A.
Place Cornavin 18
CH 1201 Geneva
Switzerland
Tel: (41) 22 738 22 11
Fax: (41) 22 738 21 38

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Perfect-Valois Ventil GmbH
Hildebrandstrasse 20, Post. 130340
4600 Dortmund 13 (Wickede)
Germany
Tel: (49) 231 218 0211
Fax: (49) 231 21 17 52

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416 683 0120
Fax: (1) 416 427 1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, FL 33315
USA
Tel: (1) 305 359 1425
Fax: (1) 305 359 0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel: (39) 2 944 9256
Fax: (39) 2 944 9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484 444851
Fax: (81) 484 446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22 3097732/3097422/3097794
Fax: (91) 22 3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111, Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapoe PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/(65) 264 0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442 (plant)
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Safeworld International
7352 Adams Road
Talent, OR 97540
USA
Tel: (1) 503 535 7661
Fax: (1) 503 535 3204

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Valve Company
1160 N. Silver Lake Road
Cary, IL 60013
USA
Tel: (1) 708 639 2124
Fax: (1) 708 639 1179

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Summitt Packaging Europe
Grot Mijdrecht 9F
3641 RV Mijdrecht
Netherlands
Tel: (31) 2979 88661
Fax: (31) 2979 87289

Summit Packaging Systems
P.O. Box 5304
Manchester, NH 03108
USA
Tel: (1) 603 669 5410
Fax: (1) 603 645 1047

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvole Aerosol Research Italiana
Via Del Pino 10
22057 Olginate (Como)
Italy
Tel: (39) 341 680 325
Fax: (39) 341 680 501

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds.
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo
Brazil 60230
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

HFC Propellant Suppliers

Aeropres Corporation
1324 N. Hearne
Suite 200
Shreveport, LA 71137
USA
Tel: (1) 318 221 6282
Fax: (1) 318 429 6739

Allied-Signal Incorporated
P.O. Box 1139R
Morristown, NJ 07962
USA
Tel: (1) 201 455 2978
Fax: (1) 201 455 2763

Atochem North America
3 Parkway
Philadelphia, PA 19102
USA
Tel: (1) 215 587 7334
Fax: (1) 215 587 7369

Ausimont
Via Principe Eugenio, 1/5
20155 Milano
Italy
Tel: (39) 2 6270 3652
Fax: (39) 2 6270 3412

Copia Associates, Inc.
9837 Neesonwood Dr.
Shreveport, LA 71106
USA
Tel: (1) 318 797 8372
Fax: (1) 318 797 0101

Diversified CPC International, Inc.
24338 W. Durkee Road
Channahon, IL 60410
USA
Tel: (1) 815 423 5991
Fax: (1) 815 423 5627

DuPont Argentina S.A.
Casilla Correo 1888
1000 Correo Central
Buenos Aires
Argentina
Tel: (54) 1 311 8167
Fax: (54) 1 311 1329

DuPont Canada Inc.
P.O. Box 2200
Streetsville
Mississauga, Ontario L5M 2H3
Canada
Tel: (1) 416 821 3300
Fax: (1) 416 821 5057

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel: (1) 302 633 1501
Fax: (1) 302 892 1705

DuPont-Mitsui Fluorochemicals Co., Ltd.
2-3, 1-Chome Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan
Tel: (81) 3 3216 8468
Fax: (81) 3 3215 0064

Elf Atochem
4 Cours Michelet
La Defense 10
Cedex 42-92091
Paris
France
Tel: (33) 1 49 00 80 46
Fax: (33) 1 49 00 70 21

Hoechst Aktiengesellschaft
Postfach 800 320
D6230 Frankfurt (Main) 80
Germany
Tel: (49) 69 305 55 02
Fax: (49) 69 305 91 79

ICI Americas Inc.
New Murphy Road & Concord Pike
Wilmington, DE 19897
USA
Tel: (1) 302 575 3000
Fax: Not available

ICI Chemicals and Polymers Ltd.
P.O. Box 13
The Heath
Runcorn, Cheshire WA7 4QF
United Kingdom
Tel: (44) 928 511 385
Fax: (44) 928 581 155

Rhone-Poulenc Chemicals Ltd.
St. Andrews Road
Avonmouth, Bristol BS11 9YF
United Kingdom
Tel: (44) 272 823 631
Fax: (44) 272 820 759

Technical Propellants Inc.
6233 N. Pulaski Road
Chicago, IL 60646
USA
Tel: (1) 312 463 5555
Fax: (1) 312 463 8061

Sources of Additional Information about this Technology:

1. Johnsen, Montfort A. Propellants II: Advanced Lecture on Aerosol Propellants. Danville, IL.

2. Radian Corporation for USEPA. "Manual for Non-CFC Aerosol Packaging: Conversion from CFC to Hydrocarbon Propellants." Washington, D.C. September, 1991.

3. UNEP Training Manual. "For the Conversion from Chlorofluorocarbon (CFC) Propellants to Alternatives, including Hydrocarbon Gases."

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.5 HCFC-22 Aerosol Propellant

Headline:

HCFC-22 is a widely available, nonflammable liquified propellant. It is being used as a substitute propellant in aerosol products that require nonflammability, such as solvent cleaning sprays, lubricants, mold release agents, aircraft maintenance products, pesticides, and medical products. Worldwide HCFC use in aerosol products is believed to be under 20,000 tons per year. HCFC-22 propellant volume growth in the future will be minimal because of its scheduled phaseout in 2030 under the Montreal Protocol.

Industry Sector:

HCFC-22 is currently used in many aerosol applications, including:

- inspection dyes
- commercial and household products
- personal care products
- lubricants
- all-propellant products such as dusters and freezants
- pesticides
- mold release sprays
- medical devices
- aircraft maintenance products
- solvent cleaning sprays
- tire inflators and sealants

ODS Reduction/Elimination Method:

CFC use is eliminated by switching to a substitute chemical and making equipment and operational procedure modifications. HCFC-22 can only be considered a transitional substitute, however, since it has an ODP and its use must also eventually be eliminated.

Composition of Alternative:

The following table presents some relevant characteristics of HCFC-22:

Chemical Composition	$CHClF_2$
Boiling Point	-40.7°C
Vapor Pressure @21.1°C @54.4°C	9.5 bar 21.7 bar
Density @21.1°C	1.21 g/cc
Solubility in H_2O @21.1°C (wt %)	3.0
Flammability Limits in Air (vol %)	Nonflammable
Flash Point	None
Kauri-Butanol Value	25.0

Toxicity:

CFC-22 exhibits very low toxicity. The U.S. Occupational Safety and Health Administration (OSHA) has set a long-term permissible exposure level (PEL) of 1,000 ppm for HCFC-22 (USEPA, 1993).

Flammability:

Nonflammable

VOC Classification[10]:

Non-VOC

Ozone Depleting Potential (ODP):

0.05

Global Warming Potential (GWP):

0.23 (as compared to CFC-12)
1,600 (as compared to CO_2) (100-year basis)

Phaseout Schedule:

HCFC-22 is an ozone-depleting substance, and is therefore scheduled for phaseout within the Montreal Protocol. The following presents the phaseout schedule as amended during the 25 November 1992 meeting in Copenhagen:

- Freeze on HCFC-22 consumption by 1996 based on cap of 3.1% 1989 CFC consumption and 100% HCFC consumption
- 35% reduction by 2004
- 65% reduction by 2010
- 90% reduction by 2015
- 99.5% reduction by 2020
- Phaseout by 2030

There is a possibility that the phaseout schedule will be accelerated if ozone layer depletion proves to be more rapid than expected. The Copenhagen Amendments to the Montreal Protocol will apply to countries operating under Article 5 after a review in 1995. In addition to the Montreal Protocol, several countries have legislated domestic accelerated phaseouts of HCFC-22. For example, in the U.S., use of HCFC-22 either by itself or blended with other compounds will be prohibited in aerosol applications as of 1 January 1994 with limited exemptions for critical uses. Similar regulations are already in effect in Germany.

[10] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

Propellant Characteristics:

Because HCFC-22 is a liquified propellant, it provides a fairly uniform and strong internal can pressure inside the aerosol container throughout the life of the product. HCFC-22 has a higher pressure than CFC-12. Therefore, similar spray characteristics can be achieved using lower quantities of HCFC-22 as compared to CFC-12. If similar quantities are to be used, stronger aerosol valves and cans need to be selected to accommodate the higher pressure. HCFC-22 propellant decomposes in water at a pH of 8.0 or more, forming chloride ions which accelerate the rate of corrosion in cans. Therefore, modifications to the formulation, valve, and can may be necessary to optimize product delivery.

Substitute Production Method and Materials:

Material Requirements

Because HCFC-22 has a high pressure, it is generally not used in aerosols without the addition of a pressure-depressing solvent or low-pressure propellant. A typical aerosol blend is 60% HCFC-142b and 40% HCFC-22. This blend has a pressure of 4.2 bar at 20°C. Ethanol and DME are also effective pressure suppressants. Mixing HCFC-142b, ethanol, or DME with HCFC-22 may slightly increase the flammability of the end-product.

Products in which the HCFC-22 is used as the propellant must often use a stronger disposable steel container in lieu of the conventional tin plate can. In addition, existing valves may have to be replaced with high pressure valves (USEPA, 1993).

Filling Processes

HCFC-22 is generally not a drop-in substitute due to its high pressure relative to CFCs. Tanks and valves on filling equipment should be modified to accommodate the higher pressure. If HCFC-22 propellant blends are used, or if the aerosol solvent has vapor pressure reducing properties, there is a possibility that HCFC-22 can be used with minimal changes to the filling process.

Health and Safety Considerations:

There are negligible toxicity concerns associated with HCFC-22.

Environmental Considerations:

Because HCFC-22 has an ODP, albeit a small one relative to CFC-11 and CFC-12, it should only be used a transitional alternative, and only in instances where propellant nonflammability is crucial.

Associated Costs:

The price of HCFC-22 relative to other non-CFC propellants may limit its acceptance as an aerosol propellant. In February 1993, the price per kilogram of HCFC-22 in the United States was approximately five times that of hydrocarbon propellants and 2 times that of DME.

The price of HCFC-22 will vary from country to country, based on availability and taxes. The current bulk price of HCFC-22 in the United States is US$2.42/kg. The price is likely to go up as the chemical is phased out.

The costs of converting from CFC-12 to HCFC-22 filling are much lower than those for converting to other alternatives. In fact, some plants may be able to accommodate HCFC-22 without any retrofits. In addition to the filling equipment itself however, new bulk storage tanks may be required. Tanks which were fabricated to contain CFC-12 may not be able to contain HCFC-22, which has a significantly higher vapor pressure. On average, however, the cost of converting to HCFC-22 is approximately half the cost of the converting to hydrocarbons (UNEP, 1991).

Current Use:

Worldwide use of HCFC-22 in aerosol products is estimated to be below 20,000 tons per year.

Availability:

HCFC-22 is widely available around the world because of its importance as a specialty refrigerant and freezant. Due to its availability, it is an attractive short-term replacement for CFC-12 aerosol propellants. However, it is only a transitional alternative because of its scheduled phaseout.

Vendors of Alternative Equipment:

Aerosol Filling Equipment Suppliers

Advam Packaging Systems
91 Darley Street
Mona Valve, NSW 2103
Australia
Tel: (61) 2 997 5533
Fax: (61) 2 997 7996

Aerofill Limited
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

Aerojet Quimica Industrial Ltda
Av. Beira Mar, 200
Salas 801/803 Costelo
RJ
Brazil
Tel: (55) 21 262 8181
Fax: (55) 21 776 1904

Aerosol Laboratory Equipment
R.D. 1, Box 75
Route 10
Walton, NY 13856
USA
Tel: (1) 607 865 7173
Fax: (1) 607 865 7175

Akron Polymer Container
540 South Main Street
Akron, OH 44311
USA
Tel: (1) 216 253 6500
Fax: (1) 216 253 8009

Autoprod Inc.
5355 115th Avenue North
Clearwater, FL 34620
USA
Tel: (1) 813 572 7753
Fax: (1) 813 573 0367

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali SpA
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 290 06075
Fax: (39) 2 290 06700

Cozzoli Machine Company
401 E. 3rd Street
Plainfield, NJ 07060
USA
Tel: (1) 908 757 2040
Fax: (1) 908 757 7386

Daellenbach Maschinenbau
Bachstrasse 25
CH-8912 Obfelden
Zurich
Switzerland
Tel: (41) 1 761 71 25
Fax: Not available

Doje Corporation
Yougdong
P.O. Box 1211
Seoul 135
Republic of Korea
Tel: (82) 2 553 4994
Fax: (82) 2 554 0451

Druk Pak AG
CH-8132 Egg
Zurich
Switzerland
Tel: (41) 1 984 2720
Fax: (41) 1 984 0715

Gem Shine Trading Co.
Shin Chiang Chung Ind. Co. Ltd.
No 23, Lane 84, Jing-Yin Street
Shu-Lin Town, Taipei Hsien
Taiwan
Tel: (886) 2 682 5549
Fax: (886) 2 685 1769

JG Machine Works, Inc.
75 Spring Street
Paterson, NJ 07501
USA
Tel: (1) 201 881 7000
Fax: (1) 201 881 0563

Jose F. Olivieri & Assoc.
Suite 906-B
623 Ponce De Leon Ave.
Hato Rey 00919
Puerto Rico
Tel: (1) 809 766 0006
Fax: (1) 809 756 5930

KP Aerofill
33-35 Clayton Road
Hayes, Middlesex UB3 1RU
United Kingdom
Tel: (44) 81 848 4501
Fax: (44) 81 561 3308

KP Aerofill
807 W. Kimberly Road
P.O. Box 3848
Davenport, IA 52808
USA
Tel: (1) 319 391 1100
Fax: (1) 319 391 4951

Laboratories Rety De Colombia
Zona Franca B-10
Apartado Aereo 29594
Barranquilla
Colombia
Tel: (57) 58 2360641
Fax: (57) 58 413472

Nalbach Engineering Co, Inc.
6139 W. Ogden Avenue
Cicero, IL 60650
USA
Tel: (1) 708 652 8900
Fax: (1) 708 652 8920

Nimmo Packaging Systems
1 Home Villa, Farley Heath
Albury, Surrey GU5 9ER
United Kingdom
Tel: (44) 483 20 3609
Fax: (44) 483 20 3625

Pamasol
Driesbuelstrasse 2
CH-8808 Pfaffikon SZ
Switzerland
Tel: (41) 55 4824 31
Fax: (41) 55 4852 15

P & P Machinery
P.O. Box 1712
Glen Vista 2058
South Africa
Tel: (27) 11 432 2188
Fax: (27) 11 682 2142

Precision Valve (India) Pvt. Ltd.
228 Pragati Ind Estate
N.M. Joshi Marg
Bombay 400 011
India
Tel: (91) 22 309 7422
Fax: (91) 22 307 0618

Precision Valve Singapore Pte. Ltd.
10/12/Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 264 0461

Reed Enterprises Inc.
52645 Thorne Drive
Elkhart, IN 46514
USA
Tel: (1) 219 264 9900
Fax: (1) 219 264 7733

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Spider Engineering, Inc.
700 South Plumosa Street
Merritt Island, FL 32952
USA
Tel: (1) 407 452 3922
Fax: (1) 407 453 8338

Super Pak S.A.
Heraclito 327 P.A.
Col. Polanco C.P. 11560
Mexico
Tel: (52) 5 545 2127
Fax: (52) 5 251 8144

Tecnomac S.p.A.
Via Garofalo, 19
20133 Milano
Italy
Tel: (39) 2 27 80 44
Fax: Not available

Terco, Inc.
496 Lunt Ave.
Schaumberg, IL 60193
USA
Tel: (1) 708 894 8828
Fax: (1) 708 894 8846

Valve Suppliers

Aboukir Engineering Industries
Aboukir-Alexandria
Egypt
Tel: (20) 3 560 1538
Fax: (20) 3 560 3392

Aerocan Ltd.
P.O. Box 4519
Nicosia
Cyprus
Tel: (357) 2 350 550
Fax: (357) 2 350 559

Aerosol Research & Development, Ltd.
Fitzherbert Road
Farlington, Portsmouth
Hants PO6 1RU
United Kingdom
Tel: (44) 705 387 782
Fax: (44) 705 380 825

Aerosol-Technique Lindal (UK)
Cherrycourt Way, Stanbridge Road
Leighton Buzzard
Bed. LU7 8UH
United Kingdom
Tel: (44) 525 381 186
Fax: (44) 525 383 304

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Avery Denison Ltd.
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 0922 614 631
Fax: (44) 0922 613 043

BLM Associates/Lablabo
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Walter C. Beard, Inc.
P.O. Box B
Middlebury, CT 06762
USA
Tel: (1) 203 758 2194
Fax: Not available

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Carnaud-Metalbox
20 A Street
Derry, NH 03038
USA
Tel: (1) 603 434 7741
Fax: (1) 603 437 5703

Carnaud-Metalbox Packaging
Nigeria Ltd.
3-7 Metal Box Road
Ogba Ind. Est
PMB 21588 Ikeja, Lagos
Nigeria
Tel: Not available
Fax: (234) 1 964 443

Carnaud-Metalbox Packaging
Singapore Ltd.
Marsiling P.O. Box 0356
1120 Woodlands Road 9173
Singapore
Tel: (65) 269 ▪111
Fax: (65) 367 0912

Clayton Corporation
866 Horan Drive
Fenton, MO 63026
USA
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Fax: (1) 314 349 5335

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Fax: (39) 2 2900 6700

Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
Germany
Tel: (49) 911 324 350
Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190 801200

EP Spray System
60 Williams Parkway, Suite J
East Hanover, NJ 07936
USA
Tel: (1) 201 515 8535
Fax: Not available

EP Spray System
30 Rue de Plan
CH-2002 Neuchatel
Switzerland
Tel: (41) 38 25 02 22
Fax: (41) 38 24 49 07

Engineered Controls International
Rego Products
100 Rego Drive
Elon College, NC 27244
USA
Tel: (1) 919 449 7707
Fax: (1) 919 449 6594

Kum Suk Chemical Co.
301-3F Ara Bldg.
705-9 Banpo-1 Dong
Seocho-Ku, Seoul
Republic of Korea
Tel: (82) 2 516 8411
Fax: (82) 2 516 8414

Kumar Aerosols (p) Ltd.
3/13-B, ASAF Ali Rd.
New Delhi 110002
India
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Fax: (91) 011 326 9761

Lindal Italiana S.R.L.
Via Piave, 7
22049 Valmadrera-Como
Italy
Tel: (39) 341 551 433
Fax: (39) 341 551 293

Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
Leighton Buzzard
Bedfordshire LU7 8UH
United Kingdom
Tel: (44) 525 381 155
Fax: (44) 525 383 304

Lindal Ventil GmbH
Industriestrasse 13
D-2060 Bad Oldesloe
Germany
Tel: (49) 4531 86001
Fax: (49) 4531 87664

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43-1
08014 Barcelona
Spain
Tel: (34) 3 314 9111
Fax: (34) 3 314 6081

Nampak Group
P.O. Box 247
Howard Place
South Africa
Tel: (27) 21 547 111
Fax: (27) 21 547 126

Newman-Green, Inc.
57 Interstate Road
Addison, IL 60101
USA
Tel: (1) 708 543 6500
Fax: (1) 708 543 8523

Novospray S.A.
Place Cornavin 18
CH 1201 Geneva
Switzerland
Tel: (41) 22 738 22 11
Fax: (41) 22 738 21 38

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Perfect-Valois Ventil GmbH
Hildebrandstrasse 20, Post. 130340
4600 Dortmund 13 (Wickede)
Germany
Tel: (49) 231 218 0211
Fax: (49) 231 21 17 52

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416 683 0120
Fax: (1) 416 427 1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, FL 33315
USA
Tel: (1) 305 359 1425
Fax: (1) 305 359 0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel: (39) 2 944 9256
Fax: (39) 2 944 9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484 444851
Fax: (81) 484 446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22 3097732/3097422/3097794
Fax: (91) 22 3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111, Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapore PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/(65) 264 0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442 (plant)
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Safeworld International
7352 Adams Road
Talent, OR 97540
USA
Tel: (1) 503 535 7661
Fax: (1) 503 535 3204

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Valve Company
1160 N. Silver Lake Road
Cary, IL 60013
USA
Tel: (1) 708 639 2124
Fax: (1) 708 639 1179

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Summitt Packaging Europe
Grot Mijdrecht 9F
3641 RV Mijdrecht
Netherlands
Tel: (31) 2979 88661
Fax: (31) 2979 87289

Summit Packaging Systems
P.O. Box 5304
Manchester, NH 03108
USA
Tel: (1) 603 669 5410
Fax: (1) 603 645 1047

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvole Aerosol Research Italiana
Via Del Pino 10
22057 Olginate (Como)
Italy
Tel: (39) 341 680 325
Fax: (39) 341 680 501

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds.
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo 60230
Brazil
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

HCFC Propellant Suppliers

Allied-Signal Incorporated
P.O. Box 1139R
Morristown, NJ 07962
USA
Tel: (1) 201 455 2978
Fax: (1) 201 455 2763

Atochem North America
3 Parkway
Philadelphia, PA 19102
USA
Tel: (1) 215 587 7334
Fax: (1) 215 587 7369

Ausimont
Via Principe Eugenio, 1/5
20155 Milano
Italy
Tel: (39) 2 6270 3652
Fax: (39) 2 6270 3412

Copia Associates, Inc.
9837 Neesonwood Dr.
Shreveport, LA 71106
USA
Tel: (1) 318 797 8372
Fax: (1) 318 797 0101

Diversified CPC International, Inc.
24338 W. Durkee Road
Channahon, IL 60410
USA
Tel: (1) 815 423 5991
Fax: (1) 815 423 5627

DuPont Argentina S.A.
Casilla Correo 1888
1000 Correo Central
Buenos Aires
Argentina
Tel: (54) 1 311 8167
Fax: (54) 1 311 1329

DuPont Canada Inc.
P.O. Box 2200
Streetsville
Mississauga, Ontario L5M 2H3
Canada
Tel: (1) 416 821 3300
Fax: (1) 416 821 5057

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel: (1) 302 633 1501
Fax: (1) 302 892 1705

DuPont-Mitsui Fluorochemicals Co., Ltd.
2-3, 1-Chome Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan
Tel: (81) 3 3216 8468
Fax: (81) 3 3215 0064

Elf Atochem
4 Cours Michelet
La Defense 10
Cedex 42-92091
Paris
France
Tel: (33) 1 49 00 80 46
Fax: (33) 1 49 00 70 21

Hoechst Aktiengesellschaft
Postfach 800 320
D6230 Frankfurt (Main) 80
Germany
Tel: (49) 69 305 55 02
Fax: (49) 69 305 91 79

ICI Chemicals and Polymers Ltd.
P.O. Box 13
The Heath
Runcorn, Cheshire WA7 4QF
United Kingdom
Tel: (44) 928 511 385
Fax: (44) 928 581 155

Rety de Colombia Ltda.
Bodega 10
P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Rhone-Poulenc Chemicals Ltd.
St. Andrews Road
Avonmouth, Bristol BS11 9YF
United Kingdom
Tel: (44) 272 823 631
Fax: (44) 272 820 759

Rocep Pressure Packs Limited
Glasgow Road, Deanpark
Renfrew PA4 8XY
Scotland
United Kingdom
Tel: (44) 41 885 2222
Fax: (44) 41 886 7464

Technical Propellants Inc.
6233 N. Pulaski Road
Chicago, IL 60646
USA
Tel: (1) 312 463 5555
Fax: (1) 312 463 8061

Sources of Additional Information about this Technology:

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2. Knopeck, Gary and Leon Zwolinski. "HCFC-22 and other alternatives to CFC propellants." Aerosol Age. July 1991.

3. Nardini, Geno. "From Policies and Strategies to Concrete Action Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride," UNEP Workshop on the Implementation of the Montreal Protocol for the Protection of the Ozone Layer. Nairobi, Kenya, November 1992.

4. Radian Corporation for USEPA. "Manual for Non-CFC Aerosol Packaging: Conversion from CFC to Hydrocarbon Propellants." Washington, D.C., USA, September, 1991.

5. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

6. UNEP Training Manual. "For the Conversion from Chlorofluorocarbon (CFC) Propellants to Alternatives, including Hydrocarbon Gases."

7. USEPA. Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Aerosols. March 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.6 Pump Sprayers (Finger-Pump and Trigger-Pump)

Headline:

Pump sprays are the largest technical alternative to aerosol propellants for product dispensing mechanisms.

Finger-Pump Sprayers are the most widely used pump-action dispensers. More than one billion units are sold in North America alone.

Trigger-Pump Sprayers are typically larger than finger-pump sprayers and used less for personal products and more in household and industrial applications.

Industry Sector:

Finger-Pump Sprayers

Typical products that are packaged in finger-pumps include:

- bug killers
- pet sprays
- hair sprays
- curl activators
- spot cleaners
- cookware lubricants
- sun tan screens
- topical lotions
- silver polish sprays
- burn sprays
- mildewcides
- lubricants
- pre-laundry cleaners
- weed killers
- colognes and perfumes
- hair moisturizers, sheens, etc.
- glass cleaners
- germicides and bactericides
- starches and fabric finishes
- facial rinses
- contact lens rinsing sprays
- throat sprays
- leaf shine sprays
- chrome polishing sprays
- stainless steel cleaners
- high image cremes and lotions

Trigger-Pump Sprayers

Trigger sprays are generally not used in personal products, but rather for cleaning purposes such as:

- home laundry detergents
- automatic dishwasher detergents
- pre-laundry spot cleaners
- disinfectant cleaners
- carpet cleaner concentrates
- concrete floor grease and oil cleaners

- vinyl top cleaners
- industrial lubricant cleaners
- automotive cleaner/wax products

ODS Reduction/Elimination Method:

CFCs are eliminated by switching to a not-in-kind substitute.

Description of Alternative/Compatibility Characteristics:

Finger-pump and trigger-pump sprayers are generally only used for water-based, hydro-alcoholic, and alcoholic formulations because the complexity of the pump valves makes them sensitive to certain formulations. The following is a partial list of product types which typically cannot be dispensed using pump sprays:

- Volatile flammables, except for ethanol, e.g., cigarette lighter fluids.
- Viscous liquids where the spray is either steamy or nonexistent. One option is to extrude the product in lotion or creme form (where pumps can be used).
- Strong solvents, e.g., nail polish removers.
- Sterile liquids.
- Acidic liquids where acetal components dissolve below a pH of 3.6.
- Moisture sensitive fluids where ambient moisture may enter through return air.
- Suspensoid fluids that may cause valve plugging.
- Foam-type emulsions where foaming will not occur unless a Zeller screen or other special device is added.
- PE-warping liquids, e.g., oleic acid and some block polymers.
- Staining liquids that cause opaque bottle stains.
- Sensitive liquids, e.g., liquids harmed by oxygen, carbon dioxide, moisture, light, or a combination.
- Two-phase liquids where phases will reform in valve chamber and resist reconstitution by hand shaking.
- High odor liquids that result in smells permeating plastics, e.g., MACE, garlic concentrates.

Some finger-pump spray valves are very similar to meter-spray aerosol valves. However, they are larger than ordinary ferrule-type and meter-spray aerosol valves and made of clear plastic. While finger-pump sprayers can be nearly identical in appearance to aerosol products, they differ in their flexibility in design. Aerosol products containing more than 120 mL are generally restricted to metallic, cylindrical containers. Finger-pump sprayers, on the other hand, can be produced in a variety of shapes and sizes.

Toxicity: N/A

Flammability:

The formulations contained within finger-pump and trigger-pump sprayers can range from 0 to 100% flammable components. If a pump dispenser is heated in a fire, the head space plastic may melt, creating holes through which the components inside may escape. If these components are flammable, they will further fuel the fire.

VOC Classification: N/A

Ozone Depleting Potential (ODP): N/A

Global Warming Potential (GWP): N/A

Phaseout Schedule: None

Propellant Characteristics:

Finger-Pump Sprayers

The finger-action valve delivers a fixed volume of product per actuation that can be varied from approximately 0.125 to 0.200 mL (Johnsen, 1990). Spray particles from finger-pumps sprayers are coarse and wet. Therefore, finger-pump sprayers are best suited for surface applications. Also, at the beginning and end of each actuation, finger sprays produce a 10 to 20 mg dribble. This occurs because the pressure climbs, plateaus, and drops during actuation. At the low pressure areas, there is not sufficient pass-through to allow the valve mechanical break-up system to function properly.

A potential disadvantage of the finger-pump sprayer is the number of times the actuator must be depressed in order to empty the container. If an 8 fluid ounce product is sprayed at the rate of 0.125 mL per actuation, 2,396 actuations will be required to empty the container. This number can be reduced by using pumps that emit larger size shots.

The finger-pump sprayer, like aerosols, has the capability of operating if inverted through the use of a double-acting ball check valve.

Trigger-Pump Sprayers

The trigger mechanism dispenses larger quantities per shot than the finger pump, usually 2-4 mL, but possibly up to 30 mL or more (Johnsen, 1990). The pinioned trigger allows for a mechanical advantage, or leverage factor, that permits the use of large dispensing chambers.

Substitute Production Method and Materials:

Finger-Pump Sprayers

The filling operation for finger-pumps is single-stage, unlike the filling operation for aerosols, which requires both a liquid filling and gassing stage.

Trigger-Pump Sprayers

Trigger-pump sprayers have the same filling operation as finger-pump sprayers.

Both finger-pumps and trigger-pumps dispense a measured quantity of product during each actuation. A variation of the standard finger-pump with a special actuator can be used to extrude viscous products and creams.

Health and Safety Considerations:

While the flammability of the pump sprayers is not an issue, when converting away from CFCs, it is important to take the necessary safeguards if the product being dispensed is flammable.

Environmental Considerations:

None

Associated Costs:

Finger-Pump Sprayers

The cost of placing a single finger-action valve on an aerosol can is considerably higher than the cost of using an aerosol valve. The standard aerosol valve has 6-8 components and sells for approximately US$44 per thousand in the United States. The finger-action valve has about 11 components, some of which must fit together with tighter tolerances than the components in aerosol valves. Therefore, these valves sell for approximately four times the price of aerosol valves.

To reduce the cost per unit of product dispensed, producers use the largest practical containers and market refill containers that use simple, low-cost screw caps. In addition, they emphasize the use of finger pumps for more costly products such as perfumes, colognes, sachets, and pharmaceuticals.

Trigger-Pump Sprayers

Trigger-pump sprayers are more costly than finger-pump sprayers. Therefore, producers of trigger-pump sprayers use larger containers and emphasize using refills to make trigger-pump sprayers more cost effective. Container sizes sometimes exceed 3,784 mL.

Current Use:

Refer to "Industry Sector."

Availability:

The finger and trigger-pump sprayer valves are generally available from the same firms that produce aerosol and other valves.

Vendors of Alternative Equipment:

Liquid Filling Equipment Suppliers

Ab. Develioglu Ticaret
Billur Sokak Ari Han Kat:5
Karakoy, Istanbul
Turkey
Tel: (90) 1 2444542
Fax: (90) 1 2448603

Acuraks, Inc.
31-8 3-chome,
Nihonbashi-Hama-cho
Chuo-ku, Tokyo 103
Japan
Tel: (81) 3 639 5751
Fax: (81) 3 639 5754

Anypack
Suite 203 1070 Ridgeway Ave.
Coquitlam, B.C. V37 1S7
Canada
Tel: (1) 604 936 4460
Fax: (1) 604 936 4461

Avery Denison Limited
Moor Road
Leeds LS10 2DE
United Kingdom
Tel: (44) 922 614 631
Fax: (44) 922 613 043

B & T Packaging
100 McLevin Ave.
Unit 6-7
Scarborough, Ontario M1B 2V5
Canada
Tel: (1) 416 297 4774
Fax: (1) 416 297 9586

Beesants Associates Pvt. Ltd.
P.O. Box 1624, Bagh Bazar
Kathmandu
Nepal
Tel: (977) 1481514650
Fax: Not available

Boato Pack
Via Grado No. 64
37074 Monfalcone
Italy
Tel: (481) 711812/482716/484555
Fax: (481) 482837

Burge Equipment Company
Unit 6, Langley Business Ct.
Workd's End
Beedon Nr. Newbury
Berkshire RG16 8R4
United Kingdom
Tel: (44) 635 248171
Fax: (44) 635 248857

Consolidated Packaging Machinery
11980 Walden Avenue
Alden, NY 14004
USA
Tel: (1) 708 293 5565
Fax: (1) 708 293 0444

Electronic Liquid Fillers
1535 S. Highway 39
LaPorte, IN 46348
USA
Tel: (1) 219 393 5541
Fax: (1) 219 324 2884

Europac Co. Ltd.
GPO Box 2604
6th Fl., Ruam Rudi Bldg.
566 Ploenchit Road
Bangkok 10500
Thailand
Tel: (66) 2 251 7705/6
Fax: (66) 2 2512350

Gregorson & Co. Pty. Ltd.
P.O. Box 214
Unit 1 340 George Street
Waterloo, N.S.W. 2017
Australia
Tel: (61) 2 318 0955
Fax: (61) 2 698 4101

Hintal AB
Box 7805
Regeringsgatan 85, 1tr
S-103 96 Stockholm
Sweden
Tel: (46) 8 204960 or 209301
Fax: (46) 8 21 42 09

Int'l Process Controls Co.
Pharmaceutical & Indust. Division
P.O. Box 11578
Tel-Aviv 61114
Israel
Tel: (972) 3 284233
Fax: (972) 3 281482 or -290552 or -296349

Intertec (Hong Kong) Co.
3402 Windsor House
311 Gloucester Road
Causeway Bay
Hong Kong
Tel: (852) 5 8949863
Fax: (852) 5 771373

Intertec Ltd.
7 Prebendal Ct.
Oxford Road, Aylesbury
Bucks HP193EY
United Kingdom
Tel: (44) 293 393999
Fax: (44) 296 393001

Kelly Electronics Pvt.
1413 Dalamal Tower
Nariman Point
Bombay 400 021
India
Tel: (91) 22 244286
Fax: Not available

Morris Corporation
P.O. Box 1451
Manila 1099
Philippines
Tel: (63) 2 867727
Fax: (63) 2 815 4763

National Instrument Company
4119-27 Fordleigh Road
Baltimore, MD 21215
USA
Tel: (1) 410 764 0900
Fax: (1) 410 764 7719

Oden Corporation
255 Great Arrow Avenue
Buffalo, NY 14207
USA
Tel: (1) 716 874 3000
Fax: Not available

P.A. Cuthbert & Co.
P.O. Box 79198
Senderwood 2145
South Africa
Tel: (27) 11 452 5806/10
Fax: (27) 11 452 5849

Papsco
John Rodes Commerce Park
700 John Rodes Boulevard
Unit A-1
Melbourne, FL 32904-1507
USA
Tel: (1) 407 723 2723
Fax: (1) 407 723 1629

Peng Ta Trading Co. Ltd.
10F-5 No. 50 Linsen N. Road
Taipei
Taiwan
Tel: (866) 2 563 8360/571 0280/511 3412
Fax: (886) 2 561 4164

Peter Binder GmbH
Schelmenwasenstrasse 22
D-7000 Stuttgart-80
(Fasanenhofost)
Germany
Tel: (49) 711 71560 51
Fax: (49) 711 71593 15

R.T.L. Representaciones Tecnicas Ltda.
Calle 33A No. 18-34
Bogota
Colombia
Tel: (57) 1 2453904
Fax: (57) 1 2878074

S.A. Ludeco N.V.
Rue Coenraets 64
1060 Brussels
Belgium
Tel: (32) 2 535 06 60
Fax: (32) 2 535 06 80

Serac, Inc.
300 Westgate Dr.
Carol Stream, IL 60188
USA
Tel: (1) 708 510 9343
Fax: (1) 708 510 9357

Tullio Bolis
Via E. Vacha No. 11
24100 Bergamo
Italy
Tel: (39) 35 301910
Fax: (39) 35 301911

Unipack Korea
SL. Young Dong
P.O. Box 2094
Seoul 135-620
Republic of Korea
Tel: (82) 2 556 9921
Fax: (82) 2 556 6788

United Dist.'s "Rali"
19, Souk El-Tewfikieh ST.
P.O. Box 1463
Cairo
Egypt
Tel: (20) 2 745288
Fax: (20) 2 760027

Valco Hellas, Ltd.
28C Akadimias Street
GR-10671 Athens
Greece
Tel: (30) 1 3630228
Fax: Not available

Yutaka Trading Co. Pte. Ltd.
P.O. Box 102
Geyland Post Office
Singapore 9138
Tel: (65) 747 0333 or 1666
Fax: (65) 747 3765

Finger- and Trigger-Pump Suppliers

AFA Corporation
One Pine Street
Forest City, NC 28043
USA
Tel: (1) 704 245 1160
Fax: (1) 704 245 4732

Airspray International, Inc.
3581 N. Federal Highway
Pompano Beach, FL 33064
USA
Tel: (1) 305 942 1122
Fax: (1) 305 942 8825

Bemas International Packaging
9 Accomodation Road
London NW11 8ED
United Kingdom
Tel: (44) 81 458 0440
Fax: (44) 81 458 0401

Bespak, Inc.
P.O. Box 5033
Cary, NC 27511
USA
Tel: (1) 919 387 0112
Fax: (1) 919 387 0116

Bespak plc
Bergen Way, No. Lynn Ind. Est.
Kings Lynn
Norfolk PE30 2JJ
United Kingdom
Tel: (44) 553 691 000
Fax: (44) 553 691 622

Betancourt Negret e Hijos
Apartado Aereo 16398
Bogota
Colombia
Tel: (57) 3 262 6297
Fax: (57) 3 260 6179

Calmar Inc.
333 South Turnbull Canyon Road
City of Industry, CA 91749
USA
Tel: (1) 818 330 3161
Fax: (1) 818 330 4337 Sales Fax

Calmar Plastics Ltd.
306 Rexdale Blvd.
Rexdale, Ontario M9W 1R6
Canada
Tel: (1) 416 743 9433
Fax: (1) 416 743 5509

Calmar Albert Belgium S.A.
120, Rue Du Petit Pont
7700 Mouscron
Belgium
Tel: (32) 56 34 30 37
Fax: (32) 56 34 64 69

Calmar Albert France
Horizon 2000, Mach 5
Av. Des Hauts Grigneux
76420 Bihorel-Les-Rouen
France
Tel: (33) 35 603536
Fax: (33) 35 602515

Calmar Albert GmbH
Ernst-Stenner-Str 17
D-5870 Hemer
Germany
Tel: (49) 2372 5040
Fax: (49) 2372 50426

Calmar Albert Italia SRL
Via Veneto 5B
40043 Bologna-Marzabotto
Italy
Tel: (39) 51 931257 or 932953
Fax: (39) 51 932904

Calmar Albert U.K. Ltd.
151 London Road
East Grinstead
West Sussex RH19 1ET
United Kingdom
Tel: (44) 34 231 3848
Fax: (44) 34 232 7710

Continental Sprayer, Inc.
27 Guenther Boulevard
St. Peters, MO 63376
USA
Tel: (1) 314 278 1600
Fax: Not available

Coster Aerosols Ltd.
Babbage Road
Stevenage
Herts SG1 2EQ
United Kingdom
Tel: (44) 438 367 763
Fax: (44) 438 728 305

Coster Technologie Speciali
Corso Como, 15
20154 Milan
Italy
Tel: (39) 2 2900 6075
Fax: (39) 2 2900 6700

Damo
204 Factopia, 196 Anyang 7 Dong
Anyang, Kyunggi-Do
Republic of Korea
Tel: (82) 343 67 2727
Fax: (82) 343 67 2720

Deutsche Aerosol-Ventil GmbH
Hana-Bunte-Str 10
D 8500 Nuernberg 84
Germany
Tel: (49) 911 324 350
Fax: (49) 911 326 3418

Deutsche Prazisions Ventil GmbH
Schulstrasse 33
6234 Hattersheim/Main
Germany
Tel: (49) 6190 80215/8010
Fax: (49) 6190 801200

Drug & Cosmetic Sales Corp.
1065 S.W. 15th Avenue
Suite #7
Delray Beach, FL 33444
USA
Tel: (1) 407 265 1700
Fax: (1) 407 265 1942

Emson Europe Ltd.
Station Approach, Four Marks
Near Aston
Hampshire GU34 5HN
United Kingdom
Tel: (44) 420 62055
Fax: (44) 420 63648

Emson Research, Inc.
118 Burr Court
Bridgeport, CT 06605
USA
Tel: (1) 203 366 4501
Fax: (1) 203 576 0280

Europak
P.O. Box 334. Industry Road
Olifantsfontein 1665
South Africa
Tel: (27) 11 316 2110
Fax: (27) 11 316 1045

Garrett-Hewitt International
147 Broadway
Hawthorne, NY 10532
USA
Tel: (1) 914 747 0004
Fax: (1) 914 747 0125

Huai Co.
627 W. Lemon Avenue
Arcadia, CA 91007
USA
Tel: (1) 818 446 7305
Fax: (1) 818 447 5882

Huai Co.
288 Chin Chou Street
Taipei 10458
Taiwan
Tel: (886) 2 502 31603
Fax: (886) 2 502 4665

Lindal Italiana S.R.L.
Via Piave, 7
22049 Valmadrera-Como
Italy
Tel: (39) 341 551 433
Fax: (39) 341 551 293

Lindal Valve Co., Ltd.
Cherrycourt Way/Stanbridge Rd.
Leighton Buzzard
Bedfordshire LU7 8UH
United Kingdom
Tel: (44) 525 381 155
Fax: (44) 525 383 304

Magiplast S.A.
J.P. Tamborini 5027
Buenos Aires 1431
Argentina
Tel: (54) 1 542 3442
Fax: (54) 1 544 8866

Mitani Valve Co., Ltd.
2-7 Kanda-Sakumacho
Chiyoda-ku Tokyo
Japan
Tel: (81) 3 3862 2031
Fax: (81) 3 3866 8257

Monturas S.A.
Guitard 43
0814 Barcelona
Spain
Tel: (34) 3 490 7667
Fax: (34) 3 490 1728

O.R. Cormack Pty. Ltd.
13 Leeds Street, Rhodes
Sydney, N.S.W., 2138
Australia
Tel: (61) 2 736 1422
Fax: (61) 2 736 3315

Perfect-Valois UK Ltd.
11 Holdom Avenue, Saxon Pk, Ind. Est.
Bletchley Milton
Keynes MK1 1QU
United Kingdom
Tel: (44) 908 270 462
Fax: (44) 908 270 471

Pfeiffer Incorporated
12 Roszel Road
Suite C104
Princeton, NJ 08540
USA
Tel: (1) 609 987 0223
Fax: (1) 609 987 0763

Precision Valve Australia PTY Ltd.
Williamson Road
P.O. Box 312
Ingleburn, N.S.W. 2565
Australia
Tel: (61) 2 605 6999
Fax: (61) 2 605 4336

Precision Valve Canada Ltd.
85 Fuller Road
Ajax, Ontario LIS 2EI
Canada
Tel: (1) 416 683 0120
Fax: (1) 416 427 1427

Precision Valve Corp.
700 S.W. 34th Street
Fort Lauderdale, FL 33315
USA
Tel: (1) 305 359 1425
Fax: (1) 305 359 0344

Precision Valve Italia S.P.A.
Via Ravello, 1/3
20081 Vermezzo (Milan)
Italy
Tel.: (39) 2 944 9256
Fax: (39) 2 944 9196

Precision Valve Japan, Ltd.
76 Niizo
Toda-Shi, Saitama-Ken 335
Japan
Tel: (81) 484 444851
Fax: (81) 484 446690

Precision Valve (India) PVT Ltd.
228 Pragti (TODI) Ind. Estate
N.M. Joshi Marg
Lower Parcel
Bombay 400011
India
Tel: (91) 22 3097732/3097422/3097794
Fax: (91) 22 3070618

Precision Valve New Zealand
102 Donnar Place, Mt. Wellington
P.O. Box 62-111, Sylvia Park
Auckland 6
New Zealand
Tel: (64) 9 5273941
Fax: (64) 9 5273514

Precision Valve Singapore PTE Ltd.
10 Pioneer Lane, Jurong 2262
Singapore
Tel: (65) 268 9333
Fax: (65) 261 0993/65 264 0461

Precision Valve South Africa PTY Ltd.
P.O. Box 92
Rossyln, 0200 Transvaal
South Africa
Tel: (27) 12 581 601
Fax: (27) 12 541 2915

Precision Valve U.K. Ltd.
Unit C, Newcombe Way
Orton Southgate
Peterborough
Cambs PE2 OSF
United Kingdom
Tel: (44) 733 238181
Fax: (44) 733 232653

Prevalco, C.A.
Av. Principal de Los Ruices
Ed. Centro Empresarial Los Ruices
Piso 2, Oficina 219
Caracas 1061
Venezuela
Tel: (58) 2 239 0261
(58) 2 238 2425
(58) 39 22508/22442
Fax: (58) 2 344194

Rety de Colombia Ltda.
Bodega 10/P.O. Box 3139
Barranquilla
Colombia
Tel: (57) 58 413 199
Fax: (57) 58 413 472

Risdon Corporation
60 Electric Avenue
Thomaston, CT 06787
USA
Tel: (1) 203 283 8271
Fax: Not available

Seaquist Canada
482 Millway Avenue
Concord, Ontario L4K 3V5
Canada
Tel: (1) 416 660 0225
Fax: (1) 416 660 0233

Seaquist Pumps
740 G Industrial Drive
Cary, IL 60013
USA
Tel: (1) 708 639 3800
Fax: (1) 708 639 1977

Seaquist-Valois Australia
11-13 Sammut Street
Smithfield, NSW 2164
Australia
Tel: (61) 2 604 3755
Fax: (61) 2 604 5141

Sethco Division
70 Arkay Drive
Hauppauge, NY 11788
USA
Tel: (1) 516 435 0530
Fax: (1) 516 435 0654

Sofab
4 rue Diderot
92156 Suresnes
France
Tel: (33) 1 47 28 26 70
Fax: (33) 1 47 28 26 71

Somova S.r.P.
via Palermo 31
20094 Buccinasco Milano
Italy
Tel: (39) 2 281 02232
Fax: (39) 2 557 00500

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Specialty Packaging Products
P.O. Box 35016
Richmond, VA 23235
USA
Tel: (1) 804 323 4300
Fax: (1) 804 323 3287

Spruhventile GmbH
Gewerbegebiet Reckholder
Wyhl. AK 7831
Germany
Tel: (49) 7642 1041
Fax: (49) 7642 8301

Tsubakimoto
1-8-3 Marunouchi
Chiyoda-Ku, Tokyo 100
Japan
Tel: (81) 3 3287 6331
Fax: (81) 3 3214 1601

T.Y. Chu & Co. Ltd.
Room 20-21 Shing Yip
Industrial Bldg.
19-21 Shing Yip Street
Kwun Tong, Kowloon
Hong Kong
Tel: (852) 3 415321
Fax: (852) 3 797 8610

Valois of America
15 Valley Drive
Greenwich, CT 06831
USA
Tel: (1) 203 661 5455
Fax: (1) 203 661 2457

Valve Precision, S.A.R.L.
11 Avenue De Laponie
B.P. 35 91941 Les Ulis Cedex A
France
Tel: (33) 1 69 86 1213
Fax: (33) 1 69 86 9073

Valvulas de Precision, S.A.
Azafran 313
Col. Granjas Mexico
Del. Ixtacalco
08400 Mexico, D.F.
Mexico
Tel: (52) 5 649 2715/
(52) 5 654 1979/1980/1847
Fax: (52) 5 654 1959

Valvulas de Precision Espanola, S.A.
Soledad 3
28530 - Morata de Tajuns
Madrid
Spain
Tel: (34) 1 873 01 31
Fax: (34) 1 873 0075

Valvulas Precisao do Brasil Ltds.
Rua Vicente Rodrigues Da Silva, 641
Jardim Piratininga
Sao Paulo 60230
Brazil
Tel: (55) 11 701 3911
Fax: (55) 11 704 1220

Valvulas Precision de Argentina SACI
Fondo de la Logua 936
1640 Martinez
Pcia. de Buenos Aires
Argentina
Tel: (54) 1 793 1031
Fax: (54) 1 112 583

W. Braun Packaging Canada Ltd.
215 Shields Court, Unit 4
Markham, Ontario L3R 8V2
Canada
Tel: (1) 418 475 7200
Fax: (1) 418 497 1308

Sources of Additional Information about this Technology:

1. Johnsen, Montfort A. Alternatives to the Aerosol Standard Packaging Form. 6 September 1990.

2. Dorman, Shirleen. "Pumps in the 90s." Spray Technology and Marketing. September 1991.

3. San Giovanni, Michael. "Alternative systems push for market share." Spray Technology and Marketing. August 1992.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.7 Dry Powder Inhalers

Headline:

Dry powder inhalers (DPIs) can be used as an alternate to metered dose inhalants (MDIs) in a majority of cases. However, DPIs cannot be used for some patient groups and some respiratory diseases. Therefore, many countries classify MDIs as an "essential" use of CFCs and permit consumption in this end use. If the medication can be satisfactorily formulated as a microfine powder, it may be possible to deliver it with a DPI, thus eliminating the use of an ozone-depleting substance as the propellant. Converting from MDIs to DPIs is, however, limited by factors that characterize the development of any new medicine, i.e., extensive research and development to reformulate the medication in dry powder form; clinical testing; development of the delivery system; patenting of both the delivery system and product formulation process; and government approval.

Industry Sector

Inhaled pulmonary drugs.

ODS Reduction/Elimination Method:

CFCs are eliminated by converting to a not-in-kind alternative. Medication ceases to rely on aerosol propulsion for delivery into subjects' lungs. An active delivery system is replaced by a passive one in which a microfine powder medication is dispersed into the airstream by the force of patient's inhalation.

Composition of Alternative:

The alternative is a not-in-kind substitute. The alternate delivery system is passive.

Toxicity:
N/A

Flammability:
N/A

VOC Classification:
N/A

Ozone Depleting Potential (ODP):
N/A

Global Warming Potential (GWP):
N/A

Phaseout Schedule:
None

Product Dispersion Characteristics:

The drug agent is placed in a holding chamber or reservoir as a dry, microfine powder. Early products delivered a single pre-measured dose that was held in a gelatin capsule. The capsule was placed within a special delivery tube, where it was punctured in order to release the powder. These devices required reloading after each use. Later products relied on a "blistered disk" that contains several doses. The "blisters" on these disks are punctured by the device to release the drug for delivery. More advanced dry powder systems hold the drug as a bulk powder and have multiple dose capacity. The bulk powder may be a pure drug or be diluted with a bulking agent such as lactose. In these more advanced systems, the bulk powder is metered into a precisely-dimensioned holding cup, leveled and compacted by a scraping device to ensure proper loading, and delivered, as in the other systems, by inhalation from the device. The powder is then dispersed into the patients lungs by the force of inhaling the powder out of the delivery tube.

Delivery of medication from the DPI to the airways relies on the inhalation capacity of the patient. Inhalation volume and suction power generate the drug particles and deliver them to active sites in the patient's airways. In some cases, therefore, subjects suffering from respiratory diseases may be unable to use DPIs because of sufficiently decreased inhalation capabilities.

The micronized drug particles that make up the dry powder formulations tend to stick to the inside of the delivery device. The drug particles may also clump together and become enlarged when exposed to atmospheric moisture. In some cases, desiccant cartridges may be necessary to help prevent problems caused by exposure to moisture. The amount of drug and particle size of the dose exiting the DPI is highly dependent on the strength, consistency, and duration of a patient's inhalation.

If drug particles become aggregated as a result of moisture-induced agglomeration or as a result of inadequately forceful inhalation, they may exceed the maximum size that can reach the lower airways or the subject's lungs. A high concentration of drug particles stuck in the upper airway may pose a risk of side effects. The problem of aggregated particles may be solved in a number of ways: the creation of a turbulent airflow within the DPI, the use of "carrier" particles to help disaggregate the powder, or the use a dry "lubricant" to smooth the particle flow through the DPI.

Substitute Production Method and Materials:

Dry powder inhalers are not-in-kind substitutes for MDIs. The pharmaceutical firm must reformulate the medication as a microfine powder. The pharmaceutical firm must also decide on the delivery method -- hard gelatine capsules, blistered disks, or bulk powder -- and produce or contract the production of the special delivery tubes.

Health and Safety Considerations: None

Environmental Considerations: None

Associated Costs:

The costs of converting from MDIs to DPIs are difficult to estimate because of the unique situation associated with each product. The conversion process may involve a number of stages, which characterize the development of any new medicine, extended over a number of years. Included in those stages are the following: extensive research and development to reformulate the medication in dry powder form; clinical testing of the new formulation; patent approval (if appropriate) of the new formulation or formulation process; development of a new inhaler design or modification of an existing inhaler design in order to meet the specific characteristics (e.g. dose size, particle size, sensitivity to humidity, clumping tendency) of the dry powder formulation; patenting (if appropriate) of the delivery system; government approval of the DPI (both the powder and the delivery system); and finally, implementation of the new technology and manufacturing.

Current Use:

Use of DPIs in Each of 20 Major Industrialized Countries in 1992[11] (% of patient days treatment satisfied by DPIs)

Australia	15.3
Austria	17.7
Belgium	0.7
Canada	13.9
Denmark	38.5
Finland	21.1
France	7.4
Germany	3.7
Ireland	10.0
Italy	0.5
Japan	0.7
New Zealand	28.7
Netherlands	57.2
Norway	40.8
South Africa	4.3
Spain	10.6
Sweden	60.0
Switzerland	20.2
United Kingdom	15.1
United States	0.6

[11] *Industry estimate based on audited market sales data. From "Metered Dose Inhalers: A Special Case. The Basis for Designating MDIs as an 'Essential Use' and Authorizing Production and Consumption of CFCs After 1995 Under the Montreal Protocol." International Pharmaceutical Aerosol Consortium, 24 May 1993.*

The full extent of DPI market penetration in Brazil, Luxembourg, Portugal, and Venezuela is unknown, but some sales are reported by the firm Boehringer-Ingelheim.

Since 1988, the use of inhalant therapy for asthma and chronic obstructive pulmonary disease (COPD) has increased in the major industrialized countries by more than 20% to nearly 10 billion patient days treatment in 1992. (One "patient days treatment" is the amount of therapy required to treat one patient for asthma or COPD for one day). In 1988, DPIs accounted for 4% of treatment, and, although use increased every year, they still accounted for only 9% of total days treatment in 1992.

The use of DPIs differs greatly from one country to another. Use of DPIs in Japan and the United States has never exceeded 2% of inhaler use, while in the Netherlands, use rose from 42% of use in 1988 to 57% of use in 1992. In Sweden, use of DPIs rose from 16% to 60% from 1988 to 1992.
The rate of increase in the use of DPIs will vary depending on several important factors including the pace and results of DPI research and development efforts, clinical studies to evaluate safety and efficacy, and governmental review of these systems; the number of medications approved for use in dry powder form; the availability of more advanced DPI systems; the preferences of physicians and patients between DPIs and metered-dose inhalers; and governmental policies and regulations concerning the use of MDIs; and cost differentials between DPIs and MDIs.

Along such lines, use of DPIs in the United States has been in limited by a consumer preference and a reluctance by physicians and pharmacists to prescribe more than one type of delivery system to patients. Potential use is further limited by the fact that some medication will not easily be formulated in an acceptable dry powder form. Such limitations seem not to have impeded the penetration of DPIs into the Dutch and Swedish markets where the DPIs account for nearly 60% of use.

Availability:

DPIs are not widely available. Except in the Netherlands and Switzerland, consumers and doctors seem to refer using MDIs, which in many countries are exempt from the phaseout because they are considered essential uses.

The three principal producers worldwide of DPIs are Astra-Draco, Boehringer-Ingelheim Corp., and Glaxo, Inc.

Vendors of Alternative Equipment:

Due to the specialized nature of products dispensed using DPIs, each application requires a unique research and development effort to design and produce both the drug/powder formulation and an inhaler specific to the physical performance characteristics of that powder. Therefore, it is unlikely that there are suppliers of generic inhaler devices. For additional information, please refer to the section titled "Sources of Additional Information about this Technology."

Sources of Additional Information about this Technology:

Astra/Draco
Box 34
S-221 00 Lund
Sweden
Tel: (46) 46 16 6500
Fax: (46) 46 33 6666

Don Banerji, MD
Director, Respiratory Clinical Development
Astra USA, Inc
50 Otis Street
Westborough, MA
USA
Tel: (1) 508 366 5090
Fax: (1) 508 366 7406

John G.D. Carpenter, PhD
Chairman
International Pharmaceutical Aerosol Consortium
United Kingdom
Tel: (44) 509 611 611
Fax: (44) 509 613 048

Ramona Jones
Glaxo
Public Affairs
Five Moore Dr.
P.O. Box 13398
Research Triangle Park, NC 27709
USA
Tel: (1) 919 549 7459
Fax: (1) 919 248 2100

Warren Lackstrom
Licensing and Product Development
900 Ridgebury Rd
Boehringer-Ingelheim Corp.
Ridgefield, CT 06877
USA
Tel: (1) 203 798 4104
Fax: (1) 203 791 6220

Peter Wyckoff, Secretary
or Matthew Plache, Attorney/Representative
International Pharmaceutical Aerosol Consortium
Gardner, Carton and Douglas
1301 K St, NW
Suite 900 East Tower
Washington, DC 20005
USA
Tel: (1) 202 408 7149
Fax: (1) 202 289 1504

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.8 HCFC-141b Aerosol Solvent

Headline:

HCFC-141b is currently the most viable alternative to CFC-113 in aerosol precision cleaning operations. It is the only alternative that is nonconductive, nonflammable, nontoxic, nonhygroscopic, and fast evaporating (Micro Care, 1992). It is unlikely that HCFC-141b will be a substitute for methyl chloroform (MCF) because the two compounds have similar ozone depleting potentials (ODPs).

Industry Sector:

HCFC-141b is an effective aerosol solvent in precision cleaning and defluxing. It is used on electrical equipment that must be cleaned while powered up, electronics that are operated in hazardous service areas, and any other items that may fail if they are cleaned with other alternative materials. Examples of such products include:

- disk drives
- avionics and avionic service connectors
- cryogenic service items
- oxygen service items
- optics
- electrical contacts
- electromechanical systems

HCFC-141b is also used occasionally in mold release agents and tire inflators. HCFC-141b blends are often used to reduce the solvency and/or flammability of HCFC-141b. An HCFC-141b and methanol blend is the ideal solvent for cleaning printed wiring assemblies (PWAs) after touch-ups. The blend replaces the CFC-113/methanol formulation. Several large companies such as AT&T and Allen Bradley in Canada have converted from the CFC-113 formulation to the HCFC-141b formulation (UNEP, 1991). An HCFC-141b/alcohol blend can be used in chemical drying applications (Micro Care, 1992).

ODS Reduction/Elimination Method:

CFC-113 is eliminated through conversion to HCFC-141b, a substitute chemical. HCFC-141b can only be considered a transitional substitute, however, since it has an ODP and its use must also eventually be eliminated.

Composition of Alternative:

The following table presents some relevant properties of HCFC-141b:

Formula	CH_3CCl_2F
Boiling Point	32°C
Vapor Pressure @21.1°C	1.7 bar-absolute
Density @21.1°C	1.24 g/cc
Solubility in water (wt %) @21.1°C	0.02
Flammability limits in air (vol %)	7.3-16.0
Flash Point	None
Kauri-Butanol Value	57

Source: Strobach, 1991

Toxicity:

Short-term testing has shown HCFC-141b to have negligible toxicity concerns. The USEPA has estimated a long-term exposure workplace guidance level (WGL) of 250 ppm and a short-term exposure emergency guidance level (EGL) of 1,000 ppm for HCFC-141b in aerosol applications (USEPA, 1993).

Flammability:

The lower explosive limit of HCFC-141b is high enough such that the chemical is considered by many companies in industry to be virtually nonflammable. However, its use still requires a gas house similar to that used with hydrocarbon propellants.

VOC Classification[12]:

Non-VOC

Ozone Depleting Potential (ODP):

0.11 as compared to CFC-11)

Global Warming Potential (GWP):

0.082 (as compared to CFC-12)

580 (as compared to CO_2) (100-year basis)

[12] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

Phaseout Schedule:

HCFC-141b is an ozone-depleting substance, and is therefore scheduled for phaseout within the Montreal Protocol. The following presents the phaseout schedule of HCFCs as amended during the 25 November 1992 meeting in Copenhagen:

- Freeze on HCFC consumption by 1996 based on cap of 3.1% 1989 CFC consumption and 100% HCFC consumption
- 35% reduction by 2004
- 65% reduction by 2010
- 90% reduction by 2015
- 99.5% reduction by 2020
- Phaseout by 2030

There is a possibility that the phaseout schedule will be accelerated if ozone layer depletion proves to be more rapid than expected. The Copenhagen Amendments to the Montreal Protocol will apply to countries operating under Article 5 after a review in 1995. In addition to the Montreal Protocol, several countries may have legislated domestic accelerated phaseouts of HCFC-141b. For example, in the U.S., use of HCFC-141b will be prohibited in aerosol applications as of 1 January 1994.

Solvent Characteristics:

HCFC-141b looks, feels, smells, and cleans like CFC cleaning products (Micro Care). It cleans oils, grease, rosin fluxes, and general contaminants. HCFC-141b is safe for use on most materials of construction, blends well with other solvents, and has low odor (Tourigny, 1992). A major disadvantage of HCFC-141b is its aggressive solvency. It attacks polystyrene-based plastics as well as virtually all polycarbonate-based plastics, causing stress fractures immediately upon contact.

In some cleaning applications, fast evaporation is critical for safety and effectiveness. In small quantities, HCFC-141b will evaporate completely and without residue in less than 15 seconds. In comparison, alcohol-based cleaners take more than 500 times longer and terpenes up to 10,000 times longer to completely evaporate (Tourigny, 1992).

Many cleaning applications require that components and equipment are cleaned while they are powered up. Therefore, the solvent must be nonconductive to prevent shorting and/or shock hazard to the operator. The solvent must also be nonflammable so that arcing or sparks do not touch off a fire. HCFC-141b is both nonconductive and nonflammable (Tourigny, 1992).

Substitute Production Method and Materials:

The transition from CFCs to HCFC-141b for defluxing is relatively easy (Micro Care, 1992). Straight HCFC-141b may be substituted directly for CFC-113 in aerosol cans for contact cleaning operations (UNEP, 1991). However, HCFC-141b cannot serve as a drop-in replacement for all solvent uses of CFC-11 and CFC-113.

Health and Safety Considerations:

Hand cleaning is an operation which requires the technician to be in constant close proximity to the cleaning solvent. As a result, technicians performing hand cleaning operations are likely to risk direct skin contact with the liquid and experience high direct exposure to solvent fumes. Many non-CFC cleaners currently on the market are unacceptable for certain hand cleaning operations due to their flammability and/or other health and safety risks. HCFC-141b is suited to this application, from a health and safety perspective, because of its nonflammable characteristics.

Environmental Considerations:

Because HCFC-141b has an ODP of 0.11, it should be used only as a direct replacement to CFC-113 in cleaning applications, and only in applications that cannot accommodate other cleaning processes or solvents, and only in the most conservative and efficient manner possible. The quantity of HCFC-141b vented into the atmosphere should be minimized to reduce its impact on the environment and to provide maximum operator safety. Currently, a hermetically sealed, low-pressure aerosol dispenser is available which is engineered to use minimal quantities of solvent in removing contaminants. This dispenser, combined with other application accessories, can reduce solvent consumption by over 60 percent (Micro Care, 1992).

Associated Costs:

Currently, HCFC-141b is almost three times the cost of CFC-113 in the United States (approximately US$5 to US$6 per kilogram) (USEPA, 1993). However, the taxes on CFCs being instituted in many countries result in the price of CFC-113 being higher than that of HCFC-141b. Nevertheless, HCFC-141b is more expensive than other currently available alternatives. The high cost of HCFC-141b will ensure that it is used only as a replacement to CFCs and only in applications where no other material is acceptable (Micro Care, 1992).

Current Use:

Companies that are phasing out their use of CFC-113 and CFC-11 but have not yet found a non-ozone-depleting alternative are increasingly turning to HCFC-141b in aerosol solvent applications.

Availability:

HCFC-141b is commercially available. However, HCFCs are transitional chemicals with a limited commercial lifetime. They will therefore only serve as a replacement to CFCs until environmentally safer chemicals are developed.

Vendors of Alternative Equipment:

HCFC-141b Solvent Suppliers

Allied-Signal Incorporated
P.O. Box 1139R
Morristown, NJ 07962
USA
Tel: (1) 201 455 2978
Fax: (1) 201 455 2763

Atochem North America
3 Parkway
Philadelphia, PA 19102
USA
Tel: (1) 215 587 7334
Fax: (1) 215 587 7369

Ausimont
Via Principe Eugenio, 1/5
20155 Milano
Italy
Tel: (39) 2 6270 3652
Fax: (39) 2 6270 3412

DuPont Argentina S.A.
Casilla Correo 1888
1000 Correo Central
Buenos Aires
Argentina
Tel: (54) 1 311 8167
Fax: (54) 1 311 1329

DuPont Canada Inc.
P.O. Box 2200
Streetsville
Mississauga, Ontario L5M 2H3
Canada
Tel: (1) 416 821 3300
Fax: (1) 416 821 5057

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel: (1) 302 633 1501
Fax: (1) 302 892 1705

DuPont-Mitsui Fluorochemicals Co., Ltd.
2-3, 1-Chome Ohtemachi
Chiyoda-Ku
Tokyo 100
Japan
Tel: (81) 3 3216 8468
Fax: (81) 3 3215 0064

Elf Atochem
4 Cours Michelet
La Defense 10
Cedex 42-92091
Paris
France
Tel: (33) 1 49 00 80 46
Fax: (33) 1 49 00 70 21

Hoechst Aktiengesellschaft
Postfach 800 320
D6230 Frankfurt (Main) 80
Germany
Tel: (49) 69 305 55 02
Fax: (49) 69 305 91 79

ICI Americas Inc.
New Murphy Road & Concord Pike
Wilmington, DE 19897
USA
Tel: (1) 302 886 3000
Fax: (1) 302 886 2972

ICI Chemicals and Polymers Ltd.
P.O. Box 14
The Heath
Runcorn, Cheshire WA7 4QG
United Kingdom
Tel: (44) 928 511 050
Fax: (44) 928 581 072

Rhone-Poulenc Chemicals Ltd.
St. Andrews Road
Avonmouth, Bristol BS11 9YF
United Kingdom
Tel: (44) 272 823 631
Fax: (44) 272 820 759

Sources of Additional Information about this Technology:

1. USEPA. Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Aerosols. March 1993.

2. Micro Care Corporation. "A Special Report Prepared for Presentation to the USEPA: HCFC-141b Is Essential to Expedite the Transition from CFC-113 in Certain Precision Cleaning Applications". January 1992.

3. Strobach, Donald R. "Possible Alternatives to 1,1,1-trichloroethane," Aerosol Age. March 1991.

4. Tourigny, Jay S. "The Use of HCFCs for Hand Cleaning Electronics after Rework and Repair." January 1992.

5. UNEP Solvents, Coatings, and Adhesives Technical Options Report. December 1991.

6. USEPA/ICOLP. Eliminating CFC-113 and Methyl Chloroform in Aircraft Maintenance Procedures. October 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

2.9 Perchloroethylene Aerosol Solvent

Headline:

Perchloroethylene can be an effective substitute for CFC-11, CFC-113, and methyl chloroform as the solvent in some aerosol formulations. Its nonflammability and strong solvency make it a desirable alternative. However, there are potential health problems associated with the use of perchloroethylene which make it important to enact strict health and safety measures to prohibit excessive exposure to the chemical.

ODS Use Sector

Aerosols, sterilants, miscellaneous uses, and carbon tetrachloride.

Industry Sector:

Perchloroethylene can be used in a wide variety of applications due to its strong solvency. It is currently most widely used in the cleaning of electronic equipment and electric motors (USEPA, 1993).

ODS Reduction/Elimination Method:

Ozone-depleting solvent use is eliminated through conversion to a substitute chemical.

Composition of Alternative:

The following table presents some relevant physical and chemical properties of perchloroethylene:

Formula	CCl_2CCl_2
Boiling Point	121.1°C
Vapor Pressure at 20°C	0.0189 bar
Density	1.62 g/cc
Flash Point	None
Kauri-Butanol Value	90

Several manufacturers of perchloroethylene have recently instituted "Solvent Stewardship Programs" aimed at controlling the use of perchloroethylene in aerosol formulations. In these programs the supplier of perchloroethylene sets a limit on the percentage of perchloroethylene that a purchaser can use in an aerosol. In purchasing the chemical, the aerosol manufacturer agrees to abide by these limits. Dow Chemical Co. has set a limit of 25 percent perchloroethylene in aerosols, while PPG Industries has set a limit of 50 percent (this limit is currently being reviewed).

Toxicity:

Extensive toxicity testing has shown perchloroethylene to be carcinogenic to animals. Therefore, the USEPA classifies the solvent as a "possible/probable human carcinogen", the International Agency for Research on Cancer (IARC) classifies it as "possibly carcinogenic to humans", and the American Conference of Governmental Industrial Hygienists (ACGIH) classifies it as "carcinogenic to animals." Specific occupational exposure limits have been set by regulatory agencies in a number of countries in order to reduce the risk of causing cancer in workers. For example, the U.S. Occupational Health and Safety Administration (OSHA) has set a long-term permissible exposure limit (PEL) of 25 ppm for perchloroethylene.

The use of perchloroethylene in aerosol applications in the United States is limited, primarily due to industry concern about the chemical's effects on worker health and safety, its effect on the environment, and impending state and local regulations governing its use.

Flammability:

Nonflammable

VOC Classification[13]:

Perchloroethylene is classified as a VOC in many countries, including the United States. However, the USEPA has recently proposed that perchloroethylene be reclassified as exempt from VOC status.

Ozone Depleting Potential (ODP):

None

Global Warming Potential (GWP):

Perchloroethylene is believed to contribute to the formation of tropospheric ozone (smog) when emitted to the atmosphere. While tropospheric ozone is considered to be a greenhouse gas, most scientists agree that its contribution to global warming is very small. Therefore, the net impact of perchloroethylene on global warming is likely to be relatively minimal.

Phaseout Schedule:

Most countries have no schedules in place to phase out the use of perchloroethylene. In addition, most have not announced any intention of eliminating its use. Many countries have, however, set strict limits on the amount of allowable emissions of this solvent. One notable exception is Sweden. The Swedish EPA issued a regulation which requires that the chlorinated solvent no longer be sold after 1 January 1993 for private (noncommercial) use.

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[13] VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.

Solvent Characteristics:

Chlorinated solvents are strong solvents. They are able to dissolve compounds such as fluorinated polymers, which are difficult to dissolve in other solvents (USEPA, 1993).

Substitute Production Method and Materials:

Perchloroethylene can be used as a substitute for CFC-11, CFC-113, or methyl chloroform as the solvent in aerosol formulations with minimal process changes. In cases where the filling equipment being used results in low leakage, there may be no changes required during the filling process. Perchloroethylene can be particularly effective in dissolving compounds that are difficult to dissolve in other solvents, such as fluorinated polymers used in water and oil repellents. When modifying the formulation, it is important to consider possible impacts on the valve and can components. Further modifications of the formulation, valve, and can may be necessary to achieve the desired product delivery.

Health and Safety Considerations:

In recent years, perchloroethylene has undergone extensive toxicological testing to determine its effects on human health and safety and the environment. As a result of this testing, perchloroethylene has been classified by several groups as a possible human carcinogen and exposure to its vapors should be severely restricted. In addition, perchloroethylene is classified as a VOC in many locations, and is regulated as a Hazardous Air Pollutant (HAP) in the United States.

Workers in the filling plant are those most likely to be exposed to high levels of perchloroethylene. Careful maintenance of liquid filling equipment to avoid leaks, and filling only in well ventilated areas, will reduce worker exposure to perchloroethylene. Monitoring of the perchloroethylene concentration in the area around the filling machines will help to ensure that the equipment is not leaking and that workers are not being exposed to high concentrations of perchloroethylene. With these adjustments, perchloroethylene can be used safely in aerosol formulations. The use of perchloroethylene is not likely to be a problem for the user in most applications because the amount of exposure will be extremely small. However, warnings should be placed on the product indicating that the aerosol should only be used in well-ventilated areas.

Environmental Considerations:

Perchloroethylene considered to be a greenhouse gas because of its contribution to the formation of tropospheric ozone (smog) when emitted to the atmosphere. Perchloroethylene is also regulated as a hazardous air pollutant in the United States. Users should be aware of and comply with national and local regulations governing the use, storage, and disposal of perchloroethylene. Sufficient ventilation and tight emissions control measures should be taken when using perchloroethylene. Also, care must be exercised when transporting and handling perchloroethylene to ensure that spills do not occur. Such spills could result in the discharge of perchloroethylene to surface water and its leaching into groundwater supplies.

Associated Costs:

Industrial grade perchloroethylene currently costs US$0.64/kg in the United States.

Current Use:

Perchloroethylene is widely used in aerosols in developing countries. Due to strict regulations governing its use, perchloroethylene is not as widely used in industrialized countries.

Availability:

Perchloroethylene is readily available worldwide from a number of manufacturers and their distributors.

Vendors of Alternative Equipment:

Perchloroethylene Solvent Suppliers

Ashland Chemical, Inc.
P.O. Box 2219
Colombus, OH 43216
USA
Tel: (1) 614 889 3333
Fax: (1) 614 889 3465

Dow Chemical
2020 Dow Center
Midland, MI 48640
USA
Tel: (1) 517 636 1000
Fax: (1) 517 832 1465

Dow Europe
Zurich, Switzerland
Tel: (41) 1 728 2111
Fax: Not available

Dow Latin America
Florida, USA
Tel: (1) 305 520 7000
Fax: Not available

Dow Pacific
Hong Kong
Tel: (852) 879 7333
Fax: Not available

Empresas Dow
Sao Paulo, Brazil
Tel: (55) 11 546 9122
Fax: Not available

ISP Chemicals Corporation
1361 Alps Road
Wayne, NJ 07470
USA
Tel: (1) 201 628 3863
Fax: Not available

ICI Americas Inc.
New Murphy Road & Concord Pike
Wilmington, DE 19897
USA
Tel: (1) 302 886 3000
Fax: (1) 302 886 2972

ICI Chemicals and Polymers Ltd.
P.O. Box 14
The Heath
Runcorn, Cheshire WA7 4QG
United Kingdom
Tel: (44) 928 511 050
Fax: (44) 928 581 072

Oxychem
5005 LBJ Freeway
Dallas, TX 75244
USA
Tel: (1) 214 404 3800
Fax: Not available

PPG Industries, Inc.
One Gateway Center
Pittsburgh, PA 15222
USA
Tel: (1) 412 434 2359
Fax: Not available

PPG Industries Caribe
1101 Chase Manhattan Building
San Juan (Hato Rey) 00918
Puerto Rico
Tel: (1) 809 764 0485
Fax: Not available

Vulcan Chemicals
P.O. Box 530390
Birmingham, AL 35253-0390
USA
Tel: (1) 205 877 3000
Fax: (1) 205 877 3448

Sources of Additional Information about this Technology:

1. Center for Emissions Control, 1025 Connecticut Ave., NW, Suite 712, Washington, D.C. 20036 USA. Tel: (1) 202-785-4374, Fax: (1) 202-223-5979.

2. USEPA. 1993. Background Document on Aerosol Products and Pressurized Dispensers Containing Class II Substances (DRAFT). 11 March 1993.

3. USEPA/ICOLP. Eliminating CFC-113 and Methyl Chloroform in Aircraft Maintenance Procedures. October 1993.

4. Reynolds, J. "Chlorinated solvents and glycol ether replacements." Spray Technology and Marketing. July 1991.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

3. Sterilants Alternative Technologies Datasheets

3. Sterilants Alternative Technologies Datasheets

3.1 Ethylene Oxide/Carbon Dioxide Sterilants

Headline:

Ethylene oxide (EtO) is used extensively by health care providers (e.g., hospitals, clinics) and industrial users (e.g., device manufacturers, contract sterilization services) to sterilize heat- and moisture-sensitive products. It is also used with products that are not compatible with radiation sterilization. EtO is the gaseous sterilant of choice because, compared to other gaseous sterilants (e.g., propylene oxide, formaldehyde, beta propriolactone, methyl bromide, and ozone), it has lower toxicity, greater diffusion rate, compatibility with and the ability to penetrate a wide variety of packaging and product materials, and superior microbial inactivation properties. EtO is most commonly used in a nonflammable mixture of 12% EtO and 88% CFC-12 (by weight), known as "12/88."

A mixture of 10% EtO (by weight) in carbon dioxide, called "10/90," is nonflammable and can be used as an alternative to EtO/CFC formulations. 10/90 must be used at higher operating pressures than 12/88 systems and hence is not a direct drop-in replacement for 12/88.

Industry Sector:

Sterilization by hospitals, contractors, manufacturers of medical equipment.

ODS Reduction/Elimination Method:

The alternative formulation of sterilant contains no CFCs.

Composition of Alternative:

The blend consists of C_2H_4O and CO_2. The most commonly used mixture is 10% EtO and 90% CO_2 by eight. Mixtures with concentrations (by weight) of 8% to 15% EtO are nonflammable and nonexplosive (UNEP, 1991).

Toxicity:

There are numerous concerns regarding the local and systemic toxic effects of EtO and its reaction products, ethylene chlorohydrin (ETCH) and ethylene glycol (ETG). EtO is extremely irritating and toxic.

Evidence suggests that EtO may cause cancers of the blood (leukemia) and other organs in humans. Exposure to high concentrations of EtO causes central nervous system depression and other neurological effects that are thought to be reversible with the cessation of exposure. Exposure to EtO gas also causes sensitization and irritation of human tissues, including the eyes and respiratory tract.

The U.S. Occupational Safety and Health Administration (OSHA) has established a long-term permissible exposure limit (PEL) (measured as an 8-hour time-weighted average) of 1 ppm for EtO and 10,000 ppm for CO_2. OSHA has also established a short-term exposure limit (STEL) of 5 ppm for EtO and 30,000 ppm for CO_2 (USEPA, 1993).

Flammability:

By itself, EtO is flammable and explosive. Therefore, all ignition sources (sparks, excess heat, and chemical catalysts, etc.) must be eliminated. EtO is one of the few chemicals that will ignite in the absence of air; and once started, EtO fires are among the most difficult to extinguish. CO_2, however, can play a role similar to that of CFC-12 in 12/88 to make EtO mixtures less flammable and less explosive. EtO/CO_2 mixtures with EtO concentrations (by weight) between 8% and 15% are nonflammable and nonexplosive. Other common mixtures -- such as 20% EtO/80% CO_2 and 30% EtO/70% CO_2, which are used to reduce polymerization (see "Sterilant Characteristics" below) -- can all form explosive gas mixtures in air. Their use, therefore, requires the same safety and equipment considerations as does pure EtO (Conviser, 1989/Morrissey and Phillips, 1993).

It is important to note that EtO/CO_2 mixtures tend to separate in their cylinders, resulting in uneven distribution of sterilant to carrier. This separation usually occurs at the beginning of cylinder use. With such a separation, too much EtO renders the mixture flammable, while too little EtO poses a sterility hazard.

VOC Classification[14]: VOC

Ozone Depleting Potential (ODP): 0

Global Warming Potential (GWP): CO_2: 1

EtO: 0

Phaseout Schedule: None

Sterilant Characteristics:

The difference in pressure between CO_2 and EtO is so large that the mixture has a tendency to separate when withdrawn from the cylinder. Maintaining uniform mix content has proven to be very difficult.

Because the 10/90 mix tends to separate, there may be the risk of uneven ratios of sterilant to carrier during delivery. As the mixture is used, the level of liquid inside decreases. This allows CO_2 to preferentially vaporize into the headspace since the vapor pressure of CO_2 is much greater than that of EtO. A progressively

[14] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

enriched EtO liquid mixture results until the liquid is depleted, possibly leaving behind a significant amount of CO_2. This separation of CO_2 from EtO would result in too much EtO some of the time, which poses a fire hazard for the worker, and too little EtO the rest of the time, which poses a risk of inadequate sterilization (Conviser, 1989/Morrissey and Phillips, 1993).

One recommended solution to avoid the separation of 10/90 mixtures is to use "unit dose" canisters. Each canister contains only the amount of EtO needed for one sterilization cycle. In this way, the entire contents of the canister are emptied into the sterilizer at once, so that the mix never separates. This solution, however, poses one serious problem. Canister changeout poses a high risk of inadvertent exposure to gases. Since a new canister is used for each cycle, a large number of canisters must be connected and disconnected, thereby increasing the risk of chronic EtO exposure. This will not likely cause a problem with small units, and, indeed, single-canister charges with 100% EtO. With larger units, however, cylinder changeout has proven prohibitively cumbersome since the cylinders (which have to be made of steel to withstand the high pressures of the CO_2/EtO mix) are very heavy. Using single charges of 10/90 could also prove logistically difficult since different sterilizer units require different amounts of sterilant to run one cycle (HHMM, 1990/Conviser, 1989).

Further increasing the risk of EtO exposure is the need to use 10/90 at higher pressures than the 12/88 mix. A 10/90 mix contains much less EtO than does the 12/88 mix (10 percent by volume in 10/90, versus 27.3 percent by volume in 12/88). As a result, the 10/90 process operates at pressure differentials that are over 3.5 times that of 12/88 blends and 10 times that of 100% EtO to achieve equivalent concentrations (Morrissey and Phillips, 1993). Many existing small units cannot handle such high pressures; if they can, though, then the changeover to a high pressure cycle can be made with equipment retrofits. If the user has had leakage and exposure problems with its equipment, then the situation will only be aggravated by using the higher pressure 10/90. And even though there are no leakage problems with 12/88, the user may experience such problems when using 10/90.

Finally, the use of 10/90 changes the chemistry of the sterilizer by introducing a slightly acidic environment. The CO_2 combined with water vapor creates an atmosphere with a pH between 5 and 6, the adverse chemical effects of which are exacerbated by sterilization temperatures (48.9°C). As a result, the 10/90 atmosphere is corrosive. Some devices that can be sterilized safely in 12/88 have been reported to corrode when in a CO_2 atmosphere. Also, 10/90 can corrode the sterilizer unit itself, unless it is made specifically for use with 10/90.

The 10/90 CO_2 atmosphere increases the rate at which EtO forms a sticky, oily, or solid polymer. At room temperature, the rate of polymer formation is 10 to 20 times faster in the presence of CO_2 than in the presence of an inert gas such as CFC-12. Polymer formation occurs even faster at higher sterilization temperatures and within the microporous structures of some device materials. Residual polymer on sterilized equipment may contain EtO, and thereby increase the risk of exposure. Polymer formed within the pores of the materials comprising some devices could change their performance and might expose both workers and patients to EtO.

Substitute Production Method and Materials:

Industry sources estimate that about 30 percent of existing 12/88 sterilization units are capable of operating with 10/90. In these cases, a conversion to 10/90 often requires retrofitting of the existing sterilizers. Some of the retrofits required in these cases include the installation of new joints and hoses. In the case of units which cannot withstand the high pressures required for 10/90 use, new sterilizing equipment will be required.

Before using 10/90 with 12/88 sterilizer equipment, users should consult sterilizer manufacturers to determine the pressure capabilities of equipment and whether retrofits are necessary and possible. Use of 10/90 can result in explosion if equipment is unable to accommodate higher operating pressures.

Health and Safety Considerations:

EtO is mutagenic, a suspected carcinogen, and explosive. Even in the form of a 10/90 mixture, EtO requires stringent safety precautions.

EtO/CO_2 mixtures are shipped as high-pressure liquid and should be handled with the care accorded any high pressure containers.

After each sterilization cycle, it is vital to enable adequate aeration in order to allow EtO to diffuse out of the equipment and packaging. The gas and its residues, which can remain on insufficiently aerated equipment and packaging, can injure physicians, equipment handlers, and patients by damaging internal tissues and causing deep and painful chemical burns to external tissues. Aeration can take a fairly long time if not supported by elevated temperature and forced ventilation, and even in a heated, force-filtered aeration cabinet it will take a minimum of 12 hours. The same aeration equipment used with 12/88 can be used with 10/90 (UNEP, 1991).

Another safety measure is available for small sterilizing units. For these small units, catalytic technology is available that fully convert EtO into CO_2 and H_2O before exhausting to the atmosphere. (See below under "Environmental Considerations.")

When using 10/90, it is important to ensure that atmospheric concentrations in the workplace do not exceed safe exposure limits. Two basic monitoring techniques are used: area monitoring and personnel monitoring. Area monitors are designed to measure the EtO concentration in air at a given point(s) in the work area. There are five generic monitor types: solid state sensors, gas chromatographs, infrared spectropherometers, photoionization detectors, and gas detector tubes. Personnel monitors are devices worn by the worker that measure the EtO concentration in the breathing zone as an index of EtO inhaled during the test period. There are four basic types of personnel monitoring systems: Charcoal tubes, chemical reaction/absorption badges, impervious collection bags coupled with gas chromatography air sampling, and impingers (Morrissey and Phillips, 1993).

Environmental Considerations:

Sterilizers and EtO rooms may or may not be vented to outside air depending on a country's national and/or local regulations. Experimental evidence indicates that releases into water and soil present less of a problem than do air emissions. The half-life of EtO in water ranges from a few hours to two weeks. Hydrolysis breaks

EtO into biodegradable products, primarily ethylene glycol. On the ground, EtO volatilizes quickly without penetrating the soil. Concentrations are not found in fish, which suggests that EtO does not follow a path up through the food chain (HHMM, 1990/Morrissey and Phillips, 1993).

If regulations require that EtO not be vented to outside air, EtO emissions may be incinerated, catalytically converted, or reclaimed. 100% EtO and CO_2 sterilant blends may be disposed of by using incinerators, which thermally oxidize the sterilants into carbon dioxide and water.

Most CO_2 used in sterilant mixtures is the recaptured by-product of other chemical processes. Therefore, while CO_2 is considered a greenhouse gas, its use in the sterilant sector is not expected to have much of an impact on global warming.

Associated Costs:

The cost per cycle of using 10/90 is similar to that of using 12/88. As the price of CFC-12 increases with the phaseout of ozone-depleting substances, the cost differential between 10/90 and 12/88 will widen in favor of 10/90.

Current Use:

United States

A study of the total quantity of EtO used in the United States in commercial and industrial sterilization indicates that in 1986, 12/88 accounted for 30 percent of use, 100% EtO for 60 percent of use, and other mixtures, including EtO/CO_2 formulations, for 10 percent of use (UNEP, 1991).

Europe

A mixture of 15% EtO/85% CO_2 is used throughout Europe. In Germany, the use of all types of EtO sterilants is limited due to health and safety concerns. Recent regulations with strict restrictions on emissions of EtO to the environment may limit use even further. Sterilization in Germany is mostly conducted with steam or formaldehyde. The same is true in the Nordic countries (UNEP, 1991).

Availability:

Ethylene oxide/carbon dioxide blends are widely available from chemical suppliers in many countries.

Vendors of Alternative Equipment:

Sterilizing Equipment Suppliers

AMSCO Brazil Servicos Ltda.
Rue Tabapua
#500-CJ84
04533-030 Sao Paulo
Brazil
Tel: (55) 11 820 4007
Fax: (55) 11 829 6442

AMSCO Europe, Inc.
Roland House
Rye Close
Ancells Business Park
Fleet
Hampshire GU13 8UY
United Kingdom
Tel: (44) 252 816 500
Fax: (44) 252 815 736

AMSCO Hong Kong Limited
34D Manulife Tower
169 Electric Road
North Point
Hong Kong
Tel: (852) 566 1211
Fax: (852) 566 1459

AMSCO International, Inc.
2424 West 23rd St.
P.O. Box 620
Erie, PA 16514
USA
Tel: (1) 814 452 3100
Fax: (1) 814 870 8423

AMSCO Japan K.K.
12F, East Tower
World Business Garden
2-6, Nakase, Mihama-Ku
Chiba City
Chiba Pref., 261-71
Japan
Tel: (81) 43 297 2821
Fax: (81) 43 297 1408

Environmental Tectonics Corp.
125 James Way
County Line Industrial Park
Southampton, PA 18966
USA
Tel: (1) 215 355 9100
Fax: (1) 215 357 4000

Getinge International, Inc.
1100 Towbin Avenue
Lakewood, NJ 08701
USA
Tel: (1) 908 370 8800
Fax: (1) 908 370 2543

Joslyn Sterilizer
5815 Country Rd. #41
Farmington, NY 14425
USA
Tel: (1) 716 398 2680
Fax: (1) 716 398 2499

MDT Corporation
P.O. Box 23077
Rochester, NY 14692
USA
Tel: (1) 716 272 5080
Fax: (1) 716 272 5033

Quetzal
Florida St.
Buenos Aires
Argentina
Tel: (54) 19 536 969
Fax: Not available

3M Health Care
3M Center Building
Building 275-4W-0
St. Paul, MN 55133
USA
Tel: (1) 612 733 5605
Fax: (1) 612 737 7681

Ethylene Oxide/CO_2 Suppliers

ARC Chemical
Division of Balchem Corp.
P.O. Box 175
Slate Hill, NY 10973
USA
Tel: (1) 914 355 2891
Fax: (1) 914 355 6314

BASF Corporation
Chemicals Div., Basic Organic Chemicals Group
100 Cherry Hill Rd.
Parsippany, NJ 07054
USA
Tel: (1) 201 316 8423
Fax: (1) 201 397 2737

IWECO
600 Hughes Straight
Houston, TX 77023
USA
Tel: (1) 713 967 5000
Fax: (1) 713 967 5023

Oxiteno S.A.
Av. Brigedeiro Luiz Antonio
1343-7 andar
Sao Paulo 01317
Brazil
Tel: (55) 11 283 6118
Fax: (55) 11 285 0327

Pennsylvania Engineering Co.
(no overseas offices)
1107-21 North Howard St.
Philadelphia, PA 19123-1697
USA
Tel: (1) 215 627 3636
Fax: (1) 215 627 7926

Quantum Chemical Europe B.V.
USI Division
P.O. Box 50
4854 ZH Bavel
Netherlands
Tel: (31) 1613 6600
Fax: (31) 1613 3500

Quantum Chemical Europe B.V.
USI Division
1431 Danforth Rd.
Scarborough, Toronto, Ontario M1J 1G8
Canada
Tel: (1) 416 431 1855
Fax: Not available

Sources of Additional Information about this Technology:

1. Conviser, S.A. "Ethylene Oxide Sterilization in the 1990s," Linde Division, Union Carbide, undated.

2. Conviser, S.A. "Hospital Sterilization Using Ethylene Oxide - What's Next?" Journal of Healthcare Material Management, July 1989.

3. Healthcare Hazardous Materials Management (HHMM). "EtO Phone Home: The Future of Sterilization in Hospitals," Vol. 3, No. 10, July 1990.

4. Morrissey, Robert F., and G. Briggs Phillips (eds.). Sterilization Technology: a Practical Guide for Manufacturers and Users of Health Care Products. Van Nostrand Reinhold. 1993.

5. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

6. USEPA. "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Sterilization." March 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

3.2 100% Ethylene Oxide Sterilants

Headline:

Ethylene oxide (EtO) is used widely by medical device manufacturers, contract sterilization services, and hospitals to sterilize medical equipment. It is able to penetrate a wide variety of packaging materials to destroy microorganisms on medical devices. EtO is especially useful for general-purpose, low-temperature sterilization of heat and moisture-sensitive products. EtO is most commonly used in a nonflammable mixture of 12% EtO and 88% CFC-12 (by weight), known as "12/88."

While not a drop-in replacement, 100% EtO systems can be considered a replacement for 12/88 in table-top units in hospitals. If steam or formaldehyde sterilization is available for equipment that can withstand moisture and temperature of at least 80°- 85°C, then the amount of equipment requiring EtO sterilization can be reduced significantly to include mostly expensive higher-technology devices such as catheters, pacemakers, and optical instruments.

Industry Sector:

Sterilization by hospitals, contractors, manufacturers of medical equipment.

ODS Reduction/Elimination Method:

The alternative formulation of sterilant contains no CFCs.

Composition of Alternative: C_2H_4O

Toxicity:

There are numerous concerns regarding the local and systemic toxic effects of EtO and its reaction products, ethylene chlorohydrin (ETCH) and ethylene glycol (ETG). Under certain conditions and for certain explosive levels, EtO can be extremely irritating and toxic. The U.S. Occupational Safety and Health Administration (OSHA) has established a long-term permissible exposure limit (PEL) (measured as an 8-hour time-weighted average) of 1 ppm and a short-term exposure limit (STEL) of 5 ppm (USEPA, 1993).

Evidence suggests that EtO may cause cancers of the blood (leukemia) and other organs in humans. Exposure to high concentrations of EtO causes central nervous system depression and other neurological effects that are thought to be reversible with the cessation of exposure. Exposure to EtO gas also causes sensitization and irritation of human tissues, including the eyes and respiratory tract.

Flammability:

100% EtO is flammable and explosive. Ignition of the liquid phase requires very high temperatures and pressures. In the gaseous phase, it is flammable at low ignition temperatures at concentrations from 3 to 100 mole percent in air. Normally, it will ignite at high temperatures (over 537°C -- the temperature of an external fire). If contaminated with some impurity (alkali, acid, possibly rust), EtO will ignite at relatively low temperatures (approximately 140°C). Therefore, all ignition sources (sparks, excess heat, and chemical catalysts, etc.) must be guarded against. EtO is one of the few chemicals that will ignite in the absence of air; and once started, EtO fires are among the most difficult to extinguish. For example, extinguishing an EtO fire requires about four times the concentration of halon-1301 as does a natural gas fire. The energy given off by an EtO fire can be very high. The temperature may exceed 2149°C, and pressures can increase tenfold (Conviser, 1989/Morrissey and Phillips, 1993).

VOC Classification[15]: VOC

Ozone Depleting Potential (ODP): 0

Global Warming Potential (GWP): 0

Phaseout Schedule: None

Substitute Production Method and Materials:

Piping, valves, controls, and sensors must be designed to be compatible with the EtO. Electrical safety, fire protection, public safety, worker protection, and other codes and regulations for the installation and use of equipment differ from one country to another. The local situation, therefore, dictates special design considerations. In general, though, 100% EtO sterilizers must be explosion proof and placed in facilities with emergency venting and blowout sections in a remote sector of the building (HHMM, 1990/Conviser, 1989).

Existing 12/88 sterilizers can be retrofitted to use 100% ethylene oxide, but the changes required are extensive and quite expensive, and may require the relocation of equipment (UNEP, 1991). While retrofitting or converting to a new 100% EtO sterilizer are large capital investments, operating costs are much lower because pure EtO is significantly cheaper than any EtO/gas mixture.

For hospital sterilizer applications, table-top units (less than 0.28 m^3 in volume) are available that work with small unit-dose (100-200 g) canisters of EtO. Using such small amounts decreases the risk of explosion and lessens the cost of safety measures. However, canister changeout is an operation that poses a high risk of inadvertent exposure to gases. These concerns however, do not seem to have impeded the use of single-canister charges of pure 100% EtO.

12/88 mixtures operate slightly above atmospheric pressure. Cycles using pure EtO operate at atmospheric pressure or below.

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[15] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

Health and Safety Considerations:

EtO is mutagenic, a suspected carcinogen, and explosive. In all forms of use, EtO requires stringent safety precautions.

Commercial 100% EtO sterilizers must be explosion proof and placed in facilities with emergency venting and blowout sections in a remote sector of the building.

After each sterilization cycle, it is vital to enable adequate aeration in order to enable EtO to diffuse from equipment and out of the packaging. The gas and its residues, which can remain on insufficiently aerated equipment and packaging, can injure both physicians, equipment handlers, and patients by damaging internal tissues and causing deep and painful chemical burns to external tissues. Aeration can take a fairly long time if not supported by elevated temperature and forced ventilation, and even in a heated, force-filtered aeration cabinet it will take a minimum of 12 hours (UNEP, 1991).

Additional safety can be obtained by using nitrogen to purge the sterilization chamber before and after use. Nitrogen purges oxygen from the system to diminish risks of explosion and fire, and it dilutes residual EtO to diminish exposure risks. Nitrogen purging also allows the sterilization process to occur in an atmospheric pressure that is high enough to allow all products currently being sterilized with 12/88 to be sterilized by 100% EtO (UNEP, 1991/HHMM, 1990).

Another safety measure is available for table-top sterilizing units. For these small units, catalytic technology is available that fully convert EtO into CO_2 and H_2O before exhausting to the atmosphere. (See below under "Environmental Considerations.")

When using EtO, it is important to ensure that atmospheric concentrations in the workplace do not exceed safe exposure limits. Two basic monitoring techniques are used: area monitoring and personnel monitoring. Area monitors are designed to measure the EtO concentration in air at a given point(s) in the work area. There are five generic monitor types: solid state sensors, gas chromatographs, infrared spectropherometers, photoionization detectors, and gas detector tubes. Personnel monitors are devices worn by the worker that measure the EtO concentration in the breathing zone as an index of EtO inhaled during the test period. There are four basic types of personnel monitoring systems: Charcoal tubes, chemical reaction/absorption badges, impervious collection bags coupled with gas chromatography air sampling, and impingers (Morrissey and Phillips, 1993).

Environmental Considerations:

Sterilizers and EtO rooms may or may not be vented to outside air depending on a country's national and/or local regulations. Experimental evidence indicates that releases into water and soil present less of a problem than do air emissions. The half-life of EtO in water ranges from a few hours to two weeks. Hydrolysis breaks EtO into biodegradable products, primarily ethylene glycol. On the ground, EtO volatilizes quickly without penetrating the soil. Concentrations are not found in fish, which suggests that EtO does not follow a path up through the food chain (HHMM, 1990/Morrissey and Phillips, 1993).

If regulations require that EtO not be vented to outside air, EtO emissions may be incinerated, catalytically converted, or reclaimed. In addition, pure EtO may be recovered by condensation under appropriate conditions and temperatures.

Associated Costs:

Pure EtO is significantly cheaper than any EtO/gas mixture. Start-up or retrofit costs for 100% EtO can, however, be high. Initial investment costs for 100% EtO mixtures are generally in the order of US$50,000 and can be significantly higher depending on the infrastructure and additional items like catalytic converters which might be required to control aeration room emissions. The operating costs are considered to be much higher than for steam or formaldehyde sterilization, but less than the cost of sterilizing with 12/88.

Current Use:

100% EtO formulations have been used for many years by medical device manufacturers in various industrialized countries, and pure EtO formulations are the gas of choice for contract facilities that sterilize moisture-sensitive equipment since they offer the lowest operating costs.

United States

Contract sterilizers and medical device manufacturers already use large 100% EtO sterilizers extensively. Use of 100% EtO is a viable option for commercial users of 12/88.

100% EtO sterilization is currently in use in hospitals in small units measuring less than 0.28 m^3. Hospitals have found that the small size of the unit affords them greater flexibility to run cycles more often during the day, rather than waiting until a large 12/88 unit becomes full late in the day.

A study of the total quantity of EtO used in the United States in commercial and industrial sterilization indicates that in 1986, 12/88 accounted for 30% of use, pure EtO for 60% of use, and other mixtures for 10% of use. The percentage of facilities using 12/88 in 1986 is much larger than that using pure EtO (76% as compared to 22%). These figures also indicate that, as far as industrial and commercial sterilizers are concerned, the average consumption of the facility using 12/88 is smaller than those using pure EtO. In addition, the recent drive to eliminate CFCs in sterilizing applications has resulted in increased usage of 100% EtO systems (UNEP, 1991).

Europe

In Germany, the use of all types of EtO sterilants is limited due to health and safety concerns. Recent regulations with strict restrictions on emissions of EtO to the environment may limit use even farther. Sterilization in Germany is mostly conducted with steam or formaldehyde. The same is true in the Nordic countries. France, Italy, Switzerland, and the United Kingdom extensively use 100% EtO in small sterilization chambers (UNEP, 1991).

Availability:

Ethylene oxide is widely available from chemical suppliers in many different countries.

Vendors of Alternative Equipment:

Sterilizing Equipment Suppliers

AMSCO Brazil Servicos Ltda.
Rue Tabapua
#500-CJ84
04533-030 Sao Paulo
Brazil
Tel: (55) 11 820 4007
Fax: (55) 11 829 6442

AMSCO Europe, Inc.
Roland House
Rye Close
Ancells Business Park
Fleet
Hampshire GU13 8UY
United Kingdom
Tel: (44) 252 816 500
Fax: (44) 252 815 736

AMSCO Hong Kong Limited
34D Manulife Tower
169 Electric Road
North Point
Hong Kong
Tel: (852) 566 1211
Fax: (852) 566 1459

AMSCO International, Inc.
2424 West 23rd St.
P.O. Box 620
Erie, PA 16514
USA
Tel: (1) 814 452 3100
Fax: (1) 814 870 8423

AMSCO Japan K.K.
12F, East Tower
World Business Garden
2-6, Nakase, Mihama-Ku
Chiba City
Chiba Pref., 261-71
Japan
Tel: (81) 43 297 2821
Fax: (81) 43 297 1408

Environmental Tectonics Corp.
(no overseas offices)
125 James Way
County Line Industrial Park
Southampton, PA 18966
USA
Tel: (1) 215 355 9100
Fax: (1) 215 357 4000

Getinge International, Inc.
1100 Towbin Avenue
Lakewood, NJ 08701
USA
Tel: (1) 908 370 8800
Fax: (1) 908 370 2543

Joslyn Sterilizer
5815 Country Rd. #41
Farmington, NY 14425
USA
Tel: (1) 716 398 2680
Fax: (1) 716 398 2499

MDT Corporation
P.O. Box 23077
Rochester, NY 14692
USA
Tel: (1) 716 272 5080
Fax: (1) 716 272 5033

Quetzal
Florida St.
Buenos Aires
Argentina
Tel: (54) 19 536 969
Fax: Not available

3M Health Care
3M Center Building
Building 275-4W-0
St. Paul, MN 55133
USA
Tel: (1) 612 733 5605
Fax: (1) 612 737 7681

Ethylene Oxide Suppliers

ARC Chemical
Division of Balchem Corp.
P.O. Box 175
Slate Hill, NY 10973
USA
Tel: (1) 914 355 2891
Fax: (1) 914 355 6314

BASF Corporation
Chemicals Division, Basic Organic Chemicals Group
100 Cherry Hill Rd.
Parsippany, NJ 07054
USA
Tel: (1) 201 316 8423
Fax: (1) 201 397 2737

IWECO
600 Hughes Straight
Houston, TX 77023
Tel: (1) 713 967 5000
Fax: (1) 713 967 5023

Oxiteno S.A.
Av. Brigedeiro Luiz Antonio
1343-7 andar
Sao Paulo 01317
Brazil
Tel: (55) 11 283 6118
Fax: (55) 11 285 0327Pennsylvania Engineering Co.
(no overseas offices)
1107-21 North Howard St.
Philadelphia, PA 19123-1697
USA
Tel: (1) 215 627 3636
Fax: (1) 215 627 7926

Quantum Chemical Europe B.V.
USI Division
P.O. Box 50
4854 ZH Bavel
Netherlands
Tel: (31) 1613 6600
Fax: (31) 1613 3500

Quantum Chemcial Europe B.V.
USI Division
1431 Danforth Rd.
Scarborough, Toronto, Ontario M1J 1G8
Canada
Tel: (1) 416 431 1855
Fax: Not available

Sources of Additional Information about this Technology:

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2. Conviser, S.A. "Hospital Sterilization Using Ethylene Oxide - What's Next?" Journal of Healthcare Material Management, July 1989.

3. Healthcare Hazardous Materials Management (HHMM). "EtO Phone Home: The Future of Sterilization in Hospitals," Vol. 3, No. 10, July 1990.

4. Morrissey, Robert F., and G. Briggs Phillips (eds.). Sterilization Technology: a Practical Guide for Manufacturers and Users of Health Care Products. Van Nostrand Reinhold. 1993.

5. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

6. USEPA. "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Sterilization." March 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

3.3 Steam Sterilization

Headline:

Moist heat, in the form of saturated steam under pressure, is the oldest, safest, best understood, and most dependable process for sterilizing biologically contaminated items. It is nontoxic, relatively inexpensive, and can be easily controlled. It is the sterilization method of choice, except in cases where items to be sterilized can be damaged by high temperature and humidity.

Industry Sector:

Sterilization by hospitals, contractors, and manufacturers of medical equipment.

ODS Reduction/Elimination Method:

Sterilization relies on high temperatures. No ODSs are used.

Composition of Alternative:

Vapor phase H_2O

Toxicity:

None

Flammability:

Nonflammable

VOC Classification:

Non-VOC

Ozone Depleting Potential (ODP):

0

Global Warming Potential (GWP):

Although water vapor in the atmosphere is considered to be a significant greenhouse gas, water vapor resulting from the use of steam sterilization does not contribute to global warming. Steam sterilization cannot be considered an anthropogenic source of greenhouse gases because no net addition of water vapor to the atmosphere occurs. Instead, the steam from sterilization comes from water that is already part of the natural water cycle.

Phaseout Schedule:

None

Sterilant Characteristics:

Steam sterilization is essentially sterilization by moist heat. The process is not effective at temperatures below 115°C, and it usually occurs at 121°C or higher, under pressure in autoclaves using saturated steam. Steam sterilization can be used for all devices that can withstand high humidity and such high temperatures. It cannot be used as a substitute for 12/88 (ethylene oxide/CFC-12) to sterilize sophisticated medical devices that are heat and moisture sensitive. Such devices, including catheters and pacemakers, cannot withstand temperatures above

38°-55°C. Steam sterilization should not be used repeatedly on non-disposable cutting instruments because it dulls blades.

Substitute Production Method and Materials:

The important parameters in steam sterilization include the following: temperature, time, elimination of air, steam quality, and the absence of superheating. Temperature and time are interrelated. As discussed, process temperatures are usually above 121°C, and can vary depending on a number of different factors, including the type of equipment, the type of packaging, and the type of autoclave. The time required is a combination of heat-up time (how long it takes for complete steam penetration, i.e. when equipment reaches the temperature of the steam) and holding time (how long the equipment is maintained at that temperature).

Elimination of air from the chamber is critical. The success of steam sterilization depends on direct contact of steam with equipment, which can be prevented by the presence of air in the chamber. Air elimination, therefore, is an absolute parameter, and no combination of temperature and time will completely sterilize equipment if air has not fully been eliminated from the chamber and the load. The elimination of air and complete steam penetration can be accomplished by either gravity displacement or prevacuum techniques.

Gravity-displacement autoclaves rely on the relative immiscibility of steam and air. Steam enters the chamber, filling it from top to bottom. As the chamber fills with steam, air is forced out through a steam-discharge line located at the bottom of the chamber. Gravity-displacement autoclaves are used to sterilize liquids, fabric loads, fabric-wrapped instruments (usually at 121°C), and for unwrapped medical instruments (flash or emergence sterilization at 134°C).

The prevacuum technique eliminates air by creating a vacuum prior to the introduction of steam into the chamber. This procedure facilitates steam penetration and permits the use of higher pressures and higher temperatures (134°-141°C). This also results in shorter cycle times. Prevacuum cycles are used for fabric loads and wrapped or unwrapped instruments.

Steam quality refers to the amount of dry steam present relative to liquid water in the form of droplets. The steam delivered from the boiler usually contains some water, but excessive amounts -- more than 3% -- are considered unacceptable. Excessive water droplets can result in drying problems and deposit boiler chemicals (which are used to prevent corrosion in the lines) or boiler amines (which may introduce toxicity problems) onto the load.

Superheated steam results when steam is heated to a temperature higher than that which would produce saturated steam. The equilibrium between liquid and vapor is destroyed, and the steam behaves as a gas, losing its ability to condense into moisture when in contact with the cooler surface of the article being sterilized. Such a process resembles dry-heat sterilization more than steam sterilization, and, under ordinary time and temperature conditions for steam sterilization, does not produce sterility.
A number of indicators are available to determine whether adequate sterilization conditions (temperature, steam penetration, etc.) have been reached. These include biological, electromechanical, and chemical indicators.

Health and Safety Considerations:

Proper safety precautions should be taken to minimize the risks associated with having high temperature materials on-site. This is particularly relevant for the areas where workers are operating the sterilization equipment.

Environmental Considerations:

No major environmental considerations.

Associated Costs:

Along with dry heat sterilization, steam sterilization is the least expensive method to operate on an ongoing basis. The only main direct day-to-day costs other than preventive maintenance and calibration are the costs of energy required to generate the steam.

Current Use:

Steam sterilization is the method used most widely in all countries for equipment that can resist high temperature and humidity. For instance, approximately 20% of the sterile medical devices sold in the United States are steam sterilized, a figure that has remained constant for the last decade.

It is likely that pharmaceutical manufacturers already use steam to the maximum extent possible. However, hospitals may be able to shift some of their current 12/88 use to steam by separating heat-resistant devices from heat-sensitive ones.

Availability:

Steam sterilization equipment is widely available is units ranging in size from tabletop units to industrial-size units.

Vendors of Alternative Equipment:

Steam Sterilizing Equipment Suppliers

AMSCO Brazil Servicos Ltda.
Rue Tabapua
#500-CJ84
04533-030 Sao Paulo
Brazil
Tel: (55) 11 820 4007
Fax: (55) 11 829 6442

AMSCO Europe, Inc.
Roland House
Rye Close
Ancells Business Park
Fleet
Hampshire GU13 8UY
United Kingdom
Tel: (44) 252 816 500
Fax: (44) 252 815 736

AMSCO Hong Kong Limited
34D Manulife Tower
169 Electric Road
North Point
Hong Kong
Tel: (852) 566 1211
Fax: (852) 566 1459

AMSCO International, Inc.
2424 West 23rd St.
P.O. Box 620
Erie, PA 16514
USA
Tel: (1) 814 452 3100
Fax: (1) 814 870 8423

AMSCO Japan K.K.
12F, East Tower
World Business Garden
2-6, Nakase, Mihama-Ku
Chiba City
Chiba Pref., 261-71
Japan
Tel: (81) 43 297 2821
Fax: (81) 43 297 1408

Environmental Tectonics Corp.
125 James Way
County Line Industrial Park
Southampton, PA 18966
USA
Tel: (1) 215 355 9100
Fax: (1) 215 357 4000

Getinge International, Inc.
1100 Towbin Avenue
Lakewood, NJ 08701
USA
Tel: (1) 908 370 8800
Fax: (1) 908 370 2543

Joslyn Sterilizer
5815 Country Rd. #41
Farmington, NY 14425
USA
Tel: (1) 716 398 2680
Fax: (1) 716 398 2499

MDT Corporation
P.O. Box 23077
Rochester, NY 14692
USA
Tel: (1) 716 272 5080
Fax: (1) 716 272 5033

Quetzal
Florida St.
Buenos Aires
Argentina
Tel: (54) 19 536 969
Fax: Not available

Sources of Additional Information about this Technology:

1. Kirk-Othmer (pub.). Encyclopedia of Chemical Technologies. 3rd edition. Vol. 21. John Wiley and Sons. 1983.

2. Morrissey, Robert F., and G. Briggs Phillips (eds.). Sterilization Technology: a Practical Guide for Manufacturers and Users of Health Care Products. Van Nostrand Reinhold. 1993.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

3.4 Formaldehyde Sterilization

Headline:

ormaldehyde has long been recognized as an effective sterilant. It is used most commonly in combination with steam to sterilize heat-sensitive medical devices. This process, known as low-temperature steam/formaldehyde (LTS/F) sterilization, is less expensive than 12/88 (ethylene oxide/CFC-12) sterilization and faster because no aeration time is required to remove residues from the sterilized product (FOE, 1990). 12/88 is more highly penetrating and operates at lower temperatures than steam/formaldehyde.

Industry Sector:

Formaldehyde is used in hospitals and dental facilities to sterilize compatible materials that cannot be steam sterilized but can withstand high humidity and a temperature of 80-85°C. Its use in hospitals is more prevalent in Europe than in the U.S.

ODS Reduction/Elimination Method:

Formaldehyde is not a drop-in substitute. Its use requires new equipment or equipment and operational procedure modifications.

Composition of Alternative:

Formula	CH_2O
Density @20°C	0.8153 g/cm_3
Boiling Point	-19°C
Flammability Limits in Air (mol %)	7.0 - 72
Ignition Temperature	430°C

Toxicity:

Formaldehyde has a pungent odor, is toxic, and extremely irritating to the eyes, nose, and throat at vapor levels as low as 0.05 to 0.5 ppm. Formaldehyde is mutagenic and a suspected carcinogen. In the United States, the Occupational Safety and Health Administration (OSHA) has restricted its use. The Permissible Exposure Limit (PEL) (measured as an 8-hour time-weighted average) set by OSHA for formaldehyde is 1 ppm, time-weighted over 8 hours. However, some European countries have not classified formaldehyde as a carcinogen, thereby allowing more widespread use.

Flammability:

Formaldehyde gas is flammable and forms an explosive mixture with air at concentrations of 7% to 72% by volume in air at ambient temperatures. The concentration of formaldehyde gas used in vapor sterilization is well below the explosive concentration range and is nonflammable. Vapor concentrations as high as 18 mg/l (1.5 volume %) have been used for sterilization.

VOC Classification[16]: VOC

Ozone Depleting Potential (ODP): 0

Global Warming Potential (GWP): Negligible

Phaseout Schedule: None

Sterilant Characteristics:

Formaldehyde gas is an effective antimicrobial agent when used under optimal conditions. At room temperature, formaldehyde is only slowly sporicidal and penetrates poorly into tubing. Unfortunately, there is no visual indication of a successful cycle when sterilizing with formaldehyde (Ayliffe, 1989).

Formaldehyde is easily detected by smell and readily dilutes and dissolves in the fluid of a water sealed vacuum pump (UNEP, 1991). When sterilization is completed, the formaldehyde breaks down into carbon dioxide, carbon monoxide, and water (FOE, 1990).

Substitute Production Method and Materials:

The most important industrial application of formaldehyde is its use in combination with steam for sterilizing heat-sensitive medical devices. Saturated steam at 80°C at subatmospheric pressure inactivates vegetative bacteria. The addition of formaldehyde to the process makes the process sporicidal. The LTS/F process operates at temperatures ranging between 65°C and 80°C. The process has been demonstrated for the disinfection and sterilization of urinary endoscopes and is used in hospitals in Europe.

After an initial vacuum is drawn on the sterilizer chamber, which ensures maximum penetration of formaldehyde vapor into the load, formalin solution is vaporized in a heat exchanger and admitted into the chamber. The chamber is evacuated again, and the impregnation cycle is repeated three times. The impregnation cycle replaces residual air with formaldehyde and allows the diffusion and absorption of formaldehyde into the load material. At the end of the impregnation cycle, the sterilizing dose of vaporized formaldehyde is injected into the chamber. After the vapor concentration reaches equilibrium, steam is admitted, and a temperature of 73°C is maintained for 2 hours to effect sterilization. At the end of the cycle,

[16] VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.

the chamber is evacuated, followed by steam wash, and another evacuation. Filtered air is then admitted to return the chamber to atmospheric pressure.

Tabletop sterilizer systems based on formaldehyde and alcohol vapor have been demonstrated to be effective for use on scalpel blades and unwrapped dental instruments, and may have potential applications to other medical devices. A sterilant formulation containing alcohol or other alcohols and 0.23% formaldehyde is registered with the USEPA and sold by MDT. Materials such as carbide steel burs and scalpel blades showed no corrosion following repeated sterilizations.

Unlike EtO sterilization, loads sterilized with formaldehyde require no aeration time.

A number of problems exist with formaldehyde sterilization: 1) Some variations of the LTS/F cycles are unreliable. In some cases, condensation collects on surfaces, preventing adequate sterilization (Ayliffe, 1989). While tests have shown that residual formaldehyde in materials is low after the completion of successful cycles, the LTS/F sterilization process is still less reliable than the ethylene oxide sterilization process (UNEP, 1991) 2) Sterilizing with formaldehyde may result in polymerization which may leave a white powder consisting of paraformaldehyde on load surfaces. 3) Formaldehyde is more of a topical sterilant and does not penetrate loads well. Some common wrapping materials are barriers to penetration for the formaldehyde vapor, making these materials unsuitable for packaging the devices prior to sterilization (UNEP, 1991).

Formaldehyde cabinets come in varying sizes. They consist of airtight units with automatic devices for dispensing formaldehyde and ammonia and for flushing sterilants into the open air (Ayliffe, 1989). Some steam sterilizers include the LTS/F process as an optional cycle. Certain 12/88 sterilizers can also be modified to incorporate a steam formaldehyde cycle.

Health and Safety Considerations:

Because formaldehyde is toxic and a suspected carcinogen, precautions must be taken to restrict worker exposure to formaldehyde. Formaldehyde has a very strong odor and may cause worker discomfort if used in high concentrations.

Environmental Considerations:

Formaldehyde is a VOC, and therefore contributes to the formation of tropospheric ozone (smog). While tropospheric ozone is considered to be a greenhouse gas, most scientists agree that its contribution to global warming is very small.

Associated Costs:

The cost of sterilizing with formaldehyde is greater than the cost of steam sterilization and lower than the cost of sterilizing with 12/88. Currently, the cost of formaldehyde ranges from US$0.24 to US$0.31 per kilogram, but it is used in sterilization in minute concentrations combined with steam or alcohol.

Current Use:

Low-temperature steam/formaldehyde sterilization processes are rarely used in the industrial sector, but are quite common in hospitals in the United Kingdom. Steam/formaldehyde processes are also used to some extent in hospitals in Germany and the Nordic countries. There is interest in formaldehyde use in Eastern Europe and the Middle East. Formaldehyde is not widely used in the U.S. because, in many cases, consistently high levels of sterility cannot be reached. In addition, there is considerable concern about exposure to health care workers (UNEP, 1991).

Availability:

Formaldehyde is commercially available worldwide.

In the United States, MDT Corporation manufactures a limited number of small, tabletop formaldehyde sterilizers. Larger sterilizers can be purchased from Getinge in Sweden and Canada (FOE, 1990).

Vendors of Alternative Equipment:

Formaldehyde Sterilizing Equipment Suppliers

AMSCO Brazil Servicos Ltda.
Rue Tabapua
#500-CJ84
04533-030 Sao Paulo
Brazil
Tel: (55) 11 820 4007
Fax: (55) 11 829 6442

AMSCO Europe, Inc.
Roland House
Rye Close
Ancells Business Park
Fleet
Hampshire GU13 8UY
United Kingdom
Tel: (44) 252 816 500
Fax: (44) 252 815 736

AMSCO Hong Kong Limited
34D Manulife Tower
169 Electric Road
North Point
Hong Kong
Tel: (852) 566 1211
Fax: (852) 566 1459

AMSCO International, Inc.
2424 West 23rd St.
P.O. Box 620
Erie, PA 16514
USA
Tel: (1) 814 452 3100
Fax: (1) 814 870 8423

AMSCO Japan K.K.
12F, East Tower
World Business Garden
2-6, Nakase, Mihama-Ku
Chiba City
Chiba Pref., 261-71
Japan
Tel: (81) 43 297 2821
Fax: (81) 43 297 1408

Environmental Tectonics Corp.
(no overseas offices)
125 James Way
County Line Industrial Park
Southampton, PA 18966
USA
Tel: (1) 215 355 9100
Fax: (1) 215 357 4000

Getinge International, Inc.
1100 Towbin Avenue
Lakewood, NJ 08701
USA
Tel: (1) 908 370 8800
Fax: (1) 908 370 2543

Joslyn Sterilizer
5815 Country Rd. #41
Farmington, NY 14425
USA
Tel: (1) 716 398 2680
Fax: (1) 716 398 2499

MDT Corporation
P.O. Box 23077
Rochester, NY 14692
USA
Tel: (1) 716 272 5080
Fax: (1) 716 272 5033

Quetzal
Florida St.
Buenos Aires
Argentina
Tel: (54) 19 536 969
Fax: Not available

Sources of Additional Information about this Technology:

1. Ayliffe, G.A.J. "The Use of Ethylene Oxide and Low Temperature Steam/Formaldehyde in Hospitals". Infection 17. Nr. 2, 1989.

2. Friends of the Earth (FOE). "CFC Free: The Best Treatment. Eliminating CFCs in Medical Device Sterilization". February 1990.

3. Morrissey, Robert F., and G. Briggs Phillips (eds.). Sterilization Technology: a Practical Guide for Manufacturers and Users of Health Care Products. Van Nostrand Reinhold. 1993.

4. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

3.5 Radiation Sterilization

Headline:

Radiation is used only for industrial sterilization (e.g., by medical device manufacturers or large contract sterilization facilities), usually to sterilize single-use products, including sutures, gloves, disposable gowns, face masks, dressings, syringes, and surgical staplers. Some industry sources estimate that radiation sterilization can only be used on approximately 50 percent of the products that can be sterilized with current CFC-12/ethylene oxide blends due to the inability of many products to withstand radiation. Its potential applicability in developing countries is likely to be extremely limited because its use (1) requires stringent health and safety precautions, (2) results in the generation of radioactive waste, and (3) is difficult to adapt to hospital-scale or smaller-scale needs.

Industry Sector:

Medical equipment manufacturers and contract sterilization facilities.

ODS Reduction/Elimination Method:

ODSs are eliminated by switching to a not-in-kind alternative.

Composition of alternative:

Gamma and electron-beam radiation are the two types of radiation currently available to sterilize equipment. Gamma radiation is generated by radioisotopes (usually cobalt-60), while electron beams are created by accelerators.

Toxicity: N/A

Flammability: N/A

VOC Classification: N/A

Ozone Depleting Potential (ODP): N/A

Global Warming Potential (GWP): N/A

Phaseout Schedule: N/A

Sterilant Characteristics:

Unlike steam or dry-heat sterilization, radiation sterilization can be used with heat sensitive and thermoplastic materials. Also, the gas permeability concerns associated with ethylene oxide and steam sterilization are not relevant. Sterilizing doses of radiation may, however, adversely affect material characteristics or performance.

Radiation may damage medical equipment, causing polymers to embrittle, discolor, or give off odors. Many companies have developed a wide range of radiostable materials that demonstrate improved performance at fairly high radiation doses (Nordion, 1992/Brinston and Wilson, 1993). Where product compatibility can be achieved, however, irradiation is a very reliable means of sterilization. The process is relatively simple to control. Sterility can be confirmed readily by physical measurements of absorbed radiation dose, and the product can be released as sterile without holding it under quarantine for sterility testing (UNEP, 1991).

Radiation produced by accelerated electrons is generally less detrimental to load materials than radiation delivered by gamma sources. Metals are virtually unchanged by sterilizing doses of gamma radiation, but polytetrafluoroethylene is severely degraded and becomes nonfunctional.

Other advantages and disadvantages of both types of radiation sterilization are listed below (Morrissey and Phillips, 1993).

Electron Beam Radiation

Advantages

- High intensity electron beams provide short exposure times with minimal degradation of materials.
- Accelerator parameters can be changed to accommodate different process requirements for various products.
- Process validation does not need to be repeated after routine maintenance of the equipment.
- The radiation source can be shut off when not needed to reduce operating costs and simplify maintenance.
- Accelerators are perceived to be less dangerous than radioactive sources.

Disadvantages

- The penetration of electrons is limited; so thicker and more complex products cannot be treated.
- Dose distributions of radiation can be uneven, certainly less uniform than with gamma rays. As a result of this, detailed dose mapping must performed on products and packages to determine maximum and minimum dose zones in order to demonstrate that all parts of the load have been sterilized.
- Multiple equipment parameters other than conveyor speed must be monitored to ensure sterilization.

- Particle accelerators require more maintenance than do radioactive sources.

- There has been less experience with electron beam sterilization than with gamma-ray sterilization.

Gamma Rays

Advantages

- The penetrating ability of gamma rays permits treatment of most medical products in shipping cartons or bundled loads.

- Radiation doses are more uniform than with electron beams, so dose mapping is required less frequently and it is less detailed.

- Modulating the number of exposed source capsules allows the emitted radiation to be matched to the throughput requirements.

- Only one process parameter, conveyor speed or dwell time, must be controlled and monitored.

- Gamma ray facilities are less complex than electron accelerator facilities, and are easier to operate and maintain.

- There has been more experience with gamma ray sterilization than with electron beam sterilization.

Disadvantages

- Low-intensity radiation requires long exposure times, which increase the likelihood of oxidative degradation of materials being sterilized.

- The steady emission of radiation from the radioisotope requires continuous operation to avoid wasting energy.

- The supply of cobalt-60 is heavily dependent on one organization. Rods are purchased and returned to the same company.

- Public perceptions of nuclear facilities could impede future operations.

Substitute Production Method and Materials:

Radiation sterilization occurs in large volumes of at least 28,317 m^3 (1 million cubic feet) per year. Items to be sterilized are placed on conveyer belts and passed through a room containing the radiative source -- either a switched-on electron accelerator or an unshielded radioisotope source. No toxic agents are involved, and products may be released on the basis of documentation that the desired radiation dose was delivered; microbiological confirmation testing is not required unless it is a local requirement. Since exposure requirements are measured in terms of the delivered dose of radiation, the procedure is time independent. Radiation exposures can be monitored with counters, electronic measuring devices, biological indicators, and chemical dosimeters.

Health and Safety Considerations:

The engineering and operation of an irradiation facility are designed to prevent exposure of personnel to high-energy electrons, gamma, and X-rays that are emitted when energetic electrons strike absorbing materials. Such requirements are usually regulated by national and local authorities, although this may not be the case in developing countries. Protection against high-energy radiation usually is provided by installing radiative sources in rooms with thick concrete walls and ceiling. The entrance and exit portals for product conveyers and maintenance must be baffled to prevent the escape of scattered electrons and gamma rays. For electron beam radiation, no radiation is produced unless the accelerator is switched on; in gamma radiation facilities, radiation is not released as long as the "source rack" -- a bundle of steel capsules that contain the radioactive isotope -- remains in a shielded position, either submerged in water or in a dry covered pit (Morrissey and Phillips, 1993).

Safe operating procedures are ensured by switches, interlock circuitry, warning lights and sirens, and radiation-measuring instruments. Treatment rooms must be evacuated and secured before the accelerator is switched on or before the source rack is removed from a shielded position. Attempts to enter the treatment room while the accelerator is on or the radiative source is exposed must be prevented or be detected by sensors that will shut off or re-shield the radiative source.

The radiation exposure of personnel must be monitored with film badges or personal dosimeters and their health should be monitored with periodic medical examinations. No adverse effects should result from working in radiation sterilization facilities that are properly designed, operated, and maintained.

Environmental Considerations:

Spent cobalt-60 is radioactive waste and should be disposed of according to appropriate safety and environmental regulations. In addition, extreme care must be used when handling the rods during shipping. Environmental concerns regarding radiation are not relevant to the electron beam process. Accelerated electrons do not have the same penetrating abilities as gamma radiation sources.

Associated Costs:

The capital cost for installing a new gamma radiation facility is approximately US$2,000,000 for a facility with a throughput of 28,317 m^3 (1 million cubic feet) per year. Most large facilities have a throughput of at least

84,951 m^3 (3 million cubic feet), so, on average, a new facility will cost US$6,000,000-US$7,000,000 (Nordion International, personal communication, June 1993)

The capital cost of installing an electron beam facility is approximately US$5,750,000. Material handling, engineering, design, support, and start-up cost an additional US$1,750,000 (Morrissey and Phillips, 1993).

Unit costs for both these methods are competitive with other sterilization techniques only at throughputs of greater than 28,317 m^3 (1 million cubic feet) per year. Unit costs of electron processing are less than those of gamma-ray irradiation in high-capacity facilities.

In addition, to the cost of the equipment itself, special permitting may be required in some localities in order to install a radiation facility. Furthermore, such facilities may not be permitted at all in some locations.

Current Use:

Radiation sterilization is used by medical device manufacturers and contract sterilization facilities, usually on single-use medical products. Half of all single-use medical products worldwide are sterilized using radiation (UNEP, 1991), and 30% to 50% of all sterilization of new medical devices is accomplished by gamma radiation (HHMM, 1990).

Radiation sterilization is not an option for hospitals due to the substantial capital costs and complex installation requirements associated with constructing a radiation facility.

New radiation facilities are costly to build, but existing plants are operating at close to capacity. Due to the high capital costs associated with using radiation sterilization equipment, in-house facilities require large production volumes.

Availability:

Both gamma and electron beam radiation are available from a limited number of suppliers internationally.

Vendors of Alternative Equipment:

Radiation Sterilizing Equipment Suppliers

Amersham International
Amersham Place
Little Chalfont
Bucks HP7-9NA
United Kingdom
Tel: (44) 24 04 4444
Fax: (44) 24 04 4008

Atomic Energy of Canada, LTD.
Accelerator Business Unit
AECL Accelerator
436 Hazeldean Rd.
Kanata Ontario K2L-1T9
Canada
Tel: (1) 613 831 2882
Fax: (1) 613 831 0108

Nordion Europe, S.A.
Zoning Industrial
B.6220 Fleurus
Belgium
Tel: (32) 71 829 211
Fax: (32) 71 829 221

Nordion International
237 Lockhart Road
Wanchai
Hong Kong
Tel: (85) 28 289 376
Fax: (85) 28 289 328

Nordion International
447 March Road
P.O. Box 13500
Kanata, Ontario K2K 1X8
Canada
Tel: (1) 613 592 2790
Fax: (1) 613 592 6937

Radiation Dynamics
151 Heartland Blvd.
Edgewood, NY 11717
USA
Tel: (1) 516 254 6800
Fax: (1) 516 254 6810

Sterigenics
P.O. Box 5030
Fremont, CA 94537-5030
USA
Tel: (1) 510 770 9000
Fax: (1) 510 770 1499

Sources of Additional Information about this Technology:

1. Brinston, R.M. and B.K. Wilson. "Converting to Gamma-Radiation Sterilization: An Overview for Medical Device Manufacturers," May 1993.

2. Healthcare Hazardous Materials Management (HHMM). "EtO Phone Home: The Future of Sterilization in Hospitals," Vol. 3, No. 10, July 1990.

3. Morrissey, Robert F., and G. Briggs Phillips (eds.). Sterilization Technology: a Practical Guide for Manufacturers and Users of Health Care Products. Van Nostrand Reinhold. 1993.

4. Nordion International, Inc. "Cobalt-60, C-188 Sources." Product Information, undated.

5. Nordion International, Inc. "Gamma Sterilizable Plastics, North American Suppliers," January 1992.

6. UNEP Technical Options Report on Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride. December 1991.

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

4. Tobacco Expansion Alternative Technologies Datasheets

4. Tobacco Expansion Alternative Technologies Datasheets

4.1 Carbon Dioxide Tobacco Expansion

Headline:

Possible alternatives to CFC-11 for expanding leaf tobacco include carbon dioxide (CO_2), nitrogen, and steam. The carbon dioxide process is the only alternative that achieves tobacco expansion equivalent to that achieved by CFC-11.

Industry Sector:

Tobacco expansion (fluffing) in the cigarette manufacturing industry.

ODS Reduction/Elimination Method:

CFC-11 is eliminated or phased out by shutting down the existing CFC-11 expansion process and equipment and implementing a new CO_2-based expansion process. In most cigarette manufacturing operations, tobacco expansion occurs in a plant distinct from the rest of the manufacturing operations. As a result, the CFC-11 plant may be kept in operation until the new plant is operational in order to prevent disrupting cigarette production and new blends are formulated using CO_2 produced expanded tobacco.

Composition of alternative:

The following table presents some physical and chemical properties of CO_2:

Formula	CO_2
Molecular Weight	44.01
Vapor Pressure @21.1°C	58.2 bar
Density (gas) g/l @0°C, 1 bar	1.9768
Density (solid) @-78.4°C	1.561
Flash Point	none
Explosive Limits in Air	none
Solubility in Water (ml/100 ml water @0°C)	170.7
Solubility in Water (ml/100 ml water @21.1°C)	85.4

Toxicity:

Concentrations of CO_2 greater than 20,000 ppm are lethal to humans. The normal concentration of CO_2 in air is approximately 300 ppm (see further discussion below).

Flammability:

Nonflammable

VOC Classification[17]:

Non-VOC

Ozone Depleting Potential (ODP):

0

Global Warming Potential (GWP):

1

Phaseout Schedule:

None

Substitute Production Method and Materials:

Carbon dioxide used in the substitute expansion process can usually be obtained from local suppliers of industrial gases or breweries where it is recovered as a by product. A switch to a CO_2-based process may also result in the elimination of some HCFC-22, which is used at some plants as a refrigerant during the CFC-11 expansion process. Ammonia may also be substituted as a refrigerant.

At the start of the CO_2-based expansion process, cut tobacco is immersed in liquid CO_2 in a pressurized impregnator vessel. The folded tobacco cellular structure is partially filled with liquid CO_2 at a temperature near or below room temperature. After soaking, excess liquid is drawn off and recovered. After complete removal of the liquid CO_2, the pressure within the impregnator is reduced in stages to atmospheric pressure recovering additional CO_2 gas; temperature is kept constant. Since CO_2 cannot exist as a liquid at atmospheric pressure, the CO_2 remaining within the tobacco structure changes to its solid, dry ice form.

The treated tobacco is conveyed to an "S" shaped tower where it is expanded in a steamheated stream of air. Rapid heating induces the dry ice to sublime (i.e., change directly from its solid to gaseous phase) to gaseous CO_2 at the same temperature as the external gas stream. In changing from dry ice to hot gas, CO_2 increases rapidly in volume, providing sufficient internal pressure to re-expand the tobacco's cellular structure by approximately 100 percent. The tobacco is removed from the air stream in a separator unit and conveyed to a reordering cylinder for moisture conditioning by spray addition of water. The conditioned, expanded tobacco may be stored or packaged.

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[17] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

The patent holder and distributor of the CO_2-based expansion process technology is AIRCO Industrial Gases in New Jersey, U.S.A. AIRCO co-developed the DIET™ process with Philip Morris and patents are cross-licensed. Through special licensing agreements, complete DIET™ plants have also been built by the British American Tobacco company (BAT). A new CO_2-based expansion process can be brought on line within two years of project initiation in plant sizes from approximately 568 to 2273 kg/hr.

Health and Safety Considerations:

CO_2 is present in normal air at about 300 ppm and is obviously compatible with life forms. It functions as a regulator of the breathing function, and increases in concentration will accelerate the rate of breathing. At atmospheric levels of 0.1% to 1.0%, there is a slight but unnoticeable increase in breathing rates, while at 2%, there is a 50% increase, and at 3%, a 100% increase. At 5%, the increase rises to 300%, and breathing becomes laborious. Humans can only withstand a level of 10% CO_2 for a few minutes. Unconsciousness will occur at 12% to 15%, and 25% will cause death in several hours. The threshold limit (in the United States) is established at 500 ppm (0.5%). CO_2 has a pungent, but not unpleasant, odor. The solid form, dry ice, can cause severe frostbite.

The U.S. Occupational Health and Safety Administration (OSHA) has set a permissible exposure level (PEL) at 10,000 ppm. This level can easily be met during a well contained tobacco expansion process by providing suitable ventilation in combination with CO_2 level monitoring devices.[18] Fail-safe devices are also included with the plant hardware to prevent accidental or uncontrollable emissions.

Environmental Considerations:

Carbon dioxide is a greenhouse gas. Increased use of CO_2 for tobacco expansion has a negligible impact on global warming, however, because the CO_2 used is a by-product of the production of other gases and commodities (e.g., beer, urea-based fertilizers, etc.). The CO_2 is captured from a stream of gas that would otherwise be emitted to ambient air. Expanding tobacco with CO_2 can result in some emissions of CO_2 from incineration of by-products.

Carbon dioxide expansion plants usually come equipped with a fume collection system and an incinerator capable of destroying the fumes and airborne particulates, including organic byproducts such as nicotine, alkaloids, and sugars. This ensures safe operation of the plant and conformance with environmental standards and regulations. As propane is used as a fuel in this process, some carbon dioxide is emitted as a product of combustion from the incinerator. Other emissions include nitrogen, oxygen, and water vapor.

Associated Costs:

New CO_2-based expansion process equipment for a 1136 kg/hr capacity plant costs approximately US$10 to US$12 million depending upon site conditions. The costs of a new building (structure), spare parts, CO_2 storage tanks, CO_2 pump, technical assistance, and turn key services (e.g., for welding, electrical, and insulation) could add a further US$2-$3 million. Freight and equipment placement costs could add about US$0.25 million.

[18] *USEPA (1993), "Notice of Proposed Rulemaking for Section 612 of the 1990 U.S. Clean Air Act Amendments."*

Beyond such one-time costs, there may be royalty costs associated with the use of a patented technology (i.e., the DIET™ process). Other operating costs include, steam, power, cooling water, potable water, compressed air, nitrogen, fuel, maintenance, and labor. These are approximately the same as operating costs associated with the CFC-11 based expansion processes.

Current Use:

Several carbon dioxide-based expansion plants are in operation at 10 tobacco companies in 14 countries.

	Location:	Capacity (kg/hour):
Philip Morris	Richmond, VA, U.S.A.	3636
	Cabarrus County, NC, U.S.A.	1818
	Toronto, Ontario, Canada	1000
	Munich, Germany	1000
	Berlin, Germany	1000
	Neuchatel, Switzerland	1000
	Bergen-op-Zoom, Netherlands	1000
B.A.T.	Southhampton, England	182
	Kuala Lumpur, Malaysia	546
	Corby, England	1818
	Macon, Georgia	2273
	Berlin, Germany	182
Rothman's	Peterlee, England	546 (3x182)
	Kuala Lumpur, Malaysia	364 (2x182)
	Bundamba, Australia	568
American Brands	Belfast, N. Ireland	182
	Manchester, England	546
	Reidsville, NC, U.S.A.	2273
Tabacalera	Cadiz, Spain	568
Tabacalera - Line II	Cadiz, Spain	568
Italian Monopoly	Bologna, Italy	1136
CNTC	Shanghai, China	568
	Ningbo, China	568
	Guangzhou, China	568
	Quingdao, China	568

R.J. Reynolds	Tobaccoville, NC, U.S.A	2273
Lorillard	Greensboro, NC, U.S.A.	1136
Japan Tobacco	Kurashiki, Japan	2273

Availability:

Plant, equipment, training and engineering assistance are available from suppliers of the equipment. Liquid CO_2 supply is readily available from suppliers of industrial gases, breweries, etc. In remote areas, a CO_2 by product recovery plant may be necessary.

Vendors of Alternative Equipment:

AIRCO Industrial Gases
575 Mountain Ave.
Murray Hill, NJ 07974
USA
Tel: (1) 908 771 1485
Fax: (1) 908 771 1672

British American Tobacco
Cedar House
39 London Rd.
Reigate
Surrey RH2 9QE
United Kingdom
Tel: (44) 737 241 133
Fax: (44) 737 241 842

Sources of Additional Information about this Technology:

Mario Uy
Plant Manager
Fortune Tobacco Corp.
Parang, Marikina
Philippines
Tel: (632) 816 3381
Fax: (632) 816 5701

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

5. Carbon Tetrachloride Alternative Technologies Datasheets

5. Carbon Tetrachloride Alternative Technologies Datasheets

5.1 Organic Solvent Cleaning

Headline:

A number of nonchlorinated organic solvents are currently available to replace carbon tetrachloride and methyl chloroform in hand-wipe cleaning applications and as active ingredients in aerosol solvent cleaners. Alternatives that have been proven effective include alcohols, ketones, and glycol ethers.

Industry Sector:

Removal of flux residue, oils, grease, and other contaminants from materials when a flammable solvent is acceptable.

ODS Reduction/Elimination Method:

Organic solvents are substituted for carbon tetrachloride in hand-wipe and aerosol spray applications. This may require new methods of application, changes in personal protective equipment, and procedural modifications.

Composition of Alternative:

A large number of organic solvents are potential substitutes for carbon tetrachloride in a variety of hand-wipe and aerosol cleaning applications. These include alcohols, ketones, esters, isoparaffinic hydrocarbons, glycol ethers, and acetates. To address the properties of these solvents and to allow for their direct comparison, four representative solvents have been selected to be addressed in this datasheet. The representative solvents are isopropyl alcohol (IPA), acetone, methyl ethyl ketone (MEK), and propylene glycol methyl ether acetate (PMA). These solvents because they are known to have been used successfully in a number of industrial solvent cleaning applications.

Toxicity:

Of the four representative organic solvents mentioned above, only acetone and MEK are currently of concern for toxicological reasons. The most common route of exposure for both is through inhalation, and worker exposure limits have been set in many countries to address this danger. In the U.S., the Occupational Safety and Health Administration (OSHA) has set a long-term permissible exposure limit (PEL) of 200 ppm and a short-term exposure limit (STEL) of 300 ppm for MEK (USEPA, 1993). While PMA is not believed to be of concern for toxicity, it should be noted that several glycol ethers are believed to have toxicity problems. These glycol ethers -- ethylene glycol methyl ether (and its acetate) and ethylene glycol ethyl ether (and its acetate) -- are often referred to as "E-Series" glycol ethers and have been shown to cause damage to the reproductive system. As noted however, propylene glycol methyl ether (and its acetate), also known as "P-Series" glycol ethers, are not believed to pose toxicity problems.

Flammability:

The majority of the organic solvents available to replace carbon tetrachloride in solvent cleaning are extremely flammable and require special care in handling. The flash points of the most common solvents are listed below:

- Isopropyl alcohol: 22.2°C
- Acetone: -17.8°C
- Methyl ethyl ketone: -3.3°C
- Propylene glycol methyl ether acetate: 33.9°C

These relatively low flash points make working with the solvents while heated or vaporized very dangerous.

VOC Classification (U.S.)[19]:

- Isopropyl alcohol: VOC
- Acetone: VOC
- Methyl ethyl ketone: VOC
- Propylene glycol methyl ether acetate: VOC

Ozone Depleting Potential (ODP):

All of the organic solvents mentioned above have an ODP of 0.

Global Warming Potential (GWP):

The GWPs of the organic solvents mentioned above have not been measured. All of the substances listed are VOCs and therefore contribute to the formation of tropospheric ozone (smog). While tropospheric ozone is considered to be a greenhouse gas (GHG), most scientists agree that its contribution to global warming is very small.

Phaseout Schedule:

There are currently no known phaseout schedules for any of the organic solvents mentioned in this data sheet.

Substitute Use Method and Materials:

Organic solvents provide an excellent alternative to the use of carbon tetrachloride in hand-wipe and aerosol cleaning applications. In both cases, cleaning using the representative solvents mentioned here can be performed in a variety of manners similar to those used for cleaning with carbon tetrachloride. In these applications, acetone, MEK, and PMA are generally used to remove oil, grease, and dirt from metal surfaces, while IPA is most often used to remove flux residues after soldering in the manufacture or repair of printed circuit board assembles.

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[19] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

In hand-wipe applications, a cloth, mop, brush, or other medium is saturated with the solvent. The part to be cleaned is then wiped manually with the saturated medium until all of the soils and contaminants are removed. In many cases, the excess solvent evaporates from the part leaving a clean, dry surface. With some solvents however, a residual film may remain on the component if the cleaner is allowed to fully evaporate. In these cases, a water rinse may follow the application of the solvent, or drying may be aided using forced air or a manual wipe with a dry cloth. Testing should be performed to determine the optimal solvent for each cleaning application. While high-vapor pressure solvents will evaporate fully leaving a clean dry part, use of a solvent which evaporates too quickly will require workers to continually apply fresh solvent to the cloth, mop, or brush in order to keep the medium saturated. On the other hand, a solvent with too low a vapor pressure will take longer to dry and may slow down the production process.

Aerosol cleaning using organic solvents as the active ingredient is performed in the same manner as that using carbon tetrachloride. However, adjustments may be required to the application method and location to account for the high flammability of most organic solvents. Unlike carbon tetrachloride, which is nonflammable, organic solvents have relatively low flash points and must be used in areas well ventilated areas in which the risk of ignition is low. Ignition sources as small as a spark have been known to ignite flammable solvents such as these. The flammability risk is further increased by the fact that the solvent is being sprayed in a fine mist, allowing it to disperse into the surrounding air. Specially designed spray nozzles may be able to reduce this flammability risk in some cases. Aerosol-type organic solvent cleaners should not be used in confined spaces, and adequate ventilation should be present in any area in which they are used.

It is possible that carbon tetrachloride is still being used in dip tank cleaning in some locations. In these cases, cleaning with organic solvents can usually be performed in equipment that previously used carbon tetrachloride. Two major changes to existing equipment will be needed to make this switch: (1) the installation of controls to recover emissions of VOCs and/or limit the exposure of workers to fumes; and (2) the use of controls to reduce the risk of fire caused by the high flammability of organic solvents. In addition, other alternatives including aqueous cleaning, semi-aqueous cleaning, and chlorinated solvent cleaning may be available to replace carbon tetrachloride in dip-tank applications.

Health and Safety Considerations:

The two principle health and safety considerations associated with the use of organic solvents are worker exposure and flammability. As described earlier, two of the four representative solvents -- acetone and MEK -- are toxic, and their use requires that worker exposure be kept to a minimum. In addition, acetone, MEK and PMA have relatively strong odors which may cause some discomfort to workers.

Flammability is another major concern when using any of the solvents addressed here. All have low flash points and are extremely flammable. For this reason, their use is usually limited to cleaning applications performed at or slightly above room temperature. For hand-wipe and aerosol cleaning using organic solvents, heating will not take place. However, if the carbon tetrachloride is being replaced in a bulk cleaning process (such as dip-tank or vapor degreasing), the organic solvent may be heated to enhance the cleaning operation. In the case of IPA, a new family of vapor degreasers has been designed that uses IPA in a vapor phase to clean parts. Whenever these solvents are heated, there must be adequate fire safety precautions taken to ensure the safety of workers. In addition to evaluating the equipment for its ability to safely use flammable organic solvents, the work area should be evaluated and potential ignition sources identified. These ignition sources should then be eliminated before use of a flammable solvent is permitted.

Environmental Considerations:

There is no bulk solvent disposal in most hand-wipe and aerosol applications of organic solvents since all of the solvent volatilizes from the surface being cleaned. In applications in which the solvent is placed on the cloth or other medium using a squirt bottle or other such method, there will be no bulk disposal of solvent. However, in applications where the cloth or medium is dipped into a bowl of solvent, the solvent in the bowl will gradually become dirty over time from the repeated dipping of the dirty cloth. When the solvent remaining in the bowl becomes too contaminated to function properly, it will need to be disposed of as a bulk solvent. In addition, cloths, mops, and other medium used in the cleaning process will be contaminated with the solvent and soils and must therefore be disposed of as required by local environmental regulations (often as hazardous waste). Furthermore, if a water rinse is used following hand-wipe of aerosol cleaning, it is likely to require treatment prior to discharge.

In the case of dip-tank cleaning, the organic solvent should be used as many times as possible until the contamination level in the solvent renders it an ineffective cleaner. All of these solvents should be treated as hazardous waste and disposed of in the proper manner. Care must be taken to ensure that the solvent does not find its way into the effluent from a facility, as discharge may pose a significant threat to receiving waters.

Associated Costs:

The largest cost associated with replacing carbon tetrachloride with organic solvents lies in the difference in price between the solvents. Equipment cost is negligible since most existing equipment can be used with organic solvents. At present, the cost of carbon tetrachloride in the United States is approximately US$0.79/kg. The costs of the alternative solvents discussed here are:

- IPA - US$ 0.62/L
- Acetone - US$ 0.66/kg
- MEK - US$ 0.63/kg
- PMA - variable[20]

In many cases, the overall consumption of solvent will decrease when using these alternatives because of their low vapor pressures. This is especially true for IPA and PMA formulations.

Current Use:

All of the organic solvents discussed above are currently in widespread use in both industrialized and developing countries. For many years, MEK has been the most widely used metal-cleaning solvent, while IPA has emerged as a popular alternative for use in the repair of printed circuit boards.

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[20] *PMA is combined with other materials by manufacturers to make a variety of formulations. The cost depends on the formulation chosen.*

Availability:

All of the organic solvents discussed above are available for purchase worldwide. They can be purchased from a number of chemical manufacturers in industrialized countries, or from their extensive network of distributors in the developing world.

Vendors of Alternative Equipment:

Organic Solvent Suppliers

Arco Chemical Company
3801 West Chester Pike
Newton Square, PA 19073
USA
Tel:(1) 215 359 2000
Fax:Not available

Ashland Chemical, Inc.
P.O. Box 2219
Colombus, OH 43216
USA
Tel:(1) 614 889 3333
Fax:(1) 614 889 3465

Dow Chemical
2020 Dow Center
Midland, MI 48640
USA
Tel:(1) 517 636 1000
Fax:(1) 517 832 1465

Dow Europe
Zurich, Switzerland
Tel:(41) 1 728 2111
Fax:Not available

Dow Latin America
Florida, USA
Tel:(1) 305 520 7000
Fax:Not available

Dow Pacific
Hong Kong
Tel:(852) 879 7333
Fax:Not available

DuPont Chemicals
Chem. Room B-13218
1007 Market Street
Wilmington, DE 19898
USA
Tel:(1) 302 633 1501
Fax:(1) 302 892 1705

Dynamold Solvents, Inc.
P.O. Box 9617
Fort Worth, TX 76147-2617
USA
Tel:(1) 817 335 0862
Fax:(1) 817 877 5203

Elf Atochem
Paris, France
Tel:(33) 1 4796 9451
Fax: Not available

Empresas Dow
Sao Paulo
Brazil
Tel:(55) 11 546 9122
Fax:Not available

Exxon Chemical Company
(Servicing North America)
P.O. Box 3272
Houston, TX 77001
USA
Tel:(1) 713 870 6000
Fax:(1) 713 870 6970

Exxon Chemical Company
(Servicing Latin America and Carribean)
P.O. Box 3272
Houston, TX 77001
USA
Tel:(1) 713 870 6394
Fax:(1) 713 870 6802

Exxon Chemical Intl.
Brussels, Belgium
Tel:(32) 3 543 3329
Fax:(32) 3 543 3495

Exxon Chemical Intl. Services
Hong Kong
Tel:(852) 582 0753
Fax:(852) 802 0279

ICI Americas Inc.
New Murphy Road & Concord Pike
Wilmington, DE 19897
USA
Tel:(1) 302 886 3000
Fax:(1) 302 886 2972

ICI Chemicals and Polymers Ltd.
P.O. Box 14
The Heath
Runcorn, Cheshire WA7 4QG
United Kingdom
Tel:(44) 928 511 050
Fax:(44) 928 581 072

Oxychem
5005 LBJ Freeway
Dallas, TX 75244
USA
Tel:(1) 214 404 3800
Fax:Not available

Texaco Chemical Co.
P.O. Box 27707
Houston, TX 77227
USA
Tel:(1) 713 961 3711
Fax:Not available

Sources of Additional Information about this Technology:

1.Center for Emissions Control, 1025 Connecticut Ave., N.W., Suite 712, Washington, D.C. 20036, USA. Tel: (1) 202-785-4374, Fax: (1) 202-223-5979.

2.USEPA, "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Solvent Cleaning," 1993.

3.Global Centre for Process Change, P.O. Box 553, Montchanin, DE 19710, USA. Tel: (1) 302 652 5597, Fax: (1) 302 652 5701

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

5.2 Chlorinated Solvent Cleaning

Headline:

Prior to the introduction of CFC-113 and methyl chloroform (TCA) as solvent cleaners, other non-ozone-depleting chlorinated solvents were widely used. It is now possible to return to the use of these chemicals in order to phase out the use of carbon tetrachloride (and CFC-113 & TCA) as the active ingredient in aerosol solvent cleaners.

Industry Sector:

Most degreasing and cleaning where nonflammable solvents are needed.

ODS Reduction/Elimination Method:

Chlorinated solvents are substituted for carbon tetrachloride as the active ingredient in aerosol spray applications. This may require procedural modifications to ensure the health of workers.

Composition of Alternative:

There are three non-ozone-depleting chlorinated solvents that are potential substitutes for carbon tetrachloride in a variety of cleaning applications: 1) perchloroethylene (PERC), 2) trichloroethylene (TCE), and 3) methylene chloride (METH). The following chart compares the relevant physical properties of each of these solvents with those of carbon tetrachloride:

	PERC	TCE	METH
Formula	CCl_2CCl_2	$CHClCCl_2$	CH_2Cl_2
Boiling Point	121.1°C	86.7°C	39.7°C
Vapor Pressure @20°C	0.0189 bar	0.0744 bar	0.518 bar
Evaporation Rate @25°C (NBAC=1)	2.59	4.50	14.5
Flash Point	None	None	None
Kauri-Butanol Value	91	130	132

Toxicity:

PERC, TCE, and METH are of concern to most regulatory agencies due to their suspected carcinogenicity. The following are the cancer classifications assigned to these chemicals by the U.S. Environmental Protection Agency (USEPA), the International Agency for Research on Cancer (IARC), and the American Conference of Governmental Industrial Hygienists (ACGIH):

- Perchloroethylene
  - USEPA -Possible/probable human carcinogen
  - IARC -Possible human carcinogen
  - ACGIH -Animal carcinogen

- Trichloroethylene
  - USEPA -Possible/probable human carcinogen
  - IARC -Not classifiable as to its human carcinogenicity
  - ACGIH -Not as a suspected human carcinogen

- Methylene Chloride
  - USEPA - Probable human carcinogen
  - IARC -Possible human carcinogen
  - ACGIH -Suspected human carcinogen

Specific occupational exposure limits have been applied to these chemicals in many countries in order to mitigate the possibility of their causing cancer in workers. These limits are discussed later, in the section titled "Health and Safety Considerations."

It is important to note that carbon tetrachloride, the ozone-depleting substance being replaced in this sector, is also classified as a probable human carcinogen by IARC.

Flammability:

Perchloroethylene, trichloroethylene, and methylene chloride are all nonflammable.

VOC Classification (U.S.)[21]:

Perchloroethylene:VOC[22]

Trichloroethylene:VOC

Methylene Chloride:Negligible photochemical reactivity (according to USEPA)

[21] *VOC classification for any chemical will vary depending on the country and sometimes the locality where it is used. The classification of a chemical as a VOC is ultimately a regulatory decision. While such a classification is based on the physical properties of a chemical and its environmental effects, the same chemical may be considered a VOC in one country and not in others. Different countries and localities are likely to have different beliefs about the degree of volatility necessary for a chemical to be classified as a VOC. These beliefs will often be a function of local air quality conditions. In this catalogue, VOC classification follows USEPA guidelines.*

[22] *The U.S. Environmental Protection Agency has recently proposed that perchloroethylene be reclassified as a "Non-VOC."*

Ozone Depleting Potential (ODP):

Perchloroethylene, trichloroethylene, and methylene chloride have an ozone-depletion potential of 0.

Global Warming Potential (GWP):

The GWPs of the chlorinated solvents mentioned above have not been measured. Some of the substances listed are VOCs and therefore contribute to the formation of tropospheric ozone (smog). While tropospheric ozone is considered to be a greenhouse gas, most scientists agree that its contribution to global warming is very small.

Phaseout Schedule:

Most countries that use perchloroethylene, trichloroethylene, and methylene chloride have no schedules in place to phase out the use of these solvents. In addition, most have not announced any intention of eliminating their use. Rather, many countries set strict limits on the allowable amount of emissions of these solvents from cleaning operations. One notable exception is Sweden. The Swedish Environmental Protection Agency has issued a regulation that bans the sale of these chlorinated solvents for private (non-commercial) use after 1 January 1993. In addition, the regulation requires that trichloroethylene use end by 1 January 1996 for professional (commercial) uses. In the U.S., these substances are not subject to a phaseout or reduction schedule, but the USEPA's Industrial Toxics Program encourages industry to voluntarily reduce all solvent usage.

Substitute Use Method and Materials:

PERC, TCE, and METH are used in solvent cleaning in a manner similar to that in which carbon tetrachloride is used.

PERC, TCE, and METH can be used in cold cleaning aerosol applications as replacements for carbon tetrachloride. While all function well in this capacity, the low vapor pressure of PERC makes it slower to dry than both TCE and METH. While no changes are required to the aerosol technology in order to begin use of a non-ozone-depleting chlorinated solvent, the location of such usage must be considered carefully. These products must not be used in a confined space due to the low worker exposure limits associated with their use. Proper ventilation will also help to reduce the concentration of solvent in the air around workers. PERC, TCE, and METH are not recommended for use in hand-wipe applications because of health concerns associated with their prolonged exposure to workers.

It is possible that carbon tetrachloride is still being used in bulk cleaning applications in some locations. In these cases, non-ozone-depleting chlorinated solvents can replace the carbon tetrachloride, sometimes in the same equipment. PERC, TCE, and METH are ideal for vapor degreasing because, like carbon tetrachloride, they are nonflammable and do not pose the risk of a serious explosion or fire when being heated or vaporized. However, due to their possible toxicity and corresponding low worker exposure limits, "tight" equipment is required which controls the emissions of these chemicals to the atmosphere. In addition, other alternatives including aqueous cleaning, semi-aqueous cleaning, and organic solvent cleaning may be available to replace carbon tetrachloride in bulk cleaning applications.

Health and Safety Considerations:

Several forms of worker exposure limits have been recommended in many countries to address the health concerns associated with PERC, TCE, and METH. In the U.S., the Occupational Safety and Health Administration (OSHA) sets Permissible Exposure Limits (PELs) for these chemicals on the basis of an 8-hour time-weighted average (TWA). The OSHA PELs for PERC, TCE, and METH are 25, 50, and 500 ppm, respectively (USEPA, 1993). For aerosol cleaning applications, frequent monitoring should be performed in the work area to determine if exposure levels are below these values.

In the case of bulk cleaning, PERC, TCE, or METH should only be used with low-emission equipment in order to maintain levels below these limits. While many existing vapor degreasers and cold cleaners can be retrofitted to better control emissions, there are specially designed machines which are built specifically for use with chlorinated solvents. Other than toxicity, the only health and safety concerns associated with the use of PERC, TCE, and METH are ones that apply to the use of all industrial solvents. These include dangers from prolonged inhalation, skin contact, and ingestion. As with any solvent, protective clothing and gloves should be worn at all times when handling PERC, TCE, and METH.

Environmental Considerations:

PERC and TCE are classified in many countries as VOCs, and are believed to contribute to the formation of tropospheric ozone (smog) when emitted to the atmosphere. In addition, all are regulated as hazardous air pollutants in the U.S. If these solvents are being used as a replacement for carbon tetrachloride in bulk cleaning, care must be exercised when disposing of spent PERC, TCE, and METH to ensure that they are not discharged to surface water and do not leach into groundwater supplies.

Associated Costs:

The cost of purchasing and using PERC, TCE, or METH is comparable to that of using carbon tetrachloride in similar solvent cleaning applications. For bulk cleaning, specially designed low-emission vapor degreasing equipment will usually cost in excess of US$150,000.

Current Use:

Prior to the introduction of CFC-113 and TCA as solvents, PERC, TCE, and METH were used in many solvent cleaning applications. However, when CFC-113 and MCF became widely available for use in industrial cleaning, many industries switched away from PERC, TCE, and METH. Now, given the impending elimination of CFC-113 and MCF, the use of PERC, TCE, and METH is again on the increase. Currently, PERC, TCE, and METH are widely used as degreasing solvents in virtually all developed countries, with a greater prevalence in Europe than in the United States. Most of these applications, however, are for bulk cleaning and occur in vapor degreasers, while the use of non-ozone-depleting chlorinated solvents in aerosol spray applications is small in comparison. Industries in many developing countries are also choosing to switch to PERC, TCE, and METH as they phase out their use of CFC-113 and MCF, and a similar switch could be made to replace their use of carbon tetrachloride solvents.

Availability:

PERC, TCE, and METH are currently available worldwide from a number of manufacturers and their distributors. In addition, vapor degreasing and cold cleaning equipment specially designed for use with bulk cleaning with chlorinated solvents is available in virtually all developed and developing countries through domestic distributors or importers.

Vendors of Alternative Equipment:

Chlorinated Solvent Suppliers

Ashland Chemical, Inc.
P.O. Box 2219
Colombus, OH 43216
USA
Tel:(1) 614 889 3333
Fax:(1) 614 889 3465

Dow Chemical
2020 Dow Center
Midland, MI 48640
USA
Tel:(1) 517 636 1000
Fax:(1) 517 832 1465

Dow Europe
Zurich, Switzerland
Tel:(41) 1 728 2111
Fax:Not available

Dow Latin America
Florida, USA
Tel:(1) 305 520 7000
Fax:Not available

Dow Pacific
Hong Kong
Tel:(852) 879 7333
Fax:Not available

Empresas Dow
Sao Paulo, Brazil
Tel:(55) 11 546 9122
Fax:Not available

ICI Americas Inc.
New Murphy Road & Concord Pike
Wilmington, DE 19897
USA
Tel:(1) 302 886 3000
Fax:(1) 302 886 2972

ICI Chemicals and Polymers Ltd.
P.O. Box 14
The Heath
Runcorn, Cheshire WA7 4QG
United Kingdom
Tel:(44) 928 511 050
Fax:(44) 928 581 072

Oxychem
5005 LBJ Freeway
Dallas, TX 75244
USA
Tel:(1) 214 404 3800
Fax:Not available

PPG Industries, Inc.
One Gateway Center
Pittsburgh, PA 15222
USA
Tel:(1) 412 434 2359
Fax:Not available

PPG Industries Caribe
1101 Chase Manhattan Building
San Juan (Hato Rey) 00918
Puerto Rico
Tel:(1) 809 764 0485
Fax:Not available

Vulcan Chemicals
P.O. Box 530390
Birmingham, AL 35253 0390
USA
Tel:(1) 205 877 3000
Fax:(1) 205 877 3448

Sources of Additional Information about this Technology:

1.Center for Emissions Control, 1025 Connecticut Ave., N.W., Suite 712, Washington, D.C. 20036. Tel: (1) 202-785-4374. Fax: (1) 202-223-5979

2.USEPA. "Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Solvent Cleaning." March 1993.

3.Global Centre for Process Change, P.O. Box 553, Montchanin, DE 19710, USA. Tel: (1) 302 652 5597, Fax: (1) 302 652 5701

Organization that Produced this Datasheet: ICF Incorporated

Peer Review Performed by: Geno Nardini

6. Annex

6. Annex A - UNEP IE/PAC

The UNEP IE/PAC Ozonaction Programme under the Multilateral Ozone Fund

The Montreal Protocol

Mounting scientific research has implicated chlorofluorocarbons (CFCs), halons, carbon tetrachloride, 1,1,1-trichloroethane, methyl bromide and hydrochlorofluorocarbons (HCFCs) in the depletion of the stratospheric ozone layer, that segment of the earth's atmosphere which protects animal and plant life from the damaging effects of ultraviolet radiation. In September 1987, nations concerned about this crisis signed the Montreal Protocol, a landmark agreement that identified the major ozone depleting substances (ODSs) and established a timetable for their eventual phase-out. Under the Montreal Protocol, ODS production and consumption of the controlled substances are to be reduced and eliminated through the development of chemical substitutes and alternative manufacturing processes.

The Multilateral Fund and the UNEP OzonAction Programme

Under the London and Copenhagen amendments to the Protocol, the Multilateral Fund (MF) was established to provide financial and technical assistance to developing countries that are Parties to the Montreal Protocol. The United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), the World Bank and the United Nations Industrial Development Organization (UNIDO) were chosen to be the Fund's implementing agencies, with UNEP being assigned the responsibility of conducting research, data gathering, and providing a clearinghouse function to:

(i)Assist Parties operating under paragraph 1 of Article 5, through country specific studies and other technical co-operation, to identify their needs for co-operation;

(ii)Facilitate technical co-operation to meet these identified needs;

(iii)Distribute, as provided for in Article 9, information and relevant materials, and hold workshops, training sessions, and other related activities, for the benefit of Parties that are developing countries; and

(iv)Facilitate and monitor other multilateral, regional and bilateral co-operation available to Parties that are developing countries.

UNEP IE/PAC's OzonAction Programme is the result of that mandate. It consists of three major elements: information exchange, training, networking, country programmes, institutional strengthening, and international halon bank management.

Information Exchange

The information exchange element of the OzonAction Programme aims to transfer information concerning policy and technical options for the phase-out of the controlled ODSs to developing countries.

OzonAction Information Clearinghouse (OAIC). The OAIC is an integrated information exchange service designed to meet the needs of developing countries through various communication media. The OAIC provides technical, policy and scientific information on a range of ODS phase-out issues including:

- descriptions of alternative technologies and product listings for each industrial use sector;
- an international directory of experts and consultants;
- technical literature abstracts, and information for ordering documents;
- descriptions of national and corporate strategies, policies, legislation, and programmes to phase out ODS;
- listings of workshops, conferences, and meetings concerning ozone depletion issues;
- bulletins containing news on phase-out intiatives.

There is no charge for using the OAIC query response service - simply phone, fax or write us with your question. Anyone with a personal computer can use the diskette version, and with the addition of a modem and communication software, the on-line system.

OzonAction Newsletter. This quarterly newsletter reports on the initiatives undertaken by countries and organizations that are implementing the Montreal Protocol. The OzonAction newsletter contains the latest news from governments and industry regarding the phase-out of the controlled ODSs, as well as science and technology updates.

Other ODS-Reduction Documents. OzonAction will publish specific technical and policy documents and brochures in response to specific information needs within industry and government.

Training

Regional Workshops. A series of regional workshops is designed to provide government and industry decision-makers with basic information on ODS control policies and strategies. Additionally, these workshops provide participants with the latest information about replacement technologies and products relating to the controlled substances.

Regional Training Courses. Based on a "train the trainer" approach, these sectorial courses impart the latest technical information and skills required to phase out ODSs (for example, service and maintenance practices, and recovery/recycling for the refrigeration sector).

National Activities. The OzonAction Programme will sponsor information campaigns at the national level to help raise the consciousness of the general public about the threat posed by the controlled ODSs. OzonAction will also be cooperating with UNDP to address specific technological issues within specific countries.

Documentation/Training Manuals. The OzonAction Programme will additionally publish technical papers, workshop proceedings, and training manuals/guidelines/handbooks.

Networking

The OzonAction Programme facilitates regional networking activities, which enable government officers in charge of their countries' National Ozone Units to interact and share information on strategies and policies to phase out ODS. Such information sharing and regional co-operation is hoped to expedite the phase-out. Presently, two ODS Officers Networks (ODSONETs) in South East Asia & Pacific and Latin America are in operation, and a third in Africa is being launched.

Country Programmes

The OzonAction Programme is conducting a series of country programmes for developing nations that have low rates of consumption for the controlled substances. The purpose of these programmes is to establish a baseline survey on the use of the controlled substances in these countries and to draw up policy strategies for their replacement and control. The data developed under this effort will establish a basis for other phase-out projects.

Institutional Strengthening

The OzonAction Programme assists the development of projects to establish National Ozone Units responsible for the implementation of the ODS phase-out in developing countries.

International Halon Bank Management

In accordance with Decision IV/26 of the Copenhagen Amendment to the Montreal Protocol, UNEP IE/PAC has established an International Halon Bank Management Information Clearinghouse which maintains a contact list for national halon banks, collects information about availability of recycled halons to the national halon banks, answers queries concerning alternative technologies or practices that substitute for halons, and develops halon banking-related documents.

For More Information About These Services

Please contact UNEP IE/PAC at:

Mr. Rajendra Shende, Coordinator
UNEP IE/PAC OzonAction Programme
39-43, quai André Citroën
75739 Paris Cedex 15
France
Tel:(33.1) 44.37.14.59
Fax:(33.1) 44.37.14.74

UNEP's Industry and Environment Programme Activity Centre (IE/PAC), formerly the Industry and Environment Office, was established in Paris in 1975 to bring industry, government, and nongovernmental organizations together to work towards environmentally sound forms of industrial development. To this end, the IE/PAC concentrates on formulating and promoting appropriate policies and strategies. More specifically, it seeks to:

- Define and encourage the incorporation of environmental criteria in industrial development;
- formulate and facilitate the implementation of principles and procedures to protect the environment;
- promote the use of safe, low and non-waste technologies (LNWT); and
- stimulate the exchange of information and experience on environmentally sound forms of industrial development throughout the world.

IE/PAC's work programme follows four principal areas: the publication of technical guides; technical cooperation; training; and information transfer. It has also developed two priority programmes: "Awareness and Preparedness for Emergencies at the Local Level" (APELL) to prevent and respond to technological accidents, and Cleaner Production.

Annex B - Glossary of Significant Terms

Article 5 Countries -- Parties to the Montreal Protocol that are considered developing countries. Article 5 countries are eligible to receive technical and financial assistance from the Multilateral Fund to phase out consumption of ODSs.

CFC -- Chlorofluorocarbon; chemicals commonly used in refrigeration, foam blowing, aerosols, sterilants, solvent cleaning, and a variety of other applications. CFCs have the potential to destroy ozone in the stratosphere.

DME -- Dimethyl Ether; a flammable aerosol propellant used in some European, Japanese, and U.S. aerosol formulations.

DPI -- Dry Powder Inhaler; can be used as an alternate technology to MDIs if the medication being dispensed can be satisfactorily formulated as microfine powder, thus eliminating the use of a chemical propellant.

EGL -- Emergency Guidance Level; a short-term worker exposure limit for chemicals set by the USEPA.

EtO -- Ethylene Oxide; used extensively by health care providers (e.g., hospitals, clinics) and industrial users (e.g., device manufacturers, contract sterilization services) to sterilize heat- and moisture-sensitive products.

HAP -- Hydrocarbon Aerosol Propellant; a flammable aerosol propellant that is widely used throughout the world.

HC -- Hydrocarbon; commonly used substitutes for CFCs in aerosol propellants. Hydrocarbons are also VOCs and their use may be restricted or prohibited in some areas.

GWP -- Global Warming Potential; potential for certain gaseous substances to contribute to the warming of the Earth's surface.

IPA -- Isopropyl Alcohol; an organic solvent which is a potential substitute to replace carbon tetrachloride. IPA is extremely flammable and requires special care in handling.

LEL -- Lower Explosive Limit; minimum concentration of a chemical in air required for the chemical to ignite.

LPGs -- Liquified Petroleum Gases; occur naturally as a constituent of wet natural gas or crude oil or produced as a by-product of petroleum refining. Hydrocarbons are derived from LPGs.

MCF -- Methyl Chloroform, also known as 1,1,1-trichloroethane; commonly used as a solvent in a variety of metal, electronic, and precision cleaning applications.

MDIs -- Metered Dose Inhalants; a method of dispensing inhaled pulmonary drugs.

MEK -- Methyl Ethyl Ketone; an organic solvent which is a potential substitute for carbon tetrachloride in a variety of hand-wipe and aerosol cleaning applications.

ODP -- Ozone-Depletion Potential; the potential for a given chemical substance to decrease the levels of ozone in the stratosphere. The substances implicated generally contain chlorine or bromine. ODP is measured relative to the chemical CFC-11, which has an ODP of 1.0.

ODS -- Ozone-Depleting Substance; any substance with an ODP greater than 0.

OSHA -- United States Occupational Health and Safety Administration

PEL -- Permissible Exposure Limit; maximum exposure to a given chemical recommended by the US Occupational Safety and Health Administration (OSHA) to protect worker health and safety.

PMA -- Propylene Glycol Methyl Ether Acetate; an organic solvent which is a potential substitute for carbon tetrachloride in a variety of hand-wipe and aerosol cleaning applications.

TCA -- 1,1,1-Trichloroethane, also known as methyl chloroform; commonly used as a solvent in a variety of metal, electronic, and precision cleaning applications.

Transitional Substances -- Chemical replacements (such as hydrochlorofluorocarbons) for CFCs and other controlled substances which have a relatively low ODP. They will be necessary in some applications in the short to medium term to enable a rapid phaseout of controlled substances to take place. These substances are scheduled to be phased out by the year 2030 under the Montreal Protocol.

UNEP -- United Nations Environment Programme

UNEP IE/PAC -- United Nations Environment Programme Industry and Environment Programme Activity Centre

USEPA -- United States Environmental Protection Agency

VOC -- Volatile Organic Compounds; compounds that will evaporate at their temperature of use and which, by a photochemical reaction, will cause atmospheric oxygen to be converted into potential smog-promoting tropospheric ozone under favorable climatic conditions.

WGL -- Workplace Guidance Level; a long-term worker exposure limit set by the USEPA.

Annex C - Contacts for Additional Information

American Conference of Governmental Industrial Hygienists (ACGIH)
Attn: William D. Kelley, Executive Secretary
Bldg. D-7
6500 Glenway Ave.
Cincinnati, OH 45211
USA
Tel:(1) 513 661 7881
Fax:(1) 513 661 7195

Center for Emissions Control (CEC)
Attn: Stephen P. Risotto, Executive Director
1025 Connecticut Avenue, N.W.
Suite 712
Washington, D.C. 20036
USA
Tel:(1) 202 785 4374
Fax:(1) 202 223 5979

Chemical Specialties Manufacturers Association (CSMA)
Attn: Ralph Engel, President
1913 I St., N.W.
Washington, D.C. 20006
USA
Tel:(1) 202 872 8110
Fax:(1) 202 872 8114

Global Center for Process Change
Attn: William G. Kenyon, Director
P.O.Box 553
Montchanin, DE 19710-0553
USA
Tel:(1) 302 652 5597
Fax:(1) 302 652 5701

International Agency for Research on Cancer (IARC)
Attn: Lorenzo Tomatis, Director
150, cours Albert-Thomas
F-69372 Lyon Cedex 08
France
Tel:(33) 1 72 73 84 85
Fax:(33) 1 72 73 85 75

National Fire Protection Association (NFPA)
Attn: Robert W. Grant, President
One Batterymarch Park
P.O.Box 9101
Quincy, MA 02269-9101
USA
Tel:(1) 617 770 3000
Fax:(1) 617 770 0700

United Nations Development Programme (UNDP)
Attn: Frank Pinto
1 United Nations Plaza
New York
NY 10017 USA
Tel:(1) 212 906 5042
Fax:(1) 212 906 6947

United Nations Environment Programme Industry and Environment Programme Activity Centre (UNEP IE/PAC)
Attn: R. Shende
39-43 Quai Andre Citroën
75739 Paris Cedex 15
France
Tel:(33) 1 44 37 14 50
Fax:(33) 1 44 37 14 74

United Nations Environment Programme Technical Options Committee for Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride
Attn: Andrea Hinwood, Chair
G.P.O. Box 4395QQ
Melbourne, Vic 3001
Australia
Tel:(61) 3 628 5290
Fax:(61) 3 628 5945

United Nations Environment Programme Technical Options Committee for Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride
Attn: Helen Tope
Environmental Protection Authority
5th Floor, 235 Queen St.
Melbourne Vic 3000
Australia
Tel:(61) 3 628 5292
Tel:(61) 3 628 5945

United Nations Environment Programme Technical Options Committee for Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride
Attn: Jose Pons Pons, Vice-Chair
Spray Quimica CA
Urb Ind SOCO
Calle Sur Edo Aragua
La Victoria 079
Venezuela
Tel:(58) 44 210 465/44 220 192
Fax:(58) 44 220 197

United States Environmental Protection Agency, Stratospheric Protection Division
6205J
401 M St., S.W.
Washington, D.C. 20460
USA
Tel:(1) 202 775 6677
Fax:(1) 202 775 6681

United Nations Industrial Development Organization (UNIDO)
Attn: Mrs. A. Tcheknavorian
P.O. Box 300
A-1400 Vienna
Austria
Tel:(43) 1 211 310
Fax:(43) 1 2307 449

United States Occupational Safety and Health Administration (OSHA)
200 Constitution Ave., N.W.
Washington, D.C. 20210
USA
Tel:(1) 202 219 8148
Fax:(1) 202 219 5986

World Bank
Attn: Mr. Ken Newcombe
1818 H. Street N.W.
Washington DC
20433 USA
Tel:(1) 202 477 1234
Fax:(1) 202 676 0483

Annex D - Data Collection Method Used to Develop the Suppliers List

Due to the large number of suppliers of alternative technologies, the lists of suppliers contained in this catalogue are not comprehensive. They were derived from a number of information sources during preparation of the catalogue. The initial list of suppliers for each datasheet was compiled from in-house resources at ICF Incorporated. These lists were then supplemented with information obtained from printed literature. This literature included trade journals, conference proceedings, technical papers, and books. Many of the suppliers ultimately included in the catalogue were identified using the 1992 and 1993 Buying Guide issues of Spray Technology magazine. Suppliers identified from the sources described above were then contacted and asked to provide information on their worldwide distributors.

A large number of individuals and organizations were contacted by ICF Incorporated during the preparation of this catalogue. The primary reason for this contact was to obtain and verify technical information. The preparation of the catalogue was an interactive process that involved ongoing contact with multiple industry experts. Many of these experts also participated in a peer review of the catalogue. All individuals and organizations that made a material contribution to the preparation of this catalogue are listed in the Acknowledgements, Lists of Suppliers (associated with the datasheets), or Points of Contact (Annex C).

Annex E - Request for Information

The catalogues are **"living"** documents that will be updated on a regular basis to reflect technological advancements, new products, and changing control measures.

Information is welcome both on alternatives to uses covered in the catalogue as well as on alternatives not discussed.

If your technology or equipment should be included in the next version, please use the form in Annex E to supply this information to:

United Nations Environment Programme
Industry and Environment Programme Activity Centre
39-43 Quai André Citroën
75739 Paris Cedex 15
France
Fax: (33) 1 44 37 14 74

AEROSOLS, STERILANTS, MISCELLANEOUS USES, AND CARBON TETRACHLORIDE ODS USES DATA FORM

Name: ______________________

Title: ______________________

Company: ______________________

Address: ______________________

____

Telephone: ______________________ **Fax:** ______________________

Use Description

Name of Use: ______________________

Brief Description of Use:

ODS Used (e.g., CFC-113): ______________________

Industry Sectors Using ODS-based Product (e.g., aerosol propellant, sterilization, tobacco expansion):

Non-ODS Alternatives Commercially Available (if necessary, please use a separate sheet for each alternative):

Name of Alternative: ______________________

Supplier(s)	Contact	Phone/Fax Numbers

Suppliers of: ☐ **Chemicals** ☐ **Equipment (Please specify)**

Company(s) Using Non-ODS Alternative:

Company	Contact	Phone/Fax Numbers

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