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CHEMICAL TECHNOLOGY AND ECONOMICS IN ENVIRONMENTAL PERSPECTIVES

TASK V - INVESTIGATION OF ALTERNATIVES FOR SELECTED AEROSOL PROPELLANT AND RELATED APPLICATIONS OF FLUOROCARBONS

ENVIRONMENTAL PROTECTION AGENCY
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CHEMICAL TECHNOLOGY AND ECONOMICS IN ENVIRONMENTAL PERSPECTIVES

Task V - Investigation of Alternatives for Selected Aerosol Propellants and Related Applications of Chlorofluorocarbons

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Project Officer
Charles Auer

Office of Toxic Substances
Environmental Protection Agency
Washington, D.C. 20460

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NOTICE

PREFACE

This report presents the results of Task V of a project entitled "Chemical Technology and Economics in Environmental Perspectives" performed by Midwest Research Institute (MRI) under Contract No. 68-01-3201 for the Office of Toxic Substances of the U.S. Environmental Protection Agency (EPA). Mr. Charles Auer was the project officer for EPA.

Contributors to portions of this task were Dr. Thomas W. Lapp, Mr. Gary L. Kelso, Mr. Howard Gadberry, Dr. Thomas Milne, Mr. Larry Breed, and Mr. Melvin Lavik. Mr. William L. Bell served as a technical consultant for the pesticidal components of this report. Dr. Lapp is project leader for this contract. This report was prepared under the supervision of Dr. Edward W. Lawless, Head, Technology Assessment Section. This program has MRI Project No. 4101-L.

Midwest Research Institute would like to express its sincere appreciation to those individuals and companies who provided technical information for this report.

Approved for:

MIDWEST RESEARCH INSTITUTE

L. J. Shannon

L. J. Shannon, Director
Environmental and Materials
Sciences Division

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INTRODUCTION

In October 1976, an interagency workgroup (comprised of representatives from the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the Consumer Product Safety Commission (CPSC)) initiated examination of regulatory options for controlling the environmental release of certain halocarbon compounds that pose a threat to stratospheric ozone. The initial concern of the work group was primarily with the use of fully halogenated chlorofluoroalkanes as aerosol propellants. Several specific aerosol propellant applications, as well as some other related applications, were brought to the attention of the work group by interested parties as possibly being "essential uses" of these substances. The purpose of this task was to investigate these applications to identify the available and technologically feasible alternatives and, to the extent possible, examine the cost factors associated with these alternatives.

It must be emphasized that the determination of the essentiality of these products for regulating purposes was not to be made by MRI in this task. These determinations were, and are being, made by the workgroup using the information generated here as well as information made available to the workgroup from other sources.

SECTION 2

SPECIFIC PRODUCT TYPES

This section presents an analysis of each of 19 specific aerosol product types that use chlorofluorocarbons. Information provided for each product type includes a general description, its utility, alternatives to it, and a brief analysis of the economic aspects of the alternatives or lack of alternatives. Within the product description and utility, data are presented for which chlorofluorocarbons are utilized, their primary and/or secondary functions, specific characteristics contributed to the product by the chlorofluorocarbons, consumers of the product, and the amount of chlorofluorocarbon used annually in the product. The alternatives portion provides a discussion of alternative propellants for aerosol products, nonaerosol methods for delivering the same goods or services, and the availability of each of the alternatives. Economic aspects were limited to the impact of the alternative delivery method on the consumer or user of the product and any impacts resulting downstream from the consumer or user.

FLYING INSECT PESTICIDES

Product Description and Utility[1,2]

These aerosol products are used by industry, institutions, and the general public for the control of flying and crawling insects. A number of different product types are included in this general category.

Space-spray aerosols are designed for volumetric treatment in and around food processing plants, restaurants, farms, hospitals, and other industrial-institutional locations for fly and other pest control. They are also used for both indoor and outdoor residential applications. The effectiveness of this type of aerosol results from its dispersion of a very finely divided product in the form of a mist or fog with a very long residence time in the atmosphere (hang time).

Total release aerosols and metered valve aerosols require the same basic spray characteristics as those for space-spray aerosols. With total release aerosols, a given quantity of insecticide is packaged in an aerosol container with a lock-open actuator to allow the total contents of the container to be released at one time. Metered valve aerosols allow only the release of a preset quantity of spray per electronically timed actuation. Normally, the quantity of spray released per actuation is of the order of 100 mg. These two systems, total release and metered, find usage against flying and crawling insects in the industrial, institutional, governmental, and commercial sector as well as for certain residential applications.

Wasp and hornet sprays are utilized primarily by industries whose workers may encounter these pests during outside activities. Linemen for utility companies are major users of this product. Immediate knockdown of the wasp or hornet is of primary importance, more so than its actual death. A second major concern of this product is electrical shock to the lineman. Serious injury and even death of the lineman can occur if the spray propellant conducts electricity. These products are often sprayed directly into or onto high voltage transformers.

The primary fluorocarbon propellants used in these products are F-11 and F-12. Annual consumption of F-11 and F-12 is difficult to assess in this market. An estimate was made by Mr. Richard Vega of Whitmire Research Laboratories, Inc., St. Louis, Missouri, that about 26,400,000 lb of F-11 and F-12 were consumed in these products in 1974, based upon figures from the U.S. Department of Commerce study, "Economic Significance of Fluorocarbons," December 1975.[2]

The removal of flying insect pesticide products from the market without replacement with an alternative would have environmental quality, human health, and human safety implications. Environmental contamination by the pesticides (i.e., pyrethrum) would be eliminated. However, pyrethrum degrades rapidly in the environment. Human health and safety would be affected both positively and negatively. On the positive side, humans would not be exposed to inhalation, absorption, or ingestion of the pesticides, some of which are acutely and chronically toxic to man. On the negative side, the control of flying insects would be foregone, and humans would be exposed to risk from these insects. One example of this risk would be the inability of utility linemen to kill stinging wasps and hornets when far above ground and unprotected from attack. Another example would be the lack of control of the housefly in restaurants, hospitals, food processing plants, etc., where this insect could transmit such diseases as cholera, dysentery, typhoid fever, plague, and tuberculosis to humans either directly or indirectly through contaminated foodstuffs.

On balance, the removal of these products from the market without replacement would have positive environmental effects but would expose man to serious risk from uncontrolled insects and disease transmission.

Alternative Products or Systems

Space Sprays--

Alternative products or systems for destroying flying insects must produce an aerosol to allow the pesticide to remain suspended in the air to be effective. Alternatives that have been tested are given in the following paragraphs.

Compressed air gun (atomizer)--This system would result in an insufficient decrease in particle size which results in a shorter hang time in the air and a reduced kill ratio. Therefore, an increased volume of insecticide would be required per unit area to be treated and an increase in the total volume of solvent would be necessary. Since more total product (ingredient plus solvent) is being utilized, an increase in application time would result. For those industries or institutions in which food may be in contact with the sprayed areas, the settled residue must be cleaned up before the food can be processed. The increased volume of total product utilized will require increased maintenance time for the cleanup procedure. An explosion or fire potential exists due to the petroleum distillate used as the solvent.

This system would increase environmental contamination and increase human exposure to the pesticides without increasing the effectiveness of the product. Human risk from fire hazards and pesticide exposure would increase.

Foggers--Thermal mechanical methods generally result in insufficient break up of the active ingredients to produce the true aerosol necessary for space-sprays. With thermal foggers, some of the active ingredient can be lost during burning of the solvent. As with atomizers, a large volume is required for treatment of the same area, resulting in longer application times. For those industries which operate three shifts per day, spraying is normally done during the shift changes. Extended application and clean up time results in an interruption of the work process and loss of productivity. Clean up time for this method would generally be less than for the atomizer, but greater than for aerosols. For thermal foggers, the use of properly trained personnel is required to insure proper operation and maintenance of the fogging equipment. During operation, a low burning temperature will result in insufficient fog production while too high burning temperatures will result in high ingredient loss. An explosion or fire potential exists due to the unburned petroleum distillate used as solvent and fuel.

Environmental contamination and human risk from pesticide exposure, and fire hazards would increase without any increase in pest control effectiveness.

Compressed gas aerosols (N_2, N_2O, CO_2)--Pressure reduction as the volume of the contents decreases is the major drawback for compressed gases other than carbon dioxide. With carbon dioxide, impact filling could be used to alleviate the pressure loss problem; however, the resultant spray is still "coarser" than that obtained with chlorofluorocarbons. This coarse spray is not acceptable for space-spray application due to the shorter residence time in the air (decreased hang time).

Hydrocarbon aerosols--Pure hydrocarbon propellants can achieve the spray characteristics necessary for space-spray applications with an overall decrease in the total cost of the product compared to using F-12 as the propellant. However, an extreme flammability and explosion problem is presented by the hydrocarbons in these systems, not only in terms of flashback, but also from accumulation of the hydrocarbons in the working area. This system would increase human risk by creating dangerous fire hazards unless fire retardants are used.

Certain additives to hydrocarbons were investigated as possible fire retardants. Water can be incorporated into the pesticide solvent system in sufficient quantities to render the aerosol spray nonflammable. While this system is typically used in household insecticide sprays, it does not produce the true aerosol spray required for efficient space-spraying. The larger particle size resulting from this combination results in a shorter hang time, more fallout, and less killing efficiency. Increased consumption of product (and therefore, increased environmental release of pesticide) would be required for the same killing efficiency of the F-12 propelled sprays. Increased maintenance and clean up time would be required due to the greater quantities of fallout. Humans would be subjected to greater exposure to the pesticides and environmental contamination would increase.

Certain chlorinated hydrocarbons, such as methylene chloride, methyl chloroform, or others, could be added to the hydrocarbon to reduce the flammability potential. Formulations of this type have been attempted but the resultant particle size was too large, resulting in insufficient hang time in the air and the same resultant problems stated for the use of water as an additive (i.e., more fallout and less killing efficiency).[3/]

Products contained in aluminum cylinders cannot be reformulated using a mixture of chlorinated hydrocarbons as nonflammable solvents due to compatibility problems with aluminum.[3/] Pure methylene chloride can be used, but no other common chlorinated hydrocarbon.

F-22 as a propellant--F-22 could be used as an alternative propellant system if it were available. Reformulation of the current products and testing of the new product in terms of efficacy would be necessary.

Reduced F-12 content--Reformulation of current products could result in a significant reduction in the quantity of F-12 consumed in space-spray applications. According to the information submitted by Whitmire Research Laboratories, Inc.,[2/] reformulation could result in a F-12 reduction from 80% by weight to 20% by weight without loss of the spray characteristics necessary for space-spray applications. Virginia Chemicals, Inc.,[3/] and Mr. William L. Bell,[1/] MRI consultant, concur that a reformulation of this type would be feasible and lead to a significant reduction in F-12 consumpton in this use category. Virginia Chemicals, Inc., however, stated that they have not attempted a reformulation of this nature and would require product testing before they would definitely concur with this method.

Wasp and Hornet Sprays--

As stated previously, immediate knockdown of wasps and hornets is of more importance than actual death. Since these products are used in and around high voltage equipment, they must be completely nonflammable, electrically nonconductive, and have a spray range of 8 to 10 ft.

This product line does not require an aerosol in the normal meaning of the term. The propellant, plus a small quantity of insecticide, remains as a jet stream instead of being dispersed as tiny particles over a large volume as in a space-spray or a normal aerosol spray. Upon contact with the wasp, hornet, or the nest, the solvent propellant rapidly evaporates to create the cooling effect used to immobilize the pest. Subsequent to the immobilization, the pesticidal ingredient (e.g., pyrethrum) acts to kill the wasp or hornet. Alternative propellant systems are suggested below, but the primary problem to be incurred in this area is the time required for reformulation of the product, insecticidal efficacy testing, and testing of flammability and dielectric properties to meet utility and telephone company specifications. The total time required would be of the order of 1 to 1-1/2 years.[4/]

Alternative propellant systems for wasp and hornet sprays are given in the following paragraphs. Approximately 40% of the total weight is due to the propellant.[4/]

Carbon dioxide plus chlorinated hydrocarbon--This propellant system is probably a feasible alternative using a nonflammable chlorinated hydrocarbon (e.g., methylene chloride) in conjunction with carbon dioxide. A component ratio of 4% carbon dioxide and 36% methylene chloride in the propellant system would appear to be an appropriate mixture to provide the same properties now available with F-12 systems.[4/]

F-22 as a propellant--F-22 would be an alternative component of the propellant system. Since the pressure of F-22 is higher than that for F-12, the composition of the propellant system would be approximately 13% F-22 and 27% nonflammable chlorinated hydrocarbon (e.g., methylene chloride).[4/]

Carbon dioxide plus nitrogen--This alternative propellant system has not been completely tested. If acceptable, it would prove to be an extremely inexpensive propellant system. A propellant composition of 4% carbon dioxide and 36% nitrogen (to provide head pressure) may be a feasible combination.[4/]

Mixtures of chlorinated hydrocarbons--Mixtures of various nonflammable chlorinated hydrocarbons may be feasible alternative propellant systems but very little research has been conducted on these types of systems.[4/]

None of these alternatives, if adopted, would have any effect on environmental quality, human health, or human safety relative to the F-12 systems.

EPA Office of Pesticide Program's Labeling Requirements--

All of the products included in this report are subject to registration with the EPA Office of Pesticide Programs and any change in the composition of such products would require reregistration of these materials. The time required for the reregistration process can, in some instances, take as long as 1 year. If product reformulation with a reduced F-12 content or other changes in formulation are to be required within specific time limitations, then either temporary labeling permits for the conversion should be considered or the time required for reregistration should be incorporated into the time limitation set forth for reformulation to accommodate new propellant systems.

Economic Considerations

Space Sprays--

Cost considerations for atomizers and foggers have been presented in a previous submission to the CFC work group by Whitmire Research Laboratories, Inc.[2/] This submission showed that the use of a bulk space spray and fogger was about three to nine times more expensive than the current chlorofluorocarbon propelled aerosol, used 200 times more petroleum oil, and was about six times more time consuming. The use of F-22 as a component of the propellant system as an alternative to F-12, would result in basically no increase in product cost to the consumer. Although F-22 is more expensive than F-11 or F-12 ($0.66/lb versus $0.42/lb),[5/] the lower cost of the added pressure depressant would equalize the higher cost of the F-22.

For the alternative involving a reduced F-12 content in the propellant system, the two formulations are as follows:[2/]

Formula I:

	% w/w
Active ingredient + solvent:	20.0
Blend of F-11 + F-12:	80.0

Formula II:

	% w/w
Active ingredient + solvent:	20.0
Nonflammable solvent:	56.0
F-12:	20.0
Carbon dioxide:	4.0

Neglecting active ingredient and solvent costs, the economics of the two propellant systems[5/] on a per pound of product basis are:

I. 80% F-11 and F-12: $0.42/lb average cost x 80% = $0.34
(F-11 $0.40/lb)
(F-12 $0.44/lb)

II. 56% nonflammable solvent: $0.22 x 0.56 = $0.12
(methylene chloride $0.21/lb)
(methyl chloroform $0.23/lb)

20% F-12: $0.44 x 0.20 = $0.09
4% carbon dioxide: negligible

Total Cost $0.21

It may be necessary for some fillers to purchase a carbon dioxide tank and filling line, but these costs would be offset by the $0.13 savings on propellant costs.

The costs to the consumer would remain about the same for these alternatives as the present cost of existing F-11 and F-12 systems.

Wasp and Hornet Sprays--

Economic factors for carbon dioxide plus methylene chloride, F-22 plus methylene chloride, and carbon dioxide plus nitrogen are presented in the following paragraphs. The cost of the current F-12 propellant systems on a per pound basis is: $0.44/lb x 0.40 = $0.18.

I. Carbon dioxide plus methylene chloride:
36% methylene chloride: $0.21 x 0.36 = $0.08
4% carbon dioxide: negligible

Total Cost $0.08

Some added cost may be incurred by some fillers for a carbon dioxide storage tank but these costs should be offset by the $0.10 savings per pound of product.

II. F-22 plus methylene chloride:
13% F-22: $0.66 x 0.13 = $0.09
27% methylene chloride: $0.21 x 0.27 = 0.06

Total Cost $0.15

III. Nitrogen plus carbon dioxide:
36% nitrogen: $0.08[6] x 0.36 = $0.03
4% carbon dioxide: negligible

Total Cost $0.03

The nitrogen price is based on high purity nitrogen gas from liquid nitrogen. This system would necessitate a liquid nitrogen storage, which can be rented from the supplier. Rental cost for a 1,500 gal. capacity storage tank would be about $250/month.[6]

In general, the use of any of the above alternative propellants should not result in any increase in cost to the consumer.

OTHER PESTICIDES

Product Description and Utility

Pesticides are packaged and sold in aerosol containers for a variety of uses. Residual sprays are applied to surfaces in homes and businesses to destroy insects such as ants, spiders, roaches, etc. House and garden sprays are applied to plants and soil to destroy various pests. Pet sprays are applied directly to animals to destroy parasites and nuisance pests.

These pesticides all depend upon their residual effect, as well as their contact effect, for effectiveness against pests. Some of them remain effective for weeks and even months after application, and are capable of destroying pests not present at the time of application.

The principal consumers of these products are households. Some commercial, industrial, and governmental establishments also use these products, but to a much lesser extent. The various products marketed are numerous and it would be very difficult to estimate the total sales and consumption of this market. Therefore, the amounts of fluorocarbons, principally F-11 and F-12, consumer annually by these products cannot be estimated.

The removal of these pesticide products from the market without replacement by an alternative would have some impacts on the environment, human health, and human safety. Environmental contamination by these pesticides would be eliminated. Human health and safety would be both positive and negatively affected. These pesticides destroy insects detrimental to man's health and safety, and these insects, if left uncontrolled, would put exposed humans at risk. On the other hand, humans would no longer be exposed to the pesticides, some of which are harmful to human health through their acute and chronic toxicities, and may receive health benefits from the absence of these pesticides. The overall health effects would be, in most cases, detrimental to humans since insects carry many diseases that are human health risks, while most of the pesticides are relatively harmless to man. This overall effect on man, however, would have to be determined on a case-by-case basis, and would depend primarily on the specific pesticide and the pest it controls.

Alternative Products or Systems

All of the applications of these products depend upon a residue of pesticide remaining on the contact surface for effectiveness against pests. The pesticides can be applied in various ways which do not require the use of an aerosol spray, or they can be applied in aerosol form using alternative propellants. Therefore, several alternative systems and products are available as effective substitutes for these surface spray aerosol products.

Alternate Propellants--[2,3]

Compressed gases such as carbon dioxide, nitrous oxide, and nitrogen are commonly used as propellants for surface spray aerosols. They dispense the product as a coarse wet spray, and are relatively safe to both humans and the environment. Some pesticide products on the market today use these gases, and the F-11 and F-12 propellants could be replaced by them without loss of pesticidal effectiveness in residual sprays.

Hydrocarbon propellants, such as butane, isobutane, and propane can also be substituted for F-11 and F-12, although the hydrocarbons are flammable and do pose a risk to human safety. This risk could be minimized in most cases by adding fire retardants or water to the hydrocarbons.

Pet sprays could use carbon dioxide or propane as propellants once FDA approval for their usage in pet sprays is obtained.

Alternate Technologies--

Nonaerosol applications of these pesticides can be effectively made by mixing the active ingredient in a suitable water or hydrocarbon emulsion carrier, and either spraying or brushing the mixture onto the intended surfaces. Spray applications can be made from any available mechanical device, such as a backpack sprayer or mechanical pump sprayer.

Economic Considerations

The economic impact on the consumer of substituting brush and nonaerosol spray applications for the aerosol cans would be a reduction in cost, since aerosol products are more expensive on an active ingredient basis than products packaged in bottles or hand-held mechanical pump spray applicators. The cost to the consumer of converting aerosol products with F-11 and F-12 propellants to aerosol products containing compressed gases or hydrocarbons would remain about the same. For small formulators-fillers, conversion to hydrocarbon propellants may increase the consumer cost for the products since expensive facilities are required to fill with the flammable hydrocarbon.[2]

SPRAY PAINTS

Product Description and Utility

Aerosol spray paint products normally are composed of the paint or enamel formulation, solvent, and propellant. These products are usually packaged in small (8- to 16-oz) containers for use by the general public and for minor industrial applications, such as "touch-up" or low volume, small area uses. For those formulations using chlorofluorocarbons, the principal propellant is F-12. The sole function of the F-12 is to provide a propellant system for the product.

In terms of total usage of aerosol spray paints, 90 to 95% of these products use hydrocarbons or hydrocarbon mixtures as the propellant.[7,8] Based on 1974 aerosol production figures[8] and assuming an average container size of 16 oz, it can be calculated that F-12 consumption for aerosol paint products would be in the range of 6 to 12 million pounds per year.

In general, spray paint formulations in small, portable aerosol containers provide a rapid and inexpensive method of applying a thin, smooth coating for occasional and touch-up paint applications. On a continued or high-volume use basis, however, this product is not an inexpensive method of delivery. The removal of F-12 as the propellant system should have no known impacts on environmental quality or human health and safety since the vast majority of the spray paint products currently utilize hydrocarbon mixtures as the propellant system.

Alternative Products or Systems

Brush Application--

This obvious method could be used provided that a uniform, thin layer of paint was not required. Brush application may be satisfactory for very specific applications.

Hydrocarbon Propellants--

This is the most universal method for the spray application of paints. Since the vast majority of spray paints are currently propelled in this manner, no formulation or other technical problems should be incurred.

In terms of actual production of hydrocarbon-propelled products, contract fillers are currently equipped to produce these items.[9] For all fillers, the same aerosol system, including cap, can and aerosol valve, can be used for hydrocarbons as is currently employed with the F-12 system.[10] For very low volume, highly specialized products, aerosol containers prefilled with hydrocarbon propellant, are available.[11] With this system, the only ingredient added to the container is the paint formulation.

Economic Considerations

There should be no economic impact associated with the use of hydrocarbon mixtures as a propellant system on consumers or users of these products. On the current retail market, hydrocarbon-propelled spray paint formulations are priced competitively with those products that are F-12-propelled. For those industries using aerosol spray paint products for small use applications and touch up work, no increased costs can be envisioned which would ultimately be passed on to the consumer in the form of higher prices.

AIR BRUSHES

Product Description and Utility

Air brushes are devices that permit precise control in the spray application of fluids (usually ink or paint colors) to the working surface without physical contact. Air brushes are most widely used in the following applications:[12,13]

- Photographic retouching
- Technical illustration (machinery, etc.)
- Automotive refinishing
- Graphic arts, advertising layout
- Poster and sign art
- Masters for engravings
- Ceramic and porcelain decoration
- Hobby and model painting
- Murals on vans and recreational vehicles
- Fine arts painting

Although the overwhelming majority of air brushes are powered (as the name suggests) by means of compressed air, CFC (F-11 and F-12) containers have been employed as an alternative source of gas since at least 1939.[13]

At present, there are five principal U.S. suppliers of air brushes. Most manufacturers offer several levels or grades of air brush equipment intended for intensive use by commercial artists (typical cost $55 to $125), and also less expensive models intended primarily for limited use by the amateur hobbyist or beginning artist.[14]

Only two manufacturers currently offer CFC propellant cans as part of their regular line. The Poosche unit is offered complete with two cans of propellant in a compact carrying case called the "Travelers' Kit.®" Badger supplies cans of propellant along with a flowrate limiting "regulator" in both 14- and 21-oz cans.

CFC cans intended for use with air brushes are equipped with a special valve which fits the screw-adjustable flow limiting regulator. Therefore, the air conditioner recharge cans that are widely available cannot normally be used. Badger Air Brush Company reported that a total of 160,000 lb of F-11 and F-12 was used during 1976. Poosche had no definite information on usage, but believed their sales of canned propellant were much smaller. Total usage probably does not exceed 250,000 lb/year.

An intensive effort was made to identify those air brush users who currently employ chlorofluorocarbon propellant, and to ascertain the type of artwork which they execute. None of the manufacturers maintain records that could identify either users or type of application.[15-19] Both Badger[15] and Poosche[16] representatives could only speculate that chlorofluorocarbon can propellant use was largely confined to amateur artists and hobbyists who did not want to spend $35 to $75 on an air compessor--particularly if they were using a $10 to $30 air brush. Discussions with leading artists' supply firms tended to confirm this view, although neither firm could recall selling canned propellants within the past 12 months.[20,21]

Interviews with a wide range of both commercial artists and fine artists within the Kansas City, Missouri, area produced unanimous expressions that few, if any serious or professional artists have ever used chlorofluorocarbons as an air brush propellant. Only one informant had ever encountered an associate who had ever tried canned propellant. This survey included advertising studios, greeting card manufacturers, automotive refinishers, commercial illustrators, motorcycle decorators, fine art teachers and artists, van painters, and photographic retouchers. All artists used either a compressed air source, or employed a tank of liquified carbon dioxide. None of the air brush users interviewed could ever recall a job where a compact and portable source of propellant was essential.

A similar survey of hobby and craft shops disclosed that virtually all outlets carry either the Badger or Poosche air brush equipment with chlorofluorocarbon can propellant.[22-25] One source estimated that up to 20% of the serious model builders in the nation own air brush equipment for detailed painting.[23] Hobby and craft shop operators estimate that the typical user purchases and uses from one to four cans of propellant, and then switches to a pneumatic tire adaptor. Only one amateur out of 25 is believed to switch to a compressor.[24]

The removal of this product from the market will have no adverse impacts on environmental quality, human health, or human safety.

Alternative Products or Systems

The requirements for air brush operation are a dry, oil-free source of gas, at controlled and steady pressures of 14 to 30 psig, and flow rates ranging from 0.1 to 0.5 standard cubic feet of gas per minute.

The alternative sources of gas suitable for air brush operation are described in the following subsections.

Small Air Compressors Attached Directly to Air Brush--

Most manufacturers offer small (i.e., 1/8 to 1/10 hp) compressors suitable for limited air brush work. These compressors cost from $30 to $80.[14]

Larger Air Compressors With Accumulator Tank--

Compressors from 1/3 to 1 hp, equipped with automatic control and a pressure tank, can be located remotely to reduce annoying noise. Such compressors and piped air lines can supply an entire studio or automotive paint shop.

Carbon Dioxide Tanks--

Various sizes of liquified CO_2 tanks are widely used for air brush operation. Large studios mainly employ 25-lb or 50-lb tanks supplying sufficient gas to operate virtually full time for 1-1/2 to 3 months between refills.

Some artists prefer to use smaller bottles holding 2.5 lb (3-in. diameter x 15-in. aluminum fire extinguisher bottle), down to the 0.5-lb "lecture bottle" (2-in. diameter x 15-in.).

These smaller containers are locally refillable. The cost of using carbon dioxide is relatively low, and the tanks are leased from the supplier.

The main deterrent to wider use of CO_2 lies in the requirement for a high quality and relatively expensive pressure reducer and regulator. The CO_2 regulator and pressure guage costs from $35 to $50.

Compressed Air Tanks--

These are not widely used without a compressor because the working capacity is limited.

Pneumatic Tires--

For the occasional air brush user who wishes to avoid the expense of purchasing a compressor or CO_2 bottle and regulator, an automobile or tractor tire can be used as a pressure source. Badger Air Brush Company offers a tire adaptor (No. 50-029) at a cost of $1.25.[14]

Economic Considerations

If 250,000 lb (approximately 330,000 12-oz cans) are purchased annually at a cost of $2.80 each, present consumer expenditures are nearly $1 million per year.

Since no figures are available regarding the number of air brush users who rely on chlorofluorocarbon propellant, an estimate can be made with the assumption that any air brush user who anticipates requiring more than six cans of propellant costing $17 will switch to some other source of gas pressure. Salesmen interviewed were in relatively good agreement that the average user purchases only from two to four cans and then goes to some other source. This suggests that the 330,000 cans sold annually may be purchased by about 100,000 relatively new air brush users. Cumulative amateur air brush owners may easily number from 250,000 to 400,000 users, the majority of whom have switched to sources other than chlorofluorocarbons.

Restrictions on the availability of chlorofluorocarbon propellant for air brush use would require that these 100,000 new users per year find an alternative source. Hobby dealers report that most of their customers choose the least expensive option--a tire adaptor costing $1.25. If as many as 20% of serious hobbyists purchased a compressor costing $35 to $70, the additional expenditure required would be roughly $1 million per year. This figure is comparable to present expenditures for chlorofluorocarbon propellant.

Three of the air brush manufacturers volunteered information that they view any restrictions on chlorofluorocarbon use as an opportunity to develop and introduce either an improved, low cost ($20 to $30) compressor, or inexpensive flow limiting regulators for use with carbon dioxide.

The impact of chlorofluorocarbon restrictions would primarily affect amateur artists and hobbyists. Restrictions would have little if any effect on commercial and graphic arts users according to a wide variety of users surveyed.

MINE WARNING DEVICE

Product Description and Utility

The purpose of the aerosol mine warning device is to warn miners throughout the mine to evacuate when there is danger. Because the more typical warning devices, such as alarm bells and lights, are susceptible to failure, or sometimes cannot be seen or heard by all miners, an odor warning is employed.

The specific product involved is manufactured by Zip Aerosol Products, and is designated as "MWD-100 Mercaptan Stench Cartridge." Each cartridge, as supplied, contains 100 g of ethyl mercaptan, plus 1 lb of F-11. The function of the F-11 is not as a propellant, but primarily as a fire inhibitor and solvent-carrier for the mercaptan. The cartridge itself is rated at 300 psi pressure, and is charged with nitrogen gas to a working pressure of 240 psi (charge pressure).[26/] Stench warning systems have been standard in U.S. mining practice for many years. A stench warning system is currently required in all metal and nonmetal mines.[27/] Similar warning systems used in construction tunneling are under OSHA regulation. Actual installations in different mines vary somewhat in design. Each cartridge is rated to provide a clearly detectable odor when dispersed into a specified number of cubic feet of air per minute. Larger mines may employ two cartridges manifolded together to provide double warning capacity. One installation in a Climax mine uses five cartridges manifolded together.[26/] In laboratory tests, the minimum detectable concentration for ethyl mercaptan is <u>1 part in 50 billion parts of air</u>.[28/] Thus, each cartridge handles a very large volume of air.

There are two basic methods of dispensing the stench into the mine ventilating air systems. Where air is distributed through the mine by ordinary (low pressure) air ducts and fans, the mercaptan and F-11 carrier are sprayed under nitrogen pressure into the air duct. Where compressed air ventilating systems using pipes instead of ducts are employed, the cartridge is discharged into the air intake. The pressure and temperature of compressed air in piped systems varies, but conditions of 150 psi and 180°F are frequently encountered. On rare occasions the air temperature near the compressor may be as high as 200°F. This temperature insures rapid vaporization of the F-11 carrier and the mercaptan. It also creates a significant hazard of ignition of the highly inflammable mercaptan unless an adequate fire suppressant agent (F-11 or equivalent) is present.

In certain earlier stench warning systems, mercaptans were mechanically injected directly into the air. This created an extreme hazard because of the low flash point and autoignition temperature of ethyl mercaptan.[28/]

It is important to understand that the purpose and function of the F-11 used in the MWD-100 cartridge is to provide a nonflammable carrier for the ethyl mercaptan which will volatilize along with the mercaptan, and suppress flame at least until the mercaptan concentration in the air stream has been diluted to below the lower explosive limit. The explosive limits for ethyl mercaptan in air are 2.8% and 18.2% by volume.[26] The minimum ignition temperature of the mercaptan in air is 299°C; in oxygen it is 261°C. No ingition temperature is available for air at 150 psi pressure, but by inference, the autoignition temperature would be below 299°C--a fairly low value, indicating an easily ignited vapor.

The properties of the present ingredients in the device are:

1. The nitrogen gas propellant is inert, nontoxic and nonflammable.

2. The F-11 used as a carrier for the ethyl mercaptan in relatively inert. The occupational standard for F-11 in air has been set at 1,000 ppm.[29] Higher concentrations can affect heart rhythms and induce fibrillation, but this happens primarily where a high concentration of vapor is inhaled. The flame inhibiting properties of F-11 are weak; it is not, by itself, a particularly efficient extinguishing agent.[30]

3. Ethyl mercaptan is an irritant and is toxic. The lowest concentration known to have caused toxic effects when inhaled by humans is 4 ppm. The inhalation LC_{50} for rats is 4,420 ppm/4 hr. The U.S. Occupational Standard (USOS) has been set at a ceiling level of 10 ppm in air.[29]

The concentrations of ethyl mercaptan delivered in mine air to the miners would be orders of magnitude lower than the toxic concentrations given above (barring some unusual accident; e.g., the rupture of a stench cartridge in an occupied room, etc.). A useful warning concentration would be 0.01 ppm of mercaptan in air.[31] Thus, a relatively toxic material is expected to be diluted into a large volume of air, rendering it virtually without any significant inhalation toxicity hazard. This is an important point because it indicates that the carrier used with the mercaptan need not have a particularly low level of toxicity since it will also be diluted in air to extremely low concentrations.

Mr. Selleck, Mitann, Incorporated, estimated that they ship approximately 1,000 cartridges per year to U.S. mines as replacements for units that have been used. Total shipments worldwide run to about 2,000 cartridges per year.[26] Thus, the quantity of F-11 discharged to the atmosphere is approximately 1,000 lb/year.

MESA standards currently require that stench warning systems be tested once per year. Thus, there is reason to expect that possibly 65 to 70% of the cartridges replaced each year were those consumed in the testing process.[32]

The removal of this product from the market without replacement by an alternative would expose mine workers to extreme health and safety risks, and would violate safety regulations in all metal and nonmetal mines.

Alternative Products or Systems

The major characteristics needed for an acceptable carrier include:

1. Miscibility with ethyl mercaptan at proportions of 100 g to 1 lb of carrier.

2. Chemical stability, noncorrosive to the DOT 300 cartridge.

3. Suppress flame or explosion over a wide range of vapor concentrations of ethyl mercaptan in air. This is the main purpose behind the use of a volatile carrier.

4. Vapor pressure characteristics approximately similar to those of F-11. The key requirement is a vapor pressure below 250 psig at 140°F. Additionally, the pressure must not drop appreciably at low temperatures; e.g., 35°F.

5. Relatively low toxic hazards. Although it might be acceptable for this particular application to use compounds having toxic properties, a much lower toxic level would be preferable.

F-11, while itself completely nonflammable, is not a particularly good flame suppressing agent.[30] Among the technically feasible flame suppressants that could be employed as replacements for F-11 are:

Candidate Replacements for F-11

Carrier Type	Designation (Halon No.)	B.P. (°F)	V.P. (70°F)	Underwriters Toxicity Class	USOS[a]
Bromochloromethane	1011	153	-	3	TWA 200 ppm
Dibromomethane	-	143	-	N.A.	N.A.
Dibromodifluoromethane	1202	73	15 psia	4	TWA 100 ppm
Bromochlorodifluoromethane	1211	24.8	36 psia	5a	
Bromotrifluoromethane	1301	-72	200 psia	6	N.A.
Mixtures of 1202 and 1301	-				
Mixtures of 1211 and 1011	-				

a/ USOS indicates that an occupational standard has been set for industrial exposures to this agent. TWA = time weighted average.

The properties of the following carriers should rule out their consideration for the reasons cited:

* Dibromotetrafluoroethane - (Halon 2402). Believed to be a cardiac sensitizer at levels of 500 ppm. Excellent extinguishing properties do not offset risks.[33] This compound could potentially play a role in the ozone depletion hypothesis.

* Methyl bromide - High toxicity, CNS poison; USOS air: CL 20 ppm.[29]

* 1,1,1-Trichloroethane - Limited flame suppression, despite relatively low toxicity.[34] Theoretically has been shown to result in ozone depletion.

In discussions with Mr. Lewis Kirk of Du Pont, he suggested the use of mixtures of either Halon 1202 plus 1301, or 1211 with 1301. By choosing the appropriate proportions, the vapor pressure of the mixture can be matched fairly well to that provided by F-11 alone.[33]

The combination of bromochloromethane (Halon 1011) with either 1211 or 1301 appears to be a promising possibility for reformulating the carrier. Similar mixtures incorporating dibromomethane (methylene bromide) offer additional possibilities.[33]

Bromochloromethane (Halon 1011), should also be considered alone as the carrier. Although its boiling point is somewhat higher than that of F-11, it still is a volatile solvent compatible with ethyl mercaptan--and a much more powerful extinguishing agent than any of the nonbrominated chlorofluorocarbons. Bromochloromethane is considerably less expensive than the fluorinated Halon extinguishing agents although it is more expensive than F-11. Despite the fact that for long-term exposures, Halon 1011 is several times more toxic than F-11 (i.e., occupational standards of 1,000 ppm for F-11 versus 200 ppm for bromochloromethane, based on 5-day, 8-hr exposure), there is little reason to expect any significant increase in the practical hazards involved for short-term exposure as diluted down in large volumes of mine air. The major reasons for considering blends of bromochloromethane with the other Halon extinguishing agents would be to obtain a more desirable vapor pressure temperature relationship, or to benefit from the incorporation of 1301. (Halon 1301 is presently the best extinguisher possessing low toxicity, but it has a high vapor pressure.)[33]

Economic Considerations

Since 1 lb of carrier is used in each cartridge, the additional cost to users of alternative carriers can be calculated directly if single agents are employed. The cost of mixtures can only be roughly estimated until the composition is known.

Cost of Present and Potential Carriers

Carrier used	Price/lb	Additional cost/cartridge
F-11	$0.36	None - (currently used)
1011	1.20	$0.84
1211	1.79	1.43[35]
1202	3.75	3.39
1301	2.15	1.79
Mixtures	-	$1.00 to $2.50

Changing to a different carrier would also incur substantial delay time to obtain any needed approval from MESA, OSHA, ICC, insurance carriers, etc. At this time it is not possible to estimate the difficulty and delay involved in clearing any change in carrier used. Because most of the proposed carriers are in commercial use as fire extinguishing agents (F-11 is not), no insurmountable obstacle is known at present to obtaining clearance to employ these agents in the mine warning device.

Mr. Ralph Foster, of the ventilation section of MESA, expressed his belief that the study and approval of some technically satisfactory replacement cartridge could be completed within 6 months to 1 year; certainly no longer than 5 years.[32/] He also indicated that MESA was currently searching for improved stench warning agents that might offer advantages over ethyl mercaptan.

MOLD RELEASE AGENTS

Product Description and Utility

Release agents are used extensively in plastics molding, rubber molding and foundries. Sprays, such as aqueous emulsions and solvent solutions, are suitable as release agents for metal castings. Both emulsion systems and, to a limited extent, chlorofluorocarbon-propelled aerosols find application in the rubber molding industry. Because of special requirements in plastics molding for intricate shapes and fine surface finishes, the chlorofluorocarbon-propelled aerosols are used extensively in this area. Other release systems currently being utilized will not provide the surface finish obtained by the use of chlorofluorocarbon propelled systems.

Propellants utilized in mold release compositions are mixtures of F-11 and F-12. Functional silicones dominate the market (75 to 80%) as the active release component,[36/] but very finely divided fluorocarbon polymers (Vydax®), waxes, zinc stearate, lecithin, and other compositions are also used.[37,38/] The aerosols, solvent sprays, and emulsions may contain as little as 1 to 3% of the active mold release agent.[37/]

Plastic Molding--

Because of the requirements for intricate shapes and fine surface finishes, an extremely fine spray of mold release agent that will deposit a film only a few microns thick on the mold surface is required. In order to achieve such a film, good wetting and spreading properties are required for the compositions. Chlorofluorocarbons, because of their low surface tension, are well suited as solvents for this purpose. Propellants other than chlorofluorocarbons have a tendency to produce imperfect surfaces on the plastic; i.e., striations, blisters, etc. The mold release composition must also be compatible with the plastic; i.e., have solvency properties that would not tend to degrade molded surfaces.[36,39/] Chlorofluorocarbons are poor solvents for most commercial plastics. Mold release agents should be free of water or other foreign material that might be deposited on mold surface. They should also be noncombustible and nontoxic in the work environment. It is estimated that approximately 1.9 to 2.3 million pounds of chlorofluorocarbons are used annually as propellants for plastic mold release agents.[37/]

Release agents may or may not be applied directly to molds at high temperature; however, even when molds are not hot, heating bands in the vicinity of the molds may be at temperatures of 600°F.[37/] As an example of a hot mold application, release agents are applied to spinnerette plates at 305°C in the hot melt spinning of nylon and polyester to prevent the bending and flicking of fibers or monofilaments as they leave the die.

Plastics molding lines may be adapted to "short runs" of different kinds of plastics, each plastic material requiring a mold release agent specific to the composition. One release application may be adequate for as many as 50 to 75 mold cycles.[37/]

The principal impacts of the removal of F-11/12 as a propellant system for mold release agents will probably occur in the economic sector. This impact will result from a loss in the aesthetic qualities currently possessed by molded plastic products due to a loss in the fine, smooth surface finish currently available with the F-11/12 propellant systems. In other applications, such as medical supplies and equipment, surface finishes may play an important role in the proper function of the equipment.

Rubber Molding--

With the advent of sophisticated synthetic materials, the differentiation between plastics and rubber molding is not sharp. For example, certain thermoplastic elastomers could be classed in either category. In general, the considerations for the two groups are similar with the following exceptions. Often rubber products are not subject to the requirements of a fine surface finish; therefore, the properties of release agents may be less critical.[40/] Molds used in the rubber industry may be hot enough to flash off water, enabling the utilization of emulsion-type release agents.[36,37/] It is reported that F-11/12 propellant mixtures are not generally used in the rubber molding industry except in those instances where an extremely fine surface finish is required.[37/] The very small quantities of F-11/12 used for these purposes would not change the consumption figures stated earlier for plastic molding to any appreciable extent. In addition to the chlorofluorocarbon-propelled aerosols, aqueous and solvent sprays containing release agents are utilized in the rubber molding industry.

Alternative Products or Systems

Hydrocarbon-Propelled Release Agents--

Hydrocarbons as solvents and propellants provide the necessary spray characteristics, but are highly flammable. In addition, they may not be compatible with some plastics. Flammability requirements can be met with formulations approximating a composition with 20% hydrocarbon, 75% 1,1,1-trichloroethane, and 5% active ingredient;[41/] however, 1,1,1-trichloroethane has poor surface tension properties and does not promote good wetting of the mold surfaces.[36/] The slower evaporation rate of 1,1,1-trichloroethane introduces production problems. Hydrocarbon propellant systems with water added to reduce flammability produce an unsuitable surface film due to insufficient particle size. This can lead to a product with a rough, uneven surface finish.[37/]

Fluorocarbon-22-Propelled Release Agents--

This propellant system could meet the technical requirements for mold release solvents and propellants.

Airless Sprays, Air Sprays, and Electrostatic Sprays--

Although these modes of delivery of mold release agents may be employed in foundry and rubber applications, they are not suitable for plastics molding.[40,42-44/] In general, these devices dispense relatively large quantities in a large particle size[37/] and tend to deposit coatings rather than thin films.[45/] When fine finishes are not required, air and airless sprays may be used to deposit coatings of release agents on molds. Solvents in which release agents are sold for spraying include mineral spirits (flash point 130°F), methylene chloride, and fluorocarbon-113.[45/]

Carbon Dioxide-Propelled Release Agents--

Carbon dioxide does not dissolve functional silicones to aid in aerosol dispersion so that even when mechanical break-up valves are used, the spray is too wet and nonuniform. Methylene chloride can be used as a cosolvent with carbon dioxide propellant, but its odor is a problem in the workplace (may cause nausea and other potential health problems after prolonged exposure in confined areas). Inaccessible areas in a mold may require inversion of the spray with consequent depletion of the noncondensable propellant charge.

Economic Considerations

Hydrocarbon Propellants--

Conversion to flammable hydrocarbon-propelled mold release agents would result in increased product liability and other insurance costs to plastics molders. These costs would be passed on to the public or to intermediaries such as appliance and automobile manufacturers and finally to the public. MRI is unable to accurately forecast the increase in product cost which would result from the increased product liability and other insurance costs incurred by the manufacturers.

Spray Systems--

Conversion to sprays would increase the cost of molded products by reason of production inefficiencies and parts rejections. A determination of specific molded plastic products that might be discontinued in the absence of fluorocarbon-propelled release agents is not possible, because the chlorofluorocarbon propellants have been available to molders throughout the rapid development of the plastics molding industry during the past 25 years.

General Economics[46,47]

Industries may depend on plastic molding techniques to achieve and maintain a competitive stance against world competition. For example, the ailing labor-intensive U.S. shoe industry, whose domestic production dropped from 536 million pairs of shoes in 1971 to 434 million pairs in 1975 because of import competition with a consequent closing of 29 plants and loss of 17,000 jobs in Missouri alone, is developing modern production methods to regain its competitive position. Among the new methods is the extensive use of molded plastic components, particularly soles and even the direct injection molding of soles onto uppers. While the production of soles would not require the smooth finish properties provided by the F-11/12 propellants, these properties would be required for the molded upper parts of the shoe.

LUBRICANTS

Both solid and liquid lubricants are packaged in aerosol containers that have fluorocarbon propellants. For clarity of presentation, solid lubricants and liquid lubricants are discussed separately below.

Solid Lubricants

Product Description and Utility--

Solid lubricants are packaged in small aerosol containers for use by the general public, in industrial applications, and in governmental maintenance of equipment. These lubricants are used primarily for maintenance and preventative maintenance purposes with minor uses in material forming and machinery assembly areas. These lubricants usually consist of a solid powder(s) dispersed in a resin thinned with a light solvent. Nearly all aerosol-sprayed solid lubricants will be flammable because the light solvent is packaged with a chlorofluorocarbon propelling agent. Current government and military specifications (e.g., MIL-L 23398B) for aerosol solid lubricants allow propellants other than a hologenated alkane to be used.

The fluorocarbon propellant most widely used is F-12. The amount of F-12 consumed annually in aerosol solid lubricant applications cannot be estimated because of the diversity of the consumer market and the wide variety of products available. In general, however, the removal of F-12 propelled products from the market should have no adverse effects on environmental quality, human health, or human safety.

Alternative Products or Systems--

Brush applications--This method could be used whenever film thickness and uniformity are not critical. Brush applications will only satisfy a very small fraction of current uses.

Dip applications--This method can be used whenever the viscosity and uniformity of the lubricant slurry can be closely controlled. Industrial users which can apply these lubricants at a station in a production line will be able to effectively use this coating method.

Alternate propellants--A number of propellant gases other than F-12 could be used. Hydrocarbons or hydrocarbons with a fire suppressant added would be suitable in many cases. Compressed gases, such as carbon dioxide or nitrogen, could be used in most applications.

Economic Consideration--

Conversion of existing F-12 filling units to hydrocarbons--This can be a costly procedure depending upon the required filling capacity. Conversion costs for a small capacity filling system (1 million units per year) are in the range of \$75,000 to \$100,000.[2] Construction of only the explosion-proof room can be \$25,000 to \$30,000.[48] Bodily injury liability premiums for hydrocarbon lines are dependent upon the type of coverage required. For \$400,000 coverage, the annual cost is approximately \$40,000; for \$2,000,000 coverage, the annual cost for limited coverage is about \$150,000.[9] Local zoning laws may also prevent such conversions. These costs may not pose a serious threat to manufacturers because most of the aerosol solid lubricants are contractor filled.

In cases where this conversion from F-12 to hydrocarbon units is made by the manufacturer, all the above costs would be passed on to the consumer in the form of higher prices. Because of the uncertainties involved, the per unit price increase cannot be estimated.

Contract filling--Contract filling costs are the same regardless of the propellant utilized in the aerosol product. Costs for the empty aerosol cans and the valves are, in general, independent of the number of units to be filled. A common aerosol valve costs \$0.036/unit.[10] The empty cans cost \$0.10/can (8-oz size), \$0.12/can (12-oz size), and \$0.13/can (16-oz size).[9] Filling costs depend upon the number of units filled and typical costs are \$0.25/unit for 10,000 units and \$0.06/unit for 2 to 3 million units on an annual production volume basis.[9]

The product cost to the consumer should not increase if alternate propellants or hydrocarbon propellants are supplied by contract fillers.

Prefilled aerosol containers--[11] For small companies producing relatively low volume products, the use of aerosol containers, prefilled with hydrocarbon propellant, may be a feasible solution. With this system, the only ingredient added to the container is the active ingredient. An automatic loader capable of filling 60 units/hr (approximately 122,000 units/year) can be purchased for \$1,000 to \$1,200. The cost of the prefilled cans is as follows:

$<$ 600 cans--cost is \$1.22/unit
$>$ 600 cans--cost is \$1.15/unit
$\sim$ 10,000 cans--cost is \$1.10/unit
$\sim$ 100,000 cans--cost is approximately \$1.00 to \$1.05/unit

Manufacturers that use prefilled aerosol containers will not have to increase prices if they switch to hydrocarbon propellants.

Switching to an alternate propellant will require some reformulation of existing products. In many instances, this reformulation may only involve the solvent system. However, testing is required, and in some cases products will have to be requalified to a specification. Reformulation, testing, and requalification is expected to require $3,000 to $10,000 per product. Consumers will have to bear this cost increase, which should be negligible in most cases on a per unit basis.

The cost of brush and dip applications are lower than aerosol applications because of reduced packaging costs.

Liquid Lubricants

Product Description and Utility--

Liquid lubricants packaged and supplied in aerosol containers are used by the general public, in industrial applications, and in the maintenance of government equipment. Specific types of lubricants include pentrating oils, gear and roller chain lubricants, clock oils, and general purpose oils. These oils are chiefly petroleum oils, but may include synthetic lubricants such as di(2-ethylhexyl) sebacate, silicones, or fluorocarbons, with appropriate additives to meet specific applications. Rust preventative oils may be similarly formulated, packaged, and applied, but may or may not function as lubricants. The chlorofluorocarbon most commonly used as the propellant is F-12.

The amount of F-12 consumed annually in aerosol liquid lubricants cannot be estimated because of the diversity of the consumer market and the wide variety of products available. The removal of F-12 propelled products from the market, however, should have no adverse effects on environmental quality, human health, or human safety.

Alternative Products or Systems--

Carbon dioxide propellant--Although devices with carbon dioxide propellants provide a coarser spray, such spray characteristics are suitable for lubricating and penetrating oil applications. Because of cost factors, many suppliers have already converted to carbon dioxide propellants from halocarbons.[49] The good solubility of carbon dioxide in hydrocarbon oils makes this propellant a technically acceptable alternative.

Hydrocarbon propellant--Since aerosol lubricant or penetrating oil compositions may contain as much as 35% light hydrocarbon oil along with propellant and vapor pressure depressants which will evaporate quickly, and since the chlorofluorocarbons will depress flame extension only when the flammable ingredient does not exceed 20 to 22%, the oil mists must be regarded as potentially flammable.[37] In view of the flammability of the oil, it would appear that hydrocarbon propellants may be used in certain applications if the containers show appropriate warnings.

Compressed air propellant--Continuous aerosol lubrication in industrial-centralized lubrications systems for bearings, gears, and slides can be provided with compressed air aerosol devices.[50]

Solvent-carried lubricants--The use of 1,1,1-trichloroethane in liquid lubricant solutions may be used as an alternative to chlorofluorocarbon-propelled aerosols for lubricating places difficult to reach. After the trichloroethane evaporates, a thin film of the lubricant remains.

Drip, brush, bath, and spray methods--These methods can be used in most applications involving gear and chain lubrication.

Oilcans, handguns, or pump bottles--Depending on the configuration of the parts to be lubricated, these devices may be adequate applicators for many consumer and industrial applications.

Economic Considerations--

The economics of converting existing F-12 filling units to hydrocarbons, of contract filling alternative propellants, or of switching to prefilled aerosol containers for liquid lubricants is similar to that discussed previously for solid lubricants. Replacement of F-12-propelled aerosol liquid lubricants with applications by drip, brush, bath, and spray methods, or with applications from oilcans, handguns, or pump bottles, should result in reduced consumer costs, since the expensive aerosol cans are not required for these application techniques.[2,9,37,48-50]

BATTERY TERMINAL PROTECTION

Product Description and Utility

This aerosol product consists primarily of a lightweight hydrocarbon oil which is applied to the terminals of new and used batteries as a corrosion preventative measure. F-12 is used in this product primarily as the aerosol propellant system, although its presence will also lend some degree of non-flammability to the hydrocarbon oil product. However, container labeling presently cautions on flammability and warns against use near heat or flame.[51/]

Battery terminal protection products are used only for industrial and professional purposes and are not available to the general public.[51/] Although no further information was obtained concerning the definition of the specific work force, it would not be unreasonable to assume that the primary focus of this product would be towards those employed in the installation of new batteries or the reconditioning of used batteries (i.e., repair garages, automotive agencies, etc.). In view of the use areas of this product, the non-flammability characteristics provided by the F-12 propellant do not appear to be mandatory. The total quantity of F-12 consumed annually for this specific application is unknown but is estimated by MRI to be small. Removal of this product from the marketplace without replacement by an alternative would presumably lead to an increase in battery terminal corrosion. Aside from this factor, there would be no known impacts on environmental quality, human health or safety resulting from removal of this product from the market without replacement by an alternative.

Alternative Methods of Application

The following methods are feasible alternatives to the product type under consideration.[49/]

Hydrocarbon Aerosol Products--

The use of a mixture of hydrocarbons would be a natural selection since the active ingredient is a hydrocarbon oil. If necessary or desirable, small quantities of chlorinated hydrocarbons could be added to improve nonflammability characteristics. No formulation problems should occur with this product. The same aerosol valves and containers can be used as for the present product containing F-12.[10/]

Carbon Dioxide Propellant--

This product type can be dispensed using carbon dioxide as the propellant, although the spray may be somewhat more coarse and at higher pressure than with a hydrocarbon or F-12 propellant. However, neither spray characteristics nor spray pressure should have any effect on the utility of this product.

F-22 Propellant--

If available, this chlorofluorocarbon would be an acceptable alternative. No problems would be anticipated in converting from F-12 to F-22 for this product.

Mechanical Pump Delivery--[52]

This method has been chosen by East Penn Manufacturing Company, Inc., a manufacturer of battery terminal protection spray. This company is currently reformulating their product for use in manual mechanical pump spray containers. According to a company spokesman, the new container package should be on the market in January 1978.

Economic Considerations[52]

At the present time, a 12-oz aerosol container of this product costs $2.00. The cost of the product using the mechanical pump spray delivery system has not been ascertained as yet, but the manufacturer anticipates the cost to be either the same as, or slightly less than, the current product.

PAPER PRODUCTS FRICTIONIZING TREATMENT INDICATOR

Product Description and Utility

Special indicator solutions are applied from small aerosol containers in quality control inspections during the manufacture of corrugated shipping boxes and large paper bags that have been treated with frictionizing agents (e.g., colloidal silica or alumina) to make skid-resistant, safer products. Fifteen to 20 different brand name frictionizing products[53] are used, including six principal classes as follows: (a) aqueous dispersions of colloidal silicas,[54] (b) modified colloidal silica dispersions,[54] (c) dispersion of fumed colloidal alumina,[55] (d) latex dispersions,[53,56] (e) nonskid varnishes,[57] and (f) mixtures of colloidal oxides.[58]

The performance of the frictionizing agent can be determined by sliding friction tests on the product,[53,56,59,60] but a visual inspection method is desirable for quality control in manufacturing to monitor the uniformity and amount of the frictionizing treatment.[61-65] Fluorescent dyes, which could be mixed with the frictionizing agent, were introduced for this purpose in the 1950's, but were largely replaced during the 1960's by a silico-sensitive indicator which gives a color when applied to treated paper products. The indicator solutions may be applied efficiently and conveniently from an aerosol container, but can also be applied by other methods. The current production of aerosol indicator solutions is about 12,000 cans per year, according to Du Pont sources.[66]

The indicator solution must wet the surface thoroughly, dry rapidly, and give a reasonably accurate measure of the frictionizing agent's presence. The composition may vary with the nature of the agent employed, but usually contains a color-forming chemical and an appropriate solvent. An indicator solution patented by E. I. du Pont de Nemours contains a chemical selected from the class of "lower-alkylamino substituted triphenylmethane lactones,"[67] such as 3,3-bis(4-dimethylaminophenyl)-6 dimethylaminophthalide.[57] The solvent must not be reactive with the dye and should have a boiling point less than 130°C. Suitable solvents include: aromatic hydrocarbons (e.g., benzene, toluene, xylenes), chlorinated solvents (e.g., ethylene dichloride), and ketones (e.g., acetone). The aerosol indicator presently marketed by Du Pont is said to contain a 0.88% solution of the lactone dye in xylene solvent with about 80% of the fluid contents consisting of chlorofluorocarbon propellant (a 50/50 mixture of F-11 and F-12).

Removal of the F-11/12 propelled product from the market would have no obvious adverse effects on environmental quality, human health, or human safety.

Alternative Products or Systems

The alternatives to the use of chlorofluorocarbon-propelled aerosol indicator solutions include: other aerosol sprays, nonaerosol sprays, and mechanical methods. Potential alternative aerosol systems are summarized in Table 2-1 and the nonaerosol systems in Table 2-2.

TABLE 2-1. ALTERNATIVE AEROSOL SYSTEMS

Propellant type	Boiling point (°F)	Vapor pressure (psig) 70°F	Vapor pressure (psig) 130°F
Carbon dioxide	-	-	-
Hydrocarbons			
Isobutane	11	45	110
Propane	-44	124	274
n-Butane	-1	-	-
Propylene	-54	171	387
"Aerothane" system			
N_2O	-127	755	-
MM ($MeCl_2$ + N_2O)	-	-	-
TT (TCE + N_2O)	-	-	-
Chlorofluorocarbons			
F-142b	15	44	107
F-227a	-16	80	193
F-218	-38	-	-
F-310	-28	-	-
Bladder system aerosols			
Kain "Eco-Pure"			
Plant "SELVAC"			
Other types			

TABLE 2-2. ALTERNATIVE NONAEROSOL SYSTEMS

Sprays
Air-line spray guns
Air-brush type sprayers
Compressed air spray bombs
Hand-pumped compressed air sprayers
Finger- or trigger-sprayers
Proprietary mechanical spray cans (nonrefillable)
Nonsprays
Sponge-top applicators
Fountain-roller applicators
Brush-top applicators

Du Pont technical personnel have stated that a satisfactory propellant system based upon carbon dioxide has been developed and tested in their laboratory for a period of 60 days or longer. Because this alternative appears to meet the requirements for indicator solution application, Du Pont intends to switch to this system as rapidly as their packager can convert the filling facility to use carbon dioxide.[66/]

At least two other suppliers of proprietary indicator solutions have stated that they have developed satisfactory application systems not based on the use of chlorofluorocarbons. Cabot Corporation is developing a finger-pump spray applicator.[68/] Nalco Chemical Company is evaluating both a sponge-top applicator and a non-F-11/12-propelled spray can package.[69/]

Economic Considerations

Conversion to carbon dioxide as an alternate propellant would require modification of existing lines, according to Du Pont sources. The cost to users is not expected to be affected significantly.[66/] Other suppliers of proprietary indicator solutions also indicate that alternative application systems are available, and that there should be little economic impact on the container industry.[68,69/]

ELECTRONIC CLEANERS

Product Description and Utility

These aerosol products find widespread usage in military, industrial, and consumer applications for the cleaning and maintenance of optical instruments, television cameras and receivers, telephone equipment, computers, medical equipment, aircraft navigation systems, satellite communication systems, radar and microwave systems, and of numerous other items. The market for these products is so wide and diffuse that the amount of annual consumption of F-12 in their use is not estimated.

The aerosol electronic cleaners currently on the market employ the use of 1,1,2-trichloro-1,2,2-trifluoroethane (F-113) as the active cleaning solvent and either F-12 or carbon dioxide as the aerosol propellant. This report will be concerned only with the use of F-12 as the aerosol propellant, and no consideration will be given to the subject of the substitutability of F-113 as the cleaning solvent.

At the present time, all military specifications of this product in aerosol form require the use of F-12 as the propellant.[70/] One of the largest volume products used by the Department of Defense is MIL-C-81302B. Of the large electronic manufacturers having company specifications, essentially all employ the use of F-12 as the propellant.[71/] In 1976, Western Electric Company, Inc., changed from F-12 to carbon dioxide as the propellant.[72/] In the retail consumer product trade, large quantities of electronic cleaners are sold for do-it-yourself television tuner cleaning and to professional television repairmen. Many of the products in this area utilize carbon dioxide as the propellant.[72/]

For retail trade items normally purchased or used by the general public, the removal of the F-12 propelled product from the market would have no known adverse impacts on environmental quality, human health, or human safety.

Alternative Products or Systems

From information stated in the previous section, it is readily apparent that an alternative propellant system does exist; in fact, it is currently used in some commercial (retail trade) products. The existing problem is concerned with the current specifications, both military and industrial, which require the use of F-12 as the propellant system. In all probability, most of the industrial specifications for F-12 relate to the military specifications since these companies are large suppliers of electronic equipment to the military.[71/] Military specifications have been compiled based on their own series of tests and use conditions. Some of the conditions under which these products may be used are not necessarily those found for normal commercial (retail trade) applications.[70] The criteria for the military use of electronic cleaners should be considered, but it is beyond the scope and intent of this brief report to evaluate the specific reasons for the military requirements for F-12 as the propellant. This is an intragovernmental problem that should be resolved by the concerned agencies.

With regard to military systems or highly developed electronic systems currently employed by industries such as airlines, the applicability of alternative systems is unknown at the present time. Thus, no statement can be made at this time regarding the impact on human health or safety for these use areas.

Carbon Dioxide--

The use of impact-filled carbon dioxide is an obvious alternative, since it is currently utilized in some consumer products. This propellant system has higher internal pressures and the pressure of the resultant spray may cause some damage to very delicate electronic parts.[71] The higher pressure, however, provides some cleaning action due solely to the force of the spray.[49] In terms of spray characteristics, the carbon dioxide is a more coarse spray than F-12, but this should not prove to be a detriment in normal applications.

Hydrocarbons--

These are not acceptable propellants because of flammability characteristics. The addition of sufficient quantities of chlorinated hydrocarbons to render the propellant system nonflammable will also result in a propellant system with detrimental properties towards the electronic components.[72] Most chlorinated hydrocarbons are not compatible with the plastic materials used in the construction of electronic components.[7]

Compressed Gases (Exclusive of CO_2)--

Compressed gas systems are generally unacceptable due to the pressure reduction as the volume of the contents decreases. For certain instances in which portability and purity of the resultant spray would not be important factors, it may be possible to employ a compressed air line (e.g., air-line spray guns or airbrush-type sprayers) as the propellant system.

F-22 as a Propellant--

F-22 could be used as an alternative propellant system for most component systems if it were available.[71,72] This propellant may have a detrimental effect on some component parts, but in general, would be acceptable.

Mechanical Delivery Systems--[73]

New mechanical systems in the developmental stages (e.g., Twist-N-Mist®, etc.) may prove to be acceptable alternatives if hermetically-sealed systems can be developed. Since most of these systems are not in the commercial production stages, the time requirement may be a year or more before sufficient quantities would be available.

Economic Considerations

Carbon Dioxide--

The use of carbon dioxide as the propellant system would prove to be advantageous to the consumer. At the present time, F-12 pressurized units contain approximately 75% F-113 and 25% F-12. Using carbon dioxide, the unit would contain about 95% F-113 and 5% propellant.[49] The cost of the two packaged systems is essentially the same since the decrease in price due to propellant is balanced by the increased amount of F-113.

F-22--

The use of F-22 as a propellant should require no changes for the manufacturer. Consumer prices should remain essentially the same as for F-12. Although F-22 currently costs 50% more than F-12, a pressure depressant would be used in the propellant mixture. Currently available materials used as depressants cost about one-half that of F-12 so that the total package balances to approximately the same cost.[5]

Mechanical Delivery Systems--

Actual costs on these systems are not specifically known at this time. It has been stated that their cost would be the same as the current aerosol containers but these are only estimates.[73]

BURGLAR ALARM SYSTEM

Product Description and Utility

This device is offered by a single manufacturer under the name Falcon Sentry® for use in homes, industry, and business. It is a mechanically triggered, spring activated, F-12 powered, horn alarm.[74] The sole function of the F-12 is to provide gas power for the horn. A 2-oz container of F-12 is the power source. When attached to a door or window, the alarm unit performs the function of alerting occupants that an entry has been attempted, and/or to frighten the intruder away by the sound of the alarm.

The principal point regarding the performance of this type of horn alarm is the loudness of the sound produced. These units produce sound levels of approximately 100 to 110 decibles (db) at 10 ft and can be heard for distances up to 1 mile when sounded outdoors. A typical loudness test is said to be approximately 106 db.[74] The reliability of alarm systems must be as high as possible. These alarms are intended to remain operable in stand-by condition for many years without need for attention. A disadvantage of battery-powered systems is the need for periodic power source replacement. However, the F-12 powered alarms do not carry the Underwriters Laboratory (UL) seal, because they do not meet the sound time requirements of the recently established UL standards.[75,76] These standards require an alarm to sound for 1/2 hr; this alarm sounds for 1 to 2 min. The alarm does meet or exceed the other UL test standards. Compliance with the UL standards is used by several insurance underwriters in qualifying premises for reduced rates on burglary coverage.[76]

Although the F-12 powered alarms have been marketed since 1973, neither sales figures nor company estimates are available for the number of units activated each year. This is because the same refill cartridge is used to power many of the company's other products. It is felt by MRI that 5,000 to 8,000 units discharged per year would be a generous estimate. This is equivalent to total F-12 emissions of 625 to 1,000 lb/year.

It is very difficult to attempt an assessment of the known or potential impacts on human safety or property loss which would result from the removal of this product from the market. As will be discussed later, several electrical or battery powered burglar alarms are available. These units do not generate the high sound levels of the F-12 alarm. Thus, the basic consideration becomes an evaluation of how many intrusions were deterred by the F-12 alarm that would not have been accomplished by the other units at lower sound levels. There are no known statistics to assist in an evaluation of this type and any attempts would be primarily conjecture.

Alternative Products or Systems

Related Devices--

Electrical or battery powered burglar alarms are available from a large number of manufacturers or suppliers.[77] The acoustic devices employed include buzzers, horns, sirens, electronic whoopers, gongs, and bells. The nearest equivalent in sound level to the F-12 powered horn would be the electrically driven klaxon type (automotive) horn.[78] Most residential units utilize smaller and simpler sounding devices that generate 85 to 90 db at 10 ft. The battery powered alarm units generally sell at prices less than $15, and often emphasize portability with a sacrifice in effectiveness.[79]

Alternative Power Sources--

Carbon dioxide--Carbon dioxide gas could be used to power a horn alarm from a "sparklet" type cartridge. Complete redesign would be required to solve the problems of pressure reduction, leakage, duration of the sound, etc. Previous attempts to use carbon dioxide for fire alarms have been unsuccessful due to low capacity and leakage.[74] One type of intrusion alarm using carbon dioxide is currently on the market (Sunbeam Stop Alarm®; Sunbeam Corporation; approximately $10).[77] This device resembles a door stop which incorporates a carbon dioxide cartridge and a special whistle. When activated by attempting to force the door open, the unit produces a series of about 20 2-sec blasts. This alarm is not intended for windows or other entry points.

F-22[74]--This chlorofluorocarbon would be an acceptable alternative for the F-12 powered alarm. The manufacturer had planned to switch to F-22 until Du Pont decided not to offer the product for such purposes pending further toxicological testing.

Hydrocarbon mixtures[74]--The use of a mixture of isobutane and propane would be a feasible method to power the alarm horn. However, the inherent risk of fire and explosion and the premiums for product liability coverage make this approach unacceptable to the manufacturer. Development of a hydrocarbon mixture containing sufficient additives to render the mixture nonflammable while still maintaining a usable pressure would be a possible alternative.

Battery power--If the F-12 powered alarm were completely redesigned, a battery operated system could be developed that would be similar to other intrusion alarms currently on the market.[74] With the present state of the art for dry cells and electric horns, it is not possible to achieve the sound level provided by the current system. Electric horns equivalent in loudness to a small F-12 powered unit would draw 2.5 to 3.5 amp at 12 v.[79] Conventional batteries are not available to supply this level of power.

Economic Considerations

F-22[74]--

The use of an alternative chlorofluorocarbon (i.e., F-22) could be accomplished at relatively moderate cost when and if clearance to use such products can be obtained. Heavier walled containers, necessitated by the increased pressure of F-22, would add about 10% to the consumer cost. Increased cost for the F-22 would be approximately 3¢/refill.

Hydrocarbon Mixtures--

If the development of a nonflammable hydrocarbon mixture would occur, it would appear that this mixture could be an alternative. The precise increase in cost to the consumer is unknown but may be of the same order of magnitude as for F-22.

Other Power Sources--

All other alternative power sources discussed would require a complete redesign of the alarm concept. MRI feels that the manufacturer would not attempt to develop alarms based on totally new principles and would drop this segment of their business. It is not possible to place a dollar value on the benefit derived by consumers who choose to install F-12 powered intrusion alarms on their premises. The total impact of this type of alarm on the overall security field is exceedingly small and a wide variety of alternate types of alarm systems is available to the user at widely varying costs.[77]

PORTABLE ACOUSTIC WARNING DEVICES

Product Description and Utility

Fluorocarbon-powered portable acoustic warning and signaling devices are manually operated horns which produce a controlled signal, when compressed F-12 is allowed to escape through an acoustical device. The customary horn device incorporates a diaphragm which is pulsed by the escaping F-12 against the horn throat, creating sound waves of a frequency, range and loudness determined by the dimensions of the driver parts, the projector trumpet or horn bell, and the physical and mechanical properties of the F-12 gas employed.

These warning devices are usually classified by either the size of the F-12 container, or by the size and length of the horn trumpet employed; the power, loudness, and audibility of the horns vary significantly. Typical F-12 containers for portable horns range in size from a 2-oz can for palm- and pocket-size units, through 8-, 12-, 14- and 16-oz cans, and seldom exceed 32 oz, the size of an ICC-approved canister.

It is estimated that more than 80% of the portable gas-powered horns marketed are sold by these 10 firms:[74,80]

Falcon Safety Products	Nautiloid Corp.
Signaltone, Inc.	Penguin Products
Buell Mfg. Co.	Gem Marine Products
Grover Products	Zurn Division of Atwood Corp.
Spartan Mfg. Co.	Clark-Cooper Corp.

Altogether, F-12 powered horns are available from 35 to 40 distributors, most of whom are associated with marine supplies,[81] and many packagers fill and supply the equipment manufacturers with F-12 replacement cans.

Portable or mounted acoustic warning devices powered by F-12 were initially introduced about 1954 for use as warning and signaling devices for boats. The major use continues to be associated with boating, and the F-12 powered horns are frequently called "boat horns" even though they are used for many nonmarine signaling and warning applications today. Some of these other applications include: bicycle horns, personal protection alarms, security alarms, distress signals, and communication signals.

Boat Horns--

Horns powered by F-12 are widely used in boating. Over 50.5 million people participate in recreational boating and over 10 million watercraft are in use in the United States. An estimated 888,700 vessels use an F-12 powered horn for a warning and signaling device.[82]

Bicycle Horns--

The number of bicycle owners who use an F-12 powered horn is not known, but experienced cyclists who regularly ride in motor traffic report that today only this type of horn provides the attention-commanding sound needed to alert motorists, as opposed to the standard bicycle bells, bulb horns, and battery-powered horns conventionally used in the past. The usage of these horns by bicyclists will probably grow in the future.

Personal Protection Alarms--

More than one million citizens have purchased and carry small F-12 powered horns for personal protection against dangers such as assaults, rape, and dog attacks. Visitors and rangers in parks use these devices as noise makers for protection against wild animals, such as grizzly bears.

Security Alarms--

Some horns have found application as a security device. For example, a number of retirement villages use them as cooperative community security alarms.

Distress Signals--

Some hikers, campers, and outdoor recreationalists carry F-12 powered horns for use as a distress signal when they enter isolated and remote areas. The horns have been found to be superior to distress flares, detonating signals, colored smoke signals, and signaling mirrors in some situations.

Communication Signals--

Horns are used as signaling devices in such activities as construction, agriculture, and forestry, and are sometimes used by athletic coaches and military trainers for large groups.

Estimates of the quantity of chlorofluorocarbons consumed annually by all types of horns vary from 350,000 lb to 1,000,000 lb.[74,80] Horns used in boating account for 60 to 70% of the total annual consumption.[74,79]

Discontinuing the use of portable acoustical warning devices without replacement by a suitable alternative could endanger the safety and health of some people who presently use these devices. The impacts of removing these products would have the most pronounced effects in boating, while other users generally have suitable alternatives available to them for the requirements that the F-12 powered horns fulfill.

Restrictions on the use of F-12 powered horns might be expected to have significant consequences for some users in recreational boating. Horns and whistles are needed to warn or alert other craft of dangerous situations or impending collision, and to attract attention of passing traffic to a boat requiring help. Because of the high ambient noise level in a motorboat, a loud and distinctive note is required for effective signaling by all boats.

During 1975, the Coast Guard received reports on 6,308 boat accidents involving 8,002 vessels. These accidents resulted in 1,466 persons killed, 2,136 serious injuries, and property damage of $10.35 million. By far the most common type of accident was collision with another boat, or objects being towed (including skiers). During that year, some 3,534 vessels were involved in 1,866 collision accidents of this type. The resulting costs were 66 fatalities, 673 persons injured, and property damage of $2,190,900.[83/]

Considering the alternatives now available, and the relative expense of all technically feasible signaling systems, the probable effects of discontinuing the use of F-12 powered horns would be that 180,000 Class A (less than 16-ft length) boats, 436,817 Class 1 (16- to 26-ft length) boats, and 825,000 sailboats would either carry no warning device or use a mouth whistle, which is inaudible to other boat operators under some circumstances. As a result, boat accidents would be expected to increase.[84,85/]

Alternative Products or Systems

Alternatives to F-12 powered portable horns are considered in two separate categories: nonmarine uses and marine uses.

Nonmarine Uses--

Portable F-12 powered horns used in bicycling, for personal protection alarms, for security alarms, for distress signals, and for communications signals all have feasible alternatives that do not require the use of a gas-powered horn. These alternatives (some of which were discussed previously) are generally inferior to the gas-powered horns since horns produce a louder and more audible sound than alternative methods. Generally, however, the alternatives are adequate for the user's needs.

Two alternative gases to the F-12 are possible, but each has its disadvantages:

Carbon dioxide--Carbon dioxide cartridge-powered whistles are marketed by the Sunbeam Corporation and are capable of generating loud (115 db) high-pitched sounds. The sound, however, is omnidirectional and therefore, less effective against assailants and animals as a personal protection device. Once activated, the carbon dioxide is used until exhausted (30 sec), and the device cannot be reused until the CO_2 cartridge is replaced.[86/] This makes the whistle impractical for bicycling, distress signals, and communication signals, which usually require a device that is capable of producing repetitive sounds.

Hydrocarbons--Pressure ranges of 40 to 60 psi are obtainable with mixtures of isobutane and propane, and it would be feasible to power horns or whistles using compressed hydrocarbons. The disadvantages of hydrocarbons in relation to F-12 are that hydrocarbons are flammable, would require a longer horn trumpet to achieve the desirable low frequency notes, and would cost more to produce due to the liability problems in hydrocarbon product manufacturing.[74,79,87]

Marine Uses--

Regulations--Audible whistle signals between vessels, or between vessels and docks, bridges, locks, etc., have been compulsory in the United States since 1890 (adopted by Presidential Proclamation, July 1, 1987).[88] Different combinations of short and long whistle blasts are mandatory for vessels approaching a river bend, changing course with respect to another vessel, passing, overtaking, leaving or approaching a dock, and in conditions of fog or reduced visibility. A series of five short blasts is recognized as a distress signal.

The current carriage requirements for boats in U.S. waters (new regulations are expected July 15, 1977) specify sound signaling equipment as summarized in Table 2-3. It is essential to note that while mouth whistles or horns are permissible for boats less than 26 ft in length, only power-operated or hand-operated signals are allowed for boats exceeding 26 ft in length. All boats larger than 40 ft are required to use power-operated whistles.

Although the requirements presently specify only one whistle, compliance with Coast Guard safety regulations often means that a standby or backup horn must also be carried aboard. The reason for a second horn is that according to the implementing regulations, Boarding Officers require that the horn or whistle signal shall be independent of the boats' primary electrical system, and must be capable of being sounded in the event that the primary power fails. The least costly and most convenient backup is usually a hand-held F-12 powered horn. Air horn systems are sometimes backed by a solenoid-actuated 32-oz, F-12 canister.

Alternatives to F-12 boat horns--Alternatives to F-12 boat horns include mouth whistles, electric horns, direct compressor driven air horns, carbon dioxide air horns, compressor-air tank driven air horns, hand-pumped single piston driven air horns, and high pressure air pack horns. The power, loudness, audibility and method of operation of these devices vary significantly.

TABLE 2-3. U.S. COAST GUARD REQUIREMENTS FOR ACOUSTICAL SIGNALS

Class	Boat length (ft)	Whistle or horn	Bell
A	< 16	None required	None
1	16 to < 26	One hand, mouth, or power-operated whistle, audible at least 1/2 mile	None
2	26 to < 40	One hand or power-operated whistle capable of producing a blast of at least 2-sec duration, and audible at least 1 mile	One
3	40 to < 65	One, power-operated whistle capable of producing blasts of 2-sec duration, and audible for at least 1 mile	One

Source: "Federal Requirements for Recreational Boats," DOT Coast Guard CG-290, July 1976.[89]

Note: No siren or acoustic device which produces a siren-like sound is permitted on any boat except law enforcement craft. Certain states, however, may specify the use of sirens for specific craft.

Mouth whistles and horns--Mouth whistles and horns can produce sounds that can be heard for only short distances, and audibility at 1/2 mile is marginal.

Electric horns--Electric horns, either the "stubby" style, or those having trumpet-shaped projectors are somewhat louder than mouth whistles. Typical output from a single electric horn may run from 102 to 106 db at 30 in.[87] so that they are often used in pairs. The frequency or note of electric horns is usually 380 to 450 Hz.

These horns are used only on boats with an electrical power supply since it is not practical to power electric horns using conventional type 12-v "lantern" batteries (i.e., dry cells). Typical electric horns draw from 2.5 up to 10 amps at 12 v. The high internal resistance and rapid polarization of zinc-carbon cells precludes their use. Within the past few years, special sealed rechargeable batteries have become available that might be suitable for powering a loud marine signaling horn. As an example, the Gates 800-0008 battery provides 5-amp-hr at 12 v, and can provide up to 5-amp current for 20 min. Such batteries are expensive and the battery unit weighs over 5 lb. No manufacturer of such a unit is known at present.

Air horns and CO_2-powered horns--These devices are considerably louder than most electric horns. A pair of 15-1/2 in. trumpet horns operated from a small air compressor will produce about 112 to 115 db measured at 30 in.[87] Frequencies range from about 220 to 360 Hz. A loudness of 116 to 118 db on the A-weighted scale is sufficient to meet the 1-mile audibility requirement for signaling. A hand-pumped, single piston-powered air horn is usually used as a standby backup for air horns in the event primary power is lost.[80]

When air-type horns are powered by F-12, a significantly louder and lower-pitched note is obtained than when compressed air or CO_2 power is used. The horns produce more acoustic output because the pressure supplied by F-12 is 40 psi, roughly double that provided by so-called direct drive air compressors. Typically, dual horns using F-12 are readily audible at distances of over 2 miles.[80] Other air horns may be powered from compressors and air tanks that operate at 60 to 80 psi, and these air horns will be as loud or slightly louder (i.e., 1 to 2 db) than the F-12 operated horns. However, F-12 power has the distinct advantage of providing a lower-pitched note due to the higher gas density and molecular weight of F-12. The preferred way to use this advantage is to make the F-12 powered horn projector or trumpet considerably shorter, less cumbersome, and also less expensive.

Alternatives available to boats, by class--Taking the alternatives to F-12 boat horns and the previously mentioned regulations together, each class of boats has different alternatives available. These alternatives are discussed for each class of boats separately.

Class A boats (less than 16 ft length)--The 4.5 million Class A boats less than 16 ft in length are not required to carry a signaling whistle. Many boaters voluntarily carry F-12 horns to signal dockside, or warn other boats. If inexpensive gas-powered portable horns were not available, experienced power boaters express the belief that many present horn users would not carry any type of signaling device,[84,85] although in theory all of the alternatives mentioned above are available. Those who used an alternative would probably use a mouth whistle or electric horn if an electrical power source is available on the boat.

Class 1 boats (16 to less than 26 ft length)--For boats 16 to 26 ft in length, Coast Guard requirements can be fulfilled by carrying a selected "police type" whistle on a lanyard. More satisfactory is an auxiliary marine horn, 9-1/4 in. long, having a 3-3/8 in. bell diameter. With good lung power, in relatively calm conditions, these devices meet the minimum requirement of audibility at 1/2 mile.

Larger size power boats (20 to 26 ft) usually have storage battery power aboard and are likely to use electric horns or air horns powered from a small electric compressor. Liquid carbon dioxide cylinders equipped with pressure regulators to reduce the 800 psi CO_2 down to 60 to 80 psi for horn use is a feasible option. Such systems are fairly expensive and require careful attention and maintenance to avoid loss of high pressure CO_2 through fittings.[80,90] Compressed air tanks are also used by some boaters in this class. The signaling capacity is not very great, and the user must be alert to refill the tanks before they become exhausted.

Class 2 boats (26 to less than 40 ft length)--For boats in this class, all of the previous alternatives except the mouth whistles or mouth horns can be used.

Class 3 and 4 boats (40 ft or longer length)--For all boats larger than 40 ft, the full range of alternative power sources are feasible except the hand-pumped horn:

- Electric horns
- Direct compressor drive air horns
- Compressor air tank air horns
- Carbon dioxide air horns
- High-pressure air pack horns

The principal issue centers around the choice of auxiliary backup power. This requires separate standby storage batteries or a second source of compressed gas (either air or CO_2). The convenience and modest cost ($24.50) of an F-12 auxiliary kit has made this route among the most popular means of providing emergency power for air horns.

Sailboats--Sailboats pose some special problems in all size classes. Most day sailers do not have electric power aboard. Sailboats in the small to medium size classes are always subject to "blowdown". Storage batteries are highly undesirable in the cockpit or below deck, especially for saltwater enthusiasts. Because sailing captains usually do not want any unnecessary fittings mounted on the deck or cockpit where lines could become fouled, permanently installed horns and whistles are conspicuous by their absence. The 1- to 2-lb F-12 horn is widely used for sailing craft. The more bulky and expensive CO_2 horn is the most likely alternative.[85/]

Larger sailboats--Cruising classes up to auxiliary-powered sailers almost always have an electrical system aboard. These craft can employ electric or air horns. They may also require either an F-12 or CO_2 standby for auxiliary power signaling.

Economic Considerations

The economic impact of replacing F-12 powered horns with suitable alternatives will vary with the uses of the F-12 horn and the specific alternatives available for each use. The economic impact on the consumer of using acceptable alternatives for the F-12 horns is discussed below for each use category.

Bicycle Horns--

Standard bicycle bells, bulb horns, and battery-powered horns are widely distributed and sold to bicyclists. The price of these devices are comparable to the price of small F-12 horns ($3.50 to $8.25),[87/] and bicyclists could select an alternative whose price is similar to the F-12 horn they now use.

Personal Protection Alarms--

Mouth-powered whistles can be substituted for F-12 horns as personal protection alarms against assault by other individuals. These whistles have a price range similar to the F-12 horns, so the consumer's cost would remain about the same.

Protection against wild animals or dogs normally requires a louder and more frightening sound than a whistle, such as the loud sound provided by an F-12 horn. The price of a suitable substitute for the F-12 horn would depend upon the consumer's choice of alternatives.

Security Alarms--

Many security alarm systems, from mouth whistles to sophisticated burglar alarms, are available as substitutes for F-12 horns. The price of these systems varies widely, depending on the degree of sophistication; systems, as simple as an F-12 horn warning device, (such as whistles) can be purchased at costs comparable to the F-12 horn.

Distress Signals--

Distress flares, detonating signals, colored smoke signals, and signaling mirrors are available substitutes for F-12 horns, and are comparably priced.

Communication Signals--

Many devices which make a loud noise can be used for communication signals, and the cost of these devices are similar to F-12 horns, depending upon the degree of sophistication desired.

Boat Horns--

The economic impact of substituting alternative warning and signaling devices for F-12 boat horns would affect current users of the F-12 boat horns. The best available estimates of marine usage of these horns by type and size of vessel is:[85,91]

Class	% Usage	Number of users
A	4	181,307
1	20	436,817
2	12	21,979
3 (standby)	5	1,071
Sailboats	30	247,500
	Total Vessels	888,674

The following direct economic effects would occur if F-12 horns were removed from the market:

- The 181,000 Class A boat owners would either forego voluntary use of any type of signaling device, would buy mouth whistles or horns similar in price to the F-12 horns, or buy electric horns that vary in price from \$12.00 to \$72.00.[78,87] The typical price range of F-12 horns used by these boat owners is \$3.50 to \$8.25.[87] Unless electrical horns are purchased, some sacrifice in safety will be involved.

- 430,000 Class 1 boat owners would have to choose between using a mouth whistle or installing electric horns at a cost of about $50 to $60.

- 25,000 Class 2, 3, and 4 boat owners would be required to replace F-12 units with alternative standby power signaling device. For air tank or standby battery systems, the cost would average $60, and CO_2 systems would range up to $125. This compares to $24.50 for an F-12 auxiliary kit.

- 825,000 sailboats would be severely limited in the choice of signaling devices. Sailing craft longer than 26 ft might install CO_2 horns ranging up to $125 in price. Smaller boats would rely on mouth whistles at a comparable cost to the F-12 horns with some sacrifice in safety.

Secondary economic effects in the form of increased accidents, increased fatalities and injuries, and increased property damage would probably occur among small boats and sailboats. The amount of economic loss due to accident increases cannot be estimated, but could be substantial.

PRESSURIZED CLEANERS

Product Description and Utility

Pressurized cleaners are portable aerosol units which deliver a blast of chlorofluorocarbon to rid a surface of dust. Aerosol dust-off agents are used (a) in photographic labs to clean negatives, enlarger lenses, and camera lenses; (b) in electronic assembly to remove dust from contact surfaces; (c) in on-site maintenance of computer tapes and heads; (d) to clean microscope slides, optical assemblies, and lenses; and (e) for numerous hobby applications.

The major manufacturers of dust-off sprays are Falcon Safety Products, Inc., Mountainside, New Jersey, and Miller-Stephenson Chemical Company, Inc., Danbury, Connecticut, which produces small quantities of portable pressurized cleaners for household consumer sales.[71,74/] Only F-12 is used in these pressurized cleaners and functions as both the propellant and the product. The total U.S. sales in 1976 was estimated to require approximately 250,000 lb of F-12.[74/] Falcon Safety Products, Inc., pressurized cleaners account for approximately 80% of the U.S. sales of new units.[71,74/] In addition to Falcon and Miller-Stephenson, there are numerous small suppliers of pressurized cleaners. Units are contract filled and labeled by the distributor.

Pressurized cleaners are packaged in 12- to 15-oz cans (most commonly 14-oz cans), and Falcon offers a 15-oz F-12 refill used with the valve attached to the 15-oz unit. Aero-Duster® (Miller-Stephenson Company) delivers 1,500, 1-sec blasts while Dust-Off® (Falcon Safety Products) advertizes 300 F-12 blasts of unspecified length. Extension nozzles can be attached to the pressurized cleaners to allow access to otherwise inaccessible areas.

If this product were removed from the market and no alternative systems were available, no obvious hazard to human health or safety would occur, nor would there be any apparent environmental problems as a result of such action for most use areas. For other areas, such as computer cleaning and electronic "clean rooms", the removal of these products may result in an effect on health and safety in certain specialized instances.

Alternative Products or Systems

Pressurized cleaners containing F-12 operate at a pressure of 70 to 78 psig.[71,74,92/] A blast of essentially pure, nontoxic (1,000 ppm TLV),[93/] nonflammable F-12 cleans lint and dust from surfaces. Industry sources[71,92/] were contacted in order to determine the technical requirements of a pressurized cleaner for electronics, clean room, photographic, and hobby use. The following list of criteria are necessary for an effective and safe pressurized cleaner:

1. Purity of contents,
2. Nonflammable,
3. Nontoxic and nonallergenic,
4. Noncorrosive,
5. Does not condense on surface,
6. Leaves no surface films, and
7. Leaves a dry target surface.

Several alternative pressure cleaner units may be available as candidate replacements for the portable F-12 units. Alternatives are divided into the following categories: other chlorofluorocarbons and compressed gases. Hydrocarbon propellants are not included even though they are nontoxic, odorless, noncorrosive, and available in pure commercial quantities. Sources contacted stated that a pressurized hydrocarbon cleaner would present a formidable flammability risk to the consumer under many use conditions.[71,92]

Chlorofluorocarbons--

Several of the experimental fluorocarbons may function as F-12 replacements, but data are insufficient for proper assessment. Available data are summarized in the tabulation below.[7,93,94] Data for F-12 are included for comparison.

Fluorocarbon No. and formula	Boiling point (°F)	Vapor pressure (psig at 70°F)	Flammability (% Vol. in air)	Toxicity
12 (CCl_2F_2)	-21.6	70.2	None	TLV - 1,000 ppm
115 (C_2ClF_5)	-38	103.0	None	6[a]
142b ($C_2H_3ClF_2$)	15	29.1	9.0-14.8	NA[b]
152a ($C_2H_4F_2$)	-13	63.0	5.1-17.1	6
218 (C_3F_8)	-38	-	None	NA
227a (C_3HF_7)	-16	67.0	None	NA
C-318 (C_4F_8)	22	25.4	None	6
22 ($CHClF_2$)	-41	123.0	None	NA

a/ Underwriters Laboratory Toxicity Rating; 6 = Least Toxic Class.
b/ NA = Not Available.

Only F-115 and F-22 are available in commercial quantities. F-115 is a fully halogenated chlorofluorocarbon and is a potential participant in the ozone depletion hypothesis. Falcon Safety Products was planning to research the suitability of F-22 as a replacement for F-12. However, recent toxicological tests indicate that F-22 may be mutagenic and teratogenic, and as such, Du Pont will not supply F-22 for use as an aerosol.[74] F-142b and

F-152a are produced only in experimental quantities. Both are flammable and the ability to satisfy the other criteria of a pressurized cleaner are not accessible due to lack of data. FC-318 was produced in experimental quantities several years ago, but Du Pont does not currently have production facilities. F-218 and F-227a are not presently manufactured and there are no plans for future production.[7]

Compressed Gases--

Carbon dioxide, nitrogen, and air are used in many situations as pressurized cleaners, and all satisfy the criteria for a pressurized cleaner. Normally, compressed carbon dioxide and nitrogen are stored in large, thick-wall containers, and compressed air is provided by a compressor. These gases are transported to the site of application through hoses connected to the compressed gas container with pressure control valves used to regulate the pressure of the gas released. Filters and oil traps are used to remove oil and other contaminants associated with the compressed air.

These delivery systems are adequate for most operations, but cannot be used when portability of the compressed gas is required. Although these gases can be contained in a small can, the volume of gas that a small aerosol can will hold is severely limited. For example, a 12- to 15-oz aerosol can filled with gaseous CO_2 would deliver less than 10 sprays before the pressure in the can would drop to a level where the unit would be nonfunctional. The same is true for compressed nitrogen and compressed air. The more compressed gas in a container, the higher the pressure required, and only a small volume of these gases can be put into an aerosol can before the pressure limit of the can is approached.

In addition, if static-free gas is required, the portable aerosol can would be unable to provide this, since to do so would require an ionization gun and an electrical supply to ionize the gas upon release.

A compressed gas in a small portable aerosol can would not be practical in many instances, unless only a small volume of gas is required and the user has access to a large cannister or compressor to periodically refill the portable unit. For example, households and small retail store operations requiring a pressurized cleaner would not find such a system practical.

Falcon Safety Products is attempting to develop a portable compressed air unit which would be marketed as a dust-off system. As yet, a suitable portable compressor unit is not available. Because of the requirement of a compressor motor, a marketable system would cost significantly more than an F-12 pressurized cleaner.[74]

Another possible alternative is a small hand-held syringe type unit sold by camera equipment suppliers as a lense cleaner. A bulb is squeezed expelling the air through an extension nozzle. However, the power of the blast is not sufficient for cleaning of electronic contacts, etc., and the blast itself is not "clean".

Economic Considerations

The only alternative available to consumers of F-12 pressurized cleaners are the compressed gases, since no alternative chlorofluorocarbons have been tested sufficiently to determine their applicability as viable alternatives to F-12. The cost of compressed gases is substantially less than the cost of F-12 pressurized cleaners on a unit volume of gas basis. A 15-oz aerosol can of F-12 delivers about 3.4 cu ft of gas and costs $5.25,[71,74,95] resulting in a cost of about $1.55/cu ft of F-12 gas delivered. A 15-oz can F-12 refill unit costs $4.40,[71,74] resulting in a cost of about $1.30/cu ft of F-12 gas delivered. By comparison, a cannister which delivers 224 cu ft of compressed nitrogen costs $5.80, and one which delivers 224 cu ft of compressed air costs $7.58, and the costs of these gases are about $0.026 and $0.034/cu ft, respectively.[96] A capital cost for the compressed gases would be incurred to purchase a pressure regulator, hose, and nozzle assembly, but as the figures show, the use of the compressed gases may yield a substantial savings over the use of F-12.

COMPUTER TAPE DEVELOPER

Product Description and Utility

This product has been developed for use on computer tapes to debug, calibrate, and maintain computer installations. In addition to visual reading of magnetic bits, it is used to determine whether a tape has been written, to determine if guides and heads are magnetized, to check recorder head alignment, and to make many other diagnostic tests. This developer is also effective with audio tape, if it was recorded at high gain, to obtain an intense magnetic imprint.[97]

Computer tape developer consists of a suspension of iron powder in trichlorotrifluoroethane (F-113) solvent. The aerosol form of this product is propelled with F-12. In addition to the aerosol form, this product is also available in bulk containers and in 2-oz bottles equipped with eye droppers. The product is applied in very small quantities to very localized areas of magnetic computer tape. The total area to be covered during normal usage would be no greater than a 1-in. diameter circle and generally an area of approximately 1/4 to 1/2 in. in diameter. Since this product is used only for on-line testing, a low pressure spray is used to prevent indiscriminant loss of the iron powder and possible contamination of other magnetic tapes.[97]

The only aerosol computer tape developer on the market is manufactured by Kyros Corporation, Madison, Wisconsin, under the name of Kyread® magnetic tape developer. Their annual market volume is less than 10,000 4-fl oz units, so that the total annual consumption of F-12 is much less than 40,000 fl oz for this product.[97]

Removal of this product from the market without replacement by an alternative would have no adverse effect on environmental quality or human health.

Alternative Products or Systems

As discussed in the preceding subsection, nonaerosol methods of delivery are currently utilized with this product: delivery from an eye dropper and brush application from bulk solutions. These delivery systems are viable alternatives to the aerosol product with the qualification that their major disadvantage is that the F-113 will evaporate rapidly if the container is not sealed, which could cause storage and handling problems.

Mechanical Delivery--

Mechanical delivery systems, such as those described during the EPA public hearings in December 1976, and January 1977,[73] should be acceptable substitutes for the aerosol product. Delivery systems in which pressure is created by a winding, twisting, or shaking mechanism would be particularly suitable since the pressure can be regulated to a certain extent. It would be necessary for these systems to be properly sealed to prevent evaporation of the product, which would reduce its shelf life substantially.

Self-Contained Systems--

A computer tape reader that resembles a small magnifying glass with an iron powder slurry sealed between two lenses is currently available and does not require exterior chemicals. It is used by simply shaking the viewer to form a uniform slurry, and then laying the viewer on top of the magnetic tape for visual inspection. This product can be used for extended periods provided it is kept in a sealed, moist humidor jar and is not damaged in handling.[98] One disadvantage of this product is that the chemical slurry does not contact the tape, but remains at a distance of the lens thickness from the tape, and this reduces the sensitivity of the device in performing inspections.[97]

Other Aerosol Propellants--

For an aerosol application method, a number of propellants have been tested as substitutes for F-12. Carbon dioxide, nitrogen, nitrous oxide, chlorinated hydrocarbons, F-22, and hydrocarbons were all tested and found unacceptable. Carbon dioxide, nitrogen, and nitrous oxide produce aerosols with high pressure, which results in iron powder being dispersed into the air. (The current F-12 aerosol operates at a low pressure of 18 to 20 psi.) Chlorinated hydrocarbons and F-22 dissolve the computer tape coating. Hydrocarbons also affect the tape coating and are flammable.[97]

Economic Considerations

Mechanical Delivery Systems--

These systems are not currently available in commercial quantities. Testimony at the public hearings indicated that the prices of such units should be approximately the same as current aerosol containers.[73]

Self-Contained System--

The current cost of the viewer is $35.00. While the cost is considerably higher than the aerosol product, it can theoretically remain in operation indefinitely.[98]

DIAMOND-GRIT SPRAY

Product Description and Utility[99]

This product is an aerosol spray formulation of Du Pont synthetic diamond used to apply a thin, uniform layer of diamond grit to laps for polishing stones in lapidary work. The product is made by Italdo Originals, and is marketed nationwide and overseas to hobbyists. The annual production volume is about 3,000 units, which are produced by one individual in a "basement" operation, and the annual consumption of F-11/12 in this product is about 4,000 oz.

Diamond Spray is a unique product which consists of Du Pont synthetic diamond suspended in aproprietary dispersant/adhesive slurry packaged in a 2-oz clear glass bottle and is dispensed as an aerosol through a spray valve with F-11/12 (70/30) as the propellant. The product is made in six accurately graded mesh sizes--600, 1,200, 8,000, 14,000, 50,000, and 100,000 mesh--and each size is individually packaged in a 2-oz glass bottle filled two-thirds full of a combination of 2 to 3 ml of the diamond-grit slurry, containing 1 carat of diamond and F-11/12.

This product is used primarily by hobbyists to coat their cutting and polishing laps with a diamond-grit surface. Before this product was developed, diamond grits were usually applied to laps coated with grease either by sprinkling or rubbing them on. This normally resulted in an uneven diamond-grit surface which would scratch the stones in the final polishing steps. This product was developed to overcome this problem since an aerosol spray can be applied more uniformly over the lap surface than manual applications and has been successfully used by hobbyists to provide an even diamond-grit surface on their laps.

Removal of Diamond Spray from the market would have no adverse impacts on environmental quality or human health.

Alternative Products or Systems[99,100]

Diamond grit is applied to polishing laps by hobbyists using three primary methods: (a) aerosol spray, (b) manual application of diamond grit in paste, and (c) sprinkling raw diamond grit on greased laps. The manual applications are suitable substitutes for the aerosol spray method with the qualification that it is more difficult to obtain a uniform diamond grit surface on the lap with manual methods than with an aerosol spray. Since uniformity of the cutting surface is important for polishing stones, particularly the final polishing step, the substitution of manual methods for an aerosol spray could cause a reduction in the quality of the stones polished (i.e., cause scratches in the stones) in some cases.

The F-11/12 propellant (in the ratio of 70/30) used in Diamond Spray was found by the developer of the product, Frederick W. Maiwurm, to be compatible with the suspension/adhesive agent used in the product, and to provide the proper velocity to the microscopic diamonds sprayed on the laps. Since this product was marketed, Du Pont has tested other propellants to find a suitable replacement for F-11/12 and has found two alternatives that are technologically acceptable, but involve human health and safety problems.

One alternative propellant developed was a mixture of Du Pont 142-B (Freon) 78%, methyl chloride 20%, and 2% slurry concentrate. This mixture, however, has been shown to be teratogenic in laboratory studies and was deemed unsuitable as an alternative to F-11/12 for human health reasons.

The other alternative propellant developed was a mixture of F-22 and methyl chloroform. Although this propellant was a technologically suitable substitute for F-11/12, the mixture showed positive results in an Ames test conducted in the laboratory, which made the propellant a potential human health risk.

Hydrocarbons, carbon dioxide, and nitrogen have all been considered as alternative propellants to F-11/12, but each does not have the proper density to keep the diamond slurry in suspension for proper dispersion of the diamond grit. Hydrocarbons were tested for suitability, and were not able to disperse the diamonds in a proper manner.[100/]

<u>Economic Considerations</u>[99,100/]

The economic impacts on the hobbyists who use Diamond Spray would be a reduction in value of the polished stones if the product is removed from the market, since manual applications of diamond grit to the polishing laps cannot achieve the required uniform polishing surface necessary to avoid scratches in the stones.

The product is currently made in a basement operation by an individual working part-time. This individual fills, labels, and ships about 3,000 units annually at a price of about $7.00/unit. The former owner of the business, Mrs. Shirley Maiwurm, who has just recently sold her business to another individual, stated that no other acceptable alternative propellant has been found for the product.[100/]

It is claimed that switching to another propellant for use in this operation would involve technological problems requiring research and development costs that would substantially raise the product price, or that if an alternative propellant is found, the use of contract fillers would raise the cost of the product to the extent that the profit margin would be substantially reduced at current prices.[99/] A price increase to offset the additional costs would be passed on to the hobbyists who buy the product.

If the product is removed from the market, hobbyists could buy the diamond grit compounds, or raw diamond grit and grease, currently on the market to coat their laps manually. In this case, the economic loss to them would be the reduction in the value of the polished stones resulting from scratches caused by a manually applied cutting surface which would in most cases be less uniform than one applied with an aerosol spray.

ELECTRONIC DIAGNOSTIC CHILLERS

Product Description and Utility

Electronic diagnostic chillers are aerosol products containing either 100% F-12 or a mixture of F-11 and F-12.[101/] A common mixture consists of 70% F-12 and 30% F-11.[101/] In the product comprised only of F-12, the aerosol propellant and active ingredient are the same material. For the mixture, the F-12 could be considered the propellant for F-11 but in reality, the F-11 only serves to raise the temperature of the resultant spray from -50°F (100% F-12) to -20°F. The sole function of this type of product is to provide a rapid, nonflammable, nontoxic method of cooling small electronic components from their operating temperatures to approximately -20 to -50°F. In addition, the fluorocarbons are also nondestructive to the components; a property not shared by materials such as chlorinated hydrocarbons.

These products are utilized to locate intermittent malfunctions in electronic equipment. Intermittent malfunctions are problems that periodically arise and then disappear. Such malfunctions are extremely difficult to trace because they appear and disappear without warning. Some may occur only when the equipment is cold and disappear when the components are at operating temperature, while with other pieces of equipment the malfunction may occur after a period of time. On an annual basis, this type of malfunction accounts for 19% (~ 14,100,000) of all bench or shop jobs completed by electronic service dealers.[102/] In very simple terms, electronic diagnostic chillers are used in the following manner. The equipment is turned on and allowed to warm to operating temperature. Using the aerosol product with an extension tube, each suspected component is systematically sprayed with F-12 or the F-11/F-12 mixture. The thermal shock will have no effect on components operating properly, but faulty components will be shocked into a failure mode and immediately identified.

Electronic diagnostic chillers are used only by trained electronic servicemen, not the general public. Most of the utilization of this product occurs in the repair of television sets and other consumer electronic equipment by local or centralized service personnel, many of whom are self-employed.[102/] However, considerable use of these products are made for the repair of industrial electronic equipment, including military electronics. It has been estimated that approximately 1 million pounds of F-12 (including a small amount of F-11) is consumed annually for this application. Of this figure, about 70% is for consumer electronics equipment (i.e., television, etc.) and the remainder for industrial and military electronics.[101/]

The primary impacts resulting from complete removal of this product from the marketplace without a replacement would be in terms of economics and available trained personnel. It has been estimated that the loss of the use of electronic diagnostic chillers would result in a 300 to 400% increase in the cost of repair for consumer products. This increase would amount to $960 to $1,140 million per year.[102] It has also been stated that the service industry does not presently have sufficiently trained personnel to compensate for the increase in work load that would be necessitated by such a removal.[102] Without an alternative, the repair procedure would be to remove and test each component on an individual basis.

Alternative Products or Systems

To the best of our knowledge, there are no other products currently in the market which can serve as an alternative for this particular product type. The following discussion of alternatives will, of necessity, be primarily concerned with products which may be adapted or developed for use in this area.

Miniature Refrigeration Units--[103]

Designed for the aerospace program, these units operate on the same principle as full-sized refrigerators and freezers but on a considerably smaller scale. Units can be constructed so that the entire system can be placed in a coffee cup. Smaller units are also available. In theory, a system might be developed to utilize these small units to provide a means of rapid cooling for small surface areas. To date, no system of this type is available.

Thermal Scanners--[103,104]

These devices have been commonly used in failure physics studies and are reliable, dependable systems. The principal disadvantage to this type of a system is that isolation of specific components is very difficult, if feasible at all. When employed, thermal scanners can be used to determine if malfunctions are occurring in various segments of the electronic arrangement but it will not specifically designate which of the components is malfunctioning.

Thermoelectric Coolers--[104]

While these devices may be applicable, they present operational difficulties which may preclude their usage. Thermoelectric coolers, in general, are rather fragile devices which must be handled with care. A heat transfer grease is generally required to insure good heat transfer from the object to the cooler. Thermoelectric coolers provide their best cooling effects if applied to flat surfaces. Since many electronic components have nonflat surfaces (e.g., rounded surfaces), very poor heat transfer properties would occur due to the very small surface contact area which would be available.

Compressed Gases--104/

Compressed air systems are currently being used by the Department of Defense night vision laboratories to attain temperatures of 77°K. With this system, compressed air is expanded through a Joule-Thompson orifice to attain these temperatures. To attain the very pure, dry air required for this system, the compressed air is passed through a series of filters and molecular sieve traps to remove traces of oil, grease, and water present in the gas. Argon gas has also been used to attain temperatures of 80°K. This gas has an advantage over nitrogen in that its specific heat is 2 to 4 times that of nitrogen; however, argon is very expensive to purchase. The temperatures attained by these systems are well below those required for electronic diagnostic chilling purposes.

For bench top diagnostic procedures, as found with small repair shops, a nonportable system which may be applicable can be proposed. If the gas from a normal tank of compressed nitrogen, as obtained from any compressed gas distributor, is passed through a small orifice (~ 4 to 5 mil opening), the resultant temperature of the gas should be in the range of -20 to -30°F. The diameter of the orifice opening can be varied through trial and error to attain the proper temperature. Pressure reduction valves may also be necessary to control the rate of gas flow. Since these tanks are normally large steel cylinders, the system would not be easily portable. A coil of stainless steel tubing could be used in conjunction with a finger-pressure release valve to provide a certain degree of portability within the confines of the workbench.

Economic Considerations

Miniature Refrigeration Units--

Currently, these miniature refrigeration units cost approximately $3,000 due to the very limited market for such products. If a large market could be developed, a price range of $300 to $400/unit might be attainable.103/ In addition, the cost of all of the developmental work needed to produce an acceptable product would be added to this basic cost. We are unable to estimate the extent of this developmental work.

Thermal Scanners--

These are expensive devices costing in the range of $5,000/unit. For more advanced systems, such as those used for military applications, the cost becomes very expensive.103/ No cost figures for the advanced systems were obtained.

Thermoelectric Coolers--

These systems could be potentially relatively inexpensive devices if a sufficiently large market could be developed. At the present time, the market for these coolers is very limited.[103/] In view of the technical problems associated with the potential use of thermoelectric coolers, it appears doubtful that a large market could be developed.

Compressed Gases--

A compressed gas system would be potentially inexpensive once the developmental work has been accomplished. Current delivery prices for tanks of purified nitrogen gas to MRI are $15.56/tank. Purchase prices for a set of pressure reduction valves could be $300 to $500 depending upon the desired quality of the valves.[104/] Developmental costs would be centered primarily on the design and fabrication of finger-pressure, trigger nozzles with the correct orifice diameter to produce the desired temperatures. These developmental costs are unknown at the present time.

FIRE ALARM SYSTEM

Product Description and Utility

This device functions as a heat-activated, gas-powered residential fire alarm. F-12, stored in a bottle with heavier walls than the usual aerosol container, powers a horn to warn of fire after an eutectic metal plug or soldered plate fuses and releases the charge at a predetermined temperature, such as 136°F.

These alarm systems function as heat detectors in contrast with other types which function as smoke detectors, but the two kinds of detectors may be used to complement each other in that each may be more effective in different kinds of fire situations. Separate UL standards exist for each of the two types of devices; UL 539 for heat detectors and UL 217 for smoke detectors.[74] There is considerable controversy regarding the relative effectiveness of the two types of detectors. UL-listed heat detectors are recognized in the National Fire Protection Association (NFPA), 74-1974 as effective warning devices but must be used in conjunction with smoke detectors.[105] It is not within the scope of this discussion to evaluate the relative effectiveness of smoke and heat detectors as alarm systems in the fire environment. These devices are used for residential protection and are not marketed for commercial or industrial use. At the present time, there are seven UL-listed manufacturers of heat detector devices; of these, five are F-12-powered and two are spring wound bells. Most gas powered devices being marketed contain 12 or 13 oz of F-12 and retail at $80 to $120, but a newly developed device will meet standards and contains only about 2 oz of F-12 and sells for approximately $20.[106]

Usages estimates of F-12 in this application range from 150,000 lb/yr[74] to 250,000 to 300,000 lb/yr.[107] If the device containing less F-12 was to achieve significant market penetration, fluorocarbon consumption would be reduced proportionately. Performance standards limit leakage to less than 0.5% of the total gas per year.[108]

Fire codes require that the horn sounds for 4 min, but manufacturers strive for longer duration signals (up to 22 min) by using larger gas charges. The alarm must be of sufficient loudness (85 db at 10 ft) to waken sleepers.[105]

F-12 is used solely as a means to power the horn. Loudness depends on gas pressure and efficiency on gas density. Optimum gas pressure is 80 to 120 psi, but horns will operate at levels of 40 psi.[107] A nonflammable power source must obviously be used.

The removal of these single station, mechanically-powered heat detector devices from the market would likely have no adverse effect on environmental quality. However, the potential effect on human health or human safety is more complex. Numerous smoke detection devices are available but, as stated earlier, the two devices serve differing functions and are subject to separate UL standards. NFPA standards recommend that the two devices be used in conjunction since many areas of residences may produce false alarms from smoke detection devices. Potentially, this could lead to the devices being disconnected by the resident. Heat detectors have been found to be inadequate warning devices for certain types of fires. However, the removal of these devices from the market would be in opposition to NFPA standards and could potentially have an effect on human health and human safety.

Alternative Products or Systems

Wound Spring--

Power for heat-activated fire alarms can be provided mechanically by spring wound devices, and two manufacturers currently manufacture and market such alarms.[74/]

F-22--

Although liquid F-22 has a higher vapor pressure than F-12, the older style device (12 to 30 oz of fluorocarbon) which is built with a heavy-walled bottle, would probably be adequate to handle the pressure. Some modification of orifice size and horn size might be required.[107/] The newer style device (2 to 4 oz of Freon) would require more device modification because a thinner-walled bottle is used.

Carbon Dioxide--

Because of the high vapor pressure of liquid carbon dioxide (830 psig at 70°F), much heavier walled bottles would be required to ensure safety. Moreover, the device would have to be redesigned to provide pressure reduction so as to avoid destruction of the horn diaphragm.

Compressed Air--

Compressed air in a bottle size suitable for residential installation provides only a 20- to 30-sec alarm[107/] which does not meet NFPA codes. Compressed air powered alarm devices are manufactured and marketed for industrial use (particularly in coal mines),[109/] but since a large air storage tank is required and intermittent pumping is necessary to maintain pressure in the tank, such a design would not be suitable for residential use.

Mixtures Based on Methylene Chloride--

Methylene chloride alone would provide less than 20 psig pressure at 136°F, which would be insufficient to power a horn. Because gases are boiled off in generating power for the horn rather than the liquid being sprayed as in the generation of an aerosol, addition of a second material to increase the vapor pressure would be an unsatisfactory alternative in that fractionation of gases would occur.

F-13B1 (Halon 1301)--

This fully halogenated fluorocarbon (bromotrifluoromethane) currently finds extensive utilization as a fire extinguishing agent in both military and civilian applications. However, because it is a fully halogenated methane, it may potentially play a role in the ozone depletion hypothesis. Aside from this potential problem area, it could be a candidate as an alternative propellant for F-12 in these devices. Due to the considerably higher pressure of 1301, it would likely be necessary to redesign the propellant container to accomodate this higher pressure. Further discussion of the current applications of 1301 and economic data are presented in the following subsection on fire extinguishing agents.

Economic Considerations

It is generally believed that losses of life and property in residential fires can be reduced through public implementation of NFPA recommendations for fire and smoke detector and alarm devices, although precise estimates of the savings cannot be made. In 1971, residential fires accounted for a loss of 6,600 lives and a property loss of $874,000,000.[110]

Spring Wound Devices--

Spring wound devices are apparently market-competitive with the gas powered devices; however, the shorter duration of warning signal from these devices may not afford equal protection from fire loss.

F-22--

Conversion to F-22 would increase the consumer cost of the older style device (12 to 13 oz freon) by 5 to 10% at most.[107] Increased cost of alarm devices may contribute substantially to resistance by consumers to purchase and install the devices, with a consequent failure to reduce risk to life and property loss from fire. Although F-22 could be substituted for F-12 in the older, heavy-walled devices using 12 to 13 oz of fluorocarbon (costing $80 to $120) with little increase in cost, the same substitution in the new devices containing 2 to 4 oz of fluorocarbon and costing about $20 could substantially increase the cost to the consumer because of the need for a heavier container.

Carbon Dioxide--

The cost of a device powered by carbon dioxide would be sufficiently large to make the device noncompetitive and result in the abandonment of its manufacture.[105]

FIRE EXTINGUISHING AGENTS

Product Description and Utility

Only five Halons are currently in use in any significant quantity as fire extinguishing agents.[70] These are:

Halon 1011 CH_2ClBr Bromochloromethane
Halon 1202 CCl_2Br_2 Dibromodifluoromethane
Halon 2402 $C_2F_4Br_2$ 1,2-Dibromotetrafluoroethane
Halon 1211 CF_2ClBr Bromochlorodifluoromethane
Halon 1301 CF_3Br Bromotrifluoromethane

Only the last four of these are fully halogenated fluorocarbons. Of these four only the last two are being used extensively in the United States.[111] The military is replacing 1011 and 1202 uses with 1301 and 1211.[70] Only 1211 and 1301 have UL certification and NFPA standards for use.[112] Only 1301 systems are approved by Factory Mutual.[113] Some State Fire Marshals[114] (e.g., Kansas) have still not certified 1211 systems for portable use, though they are widely used in Europe and this country. The small aerosol-type "fire extinguishers," using such ingredients as F-11 (Halon 113) or F-12 (Halon 122), are not approved for use by any of the major rating and testing entities.[35,114] Halons are not used as propellants in dry-chemical or other types of extinguishing systems.[35,111,115] The following discussion, thus, is restricted to the uses of Halons 1301 and 1211, in which the agent is serving a primary role as chemical agent to suppress or extinguish fires.

Halon 1301--

This compound is used almost exclusively in total flooding systems.[116] It has a unique combination of chemical effectiveness in fire suppression and low toxicity, which allows its use in total-flooding of habitable space. It is receiving increased use in both military and civilian applications for protection of computer facilities, test facilities, machinery, space fuel tanks, engine and auxiliary power installations, habitable cargo and storage space, battle tanks, electronic vans, telephone exchanges, mixing and process rooms for flammable liquid, etc. In 1975, Du Pont reported about 10,000 1301 systems in use.[116] Du Pont report about 3 million pounds of 1301 sold in 1976 and estimates sales of 15 million pounds in 1986.[116] About 300,000 pounds were estimated to have been released to the environment in 1976.[116] Installation of a 1301 system does not constitute a short term release to the environment. Due to the cost of 1301 and the need for high reliability in 1301 systems, leakage is very low and contents could exceed the life of the systems. A leakage rate of the order of 1,000 lb/year has been estimated.[116] It is believed feasible to recover and reclaim the 1301 from systems, either during tests or when the system is abandoned.[116,117] At present, new 1301 systems are often tested with Halon 122 (F-12) test gas because of its substantially lower cost.[116]

Halon 1211--

This fire extinguishing agent is used mainly in portable or local application systems but can also be used in total flooding modes for uninhabited space or for habitable space with advance warning provisions.[35] The Air Force is converting from 1011 to 1211 and 1301 for reasons of toxicity.[70] Halon 1211 is the only "clean" agent recognized by UL as effective in Class A, B, and C fires.[35]

The classification of different types of fires is as follows:

Class A - Ordinary combustible materials (e.g., wood, paper, fabric, etc.)

Class B - Flammable liquids

Class C - Electrical

It is used in situations requiring a noncontaminating agent, such as with electronic equipment, in computer rooms, telephone switchgear centers, copying rooms, etc. It is used by the Air Force for ramp patrol trucks and in other flight-related applications requiring fast delivery and chemical effectiveness. Concern has been expressed about the toxicity of the fire-induced decomposition products of 1211, especially in portable use by untrained personnel in confined space.[114,117] The agent itself has a toxicity comparable to CO_2. Like 1301, 1211 is relatively high priced and is normally contained in the delivery system for long periods of time and could be recycled or recovered.[35] Installation does not necessarily constitute total release to the environment. Over the long term, the use of Halon 1211 is expected to grow to some 3 to 5 million pounds per year.[35]

Aerosol Units--

These fire extinguishing systems are not of proven effectiveness or reliability and make use of agents, such as F-11 and F-12, which have marginal chemical effectiveness.[35] They are packaged in small aerosol-type containers with no indication of the state of the charge. Quantities are small and their throw-power is very limited. Because no ratings are available, sale of these "aerosol-agents" is illegal in some states (e.g., Kansas).[114]

The impact of removing 1301 and 1211 systems with no alternatives would be exposure to greatly increased fire losses, both human and property. Du Pont, for example, estimates that 1301 systems are currently protecting property valued in excess of $15 billion.[116] Removing the aerosol-type packaged systems would have much less impact, even without alternatives, in the light of their low effectiveness and questionable reliability.[35,114]

Alternative Products or Systems

Both the Halon agents, 1301 and 1211, are expensive ($2.15/lb and $1.40/lb, respectively),[116] and have been developed and used to meet specialized requirements in protecting life and high-value equipment and facilities. Each acts as a chemical agent and has unique physical and toxicological properties. Both are noncontaminating so that little cleanup is required after fires.[35,115,116] The agent 1301 appears to be unique in its suitability for inerting habitable space. Agent 1211 is unique in being a clean, nontoxic agent with chemical effectiveness for Class A, B, and C fires. Both agents have been developed in spite of their high cost for specialized applications and would, in most present uses, be difficult to replace without increasing fire-loss risk to both life and property.

Interchangeability of 1301 and 1211--

In general, the two agents have only limited interchangeability. There is no present alternative for 1301 in its use as a total flooding agent in habitable environments. For nonhabitable space, or with an advance warning system to permit evacuation, agent 1211 may be an adequate substitute for 1301.

Water--

This agent has good Class A fire extinguishment capabilities and can be used in total flooding (sprinkler) systems. However, water damage to facilities can be great and also its use can result in post-fire cleanup problems. Water is unacceptable for Class B and C fires.

Carbon Dioxide or Nitrogen--

Either of these materials can be used in total flooding systems; however, very large quantities are required to inert the atmosphere. The use of carbon dioxide can lead to water damage as a result of condensation. It also has poor effectiveness for Class A, B, and C fires and involves a severe weight penalty and poor range.

Dry Chemicals--

Dry chemicals can also be used in total flooding systems. This system is the leading candidate for 1211 substitution. ABC dry chemical can equal or exceed the effectiveness of 1211 in laboratory tests for Class A, B, and C fires.[115] However, equipment damage can be extensive with powder, visibility can become a problem during application, and cleanup requirements are extensive. In addition, 1211 can often penetrate obscure fires better than dry chemical.[35]

Foam Systems--

The four types of foam currently in use are: low expansion (3%), low expansion (6%), high expansion, and aqueous film forming foam (AFFF). Both types of low expansion foams use protein based, animal fat surfactants. High expansion foams achieve high aeration by detergent or surfactant additives. Each company has its own formulations of high expansion foams. AFFF, also called "light water," uses fluorinated long-chain hydrocarbons as the surface-active agents.[111]

These foams can be used in total flooding systems but can cause severe damage and post-fire cleanup problems.

Portable Fire Extinguishers--

For portable uses, 1211 can, in principle, be replaced by one or a combination of the above agents. All of these systems have received extensive testing and certification. The so-called aerosol fire extinguishing agents can be replaced with CO_2,[9] dry chemicals, or other Halons, in approved delivery systems with a net benefit in safety and reduced fire losses.

Economic Considerations

The primary economic considerations in substituting alternative agents for 1301 and 1211 are: (a) the increased cost due to damage by the alternative; and (b) the greater risk to life and property incurred by using less effective fire extinguishment systems in high-value situations.

Aside from the considerations of damage and cleanup costs following use of the agents, a comparison of small, portable fire extinguisher systems is shown in the following summary.[118,119]

Agent	Agent weight	System weight	Wholesale system cost	Effectiveness rating
1211	5 lb	11 lb	$35	10 BC
CO_2	15 lb	50 lb	$55	10 BC
Dry	5 lb	10 lb	$12	10 BC
1301		Used only in military application		
Water	2.5 gal.	-	$19	-

For total flooding systems, it is very difficult to present comparative costs in terms of dollars per cubic foot of space since each situation is basically unique and the degree of substitution is low. One source stated that the total systems costs for CO_2 and 1301 are roughly comparable.[118/] Another source stated that, aside from equipment damage, downtime, cleanup, etc., that water would be the most expensive, followed by 1301, CO_2, and dry chemicals.[119/] Foam is not currently used in total flooding systems.

DRAIN OPENERS

Product Description and Utility

Aerosol drain openers use liquefied F-12 to unclog drainpipes, and two products are currently on the market: Drain Power® (Glamorene Products Corporation, Clifton, New Jersey) and Drano Aerosol Plunger® (The Drackett Product Company, Cincinnati, Ohio). Each product is marketed in 5-oz cans, which contain 56% F-12, or about 2.8 oz of F-12 per can. The total annual sales of the products is 6 to 8 million units, so the annual consumption of F-12 for these products is between 17 and 23 million oz.[120/]

The F-12 is injected into the drainpipe by placing the dome-shaped plastic cap on the aerosol can into the drain opening and pressing down firmly on the can. The F-12 enters the pipe as a liquid and rapidly expands as a gas to over 250 times its liquid volume. A shock wave is created which travels through the hydrostatic head of water in the drainpipe to deliver its energy against the clog. Drain Power delivers 4.9 liters of gas with a recommended 1-sec burst.[121/]

These products are used primarily in homes by members of the household. Consumers Union reported that these types of drain openers were effective in unclogging drainpipe blockages in tests run in their laboratories, and were relatively safe to use, but could cause damage to drainpipes with weak joints due to the pressure developed by the blast of expanding F-12 in the drainpipe.[122/]

Removal of aerosol drain openers from the market would have no impact on environmental quality, human health, or human safety.

Alternative Products or Systems

Alternative Aerosol Propellants--

To satisfy the requirements of an aerosol drain opener, the propellant should be toxicologically safe, nonflammable, resistant to hydrolysis, economically acceptable, and have the pressure characteristics which permit packaging in conventional aerosol containers and which provide suitable pressure upon release to effectively unblock the drain. To date, F-12 has been the only propellant tested which satisfied these properties, although numerous alternative propellants have been considered.[121/]

Other fluorocarbon propellants either may be included in possible regulatory action--namely, F-11, 113, 114, and 115--or have been eliminated because of toxicological hazards such as mutagenicity or teratogenicity. F-22 and 142b have been eliminated because of toxicological hazards.

Hydrocarbon propellants have been successful in unblocking clogged drains in laboratory tests, but only at levels above their explosive limits in air. The flammability of hydrocarbons tested as drain opener propellants such as propane, has made them unacceptably unsafe under normal use conditions.

Compressed gases, such as carbon dioxide, nitrous oxide, and nitrogen, have been tested but do not meet the effectiveness requirements of the product. For these gases to be effective would require compression to pressures that exceed the safety limits of the aerosol container. Lower pressures could be used, but this would substantially reduce the effectiveness of the product.

Research to date has produced no alternative propellant that performs as well as F-12 without introducing other serious problems.[121/]

Alternative Technologies[122/]--

Clogged drainpipes can be unblocked by various chemical and mechanical methods using existing products on the market. Among the most common products are acidic and caustic chemical drain openers, manual rubber plungers, drain augers (snakes), and hydraulic-powered drain openers.

Acidic and caustic chemical drain openers are produced in liquid and granular formulations, and range from 10 to 90% caustic or acidic content. While the effectiveness of the numerous products marketed varies under different conditions and between products, all are dangerous products to use. In 1976, NEISS reports stated that over 8,800 injuries were caused by these products. Children accidentally ingested them or burned their skin, and users of the products received burns in the eyes and on the skin from improper handling or splashing of the chemicals. Consumer publications have continuously warned that the use of these products should be a last resort measure only, and then extreme caution should be exercised. These recommendations urge trying a nonchemical method first, such as a manual rubber plunger or a snake.[121,122/]

Most drain clogs, with the exception of bad blockages, can be cleaned with a simple manual rubber plunger and boiling hot water. (Even boiling hot water alone can be successful in some cases.) This device is simple to use and relatively safe to humans and the environment, though in many cases it provides only a temporary remedy.

For more permanent results, snakes have been successfully employed by plumbers and household owners alike. It is a long flexible steel cable that is fed into the drain and twisted to unblock the stoppage. Often the snake can be used to pull the debris out of the drain to permanently remove it. The flexibility of the snake allows it to go beyond the trap, if necessary, to the blockage. The disadvantage of the snake is that it may not be of sufficient length to reach the blockage.

Hydraulic-powered drain openers are similar to the manual rubber plunger in principal except that they can usually generate more force than the manual device. Hydro Plunger®, a product of IASA International, Inc., of New York City, is a manually operated water plunger that resembles a bicycle pump. Water is drawn into the 15-in. long cylinder by pulling the handle, and then expelled through a nozzle inserted into the drain by pushing the handle. Another type of device is attached to the end of a garden hose and forces water from the hose into the drain in a pulsating movement in order to unblock the clog with the water pressure.

The mechanical devices are relatively safe to use, cause no environmental problems, and are successful in unblocking clogged drains in most cases. The chemical methods are usually successful in unclogging drains by eating away the blockage, but can be harmful to the pipes, the environment, and the people using them if improperly utilized.

Economic Considerations

In late 1976, the consumer price for two aerosol products--Drain Power®, and Drano Aerosol Plunger®--was $2.36 for 5 oz and $1.75 for 5 oz, respectively. By comparison, a rubber plunger can be purchased for about $1.00, a small snake for about $5.00, and a Hydro Plunger® for $6.25. The chemical drain openers range in price from about $0.50 to $2.00 for 12 oz of granules, and from about $0.40 to $1.10 for 1 pt of liquid formulation.[122/]

In general, the most inexpensive devices are the mechanical ones (plunger, snake, and Hydro Plunger®), since they are not consumed in operation, and can last many years. The chemical products are consumed in the operation and, if severe and repetitive problems occur, may cost more to use. Substitution of the mechanical devices for the aerosol drain openers would reduce the cost to the consumer, while substitution of chemical products for the aerosol products would not affect the cost, since these products are approximately equivalent in price per operation.

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15. Supplementary Notes

16. Abstracts Several aerosol propellant and related applications of fluorocarbons were examined to identify existing and technologically feasible alternatives. Associated cost factors were also considered. Interested parties brought these fluorocarbon applications to the attention of an interagency work group (EPA, FDA, and CPSC) as being possible "essential uses" of these substances. The applications examined under the task were: flying insect insecticides, other pesticides, spray paints, air brushes, mine safety devices, mold release agents, lubricants, battery terminal protection, paper frictionalizing indicator, electronic cleaners, burglar alarm system, portable acoustic warning devices, pressurized cleaners, aerosol computer tape developer, diamond grit spray, electronic diagnostic chillers, fire alarm system, fire extinguishing agents, and drain openers.

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