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# Project Summary

# Control Technology Overview Report: CFC Emissions from Rigid Foam Manufacturing

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**Depletion of stratospheric ozone through the action of halocarbons, particularly chlorofluorocarbons (CFCs), has been the subject of extensive study and wide debate. Although many uncertainties remain, current scientific evidence strongly suggests that anthropogenic CFCs could contribute to depletion of the stratospheric ozone layer as was first postulated in 1974.**

**In the production of rigid cellular foams, CFCs are used as physical blowing agents to reduce foam density and impart thermal insulating properties. Such rigid foams include polyurethane, polyisocyanurate, polystyrene, polyethylene, polypropylene, polyvinyl chloride, and phenolic foams. Uses of these foams include building insulation, packaging materials, and single service dinnerware.**

**This report estimates total CFC emissions from the various rigid foam manufacturing processes and from the foam products themselves, and examines potential methods for reducing these emissions. Options studied include replacement of CFC-blown products with alternative products not requiring CFCs, replacement of ozone-depleting CFCs with other chemicals less likely to destroy stratospheric ozone, and recovery/recycle of CFCs released during the manufacturing processes.**

***This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Halocarbons known as chlorofluorocarbons (CFCs) are the primary suspects in the stratospheric ozone depletion theory. Since they are chemically stable, CFCs are not readily decomposed in the lower atmosphere and can survive the long time necessary for transport into the stratosphere. Once a CFC molecule has reached the stratosphere, it can be acted upon by the greater flux of short-wavelength ultraviolet (UV) radiation present in the stratosphere. This causes the CFC molecule to release halogen atoms which then become reactants in the breakdown of ozone into diatomic oxygen.

Such depletion of the earth's layer of stratospheric ozone is predicted to result in increased levels of biologically damaging UV radiation reaching the earth's surface. Related adverse environmental and health effects include increased incidences of human skin cancer, reduced yields of important food crops, and disruption of the aquatic food chain.

CFCs are widely used in several industries including rigid foam manufacturing. In that industry, CFC-11 (fluorotrichloromethane), CFC-12 (dichlorodifluoromethane), CFC-113 (trichlorotrifluoroethane), and CFC-114 (dichlorotetrafluoroethane) are used as physical blowing agents to lower foam density and to impart thermal insulating properties. CFC-11 is the primary blowing agent for rigid polyurethane and polyisocyanurate foams. The exotherm from the polymerization reaction causes volatilization of the CFC, and the vapor is trapped within the cellular matrix of the foamed polymer. The cellular structure provides the foam with its rigidity, and the CFC-11 vapor trapped within the cells gives these foams their exceptional thermal insulation value.

For nonpolyurethane foams such as extruded polystyrene foam, CFCs are also used as a primary blowing agent. CFC-12 is the predominant blowing agent used in production of extruded polystyrene foam. The main function of the CFC blowing agent in this application is to produce numerous small closed cells which provide a lightweight, rigid material that can be used in a variety of end products ranging from building insulation to disposable dinnerware. The amount of blowing agent in a given formulation depends on the property specifications of the end-use product.

CFC-11 in rigid polyurethane and polyisocyanurate foams is trapped within the polymer matrix and is referred to as "banked" CFC since the gas diffuses very slowly from the foam over the lifetime of the material. These foams are used primarily as insulation for buildings, tanks, refrigerated appliances, and refrigerated transport vehicles. As the use of these foams increases, the bank of CFCs continues to grow, essentially becoming an uncontrollable source of emissions for decades in the future. The half-life of CFC-11 in rigid polyurethane and polyisocyanurate foams is estimated at 100 years. Similarly, the CFC-12 used to blow polystyrene boardstock is banked with a half-life estimated at 40 years. In addition, CFC-11 and CFC-113 are banked in closed-cell phenolic foam for the life of the foam.

Emissions of CFCs from the production of extruded polystyrene foam sheet and rigid polyethylene, polypropylene, polyvinyl chloride, and open-cell phenolic foams are characterized as being prompt; i.e., the CFC gas is released during, or soon after, foam formation.

This study evaluated the technical options to reduce emissions of CFCs associated with rigid foams and their manufacturing processes. It emphasized the substitution of hydrocarbons for CFC-12, the capture and recycle of CFC-12 in the production of extruded polystyrene sheet, and alternative products for all rigid cellular foams. The factors involved in these priority areas were evaluated in depth. For all control technologies, engineering and economic aspects were examined, as well as barriers to control implementation. A profile of the rigid foam industry (including the number and location of active firms, process technology, and projected growth) was also prepared.

## Accomplishments/Results

### *Rigid Polyurethane/ Polyisocyanurate (PU) Foam*

Because rigid PU foam manufacturing emissions are relatively small and in-use product emissions occur slowly over an extremely long time period, it is difficult to effectively control these emissions. However, one option which can reduce future CFC emissions is to switch to substitute products which contain either smaller quantities of CFCs or none at all. Most rigid PU foam is used as insulation for commercial and residential buildings. In this application, such foams are found in a wide variety of installation configurations for roofs and walls. Because of this, the applicability and selection of substitutes is dependent upon the end use with such considerations as insulation value, fire retardancy, structural rigidity, moisture resistance, and UV radiation resistance playing an important role.

Some possible substitute insulation materials are: fiberglass batts, fiberglass board, perlite, expanded polystyrene bead board, extruded polystyrene board, fiberboard, cellular glass, insulating concrete, rock wool, and vermiculite. In most cases, to match the insulation value (R-value) of the PU foam, substitution of these alternative insulation materials for PU foam will necessitate the use of greater thicknesses and/or modifications to the installation configuration. However, except for extruded polystyrene board, all of these alternatives offer 100% reduction in CFC-11 emissions. Because extruded polystyrene board does use some CFCs, it offers approximately a 40% CFC-11 emission reduction potential.

For insulation of refrigerated appliances and transport vehicles, the use of alternative insulation materials such as fiberglass is not considered to be a viable control option. To replace the relatively small amount of foam typically found in a refrigerator would require a major redesign of the cabinet with thicker walls and thicker metal in the walls. Manufacturing labor costs would also increase. Currently, the PU foam is injected into the appliance cabinet cavity and allowed to cure in place. The cured foam adheres to the inner and outer skins of the unit providing structural rigidity. The use o substitute insulation products would require more intensive labor in which the insulation would be cut and placed into the wall cavities, and metal brackets would have to be used to attach the inne and outer walls.

Instead of alternative insulation materials one control option is to use more water in the foam formulation. The use of water to generate $CO_2$ as an auxiliary blowing agent is a technology which is well known and widely used in thi industry. Typically about 15% of the CF( blowing agent is replaced with $CO_2$, bu it is possible to replace up to about 33% $CO_2$ has a higher thermal conductivit than CFC-11, and to maintain the foam' insulation efficiency, the density of th foam can be increased. This contrc option results in higher foam cost because of increased raw materials use

In packaging applications, the therma insulating characteristics of polyu ethane foams are usually not importan and a variety of alternatives exis Possible substitutes for these applica tions are numerous and include non-CF blown loose-fill expanded polystyrene shredded and wadded paper, cellulos wadding, die-cut cardboard, wood shav ings, pre-formed expanded polystyren packing blocks, and plastic film bubbl wrap.

Use of new low ozone depleting CFC as blowing agents is a longer-ter possibility for reducing ozone-depletir CFC emissions from rigid polyurethar foams. For these foams, the identifie CFC alternatives are CFC-123 and CF( 141b. These chemicals were selected c the basis of having chemical and physic properties similar to those of CFC-1 however, each has possible drawbacl including substantially higher cost th CFC-11 and the fact that neither commercially available at the present time.

### *Rigid Polystyrene Foam*

Polystyrene (PS) is extruded into both sheet and board profiles. Extruded PS sheet is a thermoformable material which is used to make a variety of single service and packaging items such as stock food and produce trays, egg cartons, hinged carry-out containers, plates, cups, and bowls. Over 80% of extruded PS foam is manufactured as sheets. Extruded PS board is used as an insulation material in much the same way as foamed polyurethane insulation. Because the blowing agent (CFC-12) is able to permeate through the foam sheet relatively quickly, the CFC from sheet manufacture is emitted early in the product's shelf life. On the other hand, because PS board is much thicker than the sheet, the CFC is retained for a longer period of time (half-life approximately 40 years).

For PS foam sheet, the use of low ozone depleting blowing agents can reduce the emission of ozone depleting CFC-12. Such alternative blowing agents include non-fully halogenated CFCs, hydrocarbons, and inert gases. Currently, hydrocarbons such as n-pentane, isopentane, and butane are viable candidates. These hydrocarbons can eliminate use of CFC-12 in this application, but the resulting hydrocarbon emissions may be subject to state and local VOC (volatile organic compound) regulations in areas where high levels of ground-level ozone are an environmental concern. Also, there are added costs associated with increased fire protection necessary for use of the flammable hydrocarbons in the manufacturing process.

The use of carbon adsorption systems for the recovery and recycle of CFC-12 for PS sheet manufacturing can also reduce the emission of ozone depleting CFC-12. Though the system would require a substantial capital investment, this cost could be partially offset if the recovered CFC-12 could be reused.

The only other currently available control technique for CFCs from PS foam sheet is substitution with products which do not contain CFCs. A host of alternative materials are already used for the same products made with CFC-blown PS sheet. As one example, both PS and paper egg cartons can be found alongside each other in many food stores.

Since PS board is used as an insulation material and the CFC-12 is essentially trapped within the foam matrix for several years, substitution of alternative materials which do not contain CFCs is one promising control option as was true for rigid PU insulation materials.

### *Polyolefin and Phenolic Foams*

The development of closed-cell phenolic foam in 1981 has resulted in an increase in the production of phenolic foam in recent years. Improved fire retardance, low smoke generation, high temperature resistance, and good thermal properties have promoted its use as insulation material in the construction industry. As in the case of rigid polyurethane and rigid polystyrene boardstock, most CFC-11 and CFC-113 used in the production of closed-cell phenolic foam is stored, or banked, and either diffuses out slowly during the foam's lifetime, or is released when the foam is destroyed after use.

Manufacturing controls can achieve a maximum emissions reduction equal only to the amount of CFC emitted during manufacture. Quantitative emission data are not available for the types of emissions occurring during phenolic foam manufacture. Again, the most effective controls for CFCs from this type of foam will be those which not only reduce manufacturing emissions, but will also reduce the CFC bank in the products. Both chemical and product substitutes therefore are attractive control options. Currently, there are many alternative products available which are used as sheathing and roof insulating materials as was noted in the discussion of rigid polyurethane insulation foam. Since phenolic foam insulation is relatively new and currently competes with the other non-CFC containing alternatives, a change in the availability or cost of phenolic foam should not cause severe disruptions in the building trade.

Like phenolic foam, polypropylene, polyethylene, and polyvinyl chloride foams are relative newcomers to the marketplace. These foams find limited use in specialty applications such as padding for athletic equipment, decorative wrapping, and packaging of delicate electronic components. CFC emissions for these foams may be best characterized as prompt, with emissions essentially equalling consumption for a given year. Owing largely to the relatively recent appearance of these foams on the marketplace and to the fact that there are few producers of these materials, data on production, CFCs used and emitted, and control opportunities are very limited. However, it is expected that a number of alternative non-CFC containing products could be substituted for these foams in some applications, and this would be a likely market response if the cost of the polyolefin foams were to increase significantly due to a price increase in currently used CFCs. However, because of the physical attributes of polyolefin foams (e.g., multiple-drop protection, strength, static discharge protection), they are often the most cost effective packaging materials. In these instances, alternative products may not be available.

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*The complete report, entitled "Control Technology Overview Report: CFC Emissions from Rigid Foam Manufacturing," (Order No. PB 88-160 379/AS; Cost: $19.95, subject to change) will be available only from:*
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