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Project Summary

Control Technology Overview Report: CFC-11 Emissions from Flexible Polyurethane Foam Manufacturing

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An engineering evaluation of technical options to reduce chlorofluorocarbon (CFC) emissions from flexible slabstock and molded polyurethane foam manufacturing plants was performed. Included in the technical options examined were recovery and recycle of CFC-11, alternative chemicals and processes, and substitute products. Two possible emission control methods were studied in detail: substitution of methylene chloride as the auxiliary foam blowing agent and carbon adsorption/recycle of exhausted CFC-11 vapors. Promising near-term control options identified for slabstock production were methylene chloride substitution for CFC-11, and establishment of a minimum foam density to reduce the amount of auxiliary blowing agent used. For molded polyurethane foam production, use of chemical systems which eliminate the need for auxiliary blowing agents appeared to be a near-term option. Possible longer-term options included carbon adsorption with CFC-11 recovery, development of chemical systems requiring little or no auxiliary blowing agents for slabstock production, and commercialization of new alternative blowing agents. Each of the longer-term options has in common a need for additional information to adequately define the optimal implementation strategy.

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

Over the past decade, potential depletion of stratospheric ozone through the action of fully halogenated chlorofluorocarbons (CFCs) has been the subject of extensive study. This phenomenon involves complicated chemical interactions that are driven by ultraviolet (UV) radiation and occur in the upper atmosphere. Not only are the interactions extremely complex, but direct observations of them are difficult.

An important aspect of the stratospheric ozone depletion issue is the lag time between emission of CFCs into the environment and their ultimate arrival in the upper atmosphere. Since fully halogenated CFCs are not readily decomposed in the troposphere, they remain stable for the long time required for transport to the stratosphere. Because of this extended transport period, effects of current emissions are not manifested until several decades later. Once in the stratosphere, these compounds can be acted upon by UV radiation of the proper wavelengths to release chlorine species that in turn contribute to destruction of ozone. Depletion of the earth's protective layer of stratospheric ozone is predicted to result in increased biologically damaging UV radiation's reaching the earth's surface.

CFCs are widely used in several industries including flexible polyurethane foam manufacturing. In that industry, CFC-11 (fluorotrichloromethane) is used as a physical blowing agent to reduce foam density and increase softness. Another key role of the CFC-11 is to dissipate heat generated by the polyurethane formation reactions thereby controlling foam temperature during formation and curing.

Emissions of CFC-11 from the flexible foam manufacturing process are characterized as being prompt; i.e., all of the gas is released during, or soon after, foam formation. It is estimated that flexible foam production accounts for about 30% of the cumulative CFC-11 which has been released into the atmosphere.

The objective of this project was to evaluate technical options to reduce emissions of CFC-11 from flexible foam plants. In this overview study, the depth of technical evaluation was limited, in some cases, by the information available on each technology. However, two possible emission control methods were extensively studied: substitution of methylene chloride for CFC-11 as an auxiliary blowing agent and carbon adsorption/recycle of exhausted CFC-11 vapors. Also, an important component of this study was to summarize recent innovations in foam technology which have the potential to reduce or eliminate CFC-11 use.

Accomplishments/Results

Control methods under the heading of capture/destruction or capture/recycle techniques include carbon adsorption of CFC-11, thermal or catalytic incineration, liquid absorption, and direct vapor condensation. Pilot tests have shown that carbon adsorption may be feasible for CFC-11 control. However, a number of technical issues have not been satisfactorily resolved, including fouling of the carbon bed by isocyanate residue, quality of recycled CFC, and disposal of used carbon and steam condensate. The remaining control methods in this category presently suffer from either high cost or a preponderance of negative technical factors which would prevent their application for flexible foam plants.

The cost effectiveness of carbon adsorption/recycle was found to be highly variable, depending on the CFC-11 market price, recovery efficiency, facility size, and required capital investment. It is felt that this control method is more applicable to slabstock facilities than molded foam plants due to potentially more efficient capture of released blowing agent from the slabstock process. High capital costs are a substantial barrier to implementation, because the competitive nature of the foam business makes it difficult for producers to commit large sums of capital. It would also be difficult to offset annualized operating costs through the recovery credit for recycled CFC-11 unless the price of CFC-11 were to increase substantially.

The near-term possibility of methylene chloride conversion as a CFC-11 control measure is excellent, since most slabstock producers now employ this technology. It is estimated that as much as 70% of all flexible slabstock foam could be produced using this alternative blowing agent. Full conversion to methylene chloride generally requires some expenditure for foam reformulation and plant modification such as improved ventilation in foam curing areas. These costs and the increased difficulty in producing quality low density, soft foams with methylene chloride are potential impediments for such conversion. Therefore, it is possible that a fraction of the low density foam market would disappear if CFC-11 were no longer available. There is also a strong preference on the part of some producers to avoid methylene chloride owing to its own current regulatory uncertainty.

Alternative CFCs having ozone depletion potentials lower than CFC-11 are a promising long-term control method. Two primary candidates are CFC-123 and CFC-141b. CFC-123 appears to be both reasonably safe and technically feasible; however, CFC-123 production costs are expected to be higher than for CFC-11 resulting in a bulk sales price roughly two to four times that of CFC-11. Also, there is no commercial scale production of CFC-123 in the U.S. at the present time. Safety considerations are the major drawback of CFC-141b in foam blowing applications. Flexible foam blowing agents should have low flammability and low toxicity, since their vapors are usually present in detectable concentrations in the plant environment. Toxicological testing on CFC-141b has not been completed; but current reports indicate that the compound is a "weak mutagen." In addition, CFC-141b is reportedly more flammable than other substitute flexible foam blowing agents. Chemical producers have indicated that, without market incentives to produce CFC-123 or CFC-141b, commercialization is unlikely and that even if initiated, from 5 to 7 years would be required for the chemical to be commercially available.

Several recent innovations in the area of molded polyurethane foam chemical systems could ultimately reduce or eliminate the need for auxiliary blowing agents for these foams. In general, these newer systems utilize established HR (high-resilience) auxiliary blowing agent technology, but permit foam production without CFC-11. These systems employ either conventional toluene diisocyanate (TDI) reagents, or a class of isocyanates referred to as MDI (methylene diphenyl isocyanate) compounds, and families of more reactive polyols. It is not currently possible to economically achieve U.S. auto seat specifications using so-called "water-blown" MDI-based formulations. But, TID-based water-blown systems are available that can produce all currently used molded foam grades. Only slightly increased raw material costs are anticipated for these systems.

New chemical systems have also been introduced which would permit production of softer slabstock foams without the use of auxiliary blowing agents, but such systems have yet to be able to produce the super-soft, low density foams. These systems employ more reactive, and generally more expensive, polyols, and/or polyol blends.

Another slabstock process which could reduce the need for CFC-11 blowing agent has been developed in Belgium and is currently licensed by Innochem S.A. in Switzerland. This process, known as the "AB Process," is claimed to be applicable to a range of slabstock grades and some molded foam components, and substitutes formic acid for some of the water in the foam formulation. The chemical reactions release twice the volume of blowing gas as with conventional chemistry, but the additional gas released is CO. Since CO is a recognized toxic gas, extra monitoring and safety precautions are necessary. Further handling of the concentrated formic acid involves special ventilation requirements and materials of construction. There have been no reported full-scale applications, but some testing of this process has been carried out in Europe.

In addition to the technological controls discussed above, several product substitutes could be used in place of polyurethane foam for certain applications. Given appropriate market conditions, materials such as jute, cotton batting, and latex foam could once again command a portion of the cushioning market that they once enjoyed prior to the development of flexible polyurethane foam. Replacement of polyurethane foams by such materials would likely occur only if CFC-11 and methylene chloride emissions were both regulated, thus increasing the costs of the low density polyurethane foam grades.

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The complete report, entitled "Control Technology Overview Report: CHC-11 Emissions from Flexible Polyurethane Foam Manufacturing," (Order No. PB 88-160 387/AS; Cost: $25 95, subject to change) will be available only from:
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