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Project Summary

Assessment of VOC Emissions from Fiberglass Boat Manufacturing

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This report presents an assessment of volatile organic compound (VOC) emissions from fiberglass* boat manufacturing. A description of the industry structure is presented, including estimates of the number of facilities, their size, and geographic distribution. The fiberglass boat manufacturing process is then described along with the sources and types of VOC emissions. Model plants representative of typical facilities are also described. Estimates of VOC emissions are presented on per plant and national bases. VOC emissions from this industry consist mainly of styrene emission from gel coating and lamination, and acetone or other solvent emissions from clean-up activities. Potential VOC control technologies are evaluated for this industry, including a discussion of technical feasibility limited cost data are also provided.

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).

*Used in this Summary, "fiberglass" refers to fibrous glass or fiberglass-reinforced plastic, not necessarily Fiberglas™, trademark of Owens-Corning Fiberglas Corporation, Toledo, Ohio.

Introduction

The purpose of this project was to define the nature and scope of volatile organic compound (VOC) emissions from the manufacture of fiberglass marine craft. This included developing a characterization of the fiberglass boat manufacturing industry, estimating VOC emissions on per plant and national bases, speciating emissions, and identifying and evaluating potential control options.

The fiberglass boat manufacturing and repair industry consists of about 1,800 facilities. These facilities employ about 47,000 people and are located in 34 of the 48 continental United States. About 88% of these establishments are small operations, employing less than 50 people. States that have a large number of boat manufacturing facilities include California, Florida, Illinois, Indiana, Michigan, North Carolina, South Carolina, Tennessee, Texas, and Washington.

Open/Closed Contact Molding

The most common fiberglass boat production method is open contact molding. This method consists of laying up plies of fiberglass reinforcement impregnated with resin on an open male (convex) or female (concave) mold. For manufacturing boats, a female mold is generally preferred since it yields a smooth outer surface which is more desirable for hulls and decks. The layers are built up to the desired thickness and allowed to cure.

The initial layer of resin is formed without any reinforcing material by spraying gel coat (unsaturated polyester

resin, catalyst, and pigments) into the empty mold to a precise thickness. After allowing the gel coat to cure fully, laminates of resin and fiberglass are applied by machine lay-up, hand lay-up or spray lay-up. Machine lay-up involves the simultaneous mechanical application of fiberglass reinforcement material and is generally reserved for large hull boats; e.g., sailboats with deep keels. In hand lay-up, resin is brushed or sprayed on the tacky surface of the gel coat, the fiberglass reinforcement material is placed into the mold, then the laminate is completely wet out with resin and rolled by hand to remove air pockets and other imperfections. The spray lay-up method uses a chopper gun which simultaneously deposits chopped strand fiberglass and catalyzed resin on the mold, after which rollers are used, as in hand lay-up, to remove entrapped air.

Two alternative closed molding methods which have been experimented with in the fiberglass boat manufacturing industry are bag molding and resin transfer molding (RTM). Bag molding uses a bag or flexible membrane to apply vacuum or pressure during the molding operation. Vacuum bag molding applies pressure against the laminate by drawing a vacuum under a cellophane, vinyl or nylon bag which covers the laminate. Pressure bag molding forces the bag against the laminate using compressed air or steam. In the RTM process, fiberglass reinforcement consisting of continuous or chopped strand glass fiber mats is placed between halves of a mold. After the mold is closed, catalyzed resin is injected into the mold and allowed to cure. The mold is then opened and the finished part removed. The major technical difficulty in using this process for boat manufacturing is that resin void spaces may occur, rendering the part unusable. Also, highly skilled labor is required for RTM to be successful.

VOC Emissions/Controls

VOC emissions from fiberglass boat manufacturing consist mainly of acetone and styrene. There are four areas in the fiberglass boat production process where VOC may be emitted to the atmosphere: resin storage, production, assembly, and waste disposal. The major emissions sources are exhausts from gel coat spray booths, room exhausts from the lamination area, and evaporation of acetone or other solvents during clean-up. Emission factors for resin application in open contact molding range from 5 to 13 lb* styrene per 100 lb of styrene used. Emissions from gel coat application and curing are 26 to 35 lb per lb of styrene monomer used. Cleaning solvent emissions, primarily acetone, can account for 36% of the total VOC emissions and are about equal to 56% of the styrene emissions. Total VOC emissions per plant are estimated to range from 2 to 140 tons per year. Total national VOC emissions are estimated to be 20,150 tons per year.

The two general types of VOC emission control techniques available are process changes and add-on controls. The process change offering the greatest potential for VOC emission reductions at low costs is the substitution of lower VOC-containing materials. These include vapor-suppressed resins, low styrene resins, water-based emulsions for cleanup, and dibasic ester compounds for cleanup.

Vapor-suppressed resins contain additives which reduce VOC emissions during resin curing. The most common vapor suppression additive is paraffin, which migrates to the surface of the resin layer and reduces the volatilization of free styrene during resin curing. Styrene emissions reductions ranging from 20 to 35 % can be achieved on a per plant basis. Vapor-suppressed resins are not currently being used universally in the fiberglass boat manufacturing industry due to problems in secondary bonding which reduce product strength.

The emission reduction from low styrene resins is less than that of vapor-suppressed reins; however, low styrene resins are currently available and being used in the industry. Styrene emissions can be reduced by about 14% using a 35% styrene by weight resin. Conventional resins contain 40 to 50% styrene by weight. A number of boat plants have reduced the styrene content in their resins to 38 to 40% styrene with satisfactory results. Very few boat manufacturers have been able to reduce styrene content below 35% without sacrificing some of the structural integrity of the boat.

Water-based emulsions can be used to replace about 50% of the solvent used for cleanup. These emulsion cleaners would be expected to reduce clean-up emission by about 50%. The cleaners are successfully being used commercially in boat plants for resin cleanup and their use has been required as a permit restriction to reduce VOC emissions from fiberglass boat plants in some recent Best Available Control Technology (BACT) decisions. These emulsions, however, appear to be inadequate for gel coat or cured resins cleanup.

Alternative cleaning compounds containing dibasic esters (DBEs) are currently being tested at a number of fiberglass boat plants. These cleaning solutions show great potential to replace acetone completely for resin and gel coat cleanup. Due to the much lower vapor pressure of DBEs, these substitutes can provide dramatic VOC emission reductions. Based on preliminary tests, an estimated reduction in VOC emissions from clean-up activities of 75% can be achieved if DBEs are used in place of acetone. The DBE cleaner is currently two to three times more expensive than acetone; however, it lasts longer because it evaporates at a slower rate and it can be recycled.

Due to the high exhaust flow rates and the low VOC concentrations characteristic of this industry, add-on controls typically used in other VOC-emitting industries have not been applied to boat manufacturing. Three add-on control technologies were evaluated for control of VOC emissions from fiberglass boat manufacturing facilities: incineration, absorption, and adsorption.

Of the add-on controls evaluated, incineration is the only demonstrated and readily available technology for controlling VOC emissions from fiberglass manufacturing facilities. Although incineration has not been used in a boat manufacturing facility to date, it has been installed as a means of VOC control in a fiberglass tub and shower facility. Incineration can reduce VOC emissions by 90% or more; however, the cost per ton of VOC removed can be quite expensive (e.g., $15,000/ton).

There are no known applications of chemical scrubbers or absorbers to the fiberglass boat manufacturing industry. However, two systems could theoretically be used for removing styrene from exhaust air. Both Chemtact™ and the Styrex™ scrubbers have shown the ability to absorb styrene. Further testing and analysis is needed to determine the effectiveness of these systems for the high exhaust flow rates and low VOC concentrations that are typical of the industry.

Use of carbon adsorption for control of VOC emissions in the boat manufacturing

*For readers more familiar with metric units: 1 lb = 0.45 kg, and 1 ton = 907 kg.

industry may be limited due to the potential for styrene to polymerize on the carbon and deactivate the bed, and due to the vast difference in the capacity for carbon to adsorb styrene versus acetone. The adsorptive capacity of styrene is 30 %, while the capacity for acetone is only 1 to 2%, making the capture of acetone the limiting design criterion. There are no known applications of carbon adsorption to the fiberglass boat manufacturing industry, however, a fiberglass horse trailer manufacturer currently uses a carbon adsorber to control styrene emissions.

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Charles Darvin *is the EPA Project Officer (see below).*
The complete report, entitled "Assessment of VOC Emissions from Fiberglass Boat Manufacturing," (Order No. PB 90-216 532; Cost: $23.00, subject to change) will be available only from:
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