United States Environmental Protection Agency

Control Techniques Guidelines for Fiberglass Boat Manufacturing Materials

This page intentionally left blank

EPA-453/R-08-004
September 2008

Control Techniques Guidelines for Fiberglass Boat Manufacturing Materials

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Sector Policies and Programs Division
Research Triangle Park, NC

This page intentionally left blank

TABLE OF CONTENTS

This page intentionally left blank

I. Introduction

Clean Air Act (CAA) section 172(c)(1) provides that state implementation plans (SIPs) for nonattainment areas must include "reasonably available control measures" (RACM), including "reasonably available control technology" (RACT), for sources of emissions. Section 182(b)(2)(A) provides that for certain nonattainment areas, States must revise their SIPs to include RACT for each category of volatile organic compound (VOC) sources covered by a control techniques guidelines (CTG) document issued between November 15, 1990 and the date of attainment.

The United States Environmental Protection Agency (EPA) defines RACT as "the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility." 44 FR 53761 (September 17, 1979). In subsequent Federal Register notices, EPA has addressed how States can meet the RACT requirements of the Act.

CAA section 183(e) directs EPA to list for regulation those categories of products that account for at least 80 percent of the volatile organic compound (VOC) emissions, on a reactivity-adjusted basis, from consumer and commercial products in areas that violate the NAAQS for ozone (i.e., ozone nonattainment areas). EPA issued the list on March 23, 1995, and has revised the list periodically. *See* 60 FR 15264 (March 23, 1995); *see also* 71 FR 28320 (May 16, 2006), 70 FR 69759 (Nov. 17, 2005); 64 FR 13422 (March 18, 1999). Fiberglass boat manufacturing is included on the current section 183(e) list.

This CTG is intended to provide State and local air pollution control authorities information that should assist them in determining RACT for VOC from fiberglass boat manufacturing operations. In developing this CTG, EPA evaluated the sources of VOC emissions from the fiberglass boat manufacturing industry and the available control approaches for addressing these emissions, including the costs of such approaches. Based on available information and data, EPA provides recommendations for RACT for fiberglass boat manufacturing.

States can use the recommendations in this CTG to inform their own determination as to what constitutes RACT for VOC for fiberglass boat manufacturing in their particular nonattainment areas. The information contained in this document is provided only as guidance. This guidance does not change, or substitute for, requirements specified in applicable sections of the CAA or EPA's regulations; nor is it a regulation itself. This document does not impose any legally binding requirements on any entity. It provides only recommendations for State and local air pollution control agencies to consider in determining RACT. State and local pollution control agencies are free to implement other technically-sound approaches that are consistent with the CAA and EPA's implementing regulations.

The recommendations contained in this CTG are based on data and information currently available to EPA. These general recommendations may not apply to a particular situation based upon the circumstances of a specific source. Regardless of whether a State chooses to implement the recommendations contained herein through State rules, or to issue State rules that adopt different approaches for RACT for VOC from fiberglass boat manufacturing operations, States must submit their RACT rules to EPA for review and approval as part of the SIP process. EPA will evaluate the rules and determine, through notice and comment rulemaking in the SIP approval process, whether the submitted rules meet the RACT requirements of the CAA and EPA's regulations. To the extent a State adopts any of the recommendations in this guidance into its State RACT rules, interested parties can raise questions and objections about the substance of this guidance and the appropriateness of the application of this guidance to a particular situation during the development of the State rules and EPA's SIP approval process.

CAA section 182(b)(2) requires that a CTG issued after November 15, 1990 and the date of attainment include the date by which States subject to section 182(b) must submit SIP revisions in response to the CTG. Accordingly, EPA is providing in this CTG a one year period for the required submittal of a revised SIP. Pursuant to section 182(b)(2), States required to submit rules consistent with section 182(b) must submit their SIP revisions within one year of the date of issuance of the final CTG for fiberglass boat manufacturing.

II. Background and Overview

The EPA has not published a previous CTG for fiberglass boat manufacturing materials, but did publish an assessment of VOC emissions from fiberglass boat manufacturing in 1990. The 1990 assessment defined the nature and scope of VOC emissions from fiberglass boat manufacturing, characterized the industry, estimated per plant and national VOC emissions, and identified and evaluated potential control options.

In 2001, EPA promulgated the National Emission Standards for Hazardous Air Pollutants for Boat Manufacturing, 40 CFR part 63, subpart VVVV (2001 NESHAP). The 2001 NESHAP established organic hazardous air pollutant (HAP) emissions limits based on low-HAP resins and gel coats and low-emitting resin application technology.

Several of the air pollution control districts in California have specific regulations that control VOC emissions from fiberglass boat manufacturing operations, as part of their regulations for limiting VOC emissions from polyester resin operations. Several other states also have regulations that address VOC emissions from fiberglass boat manufacturing as part of polyester resin operations. A discussion of the applicability and control options found in the Federal actions, the California air district and other State rules is presented in Section V of this document.

EPA developed the recommended approaches contained in this document after reviewing the 1990 VOC assessment, the 2001 NESHAP, and existing California district and other State VOC emission reduction approaches, and after considering information obtained since the issuance of the 2001 NESHAP.

The remainder of this document is divided into six sections. Section III describes the scope of sources to which the control recommendations in this CTG could apply. Section IV describes the fiberglass boat manufacturing processes and identifies the sources of VOC emissions from those processes. Section V describes the available control approaches for addressing VOC emissions from this product category and summarizes Federal, State and local approaches for addressing such emissions. Section VI provides our recommendations for RACT for fiberglass boat manufacturing materials. Section VII discusses the cost-effectiveness of the recommended control approaches. Section VIII contains a list of references.

III. Applicability

This CTG provides control recommendations for reducing VOC emissions from the use of gel coats, resins, and materials used to clean application equipment in fiberglass boat manufacturing operations. This section addresses EPA's recommendations as to the scope of entities to which the RACT recommendations in this CTG should apply. As explained above, this document is a guidance document and provides information for States to consider in determining RACT. When State and local pollution control agencies develop RACT rules, they may elect to adopt control approaches that differ from those described in this document and/or promulgate applicability criteria that differ from those recommended here.

This CTG applies to facilities that manufacture hulls or decks of boats from fiberglass, or build molds to make fiberglass boat hulls or decks (hereinafter referred to as “fiberglass boat manufacturing facilities”). We do not extend our recommendations in this CTG to facilities that manufacture solely parts of boats (such as hatches, seats, or lockers), or boat trailers, but do not manufacture hulls or decks of boats from fiberglass, or build molds to make fiberglass boat hulls or decks. If a facility manufactures hulls or decks, or molds for hulls or decks, then the manufacture of all other fiberglass boat parts, including small parts such as hatches, seats, and lockers is also covered.

We recommend that the control approaches discussed in Section VI of this CTG apply to each fiberglass boat manufacturing facility where the total actual VOC emissions from all fiberglass boat manufacturing operations covered by the recommendations in Section VI of this CTG are equal to or exceed 6.8 kg/day (15 lb/day). An alternative equivalent threshold would be 2.7 tons per 12-month rolling period. Cleaning materials should be included in determining whether total actual VOC emissions exceed this level. If a facility has add-on controls, then emissions before the add-on controls should be used in determining if a facility meets this threshold.

The control approaches discussed in Section VI of this CTG do not extend to surface coatings applied to fiberglass boats, and do not apply to industrial adhesives used in the assembly of fiberglass boats. Surface coatings for fiberglass and metal recreational boats (pleasure craft) are addressed in the CTG for miscellaneous metal parts and plastic parts surface coating. Industrial adhesives used in boat assembly are addressed in the CTG for miscellaneous industrial adhesives. Polyester resin putties used to assemble fiberglass parts, however, are not considered adhesives and are addressed in this CTG.

We do not recommend the control approaches discussed in this CTG for facilities that emit below 6.8 kg/day because of the very small VOC emission reductions that could be achieved. Such a level is considered to be very low within the fiberglass boat manufacturing industry and is expected only from facilities producing only small numbers of small boats (such as specialty kayaks or canoes). Furthermore, based on the 2002 National Emission Inventory (NEI) and the 2004 ozone nonattainment designations, we estimated that most of the fiberglass boat manufacturing facilities located in ozone nonattainment areas (67 out of 91 facilities) emit at or above this level. Therefore, these facilities would be addressed by our recommendations in the CTG. As mentioned above, for purposes of determining whether a facility meets our recommended applicability threshold, aggregate emissions, before consideration of control, from all fiberglass boat manufacturing operations (including related cleaning activities) at a given facility are included.

In developing their RACT rules, State and local agencies should consider carefully the facts and circumstances of the affected sources in their States. As noted above, States can adopt the above recommended 15 lb/day actual VOC emissions or an equivalent applicability threshold, or they can develop other applicability criteria that they determine are appropriate, considering the facts and circumstances of the sources in their particular nonattainment areas. EPA will review the State RACT rules in the context of the SIP revision process.

Two items were used as sources of emissions data and statistical information concerning the fiberglass boat manufacturing industry as a whole. These were the 2002 National Emission Inventory (NEI) and industry survey data collected by EPA during the development of the 2001 NESHAP. The NESHAP data provided by industry represented operations in 1996 and 1997.

The NESHAP data indicate that styrene and methyl methacrylate (MMA), which are both VOC and organic HAP, account for nearly all the VOC emissions, as well as HAP emissions, from fiberglass boat manufacturing facilities. Therefore, total HAP and VOC emissions from fiberglass boat manufacturing facilities are nearly equal. The 2001 NESHAP estimated that baseline HAP emissions from boat manufacturing were 9,920 tons per year (tpy)[a], and we can assume that this estimate represents nearly all the VOC emissions as well.

In developing this CTG, the 2002 NEI database was queried for VOC emissions generated by facilities that were listed under SIC 3732, boat building and repairing. This query resulted in 223 facilities with total VOC emissions of 9,100 tpy. In the <u>Federal Register</u> notice of November 17, 2005 regarding the changes to the Section 183(e) category list and schedule for regulation, EPA reported that VOC emissions from fiberglass boat manufacturing materials, based on the 1995 NEI, were 11,000 Mg/yr (12,100 tpy).[b] The general agreement among the 2002 NEI VOC emissions, the 2001 NESHAP HAP emissions, and the 1995 NEI VOC emissions estimates, taking into

---

[a] 66 FR 44,222. August 22, 2001.

[b] 70 FR 69,760. November 17, 2005.

account possible changes in the industry over time, indicates that the query of the 2002 NEI provides a reliable estimate of the number of facilities and total VOC emissions from fiberglass boat manufacturing materials.

IV. Process Description and Sources of VOC Emissions

Several types of boats are manufactured in the United States, including sailboats, powerboats, yachts, personal watercraft, and small miscellaneous boats such as kayaks and canoes. These boats are manufactured from a variety of materials, including, but not limited to, fiberglass (also known as fiber reinforced plastic or FRP), aluminum, rotationally molded (rotomolded) polyethylene, and wood. Fiberglass is the most common material used in boat manufacturing and is the focus of this CTG.

A. Process Description

Boats made from fiberglass are typically manufactured in a process known as open molding. Separate molds are typically used for the boat hull, deck, and miscellaneous small FRP parts such as fuel tanks, seats, storage lockers, and hatches. The parts are built on or inside the molds using glass roving, cloth, or mat[c] that is saturated with a thermosetting liquid resin such as unsaturated polyester or vinylester resin. The liquid resin is mixed with a catalyst before it is applied to the glass, which causes a cross-linking reaction between the resin molecules. The catalyzed resin hardens to form a rigid shape consisting of the plastic resin reinforced with glass fibers.

The fiberglass boat manufacturing process generally follows these production steps:

1) Before each use, the molds are cleaned and polished and then treated with a mold release agent that prevents the part from sticking to the mold.

2) The open mold is first spray-coated with a clear or pigmented polyester resin known as a gel coat. The gel coat will become the outer surface of the finished part. The gel coat is mixed with a catalyst as it is applied so that it will harden. The catalyst can be mixed either inside the spray gun (internal mix) or immediately after leaving separate orifices on the spray gun (external mix). The gel coat is applied to a thickness of about 18 mils (0.018 inches). Clear gel coats are often mixed with metal flakes to create an automotive-type metallic finish over a pigmented gel coat. Pigmented gel coats are used when a solid color surface is desired. Most gel coats are pigmented. Since they do not have any pigments, clear gel coats usually have a higher VOC content than pigmented gel coats.

---

[c] Roving is a bundle of continuous glass fibers that is fed from a spool to a specialized gun that chops the roving into short fibers, mixes them with catalyzed resin, and deposits them on the mold surface in a random pattern. Cloth is a fabric made of woven yarns of glass fibers. Mat is a prepared material consisting of short glass fibers that are fixed to each other in a random pattern by a chemical binder, or are mechanically stitched to a lightweight fabric.

3) After the gel coat has hardened, the inside of the gel coat is coated with a skin coat of polyester resin and short glass fibers (either glass mat or chopped roving) and then rolled with a metal or plastic roller to compact the fibers and remove air bubbles. The skin coat is about 90 mils (0.09 inches) thick and is intended to prevent distortion of the gel coat (known as "print through") from the subsequent layers of fiberglass and resin;

4) After the skin coat has hardened, additional glass reinforcement in the form of chopped roving, chopped strand mat, or cloth is applied to the inside of the mold and saturated with catalyzed polyester resin. The resin is usually applied with either mechanical equipment or by hand using a bucket and brush or paint-type roller.

5) The saturated fabric is then rolled with a metal or plastic roller to compact the fibers and remove air bubbles.

6) More layers or “laminations” of woven glass or glass mat and resin are applied until the part is the desired thickness. The part is then allowed to harden while still in the mold. As the part cures it generates heat from the exothermic reactions that take place as the resin hardens; very thick parts may be built in stages to allow this heat to dissipate to prevent heat damage to the mold or part.

7) After the resin has cured, the part is removed from the mold and the edges are trimmed to the final dimensions.

8) The different FRP parts of the boat are assembled using small pieces of woven glass or glass mat and resin, adhesives, or mechanical fasteners. Polyester resin mixed with fillers to create putty is also often used to assemble fiberglass parts and to fill gaps between parts. The putty becomes part of the composite structure. The putties may be applied by hand, or by using mechanically powered equipment similar to a large caulking gun.

9) The interior surfaces of the boat may be coated, either by spray or brush, with pigmented gel coat that serves as a surface finish so the interior spaces have a uniform color.

10) Flotation foam is typically injected into closed cavities in the hulls of smaller boats to make the boat unsinkable and capable of floating upright if swamped.

11) After the assembly of the hull is complete, the electrical and mechanical systems and the engine are installed along with carpeting, seat cushions, and other furnishings, and the boat is prepared for shipment.

12) Some manufacturers paint the topsides of their boats to obtain a superior finish or the bottoms to prevent marine growth. However, this is not a common practice.

13) Larger boats generally also require extensive interior woodwork and cabin furnishings to be installed.

As mentioned above, fiberglass boat manufacturing facilities covered by this CTG include facilities that construct the molds or "tools" that are used to build the separate parts of the fiberglass boat. Most fiberglass boat manufacturers also build their own molds, although some obtain molds from facilities dedicated to building molds, either at a separate facility within a larger company, or as a completely separate entity. The production of molds is done using specialized resins and gel coats referred to as tooling resin and gel coat. These differ from production resin and gel coat in that they are harder, more heat resistant, and more dimensionally stable than production materials.

Construction of a mold begins with the construction of a full-size model of the part to be manufactured. This model is often called a "plug" and the mold is eventually built over the finished plug. The plug is built from rigid foam that is carved to shape. The foam is then covered with tooling resin and fiberglass and then a layer of tooling gel coat, and then sanded to its final shape and then polished and waxed so the mold will not stick to it when the mold is finished.

The mold is then built over the plug using tooling gel coat and resin and fiberglass. The tooling gel coat will become the interior surface of the mold, supported by the resin and fiberglass. The tooling resin often has inert filler added to it so it is more dimensionally stable and is able to absorb more heat from the part during the molding process. A metal framework is also added to the exterior of the mold to support the mold after it is removed from the plug. When the mold is removed from the plug, the mold will have a cavity or exterior surface that is the exact opposite of the shape of the plug and parts that will produced. The interior surface of the mold is polished and waxed so that finished parts will not stick the mold surface and they can be removed.

A single mold can be used to make many copies of the same part. Occasionally a mold may need to be repaired if the surface is damaged during part removal. These repairs are done using tooling resin and gel coat to which extra styrene has been added so the repair material will bond to the existing mold surfaces.

B. Sources of VOC Emissions

Styrene and methyl methacrylate (MMA) are the primary VOC emitted from fiberglass boat manufacturing materials. The resins contain styrene and the gel coats contain both compounds. Styrene and MMA are monomers. A monomer is a volatile organic compound that partially combines with itself, or other similar compounds, by a cross-linking reaction to become a part of the cured resin. A fraction of each monomer compound evaporates during resin and gel coat application and curing. Not all of the styrene and MMA evaporate, because a majority of these compounds are bound in the cross-linking reaction between polymer molecules in the hardened resin or gel coat and become part of the finished product. In closed molding operations, nearly all of the monomers are bound in the cross-link reactions and emissions are very low. In the remainder of this CTG, these monomers in resins and gel coats are referred to as monomer VOC. Styrene and MMA are the only monomer VOC we have identified in the resins and gel coats used in fiberglass boat manufacturing.

The fraction of monomer VOC that is emitted from resin and gel coat used for fiberglass boat manufacturing is dependent on several factors, including the initial monomer VOC content of the material, the application method, and the thickness of the part or layer that is curing. Monomer VOC emission rates are usually expressed in terms of lb monomer VOC emitted per ton of material applied (lb/ton), or kilogram per megagram (kg/Mg). Monomer VOC evaporation from gel coats is higher than from resins because gel coats are applied in thinner coats, which increases evaporation. When material is applied in thicker layers, the overlying material impedes evaporation from the underlying material, so a higher fraction is bound up during the cross linking reactions before it has a chance to evaporate.

Higher monomer VOC materials also tend to emit a higher fraction of the monomer VOC than lower monomer VOC materials. Therefore, lowering the monomer VOC content of the resin or gel coat has a two-fold effect: first, it decreases the amount of monomer VOC that could be emitted, and second, a smaller fraction of the monomer VOC that is present is emitted to the atmosphere.

The type of application equipment used also affects the fraction of monomer VOC that is emitted. Spray application equipment that atomizes the resin as it is applied creates small droplets with a high surface-to-volume ratio that increases the amount of monomer VOC that evaporates during application. Non-atomizing application methods minimize the surface area during application and reduce monomer VOC emission rates. These non-atomizing methods include resin flow coaters, which create consolidated streams of resin (like a shower head) instead of atomized droplets, pressure fed resin rollers that apply resin directly onto the part, and fluid impingement technology which creates large droplets.

Resins and gel coats may also contain non-monomer VOC that are not reactive and do not become part of the hardened resin or gel coat. All of the non-monomer VOC, if present, is assumed to be emitted. However, the non-monomer VOC constitute less than 5 percent of the total VOC in all resins and gel coats and usually comprise less than 1 percent of each resin or gel coat, by weight. Many resins and gel coats do not contain reportable amounts of non-monomer VOC, based on a review of material safety data sheets (MSDS) for resins and gel coats.

Resin and gel coat application equipment requires solvent cleaning to remove uncured resin or gel coat after each use. The solvents used to clean the application equipment are also a potential source of VOC emissions.[d] Catalyzed resin or gel coat

---

[d] In a Federal Register notice, EPA stated that the cleaning operations associated with certain specified section 183(e) consumer and commercial product categories, including fiberglass boat manufacturing, would not be covered by EPA's 2006 CTG for industrial cleaning solvents (71 FR 44522 and 44540, August 4, 2006). In the notice, EPA expressed its intention to address cleaning operations associated with these categories in the CTGs for these specified categories if the Agency determines that a CTG is appropriate for the respective categories. Accordingly, this draft CTG addresses VOC emissions from cleaning operations associated with fiberglass boat manufacturing.

will harden in the transfer hoses or application equipment if not flushed with a solvent after each use.

V. Available Controls and Existing Federal, State, and Local Recommendations/Regulations

As previously mentioned, there are two main sources of VOC emissions from fiberglass boat manufacturing materials: (1) evaporation of VOC (i.e., both monomer and non-monomer VOC) from the gel coats and resins; and (2) evaporation of VOC from the cleaning materials. This section summarizes the available control options for reducing these VOC emissions and existing federal, State, and local VOC recommendations or requirements that address these emissions.

A. Available Control Options for Resin and Gel Coat

As mentioned above, all of the non-monomer VOC in the resins and gel coat materials, if present, is assumed to be emitted. We are not aware of any control measure currently being implemented to reduce non-monomer VOC emissions from resins and gel coats used in fiberglass boat manufacturing. However, there are available options for controlling monomer VOC emission from these materials. These control options for monomer VOC emissions are described below.

1. Low monomer VOC Resins and Gel Coats

Reducing monomer VOC emissions from resins and gel coats used in open molding at fiberglass boat manufacturing facilities is achieved primarily by reducing the monomer VOC content of the materials (resin and gel coat) and by switching to non-atomizing resin application methods.

Industry and EPA-sponsored testing has experimentally measured the amount of VOC that is emitted, and formulae were developed to predict the VOC emission rates (lb VOC/ton of material applied) for different materials and application methods.[e] The resin and gel coat that were used in testing contained only monomer VOC (i.e., styrene and MMA); they did not contain non-monomer VOC.

The different resins and gel coats can be reformulated to achieve varying levels of lowered monomer VOC contents, depending of their use in boat manufacturing. Because reducing the monomer VOC content reduces emissions by two interacting mechanisms (reducing the amount of monomer VOC available to be emitted and by reducing the fraction of monomer VOC that is emitted), monomer VOC emission reduction is not linearly related to monomer VOC content. For example, reformulating a resin from 40

---

[e] This testing was done in conjunction with the development of the NESHAP for boat manufacturing (40 CFR 63, subpart VVVV) and the NESHAP for reinforced plastic composite manufacturing (40 CFR 63, subpart WWWW). The formulae that were developed were incorporated into both of these final NESHAP.

percent monomer VOC, by weight, to 35 percent monomer VOC, achieves a 28 percent VOC emission reduction if the resin is applied with atomizing spray methods.

With low-monomer VOC resins and gel coats, facility operators can achieve emission reductions without changes in equipment or work practices. Low-monomer VOC materials can also be combined with other emission reduction techniques, such as non-atomizing resin application, for additional emission reductions. For regulatory agencies, a low-monomer VOC material requirement is easy to monitor and enforce; it is also relatively easy for a facility to demonstrate compliance on a continuous basis.

2. Vapor Suppressed Resins and Gel Coats

Vapor suppressed resins and gel coats can be used to reduce monomer VOC emissions, but they can present manufacturing problems when used for boat manufacturing. Vapor suppressed resins and gel coats have an additive, typically a wax, to reduce monomer VOC evaporation by forming a film on the surface of the resin or gel coat as it cures. Monomer VOC reductions of up to 40 percent have been measured for atomizing spray-applied vapor suppressed resin compared to conventional resins; no data are available for vapor-suppressed gel coats. Vapor suppressed resins and gel coats can be used to achieve emission reductions without changes in equipment. Vapor suppressed resins can also be combined with other emission reduction techniques, such as non-atomized resin application, for additional emission reductions.

However, adding a vapor-suppressing wax to a resin or gel coat may present significant technical problems in boat manufacturing. Because boats are relatively large and complex structures, they are usually built and assembled from subassemblies that must be bonded together. In order to achieve good secondary bonds[f] between parts made with vapor suppressed resins, the wax film on the bonding surfaces must be removed, usually by sanding or grinding, before the parts can be bonded. This additional surface preparation can be labor intensive; one California manufacturer estimates that switching to vapor-suppressed resins caused a 25-percent labor increase in building parts. More importantly, the ultimate strength of those secondary bonds may also be reduced, increasing the possibility of structural failure among assembled parts.

Vapor suppressed gel coat can be used only in limited applications because the wax will also prevent bonding with the gel coat. Since gel coats are applied in a thin layer, the wax cannot be removed to allow bonding with additional layers of material. Therefore, vapor suppressed gel coat can only be used where additional layers will not be added. Vapor suppressed gel coat can be used to coat interior spaces of assembled boats where the gel coat is only being used as the final surface finish. Vapor suppressed gel coat is typically used in this application because the curing of all polyester resins is

---

[f] “Primary bonds” are created when additional resin and fiberglass is applied to resin that is still wet and has not cured. “Secondary bonds” are created when additional resin and fiberglass is applied to resin that has fully cured, such as when parts are assembled and bonded together with more fiberglass and resin.

inhibited by exposure to the air, and the wax additive ensures complete curing of the gel coat surface.[g]

3. Non-atomizing Resin Application

Changing resin application methods can also reduce monomer VOC emissions. For example, switching from atomizing to non-atomizing application of a resin with 35 percent styrene achieves a 41 percent emission reduction. If both styrene content and application method are changed to reduce emissions, the reductions can be greater than changing just the resin styrene content or application method alone. For example, changing from atomized application of resin with 40 percent styrene, to resin with 35 percent styrene that is applied with nonatomizing technology can achieve a 58 percent emission reduction.

Currently, nonatomizing technology is feasible for applying production and tooling resins only. Gel coats must still be applied with atomizing spray guns, so monomer VOC reductions from gel coat can only be achieved through the use of low monomer VOC gel coats. The only exception is gel coat that may be applied with a brush or roller to the interior areas of finished boats where the cosmetic appearance is not as critical as on the exterior.

Non-atomized resin application includes five different techniques for applying resin: bucket and brush application by hand, resin rollers, flow coaters, resin impregnators, and fluid impingement technology. All five of these techniques reduce emissions compared to atomized resin spraying techniques by eliminating the atomization of resin. The emission reductions are generally greater for higher styrene resins.

Bucket and brush application is the oldest method of applying resin to fiberglass reinforcements. Individual batches of resin are mixed with a catalyst in a bucket or pail and applied to the part by hand using a brush or paint roller. This technique was the first method used in fiberglass boat manufacturing until spray equipment and chopper guns were developed for applying resin. Currently, it is used only in limited cases for low volume production or custom work, or for fabricating small parts and bonding parts at larger production facilities.

Pressure fed resin rollers consist of a fabric roller that is fed a continuous supply of resin from a mechanical fluid pump. The fluid pump draws resin from a drum or bulk distribution line. The resin pump is mechanically linked to a separate catalyst pump. These two pumps supply the resin and catalyst in a preset ratio to a mixer in the handle of the roller. The mixer then feeds the catalyzed resin to the roller head through the handle of the roller. A valve controlled by the operator regulates the amount of resin flowing to the roller head and to the part being fabricated. The roller head is covered with a disposable fabric cover similar to a standard paint roller cover. Resin rollers are intended to be operated almost continuously during a shift to prevent the resin from hardening

---

[g] In other cases, the gel coat and resin becomes fully cured because the surface is blocked from the air by the subsequent layers of material that are added to the part.

between the mixer and the roller cover. At the end of the shift, the roller cover is discarded and the mixing unit, handle, and roller manifold are flushed with a solvent.

Flow coaters are similar to standard resin spraying equipment except that the resin leaves the tip of the flow coater in continuous consolidated streams rather than as an atomized spray. Whereas the tip of a spray gun is a single small orifice, the tip of a flow coater has a dozen or so precisely drilled holes that produce steady streams of resin, similar to a small showerhead. Flow coaters can also be fitted with a chopper head to apply chopped fiberglass roving in the same way as a conventional atomized chopper gun. The flow coaters use the same resin and catalyst pumps that are used with catalyst-injected spray equipment or resin rollers. Like resin rollers and other internal mix equipment, flow coaters are intended to be operated almost continuously during a shift to prevent the resin from hardening inside the applicator. At the end of the shift, the gun and nozzle are flushed using a solvent.

Fabric impregnators use resin covered rollers to saturate fiberglass fabric, similar to an old-fashioned wringer washer in reverse. Dry fabric is fed down through a pair of finished-metal rollers that hold a reservoir of resin to impregnate or saturate the fabric. The gap between the rollers can be adjusted to achieve a predetermined fiber-to-resin ratio. Catalyzed resin can be manually mixed and poured into the machine or continuously mixed and fed to the machine by fluid pumps that are similar to those used for resin spray equipment.

Fabric impregnators are available in a variety of sizes. Small table top units are available for impregnating narrow reinforcing tapes. Larger impregnators can be mounted on mobile bridge cranes so that impregnated fabric can be lowered directly from the impregnator into a large open mold.

Fluid impingement technology consists of a gun that dispenses two streams of resin that come together to form a fan of large droplets. The large size of the droplets minimizes emissions compared to atomized spray application. This technology is reported to be the most widely used non-atomizing technology used to apply resin.

4. Closed Molding

Closed molding is the name given to fabrication techniques in which reinforced plastic parts are produced between the halves of a two-part mold, or between a mold and a flexible membrane, such as a bag. There are four types of closed molding methods that are being used in fiberglass boat manufacturing: vacuum bagging, vacuum-assisted resin transfer molding, resin transfer molding, and compression molding with sheet molding compound. Closed molding processes as they are currently practiced cannot be used to reduce emissions during gel coat or skin coat application, because these applications must still use conventional open molding techniques. However, closed molding can be used to reduce monomer VOC emissions from the subsequent laminating steps after the gel coat and skin coat layers have been applied.

Closed molding is generally applicable to making a large number of small parts, such as hatches and locker doors, or small numbers of high performance boat hulls and decks, but it is not feasible to replace open molding with closed molding at all types of boat manufacturing facilities. However, as discussed below, one major fiberglass boat manufacturer has developed a patented closed molding process that has replaced open molding for the hulls of many of its smaller (17 to 22 feet long) powerboats.

Vacuum bagging is a partially closed molding technology. It uses techniques similar to open molding but with a modification in the resin curing stage. After resin and fiberglass have been applied, a flexible, clear plastic sheet is placed over the wet laminate and sealed along the edge of the mold to form a "bag." A porous material called a bleeder sheet is also placed under the bag and a hose connected to a vacuum pump is sealed under the edge of the bag. The vacuum pump is used to draw the air out from under the bag and press the bag down onto the part. The pressure of the vacuum removes any trapped air and excess resin from the part and presses the layers of laminated material together. This technique is used to increase the fiber-to-resin ratio, which generally increases the strength of a part, and also to obtain a good bond between FRP skins and non-FRP core materials, such as wood or foam. Core materials are often sandwiched between layers of FRP to make a thicker and stiffer part without significantly increasing the part's weight. The EPA believes that most facilities that perform vacuum bagging use it only for fabricating small parts and not for hulls, decks, and superstructures.

No data are available to quantify the emission reductions associated with vacuum bagging. However, approximately 50 percent of emissions during lamination occur during the curing stage after the resin has been applied. Since the vacuum bag covers the part during resin curing, vacuum bagging may reduce a significant fraction of these curing emissions. The emission reductions will depend on how quickly the resin is covered with the vacuum bag.

Vacuum-Assisted Resin Transfer Molding (VARTM) is a closed molding technology that uses a vacuum to pull resin into dry fiberglass reinforcements that are placed into a closed mold. The closed mold may be formed using a flexible plastic sheet or "bag" as in vacuum bagging, or by a rigid or semi-rigid cover that matches the shape of the mold. In all variations, the bag or cover is sealed to the mold and vacuum pressure is used to draw resin from an outside reservoir into the sealed mold through a system of distribution tubes and channels placed under the bag or cover.

One VARTM process that has been used by several boat manufacturers is a patented technology called the Seeman Composites Resin Infusion Molding Process (SCRIMP) which is licensed by SCRIMP Systems, LLC. In the SCRIMP process, the mold is coated with a gel coat finish and a skin coat is applied using conventional techniques. Dry reinforcements and core materials are then placed in the mold. The resin distribution system and the bag are then placed over the mold and sealed to the edge of the mold. The vacuum is then applied to pull the bag against the mold and the reinforcements and the bag is checked for leaks. Valves to the resin supply system are then opened and the resin is pulled into the reinforcements by the vacuum. When the reinforcements are thoroughly saturated with resin, the resin supply is shut off and the part is allowed to cure under a vacuum. After curing, the bag is removed and is either discarded or reused, depending on the material from which it is made. Disposable bags are made from plastic film, whereas reusable bags are made from silicone rubber. A silicone bag can be used for more than 500 parts.

Another patented closed molding process is called the Virtual Engineered Composites® (VEC®) process. In this process, resin is injected into a rigid closed mold that is already loaded with the dry fiberglass reinforcements. The process is computer controlled and the mold components can be reused many times. The company that owns this process has used it to replace open molding in the manufacture of relatively large numbers of small (17 to 22 foot) powerboats.

The VARTM and VEC® processes can significantly reduce emissions during lamination because the resin is drawn from a bulk container and distributed under an airtight bag or cover, so very little resin is exposed to the atmosphere. These processes as they are currently practiced cannot be used to reduce emissions during gel coat and skin coat application because these steps must still use conventional open molding techniques.

Resin transfer molding (RTM) uses two rigid mold halves to provide the shape for fabrication of FRP boat parts. In a typical RTM operation, gel coat is spray applied to the inside surface of both halves of the mold so that the part has two finished sides, instead of one as in open molding. After the gel coat cures, the dry reinforcement is laid inside the mold and the mold is closed with clamps. When closed, the two halves of the mold mate together with a narrow space between them equal to the thickness of the finished part. Catalyzed resin is injected into the closed mold where it saturates the fiberglass. While the part is still in the mold, the resin cures. After the resin has cured, the mold is opened and the finished part is removed.

The RTM process is most economical for making many copies of small parts, especially when a smooth finish is desired on both sides of the part. Typical applications of RTM in boat manufacturing are for making hatch covers, doors, and seats. No emissions data are available from the RTM process; however, because the resin is not exposed to the air during application or curing, the EPA predicts that little monomer VOC is emitted during fabrication by RTM compared to conventional hand and spray processes. Any monomer VOC that is emitted is released during off-gassing when the mold is opened.

Compression molding involves the use of a prepared compound such as sheet molding compound (SMC) and a large hydraulic press to produce FRP parts. The prepared SMC sheet is composed of resin and fiberglass fibers. To create a FRP part with compression molding, SMC sheets are cut to the proper size and put into a matched male and female mold. The two molds are pressed together in the hydraulic press under several tons of pressure. The SMC is forced into all areas of the mold and cures in the closed mold under high heat and pressure in a matter of minutes. Several facilities are currently using compression molding with SMC to produce hulls, decks, and other parts for personal watercraft (PWC), such as those known under the trade name Jet Ski®.

No emissions data are available from the compression molding with SMC process; however, because the resin is not exposed to the air during application or curing, the EPA predicts that little monomer VOC is emitted during fabrication with SMC compared to open molding resin application processes.

5. Add-On Control Systems

No facilities in the fiberglass boat manufacturing industry currently use add-on controls to reduce VOC emissions. The majority of VOC emissions from resin and gel coat in an open molding process occur in an open shop environment. Some emissions occur in spray booths where gel coat spraying for smaller parts may be done. The volume of air exhausted from the open shop or from spray booths is typically high, and the VOC concentration is typically low. Therefore, it is not cost-effective to use add-on controls to reduce VOC emissions from fiberglass boat manufacturing. Because of the wide availability and lower cost (compared to add-on controls) of low-monomer VOC content materials and alternative application methods, these materials and methods are used to reduce monomer VOC emissions from fiberglass boat manufacturing facilities.

B. Available Control Options for Mixing Containers

Resin and gel coat materials are usually stored and prepared for application in large containers, either large stationary tanks or 55 gallon drums. Before application, promoters may be added to the material to promote the cross linking reaction after the resin is mixed with catalyst. Thixotropic agents may also be added so that resin and gel coat will hold onto vertical surfaces without running while still in a liquid state. Since the material in these containers may be agitated to mix in these additives and to keep them mixed in during application, these containers are a potential source of VOC emissions.

To reduce VOC emissions from tanks or drums used to mix materials containing VOC, these containers can be sealed with tightly fitting covers during mixing operations. These covers can be modified with openings to allow the mixing and pumping equipment into the container, but these openings can also be sealed to reduce VOC emissions.

C. Available Control Options for Cleaning Materials

Organic solvents are commonly used to clean application equipment, including resin and gel coat spray guns and other mechanical applicators, as well as rollers and other hand tools. These organic solvents include acetone, methyl ethyl ketone (MEK), lacquer thinner, Stoddard solvent, or toluene. Water-based emulsifiers with low VOC content and organic solvents with low vapor pressures can also be used to clean the application equipment.

To control VOC emissions from cleaning materials, facilities can use water-based emulsifiers that are low VOC, as well as organic solvents (e.g., dibasic esters, DBE) with low vapor pressures. Commonly used water-based emulsifiers in the fiberglass boat manufacturing industry contain less than 5 percent VOC by weight. Dibasic esters have vapor pressures of 0.5 mm Hg or less, at 68 ° F, so they have very low evaporation rates and little of the material is lost during use. These materials can typically be recovered and recycled by the vendor. Many facilities already use both water-based emulsifiers and DBE to clean resin and gel coat application equipment.

D. Existing Federal, State, and Local Recommendations/Regulations

The following discussion is a summary of EPA, State, and local actions that address VOC emissions from fiberglass boat manufacturing.

1. The 1990 National VOC Assessment

In 1990, the EPA completed an "Assessment of VOC Emissions from Fiberglass Boat Manufacturing" (EPA/600/S2-90/019). This document characterized the fiberglass boat manufacturing industry and its processes, assessed the extent of VOC emissions from this industry, and evaluated various control options. The assessment described open molding and discussed types of closed molding in use at the time. The assessment determined that acetone (no longer considered a VOC) and styrene were the two primary VOC emitted from the industry, and the major sources of emissions were resin and gel coat applications, and evaporation of solvents during clean-up.

The 1990 assessment discussed process changes and add-on controls to reduce emissions. Specifically, it recommended substituting the high-VOC[h] resins and gel coats that were commonly used at that time with low-VOC resins (e.g., 35 percent styrene) and gel coats, and vapor suppressed resins. The document discussed add-on controls, but considered such controls not economically feasible for use in fiberglass boat manufacturing due to high exhaust flow rates and low VOC concentrations. The document also recommended using water-based emulsifiers and low vapor pressure dibasic ester (DBE) compounds for equipment cleaning.

2. The 2001 NESHAP for Boat Manufacturing

In 2001, EPA promulgated the National Emission Standards for Hazardous Air Pollutants for Boat Manufacturing, 40 CFR part 63, subpart VVVV (2001 NESHAP). The 2001 NESHAP established organic hazardous air pollutant (HAP) emissions limits based on low-HAP resins and gel coats and low-emitting resin application technology. It also established limits to reduce emissions from cleaning operations and resin and gel coat mixing containers.

The 2001 NESHAP applies to fiberglass boat manufacturers that are major sources of HAP emissions. Major sources are stationary sources that emit, or have the potential to emit, (considering controls) 10 tpy or more of any one HAP, or 25 tpy or more of any combination of HAP. The 2001 NESHAP regulated the following, with certain exceptions:

- All open molding operations, including pigmented gel coat, clear gel coat, production resin, tooling resin, and tooling gel coat;
- All closed molding resin operations;
- All resin and gel coat application equipment cleaning; and

---

[h] In this 1990 document, the authors did not distinguish between monomer and non-monomer VOC.

- All resin and gel coat mixing operations.

The 2001 NESHAP regulates the total HAP content in the materials used in each regulated operation. Specifically, the 2001 NESHAP sets a HAP content limit for each regulated open molding resin and gel coat operation. For each regulated open molding resin operation, the NESHAP established separate HAP content limits for atomized and non-atomized resin application methods. A summary of the limitations is provided in Table 1 of this CTG.

Table 1. Organic HAP Content Requirements for Open Molding Resin and Gel Coat Operations as Specified in the NESHAP for Boat Manufacturing (40 CFR 63, Subpart VVVV)

For this operation--	And this application method --	Subpart VVVV provides that you must not exceed this weighted-average organic HAP content (weight percent) requirement --
Production resin operations	Atomized	28
Production resin operations	Nonatomized	35
Pigmented gel coat operations	Any method	33
Clear gel coat	Any method	48
Tooling resin operations	Atomized	30
Tooling resin operations	Nonatomized	39
Tooling gel coat operations	Any method	40

For closed molding operations, no limits apply to the resin application operation if it meets the specific definition of closed molding provided in the NESHAP. If a molding operation does not meet the definition of closed molding that is provided in the NESHAP, then it must comply with the applicable emission limits for open molding.

A manufacturer can demonstrate compliance with the HAP emissions limit for the facility by any of the following alternatives, either alone or in combination:

- Ensure that all materials used in a particular open molding operation meet the HAP content requirements summarized in Table 1;

- Comply with the HAP content requirements in Table 1 on a weighted-average basis for all materials used within an operation, calculated on a rolling 12-month compliance period;

- Averaging emissions among operations and ensure that overall emissions do not exceed those that would occur if each operation complied separately using low-HAP materials and application methods. The facility would use "MACT Model Point Value Formulas" provided in the NESHAP to estimate HAP emission rates (kg HAP/Mg material used) for each operation and to average among operations. The facility would also use a separate equation in the rule to estimate the emissions that would occur if each operation complied separately using low-HAP materials and application methods; or

- Use an emission capture system and add-on control device to ensure that overall emissions do not exceed those that would occur if each operation complied separately using low-HAP materials and application methods.

In addition to the resin and gel coat open molding operations which, as described above, are subject to HAP content limits or emission rate limits, other operations are subject to either work practice requirements or HAP content limits in the 2001 NESHAP. These operations include resin and gel coat mixing operations in tanks or drums, and routine resin and gel coat application equipment cleaning operations.

Resin and gel coat mixing containers with a capacity of 208 liters (55 gallons) or more must be covered with tightly fitted lids. Routine resin and gel coat application equipment cleaning operations must use solvents containing no more than 5 percent HAP, but solvents used to remove cured resin or gel coat from equipment are exempt from the HAP content limits. However, the containers used to hold the exempt solvent and to clean equipment with cured resin and gel coat must be covered, and there is an annual limit on the amount of exempt solvent that can be used.

3. Existing State and Local VOC Requirements

Five States, including California, that have fiberglass boat manufacturing facilities have State and local regulations to address VOC emissions from fiberglass boat manufacturing. These rules limit VOC emissions from all types of polyester resin operations, and treat fiberglass boat manufacturing as a subset of polyester resin operations. In California, 16 Air Quality Management Districts (AQMDs) have regulations for polyester resin operations; there is no statewide rule. The other States with regulations that address polyester resin operations are Illinois (the Chicago area), Indiana, Maryland, and Washington (only in the Puget Sound area).

The existing State regulations are summarized in Table 2. For California, we have summarized only a representative sample of the regulations from the 16 AQMDs. The South Coast Air Quality Management District (SCAQMD) has the most stringent State or local regulation. Specifically, SCAQMD Rule 1162, (Polyester Resin Operations) contains monomer VOC content limits for specific types of resins, gel coats, and cleaning solvents. Furthermore, Rule 1162, requires that all resins have to be applied with non-atomizing techniques, such as resin rollers, flow coaters, or hand lay up. Rule 1162 also requires that gel coat must be applied with high efficiency spray equipment, such as high-volume low-pressure (HVLP), air assisted airless, or electrostatic spray.

However, the SCAQMD regulation is not as stringent as the 2001 NESHAP.[i] The other AQMD rules in California do not require the use of non-atomized spray application, but specify that all material spraying use high efficiency spray equipment. The other AQMD rules also tend to be less stringent than South Coast Rule 1162 because they have higher allowable monomer VOC contents for resin and gel coat.

The Illinois rule for the Chicago area, and the Maryland and Puget Sound rules also require the use of high efficiency spray techniques, but only the Chicago and Maryland rules have limits for the monomer VOC content of resin and gel coat materials. These rules are also less stringent than the 2001 NESHAP.

The Indiana rule has adopted a different approach from other state VOC rules. The Indiana rule recognizes that since the primary VOC from fiberglass boat manufacturing (styrene and MMA) are also HAP, compliance with the 2001 NESHAP achieves nearly equal VOC and HAP emission reductions. Therefore, the Indiana rule provides that compliance with the 2001 NESHAP will satisfy the need to achieve best available control technology (BACT) for new sources that are constructed after 1980. There are no separate standards for RACT for existing sources in the Indiana rule, but it is assumed that the 1980 date for new sources will mean that most sources are covered by the BACT requirement.

The local and State rules that have been identified also address application equipment cleaning operations, either through work practices or VOC content limits on cleanup materials. Some rules prohibit the use of VOC cleaning solvents, or set very low VOC limits. This is possible since acetone and methylene chloride, which are specifically exempted from the EPA's definition of VOC in 40 CFR 51.100(s), can be used as clean up solvents. However, boat manufacturers prefer to avoid using acetone because it is highly flammable, and the use of methylene chloride (a HAP) is regulated at sources that need to comply with the 2001 NESHAP.

Table 2. Summary of State and Local Requirements for VOC Emissions from Fiberglass Boat Manufacturing

State Local Area	Applies to	VOC Limit Applies To	Monomer VOC Limit (Wt% monomer VOC in material unless noted otherwise)	Work and Equipment Practices
California South Coast AQMD Rule 1162	All polyester resin operations that fabricate, rework, repair, or touch-up products for commercial,	General Purpose Polyester Resin	35	Must use non-atomized application for resin. Must use high-efficiency spray techniques for gel
		Corrosion-Resistant Resin (definition includes boat hulls and tooling/molds)	48	

---

[i] Since styrene and MMA are the primary VOC, as well as the primary HAP, emitted from resin and gel coat, the HAP limits in the NESHAP and the monomer VOC limits in State and local rules can be compared directly.

State Local Area	Applies to	VOC Limit Applies To	Monomer VOC Limit (Wt% monomer VOC in material unless noted otherwise)	Work and Equipment Practices
	military, or industrial use	Fire Retardant Resin	38	coat.
		High Strength Resin (definition includes high-performance boats)	40	
		Clear Gel Coat	44	
		Pigmented Gel Coat:		
		White and off white:	45	
		Non-White:	37	
		Primer:	28	
		Specialty Gel Coat (used with corrosion resistant, fire retardant, or high strength resins)	48	
		Closed Molding	4% maximum weight loss during curing	
		Solvent cleaning of equipment:	Comply with AQMD Rule 1171 VOC content limit = 25 g/liter (0.21 lb/gal)	
California Bay Area AQMD Rule 8-50	The manufacturing of products using polyester resins. Exempts touch up and repair during manufacture.	General Purpose Polyester Resin	35	Must use high efficiency spray equipment for any spray operations. Use collecting system if organic solvents are used for equipment cleaning.
		Corrosion-Resistant or Fire Retardant Resin	50	
		Gel coat	250 g VOC/liter of coating applied	
		Cleaning Materials	200 g VOC/liter of cleaning material	
California San Diego APCD Rule 67-12	Polyester resin operations, except marine vessel repair operations	General Purpose Polyester Resin	35	Must use high efficiency spray equipment for any spray operations,
		Corrosion-Resistant or Fire	50	

State Local Area	Applies to	VOC Limit Applies To	Monomer VOC Limit (Wt% monomer VOC in material unless noted otherwise)	Work and Equipment Practices
	that use less than 0.5 gallons of material per operating day.	Restardant Resin		except for touch up and repair using a spray gun with a container as part of the gun.
		Pigmented gel coats	45	
		Clear gel coats	50	
		Cleaning materials	200 g VOC/liter, or, a boiling point >190 C, or use a VOC reclamation system (onsite or offsite), or use less than 0.5 gallons average per day	
California Santa Barbara APCD Rule 349	Apply to all commercial and industrial polyester resin operations that use 50 or more gallons of styrene per year.	General Purpose Polyester Resin	35	Must use high efficiency spray equipment for any spray operations.
		Corrosion-Resistant or Fire Retardant Resin	50	
		Pigmented gel coats	45	
		Clear gel coats	50	
Illinois Rule 218, Subpart CC	Chicago Area	Corrosion-Resistant or Fire Retardant Resin	48	Must use high efficiency spray equipment for any spray operations.
		High Strength (>10,000 psi tensile strength), including tooling resins	48	
		Clear gel coats	50	
		Pigmented gel coat	45	
		All other materials	35	
Indiana Rule 326 IAC 8-1-6	New sources (constructed after 1980) that emit more than 25 tons per year of VOC.	Compliance with 40 CFR 63 subpart VVVV satisfies BACT. A case-by-case BACT determination is not needed. No separate standards are specified for RACT.		
Maryland Rule 26.11.19.26	Applies where the total VOC from all RPC manufacturing is 20 pounds or more per day. Does not apply to resins used for tooling or touch up and repair.	General Purpose Polyester Resin	35	If VOC emissions are 100 pounds or more per day, use airless or air-assisted spray guns or non-atomized application methods for general purpose resin application.
		High Strength, Corrosion-Resistant, or Fire Retardant Resin	50	
		Gel coat	50	
		Cleanup materials	Use non-VOC cleanup materials	

State Local Area	Applies to	VOC Limit Applies To	Monomer VOC Limit (Wt% monomer VOC in material unless noted otherwise)	Work and Equipment Practices
Washington Puget Sound Clean Air Agency Regulation II, Article 3, Section 3.08	Manufacturing operations involving the use of polyester, vinylester, gelcoat, or resin in which the styrene monomer is a reactive monomer for the resin.	Allows atomized spraying, but requires use of higher efficiency spray methods (e.g., HVLP, airless, air assisted airless). No monomer VOC content limits on materials. VOC materials used for cleanup must be collected in a closed container.		

VI. Recommended Control Options

We are recommending that this CTG covers the following operations:

- Open molding resin and gel coat operations (these include pigmented gel coat, clear gel coat, production resin, tooling gel coat, and tooling resin);
- Resin and gel coat mixing operations; and
- Resin and gel coat application equipment cleaning operations.

Based on a review of the 2001 NESHAP, and the current State and local requirements discussed above, we are recommending monomer VOC content limits and alternative monomer VOC emission rate limits for resin and gel coats used in open molding operations. The monomer VOC content limits are paired with specific methods (either atomized or non-atomized) for resin application. In addition, we are recommending a non-monomer VOC content limit for resins and gel coats used in open molding operations. We are also recommending work practices to reduce VOC emissions from resin and gel coat mixing containers, and VOC content and vapor pressure limits for cleaning materials. Our recommendations are described in more detail below.

A. Recommended VOC Limits for Gel Coats and Resins

We are recommending monomer VOC content limits and alternative monomer VOC emission rate limits for open molding operations. Our recommended monomer VOC content and emission rate limits are based on the 2001 NESHAP for boat manufacturing. As previously discussed in section IV.B of this CTG, styrene and MMA, which are the primary VOC emitted from resins and gel coats used in fiberglass boat, are the only monomer VOC we have identified in these resin and gel coat materials. Because styrene and MMA are also the primary HAP emitted by this industry, the HAP limits in the 2001 NESHAP are equally effective in reducing monomer VOC emissions from the resins and gel coats used in fiberglass boat manufacturing. As mentioned above, the 2001 NESHAP limits are more stringent than the limits provided in other Federal, State, or local actions for the control of monomer VOC emissions from fiberglass boat manufacturing. Based on the implementation of the NESHAP limits by all major source fiberglass boat manufacturers, the general availability of the resins and gel coats that meet the 2001 NESHAP limits, and the shift of the fiberglass boat manufacturing industry (including area source fiberglass boat manufacturers) to non-atomized resin application methods, we believe that the monomer VOC limits recommended in this CTG are technically and economically feasible for fiberglass boat manufacturers in ozone non-attainment areas.

Further, as previously mentioned, resins and gel coats used in fiberglass boat manufacturing may also contain non-monomer VOC, and they constitute less than 5 percent of the total VOC in all resins and gel coats and usually comprise less than 1 percent of each resin or gel coat, by weight. Accordingly, we are also recommending a non-monomer VOC content limit of no more than 5 percent by weight of the resin or gel coat. This recommended limit on non-monomer VOC is in addition to the separate monomer VOC limits being recommended for resin and gel coat. Based on our recommendation, if the non-monomer VOC content of a resin or gel coat exceeds 5 percent, then the excess non-monomer VOC over 5 percent would be counted toward the monomer VOC content. For example, if a resin contains 6 percent non-monomer VOC and 34 percent monomer VOC, then 1 percent (the amount in excess of 5 percent) of the non-monomer VOC would be counted as a monomer VOC, and the resin would be considered as having a monomer VOC content of 35 percent.

We recommend that the monomer VOC content of resin and gel coat materials be determined using SCAQMD Method 312-91, Determination of Percent Monomer in Polyester Resins, revised April 1996. In addition, we recommend that manufacturer’s formulation data be accepted as an alternative to this method. If there is a disagreement between manufacturer's formulation data and the results of a subsequent test, we recommend that States use the test method results unless the facility can make a demonstration to the States' satisfaction that the manufacturer's formulation data are correct.The recommended monomer and non-monomer VOC limits in this CTG do not apply to closed molding operations that meet the same definition of closed molding that is found in the 2001 NESHAP. We recommend that closed molding operations that do not meet this definition, such as vacuum bagging operations, meet the monomer and non-monomer VOC limits for open molding operations. That definition of closed molding is as follows:

> “Closed molding means any molding process in which pressure is used to distribute the resin through the reinforcing fabric placed between two mold surfaces to either saturate the fabric or fill the mold cavity. The pressure may be

> clamping pressure, fluid pressure, atmospheric pressure, or vacuum pressure used either alone or in combination. The mold surfaces may be rigid or flexible. Closed molding includes, but is not limited to, compression molding with sheet molding compound, infusion molding, resin injection molding (RIM), vacuum assisted resin transfer molding (VARTM), resin transfer molding (RTM), and vacuum-assisted compression molding. Processes in which a closed mold is used only to compact saturated fabric or remove air or excess resin from the fabric (such as in vacuum bagging), are not considered closed molding. Open molding steps, such as application of a gel coat or skin coat layer by conventional open molding prior to a closed molding process, are also not closed molding."[j]

Consistent with the framework established in the NESHAP, we are recommending that the recommended open molding monomer and non-monomer VOC limits described above not be applied to the following three types of materials at fiberglass boat manufacturing facilities. We are making this recommendation because the following three materials must be formulated to meet specific performance requirements, making it infeasible to reduce monomer and non-monomer VOC contents below their existing levels. We are making different recommendations for the materials identified below, and those recommendations are noted below:

(1) Production resins (including skin coat resins) that must meet specifications for use in military vessels or must be approved by the U.S. Coast Guard for use in the construction of lifeboats, rescue boats, and other life-saving appliances approved under 46 CFR subchapter Q, or the construction of small passenger vessels regulated by 46 CFR subchapter T. Production resins that meet these criteria can still be applied with nonatomizing resin application equipment, and we are recommending this as a control option for these resins

(2) Production and tooling resins, and pigmented, clear, and tooling gel coat used for part or mold repair and touch up. We recommend that the total resin and gel coat materials that meet these criteria not exceed 1 percent by weight of all resin and gel coat used at a facility on a 12-month rolling-average basis.

(3) Pure, 100-percent vinylester resin used for skin coats. We recommend that the monomer and non-monomer VOC limits not be applied to pure, 100-percent vinylester resin used for skin coats. We still recommend these monomer and non-monomer VOC limits for blends of vinylester and polyester resins used for skin coats. Pure, 100-percent vinylester resin used for skin coats can be applied with nonatomizing resin application equipment, and we recommend this as a control option for this type of resin. We also recommend that the total amount of resin materials meeting this criteria not exceed 5 percent by weight of all resin used at a facility on a 12-month rolling-average basis.

The CTG provides flexibility by recommending the same options for meeting the monomer VOC limits as provided in the 2001 NESHAP for meeting the HAP

---

[j] 40 CFR 63, subpart VVVV, §63.5779.

emission limits. To meet the recommended open molding resin and gel coat limits, the CTG recommends three options: (1) achieving the individual monomer VOC content limit through the use of low-monomer VOC materials, either by using only low-monomer VOC materials within a covered operation (as listed below in VI.A), or by averaging the monomer VOC contents for all materials used within an operation on a weight-adjusted basis; (2) meeting the numerical monomer VOC emission rate limits, which would enable a facility to average emissions among different operations using equations to estimate monomer VOC emission rates from each operation based on the material and application method; or (3) using add-on controls to achieve a numerical monomer VOC emission rate that is determined for each facility based on the mix of application methods and materials used at that facility.

The emission reductions that are achieved using the emissions averaging option (Option 2) and the add-on control option (Option 3) are equivalent to the emission reductions that are achieved by meeting the monomer VOC content limits (Option 1). Options 2 and 3 use emission factor equations to convert the monomer VOC content limits in Option 1 into equivalent monomer VOC emission rates that a facility would otherwise achieve by using the low-monomer VOC materials for specific application methods and operations.

A facility could use emission averaging (Option 2) or add-on controls (Option 3) for all open molding operations or only for some of the operations. Operations that a facility decides not to include in Options 2 or 3 would use Option 1. For filled resins, which are discussed in more detail in section VI. B, the CTG includes an adjustment factor that would allow filled resins to use any of the three options recommended above.

We are recommending that all three of these options be included in what States determine constitutes RACT for VOC emissions from these operations. That is, we are recommending that States not include just one option and exclude the other two. All three options are recommended to be included, together, so as to provide flexibility to facilities as they reduce their VOC emissions in response to State RACT determinations. Our recommendations, as described above, are consistent with the approach and flexibility we provided in the 2001 NESHAP for Boat Manufacturing.

We are also recommending that State RACT determinations allow facilities to use a combination of all three options at a single facility. For example, a facility could use emissions averaging (Option 2) for only a subset of materials and activities and Option 1 for the rest of the materials and activities at the facility. Our recommendations, as described above, are consistent with the approach and flexibility we provided in the 2001 NESHAP for Boat Manufacturing.

1. Compliant Materials Option

Under this option, facilities would use resins and gel coats that meet the applicable recommended monomer VOC content limits in Table 3 of this CTG and the non-monomer VOC content limit of 5 percent. We recommend that the applicable limits be considered met if all materials of a certain type (e.g., production resin, pigmented gel coat) meet the applicable monomer and non-monomer VOC content limits for a specific application method.

Table 3. Compliant Materials Monomer VOC Content Recommendations for Open Molding Resin and Gel Coat.

For this material--	And this application method --	This weighted average monomer VOC content (weight percent) limit is recommended --
Production resin	Atomized (spray)	28
Production resin	Nonatomized	35
Pigmented gel coat	Any method	33
Clear gel coat	Any method	48
Tooling resin	Atomized	30
Tooling resin	Nonatomized	39
Tooling gel coat	Any method	40

Alternatively, the applicable recommended limits in Table 3 above would be considered met if all materials of a certain type meet the applicable monomer VOC content limit for a specific application method on a weighted-average basis, and each resin and gel coat did not contain more than 5 percent non-monomer VOC. The weighted-average monomer VOC content would be determined based on a 12-month rolling average. A facility would use Equation 1 to determine weighted-average monomer VOC content for a particular open molding resin or gel coat material.

Equation 1:

$$\mathit{Weighted\ \ Average\ Monomer\ VOC\ Content} = \frac{\sum_{i=1}^{n}\left(M_i VOC_i\right)}{\sum_{i=1}^{n}\left(M_i\right)}$$

Where:

M_i = mass of open molding resin or gel coat i used in the past 12 months in an operation, megagrams.

VOC_i = Monomer VOC content, by weight percent, of open molding resin or gel coat i used in the past 12 months in an operation.

n = number of different open molding resins or gel coats used in the past 12 months in an operation.

2. Emissions Averaging Option

Under this option, monomer VOC emissions from the open molding resin and gel coat operations that a facility chooses to include in this emission average option would meet a facility-specific monomer VOC mass emission limit (12-month rolling average) that is determined using Equation 2. All resins and gel coats included in this option would also need to meet the recommended non-monomer VOC content limit of 5 percent.

Equation 2:

$$\text{Monomer VOC Limit} = 46(M_{R}) + 159(M_{PG}) + 291(M_{CG}) + 54(M_{TR}) + 214(M_{TG})$$

Where:

Monomer VOC Limit= total allowable monomer VOC that can be emitted from the open molding operations included in the average, kilograms per 12-month period.

M_{R} = mass of production resin used in the past 12 months, excluding any materials that are exempt, megagrams.

M_{PG} = mass of pigmented gel coat used in the past 12 months, excluding any materials that are exempt, megagrams.

M_{CG} = mass of clear gel coat used in the past 12 months, excluding any materials that are exempt, megagrams.

M_{TR} = mass of tooling resin used in the past 12 months, excluding any materials that are exempt, megagrams.

M_{TG} = mass of tooling gel coat used in the past 12 months, excluding any materials that are exempt, megagrams.

The numerical coefficients associated with each term on the right hand side of Equation 2 are the allowable monomer VOC emission rate for that particular material in units of kg/Mg of material used.

For those materials that are not included in the emissions average, the facility would resort to one of the other two recommended options for limiting monomer and non-monomer VOC emissions from resins and gel coats.

We recommend that the emissions average be calculated on a 12-month rolling-average basis and determined at the end of every month (12 times per year). We further recommend that at the end of the first 12-month averaging period and at the end of every subsequent month, a facility use Equation 3 to show that the monomer VOC emissions from the operations included in the average do not exceed the emission limit calculated using Equation 2 for the same 12-month period. (A facility would include in Equations 2 and 3 the terms for only those operations and materials included in the average.)

Equation 3:

$$\text{Monomer VOC emissions} = (PV_R)(M_R) + (PV_{PG})(M_{PG}) + (PV_{CG})(M_{CG}) + (PV_{TR})(M_{TR}) + (PV_{TG})(M_{TG})$$

Where:

Monomer VOC emissions = Monomer VOC emissions calculated using the monomer VOC emission equations for each operation included in the average, kilograms.

PV_R = Weighted-average monomer VOC emission rate for production resin used in the past 12 months, kilograms per megagram.

M_R = Mass of production resin used in the past 12 months, megagrams.

PV_{PG} = Weighted-average monomer VOC emission rate for pigmented gel coat used in the past 12 months, kilograms per megagram.

M_{PG} = Mass of pigmented gel coat used in the past 12 months, megagrams.

PV_{CG} = Weighted-average monomer VOC emission rate for clear gel coat used in the past 12 months, kilograms per megagram.

M_{CG} = Mass of clear gel coat used in the past 12 months, megagrams.

PV_{TR} = Weighted-average monomer VOC emission rate for tooling resin used in the past 12 months, kilograms per megagram.

M_{TR} = Mass of tooling resin used in the past 12 months, megagrams.

PV_{TG} = Weighted-average monomer VOC emission rate for tooling gel coat used in the past 12 months, kilograms per megagram.

M_{TG} = Mass of tooling gel coat used in the past 12 months, megagrams.

For purposes of Equation 3, a facility would use Equation 4 to compute the weighted-average monomer VOC emission rate for the previous 12 months for each open molding resin and gel coat operation included in the average.

Equation 4:

$$PV_{OP} = \frac{\sum_{i=1}^{n}(M_i PV_i)}{\sum_{i=1}^{n}(M_i)}$$

Where:

PV_{OP} = weighted-average monomer VOC emission rate for each open molding operation (PV_R, PV_{PG}, PV_{CG}, PV_{TR}, and PV_{TG}) included in the average, kilograms of monomer VOC per megagram of material applied.

M_i = mass of resin or gel coat i used within an operation in the past 12 months, megagrams.

n = number of different open molding resins and gel coats used within an operation in the past 12 months.

PV_i = the monomer VOC emission rate for resin or gel coat i used within an operation in the past 12 months, kilograms of monomer VOC per megagram of material applied. Use the equations in Table 4 to compute PV_i.

Table 4. Monomer VOC Emission Rate Formulas for Open Molding Operations[k]

For this material ...	and this application method...	Use this formula to calculate the monomer VOC emission rate...
1. Production resin, tooling resin	a. Atomized	$0.014 \times (\text{Resin VOC\%})^{2.425}$
	b. Atomized, plus vacuum bagging with roll-out	$0.01185 \times (\text{Resin VOC\%})^{2.425}$
	c. Atomized, plus vacuum bagging without roll-out	$0.00945 \times (\text{Resin VOC\%})^{2.425}$
	d. Nonatomized	$0.014 \times (\text{Resin VOC\%})^{2.275}$
	e. Nonatomized, plus vacuum bagging with roll-out	$0.0110 \times (\text{Resin VOC\%})^{2.275}$
	f. Nonatomized, plus vacuum bagging without roll-out	$0.0076 \times (\text{Resin VOC\%})^{2.275}$

---

[k] The formulae in this table were developed from EPA and industry-sponsored measurements of VOC emissions from resin and gel coat used in open molding.

2. Pigmented gel coat, clear gel coat, tooling gel coat	All methods	0.445 x (Gel coat VOC%)$^{1.675}$

The formulas in Table 4 calculate monomer VOC emission rates in kilograms of monomer VOC per megagram of resin or gel coat applied. The formulas for vacuum bagging with roll-out are applicable when a facility rolls out the applied resin and fabric prior to applying the vacuum bagging materials. The formulas for vacuum bagging without roll-out are applicable when a facility applies the vacuum bagging materials immediately after resin application without rolling out the resin and fabric. VOC% = monomer VOC content as supplied, expressed as a weight-percent value between 0 and 100 percent.

3. Add-on Control Option

If product performance requirements or other needs dictate the use of higher-monomer VOC materials than those that would meet the recommended emission limits in Table 3, a facility could choose to use add-on control equipment to meet the emission limit determined by Equation 2. However, instead of using the mass of each material used over the past 12 months in Equation 2, the facility would use the mass of each material used during the control device performance test in Equation 2 to determine the emission limit (in kg of monomer VOC) that is applicable during the test. If the measured emissions at the outlet of the control device (in kg of monomer VOC) are less than the emission limit, then the facility would be considered to have achieved the emission limit. We recommend that, during the test, the facility monitor and record relevant control device and capture system operating parameters and use the recorded values to establish operating limits for those parameters. We recommend that the facility monitor the operating parameters for the control device and emission capture system and maintain the parameters within the established operating limits. All resins and gel coats used in these controlled operations would also need to meet the recommended non-monomer VOC content limit of 5 percent.

B. Recommended Option for Filled Resins

Some facilities use resins to which fillers are added to achieve certain physical properties, particularly for building molds. The resins to which the filler is added have higher initial monomer VOC content than standard production or tooling resins, but the addition of the filler lowers the monomer VOC emission rate from the filled resin. We recommend the use of the following equation to adjust the emission rate for filled resins under all three options recommended above for limiting monomer VOC emissions from resins and gel coats. If a facility is using a filled production resin or filled tooling resin, it would calculate the emission rate for the filled material on an as-applied basis using Equation 5.

Equation 5:

$$PV_F = PV_U \times \frac{(100 - \%\ Filler)}{100}$$

Where:

PV_F = The as-applied monomer VOC emission rate for the filled production resin or tooling resin, kilograms monomer VOC per megagram of filled material.

PV_u = The monomer VOC emission rate for the neat (unfilled) resin, before filler is added, as calculated using the formulas in Table 4 of this CTG.

% Filler = The weight-percent of filler in the as-applied filled resin system.

If the filled resin is used as a production resin, we recommend that the value of PV_F calculated by Equation 5 not exceed 46 kilograms of monomer VOC per megagram of filled resin applied. If the filled resin is used as a tooling resin, we recommend that the value of PV_F calculated by Equation 5 not exceed 54 kilograms of monomer VOC per megagram of filled resin applied. If the facility is including a filled resin in the emissions averaging procedure, we recommend that the facility use the value of PV_F calculated using Equation 5 for the value of PV_i in Equation 4 of this CTG. All filled resins would also need to meet the recommended non-monomer VOC content limit of 5 percent, based on the unfilled resin.

C. Work Practices for Resin and Gel Coat Mixing Containers

In addition to the recommended monomer and non-monomer VOC limits for gel coats and resins described above, this CTG recommends that all resin and gel coat mixing containers with a capacity equal to or greater than 208 liters (55 gallons), including those used for on-site mixing of putties and polyputties, have a cover with no visible gaps in place at all times. We do not recommend the use of covers for smaller containers because they are typically only used for small hand application operations that require an open container. Also, this work practice would not apply when material is being manually added to or removed from a container, or when mixing or pumping equipment is being placed in or removed from a container. Although monomer and non-monomer VOC emission reductions achieved by implementing this work practice may not be quantifiable, we have concluded that they are beneficial to the overall goal of reducing VOC emissions.

D. VOC Content and Vapor Pressure Limits for Cleaning Materials

Cleaning solvents used to remove resin and gel coat residue from application equipment are a potential source of significant VOC emissions. However, low-VOC and low vapor pressure cleaning materials that can be used for cleaning boat manufacturing application equipment are readily available. These materials include aqueous emulsifiers that have very low VOC contents, and also organic solvents, such as dibasic esters (DBE), that have very low vapor pressures. Therefore, we are recommending that VOC cleaning solvents for routine application equipment cleaning contain no more than 5 percent VOC, by weight, or have a composite vapor pressure of no more than 0.50 mm Hg at 68 °F.

These recommended limits for cleaning materials are based on the properties of water-based emulsifiers and dibasic esters that are used as alternatives to conventional cleaning solvents, and are the basis for the equipment cleaning requirements in the 2001 NESHAP for Boat Manufacturing. Therefore, the same cleaning materials used to comply with the 2001 NESHAP will meet the VOC content and vapor pressure limits recommended in this CTG for cleaning materials. Based on the implementation of these measures by all major source fiberglass boat manufacturers, we believe that these control measures are technically and economically feasible for reducing VOC emissions from these cleaning materials and have therefore included them as our recommendations in the CTG.

Occasionally through operator error or equipment malfunctions, resin or gel coat is accidentally allowed to cure inside application equipment. To remove the cured resin or gel coat, the equipment is typically soaked in a container of methylene chloride to dissolve the cured material. Boat manufacturing facilities usually maintain a small amount (e.g., a few gallons) of methylene chloride on site for these situations. Methylene chloride is not a VOC. We recommend that only non-VOC solvents be used to remove cured resin and gel coat from application equipment.

VII. Cost Effectiveness of Recommended Control Options

Based on the 2002 NEI database, we estimate that there are 223 fiberglass boat manufacturing facilities in the U.S. Using the April 2004 ozone nonattainment designations, 91 of these facilities are in ozone nonattainment areas. Based on the 2002 NEI VOC emissions data, we estimated that 67 of the 91 facilities in ozone nonattainment areas emitted VOC at or above the recommended 6.8-kg/day (15-lb/day) VOC emissions applicability threshold. These 67 facilities, in aggregate, emit about 1,452 Megagrams per year (Mg/yr) (1,601 tons per year (tpy)) of VOC per year, or an average of about 22 Mg/yr (24 tpy) of VOC per facility.

The CTG recommends the use of low-VOC content (monomer and non-monomer VOC) resin and gel coats with specified application methods. The CTG recommends the use of covers on mixing containers to further reduce VOC emissions from gel coats and resins. The CTG also recommends the use of low-VOC and low vapor pressure cleaning materials. Because the recommendations in this CTG are based on the 2001 NESHAP for boat manufacturing, those facilities that are major sources of HAP are already complying with the 2001 NESHAP and have already adopted these control measures. Therefore, we do not anticipate additional VOC emission reductions from these major source facilities.

Because the 2001 NESHAP does not apply to area sources (i.e. sources that are not major sources of HAP), area source fiberglass boat manufacturing facilities are not currently required to implement the measures provided in the 2001 NESHAP and recommended in the CTG. We estimate that 23 area source fiberglass boat manufacturing facilities are located in ozone nonattainment areas and meet the applicability threshold recommended in the CTG, and that these facilities emit, in aggregate 104 Mg/yr (115 tpy) of VOC. We estimate that implementation of the recommended measures in the CTG would reduce VOC emissions at these 23 facilities by about 37 Mg/yr (40 tpy).

For implementing the 2001 NESHAP, the EPA estimated a cost of $3,600 per ton of HAP reduced, in 2001 dollars, or about $4,200 in 2007 dollars. Nearly all of the HAP that are reduced by the NESHAP are styrene and MMA, and styrene and MMA also account for nearly all of the VOC emitted from the processes addressed by the recommendations in this CTG. Therefore, we expect that the cost to reduce HAP and VOC are nearly equal.

However, we expect that the cost of reducing VOC through the measures recommended in this CTG would be substantially lower than the cost of reducing HAP through the 2001 NESHAP for several reasons. First, the NESHAP is now fully implemented at major sources of HAP, and resin, gel coat, and cleaning materials that are compliant with the 2001 NESHAP are readily available to all sizes of facilities. Second, the industry has experienced a shift to non-atomized resin application methods that are required to comply with the 2001 NESHAP. This shift has occurred at all sizes of facilities because of the productivity and economic benefits of using non-atomizing methods over conventional atomizing methods. Therefore, with respect to those facilities that are not subject to the 2001 NESHAP, we expect that most, if not all, are already using the materials and methods recommended by this CTG. We therefore expect that these facilities would incur little, if any, increased costs if required by a State RACT rule to implement the approaches recommended in this CTG. We estimate that the total annual cost for the 23 facilities to implement the recommended measures in this CTG would be substantially less than $168,000 in 2007 dollars.

VIII. References

Project Summary. Assessment of VOC Emissions from Fiberglass Boat Manufacturing. Publication No. EPA/600/S2-90/019. U.S. Environmental Protection Agency, Research Triangle Park, NC. June 1990.

40 CFR Part 63, Subpart VVVV - National Emission Standards for Hazardous Air Pollutants for Boat Manufacturing. §§63.5680 – 63.5776.

Economic Impact Analysis of the Boat Manufacturing NESHAP. U.S. EPA Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711. EPA Publication No. EPA/452/R-01-011. June 2001.

Bay Area (California) Air Quality Management District Regulation 8, Organic Compounds, Rule 50, Polyester Resin Operations. Adopted June 15, 1994.

San Diego (California) Air Pollution Control District Rule 67-12. Polyester Resin Operations. Amended May 15,1996.

Santa Barbara (California) Air Pollution Control District Rule 349. Polyester Resin Operations. Adopted April 27,1993.

South Coast (California) Air Quality Management District Regulation XI, Source Specific Standards, Rule 1162, Polyester Resin Operations. Amended July 8, 2005.

South Coast (California) Air Quality Management District Method 312-91, Determination of Percent Monomer in Polyester Resins, revised April 1996

Code of Maryland Administrative Regulations (COMAR) 26.11.19.26. Control of Volatile Organic Compound Emissions from Reinforced Plastic Manufacturing. Approved as part of Maryland SIP on August 19, 1999.

Puget Sound (Washington) Clean Air Agency, Regulation 2, Section 3.08, Polyester, Vinylester, Gelcoat, and Resin Operations. Revised December 9, 1993.

Indiana Administrative Code, 326 IAC 8-1-6. Volatile Organic Compound Rules; New facilities, general reduction requirements. Amended May 26, 2006.

Illinois Rule 218, Subpart CC. Organic Material Emission Standards and Limitations for the Chicago Area. Subpart CC: Polyester Resin Product Manufacturing Process. Effective January 24, 1994.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Sector Policies and Programs Division Research Triangle Park, NC	Publication No.EPA-453/R-08-004 September, 2008