

M E M O R A N D U M

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SUBJECT: Summary of Findings from the Boat Manufacturing
Presumptive MACT Process: Styrene Emission Control
Options

1.0 INTRODUCTION AND PURPOSE

Under section 112(d) of the Clean Air Act (the Act), the EPA is developing national emission standards for hazardous air pollutants (NESHAP) for the boat manufacturing source category. The EPA is required to publish final emission standards for the boat manufacturing source category no later than November 15, 2000. In order to meet this schedule, it is expected that the EPA will need to publish proposed standards by November 15, 1999.

The Act requires that the emission standards for new sources be no less stringent than the level of control achieved by the best controlled similar source in the source category. For existing sources, the level of control can be less stringent than the level of control for new sources, but it can be no less stringent than the level of control achieved by the average level of control achieved by the top 12 percent of existing sources. In categories or subcategories with fewer than 30 sources, existing sources must meet a level of control no less stringent than the average level of control of the best performing 5 sources. The NESHAP that are required to meet these criteria have come to be known as maximum achievable control technology (MACT) standards.

The MACT standards development for the boat manufacturing industry began with the identification and assembly of

stakeholder representatives from industry, State and local regulatory agencies, and EPA regional offices to develop what is known as a presumptive MACT or P-MACT. (The EPA also solicited participation from environmental groups, but no representatives elected to participate in the P-MACT process.) The P-MACT is an estimate of MACT based on readily available information that can be collected and analyzed in a short time frame. The goals of P-MACT are to (1) Identify industry, State, local, and regional EPA stakeholders early and get them involved in the standards development process; (2) To assemble and analyze readily available information on emissions and control technologies in a short time frame; (3) Determine P-MACT for new and existing sources based on the available data and the collective judgement of the stakeholders; and (4) Identify technical and policy issues that need to be addressed in the rule making and enlist the help of the stakeholders in resolving those issues. Finally, the information collected during P-MACT can be used by States that may have to make case-by-case MACT determinations under Sections 112(g) or 112(j) of the Act. The P-MACT phase of the boat manufacturing NESHAP was begun in October 1995 and focused primarily on the production of boats made from fiber reinforced plastic (FRP), also known as "fiberglass". This memorandum represents the conclusion of that phase of rule development.

This memorandum presents the results of the P-MACT phase of the Boat Manufacturing NESHAP. This memorandum includes a description of the emission control technologies that were identified that are currently used in practice by the industry and that could serve as the basis of MACT. Within the short time-frame intended for P-MACT, however, the stakeholders could not agree on specific technologies for P-MACT for either new or existing sources. In particular, the stakeholders could not agree on whether sufficient data had been collected to assess whether some control technologies were feasible for all boat

manufacturers within each subcategory and to support a specific P-MACT recommendation. The stakeholders could also not agree on how regulatory flexibility could be incorporated into a P-MACT recommendation. The EPA determined that the issues that have been raised during P-MACT should be resolved through further data collection and analysis as MACT standards are developed.

The information summarized in this memorandum was collected prior to October 1996. Additional information has been collected since that time and more information will be collected and considered before the boat manufacturing emission standards are promulgated.

The industry members that participated in the P-MACT process were nearly all members of the National Marine Manufacturers Association (NMMA) and a representative of the NMMA was also active in the P-MACT process. The States that participated in the process were California, Florida, Illinois, Maryland, Washington, and Wisconsin. The South Coast Air Quality Management District (California) and the Lincoln-Lancaster (Nebraska) Health Department also participated. The U.S. EPA was represented by EPA Region 4, EPA Region 7, EPA Region 9, the EPA Office of Air Quality Planning and Standards (EPA/OAQPS) and the EPA Office of Research and Development.

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Section 2.0 of this memorandum describes the boat manufacturing source category and its emissions. Section 3.0 describes the emission reduction technologies that are applicable to boat manufacturing and identifies technical and economic issues raised by the P-MACT participants that are associated with these technologies. Section 4.0 presents the EPA's analysis of the best controlled facilities with regard to resin use based on their utilization of emission reduction measures for resin use.

Section 5.0 summarizes the issues that were unresolved at the end of the P-MACT phase of rule development and describes how the EPA plans to resolve those issues in developing the boat manufacturing NESHAP. Finally, section 6.0 lists the printed resources from which information used in this document was taken.

2.0 THE BOAT MANUFACTURING SOURCE CATEGORY AND EMISSIONS

2.1 SOURCE CATEGORY DESCRIPTION

Boats can be manufactured from many different materials, including FRP, aluminum, rotationally molded (rotomolded) polyethylene or other thermoplastic materials, and wood. The boat manufacturing source category, for the purposes of P-MACT, includes those facilities that manufacture boats from FRP because most boats are produced from FRP and most of the available data are from these sources. The types of boats produced include sailboats, powerboats, yachts (both power and sail), personal watercraft, and miscellaneous small boats (e.g., canoes, kayaks, rowboats). The majority of boats produced (about 100,000 units per year) are small fiberglass power boats 14 to 25 feet long. However, personal watercraft (PWC) are a rapidly expanding segment of the boat manufacturing market.

The most common material used in boat manufacturing is FRP. Boats made from FRP 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 that is saturated with a thermosetting liquid resin such as unsaturated polyester or vinyl ester resin. The liquid resin is mixed with a catalyst before it is applied to the glass. The catalyzed resin hardens to form a rigid shape consisting of the plastic resin reinforced with glass fibers.

The FRP boat manufacturing process generally follows the following production steps:

- 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.
- The open mold is first spray coated with a pigmented polyester resin known as a gel coat that 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).
- 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 and then rolled with a metal or plastic roller to compact the fibers and remove air bubbles. The fibers are applied in the form of a chopped strand mat or chopped roving from a chopper gun; 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;
- After the skin coat has hardened, additional glass reinforcement in the form of chopped roving, chopped strand mat, woven roving, or woven cloth is applied to the inside of the mold and saturated with catalyzed polyester resin. The resin is usually applied with either spray equipment or by hand using a bucket and brush or paint-type roller.
- The saturated fabric is then rolled with a metal or plastic roller to compact the fibers and remove air bubbles.
- More layers 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.
- After the resin has cured, the part is removed from the mold and the edges are trimmed to the final dimensions.

- The different FRP parts of the boat are assembled using small pieces of woven glass or glass mat and resin, adhesives, or mechanical fasteners.
- Flotation foam is typically injected into closed cavities in the hulls of smaller boats to make the boat unsinkable and capable of floating if swamped.
- 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.
- Some manufacturers paint the topsides of their boats to obtain a superior finish or the bottoms to prevent marine growth.
- Larger boats generally also require extensive interior woodwork and cabin furnishings to be installed.

During the P-MACT phase, the EPA identified two subcategories in this source category. One subcategory is personal watercraft (PWC); these are defined as vessels less than 4 meters (13.1 feet) in length that use an internal combustion engine powering a water jet pump as its primary source of propulsion, and is operated by a person sitting, standing, or kneeling on, rather than within the confines of the hull. These include boats often referred to by the brand name "Jet Ski" that are manufactured by Kawasaki, although several other companies (including Yamaha, Mastercraft, and Polaris) manufacture boats in this subcategory. A separate subcategory was created for PWC because they are small boats (less than 4 meters) and are sometimes built using techniques that are not utilized for other types of larger boats. During P-MACT, the EPA collected information on 6 facilities in the PWC subcategory. All of these are probably major sources of hazardous air pollutant (HAP) (i.e., each facility has the potential to emit more than 10 tons per year of a single HAP or 25 tons per year of a combination of HAP) based on the amount of resin they consume.

The second subcategory includes all other types of boats and yachts, including sailboats, powerboats, and miscellaneous small boats. During P-MACT the EPA has collected information on 90 boat manufacturing facilities in this second subcategory and the EPA estimates that 77 of these are major sources of HAP.

In some cases, the FRP hulls and decks of PWC or boats are manufactured by a contractor for the PWC or boat manufacturer. In these cases, the EPA considered these contractors to be in the PWC or non-PWC boat manufacturing subcategory. The manufacturer that assembles the PWC or boat, but does not use any polyester resin, is not presently considered in the source category that was the subject of this P-MACT since this P-MACT addressed only emissions from polyester resins.

2.2 HAZARDOUS AIR POLLUTANT EMISSIONS

The principal HAP emitted from boat manufacturing are styrene and methyl methacrylate (MMA). Styrene is a volatile compound that is used as a cross-linking agent for connecting the monomers of polyester resins; polyester resins used in laminating contain between 30 and 50 percent styrene by weight. Methyl methacrylate is used as a cross-linking agent in addition to styrene in the polyester resins that are used as gel coats in the boat manufacturing industry. Gel coats have about 30 to 50 percent styrene and 5 percent MMA by weight.

Some fraction of the available styrene and MMA in the laminating resins and gel coats evaporates during application and curing. Not all of the styrene and MMA evaporates because the compounds are bound up in the cross-linking reaction between polyester molecules in the hardened resin and become part of the finished product. The data currently available to the EPA indicate that emission factors (pounds of emissions per pound of available HAP) are higher for gel coat application than for resin application. Emission factors are higher because gel coat is

applied in a thinner layer than resins and evaporation is higher from thinner layers.

The total HAP emissions from the boat manufacturing industry were 3,830 tons in 1993 according to the EPA's Toxic Release Inventory (TRI) database. This estimate was obtained by summing the total HAP reported by 158 facilities in SIC code 3732 (Boatbuilding and Repair). About 91 percent of these emissions are styrene and MMA. The remainder of the HAP emissions are primarily toluene and xylene, which are used as solvents in painting aluminum boats, and methylene chloride, which is used as a solvent in many cleaning operations. 1,1,1-Trichloroethane (methyl chloroform) was formerly used in large quantities as a cleanup and adhesive solvent, but is being discontinued because it is an ozone depleting substance.

The HAP emissions reported in the TRI database are generally calculated using the EPA's emission factors documented in EPA Publication No. AP-42. However, more recent data collected in separate laboratory studies by the EPA's Office of Research and Development (ORD) and the Composite Fabricators Association (CFA) indicate that the EPA's AP-42 emission factors may under-estimate styrene emissions from open molding. The ORD and CFA data indicate that actual emissions may be twice as high as estimated using AP-42 emission factors. If these data are supported by additional studies, the total emissions from the industry may be as high as 7,000 tons per year of HAP and there may be about 111 major sources.

The ORD and CFA emission studies were performed under closely controlled conditions using small (about 20 square feet) male molds in totally enclosed spray booths. The two studies indicated that several variables affect emissions, such as styrene content, resin application method, laminate thickness, and resin gel-time, but emissions are generally about twice as high as those predicted by AP-42. However, these test results

must be interpreted with some caution because the small male molds used in the tests are not representative of some of the molds found in most boat manufacturing facilities.

Most boat hull molds are large female molds and emissions may be different when using these types of molds. However, boat manufacturers use a variety of molds having different shapes and sizes. Deck molds and the molds for many of the smaller miscellaneous parts that go into a boat may be flat molds or male molds with features and surfaces very similar to the ones used in the emission studies. Other parameters that affect emission factors are the gel times and laminate thicknesses.

For the reasons noted above, not all of the P-MACT stakeholders agreed that these data should be used for comparing emission reduction potential. The NMMA will perform testing using actual boat molds to collect additional emissions data specific to boat manufacturing. The EPA is planning to use these data along with the ORD and CFA data to develop a better understanding of the effectiveness of emission reduction technologies and to develop more accurate methods for estimating emissions from the boat manufacturing industry. However, the EPA used the ORD-sponsored testing data to compare and rank emission reduction technologies for the P-MACT process because they were the most applicable and readily available data that compared the relative emission reduction potential of various pollution prevention options for FRP boat manufacturing.

3.0 EMISSION REDUCTION TECHNOLOGIES APPLICABLE TO BOAT MANUFACTURING

The following sections describe the techniques that are currently being used by PWC and non-PWC boat manufacturers to reduce emissions from resin application and, if applicable, gel coat application. In each section, the technique is described, followed by a discussion of potential emission reductions and a discussion of the benefits of that technique compared to other

molding technologies or to other emission control options. Finally there is a list of issues that were identified with each control option during the P-MACT process.

The information presented in the following sections is a summary of the information collected during P-MACT in the EPA's database for the boat manufacturing source category. Most of the information is from a survey sponsored by the NMMA and also includes information collected from case studies of well-controlled facilities that were identified by equipment vendors, in magazine articles, by P-MACT participants, and from the EPA's reinforced plastic composites NESHAP (which is a separate rule-making including products other than boats). Although the EPA will update the database with new information before the final standards are promulgated, this memorandum pertains only to the data collected during P-MACT.

3.1 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 boat manufacturing operations: vacuum bagging, vacuum-assisted resin transfer molding, resin transfer molding, and compression molding with sheet molding compound. These four technologies are discussed in the following sections.

3.1.1 Vacuum Bagging

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 has been applied (either by hand lay-up or spray lay-up), 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.

In the EPA P-MACT database, 13 facilities use vacuum bagging. One facility, Corsair Marine, vacuum bags all parts in the construction of high performance multi-hull sailboats (trimarans) including hulls as large as 31 feet. A manufacturer of large motor yachts uses vacuum bagging in the construction of internal decks, bulkheads, and stringers that have PVC foam cores. In this case, the vacuum bagging is used to compress the FRP laminates and foam core together. The EPA believes that most facilities in the EPA P-MACT database that perform vacuum bagging use it only for fabricating small parts and not for hulls, decks, and superstructures.

Emission reductions: The ORD and CFA testing program results indicate that about 50 percent of styrene emissions occur after the resin is applied, i.e., during roll-out and curing. Since a part is covered by a plastic bag after resin application, the EPA estimates that vacuum bagging may be able to reduce emissions by up to 50 percent, compared to allowing a part to cure in an open mold, if the vacuum bag is placed over the part immediately after the resin has been applied. A small amount of styrene will be emitted from the vacuum exhaust and some off-gassing may occur after the bag is removed, but these emissions are believed to be small because vacuum exhausts have been tested for similar processes and very little styrene has been detected.

In addition, it is believed that the styrene is incorporated into the cross-linking reactions and becomes part of the cured resin.

Benefits: Vacuum bagging offers the following advantages over conventional open molding, in addition to emission reductions:

- Minimized worker exposure to styrene curing emissions;
- Stronger and lighter parts with less voids and higher glass to resin ratios;
- Better bonding between FRP skins and non-FRP core materials; and
- Reduced labor and rolling equipment needs because rolling to remove air bubbles and excess resin is not needed.

Issues: Several issues have been raised with respect to vacuum bagging as a control option:

- Unless a reusable silicone bag is constructed, the vacuum bag, sealant, and bleeder sheets generally become solid waste after each part is made;
- The molds need a wider flange, compared to conventional molds, for sealing the vacuum bag to the mold;
- Increased labor and skill is required to fit and seal the bag to the mold;
- The bag must be fitted and the vacuum applied before the resin starts to cure; this can be difficult for very large parts requiring large amounts of resin and glass.
- Vacuum bagging can be difficult for complicated shapes unless a customized bag is fabricated; and
- Vacuum bagging requires the purchase and maintenance of a vacuum pump; purchase costs would be between about \$1,800 and \$7,500, depending on the size of the facility.

3.1.2 Vacuum-Assisted Resin Transfer Molding

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. Other VARTM techniques have been developed but were not explored during P-MACT development and it is not known how widely they are used in boat manufacturing.

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.

The SCRIMP process has been used by one manufacturer (TPI Composites, Inc.) to build small (13 foot) sailboats and large sailboats up to 90 feet. TPI builds about 400 boats per year using SCRIMP and also uses the process to manufacture other reinforced plastic parts, including windmill blades and exercise pools. Several other smaller boat manufacturers that are not major HAP sources are also using the process to build both power and sail boats of a variety of sizes including motor surf lifeboats for the U.S. Coast Guard. Wellcraft announced in August 1996 that it will also begin using the process to produce power boats. Wellcraft will be building about 4 hulls per week for 26 and 29 foot high performance powerboats. About 60 percent of the total resin used in these boats will be applied by the SCRIMP process. In 1997, Wellcraft plans to build larger boats with the SCRIMP process.

Emission Reductions: Significant emission reductions are possible with VARTM because the resin is pulled from a bulk container to a closed mold and very little surface area is available from which styrene can evaporate. Measurements performed by TPI, Inc. indicate that less than 0.02 percent of the available styrene is emitted during the VARTM process. This represents about a 99 percent emission reduction compared to resin applied by open molding. However, the VARTM process cannot be used for the whole boat building process because the gel coat and skin coat must still be applied by conventional methods, so the total emission reduction achieved will be lower than 99 percent.

The skin coat is about 0.09 inches thick and will represent about 10 to 30 percent of the thickness of a finished laminate, depending on the size of the boat and the function of the part which determine its necessary thickness. Taking the emissions from the skin coat into account, VARTM can achieve a 90 to 70 percent emission reduction; the reduction will be greater on

thicker parts for which the skin coat represents a smaller fraction of the total part thickness. The VARTM process does not control any of the emissions associated with gel coat application.

Benefits: The VARTM process has the following advantages over conventional open molding, in addition to emission reductions:

- Minimizes worker exposure to resin and styrene; this makes for a cleaner and more comfortable work environment and reduces the need for personal protective equipment such as respirators, gloves, and coveralls;
- Reduces the need for ventilation make-up air (and associated electrical and heating costs) to maintain styrene concentrations within acceptable exposure levels;
- Reduces the labor needed to apply resin and perform detail rolling of the laminate;
- Reduces the need for clean-up solvents for resin application equipment;
- Reduces the need for resin application equipment (e.g., spray guns, pumps, and detail rollers) and associated maintenance costs;
- Produces parts with a higher glass-to-resin ratio and fewer voids, which generally results in stronger and more durable parts;
- Can produce lighter parts if a core material is incorporated into the laminate in place of some of the fiberglass; and
- Produces more consistent parts because the fiberglass reinforcements are placed into the mold dry and can be precisely located before resin is applied and because resin application is more controlled and predictable.

Issues: Several issues have been raised with respect to the use of the VARTM process as an emission control option:

- Unless a reusable silicone bag or cover is constructed, the vacuum bag, sealant, and resin distribution system generally become solid waste after each part is made;
- The molds must have a wider flange, compared to conventional molds, for sealing the vacuum bag or cover to the mold;
- Increased skill and training is required to cut and fit the reinforcements into the mold, assemble the resin distribution system, and fit and seal the bag or cover to the mold;
- The VARTM process can be difficult for complicated shapes unless a customized bag or cover is fabricated;
- The VARTM process requires the purchase and maintenance of a vacuum pump;
- The vacuum pressure that compresses the laminates may cause print-through of the gel coat (this is a cosmetic problem that is not limited to VARTM and may require the part to be painted after it is removed from the mold; print-through is being studied by the SCRIMP patent holders in conjunction with resin suppliers);
- The vacuum pressure also produces thinner parts because the fiberglass is compressed before the resin is applied; this may require that the laminate be redesigned to incorporate a core material to maintain the same part thickness and stiffness;
- Proper resin and catalyst chemistry is needed to prevent excessive heat build-up in thick parts, to prevent print-through, and to achieve the working time needed to infuse large parts with resin; and
- The SCRIMP process is patented and users must purchase a license and pay a royalty on each part made; the current license fee is \$25,000 (which includes training and engineering support in how to use the process). The royalty is negotiable and is a maximum of \$0.20 per pound of the part made, or 5 percent of the licensee's cost to produce the part, including materials, labor, and manufacturing overhead. However, the royalty decreases as a manufacturer's volume increases so that

a facility comparable to TPI Composites would only be paying a royalty of about \$0.04 to \$0.05 per pound of part made.

3.1.3 Resin Transfer Molding

Resin transfer molding (RTM) uses two rigid mold halves to provide the shape for fabrication of FRP boat parts. In a typical resin transfer molding (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. Six boat manufacturers in the EPA P-MACT database are using RTM. One manufacturer is using RTM for producing PWC hulls and decks. No manufacturers are currently using RTM to fabricate boats larger than a PWC.

Emission Reductions: 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 styrene is emitted during fabrication by RTM compared to conventional hand and spray processes. Any styrene that is emitted is released during off-gassing when the mold is opened. The RTM process does not control any of the emissions associated with gel coat application.

Benefits: The RTM process has several advantages compared to conventional open molding in addition to emission reductions:

- RTM is more economical than open molding for producing many copies of relatively small parts such as hatch covers and seats because of reduced labor during resin application; the use of pre-formed fiberglass reinforcements can add to these labor savings;
- Minimizes worker exposure to resin and styrene; this makes for a cleaner and more comfortable work environment and reduces the need for personal protective equipment such as respirators, gloves, and coveralls;
- Reduces the need for clean-up solvents for resin application equipment;
- RTM produces more consistent parts than open molding;
- RTM can produce parts with two smooth finished sides; and
- Parts can be produced more quickly with RTM because the heat of injecting the resin accelerates the resin curing and allows for faster mold cycle times.

Issues: Several issues have been raised with respect to the RTM process as an emission control option:

- RTM molds are more costly than open molds because they must be built to withstand the pressure of the injected resin and, therefore, must have a significant steel reinforcing structure that also increases the weight of the mold;
- The cost difference between open molds and RTM molds increases as the molds become larger and more complex; small molds (such as a hatch cover) can be 4 times the price of open molds and large molds (such as a PWC) can be 10 times the price of an open mold; and
- Parts made with RTM may still require painting to achieve the same finish as with an open mold and paint solvent emissions may offset some of the emission reductions achieved by closed molding.

3.1.4 Compression Molding using Sheet Molding Compound

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 PWC. These facilities are producing parts on the order of tens of thousands per year.

Emission Reductions: 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 styrene is emitted during fabrication with SMC compared to conventional spray and hand lay up processes.

Benefits: The compression molding process with SMC has the following advantages compared to other molding technologies in addition to emission reductions:

- The rapid curing of the parts under high heat and pressure permits rapid mold cycle times and high production volumes;
- The automated process and the use of SMC reduces labor costs compared to open molding; and
- Minimizes worker exposure to resin and styrene; this makes for a cleaner and more comfortable work environment and reduces the need for personal protective equipment such as respirators, gloves, and coveralls;

- Reduces the need for clean-up solvents for resin application equipment; and
- There is no need to apply gel coat to the mold prior to molding.

Issues: Several issues have been raised with respect to compression molding with SMC as an emission control option:

- The molds required for SMC must be fabricated from metal to withstand the molding pressures and are very expensive; e.g., the cost of molds to build a PWC may be as much as \$1 million;
- The hydraulic press is also very expensive and can cost several million dollars for one large enough to handle a part the size of a PWC hull;
- Because of these high capital costs, compression molding with SMC may only be feasible for large production runs of identical parts (e.g., tens of thousands of units per year); and
- A "Class A" finish cannot be obtained from SMC so the parts must be painted after molding; this is an added cost and paint solvent emissions may offset some of the emission reductions achieved by using closed molding depending on the HAP emissions from paint compared to gel coat.

3.2 NON-SPRAY RESIN APPLICATION

Non-spray resin application includes 4 different techniques for applying resin: bucket and brush application, resin rollers, flow coaters, and resin impregnators. All four of these techniques reduce emissions compared to resin spraying techniques by eliminating the atomization of resin. These four techniques are discussed in the following sections.

3.2.1 Bucket and Brush Application

The bucket and brush technique 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 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 and bonding small parts at larger production facilities.

Emission Reductions: According to the results of the ORD testing program, non-spray resin application, including resin rollers and flow coaters, achieved about a 45-percent emission reduction (based on percent available styrene) compared to resin spraying. Bucket and brush application will probably achieve a similar emission reduction because it is also a non-spray application method.

Benefits: The advantages of this technique compared to spray application in addition to emission reductions are:

- Reduced worker exposure to styrene because the resin is not atomized; and
- No special equipment is needed so this process can be used by small shops or in situations in which other application equipment is not available, such as for assembly outside a laminating shop or for repair of existing boats.

Issues: Most boat manufacturers, except those making very small boats such as canoes and kayaks and a few other specialized types of boats, have switched to other resin application techniques because mixing batches of resin and catalyst is labor-intensive and inefficient compared to other methods. In addition, the buckets and excess resin can become a significant amount of solid waste and also wasted materials.

3.2.2 Resin Rollers

Resin rollers consist of a fabric roller that is fed a continuous supply of catalyzed 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 predetermined but adjustable ratio to a static mixer located in the handle of the roller. The static mixer then feeds the catalyzed resin to the roller head through the handle of the roller. Since atomization is not required with resin rollers, resin delivery pressures are below the delivery pressure of most resin spraying systems [i.e., less than 100 pounds per square inch (PSI)].

A valve controlled by the operator regulates the amount of resin flowing to the roller head and to the part being fabricated. The resin flow is distributed to the roller head by a manifold within the roller head. A typical roller head is about 9 inches wide by 1.5 inches in diameter and has about 150 holes that are about 1/32 inches in diameter. The roller head is covered with a disposable fabric cover similar to a standard paint roller cover. This arrangement distributes the resin uniformly around the circumference of the roller. Resin roller systems are similar in principle to the Wagner-brand Power Roller Systems available to consumers in hardware stores.

Resin rollers are intended to be operated more or less continuously during a shift to prevent the resin from hardening between the static 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. Non-HAP, non-VOC solvents can be used for solvent flushing.

Resin rollers are used to manufacture a range of boats from 12 to 40 feet in length, including both sail and power boats. In the EPA P-MACT database, there are 11 boat manufacturing facilities (including one that makes both PWC and powerboats) using resin rollers for some or all of their resin application. One facility builds as many as 3,000 power boats (19 to 21.5 feet) and 3,500 PWC per year using only resin rollers. Another facility builds about 80 large sailboats per year with only resin rollers. Those facilities that use both resin rollers and spray

equipment generally use the rollers for the hulls and the spray equipment for the decks and small parts that have more complicated shapes.

Emission Reductions: The ORD testing program measured emissions from resin rollers and found that resin rollers achieved approximately a 45-percent emission reduction (based on percent available styrene) compared to resin spraying. The ORD testing program measured styrene emissions from resin rollers that were equal to 15 percent of the available styrene.

Benefits: Resin rollers have the following advantages compared to resin spray application systems and as an emission control option.

- A higher transfer efficiency than spray systems with more resin going onto the part and less resin being lost as overspray;
- Reduced need for personal protective equipment, including respirators and coveralls;
- A cleaner and more comfortable work environment, including reduced consumption of disposable floor coverings;
- More control over final part weight and reduced variability among parts; and
- As a control option, resin rollers can be combined with low-styrene resins for additional emission reductions.

Issues: Several issues have been raised with respect to resin rollers as an emission control option.

- Switching to resin rollers from spray equipment will require capital costs to purchase the resin rollers and possibly modify the existing resin distribution and pumping equipment;
- Resin rollers may have higher maintenance costs compared to spray equipment;
- Resin rollers can be difficult to work into narrow spaces and tight corners and small parts may require

that the fabric is impregnated with resin before it is placed in the mold;

- The longer handles on resin rollers may be difficult to maneuver around the scaffolding used for working inside larger hulls;
- Work must be scheduled to keep the roller in more or less continuous use throughout a shift to prevent resin from hardening inside the handle and roller head;
- Resin rollers may require more cleaning solvent and generate more waste solvent than external mix spray equipment; and
- Resin rollers may dispense resin at a slower rate than resin spray equipment and this may lead to slower production.

3.2.3 Flow Coaters

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. At least one manufacturer produces an internal-mix resin spray gun that can be converted to a flow coater simply by switching the nozzle from a single orifice tip to a flow coater nozzle. 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. 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 predetermined but adjustable ratio to a static mixer located in the handle of the flow coater. The static mixer then feeds the

resin to the flow coater head through the handle of the flow coater. A valve controlled by the operator regulates the amount of resin being applied to the part being fabricated. Flow coaters are operated at a lower fluid pressure than resin spray equipment.

Like resin rollers and other internal mix equipment, flow coaters are intended to be operated more or less continuously during a shift to prevent the resin from hardening inside the applicator. At the end of the shift, the mixing unit, handle, and nozzle are flushed using a solvent recirculated in a closed system.

Thirteen boat manufacturers in the EPA P-MACT database use flow coaters for some or all of their resin application. Flow coaters and chopper flow coaters are used to manufacture both power and sailboats up to about 40 feet in length.

Emission Reductions: The ORD testing program measured emissions from flow coaters and found that flow coaters achieved a 45-percent emission reduction compared to resin spraying. The ORD testing program measured styrene emissions from flow coaters that were approximately 15 percent of the available styrene.

Benefits: Flow coaters have the following benefits over resin spray application systems and as an emission control option.

- A higher transfer efficiency than spray systems with more resin going onto the part and less resin being lost as overspray;
- Reduced need for personal protective equipment, including respirators and coveralls (one manufacture has noticed that the employees are able to work closer together and faster than if using spray guns);
- A cleaner and more comfortable work environment, including reduced consumption of disposable floor coverings; and

- As a control option, flow coaters can be combined with low styrene resins for additional emission reductions.

Issues: Several issues have been raised with respect to using flow coaters as an emission control option:

- Flow coaters may dispense resin at a slower rate than resin spray equipment and this may lead to reduced production;
- Switching or converting spray equipment to flow coaters will require capital expenditures; however, these costs can be relatively modest depending on the spray equipment currently used;
- Higher maintenance costs compared to spray equipment (Thoroughbred Powerboats reported that flow coaters increased valve maintenance costs approximately 5 times compared to spray gun systems);
- Some industry representatives have stated that flow coaters may not be able to shoot as far as conventional spray equipment and it may be harder to laminate from outside large molds with flow coaters;
- Work must be scheduled to keep the flow coater in use more or less continuously throughout a shift to prevent resin from hardening inside the application equipment; and
- Flow coaters may require more cleaning solvent and generate more waste solvent than external mix spray equipment.

3.2.4 Fabric Impregnators

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.

Resin 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.

At least one manufacturer is using a crane-mounted resin impregnator to lay up the hulls and other large parts of large custom motor yachts. At least three other builders of smaller custom boats are using impregnators.

Emission Reductions: No emissions data are available for resin impregnators, but they are probably comparable to other non-spray resin application methods. That is, they are probably capable of achieving a 45-percent emission reduction compared to resin spray application.

Benefits: Resin impregnators have the following advantages over resin spray application systems in addition to reduced emissions:

- Minimizes worker exposure to styrene and resin and makes for a cleaner shop environment because resin is not being spray-applied;
- Impregnators may be faster and require less labor in situations in which many layers of fabric need to be applied over a large part; and
- The builder has more control over the fiber-to-resin ratio than most other systems so impregnators may improve the quality and consistency of the laminate.

Issues: There are several issues associated with using fabric impregnators over other types of resin application systems.

- Fabric impregnators are generally not very mobile unless they are mounted on a cart or a bridge crane;
- It is necessary to move the saturated fabric from the impregnator to the part and this may offset some of the initial labor savings;

- Fabric impregnators can be difficult to clean and must be operated continuously to prevent resin from hardening on them; and
- Switching to fabric impregnators would involve some capital expenditures; basic units start at about \$10,000.

3.3 CONTROLLED SPRAYING AND SPRAY GUN OPTIMIZATION

Controlled spraying is the operation of spray equipment to minimize the amount of overspray and the distance between the spray tip of the applicator and the mold surface. According to the Composite Fabricators Association (CFA) Open Molding Styrene Emissions Test Project, the following characteristics are typical of industry application of resin with spray equipment:

- The operator normally carries the spray gun stroke approximately 6 inches off the edge of the mold;
- The spray gun tip is held approximately 18 or more inches from the surface of the mold; and
- The fan of resin being sprayed onto the mold will be directed to intercept the mold at angles ranging from 90 degrees to 45 degrees.

Under controlled-spraying conditions, the operator takes the following steps to minimize overspray:

- The spray gun stroke is stopped earlier to contain the overspray within the flange of the mold;
- The spray gun tip is held approximately 12 inches from the mold surface; and
- The fan intercept angle at the mold surface is maintained closer 90 degrees and is not allowed to be less than 80 degrees from the mold surface.

According to the CFA study, spray gun optimization is the process of setting up a spray gun to minimize emissions by selecting the appropriate spray tip (including orifice size and orifice angle) so that the gun can be held 12 to 18 inches or as close as reasonably possible from the mold surface and by

adjusting the gun's tip pressure to the lowest possible pressure that produces an acceptable fan pattern.

Controlled spraying and spray gun optimization can reduce emissions from both resin and gel coat spray application. It is not known how many boat manufacturers that use spray equipment practice controlled spraying or spray gun optimization as defined in the CFA emissions study. In the EPA P-MACT database, 26 NMMA survey respondents stated that they performed some sort of operator training; however, it is not known if this included either controlled spraying techniques or spray gun optimization. During site visits to several boat manufacturers that use resin or gel coat spray equipment, the EPA has not seen operators using controlled spraying as defined in the CFA test program. During the visits, the EPA did not determine if any spray guns were optimized.

Emission Reductions: In the ORD test program, controlled resin spraying achieved a 35-percent emission reduction compared to normal spraying (i.e., the emission factors as a percent of available styrene decreased from 27.1 percent to 17.5 percent). Controlled gel coat spraying achieved a 10 percent emission reduction (the emission factors decreased from 62.5 percent to 56.0 percent of available styrene).

In the CFA emission test program, controlled resin spraying achieved on average a 21.4 percent emission reduction based on available styrene (emission factors decreased from 21.9 to 17.2 percent with controlled spraying). Controlled gel coat spraying achieved on average a 41.6 percent emission reduction (the emission factors decreased from 54.0 percent to 31.5 percent of available styrene).

The CFA testing program found that resin spray gun optimization (without controlled spraying) yielded on average a 9.1 percent decrease in emissions (emissions decreased from 21.9 percent to 19.9 percent of available styrene). Gel coat

spray gun optimization yielded on average a 21.1 percent decrease in emissions (emission factors decreased from 54.0 percent to 42.6 percent of available styrene). The CFA study found that there is no additive effect in emission reductions if spray gun optimization is combined with controlled spraying.¹

Both the CFA and ORD testing were performed with small male molds; the emission reductions achieved for controlled versus uncontrolled spraying may be different for larger molds and molds of different shapes. In addition, different operators may also achieve different results.

Benefits: Controlled spraying and spray gun optimization have two advantages as emission control options:

- The potential to achieve significant emission reductions with no capital investments and few changes in work practices; and
- Can be combined with other emission reduction techniques, such as low styrene gel coats and resins (note, however, that reductions are not additive for all techniques).

Issues: Several issues have been raised with respect to controlled spraying and spray gun optimization as emission control options:

- Facility operators would need to retrain their workers in how they operate spray equipment and this training would need to be periodically repeated to maintain these practices;

¹The CFA testing program measured the effect of several variables on emissions, including part thickness (40 to 41 mils or 80 to 88 mils); resin styrene content (35 or 42 weight percent); resin cup gel time (15 or 30 minutes); gelcoat thickness (18 or 24 mils); gelcoat styrene content (35 or 40 weight percent); and gelcoat cup gel time (10 or 20 minutes). The average emission reductions reported for the CFA study represent the average result of several tests comparing different combinations of these variables; some combinations achieved emission reductions that deviated significantly from the average.

- With gel coat application, controlled spraying could be counter to the techniques spray gun operators use to achieve a good quality finish, especially at the edge of a mold;
- Emission reductions will be a function of part size and shape, and operator technique may not be easily quantified.
- For ergonomic reasons, facilities may not be able to comply with controlled spraying requirements on parts with complicated surfaces or on large parts that are not easily accessible by the spray gun operator; and
- Controlled spraying and spray gun optimization could be difficult (perhaps impossible) for regulatory agencies to monitor and enforce between inspections.

3.4 LOW STYRENE RESINS AND GEL COATS

The EPA has no definition at this time of what is considered a "low styrene" resin or gel coat, but, for example, the South Coast Air Quality Management District in California has established a 35-percent styrene limit for general purpose polyester resins in Rule 1162. However, Rule 1162 has an exemption for corrosion-resistant materials that includes polyester resins used in boat hulls; the monomer content limit for corrosion-resistant materials is 48 percent by weight. Rule 1162 establishes a 45 percent monomer limit for pigmented gel coat. The resin styrene contents in the EPA P-MACT database generally range from 30 to 50 percent styrene by weight. About 25 percent of the facilities in the EPA P-MACT database use bulk resins with styrene contents of 35 percent or below. The gel coat combined styrene and MMA contents in the EPA P-MACT database range from 30 to 45 percent by weight. However, it is not possible to use these gel coat data for comparison because gel coats vary significantly in density and pound-per-gallon HAP contents are needed to accurately compare potential emissions among gel coats.

Emission Reductions: In the CFA emissions study, a 35-percent styrene resin emitted an average of 27.6 percent less styrene than a 42-percent styrene resin in a hand lay-up operation. In a spray lay-up operation, the 35-percent resin emitted an average of 48.6 percent less styrene than the 42-percent styrene resin.

Also in the CFA study, a 35-percent styrene gel coat achieved a 22.1-percent reduction compared to a 40-percent styrene gel coat. The ORD study measured a 36.4-percent reduction switching from a 38.7-percent HAP gel coat to a 25.4-percent HAP gel coat. The pound per gallon HAP content was not recorded in either the CFA or the ORD test reports.

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

Issues: Industry representatives have argued that there are several issues associated with low styrene resins and gel coats.

- Low styrene materials may have reduced physical performance because there is less styrene available for cross-linking polyester molecules in the cured resin or gel coat;
- Low styrene materials may have higher viscosity, which may make them harder to apply;
- Low styrene resins have less styrene available to dissolve the binder in chopped strand mat; it may be harder to wet-out these types of reinforcements unless binderless mat is used;

- Some low styrene resins and gel coats are more permeable to water and, therefore, more susceptible to osmotic blistering if used on boats that are intended to be kept in the water for extended periods of time; and
- It may be more difficult to achieve good secondary bonds because low styrene resins are less forgiving of dust and contaminants on the laminate surface.

3.5 VAPOR SUPPRESSED RESINS AND GEL COATS

Vapor suppressed resins and gel coats have an additive, typically a wax, that reduces styrene evaporation by forming a film on the surface of the resin or gel coat as it cures. There is only one facility in the EPA P-MACT database (Catalina Yachts) using a significant quantity of vapor suppressed resins; this is a sailboat manufacturer producing 600 to 800 boats per year in the 8 to 42 foot range. There are other manufacturers in the EPA P-MACT database that are using vapor suppressed gel coats, but these are in relatively small quantities and only for coating finished parts that will not have additional fiberglass laminated onto them.

Emission Reductions: The ORD study measured a 40 percent emission reduction from a vapor suppressed resin compared to a conventional resin; both resins were applied by spray equipment. No data are available for vapor-suppressed gel coats.

Benefits: Vapor suppressed resins can be used to achieve emission reductions without significant capital expenditures. They can also be combined with other emission reduction techniques, such as spray gun optimization or non-spray resin application, for additional emission reductions.

Issues: Adding a vapor-suppressing wax to a resin may present significant technical problems. In order to achieve good secondary bonds between parts made with vapor suppressed resins, the wax film on the bonding surfaces must be removed 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 the molding shop. The ultimate strength of those secondary bonds may also be reduced.

3.6 ADD-ON CONTROL DEVICES

The EPA is currently aware of only one manufacturer, Bombardier in Benton, Illinois, that is using an add-on control device to limit emissions from boat manufacturing. Bombardier manufactures small jet boats that are 14 to 18 feet long and up to 8 feet wide. The facility is using a thermal oxidizer to control the exhaust from the spray booths in which both gel coating and laminating are performed. Only the spray booths on one of two production lines are controlled by the device. Bombardier uses managed air flow to maximize the concentration of styrene in the exhaust while minimizing worker exposure to styrene. (Managed air flow includes practices such as directing styrene vapors away from workers' breathing zones rather than diluting the vapors.)

Two other facilities in the EPA P-MACT database indicated that they were using carbon adsorbers to limit styrene emissions. However, based on follow-up contacts with those two facilities, the EPA is not considering those devices in further control option analyses. One facility was circulating building air through carbon beds, but has discontinued the practice. The second facility has carbon beds on their gel coat spray booth exhaust and on the exhaust from drop-down hoses in the laminating area. However, no data are available on the performance of these controls or on how frequently the carbon beds are regenerated or replaced, which is important for maintaining emission control efficiency.

In the United States, add-on controls have been applied more frequently in the fiber reinforced plastics/composites industries than in boat manufacturing. Five facilities that perform gel

coating or resin spray up processes have installed thermal or catalytic oxidizers. Another facility manufacturing bathware has installed a Polyad™ polymeric concentrator/oxidizer system. A concentrator that converts styrene emissions from a dilute high volume stream to a low-volume concentrated stream is the most likely type of add-on control technology to be applicable to a boat manufacturing facility because the emissions are normally too dilute for conventional oxidizers.

Emission Reductions: No emissions data are currently available for the thermal oxidizer at the Bombardier facility. Thermal oxidizers and other add-on controls are capable of 95 to 98 percent destruction efficiency. However, the overall control efficiency of the Bombardier facility is also dependent on the capture efficiency of the managed air system. For the Bombardier facility, the EPA assumed in the P-MACT analysis that if 50 percent of the resin is applied and cured in the spray booths that are vented to the oxidizer and if those booths have a 90-percent capture efficiency, then the overall control efficiency for this facility is about 40 percent.

Benefits: An add-on control device, such as a thermal oxidizer, allows the manufacturer to control emissions without having to limit the styrene content of the resin being applied or the way it is applied. Well designed systems can achieve upwards of 95 percent emission reductions.

Issues: Add-on controls generally have significant capital and operating costs compared to available pollution-prevention technologies.

4.0 THE EPA'S RANKING OF WELL-CONTROLLED FACILITIES

To determine which boat manufacturers in the EPA P-MACT database are the best controlled facilities, the EPA ranked the facilities using an estimated ton of emissions per ton of resin applied (ton/ton) factor to reflect the extent that emission reduction measures were used by each facility. The ORD test

results and other data were used to compute a ton/ton value for each resin used by a manufacturer, depending on the styrene content and resin application method. If a manufacturer used more than one type of resin or more than one application method, then the ton/ton value was prorated according to the amount of each resin applied with each method.

The ton/ton emission factors were used to rank facilities from the best-controlled facility (low ton/ton emissions) to the least-controlled facility (high ton/ton emissions). The analysis included only laminating resins and did not include gel coats because appropriate data on gel coat styrene contents were not available. (Because gel coats vary in density, styrene and MMA contents among gel coats must be compared on a pound per gallon basis, but these data were not available.)

TABLE 1. STYRENE EMISSION FACTORS USED IN THE RANKING ANALYSIS

Process	Emission Factor (Percent Available Styrene)	Reference
Closed molding (RTM, SMC, VARTM)	1.0	TPI, Inc.
Vapor suppressed resin, controlled spraying	10.6 ^a	ORD Test Results
Non-spray resin application (flow coaters, resin rollers, hand application)	15.3 ^b	ORD Test Results
Normal resin spraying	27.1 ^c	ORD Test Results

^a Test conditions: 43.5 percent styrene, 17 minute cup gel time; average laminate thickness was 95 mils.

^b Test conditions: 38.3 percent styrene, 20 minute cup gel time; average laminate thickness was 79 to 89 mils.

^c Test conditions: 38.3 percent styrene, 20 minute cup gel time; average laminate thickness was 90 mils.

The styrene emission factors used in the ranking analyses are listed in Table 1. The emission factors for spray resin application and non-spray resin application were taken from the results of the ORD testing program. For closed molding (including RTM, compression molding with SMC, and VARTM) the EPA assumed an emission factor of 1 percent of available styrene. This emission factor was based on the results of testing at TPI Composites, Inc. that demonstrated that styrene emissions during the VARTM process are less than 0.02 percent of available styrene.

Separate ranking analyses were performed for PWC manufacturers and boat manufacturers. The results are described in sections 4.1 and 4.2 for PWC manufacturers and non-PWC boat manufacturers, respectively. The Act requires that new sources

meet the level of control achieved by the best controlled similar source in a category or subcategory. Existing sources can meet a level of control less stringent than that achieved by new sources, but no less stringent than the level of control achieved by the average of the top 12 percent of sources. If there are fewer than 30 sources in a category or subcategory, then existing sources must achieve a level of control no less stringent than the average of the top 5 sources. The rankings presented in the following sections represent the EPA's preliminary analysis of the data collected during P-MACT according to these criteria.

4.1 RANKING ANALYSIS RESULTS FOR PWC MANUFACTURERS
Table

TABLE 2. ALL PWC MANUFACTURING FACILITIES IN THE EPA P-MACT DATABASE
(Listed from best controlled to least controlled)

Facility ID	Facility Name	Number of Units Produced	Calculated EF Ton/ton	Resin Appl Tech and % Applied	Styrene %
D9	Kawasaki	37,164 in 1993	0.005	90% SMC, 10% RTM	SMC: 29 RTM: 50
E2	Applied Composites	20,000/yr approx.	0.005	100% SMC	31 to 43
	Navistar	--	0.005	100% SMC	--
	Unknown*	3,500 in 1995 (approx.)	0.0673	100% Resin rollers or by hand	44
A1	Gold Shield	2000/yr approx.	0.103	60% spray, 40% brush	46
	Unknown*	5,712 in 1993	0.122	Chopper and spray	45

* Industry voluntary survey respondents were encoded and the names were not provided to the EPA unless they were duplicates of case-studies.

2 lists the results of the PWC ranking analysis. There are 6 facilities in the EPA P-MACT database. The best controlled sources use closed molding to manufacture PWCs with either resin transfer molding (RTM) or with compression molds and sheet molding compound (SMC). One facility (Kawasaki Motors Manufacturing of America) is an integrated facility that manufactures over 30,000 units per year from SMC and also assembles the finished PWCs. The other well-controlled facilities build PWC parts from SMC on a contract basis for the

end manufacturers that actually assemble, distribute, and market the PWCs. The EPA assumed that these end manufacturers do not use polyester resin, except possibly for assembly, but assembly operations were not included in this ranking analysis.

It should be noted that the best-controlled PWC manufacturers that use closed molding all have very high production volumes (greater than 20,000 units per year). Several industry representatives have indicated that closed molding using RTM and SMC is not feasible for producing low volumes of PWC (e.g., fewer than 15,000 units per year for each model) because of the significant capital costs for molds and presses. Some of these costs can be defrayed, however, by having an outside contractor make the parts from company-owned molds.

During MACT development, an alternative level of control for smaller PWC manufacturers that could be met without RTM or SMC technology will be investigated. At these lower production levels, the best controlled facility uses non-spray resin application techniques to manufacture PWC. This investigation will also examine the costs of SMC and RTM technologies and other closed molding technologies, such as VARTM, or abatement (add-on) controls that are equivalent to closed molding. In addition, if a separate level of control based on production is warranted, the analysis will determine at what production level closed molding is a cost effective control option and more stringent standards should apply. Finally, the analysis will consider how PWC manufacturers should be regulated if they are located with other sources with which the control costs could be shared.

4.2 RANKING ANALYSIS RESULTS FOR NON-PWC BOAT MANUFACTURERS
Table

TABLE 3. BEST CONTROLLED NON-PWC BOAT MANUFACTURING FACILITIES
(Top 11 facilities, listed from best controlled to least controlled)

Facility Name (ID)	Types of Products	Number of Units Produced	Length (ft) (bow to stern)	Calculated EF Ton/ton	Resin Appl Tech and % Applied	Styrene %	Add-on Controls
TPI, Inc.	Sailboats	400 in 1993	13, 25 to 64	0.00922	95% Resin Infusion, 5% spray	40?	
Corsair Marine Sailboats	Trimaran Sailboats	70 per year	24, 27, 31	0.0351	100% Non-spray; 90% vacuum-bag	42	
Tracker Marine	Powerboats	5,000 per year	16 to 21	0.0528	100% Resin rollers or by hand	34.5	
Island Packet Yachts (D6)	Sailboats	85 in 1994	40	0.0606	100% Resin rollers or by hand	39.6	
Unknown (C2) *	Powerboats	1,857 in 1994	20	0.0636	50% spray, 50% flow coater	30	
Bombardier	Powerboats	(Unknown)	15	0.0644	Assumed 100% spray	40?	Oxidizer on 1 of 2 lines; 40% control assumed.
Catalina Yachts	Sailboats	600 to 800 per year	8 to 42	0.0659	Spray, 50% of resin is vapor supp.	35	
Unknown (E2) *	Powerboats	3,000 in 1995 (approx.)	20	0.0673	100% Resin rollers or by hand	44	
Thoroughbred	Powerboats	50 in 1993	40	0.0673	100% Flow coaters	44	
Sunfish Laser (I4)	Sailboats	2,370 in 1993	13	0.0683	95% Resin Rollers, 5% spray	43	
Unknown (E6) *	Powerboats	3,500 in 1993	18	0.0699	Spray, chopper, 50% resin roller	33	

* Industry voluntary survey respondents were encoded and the names were not provided to the EPA unless they were duplicates of case-studies.

3 lists the results of the ranking analysis for non-PWC boat manufacturing facilities. The table lists the top 11 facilities in the EPA P-MACT database; these also represent the top 12 percent of facilities. For the non-PWC boat manufacturing subcategory, the best controlled source (TPI, Inc.) uses the patented SCRIMP version of the VARTM process to manufacture small, mid-size, and large sailboats, including both racing and

cruising sailboats. This facility also manufactures large windmill blades and exercise pools, among other things, using the VARTM process.

Other well-controlled facilities in the non-PWC boat manufacturing subcategory use a combination of low styrene resins and non-spray resin application techniques, such as resin roller or flow coaters or by bucket and brush. One facility also uses vacuum bagging in conjunction with non-spray resin application. Styrene contents range from 30 to 44 percent and the percent of resin applied with non-spray application technology ranges from 50 to 100 percent. (Those resin styrene contents that are marked by a question mark are assumed.) In those cases where a facility does not use 100-percent non-spray resin application, they are still in the process of shifting over to non-spray resin application or they prefer to use spray application for some parts, such as decks and small parts.

It is important to keep in mind that additional facilities may have adopted pollution prevention techniques, such as non-spray application and low-styrene resins, since the NMMA survey was completed (early 1995) and these facilities may affect the MACT level of control.

5.0 NEXT STEPS IN DEVELOPING THE BOAT MANUFACTURING NESHAP

The EPA and the P-MACT participants have identified several significant issue areas that need to be resolved in developing the boat manufacturing NESHAP. To address these issues, the P-MACT participants have agreed to form small groups to address each issue area. These "issue groups" will be collecting and analyzing the information needed to resolve these issues. Separate groups have been formed to address the issues described in sections 5.1 through 5.8 of this memorandum. The bullets under each issue category briefly describe the scope of each issue. These issues were provided to the issue group participants as an initial list of questions and comments. These

issues may be refined as additional information is collected and each group further develops its mission.

5.1 CONTROLLED SPRAYING

How will "controlled" spraying be incorporated into the MACT standard?

- If the standard allows resin spraying, should controlled spraying be an alternative means for compliance or should it be a mandatory requirement?
- How should controlled spraying be defined in a regulatory framework?
- What level of emissions reductions can be achieved and on what do they depend?
- Industry has agreed to develop a controlled spray guideline that manufacturers must follow in order to receive emission reduction credit.

5.2 EMISSIONS DATA

What emissions data are needed for the MACT standards development? The NMMA has volunteered to fund additional emissions testing using a full-sized boat hull mold.

- How much emission reduction credit should be given for non-spray techniques, closed molding, vacuum bagging, and gel coating?
- How should the NMMA test program be used for MACT development?
- Should the test program examine the various aspects of spray and non-spray (rollers and flow coaters) equipment usage to define the level of transfer efficiency and recommended limitations of such equipment? (May be a cross cutting issue with controlled spraying issue group.)

5.3 CLOSED-MOLDING FOR PWC

At what level of production is it feasible for industry to use closed molding, such as RTM or compression molding with SMC?

- Should there be a separate level of control for low-volume, entry level major sources in PWC manufacturing?

- A cost analysis will be needed for closed molding PWC production.

Should PWC manufacturers (parts vendors) that are collocated in the reinforced plastics parts source category be evaluated separately from other PWC manufacturers?

Parts made with SMC or RTM may need painting in place of, or, in addition to gel coat application. Would the emissions from painting offset the emission reductions from closed molding?

- What are the relative emissions from painting and gel coat application compared to open versus closed molding?
- Are emission standards needed for the painting operations?
- Data are needed on current post-mold coatings for SMC and other closed mold coatings with similar uses.

5.4 CLOSED MOLDING FOR NON-PWC BOAT MANUFACTURING

Is closed molding feasible for hulls, decks, and superstructures considering costs, cosmetics, production volume, solid waste, and structural performance issues?

What emission reductions can be achieved using closed molding, such as VARTM (infusion molding) and how applicable is it to small and large parts?

- Can reliable emission measurements or estimates be obtained?
- Should closed molding emissions be addressed in the NMMA emissions testing program?

5.5 LOWER HAP GEL COATS AND RESINS

How should gel coat emissions be regulated?

- How should HAP content data for gel coats on a pound-per-gallon basis be collected (i.e., to compare the emission potential of one gel coat to another)?
- Should gel coat emissions be part of the NMMA test program?

- How can low HAP gel coats be used to reduce emissions?
- What are the performance limitations, if any, of low HAP gel coats?

How can low HAP resins be used to reduce emissions?

- What are the performance limitations, if any, of low HAP resins?

5.6 MATERIAL SUBSTITUTION/FORMAT OF THE STANDARD

- Should material substitution be allowed as a regulatory option to reduce HAP emissions (e.g., replacing polyester resins with lower or zero HAP materials)?
- No credit should be given for material substitution within exempt activities.
- What would be the format of the material substitution option and how would it be enforced?
- What are the life-cycle costs of the substituted material and would this material be shifting pollution to other industries or media?
- Enforcement costs need to be accounted for when considering the cost effectiveness of material substitution.
- Case studies need to be performed of facilities presently using material substitution.
- The record keeping and reporting requirements need to be developed.

5.7 EXEMPT SOURCES AND APPLICABILITY

- Should any processes in fiberglass boat manufacturing be exempt because they are insignificant HAP emission sources? (The NMMA has provided a list of sources they recommend exempting.)
- What are the HAP emissions from these sources?

5.8 SMALL PARTS

- What should be the definition of small parts?

- Should small parts be regulated separately from hulls, decks, and superstructures?

6.0 RESOURCES

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