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CONFIDENTIAL
WORKING DRAFT

EMISSION FACTOR EVALUATION FIBERGLASS REINFORCED PLASTIC OPEN MOLDING

June 1996

Prepared for:

National Marine Manufactures Association
3050 K St., NW
Washington, DC 20007

Prepared by:

ERM-NORTHEAST
175 Froehlich Farm Boulevard
Woodbury, New York 11797

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LIST OF ACRONYMS

A	- Air Emission Measurement Method
a	- Method of Measurement Not Provided
AAA	- Air-Assisted Airless Spray Gun
AS	- Available Styrene
BPO	- Benzoyl Peroxide
C	- Calculated
C(S)ARB	- California (State) Air Resources Board
CFA	- Composite Fabricators Association
CFM	- Cubic Feet Per Minute
CM	- Closed Molding
DGC	- Diacid Glycol Condensate
DOW	- DOW Chemical
E	- Estimated Emission Factor
EF	- Emission Factor
EM	- Emission Measurement
EPA	- Environmental Protection Agency
ERM	- ERM-Northeast, Inc.
FRP	- Fiber Reinforced Plastic
G	- Gravimetric Method
GE	- Gelcoat
Grav	- Gravimetric Measurement
HL	- Hand Layup
HVLP	- High Volume Low Pressure Spray Gun
LP	- Low Profile Resin
LS	- Low Styrene Resin
LSE	- Low Styrene Emission Resin
MACT	- Maximum Achievable Control Technology
MC	- Marble Casting - Not Used in Boat Manufacturing
MNTAP	- Minnesota Technical Assistance Program
NA	- Not Applicable
NB	- No Testing Provided to Substantiate Emission Factor
NI	- None Identified
NIOSH	- National Institute of Occupational Safety and Health
NMMA	- National Marine Manufacturing Association
NP	- Not Provided
NVS	- Non-Vapor Suppressed
O-D	- Ortho/Dcpd Mixed Resin Base
OSHA	- Occupational Safety and Health Administration
P	- Emission Factor provided
PHS	- Public Health Service
R	- Resin
RACT	- Reasonably Available Control Technology
RTI	- Research Triangle Institute

LIST OF ACRONYMS (continued)

S	- Styrene Emissions
SAI	- Science Applications, Inc.
SCAQMD	- South Coast Air Quality Management District
SL	- Spray Layup
SRI	- Southern Research Institute
TWA	- Time Weighted Average
VOC	- Volatile Organic Compound
VS	- Vapor Suppressed
VSW	- Vapor Suppressed and Wax
X	- Emission Factor Determined Elsewhere

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) has prepared and distributed a document titled, A Discussion of the Present AP-42 Factors Underestimating VOC (or Monomer Evaporative) Emissions for Polyester Resin Material Operation, which was based on a study conducted by Research Triangle Institute (RTI). The document concluded that the current EPA AP-42 FRP open molding emission factors underestimate FRP fabrication emissions by a factor of two. This document also referenced additional emission studies being conducted by the Composite Fabricators Association (CFA) and Dow Chemical.

The National Marine Manufacturer's Association (NMMA) has retained ERM to conduct an evaluation of the emission factors associated with FRP open molding operations in response to this EPA document. The objectives of this investigation were to:

- assess the validity of the AP-42 emission factors developed for FRP open molding processes;
- assess the validity of RTI's claims regarding emissions from FRP open molding processes;
- evaluate the emission factors developed by RTI, CFA and DOW;
- evaluate whether the AP-42, RTI or other referenced open molding FRP emission factors are representative of boat building FRP operations; and
- identify representative emission factors for the boat building FRP industry.

ERM also reviewed all the emission studies and their associated documents, which were referenced in the EPA document.

The following conclusions were reached:

- the emission factors derived from the AP-42 and the EPA discussion documents are not representative of boat building FRP open molding fabrication processes;
- the boat plant emission factors are generally within the AP-42 emission factor ranges;
- insufficient information was available to accurately estimate emissions factors using the EPA Discussion Document References;
- neither the RTI Report nor its support documents demonstrate that the AP-42 emission factors underestimate FRP full-scale fabrication emissions by a factor of two;
- lab-scale and bench-scale studies, as well as small FRP fabrication studies, are not representative of the boat building process and generally overestimate boat building emission factors;
- the size and shape of boat molds results in less overspray and consequently lower process emissions than fabrication of products using small, flat and/or convex molds; and
- differences in raw materials, operating parameters (e.g., application technique, curing time and gel time) and fabrication process (e.g., heated curing) significantly affect FRP open molding emission factors.

1.0 *INTRODUCTION*

ERM-Northeast, Inc. (ERM) was retained by the National Marine Manufacturers Association (NMMA) to conduct an evaluation of emission factor for fiberglass reinforced plastic (FRP) open molding. This document has been prepared to summarize the procedures, results and conclusions of this emission factor evaluation.

1.1 *PROJECT SCOPE*

Following the first boat manufacturing presumptive "maximum achievable control technology" (MACT) meeting, Madelaine Strum, U.S. Environmental Protection Agency (EPA) prepared and distributed a discussion document titled, *A Discussion Of The Present AP-42 Factors Underestimating VOC (Or Monomer Evaporative) Emissions For Polyester Resin Material Operation*, November 1995. Preparation of this document had been requested at the presumptive MACT meeting by meeting participants.

According to this discussion document, Research Triangle Institute (RTI) had completed a study for EPA which concluded that the current EPA AP-42 FRP open molding emission factors underestimate FRP fabrication emissions by a factor of two.

Emission factors for FRP open molding are provided in Section 4.12, Polyester Resin Plastics Product Fabrication, of EPA's AP-42 document, *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*. This document contains emission factors for numerous industrial processes. However, these emission factors are averages of all emissions data for the selected process and generally do not take parameters effecting emissions (e.g., temperature, etc.) into account (EPA, 1985).

In addition to the RTI report, the EPA discussion document also referenced additional FRP fabrication emission studies being conducted by the Composite Fabricators Association (CFA) and Dow Chemical.

As a response to this discussion document, NMMA retained ERM to perform an emission factor evaluation for FRP open molding operations. The objectives of this study were to:

- assess the validity of the AP-42 emission factors developed for FRP open molding processes;
- assess the validity of RTI's claims regarding emissions from FRP open molding processes;
- evaluate the emission factors developed by RTI, CFA and DOW;
- evaluate whether the AP-42, RTI or other referenced open molding FRP emission factors are representative of boat building FRP operations; and
- identify representative emission factors for the boat building FRP industry.

In addition to the EPA discussion document, the RTI report and their source documents, other FRP open molding fabrication emission studies, including but not limited to boat building emission studies, were reviewed. A summary of the documents reviewed for this emission factor evaluation is presented in Appendix A to this document, the Bibliography.

1.2 *REPORT ORGANIZATION*

This evaluation is organized into the following sections:

Section 2.0: Emission Factor Development And General Applicability To FRP Manufacturing

Section 3.0: Boat Building (general boat building industry information, typical boat plant)

Section 4.0: FRP Open Molding Emission Factors (emission studies reviewed, evaluation of emission factors)

Section 5.0: Conclusions and Recommendations

2.0 *EMISSION FACTOR DEVELOPMENT AND GENERAL APPLICABILITY TO FRP MANUFACTURING*

As previously discussed, EPA has compiled emission factors for numerous industrial processes in their AP-42 document. This document was originally based on a Public Health Service (PHS) Publication, No. 999-AP-42, by the same name. The PHS document was revised by EPA and four new editions were published in 1972, 1973, 1976 and 1985. In September 1988, Supplement B to the fourth edition of AP-42, which provided emission factors for the polyester resin plastic products fabrication, was issued by the EPA.

AP-42 emission factors, which were generated using average emission rates for selected process, generally did not take parameters effecting emissions (e.g., temperature, etc.) into account (EPA, 1985). As a result, the AP-42 emission factors are insensitive to process variations that affect emissions and to the variability within industries included in an AP-42 source category. Consequently, emission factors are not suited for estimation of facility emissions, but are more appropriate for estimation of overall emissions from a number of sources, such as emissions inventory efforts. Although the AP-42 emission factors are not a higher accurate estimation tool, they are routinely used by regulators and industries to estimate air emissions at individual facilities.

AP-42 emission factors are generally expressed as the weight of the air pollutant divided by either the unit weight or volume of the source material or the distance or duration of the activity. For polyester resin plastic products fabrication, emission factors are presented as pounds of styrene emitted per pound of available styrene. This measurement technique normalizes emission estimates based on the styrene content of the raw materials used (e.g., resin and gelcoat).

3.0 *BOAT BUILDING*

This section provides general information regarding the boat building industry and a description of the "typical" boat building plant. Information contained in this section was obtained from the NMMA Member Survey - *MACT Floor Determination for Fiberglass Boat Manufacturing* (NMMA, 1996). This survey response, which contains information submitted by NMMA members, contains production information for the year 1994.

3.1 *GENERAL INDUSTRY INFORMATION*

Numerous boat building plants are located in the U.S.. The majority of these plants are located on the northwest, southwest and southeast coast. The NMMA survey classified boat plants according to the total number of full-time equivalent employees as follows:

Minimum:	11-25
Average:	751-1,000
Medium:	1,001-1,500
Maximum:	>1,500

Boat building facilities range in size from under 100 to over 1,500 full-time employees and manufacture a variety of FRP sail boats and power boats. Boats range in size from ten feet to over seventy feet and from six to twelve feet in width. The majority of boat plants in the U.S. employ over 1,500 production workers. Boats plants work on varied shift and work schedules. The majority of boat manufactured in 1994 were between 14 and 25 feet long. (NMMA, 1996)

The two main VOC-containing raw materials used to build boats are resin and gelcoat. The largest quantity of resin used in boat manufacturing is nominal bulk resin which contains from 32-36% styrene. Smaller quantities of tooling resin (36-52% styrene), nominal barrier coat resin (20-31% styrene) and putty and gunk (12-19% styrene) are also used. Gelcoats used at boat plants can be either solely styrene based (29-38% styrene) or can also contain come methyl methacrylate (26-50% styrene and 3-9% methyl methacrylate). Smaller quantities of initiators are also used. The two main initiators used are MEKP type and Benzoyl Peroxide (100%). MEKP-type catalyst contains 2-5% methyl ethyl ketone and 32-52% dimethyl phthalate. (NMMA, 1996)

Peak resin usage ranges from 4 tons per month for minimum boat plants to 210 tons per month for maximum plants. Gelcoat usage ranges from 0.55 tons per month for minimum plants to 42 tons per month for maximum plants. (NMMA, 1996)

Boat builders mainly utilize a variety of FRP open contact molding methods for application of gelcoat and resin. For application of gelcoat, all survey respondents use spray guns and 15% also use brushes. For resin application, 90% use spray guns, 88% use chopper guns, 12% use pressure rollers, 15% use flow coaters and 66% use a combination of handlayup and spray guns. In addition, some builders also use non-open contact molding methods for resin application, 8% use resin transfer, 15% use bag molding and 6% use other molding methods (e.g., foam injection, cold press and vacuum bags). (NMMA, 1996)

With regard to resin application equipment, 90% use spray guns, 88% use chopper guns, 12% use rollers and 15% use flow coaters. As demonstrated by the above responses, operations at individual boat plants are extremely varied; an individual boat builder may use a combination of molding techniques and associated application equipment at their facility for application of FRP raw materials. (NMMA, 1996)

Air flow rates for lamination areas, spray booth and other shops and booths vary widely. Ventilation rates range from 70,000 cfm (minimum plants) to

280,000 cfm (maximum plants) for lamination areas; from 750 cfm (minimum plants) to 215,000 cfm (maximum plants) for spray booths; and from 1,125 cfm (minimum plants) to 104,000 cfm (maximum plants) for other shops and booths (e.g., mold, fabrication, wood, grinding, parts inspection). Most plants have gel spray, lamination, paint and grinding booths. (NMMA, 1996)

3.2 *DESCRIPTION OF A TYPICAL BOAT BUILDING PROCESS*

The following is a typical process used to manufacture high-volume production-model FRP power boats using open molding techniques:

1. The boat mold is brought out of storage, cleaned, repaired, if necessary, and waxed.

2. The waxed mold is placed within the gelcoat spray booth and a thin layer of gelcoat sprayed onto the open surface of the waxed mold. (If necessary the coated mold is placed beneath heat lights to accelerate gelcoat curing.)

3. The gelcoated mold is moved to another spray booth where the first layer of reinforced resin, the skin coat, is applied with a chopper gun.

4. During or immediately after application of the skin coat, workers manually roll down the applied laminate to remove trapped air bubbles.

5. Steps 3 and 4 are repeated until the desired boat wall thickness is achieved and the coated mold is left to cure.

6. Pre-fabricated wooden supports and other structural pieces are laminated into the part using the chopper gun.

7. After the part has been cured to an acceptable strength level, it is removed from the mold and the mold is returned to storage.

8. The boat is finished using grinding, sanding gluing, coating, painting and other final assembly operations.

4.0 *FRP OPEN MOLDING EMISSION FACTORS*

This section provides a description of the FRP open molding emission factor sources reviewed along with an evaluation of the validity of these sources and their applicability to boat building FRP open molding operations.

4.1 *INFORMATION REVIEWED*

Three groups of information were reviewed for this FRP open molding emission factor evaluation. They include:

1. AP-42, *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources,* and its source documents;
2. EPA FRP open molding discussion document *A Discussion Of The Present AP-42 Factors Underestimating VOC (Or Monomer Evaporative) Emissions For Polyester Resin Material Operation*, and its referenced studies; and
3. additional FRP open molding emission studies and related documents.

A listing of these documents is provided in the Bibliography contained in Appendix A of this report. In addition, an overview of these documents, which includes the document description, type of emission study, product fabricated and a description of the FRP fabrication process, is presented in Table 4-1.

4.1.1 *AP-42*

As discussed in Section 2.0, emission factors for polyester resin plastic products fabrication were incorporated into AP-42 in September 1988. These emission factors addressed the following FRP fabrication processes: hand layup, spray layup, continuous lamination, pultrusion, filament winding, marble casting and closed molding.

For spray layup and hand layup (the two FRP open molding processes used for boat building), separate emission factors were provided for application of resin and gelcoat. Emission factors for all other fabrication processes were provided only for resin. Resin and gelcoat emission factors were also provided for non-vapor suppressed (NVS) and vapor suppressed (VS) materials. The AP-42 emission factors for spray layup and hand layup are:

	Resin		**Gelcoat**	
Process	**NVS**	**VS**	**NVS**	**VS**
Hand Layup	5-10	2-7	26-35	8-25
Spray Layup	9-13	3-9	26-35	8-25

These AP-42 emission factors were obtained from a number of different sources and emission studies. The following documents, provided as AP-42 references, were reviewed to identify and evaluate the derivation of the AP-42 FRP open molding emission factors:

- *Control Techniques for Organic Gas Emissions from Fiberglass Impregnation and Fabrication Processes,* Science Applications, Inc., June 1982.
- *Modern Plastics Encyclopedia,* October 1986.
- *Styrene Polymers: Technology and Environmental Aspects,* Applied Science Publishers, Ltd., 1979.
- *Staff Report, Proposed Rule 1162 - Polyester Resin Operations,* South Coast Air Quality Management District, January 1987.
- *Extent of Exposure to Styrene in the Reinforced Plastic Boat Making Industry,* National Institute for Occupational Safety and Health, March 1982.
- L. Walewski and S. Stockton, "Low-Styrene-Emission Laminating Resins Prove It in the Workplace", *Modern Plastics,* 62(8):78-80, August 1985.
- *Styrene Emissions - How Effective Are Suppressed Polyester Resins?,* Ashland Chemical Company, 1979.
- *Emission Factor Documentation for AP-42 Section 4.12: Polyester Resin Plastics Product Fabrication,* Pacific Environmental Services, Inc., November 1987.

A complete bibliography of these documents is presented in Appendix A and document overviews are presented in Table 4-1. In addition, the emission factors identified in these documents along with the associated FRP product fabricated is provided in Table 4-2.

The emission factors for spray layup of gelcoat and spray layup of resin were both obtained from the above-referenced study conducted by the Science Applications, Inc. (SAI). This document contained a review of available emission data for fiberglass fabrication processes and the results from emissions studies conducted by SAI to determine emissions factors.

The emission factor for spray layup of gelcoat was obtained from a study conducted by SAI at a synthetic marble bathroom products fabrication plant, identified as Plant C. This emission factor, 26%-35% of available styrene (AS) for spray application of gelcoat, was considered by SAI to be the upper bound limit since the emissions measurement collected may have also included emissions from resin pouring and curing. The emission factor for spray layup of resin (i.e., 9%-13% AS) was obtained from a study conducted by SAI at a tank coating plant, identified as Plant B. A description of the fabrication processes used at Plant B and Plant C are provided in Table 4-1.

SAI recommended use of the Plant B and Plant C emission factors since they considered them to be more accurate than the emission factors derived from the available studies. Because the majority of the available studies were old and were not conducted with the intention of developing emission factors, information needed to develop emission factors (i.e., styrene content) and to evaluate the reliability of the information (emission measurement techniques) were not always available and had to be assumed.

In addition to the spray layup, emission factors for hand layup FRP fabrication processes also recommended by SAI in their study (SAI, 1982). SAI's selected gelcoat hand layup emission factor (i.e., 47% AS) was obtained from a lab test conducted by Shasta County, and SAI's selected resin hand layup emission factor (i.e., 16%-35% AS) was obtained from a lab test conducted by Kingston Polytechnic, England.

Although both of the SAI hand layup emission factors were originally proposed as the AP-42 emission factors, these values were not adopted (Pacific Environmental Services. Instead, hand layup emission factors for both resin and gelcoat provided by Aristech Chemical Corporation, Polyester Unit, were adopted (Pacific Environmental Services, 1987).

In a letter to EPA regarding the proposed AP-42 emission factors, Aristech recommended alternate emission factors for hand layup emissions. Aristech commented that the hand layup emissions for gelcoat application could not greater than those for spray layup and thus the hand layup emission factor should be at least equal to the spray layup emission factor (i.e., 26%-35% AS). In addition, Aristech also commented that according their studies, emission factors for hand layup application of resins were closer to 5%-10% AS than 16%-35% AS. The basis of Aristech's resin hand layup emission factor appears to be laboratory testing conducted by Ashland Chemical Company (Ashland, 1979). Both of the Aristech recommended values were adopted as the AP-42 emission factors.

In conclusion, the AP-42 emission factors are based on emission testing conducted at a synthetic marble bathroom products fabrication plant (gelcoat spray layup), a tank coating plant (resin spray layup), and a resin manufacturer's lab (resin hand layup). The emission factor for gelcoat hand layup is not based on an emission study, but rather a recommended value. In addition to the SAI tests and the tests conducted by Shasta County and Kingston Polytechnic, the SAI document also contains emission studies for other bathroom product fabrication plants and laboratory tests.

Additional discussion regarding the selected AP-42 emissions factors and their applicability to boat building FRP open molding activities is presented in Section 4.2.

4.1.2 *EPA FRP Open Molding Discussion Document References*

As discussed in Section 1.1, following the first boat manufacturing presumptive MACT meeting, the USEPA distributed a discussion document addressing emissions from fiberglass fabrication processes. According to this discussion document, a study conducted by RTI in cooperation with EPA indicated that the current EPA AP-42 FRP open molding emission factors underestimate process emissions. As part of their study, RTI reviewed existing emission studies for various FRP fabrication plants, conducted lab tests to generate open molding emission factors and compared their emission factors to the EPA AP-42 emission factors. A summary of RTI's study is presented in *Evaluation of Pollution Prevention Techniques To Reduce Styrene Emissions from Open Contact Molding Processes, Draft Report,* September 1995 (RTI, 1995).

The following emission studies referenced in the November 1995 EPA discussion document and in the RTI report have been reviewed:

- Draft Project Report, *Evaluation of Pollution Prevention Techniques To Reduce Styrene Emissions from Open Contact Molding Processes,* RTI, September 1995;
- Composite Fabricators Association, *Open Molding Styrene Emissions Study: Overview and Summary of Hand Lay-up Emissions Study,* 1995;
- Radian Corporation, *Determination of Styrene Emissions from the Cultured Marble and Sink Manufacturing Industry, Final Report, Venetian Marble, Richmond, VA,* prepared for USEPA Emission Measurement Branch, April 1992;

- Radian Corporation, *Determination of Styrene Emissions from the Cultured Marble and Sink Manufacturing Industry, Final Report, General Marble, Lincolnton, NC*, prepared for USEPA Emission Measurement Branch, August 1992;

- *Demonstration of Capture and Control Efficiency for a Styrene Emission Source*, Cortec Facility, Radian and IT Corp., 1994; and

- Bison Engineering, *Emission Compliance Test, Styrene and Visible Emissions: Fiberglass Reinforced Plastic Lay-up Facility*, Idaho Permit to Construct 860-0035, August 1993.

A complete bibliography of these documents is presented in Appendix A and document overviews are presented in Table 4-1. In addition, the emission factors identified in these documents along with the associated FRP product fabricated is provided in Table 4-2.

The RTI report included RTI's evaluation of available emission data for fiberglass fabrication processes and the results from emissions studies conducted by RTI to determine spray layup emissions factors. RTI's study involved lab-scale testing of various resin and gelcoat formulations using box molds and varying operating parameters. Studies referenced in RTI's document (i.e., Venetian Marble, General Marble, Cortec and Bison) involved emission testing during FRP fabrication processes for synthetic marble bathroom sinks, panels and pipes. The CFA study evaluated hand layup emission factors in a laboratory setting.

Discussion regarding the applicability of RTI and CFA's studies to boat building as well as RTI's evaluation of the current AP-42 emissions is presented in Section 4.2.

4.1.3 *Additional FRP Open Molding Emissions Studies*

Additional FRP open molding emission studies were also reviewed to evaluate the appropriateness of the AP-42 and RTI derived emission factors for application to boat building FRP open molding processes. Some of the emission studies were conducted at boat plants. Following is a listing of the additional documents reviewed:

- Minnesota Technical Assistance Program (MNTAP), *Reducing Styrene Emissions in Fiber Reinforced Plastic Operations*, March 1993;
- Radian Corporation, *Volatile Organic Compound Control at Specific Sources in Louisville, KY and Nashville, TN*, prepared for EPA, December 1981;
- Boat Plant A Emission Study, 1989;
- Boat Plant B Emission Study, 1989;
- Boat Plant C Emission Study, 1988;
- Boat Plant D Emission Study, 1992;
- USEPA, *Guides to Pollution Prevention, The Fiberglass-Reinforced and Composite Plastics Industry*, October 1991;
- Radian Corporation, *Locating and Estimating Air Emissions from Sources of Styrene*, Interim Report, prepared for EPA, October 1991; and
- USEPA, *Assessment of VOC Emissions from Fiberglass Boat Manufacturing*, May 1990.

A complete bibliography of these documents is presented in Appendix A and document overviews are presented in Table 4-1. In addition, the emission factors identified in these documents along with the associated FRP product fabricated is provided in Table 4-2.

The MNTAP study involved bench-scale testing at a full-scale FRP fabrication facility. The Radian study and the emission studies for Plants A, B and C were conducted at full-scale boat building plants. In contrast, the emission study for Plant D, a full-scale facility, involved lab-scale testing. The last three documents listed provide only general FRP fabrication information and/or contain emissions estimates based on the AP-42 emission factors.

4.2 *EVALUATION OF FRP OPEN MOLDING EMISSION FACTORS AND THEIR APPLICABILITY TO BOAT BUILDING*

A number of different factors effect emissions from FRP processes. The validity of the FRP open molding emission factors and their applicability to boat building were determined by comparing the following information obtained from the source emission studies:

- overall quality and adequacy of emissions-related information;
- scale and size of the process being tested;
- product fabricated and the associated FRP fabrication process; and
- other factors affecting emissions:
  - resin type and catalyst;
  - applicator, application technique;
  - curing time and gel time;
  - emission measurement technique and procedures;
  - laminate thickness; and
  - facility size, air flow rates and temperature.

To facilitate evaluation of this information, a number of summary tables were developed. A summary of the FRP products fabricated during these emission studies is provided in Table 4-3; a summary of the above listed parameters that may affect emissions is provided in Table 4-4; a listing of emission factors for each source document according to fabrication process and product is provided in Table 4-5; and a summary of emission factors according to product is provided in Table 4-6.

4.2.1 *Overall Quality the Source Documents*

<u>*AP-42 Emission Factors*</u>

The development of the AP-42 spray layup emission factors in the SAI report was fairly well documented. Adequate information (e.g., emission rates, raw chemical usage, styrene content) was collected during the SAI studies to estimate spray layup emission factors for the product fabrication processes being tested (i.e., spray layup and curing of gelcoat outer coating on cured sinks and spray layup of resin tank coating). However, because sample collection for Plant C was not well controlled, non-gelcoat spray layup processes may have also been sampled. Consequently, the gelcoat spray layup emissions for Plant C may have been overestimated. The emission factor for Plant C is therefore qualified with an "E". {Note: all emission factors requiring assumption of information not provided or incorporating emission from other processes are qualified in the tables with an "E".}

Development of the hand layup emission factors was not well documented. Sufficient information was not provided in the Ashland report to confirm the resin hand layup emission factors and no documentation was provided to validate the gelcoat handlayup emission factors.

EPA Discussion Document Referenced Emission Factors

The RTI Report provided: (1) a comparison of emission factors derived from the above-referenced FRP emission studies and current AP-42 emission factors; and (2) spray layup emission factors developed in their lab tests. RTI resin and gelcoat spray layup emission factor tables are presented as Tables 4-7 and 4-8 in this document. Based on their evaluation, RTI concluded that the EPA AP-42 emission factors at FRP manufacturing facilities were approximately two times higher than the current FRP open molding spray layup AP-42 emission factors.

Evaluation of the RTI-referenced emission studies indicates that insufficient information was available in these studies to accurately estimate emission factors. The information that RTI was required to assume to formulate emission factors for these facilities (i.e., styrene content, hours of operation, stack emissions, collection efficiency, raw materials usage) is very sensitive to change and can result in large variations in the emission factors estimated.

The resin spray layup emission factor determined by RTI for the GEA Dynamic facility was based on emission measurements collected from grab samples and included emissions from gelcoat spray layup and filament winding operations. Due to the use of non-continuous emission measurement methods and inclusion of emissions and materials usage from non-resin sprayup operations, the accuracy of this emission factor is suspect.

In addition, to formulate the gelcoat spray layup emission factor for the General Marble facility, RTI had to assume the styrene content of the gelcoat, the number of hours during which gelcoating occurred, the cumulative stack emissions and the capture efficiency of the exhaust stacks tested. Although Radian had collected emission measurements from the gelcoat spray booth stack and the gelcoat drying oven inlet and outlet stacks, RTI included only the spray booth stack and drying oven outlet stack emissions in their emission factor determination. Correcting RTI's calculation to include gelcoat spraying and drying emissions from all three stacks, results in an emission factor of 111%.

Obviously, there is something wrong with this estimation since the amount of styrene emitted cannot be greater than the amount of styrene available. Possible problems with this emission factor estimation include: (1) overestimation of the gelcoating hours of operation; (2) collection of styrene emissions from nearby non-gelcoat sources, such as resin pouring; (3) underestimation of gelcoat raw material usage; (4) inaccurate emission measurement; (5) non-concurrent stack emission measurements; and/or (6) underestimation of the styrene content. Based on the unattainable gelcoat spray layup emission factor determined for this facility and the potential problems associated with its estimation, the accuracy of this emission factor is suspect. Problems were also identified in the generation of the emission factors for the Venetian Marble and Cortec facilities. All these emission factors are qualified with an "E" in the summary tables.

Due to the lack of sufficient information and the sensitivity of the assumptions used to formulate the emission factors for these facilities, the accuracy of the emission factors developed from studies conducted at Venetian Marble, General Marble, Cortec and GEA Dynamic are suspect and should not be used to evaluate the accuracy of AP-42 emission factors.

In contrast, the development of the RTI spray layup emission factors and the CFA hand layup emission factors were fairly well documented. Adequate information (e.g., emission rates, raw chemical usage, styrene content) was collected during the SAI and CFA studies to estimate spray layup emission factors for the product fabrication processes being tested (i.e., spray layup of resin and gelcoat onto a laboratory box mold) and hand layup processes being tested (i.e., hand layup of resin in a lab). In addition, quality control procedures were followed.

Additional Document Emission Factors

Emission studies were identified in six of the additional documents reviewed. These are identified in the tables as: MNTAP; EPA/Radian, Hydro-Sports; Boat Plant A; Boat Plant B; Boat Plant C; and Boat Plant D. The MNTAP, Boat Plant A, B, C and D emission studies are all well documented. Adequate information (e.g., emission rates, raw chemical usage, styrene content) was collected during these studies to estimate emission factors for the product fabrication processes being tested (i.e., resin spray layup bench-scale tests, resin and gelcoat spray layup at boat building plants and resin and gelcoat lab-scale spray layup).

The document containing the Hydro-Sports emission study, *Volatile Organic Compound Control at Specific Sources in Louisville, KY and Nashville, TN*, contains an overview of this study and a summary of emissions information. Sufficient information is not provided in this document to verify the summary information provided. Emission factors from this study are therefore considered to be estimated.

4.2.2 *Scale And Size Of The Process Being Tested*

Emissions studies demonstrate that lab and bench-scale studies as well as emission studies for small scale FRP fabrication processes are not representative of boat building FRP processes. Due to variable FRP fabrication process parameters (e.g., higher percentage of overspray, thinner laminate thickness, smaller mold size, different mold shapes, etc.), lab and bench-scale studies and studies for fabrication of small products overestimate emission factors for large scale FRP open molding processes.

As shown in Tables 4-2 and 4-5, numerous emission factors are derived from lab and bench-scale tests. As shown in Table 4-5, emission factors from these small-scale tests are generally higher than emission factors derived from full-scale tests and are always higher than emission factors derived from full-scale boat building tests. Emission factors for smaller products (e.g., bathroom products, counters panels, small boat parts) and for flat and/or convex surfaces (i.e., molded sinks, counters, panels, box molds) are also generally higher than those for boats.

Higher emission factors for lab and bench-scale studies and small FRP product molding are probably due to the higher percentage of overspray experienced during these studies and the thinner laminate thickness needed for these products. Because emission factors are higher for oversprayed materials than applied laminate, a process experiencing high overspray will have a higher emission factor than a process using the same amount of material with less overspray. Small, convex and/or flat molds have considerably higher overspray than large concave molds. In addition, studies clearly demonstrate that FRP fabrication emissions decrease with increased laminate thickness (CFA, 1995). Additional discussion regarding laminate thickness is presented in Section 4.2.4.

4.2.3 *Product Being Fabricated and the FRP Fabrication Process*

Although the open molding processes for the various FRP products manufactured are similar, process emissions may vary considerably depending upon the sequence of processing and the curing techniques.

EPA and RTI emission factors for full-scale gelcoat spray layup were derived from either synthetic marble bathroom product fabrication processes or panel fabrication. Some bathroom products were gelcoated after molding and all gelcoated bathroom products and panels were cured in an oven. At boat building facilities, the mold is gelcoated prior to any resin application and the gelcoated molds are never? heat cured. Increase emissions with increased temperature has been clearly documented in numerous studies.

The EPA-42 resin spray layup emission factor was derived from a full-scale tank coating process. This process, which entails application of resin to the outside, convex surface of a tank, is not representative of the boat building process. The EPA discussion document resin spray layup emission factor was derived from an emission test conducted at GEA Dynamic facility, a counter, panel and pipe fabricator. Although this test was used in the RTI report to evaluate resin application emissions, this emissions from this test also included emissions from gelcoat spray layup and filament winding operations. Not only is this test not representative of boat fabrication, it is also not representative of resin spray layup for panel fabrication.

As shown on Table 4-6, available full-scale emission information for hand layup of resin and gelcoat is extremely limited. This corresponds to limited use of hand layup in the FRP open molding fabrication industry.

4.2.4 *Other Factors Affecting Emissions*

Identification of the other parameters affecting emissions for the source documents is provided in Table 4-3. Although these factors affect emissions, sufficient information is not available for all parameters to make qualitative comparisons between the various FRP fabrication products.

The following additional factors are discussed below:

- raw materials (styrene content, catalyst);
- hand rolling time;
- applicator and application technique;
- air flow;
- emission measurement technique and procedures;
- laminate thickness;
- curing time and gel time; and
- temperature and humidity.

Raw Materials

Six of the referenced emission studies (Ashland, Kingston Polytechnic, USS Chemicals, CFA, RTI and MNTAP) evaluated changes in raw materials to accomplish emissions reduction. Testing conducted in these studies, all lab-scale, demonstrated that use of low VOC resins and gelcoats, vapor suppressed resins and low styrene emission resins reduce spray and hand layup emission and emission factors. In addition, the MNTAP and RTI studies also demonstrated that use of BPO catalyzed resins reduces emission factors; however, the percent reduction from this change varied widely between the two tests.

Hand Rolling Time

The Kingston Polytechnic Study, referenced in the SAI document, evaluated the effects of rolling time on hand layup emissions. According to this study [SAI, 1982], emissions increase with increased rolling time. According to the Boat study, rolling accounts for 1% of total emissions from resin application [EPA, 1990].

Application Technique

The majority of studies used chopper guns for resin application; the Cortec panel fabrication plant used automated HVLP spray guns. During the RTI lab tests, AAA and HVLP spray guns were tested. The type of spray gun had little effect on emissions for gelcoat and resin application; however, controlled operator (i.e., careful) spraying reduced gelcoat and resin spray layup emissions by 24% and 35%, respectively. In addition, the RTI study also demonstrated a considerable decrease in resin hand layup emissions (52%) with the use of flow coaters and pressure fed rollers.

Air Flow

Although the Kingston Polytechnic study concluded that emissions increased with wind speed, the CFA study and the RTI studies concluded that the effect of air flow on hand and spray layup emissions was insignificant. Consequently, although air flow rates at boat plants are higher than those at other FRP open molding fabrication plants, emission factors are not expected to be higher at these high air flow facilities.

Emission Measurement Technique And Location

Due to the non-continuous nature of many operator-dependent fabrication processes, emission spikes are expected throughout the fabrication process.

Consequently, emission measurement techniques that characterize emissions throughout the entire fabrication process must be used. Three types of emission measurement techniques were used in the referenced air emission studies: mass balance, vapor sample collection and analysis, and real-time emission measurement. Since vapor sample collection results in a grab sample result, these one-time results are often correlated with real-time emission estimates to obtain long-term emission measurements. RTI, which estimated emission factors using both mass balance and real-time emission measurement techniques, found that the results obtained via these techniques were in good agreement.

Emission measurements in the GEA Dynamic study were determined via grab charcoal tube samples without real-time measurement correlation. Consequently, the emission factors developed for this study are suspect.

Emission measurements at Boat Plants A and B were also determined via charcoal tube grab samples. However, multiple short-term (2-hour) and long-term (eight and nine-hour) samples were collected to evaluate emissions over the process cycle. Using the short-term results, average process vapor concentrations were determined. The higher of the short-term average value and the long-term value was then selected and used to estimate emissions at each of these facilities.

Laminate Thickness

The CFA study demonstrated that laminate thickness has a significant effect on emissions. Increasing the laminate thickness from 0.041 inches to 0.088 inches decreased emission factors approximately 31%. As discussed in Section 4.2.2, since the laminate thickness for boats is considerably thicker than the thickness for smaller FRP products, the emission factor for boat fabrication are expected to be lower.

Curing Time And Gel Time

Both the Radian Cortec and CFA studies observed emissions and emission factor decreases with faster gel time; and the RTI study observed a decrease in emissions with cure time.

Temperature

As with any evaporative loss, emissions from FRP processes increase with temperature; an increase in emissions was observed by Kingston Polytechnic in their study. Consequently, emission studies with heated curing would be higher than those with ambient temperature curing. Heated curing was conducted in at least two of the referenced studies (SAI Plant C and General Marble).

TABLES

TABLE 4-1
NMMA Emission Factor Evaluation
Description of Emission Factor References

Reference	Description	Products Manufactured	Process Description
AP-42 References			
Science Applications, Inc., <u>Control Techniques for Organic Gas Emissions from Fiberglass Impregnation and Fabrication Processes</u>, June 1982.	Study conducted for the CSARB to: (1) inventory air emissions from facilities producing fiberglass reinforced plastic products in Calif.; (2) develop emission factors; and (3) evaluate vapor control technologies. Most of the suggested emission factors from this document were adopted as the AP-42 emission factors.	Four studies referenced and three tests conducted by SAI (see below).	see below
Dade County	Florida County conducted lab tests and a test at a fabrication plant (fabrication plant emissions were not provided).	lab	HL resin emission only provided for vapor suppressed resin
BAAQMD	Emission compliance tests conducted at six facilities in the Calif. Bay Area from '74-'78.	bath products, pipes	SL gel SL resin
Ashland Chemical	Vendor conducted tests to evaluate the effectiveness of vapor suppressants on styrene emissions. {see A8}	lab	SL resin
Shasta County	County conducted lab tests at one of the facilities in its jurisdiction.	lab	1) HL gel & cure for 66 min 2) measure weight loss 3) HL resin w/roving & cure for 50 min 4) measure weight loss 5) HL fire retardant resin w/roving.
Kingston Polytechnic	Lab tests with four types of resin; with and without vapor suppressants; with roving or glass mat. Ambient temperature, air velocity, amount of hand rolling, reinforcement type, styrene content and wax conc. controlled.	lab	HL resin
SAI-Plant A	SAI study at a continuous lamination plant	panels	continuous resin lamination

TABLE 4-1 (con't)
NMMA Emission Factor Evaluation
Description of Emission Factor References

Reference	Description	Products Manufactured	Process Description
SAI-Plant B	SAI study at a tank manufacturing plant.	tank coating	coatings applied to one quarter of the tank at a time 1) SL resin pre-coat 2) SL resin w/roving 3) turn tank & repeat coatings
SAI-Plant C	SAI study at a synthetic marble plant in the South Coast Air Basin, California.	synthetic marble bath products	1) MC - pour resin/ catalyst/filler mixture into partially closed mold 2) cure for a few minutes 3) remove mold 4) cure resin in oven 5) SL gel coat 6) cure gel coat in oven
Modern Plastics Encyclopedia, October 1986.	General information regarding the fiberglass reinforced plastics industry.	NA	NA
Styrene Polymers: Technology and Environmental Aspects, Applied Science Publishers, Ltd., 1979.	General information regarding the fiberglass reinforced plastics industry.	NA	NA
Staff Report, Proposed Rule 1162 - Polyester Resin Operations, South Coast Air Quality Management District, January 1987.		NA	NA
Extent of Exposure to Styrene in the Reinforced Plastic Boat Making Industry, National Institute for Occupational Safety and Health, Cincinnati, OH, March 1982.	Study to determine worker exposure at seven boat manufacturing plants. Study indicated that 20.6% of air samples exceeded the then current OSHA 8 hr TWA of 100 ppm styrene; and 55% exceeded 50 ppm styrene. Increased ventilation was recommended to reduce worker exposure levels.	boats	Study demonstrated that emissions between boat manufacturing plants is very variable.
Low-Styrene-Emission Laminating Resins Prove It in the Workplace, Modern Plastics, August 1985.	USS Chemicals conducted lab and facility tests to quantify reductions in indoor air styrene concentrations provided by low styrene resins. Use of the LSE resin resulted in an average styrene concentration reduction of 54% at a Florida boat facility and 31% at a California boat manufacturing facility.	lab boats	resins were applied to gel coated molds SL resin with and without roving HL resin

TABLE 4-1 (con't)
NMMA Emission Factor Evaluation
Description of *Emission Factor References*

Reference	Description	Products Manufactured	Process Description
Styrene Emissions - How Effective Are Suppressed Polyester Resins?, Ashland Chemical Company, 1979.	Ashland Chemicals conducted lab and facility tests to evaluate reduction in styrene emissions using vapor suppressed resins. Ashland Chemicals claimed a 57-80% reduction in styrene emissions in the lab and a 70% reduction in emissions during production trials.	lab unknown facilities	resins testing lab: pour/MC facilities: HL and SL
Emission Factor Documentation for AP-42 Section 4.12: Polyester Resin Plastics Product Fabrication, Pacific Environmental Services, Inc., November 1987.	Pacific Environmental provided documentation regarding selection of the AP-42 emission factors. Emission factors selected in the SAI documented were adopted for resin and gelcoat spray layup and emission factors provided by Aristech were adopted for resin and gelcoat hand layup. Aristech referenced their study (believed to be [Ref. A8]) for the resin hand layup emission factor and suggested that the hand layup emission factor be equal to the spray layup SAI emission factor.	synthetic marble bathroom products tank coating lab	miscellaneous
M. Strum Memo References			
EPA/Southern Research Institute testing at Eljer Plumbingware (now Carolina Classic).	Document could not be obtained		
EPA/Radian testing at Venetian Marble. {EPA/Radian, Venetian}	Conducted by Radian for EPA to determine styrene emissions rates from cultured marble and sink mfg. Emission factors were not determined in report.	synthetic marble tubs, sinks, showers, counters and panels	1) SL gel coat 2) pump resin/catalyst/marble filler into open molds and cure at room temperature (MC)
EPA/Radian testing at General Marble. {EPA/Radian, General}	Study conducted by Radian for EPA to determine styrene emissions rates from cultured marble and sink manufacturing. Emission factors were not determined in Radian report.	synthetic marble sinks	1) SL gel coat 2) cure gel coat in oven 3) apply resin/catalyst/marble filler by hand to molds; close mold; agitate mold to remove bubbles and cure closed mold in oven (MC/CM)

TABLE 4-1 (con't)
NMMA Emission Factor Evaluation
Description of Emission Factor References

Reference	Description	Products Manufactured	Process Description
Radian Corporation, and IT Corporation, Demonstration of Capture and Control Efficiency for a Styrene Emission Source, June 1994. {Cortec}	Conducted by Radian and IT Corporation to determine capture and control efficiencies of a vapor control system (catalytic oxidation) for a styrene emission source. Emission factors were not determined in Radian report.	panels and pipes	1) SL gelcoat onto a mylar sheet with a high volume low pressure sprayer; 2) cure gel coat; 3) apply resin (technique is neither provided nor evaluated in this document)
Bison Engineering, Emission Compliance Test, Styrene and Visible Emissions: Fiberglass Reinforced Plastic Lay-up Facility, Idaho Permit to Construct 860-0035, August 1993.	Study conducted by Bison Engineering for GEA Dynamics to determine styrene emissions for permit compliance. Emission factors were not determined in Bison report.	panels	1) lay up panel designs on molds with cloth, mat and chopped fiberglass 2) SL resin 3) cure resin some molds are gelcoated first
Lasco Bathware in Maopa, Nevada.	Document could not be obtained		
Aquaglass, Oregon.	Document could not be obtained		
Composite Fabricators Association, Open Molding Styrene Emissions Study: Overview and Summary of Hand Lay-up Emissions Study, 1995.	Study to determine: (1) baseline emissions and emission factors from hand layup of resin using typical industry techniques and conditions; and (2) the effect of thickness, gel time, air flow and styrene content on air emissions and emission factors.	not identified - lab?	HL resin w/MEKP & chopped strand mat variables: resin content; gel time; air flow; laminate thickness.
Draft Project Report, Evaluation of Pollution Prevention Techniques To Reduce Styrene Emissions from Open Contact Molding Processes, Research Triangle Institute in cooperation with USEPA, September 1995.	Study conducted by RTI for EPA to validate the effectiveness of vapor control technologies for open contact molding processes. As part of this study, pilot coating tests were conducted and emission factors were estimated for documents B1 through B5.	lab tests - box mold	experiments SL gel - flow coater or pressure feeder HL resin SL resin
Other References			
Minnesota Technical Assistance Program, Reducing Styrene Emissions in Fiber Reinforced Plastic Operations, March 1993.	Study to determine emission reductions from the use of low-styrene resins and from catalyst modifications. Study evaluated: cost, equipment modifications, workability and physical properties of the laminate.	Lab tests at a facility that produces a variety of open molded products, including cabs for heavy equipment and flumes.	SL resin using: 1) 46% styrene resin w/MEKP; 2) 43.9% styrene resin w/BPO; 3) 38% styrene resin w/MEKP; 4) 33.1% styrene resin w/MEKP.

TABLE 4-1 (con't)
NMMA Emission Factor Evaluation
Description of Emission Factor References

Reference	Description	Products Manufactured	Process Description
USEPA, <u>Guides to Pollution Prevention, The Fiberglass-Reinforced and Composite Plastics Industry,</u> October 1991	Guidance document for waste minimization Does not include any process-specific information or emissions.	NP	NP
Radian Corporation, <u>Locating and Estimating Air Emissions from Sources of Styrene,</u> Interim Report, prepared for EPA, October 1991.	Includes EPA and CARB emission factors. Does not include any other process-specific information or emissions.	NP	NP
USEPA, <u>Assessment of VOC Emissions from Fiberglass Boat Manufacturing,</u> May 1990.	Overview of the boat manufacturing industry, emissions and emissions control technologies.	boats	no emissions information provided
Radian Corporation, <u>Volatile Organic Compound Control at Specific Sources in Louisville, KY and Nashville, TN,</u> prepared for EPA, December 1981.	Evaluation of RACT compliance for VOC sources in TN and KY.	boats (14-24')	SL gelcoat HL resin - decks and hulls SL resin - small parts
Boat Plant A, 1989.	Source emission testing conducted in accordance with state air protocol.	boats (18-22')	1) SL gelcoat 2) cure 3) SL resin w/chop gun 4) hand roll applied resin 5) repeat steps 3 and 4 until desired thickness is achieved
Boat Plant B, 1989.	Source emission testing conducted in accordance with state air protocol.	boats (22-30')	1) SL gelcoat 2) cure 3) SL resin w/chop gun 4) hand roll applied resin 5) repeat steps 3 and 4 until desired thickness is achieved
Boat Plant C, 1988.	Emission testing - purpose of testing not provided.	boats	SL resin SL gelcoat
Boat Plant D, 1992.	Laboratory gravimetric testing at a boat manufacturing facility to determine emissions.	boats-however lab testing conducted	SL resin SL gelcoat

<u>Notes:</u>
SL: spray layup
NP: not provided
NA: not applicable

CM: closed molding
HL: hand layup
MC: marble casting - not used in boat manufacturing

Table 4-2 CONFIDENTIAL WORKING DRAFT

NMMA Emission Factor Evaluation

Comparison of Emission Factors for Resins and Gel Coats

Document	Product Type	Emissions Factors (NVS), %AS				Notes
		Gel Coat Layup		Resin Layup		
		Hand	Spray	Hand	Spray	
AP-42		26-35	26-35	5-10	9-13	
AP-42 References						
SAI Report	Information provided below for studies contained in this document.					
BAAQMD	bath products, pipes		26-28 P[a] P[a] 7-38		8-27 P[a]	7 tests; point(s) of measurement unknown
Ashland Chemical	lab			10.5 C/G		emission factors may apply to diff formulations; at least one formulation includes curing (approx. 60 min); point(s) of measurement unknown. (See A8)
Shasta County	lab	47 P[a]		8 P		curing emissions included; curing times: gel (66 min) & resin w/roving (50 min); application/curing distribution unknown.
Kingston Polytechnic	lab			16-35 P[1]		ambient temperature, air velocity, amt of hand rolling, reinforcement type, styrene content and wax conc. controlled; range of emissions provided; point of measurement unknown.
SAI-Plant A	panels					NA-lamination process
SAI-Plant B	tank coating				9-13 *C/A	coatings applied to one quarter of the tank at a time; 145 min of this 200 min process measured; emissions probably include application and some curing.
SAI-Plant C	synth marble bath products		29-35 *E	MC-NA		resin applied first, then outer gel coating; EFs assume all emissions measured are from application of gel coating; EFs include gel spraying, perhaps gel curing, & probably some resin pouring & curing
Modern Plastics I	NA					no testing, general FRP info only
Applied Science	NA					no testing, general FRP info only
SCAQMD, Proposed Rule 1162	general FRP?					awaiting document
NIOSH	boats					EFs could not be determined since chemical usage was not provided

Table 4-2 (con't)

NMMA Emission Factor Evaluation

Comparison of Emission Factors for Resins and Gel Coats

CONFIDENTIAL
WORKING DRAFT

Document	Product Type	Emissions Factors (NVS), %AS: Gel Coat Layup — Hand	Gel Coat Layup — Spray	Resin Layup — Hand	Resin Layup — Spray	Notes
AP-42		26-35	26-35	5-10	9-13	
Aristech to EPA[2]	unknown	26-35 P[bc]	26-35 X	5-10 P[*4]	9-13 X	document was not available; information was available in [A9] regarding Aristech's suggested EFs; Aristech did not contest the spray layup EFs; comments re: hand layup provided in the footnotes.
Modern Plastics	lab, boats					EFs could not be determined since chemical usage was not provided
Ashland Chemical II	lab, production			10.5 C/G		difficulty obtaining emission factors presented in Ashland study and adopted by AP-42
Pacific Environmental	general FRP	26-35 X	26-35 X	5-10 X	9-13 X	documents selection of the AP-42 emission factors; SAI suggestions [A1] adopted for spray layup EFs; Aristech suggestions [A6] adopted for hand layup EFs.
EPA Discussion Documents						
EPA/SRI Eljer	bath products?					document not available {RTI estimate: gel sprayup 66%}
EPA/Radian, Venetian	synth marble sinks, panels		1.1 E	MC-NA		reportedly, there is a conversion factor error in the Radian calculations - air flow rate appears to be low; gel curing is not included in the EF; %styrene was not identified. {RTI estimate: gel sprayup 68%}
EPA/Radian, General	synth marble sinks		>100 E	MC-NA		information provided in study is suspect; %styrene not provided; emission measurements for multi-stack ops collected during diff time periods; hours of operation assumed may be excessive.
Radian/IT, Cortec	panels		22-37 E			styrene content not provided; 31% EF - "baseline gel"; 22% EF - "high performance gel" {RTI estimate: baseline gel EF - 42%}
Bison, GEA Dynamic	panels, pipes				22-27 E/A	EFs are suspect; grab samples; resin application to mandrels conducted during all runs; gelcoating included in the run w/the highest EF; unknown whether curing was included.

Table 4-2 (con't)
NMMA Emission Factor Evaluation
Comparison of Emission Factors for Resins and Gel Coats

Document	Product Type	Emissions Factors (NVS), %AS				Notes
		Gel Coat Layup		Resin Layup		
		Hand	Spray	Hand	Spray	
AP-42		26-35	26-35	5-10	9-13	
Lasco Bathware	bath products?					document not available
AquaGlass	bath products?					document not available
CFA Hand Layup	lab?			10-12 C/G 18-21	C/G	lower EF range for 35% styrene; higher range for 42% styrene; study evaluated the effect of resin thickness, air flow, gel time and styrene content of emissions.
RTI	lab-box mold		53-55 C/A 57-90 C/G	14-15 C/A 14-15 C/G	17-24 C/A 16-23 C/G	HL: resin w/ flow coater & pressure feeder; ambient temperature curing; SL: effects of air flow, spray equipment, spray technique and formulation on emissions evaluated; application/curing distribution measured
Other Studies						
MTAP	bench scale test at a FRP facility				6-10 C/A 8-14 C/G	styrene content varied from 33.1% to 46%; different catalysts (MEKP & BPO) tested; min EFs for BPO catalyzed resin w/43.9% styrene; max EFs for MEKP catalyzed resin w/46% styrene; application/curing distribution measured
EPA RREL	general FRP					no testing, general FRP info only
EPA/Radian, Styrene...	general FRP					no testing, general FRP info only
MB MACT memo	general FRP					compendium of extrapolated emissions from the RTI report
NMMA MACT Study	boats					no emissions information provided in the draft copy of Sections 1 and 2.
memo re: use of EFs	NA					no testing
Boat Study	boats					average industry wide emissions based on AP-42 EFs.
EPA/Radian, Hydro-Sports	boats (14'-24')		12.4 E[a]	8.1 E[a]	82.5 E[a]	EPA RACT compliance study; hourly emission rates provided without a source; values may be overestimated
Boat Plant A	boats (18'-22')		18.6 C/A		12.8 C/A	industry study
Boat Plant B	boats (22'-30')		32.3 C/A		16.7 C/A	industry study
Boat Plant C	boats		26.3 C/A		18.4 C/A	industry study

Table 4-2 (con't)
NMMA Emission Factor Evaluation
Comparison of Emission Factors for Resins and Gel Coats

Document	Product Type	Emissions Factors (NVS), %AS				Notes
		Gel Coat Layup		Resin Layup		
		Hand	Spray	Hand	Spray	
AP-42		26-35	26-35	5-10	9-13	
Boat Plant D	lab- flat boards		**72.8** C/G		**19.3-20.5** C/G	Boat manufacturer conducted a styrene emissions study using flat boards. Lower EF for resin w/chop mat; higher EF for resin w/woven roving.

Notes:

Values greater than the AP-42 emission factor are presented in bold.

* Value determined in this document was adopted as the AP-42 emission factor.

(1) Identified in SAI as the selected emission factor, but was not adopted as the AP-42 emission factor based on Aristech comments (see Document [A6]).

(2) Although this document could not be obtained, sufficient information was provided in Document [A9] to identify the EFs suggested.

(3) Aristech commented that spray layup EFs should not be less than hand layup EFs and suggested that hand layup EFs for gel coat be equal to those for spray layup.

(4) Aristech commented that that based on their studies, hand layup EFs for resin were closer to 5-10 than 16-35.

EF: emission factor
NA: Not Applicable
MC: marble casting operation - resin layup emission factor is not applicable for boat manufacturing.

C: calculated

E: estimated emission factor; insufficient information provided to accurately determine the emission factor; information (e.g., styrene content) assumed.

P: emission factor provided (sufficient information was not provided to verify the value).

X: emission factor determined in another document was referenced in this document.
G - Gravimetric method
A - Ambient or stack sample

TABLE 4-3
FRP Open Molding Emission Factor Evaluation
Products Evaluated in Reference Documents

	lab	full-scale applications					Comments
		synthetic marble showers, tubs, sinks & sills	counters, panels	pipes, pipe liners	boats	other	
AP-42 References							
SAI Report	Information provided below for studies contained in this document						
Dade County	x						
BAAQMD		x (SL-GE)-low end					
Ashland	x						
Shasta Co.	glass plates(1)						
Kingston Poly.	x(2)						
Plant A			x				
Plant B						**tank coating**	(SL-R)
Plant C		x (SL-GE)-high end					
Modern Plastics I							no testing, general FRP info only
Applied Science							no testing, general FRP info only
SCAQMD Rule 1162							
NIOSH					x(3)		
Aristech to EPA							comment letter on draft AP-42 EFs; acc. to [A9], provided EFs
Modern Plastics II	x				x(3)		
Ashland Chemical	x (SL-R)						
Pacific Environmental							no testing, general FRP info only
EPA Discussion Document References							
EPA/SRI Eljer							document not available
EPA/Radian, Venetian		x					
EPA/Radian, General		x					
Radian/IT, Cortec			x				
Bison, GEA Dynamic			x	x			

TABLE 4-3 (con't)
FRP Open Molding Emission Factor Evaluation
Products Evaluated in Reference Documents

	lab	full-scale applications					Comments
		synthetic marble showers, tubs, sinks & sills	counters, panels	pipes, pipe liners	boats	other	
AP-42 References							
Lasco Bathware							document not available
AquaGlass							document not available
CFA Hand Layup	x						
RTI	box mold						
Other References							
MNTAP	x(4)			flumes			
EPA RREL							no testing, general FRP info only
EPA/Radian, Styrene...							no testing, general FRP info only
Boat Study					x(3)		avg industry wide emissions based on AP-42 emission factors
EPA/Radian, Hydro-Sports					x		due to lack of info, EFs were estimated
Boat Plant A					x		industry study
Boat Plant B					x		industry study
Boat Plant C					x		industry study
Boat Plant D	x						lab tests conducted at a boat plant

Notes:

(1) Recommended in the SAI document as the gelcoat hand layup EF, but contested by Aristech as too high.

(2) Recommended in the SAI document as the resin hand layup EF, but contested by Aristech as too high.

(3) Although document addresses boat plants, sufficient information was not available in this document to determine emission factors.

(4) Facility also produces a variety of open molded products, including cabs for heavy equipment.

SL: spray layup emission factor source
HL: hand layup emission factor source
R: resin; GE: gelcoat
Adopted gelcoat hand layup emission factor does not appear to have a product source. (i.e., EF was not based on any testing)

Table 4-4
Emission Factor Evaluation
Comparison of RFP Open Molding Parameters

FRP Industry Reference	Product	Styrene Content Resin & Gel	Catalyst	Gel/Resin Application Techniques	Hand Layup	Sprayup		Other Parameters That May Effect Emission Factors							Particulate Emissions	%AS Emissions - Appliction/ Curing	Applicability to Boat Manufacturing
					Rolling Time	Applicator	Distance	Surface	Air Flow	Emission Measurement Technique	Emission Measurement Location	Laminate Thickness	Curing/Gel Time, min	Ambient Temp/ RH			
AP-42 & References	fiberglass products	typically 43% resin 35% gel	typically MEKP		EF inc w/RT				EF inc w/AF				EF inc w/CT	EF inc w/T			
SAI Report																	
BAAQMD*	bath products, containers	40-53% resin 38-42% gel	NP	SL*/SLor MC	NA	chopper gun	NP	curved	NP	NP	spray booth exhaust	NP	NP	NP	NP	NP	
Ashland Chemical	See A8 for more detailed information																
Shasta County	lab	NP	NP	HL/HL	NP	NA	NA	flat, 1-D?	NP	gravimetric	after each coat	NP	gel: 66 resin: 50	NP	NP	NP	
Kingston Polytechnic*	lab	NP (VS/NVS)	NP	- /HL*	S inc w/RT	NA	NA	NP	S inc w/WS	gravimetric	NP	NP	NP	S inc w/T	NP	NP	
SAI-Plant A	panels			continuous lamination													
SAI-Plant B*	tank coating	45-49%resin	NP	?/SL*	NA	NP	NP	curved, convex	1.5 m3/sec	char w/OVA	shed exhaust	NP	200 min spray & cure	ambient	NP	NP	
SAI-Plant C	synth marble bath products	37% r (VS/NVS) 40% gel	NP	SL/MC	NA	NP	NP	curved, concave & convex	3.4 m3/sec	char w/OVA	gel spray booth	NA	heated curing	heated curing	NP	NP	
Modern Plastics I	general FRP - no emissions information																
Applied Science	general FRP - no emissions information																
SCAQMD Rule 1162																	
NIOSH	boats	+-40%resin	NP	SL/HL,SL	NP	chopper gun, etc.	NP	curved, concave	NP	charcoal tube	various work stations	NP	NP	NP	NM	NP	cannot be calc EFs; no chemical usage given
Aristech to EPA	unknown - EFs provided in document referenced in [A9] - no other process specific information provided																
Modern Plastics	lab, boats	44% resin 36%LSE resin	1.25% MEKP	NP/SL	NA	chopper gun	NP	misc	NP	lab: gravimetric boats: charcoal	worker exposure areas	NP	CT: 23-24	NP	NP	NP	cannot be calc EFs; no chemical usage given
Ashland Chemical	lab	45% resin	NP	- /MC(pour)	NP	NP	NP	flat, 1-D	NP	gravimetric		3-ply	GT: 20 CT: 48	NP	NM	NP	
	? plants	NP	NP	- /HL,SL	NP	NP	NP	NP	NP	OVA	worker exposure areas; exhausts	3-ply	same as above?	NP	NM	NP	
Pacific Environmental	general FRP																
M. Strum Memo References										S may be low due to charcoal							
EPA/SRI Eljer	bath products? - document not available																
EPA/Radian, Venetian	synth marble bath products	NP	NP	SL/MC	NP	NP	NP	curved, concave	0.07 dsm3/sec	OVA	spray booth	NP	NP	NP	very low	NA - only gel spray measured	
EPA/Radian, General	synth marble bath products	NP	NP	SL/MC	NP	NP	NP	curved, concave	0.7-6 dsm3/sec	Tedlar bag w/ GC/FID	gel spray booth, gel cure oven, resin cure oven, mixing room	NP	NP	heated curing	moderate, good dust collection	gel: 45% spray, 55% cure??	
Radian/IT, Cortec	panels	NP	NP	SL/ -	NA	automated HLVP	NP	NP	<3 m3/sec	gravimetric	after curing	single	CT: 8-10 min E dec w/ faster GT	NP	NM	gel: 32% spray, 68% cure	
Bison, GEA Dynamic	panels	35-45% resin	NP	NP/SL	NA	NP	NP	flat, 1-D	4.7-5.3 m3/sec	charcoal tube	three outlet stacks	NP	NP	NP	NM	NP	

Table 4-4
Emission Factor Evaluation
Comparison of RFP Open Molding Parameters

					Hand Layup	*Sprayup*		*Other Parameters That May Effect Emission Factors*									
FRP Industry Reference	*Product*	*Styrene Content Resin & Gel*	*Catalyst*	*Gel/Resin Application Techniques*	*Rolling Time*	*Applicator*	*Distance*	*Surface*	*Air Flow*	*Emission Measurement Technique*	*Emission Measurement Location*	*Laminate Thickness*	*Curing/Gel Time, min*	*Ambient Temp/RH*	*Particulate Emissions*	*%AS Emissions - Appliction/ Curing*	*Applicability to Boat Manufacturing*
Lasco Bathware	bath products? - document not available																
AquaGlass	bath products? - document not available																
CFA Hand Layup	lab?	35%&42%resin EFs dec (16%) w/dec %styr	MEKP	- /HL	NP	NA	NA	NP	minor dec in EFs w/dec AF	THA, FID, GC	stack venting process chamber	sign EF dec (31%) w/inc thickness	mod. EF dec (18%) w/ faster GT	NP	NM	NP	
RTI	information for gel coat and resin provided separately below									THC/FID/grav							
gel coat test parameters	lab - box mold	38.7%reg [iso] 25.4%lv[iso/npg]	MEKP	SL	NA	AAA & HLVP spray guns	NP	flat, convex mold		gravimetric & FID	exhausts	NP	CT: 17-30	73F/58%	NM	32-50% spray; 50-68% curing	boat molds are not flat
gel coat test results		EF dec 3%		E dec 24% w/controlled SL; less mat'l usage		insign effect on E			insign effect on S	measurement techniques in good agreement			E decrease with CT				
resin test parameters	lab - box mold	38%lp [dcpd] 35%lv [dcpd] 43.5%VS[ortho] 43.3%VSw[ortho] 42.6% [dcpd]	MEKP MEKP MEKP MEKP BPO	modified HL (flow coater & pressure fed roller) & SL	NP	AAA spray gun	NP	flat, convex mold		see above	see above	NP	CT: 17-30	see above	NM	38-63% spray; 37-62% curing	boat molds are not flat
resin test results		formulation: lv resin red E 36%; VS resin red E 39%; BPO catalyst red E 3% application: controlled SL red E 35%; modified HL red E 52% from SL; modified HL consumed less mat'ls							insign effect on S				see above				
Other References	-																
MNTAP	bench-scale test; facility produces a variety of products	resin only 46%[ortho] 44% [ortho] 38% LSE [o/d] 33% 1162 [o/d]	MEKP BPO MEKP MEKP	- /SL	NA	Glas-Craft LPA Series	NP	flat	NP	open-cup static; gravimetric	before and after curing	NP	GT: 18-22 min	68+-1/<40%	NM	69-76% spray; 24-31% curing	
MNTAP results	42% EF reduction w/BPO catalyst substitution; 9-11% EF reduction w/LSE resins																
EPA RREL	general FRP - no emissions information																
EPA/Radian, Styrene...	general FRP - no emissions information																
Boat Study	boats	AP-42 values cited	mostly MEKP & BOP	SL/HL & SL	1% styrene loss from application	10% overspray loss; some os polymerizes; inc spray gun pressure inc os	NP		32-585 m3/sec(2); greater air flow may inc E	NA	NA	reinforcement matls: 0.008-0.80"	8% of styrene lost before polymerization complete	T in E	NP	NP	emissions information not applicable since AP-42 derived
EPA/Radian, Hydro-Sports	boats (14'-24')	42% resin 25% gel	NP	SL/HL-hulls & SL-small parts	NP	NP	NP	hulls - concave, curved	NP	NP	NP	NP	NP	NP	NP	NP	process is directly applicable; however, insufficient information to definitively calculate the emission factors
Plant A	boats (18'-22')	38% resin 34% gel	NP	SL/SL	NP	NP	NP	concave, curved	104,034 dscfm	charcoal tube (EPA 18)	exhaust	NP	NP	81F/	NM	NP	directly applicable
Plant B	boats (22'-30')	38% resin 30.4% gel	NP	SL/SL	NP	NP	NP	concave, curved	20-69,000 dscfm	charcoal tube (EPA 18)	exhaust	NP	NP	79F/	NM	NP	directly applicable
Plant C	boats	40% resin 35% gel	NP	SL/SL	NP	NP	NP	concave, curved	6500-7400 cfm	charcoal tube (EPA 18); PID; good correlation	exhaust	NP	NP	NP	NM	NP	directly applicable

Table 4-4
Emission Factor Evaluation
Comparison of RFP Open Molding Parameters

FRP Industry Reference	Product	Styrene Content Resin & Gel	Catalyst	Gel/Resin Application Techniques	Hand Layup	Sprayup		Other Parameters That May Effect Emission Factors							Particulate Emissions	%AS Emissions - Appliction/ Curing	Applicability to Boat Manufacturing
					Rolling Time	Applicator	Distance	Surface	Air Flow	Emission Measurement Technique	Emission Measurement Location	Laminate Thickness	Curing/Gel Time, min	Ambient Temp/ RH			
Plant D																	
resin w/chop	lab, flat boards	30-50% resin	MEKP	-/SL	NP	NP	NP	flat, 1-D	NP	gravimetric	NA	NP	120 min	75F	NM	NP	lab testing, not directly applicable
resin w/woven roving	lab, flat boards	30-50% resin	MEKP	-/HL	NP	NP	NP	flat, 1-D	NP	gravimetric	NA	NP	120 min	75F	NM	NP	
gelcoat	lab flat boards	30% gelcoat	MEKP	SL/-	NP	NP	NP	flat, 1-D	NP	gravimetric	NA	NP	60 min	75F	NM	NP	

Notes:

(1) Unless otherwise noted, resins were non-vapor suppressed (NVS).

(2) Estimated total plant exhaust flow rate. Range spans from small plants producing small boats (i.e., <30 ft) to large plants producing large boats (i.e., >30 ft).

* EF determined during study adopted as the AP-42 EF.

S: styrene emissions
EF: styrene emission factors
SL: spray layup
HL: hand layup
MC: marble casting, not a boat mfg process
NP: information not provided
NA: not applicable
conv: conventional
LSE: low styrene emission resin
lp: low-profile resin
lv: low-VOC
VS: vapor/styrene suppressed
VSw: vapor/styrene suppressed + wax
[ ]: base for gel or resin, if available
[o/d]: ortho/dcpd mixed resin base
HVLP: high volume low pressure spray gun
AAA: air-assisted airless spray gun
WS: wind speed
RT: rolling time
AF: air flow
T: temperature
CT: cure time
GT: gel time

TABLE 4-5
FRP Open Molding Emission Factor Evaluation
Detailed Product Line Emission Factors

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Non Vapor Suppressed

	Manufacturing Processes Tested				
	boats	synthetic marble showers, tubs, sinks & sills	counters, panels	other	lab
Resin Spray Layup; AP-42 EF: 9-13					
Range	13-18	**8-27 P[a]**	**22-27 E**	9-13	**8-24**
AP-42 References					
BAAQMD		**8-27 P[a]**			
SAI-Plant B				9-13	
EPA Discussion Document					
Bison			**22-27 E**		
RTI					**16-24**
Other Sources					
MNTAP					**8-14**
EPA/Radian, Hydro-Sports	**82.5 E[a]**	<--small parts			
Boat Plant A	12.8				
Boat Plant B	**16.7**				
Boat Plant C	**18.4**				
Boat Plant D					**19.3-20.5**
Resin Hand Layup; AP-42 EF: 5-10					
Range	8.1 E[a]				**8-35 P**
AP-42 References					
Shasta County					8 P
Kingston Polytechnic					**16-35 P**
Ashland Chemical					**10.5**
Aristech to EPA					5-10
EPA Discussion Document					
CFA Hand Layup					**10-21**
Other Sources					
EPA/Radian, Hydro-Sports	8.1 E[a]	<--decks & hulls			
Gelcoat Spray Layup; AP-42 EF: 26-35					
Range	12.4-32.3	**7-38 P[a]**	22-37 E		**53-72.8**
AP-42 References					
BAAQMD		26-28; **7-38 P[a]**			
SAI-Plant C		29-35 E			
EPA Discussion Document					
EPA/Radian, Venetian		1 E			
EPA/Radian, General		**111 E**			
Radian/IT, Cortec			22-37 E		
RTI					**53-60**

TABLE 4-5 (con't)
FRP Open Molding Emission Factor Evaluation
Detailed Product Line Emission Factors

Non Vapor Suppressed

	Manufacturing Processes Tested				lab
	boats	synthetic marble showers, tubs, sinks & sills	counters, panels	other	
<u>Other Sources</u>					
EPA/Radian, Hydro-Sports	12.4 E[a]				
Boat Plant A	18.6				
Boat Plant B	32.3				
Boat Plant C	26.4				
Boat Plant D					**72.8**
Gelcoat Hand Layup; AP-42 EF: 26-35					
Range				26-35 P[nb]	**47 P[a]**
<u>AP-42 References</u>					
Shasta County					**47 P[a]**
Aristech to EPA				26-35 P[nb]	

Vapor Suppressed

	Manufacturing Processes Tested				lab
	boats	synthetic marble showers, tubs, sinks & sills	counters, panels	other	
Resin Spray Layup; AP-42 EF: 3-9					
Range					**9.5-10.3**
<u>EPA Discussion Document</u>					
RTI					**9.5-10.3**
Resin Hand Layup; AP-42 EF: 2-7					
Range					2.35-6.3
<u>AP-42 References</u>					
Dade County, Florida					5.6-6.3
Ashland Chemical					2.35

<u>Notes:</u>

Values greater than the AP-42 emission factor are presented in bold.
Emission factors presented as percent of <u>available</u> styrene.
Unless otherwise identified, estimated emission factors were not considered for the range value.
E: estimated EF; insufficient information provided to accurately determine EF; information (e.g., styrene content, hours of operation) assumed and/or emission from various FRP processes were combined.
P: EF provided; however, sufficient information was not provided to verify the EF.
a: method of measurement not provided.
nb: no testing provided to substantiate emission factor; as per Aristech's comment letter, range was assumed to be equal to spray layup

TABLE 4-6
Emission Factor Evaluation - FRP Open Molding Emission Factor Evaluation
Product Line Emission Factors

Non Vapor Suppressed

Material	Application Method	AP-42 Emission Factors	Manufacturing Processes Tested				
			boats	synthetic marble showers, tubs, sinks & sills	counters, panels	other	lab
Resin	spray layup	9-13	13-18	8-27 P[a]	22-27 E	9-13	8-24
Resin	hand layup	5-10	8.1	NA	NI	NI	8-35 P
Gelcoat	spray layup	26-35	12.4-32.3	7-38 P[a]	22-37 E	NI	53-72.8
Gelcoat	hand layup	26-35	NA	NI	NI	26-35 P[nb]	47 P[a]

Vapor Suppressed

Material	Application Method	AP-42 Emission Factors	lab
Resin	spray layup	3-9	9.5-10.3
Resin	hand layup	2-7	2.35-6.3
Gelcoat	spray layup	8-25	NI
Gelcoat	hand layup	8-25	NI

TABLE 4-6 (con't)
Emission Factor Evaluation - FRP Open Molding Emission Factor Evaluation
Product Line Emission Factors

Notes:

Values greater than the AP-42 emission factor are presented in bold.

Emission factors presented as percent of available styrene.

Unless identified, estimated emission factors are not included in this summary table.

E: estimated EF; insufficient information provided to accurately determine EF; information (e.g., styrene content) assumed. and/or emission from various FRP processes were combined.

P: EF provided (sufficient information was not provided to verify the EF).

a: method of measurement not provided.

nb: no testing provided to substantiate emission factor; range assumed to be equal to spray layup

NI: none identified

NA: process is not applicable for this product (e.g., resin is applied to sinks, etc., via a marble casting process)

TABLE 4-7

RTI's Comparison of EPA AP-42 Emission Factors and Emission Factors Derived from Other Resin Test Results (in %AS)

Emission Factor Evaluation - FRP Open Molding

Emission Factor Source	**Resin sprayup (VS)**	**Ratio to AP-42 midpoint**	**Resin sprayup (NVS)**	**Ration to AP-42 midpoint**
AP-42 emission factor	3 - 9	1.0	9 - 13	1.0
EPA/Southern Research Institute (SRI) testing at Eljer Plumbingware (now Carolina Classics	16	2.7	NA	NA
Dow/RTI Method 25A-mass balance comparison testing at Freeport, TX (6-10 March 1995)	NA	NA	24	2.2
Bison Engineering testing at GEA Dynamic Fabricators, ID	NA	NA	24	2.2
RTI resin experiment at Reichold, June-July 1995, run R10 (NVS resin with "normal" spraying technique)	NA	NA	27.1	2.5
RTI resin experiment at Reichhold, June-July 1995, with "controlled" spraying technique	10.6	1.8	17.5	1.6

NA = Not applicable.
NVS = Non-vapor-suppressed.
VS = Vapor-suppressed.
Source: Kong, M. Baher, R. Wright, A. Clayton, Draft Project Report, Evaluation of Pollution Prevention Techniques To Reduce Styrene Emissions from Open Contact Molding Processes, Draft Report, Research Triangle Institute in cooperation with USEPA, EPA Cooperative Agreement CR 818419-03, September 1995.

TABLE 4-8

RTI's Comparison of EPA AP-42 Emission Factors and Emission Factors Derived from Other Gelcoat Test Results (in %AS)
Emission Factor Evaluation - FRP Open Molding

Emission Factor Source	Gel coat sprayup (NVS)	Ratio to AP-42 midpoint
AP-42 emission factor	26-35	1.0
EPA/Southern Research Institute (SRI) testing at Eljer Plumbingware (now Carolina Classics)	66	2.2
EPA/Radian (RTP) testing at Venetian Marble, VA	68	2.2
EPA/Radian (RTP) testing at General Marble, NC	97	3.2
Radian (Ohio) testing at CORTEC, OH	42/29*	1.4/1.0
Preliminary CFA/Dow testing at Freeport, TX (4-5 January 1995)	64	2.1
Dow/RTI Method 25A-mass balance comparison testing at Freeport, TX (6-10 March 1995)		
RTI pilot experiment at Reichhold, June 1995, "normal" spraying technique	62.5	2.0
RTI pilot experiment at Reichhold, June 1995, "controlled" spraying technique	54.1	1.8
RTI gel coating experiment at Reichhold, June 1995, "controlled" spraying technique	56.0	1.8

NVS = Non-vapor-suppressed.
*42% = baseline" gelcoat, 29%="high performance" gel coat with "fast" gel time. Robotic spray guns inside a total enclosure.
source: Kong, M. Bahner, R. Wright, A. Clayton, Draft Project Report, Evaluation of Pollution Prevention Techniques To Reduce Styrene Emissions from Open Contact Molding Processes, Draft Report, Research Triangle Institute in cooperation with USEPA, EPA Cooperative Agreement CR 818419-03, September 1995.

5.0 *CONCLUSIONS AND RECOMMENDATIONS*

Following are the conclusions of the emission factor evaluation for FRP open molding:

- the EPA discussion documents are not representative of boat building FRP open molding fabrication processes;

- the boat plant emission factors are generally within the AP-42 emission factor ranges

- insufficient information was available to accurately estimate emissions factors using the EPA Discussion Document References;

- neither the RTI Report nor its support documents demonstrate that the AP-42 emission factors underestimate FRP full-scale fabrication emissions by a factor of two;

- lab-scale and bench-scale studies, as well as small FRP fabrication studies, are not representative of the boat building process and generally overestimate boat building emission factors;

- the size and shape of boat molds results in less overspray and consequently lower process emissions than fabrication of products using small, flat and/or convex molds; and

- differences in raw materials, operating parameters (e.g., application technique, curing time and gel time) and fabrication processes (e.g., heated curing) significantly affect FRP open molding emission factors.

APPENDIX A:

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APPENDIX B:

Emission Factor Calculations

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TABLE B-1

Gelcoat Spray Layup Emission Factor Calculations

Emission Factor Evaluation - Open Molding

FRP Industry References	Product	Gelcoat Type	Styrene Content	Vapor Conc mg/m3	Air Flow dscm/m	Emission Rate lb/hr	Spray Layup Emission Factor, %AS: Total via EM	Application Only	Curing Only	Total via Grav
AP-42 Emission Factor (Independent of Measurement Technique)							26-35%			26-35%
A AP-42 & References										
A1. SAI Report										
BAAQMD*	bath prod, containers		38-42%				26-28% P[a] 7-38% P[a]			
SAI-Plant C*	syn marble		40%	78.0	204	2.10	29% E			
	bath prod		40%	94.0	204	2.54	35% E			
A6. Aristech to EPA	unknown		NP				26-35% X			
A9. Pacific Environmental	FRP products		NA				26-35% X			
B M. Strum Memo References										
B2. EPA/Radian, Venetian	syn marble bath prod		NP (48%)[b]	166.1	4.39	0.10	1.1% E			
B3. EPA/Radian, General	syn marble bath prod	3 stacks (1 spraybooth & 2 ovens)	NP (48%)[b]	107.7 333.0 158.0	347 106 68	4.94 4.68 1.42	111% E	50%	61% heated curing	
B4. Radian/IT, Cortec	panels	baseline	NP (35%)[c]					12%	25%	37% E
		faster cure time	NP (35%)[c]					NP	NP	22% E
B9. RTI	lab - box mold	regular; iso-based	38.7%	22.7	247	0.74	55%	27%	30%	57%
		low VOC; iso/npg-based	25.4%	13.2	248	0.43	53%	29%	31%	60%
C Other References										
C8. EPA/Radian, Hydro-Sports	boats (14'-24')		25%			1.4	12.4% E[a]	7.1%	5.3%	
C9. FW, Frisbee Street	boats (18'-22')	5% MMA	34%	74.4	911	8.96	18.6%			
C10. FW, Cruiser Plant	boats (22'-30')	5-10% MMA	30.40%	82.2	452	4.92	32.3%			
C11. FW, 13th Street	boats	MMA	35%	239.8	210	6.64	26.4%			
C12. Salisbury Bayliner	flat boards		30%							72.8%

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TABLE B-1
Gelcoat Spray Layup Emission Factor Calculations
Emission Factor Evaluation - Open Molding

Notes:

* Value determined/provided in this document was adopted as the AP-42 emission factor.

Values greater than the AP-42 emission factor are presented in bold.

%AS: Emission factor presented as percent of available styrene.

EM: emission measurement (e.g., charcoal tube vapor sample collection with lab analysis)

Grav: gravimetric measurement

Total [Emission Factor]: includes styrene emissions from both application and curing

E: estimated emission factor; insufficient information provided to accurately determine the emission factor; information (e.g., styrene content) assumed.

P: emission factor provided (sufficient information was not provided to verify the value).

X: emission factor determined in another document was referenced in this document.

a: method of measurement not provided.

b: Styrene content of 48% provided by "Bathroom Designs" {Source: RTI calculation notes}

c: Styrene content of 35% assumed; gelcoat used by Bison, a panel manufacturer, contains 35% styrene. Gelcoat EF could not be calculated for Bison since gelcoat spraying was not evaluated separately from resin spraying.

NP: not provided

NA: not applicable

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TABLE B-2
Resin Spray Layup Emission Factor Calculations
Emission Factor Evaluation - FRP Open Molding

FRP Industry References	Product	Resin Type	Styrene Content	Vapor Conc mg/m3	Air Flow dscm/m	Emission Rate lb/hr	Spray Layup Emission Factor, %AS: Total via EM	Application Only	Curing Only	Total via Grav
AP-42 Emission Factor (Independent of Measurement Technique)							9-13%			9-13%
A AP-42 & References										
A1. SAI Report										
BAAQMD	bath prod, containers		40-53%							8-27% P[a]
SAI-Plant B*	tank coating		49%	909.0	90	10.82	9%			
			45%	1174.0	90	13.98	13%			
A6. Aristech to EPA	unknown		NP				9-13% X			
A9. Pacific Environmental	FRP products		NA				9-13% X			
B M. Strum Memo References										
B5. Bison, GEA Dynamic	panels	Run #1	37.5%	254.9 176.9	297 286	16.72	22% E	grab sample; incl mandrel resin application		
		Run #2	38.8%	170.5 220.4	314 300	15.84	23% E	grab sample; incl mandrel resin application		
		Run #3	39.8%	255.3 254.6	306 283	19.86	27% E	grab sample; incl mandrel resin & gel coat appl		
B9. RTI	lab - box mold	dcpd/lp	38.3%	24.3	242	0.78	17.2%	9.0%	7.9%	16.9%
		dcpd/ls	35%	21.6	242	0.69	17.2%	8.7%	7.5%	16.2%
		ortho/vs	43.5%	15.3	242	0.49	10.3%	7.1%	3.2%	10.2%
		ortho/vsw	43.3%	11.2	242	0.36	10.2%	6.5%	3.0%	9.5%
		dcpd/neat	42.6%	24.4	242	0.78	23.9%	10.5%	12.1%	22.6%
C Other References										
C1. MNTAP	bench-scale	ortho	46%					10.2%	3.7%	13.9%
		ortho	44%					5.5%	2.5%	8.0%
		o-d/ls	38%					9.2%	3.4%	12.6%
		o-d/1162	33%					9.4%	3.0%	12.4%
C8. EPA/Radian, Hydro-Sports	boats (small parts)		42%			1.3	82.5% E[a]	12.7%	69.8%	

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TABLE B-2

Resin Spray Layup Emission Factor Calculations

Emission Factor Evaluation - FRP Open Molding

FRP Industry References	Product	Resin Type	Styrene Content	Vapor Conc mg/m3	Air Flow dscm/m	Emission Rate lb/hr	Spray Layup Emission Factor, %AS: Total via EM	Application Only	Curing Only	Total via Grav
AP-42 Emission Factor (Independent of Measurement Technique)							9-13%			9-13%
C9. FW, Frisbee Street	boats (18'-22')	dgc	38%	31.7	1,741	41.23	**12.8%**			
	2 stacks			87.1	2,946					
C10. FW, Cruiser Plant	boats (22'-30')	dgc	38%	19.4	773	29.57	**16.7%**			
	3 stacks			36.1	1,629					
				76.4	1,960					
C11. FW, 13th Street	boats		40%	213.9	1,288	36.46	**18.4%**			
C12. Salisbury Bayliner	flat boards	w/chop	30-50%							**20.5%**
	flat boards	w/roving	30-50%							**19.3%**

Notes:

Values greater than the AP-42 emission factor are presented in bold.
* Value determined in this document was adopted as the AP-42 emission factor.
%AS: Emission factor presented as percent of available styrene.
EM: emission measurement (e.g., charcoal tube vapor sample collection with lab analysis)
Grav: gravimetric measurement
Total [Emission Factor]: includes styrene emissions from both application and curing
ls: low styrene resin
lp: low-profile resin
vs: vapor/styrene suppressed
vsw: vapor/styrene suppressed + wax
o-d: ortho/dcpd mixed resin base
dgc: diacid glycol condensate
E: estimated EF; insufficient information provided to accurately determine EF; information (e.g., styrene content) assumed.
P: EF provided (sufficient information was not provided to verify the EF).
X: EF determined in another document was referenced in this document.
a: method of measurement not provided.
NA: not applicable
NP: not provided

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TABLE B-3

Resin Hand Layup Emission Factor Calculations

Emission Factor Evaluation - FRP Open Molding

AP-42 Emission Factor (Independent of Measurement Technique) — Total via EM: 5-10%; Total via Grav: 5-10%

Document/Study	Product	Resin Type	Styrene Content	Vapor Conc mg/m3	Air Flow dscm/m	Emission Rate lb/hr	Hand Layup Emission Factor, %AS: Total via EM	Application Only	Curing Only	Total via Grav
A AP-42 & References										
A1. SAI Report										
Dade County	lab	vs	40-44%				6-6.3% P[a]			
Ashland Chemical	lab		45%							10.5%
	lab	vs	36%							2.35%
Shasta County	lab		NP							8% P
Kingston Polytechnic	lab		NP							**16-35%** P[d]
A6. Aristech to EPA*	unknown		NP				5-10% P[bc]			
A9. Pacific Environmental	FRP products		NA				5-10% X			
B M. Strum Memo References										
B8. CFA Hand Layup	lab?	ortho	42%	thick laminate; fast gel time						**11.6%**
		ortho	42%	thin laminate; slow gel time						**21.2%**
		ortho/ls	35%	thick laminate; fast gel time						9.9%
		ortho/ls	35%	thin laminate; slow gel time						**17.7%**
B9. RTI	lab - box mold	dcpd/lp	38.3%	16.4	242	0.52	**14.0%**	6.8%	6.9%	**13.8%**
		dcpd/lp	38.3%	15.5	240	0.49	**15.1%**	8.9%	6.2%	**15.1%**
C Other References										
C8. EPA/Radian, Hydro-Sports	boats - deck & hulls		42%			7.4	8.1% E[a]	1.0%	7.1%	

Notes:

* Value determined/provided in this document was adopted as the AP-42 emission factor.

Values greater than the AP-42 emission factor are presented in bold.

%AS: Emission factor presented as percent of available styrene.

EM: emission measurement (e.g., charcoal tube vapor sample collection with lab analysis)

Grav: gravimetric measurement

Total [Emission Factor]: includes styrene emissions from both application and curing

E: estimated emission factor; insufficient information provided to accurately determine the emission factor; information (e.g., styrene content) assumed.

P: emission factor provided (sufficient information was not provided to verify the value).

X: emission factor determined in another document was referenced in this document.

Notes, cont'd:

TABLE B-3

Resin Hand Layup Emission Factor Calculations

Emission Factor Evaluation - FRP Open Molding

a: method of measurement not provided.

b: Aristech commented that their studies indicated that hand layup EFs for resin were closer to 5-10 than 16-35. EPA then adopted the Aristech values.

c: Low value corresponds to the percent of available styrene lost after 0.2 hour; the higher value represents the percent of available styrene lost after 0.8 hour.

d: Although this value was recommended in SAI report to be the AP-42 emission factor, this value was not adopted based on Aristech comments (see Document [A6]).

NP: not provided

NA: not applicable

TABLE B-4
Gelcoat Hand Layup - Emission Factor Calculations
Emission Factor Evaluation - FRP Open Molding

AP-42 Emission Factor (Independent of Measurement Technique) 26-35%

FRP Industry References	Product	Gelcoat Type	Styrene Content	Vapor Conc mg/m3	Air Flow dscm/m	Emission Rate lb/hr	EFs, %AS Overall via Grav
A **AP-42 & References**							
A1. SAI Report							
Shasta County	lab		NP				47% P[a]
A6. Aristech to EPA	unknown		NP				26-35% P[bc]
A9. Pacific Environmental	FRP products		NA				26-35% X

Notes:

* Value determined in this document was adopted as the AP-42 emission factor. Document is therefore considered to be the emission factor source.
Values greater than the AP-42 emission factor are presented in bold.
%AS: Emission factor presented as percent of available styrene.
EM: emission measurement (e.g., charcoal tube vapor sample collection with lab analysis)
Grav: gravimetric measurement
Total [Emission Factor]: includes styrene emissions from both application and curing
E: estimated emission factor; insufficient information provided to accurately determine the emission factor; information (e.g., styrene content) assumed.
P: emission factor provided (sufficient information was not provided to verify the value).
X: emission factor determined in another document was referenced in this document.
a: method of measurement not provided.
b: Identified in SAI as the selected emission factor, but was not adopted as the AP-42 emission factor based on Aristech comments (see Document [A6]).
c: Aristech commented that spray lay-up EFs should not be less than hand lay-up EFs and suggested that hand lay-up EFs for gel coat be equal to those for spray lay-up.
NP: not provided
NA: not applicable