Reducing Emissions in Fiberglass Reinforced Plastics Manufacturing

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) conducts tests of facilities to facilitate its environmental programs. The data from these tests have supported the Maximum Achievable Control program and are being supplied for use in updating the AP-42 guide (U.S. EPA, 1988) for the states and others to develop emission estimates.

EPA has proposed National Emission Standards for Hazardous Air Pollutants (NESHAPs) for the fiber-reinforced plastics and composites (FRP/C) industry. These standards, being developed to reduce the emission of styrene from FRP/C facilities, were proposed in August 2001.

Pollution prevention techniques may help FRP/C companies substantially reduce their styrene emissions. However, information is needed about the percentage reduction in emissions that pollution prevention approaches can achieve. To meet this need, EPA's Air Pollution Prevention and Control Division and Research Triangle Institute (RTI) determined baseline emissions and evaluated reductions in styrene emissions that can be achieved through a variety of pollution prevention approaches for the FRP/C industry.

This paper summarizes our evaluation of pollution prevention techniques, so that technical assistance providers can provide better information to FRP/C facilities about pollution prevention options. It gives background about the industry, describes the goals of this research, summarizes the testing program, and provides some key preliminary results and conclusions from the research.

BACKGROUND

The FRP/C industry (excluding boat building) includes over 750 facilities nationally in as many as 33 Standard Industrial Classification (SIC) categories ranging from transportation to electronics and consumer products. Products manufactured include bathtubs and shower stalls, spas, truck caps and vehicle parts, tanks and pipes, appliances, ladders, and railings. According to a 1993 industry screening survey, more than two-thirds of FRP/C facilities have fewer than 50 workers (LaFlam and Proctor, 1995).

More than 75% of the resin used in composites manufacturing is polyester resin that contains styrene as a cross linking agent (SPI, 1992). A portion of this styrene is emitted during and after application of the resin. Annual FRP/C industry styrene emissions based on EPA's Toxic Release Inventory are estimated to be 17,100 tons (U.S. EPA, 1995).

The FRP/C industry employs a variety of manufacturing processes. As shown in Table l, the main manufacturing process is open molding (gel coat and resin spraying). Estimates indicate that open molding is responsible for approximately 75% of the styrene emissions from the FRP/C industry. The open molding process usually consists of the spraying of a wet (uncured) gel coat or resin to a mold in an open environment. Styrene is emitted both during and after the application process.

Table 1: Manufacturing Processes Employed by the FRP/C Industry

Manufacturing Process	Estimated % of Facilities Employing Process*
Open Molding (gel coat and resin spraying)	60
Compression Molding	17
Filament Winding	12
Pultrusion	8
Cultured Marble Casting	6
Continuous Lamination	5

* Column total exceeds 100% because many facilities employ more than one type of manufacturing process. Data are from LaFlam and Proctor (1995).

Facilities have chosen to use high ventilation rates to maintain styrene levels below the 50 ppm worker exposure limit established by the Occupational Safety and Health Administration (OSHA). Control of such high-volume, low-concentration waste streams is expensive with conventional end-of-pipe control technologies. This makes pollution prevention an attractive alternative for reducing styrene emissions.

Pollution prevention approaches are also attractive because, unlike carrier solvents used for conventional solvent-borne paints, styrene is an important component of the FRP curing chemistry. Since styrene is not a carrier solvent, it is not evaporated during the manufacturing process. The styrene is bound in the polymerization of the resin and most of the styrene is utilized in this cross-linking reaction. Preventing the emission of styrene also decreases the amount of styrene needed in manufacturing.

RESEARCH GOALS AND TESTING PROGRAM

This research was conducted to quantify styrene emission reductions achievable through various pollution prevention techniques (see Table 2).

Emissions testing was conducted in an isolated spray booth at the Reichhold Chemicals' physical testing laboratory, located in Research Triangle Park, North Carolina. Although the facility is not a production facility, it is typical of spray booths at FRP/C facilities. Laboratory conditions (e.g., temperature, relative humidity) were carefully controlled, and background concentrations of volatile organic compounds (VOCs) were minimal. Air velocity in the booth was controlled through the use of a baffle located behind the application equipment operator.

The mold used and the choice of equipment operator were not changed during the testing. Tests employed three identical, box-shaped, male molds, with dimensions 2 ft (0.6 m) high by 2.5 ft (0.76 m) long by 2 ft (0.6 m) wide. A 2 in. (5 cm) flange surrounded the bottom of the mold for ease of part removal. The total mold area, including the flange, was 24.5 ft^2(2.28 m^2). An experienced spray equipment operator applied gel coats and resins during the tests.

Emissions from processes employing pollution prevention options were compared to a baseline case to examine reductions achieved. Emissions were analyzed by EPA Method 25A using a total hydrocarbon analyzer with a flame ionization detector (FID). Five factors were examined to determine their impact on styrene emissions: linear air flow velocity in the booth, operator spraying technique, gel coat formulation, resin formulation, and application equipment. Baseline case conditions and pollution prevention options examined are summarized in Table 2.

Table 2: Baseline Test Conditions and Pollution Prevention Options Evaluated

Factor	Base Conditions	Pollution Prevention Option
Spray Technique	Experienced operator, normal technique (i.e., without consciously controlling overspray)	Experienced operator, controlled spraying technique
Air Flow Velocity	100 ft/min (0.5 m/s)	40 ft/min (0.2 m/s)
Application Equipment	Air-assisted airless spray (external catalyst mixing)	1. High-volume, low-pressure (internal catalyst mixing)[1] 2. High-volume, low-pressure (external catalyst mixing)[1] 3. Flow coater (internal catalyst mixing)[2] 4. Pressure fed roller (internal catalyst mixing)[2]
Gel Coat	Isophthalic acid-based gel coat[3] (styrene content 38.7%) methyl ethyl ketone peroxide catalyst; 18-24 mils (0.00046-0.00061 m) coating thickness	Isophthalic acid/neopentyl glycol-based gel coat ("low VOC," styrene content 25.4%) / methyl ethyl ketone peroxide catalyst
Resin	Dicyclopentadiene-based low-profile resin (styrene content 38.3%)/ methyl ethyl ketone peroxide; 70-100 mils (0.0018-0.0025 m) coating thickness	1. Dicyclopentadiene-based low-styrene resin (styrene content 35.3%) / methyl ethyl ketone peroxide catalyst 2. Orthophthalic-acid-based styrene suppressed resin / methyl ethyl ketone peroxide catalyst 3. Orthophthalic-acid-based styrene suppressed resin plus 0.1% wax / methyl ethyl ketone peroxide catalyst

[1] Application equipment used for gel coat tests only.
[2] Application equipment used for resin test only.
[3] Gel coats contained no methyl methacrylate to allow assumption that total emissions were styrene.

Gel coats were provided by Cook Composites and Polymers. All resins and catalysts were provided by Reichhold Chemicals. Application equipment and a trained operator were provided by Magnum Industries. Fiberglass roving used as a reinforcement material was provided by PPG Industries.

The flow coater and pressure fed roller require more time for application just as using a roller would require more time in painting as compared to spraying. The large molds used in these tests were similar to molds used in many production facilities and did not involve intricate shapes. The flow coaters could be used in most applications, but the application time is the determining factor.

RESULTS AND CONCLUSIONS

All tests were conducted in triplicate, at a minimum, to permit statistical analysis of the results obtained. Results were expressed in total grams (g) of styrene emitted, grams of styrene emitted per square meter (g/m^2) of mold surface, and emissions as a percentage of available styrene. Emissions reductions were evaluated in comparison with baseline test conditions as described in Table 2.

Pilot tests, conducted to evaluate the effects of linear air velocity and operator spraying technique on emissions, indicated that:

1) Over the velocity range examined, linear air velocity had no effect on styrene emissions.
2) Controlled gel coat spraying technique reduced styrene emissions by 24% when compared to normal spraying technique (emission factor reduced from 225 to 172 g/m^2).

Gel coat testing indicated that:

1) Low-VOC gel coat formulation reduced styrene emissions by 28% compared to the regular gel coat (emission factor reduced from 170 to 122 g/m^2);
2) Low-VOC gel coat required higher air pressure and larger tip size to improve the spray pattern for application;
3) No significant emission differences were found from application with high-volume, low-pressure (HVLP) spray equipment versus air-assisted airless equipment; and
4) No significant emission differences were found from application with internal-catalyst-mix spray guns versus external-catalyst-mix spray guns.

Evaluations of resin formulations indicated that:

1) The low-styrene resin reduced emissions by 11% (from 195 to 173 g/m^2) as compared with a conventional low-profile resin.
2) The styrene-suppressed resin emitted 35% less styrene than the conventional low-profile resin (from 195 to 126 g/m^2).
3) The styrene-suppressed resin with 0.1% wax emitted 40% less styrene than the conventional low-profile resin (from 195 to 117 g/m^2).

Evaluations of resin application equipment indicated that:

1) Flow coating equipment resulted in 31% lower emissions than *controlled* spraying (emission factor reduced from 195 to 135 g/m^2);

2) Flow coating equipment resulted in 51% lower emissions than *normal* spraying (emission factor reduced from 278 to 135 g/m^2).
3) Pressure-fed roller equipment resulted in 33% lower emissions than *controlled* resin sprayup (emission factor reduced from 195 to 131 g/m^2).
4) Pressure-fed roller equipment resulted in 53% lower emissions than *normal* resin sprayup (emission factor reduced from 278 to 131 g/m^2).

Based on the results of these tests, the following pollution prevention approaches are recommended for FRP/C open mold operations:

- use operator training to improve technique and reduce overspray;
- use non-spray application equipment, where feasible;
- use styrene-suppressed or low-styrene materials, where feasible; and
- adjust catalyst ratios, where feasible, to reduce cure time.

These test results show that significant reductions in styrene emissions can be achieved at minimal cost through selection of processes and application techniques that prevent pollution. Pressure-fed roller equipment provided the best reductions in comparison to spray techniques.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Composite Materials	Pollution Prevention	13B
Styrene		Stationary Sources	07C
Plastics		Fiberglass	11I
Fiberglass Reinforced Plastics (FR/P)			11D
Emission			14G

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