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Technical Discussion of the Unified Emission Factors for Open Molding of Composites

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1.0 Introduction

From 1996 through 1998, the Composites Fabricators Association (CFA) conducted extensive styrene emissions testing at the Dow Chemical facility at Freeport, Texas. The CFA testing program consisted of three test phases, which investigated the effects of various process parameters on the styrene emissions from the open molding of composite parts. The test protocol used in the CFA testing is described in the November 18, 1998 CFA report entitled "*Styrene Emissions Test Protocol & Facility Certification Procedures, Revision 2.1*." The results of the CFA Phase I testing are detailed in the September, 1996 CFA report entitled "*Phase I - Baseline Study; Hand Lay-up, Gel Coating, Spray Lay-up including Optimization Study*." The results of the CFA Phase II and III testing are listed in the appendix to this document.

On February 28, 1998, Engineering Environmental Consulting Services (EECS), on behalf of the CFA, released a report entitled "*CFA Emission Models for the Reinforced Plastics Industries*." This report details a set of equations and factors developed from the CFA test data. These equations and factors predicted the styrene emission rates from typical lamination processes employed by the reinforced plastics industry. The report was subsequently posted on the EPA CHIEF web site as a possible replacement for the obsolete AP-42 factors for reinforced plastics.

In 1997, the National Marine Manufacturers Association (NMMA) also conducted styrene emission testing using the CFA test protocol. The NMMA testing focused on the emissions from the open molding of large composite boat parts. The results of this testing are described in the August 1997 NMMA report entitled "*Baseline Characterization of Emissions from Fiberglass Boat Manufacturing*." The NMMA report was also posted on the EPA CHIEF web site as part of the AP-42 replacement process.

In November 1998, the CFA and NMMA tentatively agreed to merge the data from their respective test programs. The merged data sets were used to develop a new set of equations and factors, which are discussed herein. These new emission factors unify the methodology employed by boatbuilders and non-boatbuilders for estimating the VOC and HAP emissions from the open molding of composite parts. For this reason, these new emission factors have been named the "Unified Emission Factors" (UEF).

The Unified Emission Factors are not really new - most of the UEF equations and factors are exactly the same as those equations and factors originally described in the 1998 CFA Emission Model report. Instead, the UEF contain several extensions and improvements to the original equations and factors. In some cases, these improvements were developed in cooperation with State EPA officials, in order to cope with the complexities and difficulties encountered in the application of the emissions factors during the permitting of processes at actual reinforced plastics facilities.

To help the reader understand the minor differences between the UEF and the original CFA emissions models, an annotated version of the original 1998 CFA Emission Model report is provided as a separate document. This annotated report is identical to the original report except that those sections that are made obsolete by the UEF are struck through and the reason for the obsolescence is noted within brackets in bold italics. The reader can compare the original report, which is presently still available on the EPA CHIEF website, to the annotated version in order to see the impact of the new UEF.

2.0 Terms and Definitions

Controlled spraying -

Controlled spraying is a method to increase spray material transfer efficiency and reduce styrene emissions for atomized spray application. Wet surface area is a major factor that affects the styrene emission rate. Atomized spray application contributes to increased surface area in two ways. First, a relatively greater amount of atomization is caused by the higher gun tip pressure, because the smaller atomized aerosol particles have a greater relative wet surface area in the spray gun fan pattern. Second, overspray (spray material that travels off-mold) increases the wet surface area. The purpose of controlled spraying is to minimize the wet surface area by reducing the amount of atomization and overspray.

A controlled spraying program consists of the following three elements, which function synergistically to increase gun transfer efficiency and decrease styrene emissions:

***Spray Gun Pressure Calibration* –** provides a procedure to determine the minimum gun tip pressure for any combination of spray equipment, materials, or conditions.

Operator Training - optimizes the operator spraying technique to maximize transfer efficiency and minimize styrene emissions. An operator training program outlines methods for spray gun handling and application techniques focused on reducing overspray and therefore increasing transfer efficiency and decreasing styrene emissions.

***Overspray Containment Flanges* –** reduces overspray through the installation of mold perimeter flanges that limit "off-mold spray" from the edge of the mold. These flanges can be built into the mold, or consist of removable masking around the perimeter of the mold.

Controlled spraying can be introduced in all cases where atomized spray application is currently used. In order to qualify as controlled spraying, all three of the above elements must be in place and documented, as outlined in the "*CFA Controlled Spraying Handbook*."

Covered-cure -

Covered-cover refers to an impervious film or barrier that is applied to the wet surface of the mold just after the application of the resin. This barrier may be applied immediately after the roll-out phase, or just after the application phase without any subsequent roll-out. Once in place, this barrier is assumed to 100% effective at preventing the evaporation and emission of styrene (or other HAP) vapor from the uncured composite laminate. Presumably, the barrier film has no effect whatsoever upon the emissions that occur during the application phase. The covered-cure technique includes vacuum-bagging and press-molding.

Filament application -

In the filament winding process, the resin is applied to a continuous strand of glass roving, which is a rope-like bundle made from fine glass filaments. This glass roving is passed through a dip tank that contains liquid resin. The resin in the dip tank wets the glass, and then the wet roving is tightly wound around a rotating mold, called a mandrel. Filament winding is normally used to make cylindrical FRP parts, such as storage tanks, reaction vessels, duct work, process stacks, and piping.

Gelcoat spray application -

Gelcoat spray application uses a mechanical fluid delivery system to apply gelcoat to the open mold surface. Typically, a pressurized spray gun is used to coat the mold with a fine mist of catalyzed gelcoat aerosol droplets. Note that gelcoat must be applied with atomized spray equipment, and cannot be applied using non-atomized equipment.

Manual application -

Manual application refers to the hand application of resin using a “bucket and tool,”and is generally regarded as the simplest fiberglass lamination process. Dry glass fiber reinforcement, in the form of chopped strand mat, woven roving or cloth fabrics, is first cut and then fitted into or onto the open mold surface. A small precise quantity of catalyst is added to cups or small buckets full of resin, and the catalyzed resin is then quickly poured onto the dry glass reinforcement.

Mechanical atomized application -

Mechanical atomized application uses a mechanical fluid delivery system, such as a spray gun to apply catalyzed resin to the mold or glass reinforcement or a “chopper gun” to simultaneously apply catalyzed resin and chopped glass fibers to the mold surface. Both of these guns atomize the resin stream, forming a fine mist of resin aerosol droplets.

Mechanical non-atomized application -

Mechanical non-atomized application employs a mechanical fluid delivery system to apply resin to the glass reinforcement without atomizing the resin fluid stream. Non-atomized application equipment includes flow coaters, flow choppers, and pressure-fed rollers. Flow coater guns and flow choppers guns are not considered to be “spray guns” due to the absence of spray atomization.

While mechanical non-atomized application can be used in a wide range of production settings, it may not be suitable for all spray application. For example, flow coaters and flow choppers may not be feasible where the material must be projected over a long distance to reach across a large mold surface or into a “deep-draw” mold geometry. Problems have been reported when flow choppers were used to coat vertical mold surfaces. In the case of pressure-fed rollers, roll stock fiberglass must be used, which can greatly complicate the cutting and positioning of glass reinforcement within a complicated mold geometry. Hence, mechanical non-atomized application is not a universal substitute for all mechanical atomized application (which uses standard spray lay-up or “chopper” guns) due to these technical and economic considerations.

Roll-out -

Roll-out refers to a manual operation that uses squeegees, special roller tools, or stiff brushes to spread out the resin applied to the glass reinforcement, smooth down the tangled mass of glass fibers, and remove the air bubbles trapped in the wet glass fibers.

Vapor-suppressed resin -

A vapor-suppressed resin contains a small amount of a vapor suppressant additive, which is usually a wax or wax-like substance. The vapor suppressant is dissolved or dispersed in the resin, and migrates to the surface forming a waxy layer on the still wet resin. This waxy layer inhibits the evaporation of styrene from the curing laminate surface, and works best when the wet surface is left undisturbed. During the application and roll-out phases, the surface is highly disturbed and fresh resin and styrene is continuously exposed to the air, which reduces the effectiveness of the suppressant. Hence, vapor suppressants do not appear to affect the emission rate during the application phase, only partially affect the emission rate during the roll-out phase (because the wet surface is disturbed by the action of the rollers), and fully affect the emission rate during the curing phase.

The type of vapor suppressant should be carefully matched to each resin system - some suppressants seem to work better for a particular resin type than another. Suppressants are reportedly not as effective when used with filled resin systems. The CFA has developed a test protocol called the "*CFA Vapor Suppressant Effectiveness Test Method* " to estimate the emission rates that occur during the roll-out and cure phases of the lamination process. This test will to used to verify the effectiveness of each resin/suppressant combination.

Vapor suppressants cannot be used in all applications, due to serious problems with secondary bonding. Secondary bonding refers to the chemical and mechanical bonds that develop between the successive layers of resin and glass that are applied to the mold to build-up the finished laminate. The vapor suppressant film can decrease the adhesion between these successive laminate layers, causing the structural integrity of the laminate to be weakened. In critical applications, such as storage tanks or other load bearing structures, a laminate bond failure can lead to a catastrophic failure of the structure. Vapor suppressants cannot be used for gel coat application, because nearly all gelcoats require a very strong secondary bond with the subsequent laminate layer.

3.0 New Features of the Unified Emission Factors

The UEF contains the following improvements over the CFA Emission Model released in 1998:

* Default emission factors for styrene contents outside the available data range (33 to 50%)
* Non-atomized application equation
* Controlled spray factor for boatbuilding operations
* Unique vapor-suppressed resin (VSR) factors for specific suppressant/resin formulations
* Covered-cure factor
* Methyl methacrylate (MMA) emission factor

These improvements are discussed in the following six sections.

3.1 "Default" factors for styrene contents outside the available data range

During the initial development of the original CFA Model, the CFA did not recommend extrapolating the emission factor equations for resin and gelcoat formulations with styrene contents outside the range of available test data, which was approximately 33% to 50% styrene content by weight. However, several resins formulations with monomer contents below 33% have been developed recently, and these resins are now commercially available. Very limited emission test data is available for these low styrene content formulations.

As a practical matter, conservative emission factors must be recommended to include these low-content formulations. Otherwise, the emission factor approach would not have be inclusive enough to be useful as a practical regulatory tool. Several State EPA regulatory officials recognized this problem and suggested a reasonable compromise approach for incorporating these new low-styrene formulations in the absence of actual data, as follows:

> For materials with styrene contents **below 33%**, the fixed emission factor at the 33% endpoint, expressed as the percentage of available styrene monomer, is applied to the available styrene content in the low-content formulation.
>
> For materials with styrene contents **above 50%**, the current UEF equations are simply extrapolated using the corresponding monomer content value. Extrapolation is recommended in this case, because the fixed emission factor approach would result in less conservative factors for materials with contents above 50%.

The UEF equations for Manual, Mechanical Atomized, and Gelcoat application are plotted in **Figure 1**, **Figure 2**, and **Figure 3** respectively. These figures show the relationship between styrene emissions and styrene content, and project the new recommended emission rates for materials with styrene contents below 33% and above 50%. Furthermore, all of the available data points from the available emission reports (CFA, NMMA, and RTI) are also plotted over the corresponding linear curves to show the scatter of the available data. The RTI data was taken from Appendix E of the September 1985 draft RTI report entitled "*Evaluation of Pollution Prevention Techniques to Reduce Styrene Emissions from Open Contact Molding Processes*."

Figure 1 - UEF Manual Equation with Scatter Plot of Available Data

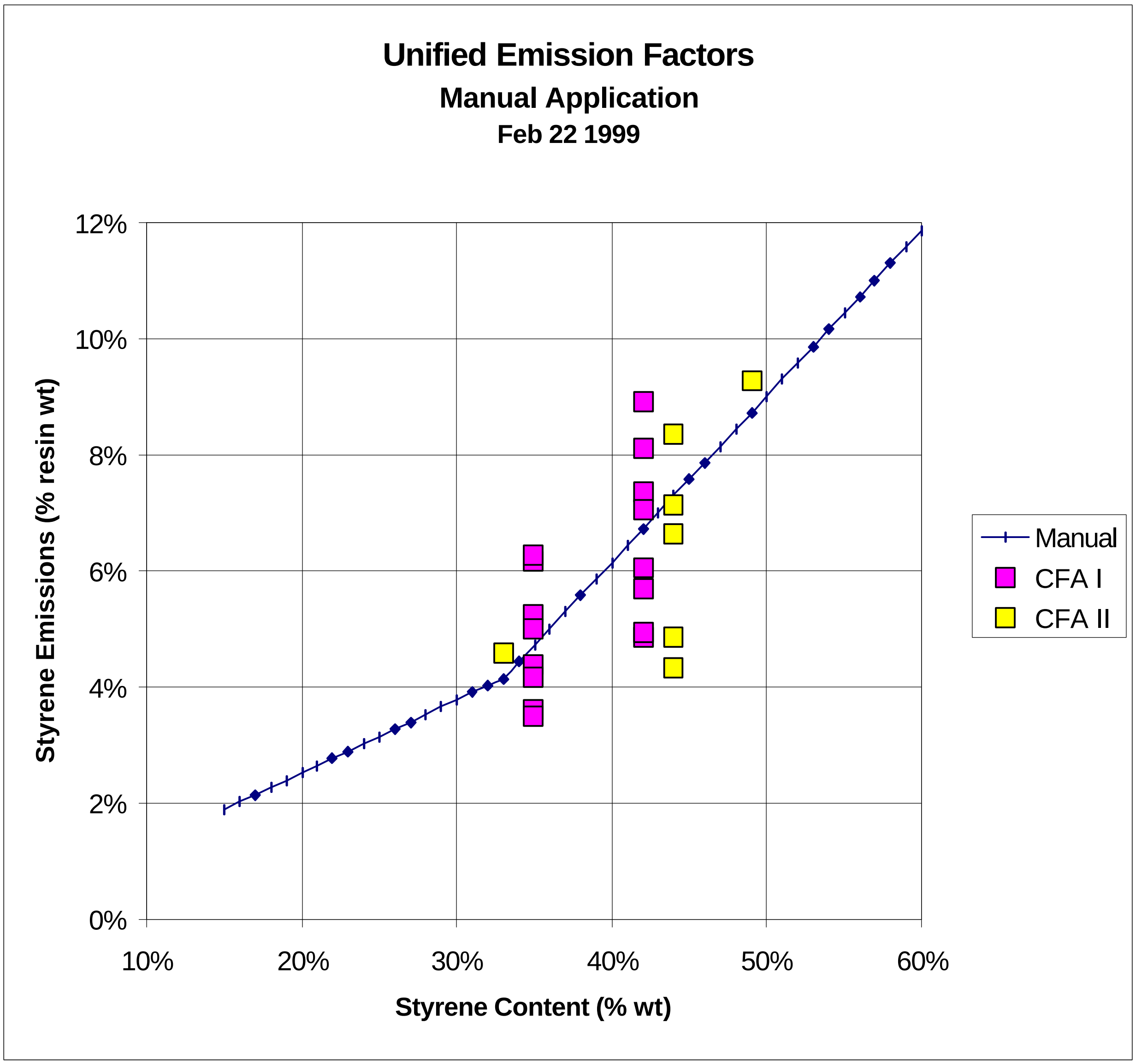


Figure 2 - UEF Mechanical Atomized Equation with Scatter Plot of Available Data

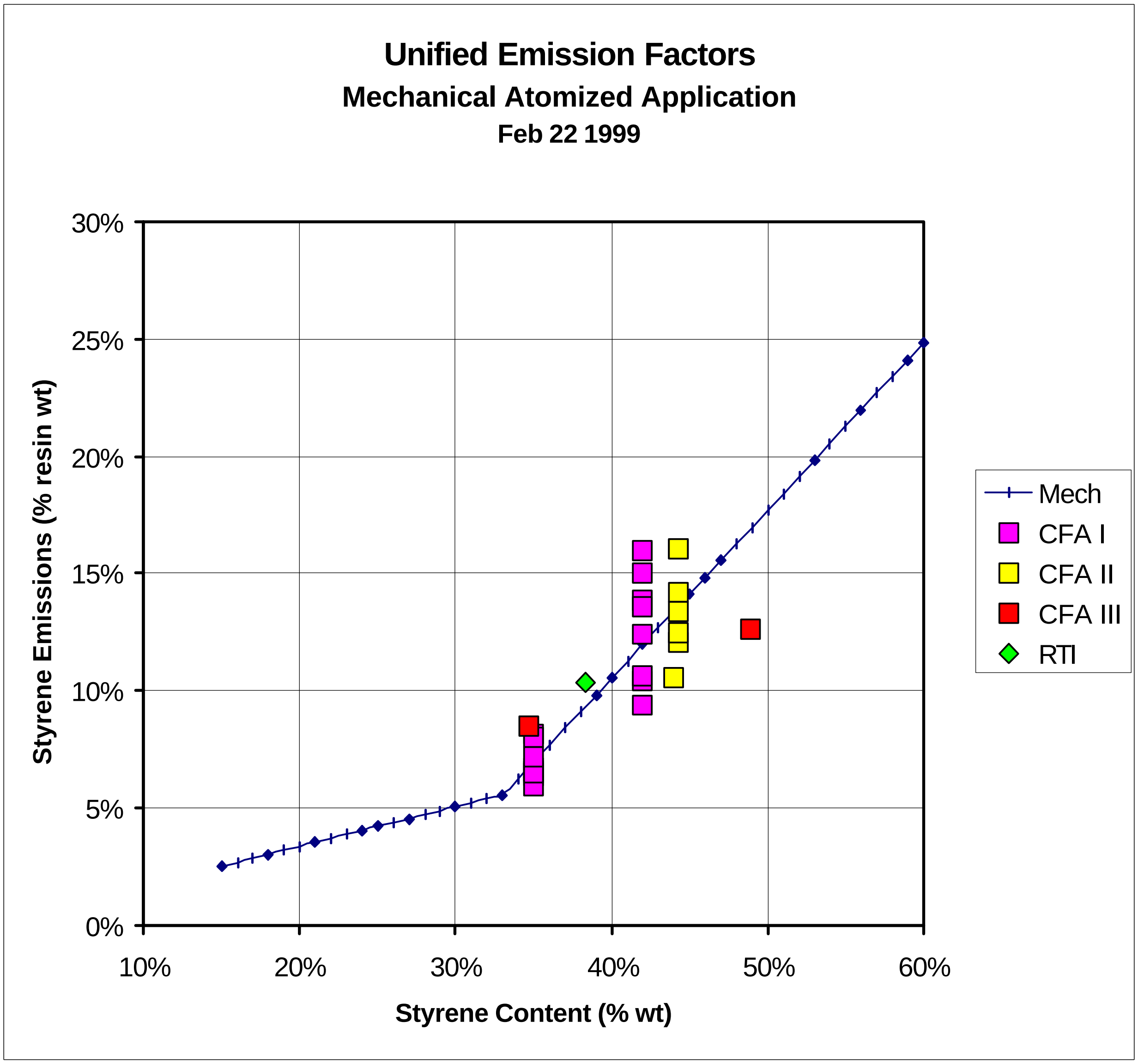
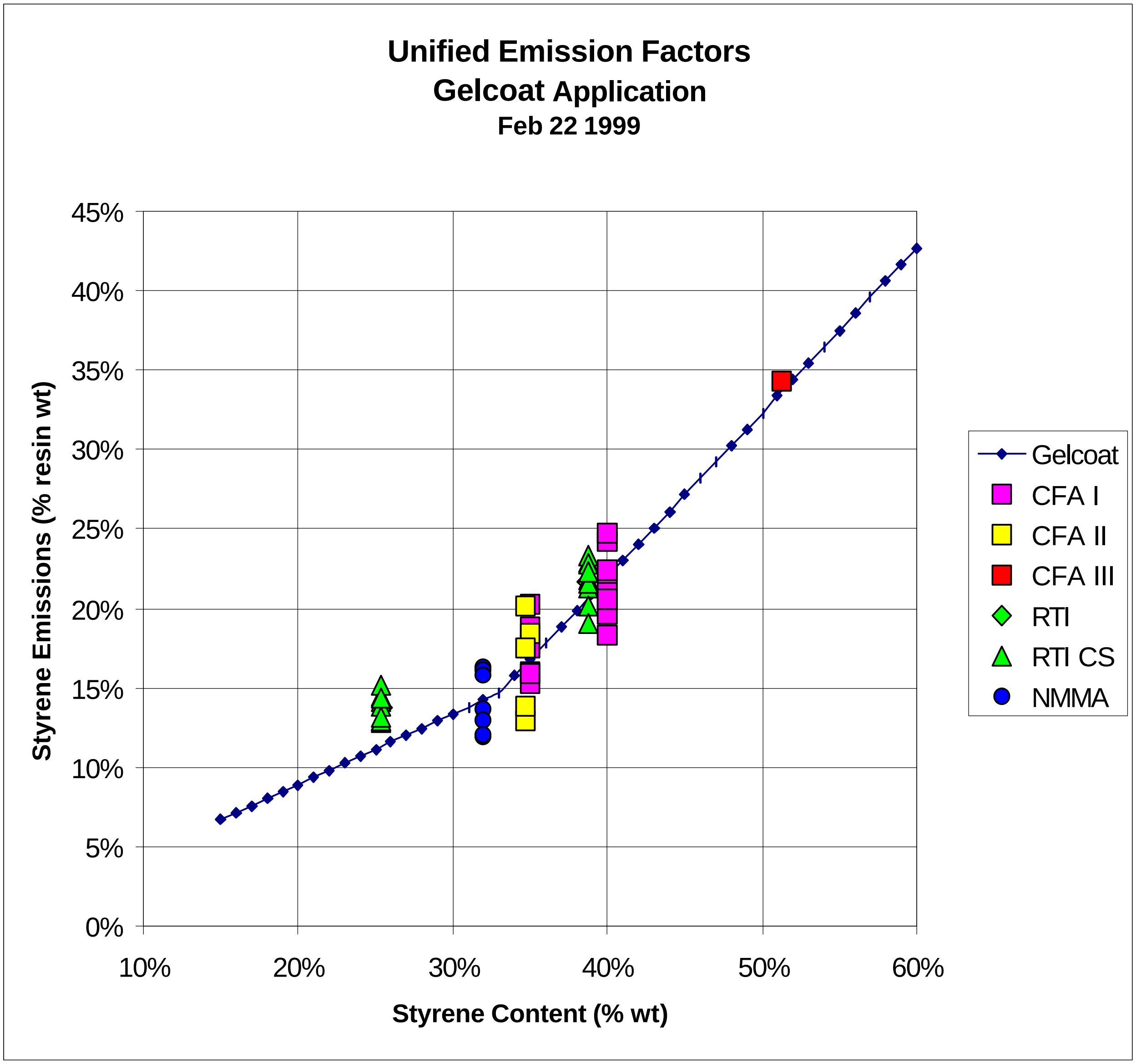


Figure 3 - UEF Gelcoat Equation with Scatter Plot of Available Data



3.2 Non-atomized application equation

A limited amount of styrene emission test data was available for estimating emissions from flow coaters and pressure-fed rollers when the initial emission factor for Mechanical Non-Atomized application was first developed by the CFA in late 1997. After the CFA and NMMA data sets were merged in November 1998, the additional non-atomized mechanical data collected by the NMMA was combined with the available CFA data to produce a new and more accurate equation for the Mechanical Non-Atomized application of resin:

$$\text{styrene emission rate (lb/lb)} = 0.157 \times (\%\ \text{styrene}) - 0.0165$$

The new NMMA non-atomized data set is listed in **Table 1**, and the associated linear regression analysis of the merged (CFA and NMMA) data is shown in **Table 2**. The corresponding UEF equation for Mechanical Non-Atomized application is plotted in **Figure 4** on page 11. Note how well the new equation fits the available data points.

3.3 Controlled spray factor for boatbuilding operations

The CFA controlled spray program is described in the September1998 CFA report entitled "*Controlled Spraying Handbook - Composites Open Molding Spray Applications*." According to the CFA report, an effective controlled spray program has three requirements:

* Close containment of overspray by mold flanges
* Spray gun pressure calibration
* Spray operator training

The NMMA emissions testing investigated the emissions from the spray lay-up (Mechanical Atomized application) of large boat parts. The geometry of the large concave boat molds used in the NMMA testing minimized the resin overspray without special mold flanges. Moreover, the spray gun pressures during the NMMA testing were reportedly optimized in accordance with the CFA controlled spray guidelines, and the spray gun operators were well trained and experienced in good work practices for minimizing spray gun emissions. Therefore, the spray lay-up process tested by the NMMA was actually the Mechanical Controlled Spray application process.

The NMMA test data strongly supports the accuracy of the controlled spray factor used to modify the UEF Mechanical Atomized equation. The near perfect agreement between the NMMA data and the UEF equation for Mechanical Controlled Spray is shown in **Figure 5**. The NMMA data validates the effectiveness of controlled spray, and suggests that the fabrication of large boat parts, with proper gun calibration and operator training, is inherently "controlled" due to the geometry of the boat molds.

Table 1 - NMMA Mechanical Non-Atomized Application Data

RUN #	NMMA #	PROCESS	PART	HAP CONTENT		
					(% sty)	(% resin)
410-01	14-1	Non-Atomized	18 ft Deck	35.1%	11.1%	3.9%
411-02	14-2	Non-Atomized	18 ft Deck	35.1%	12.1%	4.2%
410-02	13-1	Non-Atomized	18 ft Hull	35.1%	10.5%	3.7%
411-03	13-2	Non-Atomized	18 ft Hull	35.1%	10.5%	3.7%
415-01	16-1	Non-Atomized	18 ft Deck	42.2%	12.2%	5.1%
416-01	16-2	Non-Atomized	18 ft Deck	42.2%	14.0%	5.9%
416-02	15-2	Non-Atomized	18 ft Hull	42.2%	10.6%	4.5%
415-02	15-1	Non-Atomized	18 ft Hull	42.2%	11.6%	4.9%

Table 2 - Linear Regression of Mechanical Non-Atomized Application Data

33.7%	9.9%	3.3%
33.7%	12.5%	4.2%
33.7%	9.8%	3.3%
35.1%	10.5%	3.7%
35.1%	10.5%	3.7%
35.1%	11.1%	3.9%
35.1%	12.1%	4.2%
42.1%	10.3%	4.4%
42.2%	11.6%	4.9%
42.2%	14.0%	5.9%
42.2%	12.2%	5.1%
42.2%	10.6%	4.5%
44.4%	11.6%	5.2%
44.4%	12.9%	5.7%
44.4%	11.4%	5.1%
EXCLUDED:		
42.1%	7.6%	3.2%
48.9%	18.4%	9.0%

Regression Output:		
Constant		-0.01648
Std Err of Y Est		0.004418
R Squared		0.732541
No. of Observations		15
Degrees of Freedom		13
X Coefficient(s)	0.15675	
Std Err of Coef.	0.026269	

0.157 x %Styrene - 0.0165
recommended model

Figure 4 - UEF Mechanical Non-Atomized Equation with Scatter Plot of Available Data

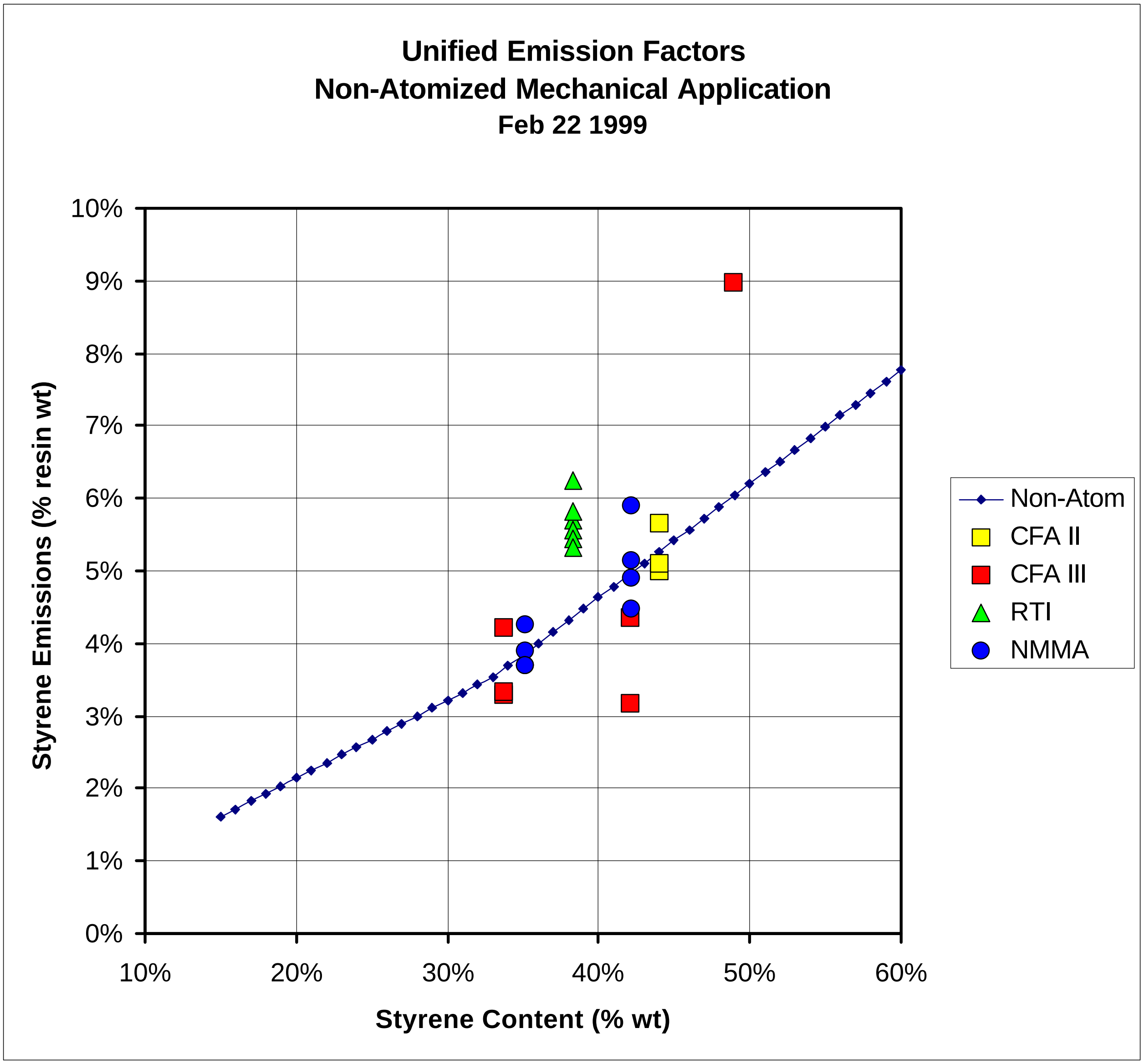
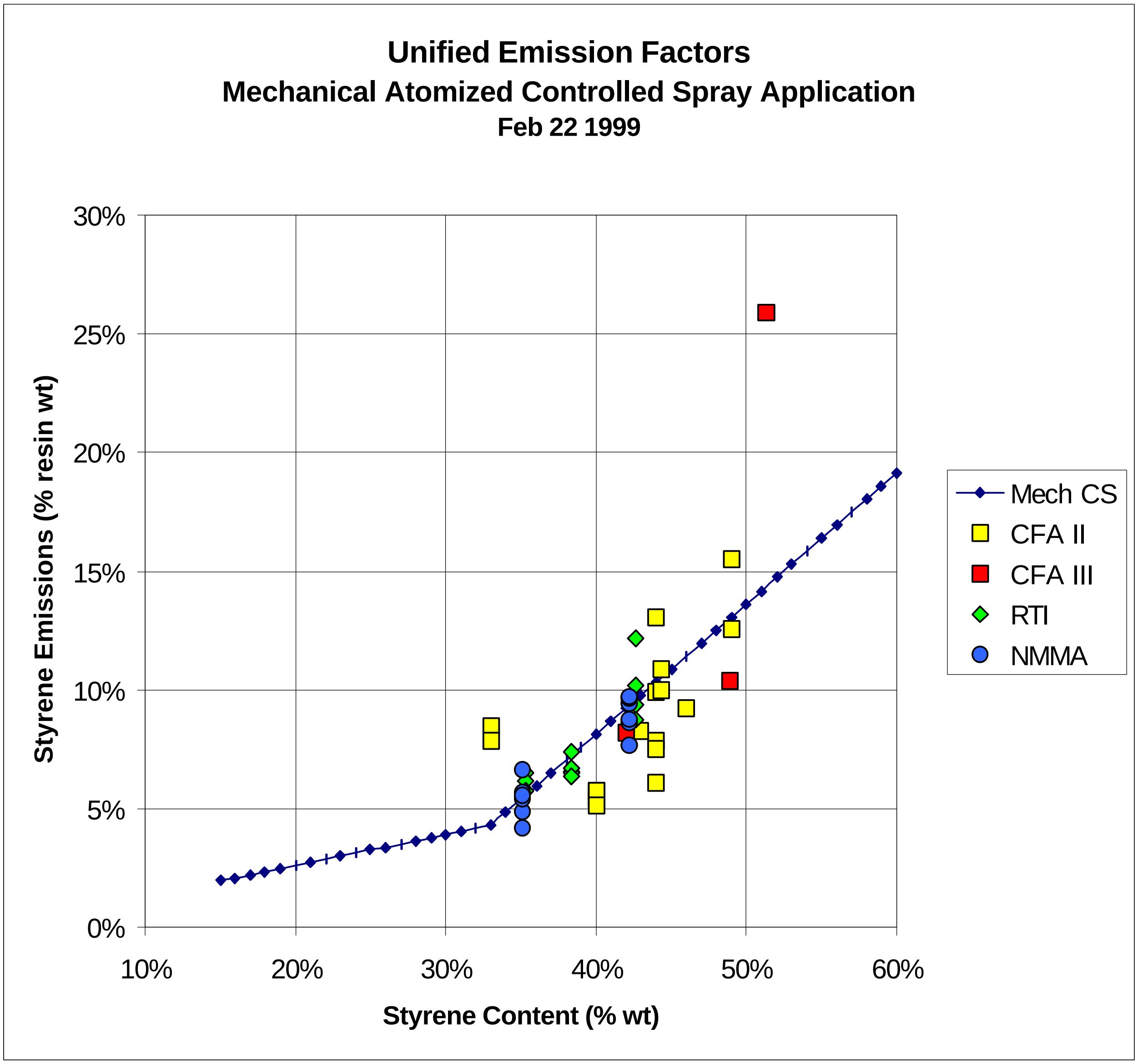


Figure 5 - UEF Mechanical Controlled Spray Equation w/ Scatter Plot of Available Data



3.4 Unique vapor-suppressed resin factors for specific resin formulations

In 1998, Reichhold conducted a series of emission tests for several different resins types that included dicyclopentadiene (DCPD), isophthalic, vinyl ester, terephthalic, and bisphenol resins. The purpose of these tests was to investigate the effect of vapor suppressants on a wide assortment of resin types and formulations. Reichhold used the *CFA Vapor Suppressant Effectiveness Test Method* developed by the CFA as part of the reinforced plastics industry MACT proposal.

As shown in **Figure 6**, the Reichhold testing revealed a wide variation in the effectiveness of vapor suppressants for the different resin types tested by Reichhold. Moreover, the effectiveness of vapor suppressants appeared to decrease for the same type of resin at a higher styrene monomer content. For example, a 33% styrene content vapor-suppressed DCPD resin had an emission reduction factor of about 65%, but a 48% styrene content vapor-suppressed DCPD resin only had about a 14% reduction factor. When a thixotropic agent was added to the 33% styrene content vapor-suppressed DCPD resin, the reduction factor fell from 65% to nearly zero. The Reichhold vapor suppressant data suggests that the effect of vapor suppressant may be strongly affected by resin type, resin additives, and monomer content.

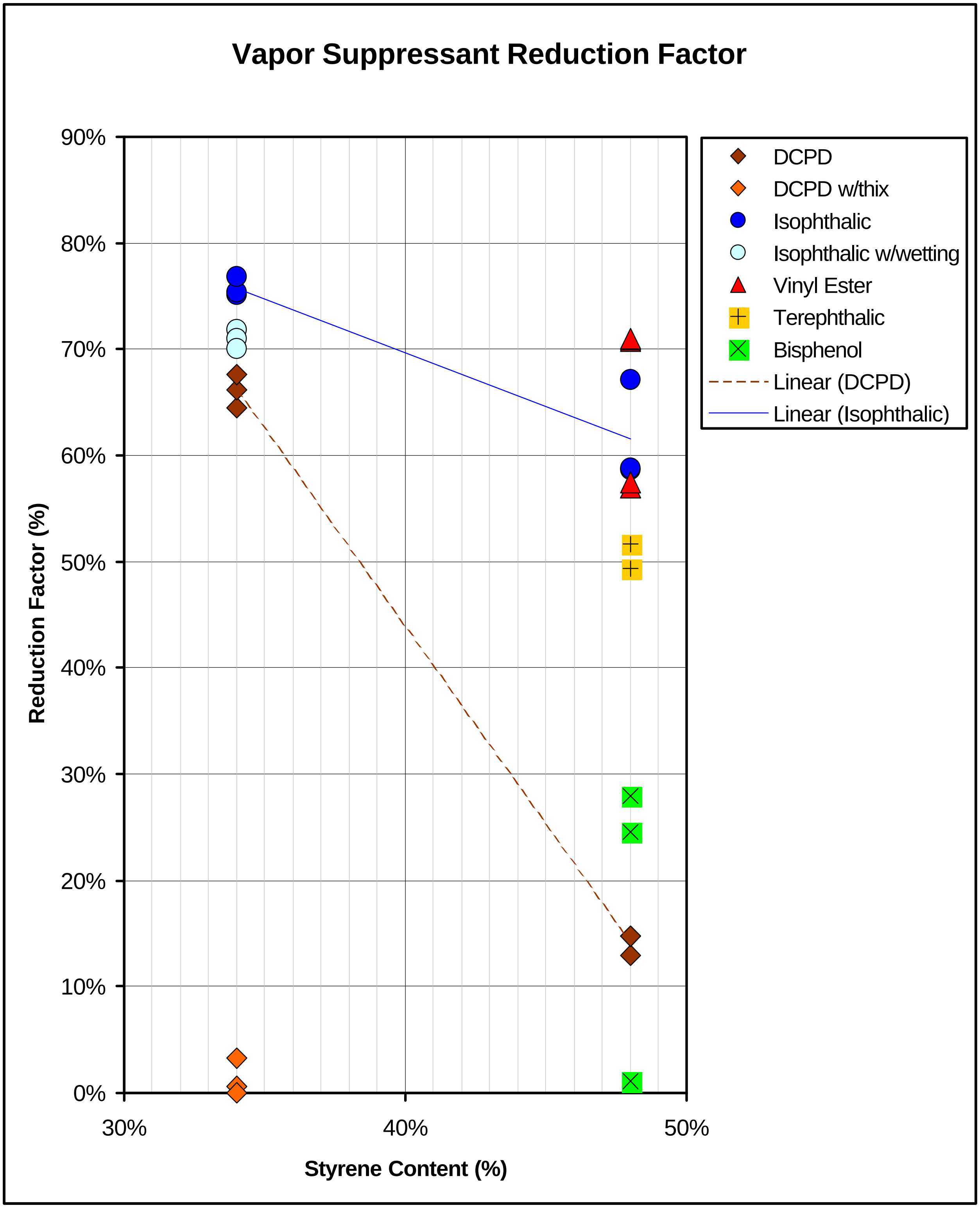
Based on the vapor suppressant data that was available in 1997, the original CFA Emission Model assumed that a linear equation would predict the effect of vapor-suppressed resins on emissions from Manual application of resin, and fixed reduction factors were suitable for Mechanical Atomized, and Mechanical Non-Atomized application of vapor-suppressed resins. The results of the recent Reichhold testing now question these original assumptions.

To resolve this apparent problem, the UEF now utilizes unique emission factors for each resin/suppressant formulation. These unique factors will be developed from actual emission data test. The vapor-suppressed resin emission factors incorporated into the UEF are based on the following assumptions:

* The total emission rate predicted for the non-suppressed process (Manual, Mechanical Atomized, or Mechanical Non-Atomized) are modified by the results of the *CFA Vapor Suppressant Reduction Test* method for each specific resin/suppressant formulation.
* The contributions to the total emission rate for each emission phase generally conform to the partitioning observed during the CFA Phase I testing. The details of this partitioning of emissions are discussed in the following section.
* No (0%) suppressive effect occurs during the application emission phase.
* Full (100%) suppressive effect occurs during the roll-out and cure emission phases.

The different emission phases and the average contribution of each phase to the total emissions are described in the next section.

Figure 6 - Reichhold data for Vapor Suppressant Reduction Effect



Gelcoat is not usually vapor-suppressed, because the suppressant film would interfere with the bond between the gelcoat layer (usually the first layer applied to the mold surface) and the subsequent laminate layers. For this reason, vapor-suppressed gelcoat application is not included in the UEF.

Emission phases - three distinct emission phases were observed during the open molding lamination test runs conducted by the CFA. These three emission phases consisted of:

Application
Roll-out
Cure

Partitioning of total emissions by emission phase - several of the emission profiles (which are continuous plots of the outlet styrene concentration versus the elapsed time) recorded during the CFA test runs were averaged together to produce a "typical" emission profile for each application type. Plots of the typical emission profiles for Mechanical application and Manual application are shown in **Figure 7** and **Figure 8**, respectively. These typical profiles were integrated to estimate the percentage of total emissions that occurs during each emission phase as follows:

Mechanical Application	
Spray application	55 %
Roll-out	30 %
Cure	15 %
Manual Application	
Bucket and tool application	50 %
Roll-out	30 %
Cure	20 %

Practically all of the commercially-available vapor suppressants reduce styrene emissions by forming an impervious waxy film on the wet, uncured resin surface. This waxy film is only effective when the surface is undisturbed. Therefore, suppressants do not affect emissions during the application phase, only partially affect emissions during the roll-out phase (because the wet surface is disturbed by the action of the rollers), and completely affect emissions during the curing phase. The *CFA Vapor Suppressant Effectiveness Test Method* is designed to measure the emissions that occur during the roll-out and cure phases of the lamination process.

Mechanical Application Example

$$\underbrace{50\%}_{\text{VSR reduction factor (from test)}} \times \underbrace{(30\% + 15\%)}_{\text{rollout \& cure contribution}} + 100\% \times \underbrace{(55\%)}_{\text{application contribution}} = \underbrace{77\%}_{\text{specific UEF VSR factor}}$$

Manual Application Example

$$\underbrace{50\%}_{\text{VSR reduction factor (from test)}} \times \underbrace{(30\% + 20\%)}_{\text{rollout \& cure contribution}} + 100\% \times \underbrace{(50\%)}_{\text{application contribution}} = \underbrace{75\%}_{\text{specific UEF VSR factor}}$$

Figure 7 - Emission Phases during Mechanical Application (from CFA Phase I Data)

Average Emissions Profile - All Hand Lay-Up Runs

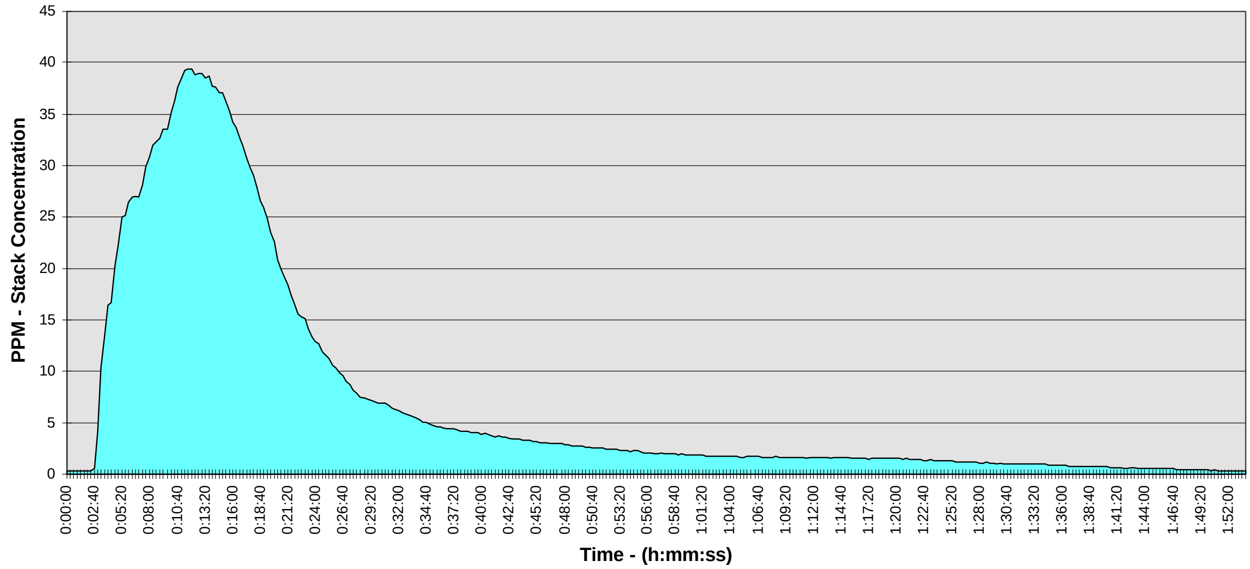
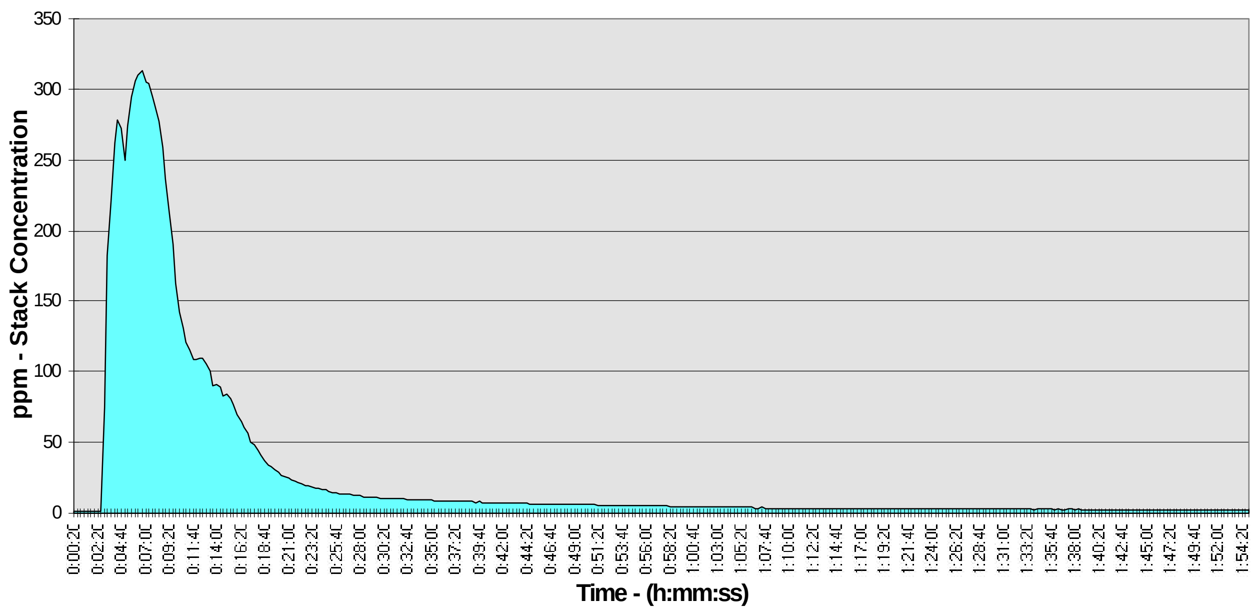


Figure 8 - Emission Phases during Manual Application (from CFA Phase I Data)

Average Emissions Profile - All Spray-Up Runs



3.5 Covered-cure factor

The term “covered cure” refers to an impervious barrier that is placed over the wet surface of the open mold. This barrier may be applied immediately after the roll-out phase, or just after the application phase without any subsequent roll-out. Once in place, this barrier is assumed to 100% effective at preventing the evaporation and emission of styrene (or other HAP) vapor from the uncured composite laminate. Presumably, the barrier film has no effect whatsoever upon the emissions that occur during the application phase.

If the barrier film is applied just after the application phase (Manual or Mechanical), the covered-cure factor is based on the following assumptions, which are very similar to the assumptions made for vapor-suppressants:

* the contributions to the total emissions of each emissions phase (application, roll-out, and cure) are based on partitioning observed during the CFA Phase I testing for Manual and Mechanical application (discussed above)
* no (0%) suppressive effect occurs during the application phase
* full (100%) suppressive effect occurs during the roll-out and cure phases

If the barrier film is applied after the roll-out phase (Manual or Mechanical), the covered-cure factor is based on the following assumptions:

* the contributions to the total emissions of each phase are based on CFA testing
* no (0%) suppressive effect occurs during the application and roll-out phases
* full (100%) suppressive effect only occurs during the cure phase

Based on these assumptions, the “post-application” closed cure factors are equal to:

for manual application -	Non-VSR process factor × 0.50
for mechanical application -	Non-VSR process factor × 0.55

and the “post-roll-out” closed cure factors are equal to:

for manual application -	Non-VSR process factor × 0.80
for mechanical application -	Non-VSR process factor × 0.85

3.6 *Methyl methacrylate (MMA) emission factor*

Methyl methacrylate (MMA) is a colorless liquid with an acrid, fruity odor, and has the following properties:

CAS registry number	80-62-6
molecular formula	$CH_2C(CH_3)COOCH_3$
vapor pressure	30 mm Hg at 20 °C and 40 mm Hg at 25.5 °C

The greater vapor pressure of MMA makes it much more volatile than styrene. For this reason, a relatively small amount of MMA content can cause a disproportionately larger amount of MMA emissions when compared to styrene.

MMA is readily polymerized to form polymers or copolymers that find widespread use in the manufacture of plastics, coatings, dental restorations and surgical implants. MMA is sometimes present as a secondary monomer in the gelcoats and speciality resins used at reinforced plastics facilities. The MMA is added to resin and gelcoat formulations to increase the UV-resistance, improve the surface finish, and to impart greater toughness.

MMA is both a VOC and a listed HAP, and can be a significant part of the total HAP emissions from reinforced plastics facilities, especially from gelcoating operations that incorporate MMA-based resins. Hence, MMA emissions are subject to the provisions of Section 112, and should be estimated separately from styrene emissions.

The CFA test program only investigated styrene emissions from resins and gelcoats that did not contain any MMA. The testing conducted by RTI (EPA contractor) also only investigated styrene emissions. Fortunately, the NMMA testing included a typical gelcoat formulation that contained 32% styrene and 5% MMA by weight of resin. The NMMA testing reported the following MMA emission rate values for three test runs using this formulation:

73.2% of MMA content
75.6% of MMA content
78.6% of MMA content

Based upon these three NMMA test runs, a fixed emission factor of 75%, expressed as a percentage of available MMA, is recommended for spray operations that use materials that contain MMA. This factor should by applied to the amount of available MMA monomer to determine the corresponding amount of MMA emissions.

4.0 Instructions and Examples for the UEF Table

A simple tabular format has been developed by the CFA to encapsulate the new UEF information on one sheet of paper. This tabular format is called the "UEF Table," and is shown in **Table 3** on page 23.

This section contains instructions for using the UEF Table to find the proper emission factor for a specific resin or gelcoat material and application process. Instructions are also provided for estimating the total emission rate for an entire FRP facility. Several examples are included to illustrate these instructions.

How to find the proper emission factor using the UEF Table

Before using the UEF Table, the following information must be obtained:

Styrene content of the resin/gelcoat material

The styrene content of the resin/gelcoat materials can be obtained from the associated MSDS information, the Q/A certification sheet sent with most bulk resin shipments, or by calling the resin supplier or manufacturer. Occasionally, the MSDS will specify a broad range for the styrene content, such as 20 to 50% styrene by weight. This is a short-cut used by the resin supplier to avoid listing more specific information for each resin formulation. The average value for such a broad range (average 35% for the example above) should not be used. Instead, the resin supplier should be asked to provide more precise estimates of the actual monomer contents for each material.

Application process used to apply the material

The correct application process must be identified from the following major types; Manual, Mechanical Atomized, Mechanical Non-Atomized, Filament, or Gelcoat Spraying.

Vapor-suppressant data - the VSR reduction factor (if used)

Determine if vapor suppressant is added to the resin formulation. If so, the VSR reduction factor for that specific resin/suppressant mixture must be obtained from the resin supplier, or must be determined at the plant according to procedures detailed in the *CFA Vapor Suppressant Effectiveness Test* (this test protocol is available from the CFA).

Special pollution prevention techniques (if used)

Determine if Controlled Spraying and/or Covered-Cure are used with any of the application processes.

Now with this information at hand, refer to the UEF Table on the following page.

Table 3 - Unified Emission Factor (UEF) Table

Unified Emission Factors for Open Molding of Composites

Emission Rate in Pounds of Styrene Emitted per Ton of Resin or Gelcoat Processed

Application Process

Styrene content in resin/gelcoat, % [1]	<33 [2]	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	>50 [2]
Manual	0.126 x %styrene x 2000	83	89	94	100	106	112	117	123	129	134	140	146	152	157	163	169	174	180	((0.286 x %styrene) - 0.0529) x 2000
Manual w/ Vapor Suppressed Resin VSR [3]	**Manual emission factor** [listed above] x (1 - (0.50 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Atomized	0.169 x %styrene x 2000	111	126	140	154	168	183	197	211	225	240	254	268	283	297	311	325	340	354	((0.714 x %styrene) - 0.18) x 2000
Mechanical Atomized with VSR [3]	**Mechanical Atomized emission factor** [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Atomized Controlled Spray [4]	0.130 x %styrene x 2000	86	97	108	119	130	141	152	163	174	185	196	207	218	229	240	251	262	273	0.77 x ((0.714 x %styrene) - 0.18) x 2000
Mechanical Controlled Spray with VSR	**Mechanical Atomized Controlled Spray emission factor** [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Non-Atomized	0.107 x %styrene x 2000	71	74	77	80	83	86	89	93	96	99	102	105	108	111	115	118	121	124	((0.157 x %styrene) - 0.0165) x 2000
Mechanical Non-Atomized with VSR [3]	**Mechanical Non-Atomized emission factor** [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Filament application	0.184 x %styrene x 2000	122	127	133	138	144	149	155	160	166	171	177	182	188	193	199	204	210	215	((0.2746 x %styrene) - 0.0298) x 2000
Filament application with VSR [3]	0.120 x %styrene x 2000	79	83	86	90	93	97	100	104	108	111	115	118	122	125	129	133	136	140	0.65 x ((0.2746 x %styrene) - 0.0298) x 2000
Gelcoat Application	0.445 x %styrene x 2000	294	315	336	356	377	398	418	439	460	481	501	522	543	564	584	605	626	646	((1.03646 x %styrene) - 0.195) x 2000
Gelcoat Controlled Spray Application [4]	0.325 x %styrene x 2000	215	230	245	260	275	290	305	321	336	351	366	381	396	411	427	442	457	472	0.73 x ((1.03646 x %styrene) - 0.195) x 2000
Covered-Cure after Roll-Out	**Non-VSR process emission factor** [listed above] x (0.80 for Manual <or> 0.85 for Mechanical)																			
Covered-Cure without Roll-Out	**Non-VSR process emission factor** [listed above] x (0.50 for Manual <or> 0.55 for Mechanical)																			

Emission Rate in Pounds of Methyl Methacrylate Emitted per Ton of Gelcoat Processed

MMA content in gelcoat, % [6]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	≥20
Gel coat application [7]	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	0.75 x %MMA x 2000

Notes

1. Including styrene monomer content as supplied, plus any extra styrene monomer added by the molder, but before addition of other additives such as powders, fillers, glass,...etc.
2. Formulas for materials with styrene content < 33% are based on the emission rate at 33% (constant emission factor expressed as percent of available styrene), and for styrene content > 50% on the emission rate based on the extrapolated factor equations; these are not based on test data but are believed to be conservative estimates. The value for "% styrene" in the formulas should be input as a fraction. For example, use the input value 0.30 for a resin with 30% styrene content by weight.
3. The VSR reduction factor is determined by testing each resin/suppressant formulation according to the procedures detailed in the ***CFA Vapor Suppressant Effectiveness Test.***
4. See the ***CFA Controlled Spray Handbook*** for a detailed description of the controlled spray procedures.
5. The effect of vapor suppressants on emissions from filament winding operations is based on the ***Dow Filament Winding Emissions Study.***
6. Including MMA monomer content as supplied, plus any extra MMA monomer added by the molder, but before addition of other additives such as powders, fillers, glass,...etc.
7. Based on gelcoat data from ***NMMA Emission Study***

Instructions for using the UEF Table

Step 1 Find the correct application process in the leftmost column of the UEF Table

Step 2 Find the correct styrene content across the top row of the UEF Table.

Step 3 Locate the cell at the intersection of the selected row and column. This cell contains the correct emission factor (in units of pounds styrene emitted per ton of material applied) that corresponds to the application process and styrene content of the resin/gelcoat material applied. In the following cases, the intersecting cell will contain an equation instead of a value. If the styrene content is lower than 33% by weight, use the equation in the second to the leftmost column to compute the emission rate. If the styrene content is greater than 50% by weight, use the equation in the rightmost column to compute the emission rate. For both equations, the styrene content value should be input as a fraction. For example, use the input value "0.42" to represent 42%.

Step 4 (*for vapor-suppressed resins*). If vapor-suppressed resins are used, the basic emission factor for the corresponding non-vapor-suppressed application process is first determined. Then, the VSR reduction factor for that specific resin/suppressant mixture and the corresponding non-vapor-suppressed process emission factor are inserted into the corresponding vapor-suppressed emission equation in the UEF Table.

Step 5 (*for non-suppressed resins that use the covered-cure technique*). The appropriate covered-cure factor depends on whether the covering is placed after the wet laminate is rolled-out, or whether the covering is applied directly to the wet laminate without any roll-out. The covered-cure factor is multiplied by the corresponding non-VSR application process emission factor as shown in the VSR Table. The effect of vapor suppressant is not allowed, because the impervious cover takes the place of the waxy surface film formed by the vapor suppressant.

Examples

<u>Example 1</u> - Manual Application of a Standard Production Resin

This example assumes typical manual application (using a bucket and brush) of a standard 40% styrene content production resin. The correct application type in the UEF Table is the row labeled "Manual," and the correct styrene content is the column labeled "40." The intersecting cell contains the value "123," so the emission factor is **123** pounds of styrene emitted per ton of resin applied.

<u>Example 2</u> - Mechanical Atomized Application of a Standard Production Resin

This example assumes typical mechanical atomized application (using a standard atomizing chopper gun) of a standard 40% styrene content production resin. The application type in the UEF Table is the row labeled "Mechanical Atomized," and the styrene content is the column labeled "40." The intersecting cell contains the value "211," so the emission factor is **211** pounds of styrene emitted per ton of resin applied.

<u>Example 3</u> - Mechanical Controlled Spray Application of a High-Styrene Content Resin

This example assumes mechanical atomized application (using a standard atomizing chopper gun) of a high 55% styrene content specialty tooling resin. However in this example, the facility has adopted the CFA Controlled Spray program and has trained the chopper gun operators accordingly. Hence, the correct application type in the UEF Table is the row labeled "Mechanical Controlled Spray," and the correct styrene content is the column labeled "> 50." The intersecting cell contains the equation **"0.77 x (0.714 x %styrene - 0.18) x 2000"** so the emission factor is computed as follows:

$0.77 \times (0.714 \times 0.55 - 0.18) \times 2000 =$ **328** pounds of styrene emitted per ton of resin applied

<u>Example 4</u> - Mechanical Non-Atomized Application of a Vapor-Suppressed Resin

This example assumes mechanical non-atomized application (using a special flowcoating applicator gun) of a 42% styrene content vapor-suppressed resin. The resin supplier tested the resin/suppressant mixture according to the procedures detailed in the *CFA Vapor Suppressant Effectiveness Test*, and thereby determined that this specific suppressed resin formulation had a VSR reduction factor of 0.70. The correct application type in the UEF Table is the row labeled "Mechanical Non-Atomized w/ VSR," which contains the equation "**Mechanical Non-Atomized emission factor x (1 - 0.45 x specific VSR reduction factor)**" that references another row labeled "Mechanical Non-Atomized." The correct styrene content is the column labeled "42." The intersecting cell for "Mechanical Non-Atomized" and "42" styrene content contains the value "99." Therefore, the correct emission factor for non-atomized application of this specific vapor-suppressed resin is computed as follows:

$99 \times (1 - 0.45 \times 0.70) =$ **68** pounds of styrene emitted per ton of resin applied

<u>Example 5</u> - Spray Application of a Low-Styrene Gelcoat that contains some MMA

This example assumes spray application (using a standard atomizing gelcoat spray gun) of a 28% low-styrene gelcoat that also contains 10% MMA. The correct application type in the UEF Table is the row labeled "Gelcoat Spray Application," and the correct styrene content is the column labeled "< 33." The intersecting cell for "Gelcoat Spray Application" and "< 33" styrene content contains the equation "**0.445 x %styrene x 2000**." Therefore, the correct emission factor for the spray application of this low-styrene gelcoat is computed as follows:

$0.445 \times 0.28 \times 2000 =$ **249** pounds of <u>styrene</u> emitted per ton of gelcoat applied

The MMA emissions are calculated separately according to the lower section of the UEF Table. A gelcoat with a MMA content of 10% corresponds to a MMA emission factor of **150** pounds of <u>MMA</u> emitted per ton of gelcoat applied. Based on content, the MMA has a much higher relative emission rate than the styrene monomer, due to the higher vapor pressure of the MMA.

The total HAP emissions for this example is 249 + 150 = **399** pounds of <u>HAP</u> per ton of gelcoat.

<u>Example 6</u> - Controlled Spray Application of a High-Styrene Content Gelcoat

This example assumes spray application (using a standard atomizing gelcoat spray gun) of a high 52% styrene content tooling gelcoat. However in this example, the facility has adopted the CFA Controlled Spray program and has trained the gelcoat gun operators accordingly. Hence, the correct application type in the UEF Table is the row labeled "Gelcoat Controlled Spray Application," and the correct styrene content is the column labeled "> 50." The intersecting cell contains the equation "**0.73 x (1.03646 x %styrene - 0.195) x 2000**" so the emission factor is computed as follows:

$0.73 \times (1.03646 \times 0.52 - 0.195) \times 2000 =$ **502** pounds of styrene emitted per ton of gelcoat applied

<u>Example 7</u> - Mechanical Non-Atomized Application of a Low-Styrene Resin with Covered-Cure

This example assumes mechanical non-atomized application (using a special flowcoating applicator gun) of a 29% low-styrene resin and the use of the covered-cure technique applied after the laminate is rolled-out. The correct application type in the UEF Table is the row labeled "Covered-Cure after Roll-Out," which contains the equation "**Non-VSR process emission factor x (0.80 for Manual <or> 0.85 for Mechanical)**." The referenced non-VSR process is the row labeled "Mechanical Non-Atomized." The correct styrene content is the column labeled "< 33." The intersecting cell for "Mechanical Non-Atomized" and "< 33" styrene content contains the equation "**0.107 x %styrene x 2000**." Therefore, the correct emission factor for non-atomized application of this low-styrene resin using covered-cure is computed as follows:

$0.107 \times 0.29 \times 2000 \times (0.85) =$ **53** pounds of styrene emitted per ton of resin applied

How to use the UEF table to determine the emission rate for a FRP facility

The following procedure utilizes a simple spreadsheet to compute the styrene emissions from the lamination operations at an entire FRP facility. A example spreadsheet is shown in **Table 3** on the next page.

Instructions

Step 1 List the amounts of each resin/gelcoat material used in each application process.

List the material type in **Column A**, the process type in **Column B**, and the usage amount (in tons per period) for the reporting period of interest (daily, weekly, monthly, or annual) in **Column C**.

Step 2 List the styrene monomer contents for each resin/gelcoat material

List the styrene content in **Column D**.

Step 3 Determine the corresponding styrene emission factor for each resin/gelcoat material and application process combination by referring to the UEF Table. Follow the instructions given above to determine the

List the styrene emission factor (in units of pounds per ton) in **Column E**.

Step 4 Estimate the styrene emission rate for each resin/gelcoat material and process combination using the equation:

Column C × **Column E** = **Column F**

Step 5 Sum all of the individual material/process emission rates in **Column F** to compute the total styrene emission rate for the entire FRP facility.

Table 4 - Spreadsheet Method to Estimate Emissions from a FRP Facility

Column A Resin/Gelcoat Material Description	Column B Application Process Description	Column C Amount Used in Period	Column D Styrene Content by wt	Column E UEF Table Emission Factor	Column F Styrene Emission Rate
		(ton/period)	(%)	(lb/ton)	(lb/period)
Prod Resin A	Manual	3	42%	134	402
	Mechanical	18	42%	240	4,320
	Non-Atomized	20	42%	99	1,980
Prod Resin B	Manual	2	38%	112	224
	Mechanical	25	38%	183	4,575
	Non-Atomized	45	38%	86	3,870
Tooling Resin	Manual	5	50%	180	900
Prod Gelcoat A	Spray	55	45%	543	29,865
	Controlled Spray	40	45%	396	15,840
Prod Gelcoat B	Spray	30	40%	460	13,800
Tooling Gelcoat	Spray	2	50%	646	1,292
		Total Emission Rate (lb/period)			77,068

5.0 Appendix

This appendix contains the following items:

* CFA Phase II test data - Table 5.

* CFA Phase III test data - Table 6.

* Annotated version of the original 1998 CFA emission model report -.

An annotated version of the original February 28, 1998 CFA model report entitled "*CFA Mission Models for the Reinforced Plastics Industries*" is provided as a separate document to be included at the end of this appendix. This annotated report is identical to the original report except that those sections that are made obsolete by the UEF are ~~struck through~~ and the reason for the obsolescence is noted within brackets in [***bold italics***].

The inclusion of an annotated version of the original report should help to clear up any confusion caused by the introduction of the UEF. The reader can compare the original report, which is presently still available on the EPA CHIEF, to the annotated version provided herein in order to see the impact of the new UEF.

Table 5 - CFA Phase II Test Data

Table No.	Run No.	Data ID	Application Method	Controlled Spray	Vapor Suppressant	Thickness (in)	Gel time (min)	Flow Rate (lb/min)	Air Flow (fpm)	Mold Size	Resin Type	Initiator Type	Styrene Content (% wt)	Styrene Emission (% AS)	Styrene Emission (% resin)
1	1	022697A	Hand Lay-Up	na	Non-VS	0.08	15	na	100	14 ft^2 flat		MEKP	44%	9.9%	4.3%
1	2	022697B	Spray-Up	CS	Non-VS	0.08	15		100	14 ft^2 flat		MEKP	44%	17.9%	7.9%
1	3A	022797A	Flow Chop	na	Non-VS	0.08	15		100	14 ft^2 flat		MEKP	44%	11.4%	5.0%
1	3B	022797B	Flow Chop	na	Non-VS	0.08	15		100	14 ft^2 flat		MEKP	44%	11.6%	5.1%
1	4	022797C	Pressure Roller	na	Non-VS	0.08	15		100	14 ft^2 flat		MEKP	44%	12.9%	5.7%
11	3	030796B	Gelcoating	CS	Non-VS	0.018	11		100	37.28 ft^2 base		MEKP	41%	31.4%	12.7%
4 & 6	1	052996A	Hand Lay-Up	na	Non-VS	0.08	28	na	100	28.08 ft^2 base	GP	MEKP	44%	15.0%	6.6%
4	2	052996B	Hand Lay-Up	na	Non-VS	0.167	28	na	100	28.08 ft^2 base		MEKP	44%	16.1%	7.2%
6	2	053096A	Hand Lay-Up	na	VSR	0.08	28	na	100	28.08 ft^2 base	GP	MEKP	44%	7.0%	3.1%
4 & 6	3	053096B	Hand Lay-Up	na	Non-VS	0.08	28	na	100	28.08 ft^2 base		MEKP	44%	18.8%	8.4%
6	4	060396B	Hand Lay-Up	na	Non-VS	0.08	28	na	100	28.08 ft^2 base	VE-HS	MEKP	49%	19.0%	9.3%
6	5	060496A	Hand Lay-Up	na	VSR	0.08	28	na	100	28.08 ft^2 base	VE-HS	MEKP	49%	7.4%	3.6%
6	6	060496B	Hand Lay-Up	na	VSR	0.08	28	na	100	28.08 ft^2 base	VE-LS	MEKP	33%	8.7%	2.9%
6	7	060596A	Hand Lay-Up	na	Non-VS	0.08	28	na	100	28.08 ft^2 base	VE-LS	MEKP	33%	13.8%	4.6%
6	8	060596B	Hand Lay-Up	na	VSR	0.08	28	na	100	28.08 ft^2 base	VE-LS	MEKP	33%	8.1%	2.7%
5	1	061296A	Spray-Up	CS	Non-VS	0.187	28	4	100	28.08 ft^2 base		MEKP	44%	17.0%	7.5%
5	2	061296B	Spray-Up	norm	Non-VS	0.187	28	4	100	28.08 ft^2 base		MEKP	44%	23.9%	10.6%
5 & 7 & 10	3	061396A	Spray-Up	CS	Non-VS	0.08	28	4	100	37.28 ft^2 base		MEKP	44%	22.3%	9.9%
7	2	061396B	Spray-Up	CS	VSR	0.08	28	4	100	28.08 ft^2 base	GP	MEKP	44%	13.2%	5.8%
4	4	080196A	Hand Lay-Up	na	Non-VS	0.226	28	na	100	28.08 ft^2 base		MEKP	44%	11.0%	4.9%
5	4	080196B	Spray-Up	CS	Non-VS	0.187	28	4	100	28.08 ft^2 base		MEKP	44%	13.8%	6.1%
7	3	080696A	Spray-up	CS	Non-VS	0.08	28	2	100	28.08 ft^2 base	GP	MEKP	44%	29.5%	13.1%
7	4	080796A	Spray-up	CS	VSR	0.08	28	2	100	28.08 ft^2 base	GP	MEKP	44%	22.9%	10.1%
7	5	080896A	Spray-up	CS	Non-VS	0.08	28	2	100	28.08 ft^2 base	VE-LS	MEKP	43%	24.6%	8.3%
7	6	080896B	Spray-up	CS	Non-VS	0.08	28	4	100	28.08 ft^2 base	VE-LS	MEKP	33%	25.0%	8.4%
7	7	081296B	Spray-up	CS	Non-VS	0.08	28	4	100	28.08 ft^2 base	VE-LS	MEKP	33%	23.3%	7.9%
7	8	081396A	Spray-up	CS	VSR	0.08	28	4	100	28.08 ft^2 base	VE-LS	MEKP	33%	12.4%	4.2%
7	9	081396B	Spray-up	CS	VSR	0.08	28	2	100	28.08 ft^2 base	VE-LS	MEKP	33%	18.5%	6.3%
7	10	081596A	Spray-up	CS	Non-VS	0.08	28	2	100	28.08 ft^2 base	VE-HS	MEKP	49%	31.8%	15.5%
7	11	081696A	Spray-up	CS	Non-VS	0.08	28	4	100	28.08 ft^2 base	VE-HS	MEKP	49%	25.7%	12.6%
7	12	081696B	Spray-up	CS	VSR	0.08	28	4	100	28.08 ft^2 base	VE-HS	MEKP	49%	12.4%	6.0%
7	13	082796A	Spray-up	CS	VSR	0.08	28	2	100	28.08 ft^2 base	VE-HS	MEKP	49%	18.9%	9.2%

Table 5 - CFA Phase II Test Data, continued

Table No.	Run No.	Data ID	Application Method	Controlled Spray	Vapor Suppressant	Thickness (in)	Gel time (min)	Flow Rate (lb/min)	Air Flow (fpm)	Mold Size	Resin Type	Initiator Type	Styrene Content (% wt)	Styrene Emission (% AS)	Styrene Emission (% resin)
3	1	082996A	Spray-up	CS	Non-VS	0.16	15		100	28.08 ft^2 base	60% filled	MEKP	46%	21.5%	4.2%
3	2	090496A	Spray-up	CS	Non-VS	0.16	15		100	28.08 ft^2 base	60% filled	MEKP	46%	17.4%	3.4%
3	3	090496B	Spray-up	CS	Non-VS	0.16	15		100	28.08 ft^2 base	30% filled	MEKP	46%	18.9%	6.1%
3	4	090596A	Spray-up	CS	Non-VS	0.16	15		100	28.08 ft^2 base	unfilled	MEKP	46%	20.1%	9.2%
3	5	090596B	Spray-up	CS	VSR	0.16	15		100	28.08 ft^2 base	60% filled	MEKP	46%	17.6%	3.4%
8	1	091796A	Gelcoating	norm	Non-VS	0.018	11	4	100	127.9 ft^2 F		MEKP	35%	37.4%	13.0%
8	5	091796B	Gelcoating	norm	Non-VS	0.018	11	4	100	127.9 ft^2 F		MEKP	35%	39.8%	13.8%
8	2	091896A	Gelcoating	CS	Non-VS	0.018	11	4	100	127.9 ft^2 F		MEKP	35%	31.0%	10.8%
9	1	092596A	Spray-Up	CS	Non-VS	0.08	21	4	100	127.9 ft^2 F		MEKP	44%	22.5%	10.0%
9	2	092596B	Spray-Up	norm	Non-VS	0.08	21	4	100	127.9 ft^2 F		MEKP	44%	27.3%	12.1%
9	5	092696A	Spray-Up	norm	Non-VS	0.08	21	4	100	127.9 ft^2 F		MEKP	44%	28.2%	12.5%
8 & 11	2	101596A	Gelcoating	norm	Non-VS	0.018	11	4	100	127.9 ft^2 M		MEKP	35%	52.8%	18.5%
11	1	101695C	Gelcoating	norm	Non-VS	0.018	11		100	37.28 ft^2 base		MEKP	35%	50.5%	17.5%
8 & 11	4	101696A	Gelcoating	CS	Non-VS	0.018	11	4	100	127.9 ft^2 M		MEKP	35%	41.1%	14.3%
11	5	101795B	Gelcoating	norm	Non-VS	0.018	11		100	37.28 ft^2 base		MEKP	35%	58.0%	20.2%
9 & 10	4	101796A	Spray-Up	CS	Non-VS	0.08	21	4	100	127.9 ft^2 M		MEKP	44%	24.6%	10.9%
9 & 10	4	101796B	Spray-Up	norm	Non-VS	0.08	21	4	100	127.9 ft^2 M		MEKP	44%	30.2%	13.4%
10	1	111695A	Spray-Up	norm	Non-VS	0.08	21		100	37.28 ft^2 base		MEKP	44%	33.1%	14.2%
5	5	120595A	Spray-Up	norm	Non-VS	0.08	28	4	100	28.08 ft^2 base		MEKP	44%	38.0%	16.0%
10	5	120595B	Spray-Up	norm	Non-VS	0.08	21		100	37.28 ft^2 base		MEKP	44%	38.0%	16.0%
2	1	103096A	Spray-Up	CS	Non-VS	0.08	13	4	100	28.08 ft^2 base		BPO	40%	13.3%	5.4%
2	2	103096B	Spray-Up	CS	Non-VS	0.08	13	4	100	28.08 ft^2 base		BPO	40%	14.3%	5.8%
2	3	103096C	Spray-Up	CS	Non-VS	0.08	13	4	100	28.08 ft^2 base		MEKP	40%	13.7%	5.5%
2	4	103196A	Spray-Up	CS	Non-VS	0.08	13	4	100	28.08 ft^2 base		MEKP	40%	13.7%	5.5%
2	5	103196B	Spray-Up	CS	Non-VS	0.08	10	4	100	28.08 ft^2 base		MEKP	40%	14.3%	5.7%
2	6	110696A	Spray-Up	CS	Non-VS	0.08	10	4	100	28.08 ft^2 base		BPO	40%	12.6%	5.1%

Table 6 - CFA Phase III Test Data

Test Run #	Process Tested	Testing Conditions see note below	Styrene Content (% resin wt)	Styrene Emitted (% resin wt)
First Session at Dow Freeport				
033198A	Gelcoating	CS	25.8	12.26
033198B	Gelcoating	CS	28.7	12.55
033198C	Gelcoating	CS	28.7	11.97
033198D	Gelcoating	CS	25.1	10.83
040198A	Flow Chop		33.7	3.29
040198B	Flow Chop		33.7	3.33
040298A	Pressure-fed Roller		33.7	4.21
040298C	Pressure-fed Roller	VS	33.7	2.14
040298C	Flow Chop	VS	33.7	1.62
040298D	Flow Chop	VS	42.05	1.14
040398A	Pressure-fed Roller	VS	42.05	1.78
040398B	Flow Chop		42.05	3.18
040398C	Replicate of 121495A		N/A	11.90
040398D	Flow Chop	VS	33.7	1.66
Second Session at Dow Freeport				
052798A	Flow Chop		42.05	4.35
052798B	Flow Chop	VS	42.05	0.81
052798C	Flow Chop		48.9	8.98
052798D	Flow Chop	VS	48.9	2.90
052898A	Spray Lay up	CS	42.05	8.20
052898B	Spray Lay up	VS & CS	42.05	4.26
052898C	Spray Lay up	CS	48.9	10.36
052898D	Spray Lay up	VS & CS	48.9	5.88
052998A	Gelcoating	Clear	51.3	34.32
052998B	Gelcoating	Clear CS	51.3	25.91
052998C	Spray Lay up		48.9	12.63
052998D	Spray Lay up		34.7	8.54

Notes

# = test date
052798B = 2nd run on May 27, 1998

VS = vapor suppressed resin
CS = control spray application

The annotated version of the original February 28, 1998 CFA report entitled “CFA Emission Models for the Reinforced Plastics Industries” is provided as a separate document.