Non Atomized

Resin

Comparison for Conformance Manual

Produced for MVP Equipment ONLY.

Results on Competitive Equipment will Vary

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The purpose of this manual is to provide a guide to recognizing the subtle, yet significant, differences in non-atomized resin vs. atomized resin.

HISTORY

Emission reduction

In recent years, the awareness among government organizations of the problems caused by styrene emissions both inside and outside the workshop has increased. The industry struggles through research to develop equipment that meets current standards and anticipates future regulations. Recent studies by the Clean Manufacturing Technology and Safe Materials Institute (CMTI) at Purdue University and the U.S. based Composites Fabricators Association (CFA) prove that FIT® technology (consisting of a low pressure pumping system, modular gun, combined with a unique nozzle and mix chamber) can significantly reduce styrene emissions.

Research has shown that styrene emissions can be increased by atomization created by high pressures at the gun and spray techniques previously thought acceptable. The use of flowcoat technology was found to significantly reduce styrene emissions for wet-out. When correctly used, flow coat technology, which does not atomize the resin, reduces VOC's during wetout because of the simple geometry of the resin flow.

A flow coat style nozzle provides continuous streams of catalyzed resin continuously flowing onto the open mold. These resin streams reach the mold intact without atomizing. A spray fan, unlike flowcoat, breaks into droplets and atomizes before reaching the mold surface. Most of the research on VOC's for spray is based on droplet size, and as the diameters of the resin droplets decrease, the overall surface area of the resin increases, which increases emission. In fact, if the "spray" droplets get too small, they don't even reach their target; they drift off as fumes into the atmosphere.

The FRP industry embraced the new FloCoat technology as a viable and cost effective means for reducing styrene emissions, however the individual linear streams proved to be challenging for filled resin systems. The difficulty of chopping glass into the resin streams required the operator to increase pump pressures to such a high level that the streams broke into droplets, producing atomization and misting. This high velocity creates a spray fan similar to airless spray techniques, therefore reducing the benefits of flow coating.

While flow coating worked well with unfilled resin, it did not work with filled systems as the fillers in the resin would plug the holes associated with a FloCoat nozzle. At this time, governmental agencies were demanding a reduction in the emission levels of filled resins applications. To reduce emissions in these applications meant an entirely new and radical technology would have to be developed. That technology was Fluid Impingement Technology (FIT®).

The FIT® System uses low-pressure impinging streams to break resin into large droplets after mixing.

The unique 2-hole FIT® tip design creates a sheet when the two streams intersect. The sheet carries forward and breaks up into ligaments which then break up into large droplets.

Atomized Systems

Standard nozzles require excessive pressures to develop patterns. True low pressure fluid impingement produces patterns that are 50% wider at a fraction of the pressure with less overspray.

Competitive nozzles use 3 streams instead of 2 resulting in a loss of impingement energy at impingement point.

Why FIT® ?

In a recent independent field test conducted by order of a state environmental agency in the United States, emission factors with an average emission level of 4.1% were reported for an FRP manufacturer using the newly patented Fluid Impingement Technology (FIT®).

The state required the manufacturer to conduct independent tests measuring styrene emissions for conformance to EPA standards. The manufacturer produces large underground storage tanks using polyester resins that contain liquid styrene monomer. The test was conducted on the production of four different underground storage tanks ranging from an 8' - 10' diameter mold, utilizing four complete MVP SuperFIT® units with 3:1 pumps.

This stack test, conducted over two days in April, 2001 with 10,000 pounds of resin used, determined the styrene emission rates from four different UST molding stations. The calculations showed the quantity of styrene emitted per pound of styrene monomer consumed, and the quantity of styrene emitted per pound of raw resin consumed. *In the only documented field tested measurements available today,* emission levels as low as 2.2% were measured.

FLUID PRESSURES

Pressure plays a key role in obtaining a proper non-atomized pattern.

Typical pumps use compressed air to generate spray pressure.

Resin pumps can be 11:1, 6:1 or 3:1 ratio pumps. This means for every 1 psi (pound per square inch) you would get 11, 15 or 20 psi of pump pressure.

The pump then forces the resin through the hose to the spray gun. While traveling through the hose there is significant loss of pressure due to friction called Line Loss or Pressure Drop.

The average resin spray system loses about 2 psi per foot. The average spray system has 25 feet of hose which results in a 50 psi pressure drop (2 psi x 25 ft.) **See Figure 1 for Non-Atomized pressure drops, and Figure 1a for Atomized results.**

Figure 1 - Non-Atomized

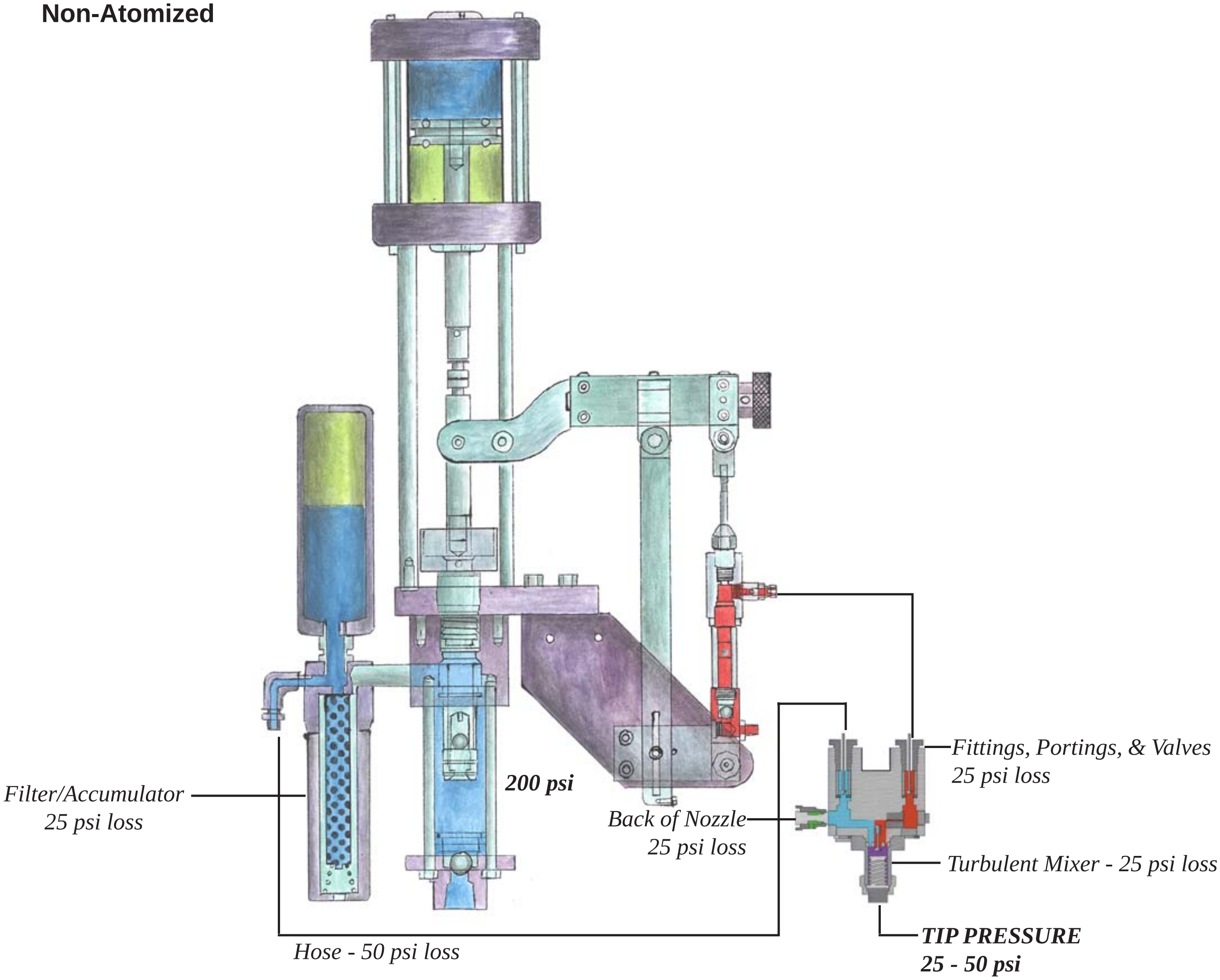
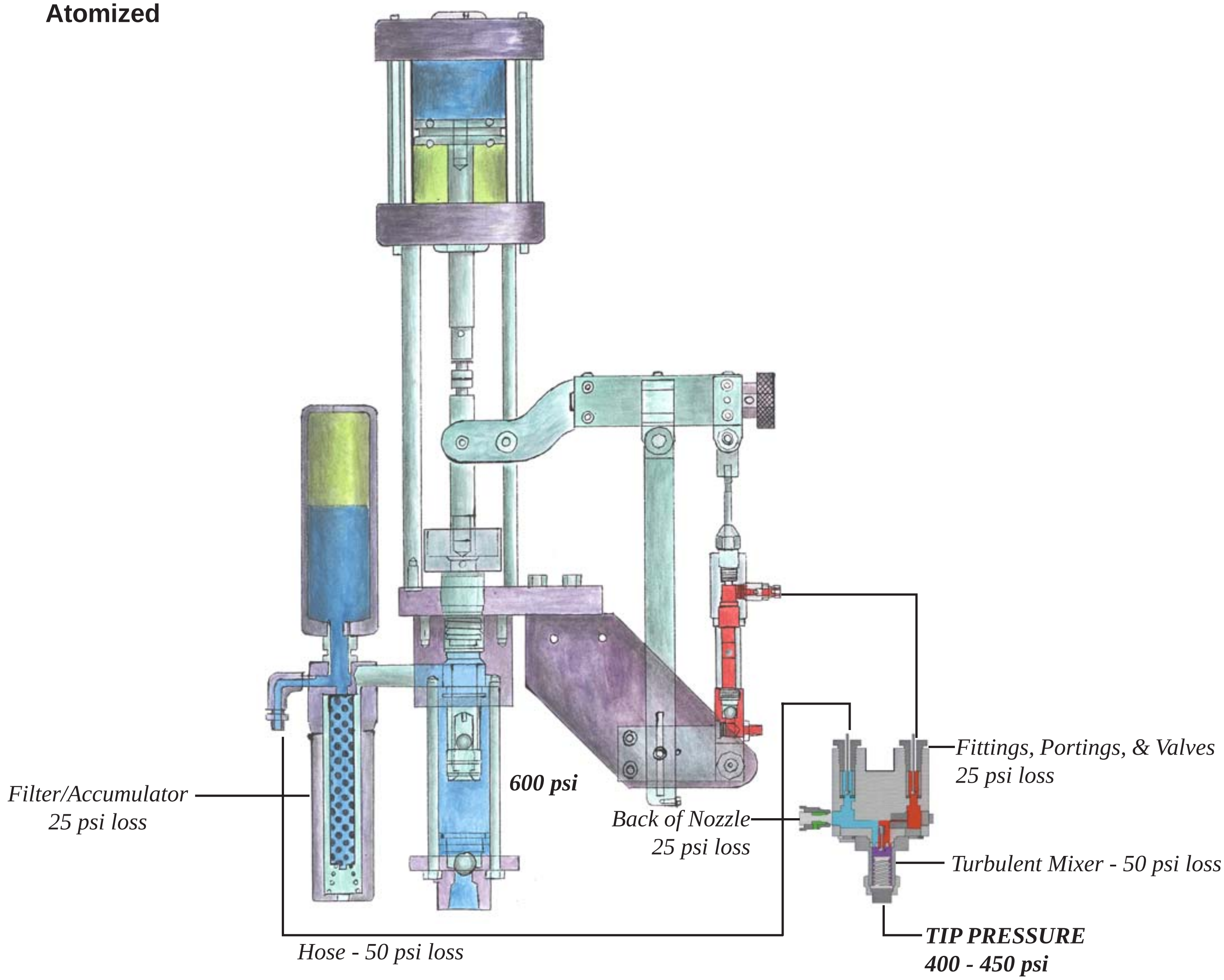
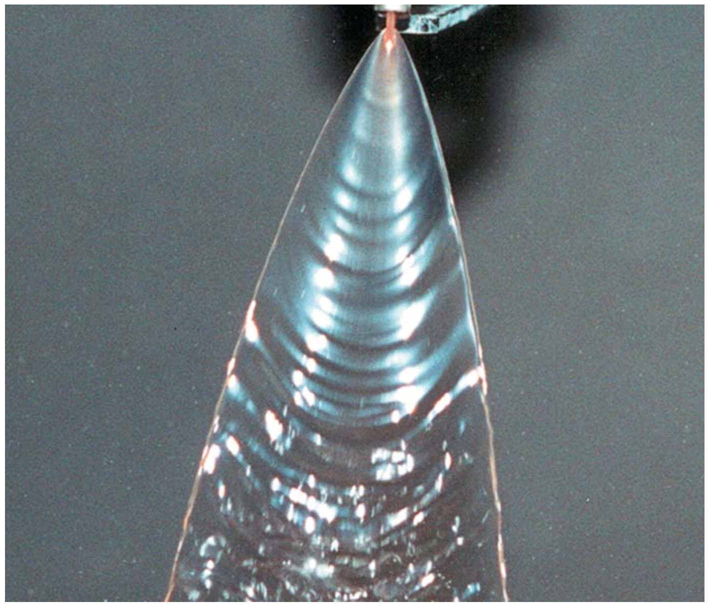


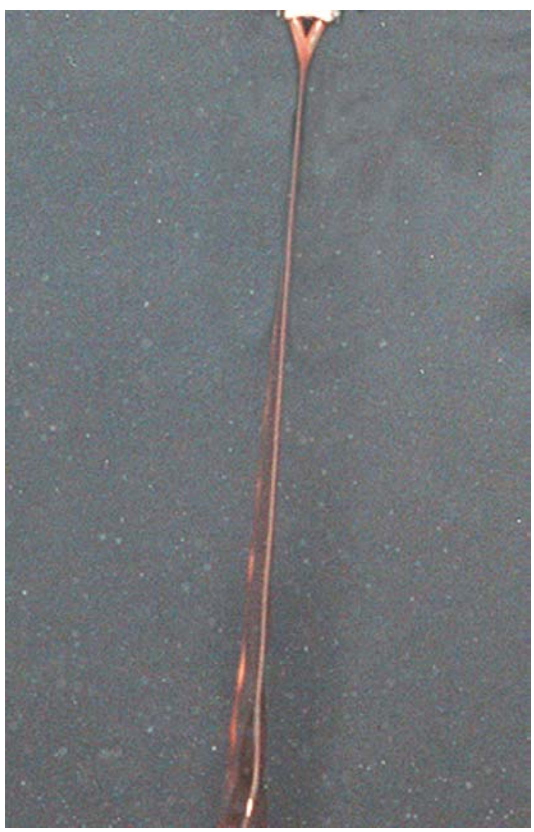
Figure 1a - Atomized



IMPINGEMENT FAN

FIT® impinge pattern on a 3:1 pump at 20 psi. Note “defined wave” pattern continues nearly to target with a minimum of atomization.





PROPER ADJUSTMENTS FOR NON-ATOMIZED RESIN APPLICATION

Fluid Pumps

The most common type of resin pump is termed an “air over fluid pump”. An air driven piston drives a fluid piston, which forces the material out to the spray gun at high pressure. The difference between the diameter of the air piston and the fluid piston is termed the *pump ratio*. Pump ratios usually range from about 11:1 up to 33:1. By multiplying the air input pressure by the pump ratio the fluid pressure at the spray tip can be determined.

Example:

- Pump Ratio = 11:1
  (11 psi of fluid pressure for every 1 psi of air pressure)
- Pump air pressure set at 40 psi
- Multiply: Pump Ratio x Pump Pressure Setting to determine the tip pressure
- 11 psi x 40 psi = 440 psi fluid tip pressure

SPRAY GUN SET-UP & PRESSURE CALIBRATION

(courtesy of ACMA “Controlled Spray Training” Program)

1. Flow Rate

Flow rate is the amount of material sprayed in a given period. The flow rate is primarily controlled by the size of the spray tip, pump pressure, resin viscosity and resin temperature. Flow rate considerations include:

• Large parts, requiring large amounts of resin, are usually sprayed with larger size tips. Smaller parts, or parts with more detailed shapes, may be easier to spray with lower flow rates using smaller orifice fluid tips.

• The viscosity (thickness) of resin will affect both the flow rate and fan pattern.

• The formulated viscosity is normally adjusted by the material manufacturer, but is affected by temperature. Cooler material will be thicker and will reduce the flow rate; where warmer resin is lower in viscosity and flows at a higher rate.

2. Determining Proper Fluid Pressure

Determining the ideal pump pressure for a specific combination of material and equipment is an important element of controlled spraying. Because of the many variables in the materials delivery system there is not a specific set pressure for a spray gun, nor can a specific pressure limitation be set. These variables require that each spray unit, with a specific material, operated under specific conditions be adjusted to produce an ideal spray pattern. There are a myriad of variables that affect the optimal pressure selling of any given application unit. These variables include:

Equipment design

- Fluid pump ratio (air input pressure to fluid pressure generated)
- Fluid tip design and configuration
- Design of filter and fluid lines
- Number of fittings or elbows in fluid lines
- Requirement for a surge chamber
- Internal or external initiator mixing

Material

- Inherent resin rheology
- Formulated viscosity
- Use of filled systems

Operating Conditions

- Material temperature
- Residual build-up in fluid lines
- Condition of pump packings
- State of filter particle accumulation
- Required spray distance from mold
- Geometry of mold (i.e., highly contoured or flat)
- Size of mold
- Accuracy and wear of pressure gauges and air pressure regulators

Equipment Set-up

- Fluid tip orifice size Length of fluid lines ID of fluid lines
- Size of filter screen mesh
- Height of fluid lines with overhead boom Adjustment of spray gun fluid needles Adjustment of spray gun trigger Required flow rate
- Required fan pattern width

2.1 The Objective of Spraying at Low Pressure

The objective of this spray gun pressure calibration method is to determine the lowest pressure at which any application unit will operate, while acknowledging that the pressure range may vary widely based on the combination of complex variables. It is always an advantage to spray at the lowest possible pressure. The lowest pressure will:

- Reduce Styrene Emissions
- Minimize overspray
- Create better working conditions
- Enhance catalyst mixing
- Reduce material usage / cost
- Reduce equipment wear
- Reduce high pressure hazards
- Reduce static charge build-up
- Increase product quality

In all cases, with resin application equipment, *minimum pressure provides maximum performance* in terms of, transfer efficiency, emissions, and finished product quality.

3. Pressure Calibration Procedure

The spray gun pressure calibration procedure is a simple and straightforward approach to determining the proper fluid pressure for any combination of equipment, material, and conditions. This procedure is appropriate for all atomized and non-atomized application equipment, including both internal and external initiator delivery systems.

Step I - Verify that the resin is the correct temperature, and has been properly mixed according to the manufacturer's recommendations.

Step 2 - Verify that the fluid tip is in good condition (without excess wear and capable of producing an acceptable spray pattern); and the orifice size is within a suitable in flow rate range and fan pattern width for the given job.

Step 3 - Reduce the pump air input pressure down the level where the pump will no longer stroke.

Step 4 - If the unit uses external assist air, set the air assist pressure in the middle of the normal range and according to the manufacturers' recommendations.

Step 5 - Aim the spray gun at a disposable surface covering on the floor, maintaining a distance of 12" to 18" and perpendicular to the floor.

Step 6 - Increase the pump pressure to the point where the pump just begins to stroke. Quickly pull and release the trigger to provide a "snapshot" spray pattern.

Step 7 - Record the results on the Spray Gun Calibration Worksheet.

Step 8 - Repeat the procedure, increasing pump pressure in 5 psi increments until the spray pattern is fully developed.

Step 9 - If using air-assist equipment, once a fully-developed spray pattern is attained, fine-tune the air assist pressure for final shaping of the fan pattern. Use the lowest air-assist pressure that produces a symmetrical spray pattern.

Step 10 - Do not increase the pressure past this point. Any increase in pump pressure past the point of creating a fully-developed spray pattern will result in an over-developed spray pattern.

Step 11 - Record this pressure the final pump pressure and air-assist pressure on the spray gun calibration worksheet.

4. Determining the Proper Spray Pattern

The size and shape of a fan pattern results from a unique combination of orifice size, fluid tip geometry, and resin flow characteristics. The required fan pattern width is specific to the size and configuration of the part being sprayed. The size of the spray pattern should match the spraying requirements. For example, spraying a large flat part benefits from producing a wide fan pattern. A small part or one with a complex shape may require a narrow fan pattern. There is, however, one trait all spray patterns have in common; a symmetrical shape where the material is distributed evenly across the length and width of the spray pattern.

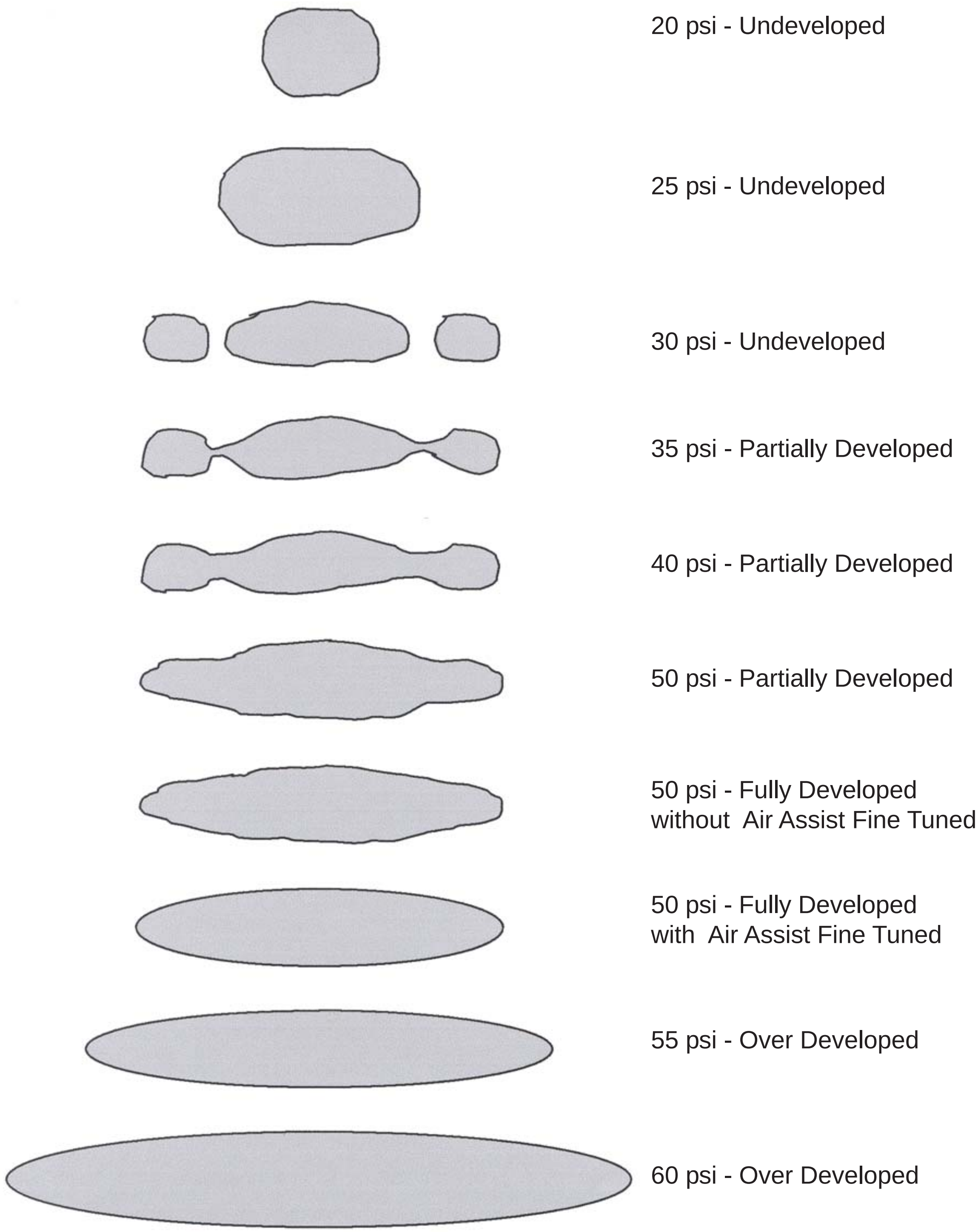
Fan patterns develop from a straight stream of resin, produced at very low fluid pressures, to an elongated oval pattern with increasing pressure. An *under-developed* spray pattern does not exhibit an oval configuration. A *partially-developed* spray pattern may have an irregular oval shape. A *fully-developed* spray pattern will be a uniform oval shape of the proper working width, An *over-developed* spray pattern presents a uniform oval shape that is wider than a fully-developed pattern, and produces increased atomization resulting from increased tip fluid pressure. This excess atomization is apparent by the increase in overspray surrounding the spray pattern.

As the fluid pressure reaches a specific optimum level for a specific combination of factors, a symmetrical elliptical shaped spray pattern develops. This pattern may need slight fine-tuning, with incremental pressure adjustments; or in the case of an air-assist spray gun, may be refined with additional air-assist pressure adjustments. The goal of air-assist/fluid pressure adjustments is to determine the combination that requires the lowest pressures, while producing a workable spray pattern.

Pump pressures and/or air-assist pressures set to greater than required levels to produce a fully-developed uniform spray pattern are considered excessive.

EXAMPLES OF SPRAY PATTERN DEVELOPMENT

Note: These pressures are for illustration purposes only. Actual pressures will vary with specific equipment, resin, spray tip size and angle, material temperature and other factors.



SPRAY GUN CALIBRATION WORKSHEET - EXAMPLE

Date:_______________ Operator:____

Spray Unit Designation:____

Resin Designation:____

Spray Tip Size & Angle:____

Spray Tip Condition: New_____ Used_____

Spray Gun Pressure Calibration Record				
Pump Pressure Setting	Air Assist Pressure Setting	Spray Pattern Development		
		Under Developed	Partially Developed	Fully Developed
10 psi				
15 psi				
20 psi				
25 psi				
30 psi				
35 psi				
40 psi				
45 psi				
50 psi				
55 psi				
60 psi				
65 psi				
70 psi				
75 psi				
80 psi				
85 psi				
90 psi				
100 psi				

Final Pump Pressure Setting: ____________________ psi

Initial Air Assist Pressure Setting: ____________________ psi

Final Air Assist Pressure Setting: ____________________ psi

Signature:____

Styrene Source Test Report for the Underground Storage Tank Operation

April 25-26, 2001 Test Period

prepared for:

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Maryland Department of the Environment
2500 Broening Highway
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By a recognized authority on styrene emissions and testing

May 14, 2001

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SECTION I Introduction

The purpose of this report is to detail the test results for styrene vapor emissions from a fiberglass reinforced plastic underground storage tank (UST) manufacturing operation at a facility located in ___________. This facility is owned by the _________________ Corporation and is henceforth called the ___________. The _____________ produces large UST parts using polyester resins that contain liquid styrene monomer. Styrene vapor is emitted as a consequence of the lamination processes used at the plant.

This stack test determined the styrene emission rates from four different UST molding stations on two consecutive, days, April 25, 2001 and April 26, 2001, and calculated the quantity of styrene emitted per pound of styrene monomer consumed and the quantity of styrene emitted per pound of raw resin consumed. This information is required as a condition of the Part 70 (Title V) operating permit issued to the __________by the Maryland Department of the Environment (MDE).

The test consisted of two simple field measurements. First the actual exhaust flow rate was determined using standard velocity traverse measurement techniques and flow calculation procedures for circular (and in one case, rectangular) ducts, Second, the styrene concentration of the exhaust was determined using a precision sampling train and several charcoal adsorption tubes. The sampling train pump drew a small measured volume of the exhaust stream through the charcoal tube, where the styrene vapor was absorbed onto the activated carbon granules. The charcoal sample tube was carefully stored and then delivered to a certified laboratory for subsequent GC analysis. The laboratory desorbed the styrene vapor trapped in the carbon using carbon disulfide and then determined the styrene content in the sample. A blank sample tube was also analyzed by the laboratory to determine the, detection limit of the analysis procedure. The styrene content of each sample was divided by the sample volume to calculate the styrene concentration. Finally, the exhaust stack styrene emission rate was calculated by multiplying the measured exhaust flow rate by the measured styrene concentration.

SECTION II Discussion of Testing Procedures and Results

II. A. Plant Production Activity

All general production activities were the same as described in the test protocol document submitted to the MDE on November 15, 2000. In order to complete the measured styrene emission rates with the corresponding production activity, the following plant production data was recorded by personnel during the test days:

- Production shift start and stop times - 6:00 am to 2:00 pm.
- Number of work breaks - two 15-minute breaks and one 30-minute lunch period.
- Resin usage per mold.
- Resin analysis data - manufacturer’s resin certification sheet.

II. B. Source Description

The styrene vapor emission sources that were involved this test consisted of the following four (4) UST molding stations:

UST I	eight-foot diameter UST mold (Mold 1)
UST 2	eight-foot diameter UST mold (Mold 2)
UST 3	six-foot diameter UST mold (Mold 9)
UST 4	ten-foot diameter UST mold (Mold 10)

These different mold sizes were selected to represent the range of UST part sizes produced at the plant.

The source testing simultaneously sampled each of the four exhaust streams from these four UST molding stations. The exterior building doors were closed during the testing periods to the greatest extent possible. This caused any styrene emissions that were fugitive to the building to be drawn towards the UST exhaust streams.

A vorticity survey was conducted during the pre-survey activities performed on April 24, 200 1. No vorticity was observed in the duct flow at the traverse points. However, the exhaust velocity in the 6-foot mold duct was too low to be measured with a pitot tube/manometer, so the traverse location for UST 3 was relocated to the rectangular exhaust duct inside the rotating mold. The relative locations of the duct traverse locations are given in Table A.

TABLE A
Stack Traverse Locations (as duct diameters)

Source	Upstream	Downstream
UST I - 8' Deq = 30"	170" (5.7 D)	> 60" (> 2.0 D)
UST 2 - 8' Deq = 30"	17011 (5.7 D)	> 60" (> 2.0 D)
UST 3 - 6' Deq = 16.4"	142" (8.6 D)	20" (1.3 D)
UST 4 - 10' Deq = 30"	170" (5.7 D)	> 60" (> 2.0 D)

II. C. Revised EPA Method 18 Test Procedures

The, styrene vapor source test method employed for the ________ was the revised EPA Method 18, incorporating NIOSH Method 1501 adsorption tube collection as specified in Section 7.4 and the new dual train "spiked" and "unspiked" recovery factor procedures as specified in Section 7.6. This method is henceforth simply referred to as *"Method 18".* In general, the Method I 8 approach used standard procedures to measure the exhaust stack flow rates with a pitot tube/manometer combination. The sampling flow rates were provided by precision-metered and calibrated sampling trains. The NIOSH Method 1501 procedures were followed to collect and analyze the styrene vapor concentration present in the exhaust. The actual flow rates through the sorbent tubes were set to prevent sample breakthrough and to keep the styrene-to-carbon mass loading ratio within the validated loading range.

Exhaust Flow Rates - the exhaust flow rate in each duct was calculated by multiplying the cross-sectional area by the average exhaust velocity. The average velocity was measured with a standard digital micro manometer and a pitot tube. The manometer was a Dwyer Instruments Model #127-00 manometer, with a 0.0' to 4.00" water column static pressure range and a 0.01 scale precision. The pitot tube was a Dwyer model #160-36 stainless steel pitot tube with a 36" insertion length-that complied with ASERAE and AMCA specifications (a 24' long pitot tube was-used inside UST 3). The equation used to calculate air velocity from the pitot pressure difference reading was:

$$\text{Air Velocity (fpm)} = 1096.2 \times \frac{\text{Velocity pressure (in wg)}^{0.5}}{\text{Air density (lb/ft}^3)^{0.5}} \qquad \text{[eq 1]}$$

A pitot tube correction factor was not needed, because a standard "L-type' pitot was used. The dry air density of the exhaust was calculated by using the equations for the ASERAE psychrometric tables. The wet-bulb temperature, dry-bulb temperature, static pressure, and the barometric pressure of the exhaust air were used to accurately estimate the corresponding relative humidity and air density of the exhaust.

Spiking Procedures - the spiked sorbent tubes were prepared in accordance with the, procedures listed in Method 18, Section 7.6.3. The spiked sorbent tubes were pre-loaded with an initial styrene mass by adding 15 µl of lab-grade, styrene liquid to the top of main charcoal section in the sorbent tube. About 60 liters of pure air were then passed through the tube to evaporate and aspirate the styrene through the main sorbent section. The spike mass (15 µl x 0.9 = 13.5 mg) was about 33% of the mass of styrene expected to be collected on the unspiked sorbent tube. For an uncoated activated charcoal tube with an 800 mg front section, the ideal maximum spike mass was about 15 mg. The spiking was conducted at the site on the afternoon of April 3, 2001, which was as close to the test period as was feasible. The spiked tubes were stored at 40ºF in a small refrigerator at the plant site.

In order to further verify the accuracy of the laboratory analysis, a set of three field calibration samples were included with the test samples for each test run. The results of the calibration samples and the corresponding styrene recovery values are listed in **Table B** as follows:

TABLE B Spike Load Recovery

	EXPECTED LOAD (mg)	MEASURED LOAD (mg)	RECOVERY (%)
DAY 1			
CAL 1	13.5	13.3	98.5 %
CAL2	13.5	13.2	97.8 %
CAL3	13.5	13.4	99.3 %
DAY 2			
CAL4	13.4	13.1	97.0%
CAL5	13.4	13.0	96.3 %
CAL6	13.4	13.3	98.5 %
		average	**97.9 %**

As shown, the average recovery of the spike loads was nearly perfect.

Recovery Factor - as specified by Method 18, a recovery factor was calculated for each sample tube pair by comparing the initial mass of styrene in the 'spiked tubes" to the total mass of styrene collected. This recovery factor was computed as follows:

$$R = \frac{M_S - (V_s/V_u) \times M_U}{S} \qquad \text{[eq 1]}$$

where M_s = the mass of styrene measured on the spiked tube (mg)
V_s = the volume of stack gas passed through the spiked tube (L)
M_u = the mass of styrene measured on the unspiked tube (mg).
V_u = the volume of stack gas passed through the unspiked tube (L) = the initial mass of styrene spiked onto the sorbent tube (mg)

The average value of R for all of the sample sets on Day 1 was 0.985 and on Day 2 was 0.994, which was well within the acceptance range $0.70 \leq R_{AVE} \leq 1.30$.

Styrene Concentration - the styrene concentration reported for each stack was given by:

Reported Concentration Result (ppm) = Measured Concentration (ppm)/R [eq 2]

Emission Rate - a styrene emission rate was calculated for each stack by multiplying the reported styrene concentration in the measured exhaust flow rate adjusted by a density correction factor (to account for standard pressure, temperature, and moisture content) as follows:

Emission Rate = Reported Concentration x Measured Flow Rate x Density Factor [eq 3]

Emission Factor - a styrene emission factor was calculated for each test run by dividing the styrene emission rate for each molding operation by the amount of resin used in each molding station:

Emission Factor = Ó Emission Rates ÷ ÓResin Consumed [eq 4]

A styrene emission factor was calculated for each test run by dividing the styrene emission rate by the amount of styrene monomer used in each molding station:

Emission Factor = ÓEmission Rates ÷ ÓStyrene Monomer Consumed [eq 5]

II. D. Field QA/QC Procedures

There were no changes to the QA/QC procedures detailed in the protocol document the pitot tube and manometer connections were leak-checked before and after the test by creating a 3" negative static pressure within the tube barrel, and visually observing any change in the pressure readings over a three minute period. The sample trains were also leak-checked before and after using the same technique. No leaks were detected at any time. The digital thermometers were calibrated against a certified glass-bulb laboratory thermometer before and after the test. The calibration errors for both thermometers were less than 1º F at all calibration points across the entire range from 50 to 90º F.

II. E. Unusual Events During the Test

Sample breakthrough - according to the laboratory analysis reported in Table 4, none of the sample tubes had a detectable amount of styrene in the backup sorbent section. This indicates that sample breakthrough did not occur during the testing, and all of the styrene that was collected was reported.

Sample train flow rate fluctuations - none of the sampling trains exhibited variations in flow rate greater than ± 4% between the pre-test and post-test calibration measurements. The largest variation was -3.2% for sample #5 on Day 2. The flow rate values for all sampling trains were adjusted by simply averaging the pre-calibration and post-calibration flow rate values together. The sample trains flow rate values for Day 1 and Day 2 are noted in **Table 3** and **Table 4**, respectively.

The rotameter log data for sample pair #13 and #S-13 indicated a steady decline in the sampling flow rate during Day 2. However, the pre- and post-calibration data did not indicate a problem, and the sample recovery for this pair was 94.6%. For these reasons, the sample pair was retained. The rotameter log data did not indicate any problems with the other sampling flow rates.

Sample rejection - the low recovery value for sample OS-3 on Day 1 was rejected due to the poor recovery. This was the only recovery value that was rejected.

Open exterior doors - the exterior doors were opened periodically during the testing periods to move materials and parts out of the building by forklift. These doors were only open for brief intervals of less than five minutes, and did not affect the capture of emissions inside the molds.

Weather related events - the sampling equipment was located indoors, so it was unaffected by the weather. However, the weather was ideal during the source testing.

II. F. Laboratory QAIQC Data

The MDE requested specific information regarding the laboratory analysis of the styrene samples. Some of this original raw data was provided in fan-fold and paper roll formats. For this reason, the original raw laboratory information is included with the final report submitted to the MDE office. Please note that there are no other copies of this data besides these originals.

The MDE should contact _______________, the AML IH Lab Manager by phone at __________ for answers to any further questions regarding the laboratory data or analytical procedures.

SECTION III Styrene Source Test Results

This section details the results of the April 25-26, 2001 styrene source test at the _______ Plant. These results are presented as Quattro Pro spreadsheets, which list the necessary parameters, the original data, and the subsequent calculations.

The Day 1 exhaust flow rate calculations for UST 1 through UST 4 are listed in **Table 1a** through **Table 1d**, respectively. The Day2 exhaust flow rate calculations for UST 1 through UST 4 are listed in **Table 2a** through and **Table 2d**, respectively. No flow vorticity which would have adversely affected the flow measurements, was detected during the pre-survey on April 24, 2001 Three separate velocity traverses were conducted on each exhaust duct during each test day one traverse in the morning, one at midday, and one in the afternoon. The average measured exhaust flow rate values for each mold were in close agreement with each other, and closely matched the expected exhaust flow rates.

The pre-calibration and post-calibration data calculations for the sampling train are shown in **Table 3** for Day 1 and **Table 4** for Day 2. These calculations were needed to determine the sampling volumes, and to verify a constant sampling flow rate during the test. This data confirmed that the flow rates for the accepted sampling trains operated within normal performance limits during the test.

The results of the laboratory analysis of the styrene sample loads on both the front and back sections, and the corresponding sample volumes, are listed in **Table 5** for Day 1 and **Table 6** for Day 2. None of the source samples showed a detectable amount of styrene on the back section, so breakthrough did not occur during the testing.

The amounts of resin and styrene monomer consumed by each molding station during both test days, as reported by______are listed in **Table 7**.

The average sample recoveries and reported styrene concentrations for each set of UST molding station samples are computed in **Table 8** for Day I and **Table 9** for Day 2.

The average sample recoveries for the stack samples and calibration samples were:

	DAY 1		DAY 2	
Samples:	UST I	101.5%	UST I	98.6%
	UST 2	95.6%	UST 2	95.1 %
	UST 3	104.7%	UST 3	99.3 %
	UST 4	99.4%	UST 4	101.7 %
	All molds	100.3%	All molds	98.7%
	Calibration:	98.5 %	Calibration:	97.3 %

which were internally consistent and well within the acceptable 70 to 130% range.

The summary of the test results and styrene emissions factors are given in **Table 10** in the following Section IV.

TABLE 1a: UST 1 Exhaust Flow Rate Calculation for DAY 1

UST 1 – 8' mold

April 25, 2001

Barometric	29.71	in Hg	29.74	in Hg	29.77	in Hg
Static	-1.10	in wg	-1.10	in wg	-0.98	in wg
Dry Bulb	67.6	F	70.5	F	66.4	F
Wet Bulb	54.9	F	53.4	F	57.8	F
Moisture	0.0064 lb/lb		0.0048 lb/lb		0.0083 lb/lb	
Density	0.0738 lb/ft^3		0.0736 lb/ft^3		0.0739 lb/ft^3	

	L	R	L	R	L	R
1	0.02	0.02	0.02	0.02	0.01	0.02
2	0.03	0.02	0.02	0.02	0.02	0.03
3	0.04	0.03	0.04	0.03	0.04	0.03
4	0.05	0.04	0.05	0.03	0.05	0.04
5	0.05	0.05	0.05	0.04	0.05	0.04
6	0.04	0.04	0.04	0.04	0.04	0.04
7	0.04	0.04	0.04	0.04	0.04	0.04
8	0.04	0.04	0.04	0.04	0.04	0.04
9	0.04	0.04	0.04	0.04	0.04	0.04
10	0.03	0.04	0.03	0.04	0.03	0.03
11	0.03	0.03	0.02	0.03	0.02	0.02
12	0.01	0.02	0.02	0.01	0.02	0.02

Duct Diameter	30.0 in
Duct Area	4.91 sq ft

1	571	571	572	572	403	570
2	699	571	572	572	570	699
3	807	699	808	700	807	699
4	903	807	904	700	902	807
5	903	903	904	808	902	807
6	807	807	808	808	807	807
7	807	807	808	808	807	807
8	807	807	808	808	807	807
9	807	807	808	808	807	807
10	699	807	700	808	699	699
11	699	699	572	700	570	570
12	404	571	572	404	570	570

Average Velocity	740 fpm	722 fpm	72i fpm
Actual Flow rate	3,634 acfm	3,545 acfm	3,538 acfm
Standard Flow rate	3,576 dscfm	3,488 dscfm	3,472 dscfm

Mean Flow Rate	3,512 dscfm
Mean Air Density	0.0738 lb/cu ft

TABLE 1b: UST 2 Exhaust Flow Rate Calculation for DAY 1

UST 2 - 8' mold

April 25, 2001

Barometric	29.71	in Hg	29.74	in Hg	29.77	in Hg
Static	-1.14	in wg	-1.11	in wg	-1.14	in wg
Dry Bulb	70.2	F	71.4	F	67.1	F
Wet Bulb	51.6	F	51.8	F	51.8	F
Moisture	0.0040	lb/lb	0.0038	lb/lb	0.0048	lb/lb
Density	0.0737	lb/ft^3	0.0736	lb/ft^3	0.0742	lb/ft^3

	L	**R**	**L**	**R**	**L**	**R**
1	0.02	0.02	0.02	0.02	0.02	0.02
2	0.02	0.03	0.03	0.03	0.02	0.03
3	0.03	0.05	0.03	0.04	0.03	0.04
4	0.04	0.05	0.04	0.04	0.04	0.04
5	0.05	0.05	0.04	0.05	0.04	0.05
6	0.05	0.05	0.05	0.05	0.05	0.05
7	0.06	0.06	0.05	0.05	0.05	0.05
8	0.06	0.06	0.06	0.06	0.06	0.06
9	0.05	0.06	0.05	0.05	0.05	0.05
10	0.04	0.05	0.04	0.04	0.05	0.04
11	0.03	0.04	0.03	0.03	0.03	0.03
12	0.01	0.02	0.02	0.02	0.03	0.01

Duct Diameter 30.0 in
Duct Area 4.91 sq ft

1	571	571	572	572	569	569
2	571	700	700	700	569	697
3	700	903	700	808	697	805
4	808	903	808	808	805	805
5	903	903	808	904	805	900
6	903	903	904	904	900	900
7	989	989	904	904	900	900
8	989	989	990	990	986	986
9	903	989	904	904	900	900
10	808	903	808	808	900	805
11	700	808	700	700	697	697
12	404	571	572	572	697	403

Average Velocity	808 fpm	789 fpm	783 fpm
Actual Flow rate	3,964 acfm	3,874 acfm	3,844 acfm
Standard Flow rate	3,896 dscfm	3,807 dscf,	3,772 dscfm

Mean Flow Rate	3,825 dscfm
Mean Air Density	0.0738 lb/cu ft

TABLE 1c: UST 3 Exhaust Flow Rate Calculation for DAY 1

UST 3 – 6’ Mold

April 25, 2001

Sea-level Barometric	30.19 in Hg	30.25 in Hg
Actual Barometric	29.71 in Hg	29.77 in Hg
Static	-1.42 in wg	-1.46 in wg
Dry Bulb	67.1 F	70.0 F
Wet Bulb	51.1 F	50.7 F
Moisture	0.0044 lb/lb	0.0035 lb/lb
Density	0.0740 lb/ft^3	0.0738 lb/ft^3

	1	2	3	1	2	3
1	0.22	0.25	0.23	0.25	0.25	0.20
2	0.32	0.37	0.22	0.33	0.44	0.28
3	0.28	0.41	0.27	0.32	0.42	0.24
4	0.28	0.34	0.30	0.32	0.34	0.28
5	0.32	0.32	N/A	0.29	0.31	N/A
6	0.25	0.26	N/A	0.22	0.27	N/A
7	0.19	N/A	N/A	0.18	N/A	N/A
8	0.07	N/A	N/A	0.07	N/A	N/A

Equivalent Diameter	16.4 in
Duct Area	1.46 sq ft

1	1,891	2,015	1,933	2,018	2,018	1,805
2	2,280	2,452	1,891	2,391	2,677	2,136
3	2,133	2,581	2,094	2,283	2,616	1,977
4	2,133	2,350	2,208	2,283	2,354	2,136
5	2,280	2,280	N/A	2,174	2,247	N/A
6	2,015	2,055	N/A	1,893	2,097	N/A
7	1,757	N/A	N/A	1,712	N/A	N/A
8	1,068	N/A	N/A	1,068	N/A	N/A

Average Velocity	2,079 fpm	2,101 fpm
Actual Flow Rate	3,031 acfm	3,064 acfm
Standard Flow Rate	2,991 dscfm	3,015 dscfm

Mean Flow Rate	3,003 dscfm
Mean Air Density	0.0493 lb/ft^3

TABLE 1d: UST 4 Exhaust Flow Rate Calculation for DAY 1

UST 4 – 10’ Mold

April 25, 2001

Barometric	29.71 in Hg	29.74 in Hg	29.77 in Hg
Static	-2.38 in wg	-2.21 in wg	-2.40 in wg
Dry Bulb	67.5 F	68.4 F	70.7 F
Wet Bulb	51.8 F	52.0 F	52.5 F
Moisture	0.0047 lb/lb	0.0046 lb/lb	0.0043 lb/lb
Density	0.0737 lb/ft^3	0.0737 lb/ft^3	0.0735 lb/ft^3

	L	R	L	R	L	R
1	0.14	0.24	0.14	0.24	0.14	0.23
2	0.17	0.25	0.20	0.28	0.18	0.26
3	0.27	0.31	0.28	0.33	0.25	0.30
4	0.31	0.31	0.33	0.33	0.31	0.32
5	0.30	0.30	0.32	0.31	0.30	0.29
6	0.29	0.28	0.29	0.29	0.27	0.26
7	0.27	0.26	0.27	0.28	0.26	0.26
8	0.26	0.26	0.28	0.27	0.27	0.25
9	0.27	0.26	0.29	0.25	0.29	0.25
10	0.27	0.24	0.26	0.23	0.27	0.22
11	0.16	0.19	0.16	0.19	0.19	0.17
12	0.10	0.15	0.10	0.14	0.09	0.15

Duct Diameter 30.0 in
Duct Area 4.91 sq ft

1	1,511	1,979	1,511	1,979	1,513	1,940
2	1,665	2,020	1,806	2,137	1,716	2,062
3	2,099	2,249	2,137	2,320	2,022	2,215
4	2,249	2,249	2,320	2,320	2,252	2,288
5	2,212	2,212	2,285	2,249	2,215	2,178
6	2,175	2,137	2,175	2,175	2,102	2,062
7	2,099	2,059	2,099	2,137	2,062	2,062
8	2,059	2,059	2,137	2,099	2,102	2,022
9	2,099	2,059	2,175	2,020	2,178	2,022
10	2,099	1,979	2,059	1,937	2,102	1,897
11	1,616	1,761	1,616	1,761	1,763	1,668
12	1,277	1,564	1,277	1,511	1,213	1,566

Average Velocity	1979 fpm	2010 fpm	1968 fpm
Actual Flow Rate	9713 acfm	9867 acfm	9659 acfm
Standard Flow Rate	9544 dscfm	9696 dscfm	9491 dscfm

Mean Flow Rate	9577 dscrfm
Mean Air Density	0.0736 lb/ft^3

TABLE 2a: UST 2 Exhaust Flow Rate Calculation for DAY 2

UST 1 – 8’ Mold

April 26, 2001

Barometric	29.77 in Hg	29.77 in Hg	29.77 in Hg
Static	-1.09 in wg	-1.14 in wg	-1.01 in wg
Dry Bulb	64.2 F	73.4 F	73.6 F
Wet Bulb	51.8 F	56.8 F	54.9 F
Moisture	0.0054 lb/lb	0.0061 lb/lb	0.0050 lb/lb
Density	0.0745 lb/ft^3	0.0731 lb/ft^3	0.0733 lb/ft^3

	L	R	L	R	L	R
1	0.01	0.02	0.01	0.01	0.01	0.02
2	0.02	0.02	0.02	0.02	0.02	0.02
3	0.04	0.03	0.04	0.03	0.045	0.03
4	0.05	0.03	0.05	0.03	0.05	0.03
5	0.05	0.03	0.05	0.04	0.05	0.03
6	0.04	0.04	0.04	0.04	0.05	0.04
7	0.04	0.04	0.03	0.03	0.04	0.04
8	0.04	0.04	0.03	0.03	0.04	0.04
9	0.04	0.04	0.03	0.04	0.04	0.04
10	0.03	0.03	0.03	0.03	0.03	0.03
11	0.02	0.03	0.02	0.03	0.02	0.03
12	0.01	0.02	0.01	0.02	0.01	0.02

Duct Diameter 30.0 in
Duct Area 4.91 sq ft

1	402	568	406	406	405	573
2	568	568	574	574	573	573
3	803	696	811	702	859	701
4	898	696	907	702	906	701
5	898	696	907	811	906	701
6	803	803	811	811	906	810
7	803	803	702	702	810	810
8	803	803	702	702	810	810
9	803	803	702	811	810	810
10	696	696	702	702	701	701
11	568	696	574	702	573	701
12	402	568	406	574	405	573

Average Velocity	702 fpm	684 fpm	714 fpm
Actual Flow Rate	3,446 acfm	3,355 acfm	3,503 acfm
Standard Flow Rate	3,423 dscfm	3,270 dscfm	3,424 dscfm

Mean Flow Rate	3,372 dscfm
Mean Air Density	0.0736 lb/ft^3

TABLE 2b: UST 2 Exhaust Flow Rate Calculation for DAY 2

UST 2 – 8’ Mold

April 26, 2001

Barometric	29.77 in Hg	29.77 in Hg	29.77 in Hg
Static	-1.15 in wg	-1.09 in wg	-1.00 in wg
Dry Bulb	64.4 F	76.5 F	76.6 F
Wet Bulb	50.9 F	56.3 F	55.4 F
Moisture	0.0049 lb/lb	0.0051 lb/lb	0.0046 lb/lb
Density	0.0745 lb/ft^3	0.0728 lb/ft^3	0.0729 lb/ft^3

	L	R	L	R	L	R
1	0.01	0.02	0.01	0.02	0.02	0.01
2	0.02	0.03	0.02	0.03	0.02	0.03
3	0.03	0.04	0.03	0.04	0.03	0.04
4	0.03	0.04	0.03	0.04	0.04	0.04
5	0.04	0.04	0.04	0.04	0.04	0.05
6	0.04	0.04	0.04	0.04	0.04	0.04
7	0.05	0.05	0.05	0.05	0.05	0.05
8	0.04	0.04	0.05	0.05	0.05	0.05
9	0.05	0.04	0.05	0.04	0.05	0.05
10	0.04	0.04	0.04	0.04	0.04	0.04
11	0.03	0.03	0.03	0.03	0.03	0.03
12	0.01	0.02	0.02	0.01	0.02	0.02

Duct Diameter 30.0 in
Duct Area 4.91 sq ft

1	402	568	406	575	574	406
2	468	696	575	704	574	703
3	696	803	704	813	703	812
4	696	803	704	813	812	812
5	803	803	813	813	812	908
6	803	803	813	813	812	812
7	898	898	909	909	908	908
8	803	803	909	909	908	908
9	898	803	909	813	908	908
10	803	803	813	813	812	812
11	696	696	704	704	703	703
12	402	568	575	406	574	574

Average Velocity	730 fpm	746 fpm	765 fpm
Actual Flow Rate	3,583 acfm	3,664 acfm	3,758 acfm
Standard Flow Rate	3,559 dscfm	3,557 dscfm	3,652 dscfm

Mean Flow Rate	3,589 dscfm
Mean Air Density	0.0734 lb/ft^3

TABLE 2c: UST 3 Exhaust Flow Rate Calculation for DAY 2

UST 3 – 6’ Mold

April 26, 2001

Sea-level Barometric	30.25 in Hg	30.25 in Hg	30.25 in Hg
Actual Barometric	29.77 in Hg	29.77 in Hg	29.77 in Hg
Static	-1.39 in wg	-1.37 in wg	-1.36 in wg
Dry Bulb	66.2 F	73.4 F	69.4 F
Wet Bulb	50.9 F	57.9 F	49.1 F
Moisture	0.0045 lb/lb	0.0068 lb/lb	0.0028 lb/lb
Density	0.0743 lb/ft^3	0.0731 lb/ft^3	0.0741 lb/ft^3

	1	2	3	1	2	3	1	2	3
1	0.20	0.20	0.12	0.20	0.20	0.19	0.20	0.22	0.19
2	0.31	0.37	0.21	0.29	0.39	0.24	0.27	0.36	0.22
3	0.27	0.35	0.3	0.28	0.37	0.28	0.28	0.37	0.30
4	0.25	0.25	0.20	0.27	0.29	0.25	0.23	0.29	0.22
5	0.25	0.24	N/A	0.27	0.26	N/A	0.27	0.28	N/A
6	0.19	0.20	N/A	0.20	0.21	N/A	0.19	0.23	N/A
7	0.15	N/A	N/A	0.14	N/A	N/A	0.16	N/A	N/A
8	0.09	N/A	N/A	0.10	N/A	N/A	0.11	N/A	N/A

Duct Diameter 16.4 in1.46 sq ft
Duct Area

1	1,799	1,799	1,393	1,814	1,814	1,768	1,801	1,889	1,756
2	2,240	2,447	1,843	2,184	2,533	1,987	2,093	2,417	1,889
3	2,090	2,380	1,929	2,146	2,467	2,146	2,131	2,450	2,206
4	2,011	2,011	1,799	2,107	2,184	2,028	1,932	2,169	1,889
5	2,011	1,971	N/A	2,107	2,068	N/A	2,093	2,131	N/A
6	1,753	1,799	N/A	1,814	1,858	N/A	1,756	1,932	N/A
7	1,558	N/A	N/A	1,672	N/A	N/A	1,611	N/A	N/A
8	1,217	N/A	N/A	1,282	N/A	N/A	1,336	N/A	N/A

Average Velocity	1,892 fpm	1,999 fpm	1,971 fpm
Actual Flow Rate	2,759 acfm	2,915 acfm	2,875 acfm
Standard Flow Rate	2,733 dscfm	2,841 dscfm	2,840 dscfm

Mean Flow Rate	2,805 dscfm
Mean Air Density	0.0738 lb/ft^3

TABLE 2d: UST 4 Exhaust Flow Rate Calculation for DAY 2

UST 4 – 10’ Mold

April 26, 2001

Barometric	29.77 in Hg	29.77 in Hg	29.77 in Hg
Static	-2.28 in wg	—2.29 in wg	-2.41 in wg
Dry Bulb	64.0 F	74.1 F	69.4 F
Wet Bulb	49.5 F	56.7 F	52.5 F
Moisture	0.0043 lb/lb	0.0059 lb/lb	0.0046 lb/lb
Density	0.0745 lb/ft^3	0.0728 lb/ft^3	0.0736 lb/ft^3

	L	R	L	R	L	R
1	0.15	0.25	0.16	0.24	0.13	0.23
2	0.19	0.26	0.18	0.25	0.15	0.25
3	0.25	0.33	0.24	0.32	0.23	0.31
4	0.33	0.31	0.29	0.33	0.30	0.32
5	0.32	0.29	0.30	0.29	0.29	0.28
6	0.29	0.26	0.28	0.26	0.28	0.25
7	0.27	0.26	0.24	0.26	0.26	0.25
8	0.28	0.26	0.27	0.26	0.27	0.24
9	0.30	0.26	0.29	0.26	0.28	0.24
10	0.29	0.24	0.27	0.22	0.28	0.21
11	0.20	0.20	0.18	0.19	0.18	0.18
12	0.09	0.14	0.08	0.14	0.10	0.14

Duct Diameter 30.0 in
Duct Area 4.91 sq ft

1	1,556	2,009	1,626	1,991	1,457	1,938
2	1,751	2,048	1,724	2,032	1,565	2,021
3	2,009	2,308	1,991	2,299	1,938	2,250
4	2,308	2,237	2,188	2,335	2,214	2,286
5	2,273	2,163	2,226	2,188	2,177	2,139
6	2,163	2,048	2,150	2,072	2,139	2,021
7	2,087	2,048	1,991	2,072	2,061	2,021
8	2,126	2,048	2,112	2,072	2,100	1,980
9	2,200	2,048	2,188	2,072	2,139	1,980
10	2,163	1,968	2,112	1,906	2,139	1,852
11	1,797	1,797	1,727	1,771	1,715	1,715
12	1,205	1,503	1,149	1,521	1,278	1,512

Average Velocity	1,994 fpm	1,980 fpm	1,943 fpm
Actual Flow Rate	9,790 acfm	9,718 acfm	9,539 acfm
Standard Flow Rate	9,724 dscfm	7,433 dscfm	9,361 dscfm

Mean Flow Rate	9,506 dscfm
Mean Air Density	0.0736 lb/ft^3

TABLE 3 Sampling Train Calibration Data for DAY 1

Listed times are those required to draw 100 milliliters of air, in seconds

Train #	Pre-Calibration 4/24/01 T1	T2	T3	average	flow rate	Post-Calibration 4/25/01 T1	T2	T3	average	flow rate	change	average flow rate
	(sec)	(sec)	(sec)	(sec)	(lpm)	(sec)	(sec)	(sec)	(sec)	(lpm)	(%)	(lpm)
1	12.21	12.26	12.22	12.23	0.491	12.54	12.59	12.58	12.57	0.477	-2.7	0.484
S-1	17.88	17.89	17.87	17.88	0.336	17.85	17.80	17.78	17.81	0.337	0.4	0.336
2	12.12	12.08	12.14	12.11	0.495	12.18	12.21	12.18	12.19	0.492	-0.6	0.494
S-2	18.89	18.89	18.90	18.89	0.318	18.54	18.56	18.50	18.53	0.324	1.9	0.321
3	12.39	12.41	12.40	12.40	0.484	12.46	12.50	12.46	12.47	0.481	-0.6	0.482
S-3	19.20	19.18	19.19	19.19	0.313	19.26	19.23	19.21	19.23	0.312	-0.2	0.312
4	12.11	12.08	12.07	12.09	0.496	12.17	12.18	12.20	12.18	0.492	-0.8	0.494
S-4	19.88	19.85	19.83	19.85	0.302	19.58	19.54	19.54	19.55	0.307	1.5	0.305
5	12.40	12.40	12.43	12.41	0.483	12.12	12.13	12.13	12.13	0.495	2.3	0.489
S-5	19.41	19.44	19.40	19.42	0.309	19.48	19.46	19.47	19.47	0.308	-0.3	0.309
6	12.10	12.09	12.06	12.08	0.497	12.13	12.09	12.11	12.11	0.495	-0.2	0.496
S-6	19.19	19.15	19.15	19.16	0.313	19.36	19.34	19.35	19.35	0.310	-1.0	0.312
7	12.12	12.16	12.12	12.13	0.495	11.84	11.85	11.81	11.83	0.507	2.5	0.501
S-7	18.31	18.29	18.31	18.30	0.328	18.51	18.49	18.47	18.49	0.324	-1.0	0.326
8	12.39	12.40	12.38	12.39	0.484	12.33	12.39	12.30	12.34	0.486	0.4	0.485
S-8	19.25	19.25	19.29	19.26	0.311	19.19	19.12	19.10	19.14	0.314	0.7	0.313
9	11.90	11.93	11.90	11.91	0.504	12.16	12.12	12.12	12.13	0.495	-1.8	0.499
S-9	18.63	18.61	18.60	18.61	0.322	18.24	18.28	18.32	18.28	0.328	1.8	0.325
10	12.11	12.05	12.05	12.07	0.497	12.20	12.16	12.20	12.19	0.492	-1.0	0.495
S-10	19.61	19.65	19.60	19.62	0.306	19.72	19.77	19.76	19.75	0.304	-0.7	0.305
11	12.41	12.45	12.46	12.44	0.482	12.45	12.40	12.38	12.41	0.483	0.2	0.483
S-11	19.24	19.26	19.21	19.24	0.312	18.99	18.99	18.97	18.98	0.316	1.3	0.314
12	12.68	12.68	12.64	12.67	0.474	12.74	12.69	12.70	12.71	0.472	-0.3	0.473
S-12	19.38	19.40	19.35	19.38	0.310	19.22	19.26	19.19	19.22	0.312	0.8	0.311

TABLE 4 Sampling Train Calibration Data for DAY 2

Listed times are those required to draw 100 milliliters of air, in seconds

Train #	Pre-Calibration 4/25/01					Post-Calibration 4/26/01					change	average flow rate
	T1	T2	T3	average	flow rate	T1	T2	T3	average	flow rate		
	(sec)	(sec)	(sec)	(sec)	(lpm)	(sec)	(sec)	(sec)	(sec)	(lpm)	(%)	(lpm)
13	12.50	12.47	12.46	12.48	0.481	12.12	12.20	12.13	12.15	0.494	2.7	0.487
S 13	17.71	17.74	17.67	17.71	0.339	17.53	17.52	17.49	17.51	0.343	1.1	0.341
14	12.16	12.16	12.16	12.16	0.493	12.25	12.32	12.29	12.29	0.488	-1.0	0.491
S 14	18.48	18.47	18.46	18.47	0.325	18.75	18.70	18.71	18.72	0.321	-1.3	0.323
15	12.04	11.95	11.98	11.99	0.500	12.12	12.14	12.08	12.11	0.495	-1.0	0.498
S 15	19.13	19.14	19.19	19.15	0.313	19.29	19.30	19.29	19.29	0.311	-0.7	0.312
16	11.71	11.75	11.71	11.72	0.512	12.10	12.15	12.04	12.10	0.496	-3.1	0.504
S 16	18.96	18.96	18.98	18.97	0.316	18.97	18.98	19.03	18.99	0.316	-0.1	0.316
17	12.28	12.23	12.20	12.24	0.490	11.94	11.95	11.92	11.94	0.503	2.5	0.496
S 17	19.07	19.02	18.99	19.03	0.315	19.11	19.18	19.12	19.14	0.314	-0.6	0.314
18	11.66	11.68	11.70	11.68	0.514	12.01	11.99	11.96	11.99	0.501	-2.6	0.507
S 18	19.16	19.20	19.20	19.19	0.313	18.97	19.08	19.09	19.05	0.315	0.7	0.314
19	12.12	12.16	12.12	12.13	0.495	12.05	12.06	11.96	12.02	0.499	0.9	0.497
S 19	18.44	18.49	18.43	18.45	0.325	18.11	18.20	18.18	18.16	0.330	1.6	0.328
20	12.02	12.03	12.00	12.02	0.499	12.45	12.41	12.40	12.42	0.483	-3.2	0.491
S 20	19.15	19.18	19.19	19.17	0.313	18.99	19.01	18.96	18.99	0.316	1.0	0.314
21	11.83	11.83	11.86	11.84	0.507	12.12	12.13	12.15	12.13	0.495	-2.4	0.501
S 21	18.09	18.05	18.09	18.08	0.332	18.09	18.13	18.10	18.11	0.331	-0.2	0.332
22	12.32	12.32	12.34	12.33	0.487	12.16	12.14	12.10	12.13	0.495	1.6	0.491
S 22	19.35	19.33	19.34	19.34	0.310	19.56	19.52	19.51	19.53	0.307	-1.0	0.309
23	12.32	12.34	12.26	12.31	0.488	12.44	12.48	12.43	12.45	0.482	-1.2	0.485
S 23	19.20	19.22	19.17	19.20	0.313	19.36	19.32	19.30	19.33	0.310	-0.7	0.312
24	12.36	12.33	12.35	12.35	0.486	12.28	12.30	12.27	12.28	0.488	0.5	0.487
S 24	19.04	19.05	19.09	19.06	0.315	18.94	19.03	18.97	18.98	0.316	0.4	0.315

TABLE 5: Styrene Sample Analysis Results for Day 1

Sample #	Train #	Stack #	Flow (mL/min)	Time (min.)	Volume (L)	Styrene (mg) Front	Back	%
1	1	UST 1	484	480	232.2	122.0	<0.011	
S1	S1	UST 1	336	480	161.4	98.7	<0.011	
2	2	UST 1	494	480	237.0	122.0	<0.011	
S2	S2	UST 1	321	480	153.9	92.7	<0.011	
3	3	UST 1	482	480	231.6	124.0	<0.011	
S3	S3	UST 1	312	480	149.9	90.3	<0.011	
4	4	UST 2	494	480	237.3	107.0	<0.011	
S4	S4	UST 2	305	480	146.2	77.1	<0.011	
5	5	UST 2	489	480	234.8	106.0	<0.011	
S5	S5	UST 2	309	480	148.1	82.7	<0.011	
6	6	UST 2	496	480	238.1	114.0	<0.011	
S6	S6	UST 2	312	480	149.6	83.3	<0.011	
7	7	UST 3	501	480	240.4	106.0	<0.011	
S7	S7	UST 3	326	480	156.6	82.6	<0.011	
8	8	UST 3	485	480	232.9	97.9	<0.011	
S8	S8	UST 3	313	480	150.0	76.5	<0.011	
9	9	UST 3	499	480	239.6	103.0	<0.011	
S9	S9	UST 3	325	480	156.1	82.5	<0.011	
10	10	UST 4	495	480	237.5	71.3	<0.011	
S10	S10	UST 4	305	480	146.3	59.1	<0.011	
11	11	UST 4	483	480	231.8	72.4	<0.011	
S11	S11	UST 4	314	480	150.7	60.4	<0.011	
12	12	UST 4	473	480	227.0	70.8	<0.011	
Blank	N/A	Blank	N/A	N/A	N/A	0.0	<0.011	
Cal 1	N/A	cal	N/A	N/A	N/A	13.3	<0.011	98.5%
Cal 2	N/A	cal	N/A	N/A	N/A	13.2	<0.011	97.8%
Cal 3	N/A	cal	N/A	N/A	N/A	13.4	<0.011	99.3%
								98.5%

TABLE 6: Styrene Sample Analysis Results for Day 2

Sample #	Train #	Stack #	Flow (mL/min)	Time (min.)	Volume (L)	Styrene (mg) Front	Back	%
13	1	UST 1	487	480	233.9	83.0	<0.011	
S 13	S1	UST 1	341	480	163.5	70.8	<0.011	
14	2	UST 1	491	480	235.6	84.2	<0.011	
S 14	S2	UST 1	323	480	154.9	66.6	<0.011	
15	3	UST 1	498	480	239.0	81.2	<0.011	
S 15	S3	UST 1	312	480	149.8	66.8	<0.011	
16	4	UST 2	504	480	241.9	59.0	<0.011	
S 16	S4	UST 2	316	480	151.7	49.0	<0.011	
17	5	UST 2	496	480	238.3	57.5	<0.011	
S 17	S5	UST 2	314	480	150.9	49.8	<0.011	
18	6	UST 2	507	480	243.4	58.4	<0.011	
S 18	S6	UST 2	314	480	150.7	49.3	<0.011	
19	7	UST 3	497	480	238.4	78.3	<0.011	
S 19	S7	UST 3	328	480	157.3	64.	<0.011	
20	8	UST 3	491	480	235.8	76.5	<0.011	
S 20	S8	UST 3	314	480	150.9	64.0	<0.011	
21	9	UST 3	501	480	240.3	79.3	<0.011	
S 21	S9	UST 3	501	480	240.3	79.3	<0.011	
22	10	UST 4	491	480	235.5	42.0	<0.011	
S 22	S10	UST 4	309	480	148.2	37.9	<0.011	
23	11	UST 4	485	480	232.7	37.8	<0.011	
S 23	S11	UST 4	312	480	149.5	40.7	<0.011	
24	12	UST 4	487	480	233.9	41.4	<0.011	
S 24	S12	UST 4	315	480	151.4	40.1	<0.011	
Blank	N/A	Blank	N/A	N/A	N/A	<0.011	<0.011	
Cal 1	N/A	cal	N/A	N/A	N/A	13.1	<0.011	97.0%
Cal 2	N/A	cal	N/A	N/A	N/A	13.0	<0.011	96.3%
Cal 3	N/A	cal	N/A	N/A	N/A	13.3	<0.011	98.5%
								97.3%

TABLE 7: Material and Monomer Usages

Styrene Material Usages & Usage Rates – April 25, 2001

Source	Volumetric Usage Amount (gal)	Resin Density (lb/gal)	Resin Mass (lb)	Actual Time (hr)	Ave Hr Resin Usage Rate (lb/hr)	Styrene Content (lb/lb)	Styrene Mass (lb)
UST 1 (8')	119.3	9.01	1074.9	8.00	134.4	43.6%	468.7
UST 2 (8')	127.4	9.01	1147.9	8.00	143.5	43.6%	500.5
UST 3 (6')	87.0	9.01	783.9	8.00	98.0	43.6%	341.8
UST 4 (10')	184.0	9.01	1657.8	8.00	207.2	43.6%	722.8
					583.1 ave lb/hr		

AOC, Vipel F764-PTT-25, Lot #F-32028, 3/24/2001

Styrene Material Usages & Usage Rates – April 26, 2001

Source	Volumetric Usage Amount (gal)	Resin Density (lb/gal)	Resin Mass (lb)	Actual Time (hr)	Ave Hr Resin Usage Rate (lb/hr)	Styrene Content (lb/lb)	Styrene Mass (lb)
UST 1 (8')	112.3	9.01	1011.8	8.00	126.5	43.6%	441.2
UST 2 (8')	144.2	9.01	1299.2	8.00	162.4	43.6%	566.5
UST 3 (6')	89.2	9.01	803.7	8.00	100.5	43.6%	350.4
UST 4 (10')	187.2	9.01	1686.7	8.00	210.8	43.6%	735.4
					600.2 ave lb/hr		

AOC, Vipel F764-PTT-25, Lot #F-32028, 3/24/2001

TABLE 8: Sample Recovery and Reported Concentrations for Day 1

Average Recover	**100.3%**
Density Factor	**0.97**

UST 1	**8' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 1	13.5	98.7	85.2	161.4	156.5	0.544	125.7	1.033
	S 2	13.5	92.7	79.2	153.9	149.3	0.530	122.5	0998
	S 3	13.5	90.3	76.8	149.9	145.4	~~0.528~~	~~122.0~~	~~0.743~~ *reject*
							Ave:	**124.1**	**1.015**
			"Mu"			**"Vu"**			
Unspiked	1		122.0	122.0	232.3	225.3	0.541	125.0	
	2		122.0	122.0	237.0	229.9	0.531	122.6	
	3		124.0	124.0	231.6	224.6	0.552	127.5	
							Adjusted Conc. 121.9 ppm		
							Ave:	**123.8**	

UST 2	**8' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 4	13.5	77.1	63.6	146.2	141.8	0.449	103.6	0.829
	S 5	13.5	82.7	69.2	148.1	143.7	0.482	111.2	1.172
	S 6	13.5	83.3	69.8	149.6	145.1	0.481	111.1	0.866
							Ave:	**108.6**	**0.956**
			"Mu"			**"Vu"**			
Unspiked	4		107.0	107.0	237.3	230.2	0.465	107.3	
	5		106.0	106.0	234.8	227.7	0.465	107.5	
	6		114.0	114.0	238.1	230.9	0.494	114.0	
							Adjusted Conc. 114.7 ppm		
							Ave:	**109.6**	

UST 3	**6' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 7	13.5	82.6	69.1	156.6	151.9	0.455	105.1	1.005
	S 8	13.5	76.5	63.0	150.0	145.5	0.433	100.0	0.996
	S 9	13.5	82.5	69.0	156.1	151.5	0.456	105.2	1.139
							Ave:	**103.4**	**1.047**
			"Mu"			**"Vu"**			
Unspiked	7		106.0	106.0	240.4	233.2	0.455	105.0	
	8		97.9	97.9	232.9	225.9	0.433	100.1	
	9		103.0	103.0	239.6	232.4	0.443	102.4	
							Adjusted Conc. 97.9 ppm		
							Ave:	**102.5**	

UST 4	**10' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 10	13.5	59.1	45.6	146.3	141.9	0.321	74.2	1.124
	S 11	13.5	60.4	46.9	150.7	146.2	0.321	74.1	0.987
	S 12	13.5	58.3	44.8	149.2	144.7	0.310	71.5	0.871
							Ave:	**73.3**	**0.994**
			"Mu"			**"Vu"**			
Unspiked	10		71.3	71.3	237.5	230.3	0.310	71.5	
	11		72.4	72.4	231.8	224.8	0.322	74.4	
	12		70.8	70.8	227.	220.2	0.322	74.3	
							Adjusted Conc. 73.8 ppm		
							Ave:	**73.4**	

TABLE 9: Sample Recovery and Reported Concentrations for Day 2

average recover: **98.7%**
density factor **0.97**

UST 1	**8' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 13	13.5	70.8	57.3	163.5	158.6	0.361	83.4	0.946
	S 14	13.5	66.6	53.1	154.9	150.2	0.353	81.6	0.833
	S 15	13.5	66.8	53.3	149.8	145.3	0.367	84.7	1.177
							Ave:	**83.2**	**0.986**
			"Mu"			**"Vu"**			
Unspiked	13		83.0	83.0	233.9	226.9	0.366	84.5	
	14		84.2	84.2	235.6	228.6	0.368	85.1	
	15		81.2	81.2	239.0	231.8	0.350	80.9	
								Adjusted Conc. 84.7 ppm	
							Ave:	**83.5**	

UST 2	**8' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 16	13.5	49.0	35.5	151.7	147.2	0.241	55.7	0.888
	S 17	13.5	49.8	36.3	150.9	146.4	0.248	57.3	0.991
	S 18	13.5	449.3	35.8	150.7	146.1	0.245	56.6	0.974
							Ave:	**56.5**	**0.951**
			"Mu"			**"Vu"**			
Unspiked	16		59.0	59.0	241.9	234.6	0.251	58.1	
	17		57.5	57.5	238.3	231.2	0.249	57.4	
	18		58.4	58.4	243.4	236.1	0.247	57.1	
								Adjusted Conc. 60.5 ppm	
							Ave:	**57.5**	

UST 3	**6' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 19	13.5	64.0	50.5	157.3	152.6	0.331	76.4	0.914
	S 20	13.5	64.0	50.5	150.9	146.4	0.345	79.7	1.113
	S 21	13.5	65.4	51.9	159.2	154.4	0.336	77.6	0.953
							Ave:	**77.9**	**0.993**
			"Mu"			**"Vu"**			
Unspiked	19		78.3	78.3	238.4	231.3	0.339	78.2	
	20		76.5	76.5	235.8	228.7	0.334	77.3	
	21		79.3	79.3	240.3	233.1	0.340	78.6	
								Adjusted Conc. 78.5 ppm	
							Ave:	**78.0**	

UST 4	**10' mold**	**"S" Spike Amount (mg)**	**"Ms" Measured Amount (mg)**	**Sample Amount (mg)**	**Sample Volume (L)**	**Vs" Sample Volume (L at STP)**	**Mass Conc (mg/L)**	**(at STP) Volume Conc (ppm)**	**"R" Recovery Factor**
Sample	**Train**								
Spiked	S 22	13.5	37.9	24.4	148.2	143.7	0.170	39.2	0.850
	S 23	13.5	40.7	27.2	149.5	145.0	0.188	43.3	1.215
	S 24	13.5	40.1	26.6	151.4	146.9	0.181	41.8	0.985
							Ave:	**41.4**	**1.017**
			"Mu"			**"Vu"**			
Unspiked	22		42.0	42.0	235.5	228.4	0.184	42.5	
	23		37.8	37.8	232.7	225.7	0.167	38.7	
	24		41.4	41.4	233.9	226.8	0.183	42.1	
								Adjusted Conc. 40.4 ppm	
							Ave:	**41.1**	

SECTION IV Conclusions and Recommendations

Conclusions

The following test results were computed from the April 25-26, 2001 styrene source testing data:

		DAY I	DAY2
Average Flow Rates (dsfcm)	UST 1 - 8' dia	3,512.	3,372
	UST 2 - 8' dia	3,825	3,589
	UST 3 - 10' dia	3,003	2,805
	UST 4 - 10' dia	9,577	9,506
Average Styrene Emission Rate for an 8- hour production shift (lb styrene emitted per hour)	UST 1 - 8' dia	7.0	4.6
	UST 2 - 8' dia	7.1	3.5
	UST 3 - 10' dia	4.8	3.6
	UST 4 – 10’ dia	11.5	6.2
	All UST - TOTAL	**30.3**	**18.0**
Styrene Emission Factor based on Raw Material Usage (lb styrene per lb resin)	UST I - 8' dia	0.052	0.037
	UST 2 - 8' dia	0.050	0.022
	UST 3 - 10' dia	0.049	0.036
	UST 4 - 10' dia	0.055	0.030
	Average factors	**0.0514**	**0.0309**
Styrene Emission Factor based on Monomer Usage (lb styrene per lb styrene monomer used)	UST 1- 8' dia	0.119	0.084
	UST 2 - 8' dia	0.114	0.050
	UST 3 - 10' dia	0.112	0.082
	UST 4 - 10’dia	0.127	0.068

A detailed summary of the April 25-26, 2001 UST source test results is listed in **Table 10**.

Source Test Daily Log

Plant: **Date: 4/25/2001**

No.	Time	Tip	Heat	Flow	Comments
1	6:15 AM	9050	8	1.0+	65 psi air motor pressure
	6:32 AM		8	1.0	61 psi air motor pressure
	8:31 AM		6.5	1.0	
	2:00 PM				Resin usage 119.3 gallons
2	6.20 AM	9050	7	0.9	61 psi air motor pressure,
	7:28 AM		7	0.9+	60 psi air motor pressure
	10:17 AM		7.5	0.9+	60 psi air motor pressure
	2:00 PM				Resin usage 127.4 gallons
8	6:25 AM	9050	8	0.9	60 psi air motor pressure
	8:43 AM		9	1.0	60 psi air motor pressure
	2:00 PM				Resin usage 87 gallons
9	6:30 AM	9050	8	1.1	70 psi air motor pressure
	7:22 AM		7	0.9	70 psi air motor pressure
	10:45 AM			1.1	70 psi air motor pressure
	1:12 PM		6.5	1.0	70-psi air motor pressure
	2:00 PM				Resin usage 184 gallons

Filters were changed at 6:00, 8:00, 10:00, and 12:00

Other molding station pressure readings were taken, but not recorded. These were monitoring readings only.

Source Test Daily Log

Plant: **Date: 4/25/2001**

No.	Time	Tip	Heat	Flow	Comments
1.	6:09 AM	9050	9	1.0	60 psi air motor pressure
	8:00 AM				60 psi air motor pressure
	9:55 AM		8	1.1	60 psi air motor pressure
	11:30 AM			0.9	60 psi air motor pressure
	2:00 PM				Resin Usage 112.3 gallons
2	6:20 AM	9050	7	0.9+	60 psi air motor pressure
	10:00 AM		7		60 psi air motor pressure
	12:30 AM			1.0	60 psi air motor pressure
	2.00 PM				Resin Usage 144.2 gallons
8	6:03 AM	9050	9	0.8	50 psi air motor- pressure
	11:30 AM		8	0.9	50 psi air motor pressure
	12:30 AM			0.9	50 psi air motor pressure
	2:00 PM				Resin usage 89.2 gallons
9	6:06 AM	9050	8	0.9+	70 psi air motor pressure
	11:30 AM		9		70 psi air motor pressure
	12:30 PM		9	1.1	70 psi air motor pressure
	2:00 PM				Resin usage 187.2

Filters were change at 6:00, 8:00, 10:00, and 12:00
Other molding station pressure readings were taken, but not recorded. These were monitoring readings only.

AOC® World Leader in Resin Technology

2552 Industrial Drive
Valparaiso, IN 46383-9510
(219) 465-1611

CERTIFICATE OF ANALYSIS

…C ORDER NO: 25934

CUSTOMER ORDER NO:

ATTENTION: QUALITY ASSURANCE MANAGER

…TE OF SHIPMENT: 04/11/01
…RAND NAME: VIPEL
…RODUCT: F764-PTZ-17
…RMER NAME:
…TCH #: 44

POUNDS SHIPPED: 44570
TRAILER NUMBER: HT21720
AOC PRODUCT CODE:
CUSTOMER PART NUMBER:

…operty	Units	Test Method	Test Result
…ISC, N01/77F(LVT #3 @ 60)	CPS	V2500T	558.0000
…IX, (LVT #3 @ 6/60)		V2500T	1.9400
…YRENE CONTENT	PERCENT	CALCULATED	43.6009
…EL, N01/77F(1.0% HP-90)	MINUTES	C1001	17.0300
…EL-PEAK	MINUTES	C1001	16.5000
…-TEMPERATURE	DEGREES F	C1001	411.3000
…PER GALLON @ 77F, N01	POUNDS	W0401	9.0100
…ENDOR CATALYST LOT		N/A	220739.0000

Certificate of Analysis Remarks

…IS PRODUCT IS DESIGNED TO YIELD A 20-MINUTE GEL TIME VIA S TEST METHOD.

…LITY ASSURANCE: [signature]

TECHNICAL SERVICE MANAGER: ED KLEESE

ISO 9002 Registered Quality System

CMA MEMBER RESPONSIBLE CARE

TABLE 10: Styrene Source Test Summary

STYRENE EMISSION RATES & EMISSION FACTORS DAY 1 - April 25, 2001

Source	Average Period Flow Rate (dscfm)	Reported Styrene Conc. (ppmv)	Actual Time Period (hr)	Period Styrene Emissions (lb styrene)	Hourly Styrene Emission Rate (lb/hr)	Monomer Usage (lb styrene)	Styrene Emission Factor (lb/lb styrene	Styrene Emission Factor lb/lbresin
UST 1-8'	3,512	121.9	8.00	55.6	7.0	468.7	11.9%	5.2%
UST 2-8'	3,825	114.7	8.00	57.0	7.1	500.5	11.4%	5.0%
UST 3-6'	3,003	97.9	8.00	38.2	4.8	341.8	11.2%	4.9%
UST 4-10'	9,577	73.8	8.00	91.8	11.5	722.8	12.7%	5.5%
			Totall Emission Rate		30.3	2,003.7	Avg. of 4 runs	5.14%

STYRENE EMISSION RATES & EMISSION FACTORS DAY 2 - April 26, 2001

Source	Average Period Flow Rate (dscfm)	Reported Styrene Conc. (ppmv)	Actual Time Period (hr)	Period Styrene Emissions (lb styrene)	Hourly Styrene Emission Rate (lb/hr)	Monomer Usage (lb styrene)	Styrene Emission Factor (lb/lb styrene	Styrene Emission Factor lb/lbresin
UST 1-8'	3,372	84.7	8.00	37.1	4.6	441.2	8.4%	3.7%
UST 2-8'	3,589	60.5	8.00	28.2	3.5	566.5	5.0%	2.2%
UST 3-6'	2,805	78.5	8.00	28.6	3.6	350.4	8.2%	3.6%
UST 4-10'	9,506	40.4	8.00	49.9	6.2	735.4	6.8%	3.0%
			Totall Emission Rate		18.0	2,093.4	Avg. of 4 runs	3.09%

Avg. of 8 runs	4.11%
CFA UEF factor	5.20%
% of UEF	79.1%

Revalidation of Emission Rates from Non-Atomizing Spray Equipment

Larry Craigie, CCT

The advent of flow coater or multi-orifice application equipment went a long way towards reducing emissions generated during the lamination process. This technology made it to the market place just as the CFA emissions testing program was coming to an end at the laboratories at Dow Chemical. The program was extended and data was generated which was used to develop the Unified Emission Factors for mechanical non-atomized application. The technology did not work for all applications but for those that were able to use the mufti- orifice equipment, they were able to claim reductions of 30 to 60 per cent depending upon the styrene content of the resin being used.

Over the last few years, equipment manufacturers have developed new non- atomizing equipment and made improvements so that it could be used in more applications, thus giving more fabricators the opportunity to use equipment that significantly lowers emissions. The improvements in the non-atomizing application equipment can be compared to the advances in computer technology. The first computers were massive in size, consuming large rooms and enormous amounts of energy, where today's computer's are more powerful, fit in a briefcase and run on batteries. The internal speed of early personal computers was 4 million hertz, and today they are available at over 2 billion hertz, over 50,000 times as fast. But even more to the point, the new computers that can be held in your hand do not look anything like the massive computers of the 1950's and 1960's. In the composites industry, the spray patterns from the new non-atomizing application equipment do not look like the patterns from original multi-orifice application equipment. To an untrained eye, the spray patterns from new non-atomizing equipment look very similar to a spray pattern from typical atomizing application equipment. Yet, the equipment is non-atomizing and provides the benefits of more utility and maintains or improves emission reductions.

In the case of faster and smaller computers, it was easy to measure the improvements in capabilities. But with lamination equipment, emission reduction is not as easily determined. The application equipment manufacturers published data indicated that emission reductions are as good as or better than from mufti-orifice/flow coater equipment. But where is the proof?

When we realized that independent data had not been generated to support the low emission claims of new impingement and single orifice non-atomizing equipment, plans were made to develop the required data. The equipment manufacturers had spent considerable time and dollar's developing the new non-atomizing equipment and had tested them at laboratories such as CMTI. But there were problems with the data. Most of the data generated used a single resin, thus data was not available to generate a series of emission factors similar to the information in the Unified Emission Factor table. There was not data from a range of resins (HAP contents 25 per cent - 48 per cent) that could he used to evaluate an emission factor model and back-up the claims of low emissions.

Atomized Spray Application

One of the most widely used pollution prevention technologies in open molding is based on non-atomizing application equipment. Fabricators will be depending upon non-atomized application to meet the expected MACT requirements. The concern is that an air quality inspector might not understand how equipment that produces a pattern similar to an atomized pattern can produce such low emission levels. If there is confusion about the technology, the option to use it may be lost. It was decided that the data supporting this emission reduction technology must be readily available.

The definition of non-atomized application has evolved also. It started out as "maintaining a continuous stream of resin three inches from the gun". This would have been very difficult for an agent to enforce. It is difficult to observe the spray pattern when applying gel coat. When spray/chopping, the view of the spray pattern is further clouded.

Non-Atomized Spray Application

Now, the following definition has been proposed to the EPA:

Mechanical non-atomized application means the use of a device for applying resin or gel coat that a) has been provided by the device manufacturer with documentation showing that use of the device results in HAP emissions that are no greater than the emissions predicted by the applicable non-atomized application equation(s) in Table I to Subpart WWWW of Part 63; and b) is operated according to the manufacturer's directions, including instructions to prevent the operation of the device at excessive spray pressures.

Table I to subpart WWVVW of Part 63 is the United Emissions Factors Table.

Test Development

Rob Haberlein of Engineering Consulting Services set up a test design that would generate the required data with a minimum number of individual tests. A call went out to suppliers and equipment manufacturers for funds, equipment, manpower and materials to conduct the study. GS Manufacturing and Magnum Venus Products graciously agreed to supply the needed funds along with equipment and a technician to conduct the tests. Cook Composite Polymers, Dow Chemical, and InterPlastic Corporation provided the laminating resins. PPG supplied the gun roving for the tests.

The testing was conducted at the Indiana Clean Manufacturing Technology & Safe Materials Institute at Purdue University.

CMTI maintains the Coatings Application Research Laboratory (CARL) under the direction of Jim Noonan and Jean Hall. This laboratory is a comprehensive research and development facility to investigate emission technologies. All of the emissions testing associated with this test program was conducted at the CARL facility.

The CARL facility contains a spray booth enclosure that is ventilated through an exhaust stack. The spray booth enclosure meets the EPA Method 204 criteria for a permanent total enclosure. Therefore, 100% of the emissions released inside the booth are captured. The exhaust air, flow rate, styrene concentration in the booth exhaust, background concentration in the supply air to the booth, exhaust air temperature, exhaust air humidity, and resin delivery rate are measured and recorded by a computerized data acquisition system that computes the corresponding styrene emission rate.

Laminating Resin Selection

The test setup at the CARL facility utilizes EPA Method 25A, which relies upon a flame ionization detector (FID) instrument to measure the styrene concentration in the exhaust flow. However, this total organic analyzer will detect all organic compounds (those containing carbon molecules) in the exhaust, and could falsely report these other compounds as styrene emissions. For this reason, the resin formulations used for the testing only contained styrene monomer, and did not contain any monomer's such as vinyl toluene.

Test Plan Description

The procedures detailed in the test protocol document entitled 'CFA Styrene Emissions Test Protocol & Facility Certification Procedures, Revision 2.1' published by the CFA on November 18, 1998 was followed by CMTI to determine the styrene emission rate for each test run. The completed test matrix of the test runs is shown in Table 1.

Testing

The run parameters established included resin flow rate of 4 lbs/ minute, gel time of 15 minutes glass content of 30 per cent. Tip pressures were adjusted to obtain a good fan pattern for each resin. After spray- up was completed, the laminate was compacted (rolled) for four minutes. The gun operator was instructed to employ controlled spraying techniques, gun held 12 to 18 inches from the mold and maintained at a near 900 angle to the surface. Spray was to cover the mold surface and up to 50% of the flange face surrounding the mold. Both the atomized and non-atomized application tests used the same run and application parameters.

Control Tests

The first order was to establish that the operators could duplicate the data from the base line study. If similar results from the base line study were generated, then this would verify that the procedures and equipment were working property.

The control was designated as a 35 percent styrene bisphenol-A vinyl ester. The styrene content of the tested resin was actually 34.0%. According to the UEF model, the emissions expected from the atomized spray of this resin should be 97 pounds of emissions for every ton of resin applied. The results from the testing at CMTI gave emission values of 79 to 87 pounds of emission per ton of product sprayed. This is well with the experimental range from the base line study. The results from all of the atomized application tests are found in Table 2.

Non Atomized Testing Results

A total of twenty-five runs were conducted during the testing program. Five runs were not used in the analysis for a variety of reasons. There were 8 atomized application runs and 13 Non-atomized runs that were included in the final analysis. Table 3 contains a list of the excluded tests and the rationale. The emission results from the non- atomizing tests are found in Table 4.

Graph 1 is the best way to explain how the testing portion of the proposed definition of non-atomized application is supposed to work. The red line represents the values in the UEF. Per the definition, for equipment to be classified as non-atomizing, data from the testing of the gun when fit to a curve, the curve must fall on or below the UEF curve for non-atomized application.

In this case, all the data was below the values in the UEF. And when all of the data was combined, the results indicate better performance overall than predicted by the UEF. The data did not indicate that the emissions would be significantly less than predicted by the UEF. In some cases, the emissions were 20 per cent lower than predicted by the UEF, but in others it was only a 2 or 3 percentage drop.

Any equipment manufacturer that possesses this type of data should be able to state that their equipment meets the definition of non- atomizing equipment. For a shop to claim that they are spraying with non-atomizing equipment, they must be operating the equipment according to the manufacturer’s directions, including instructions to prevent the operation of the device at excessive spray pressures.

The equipment manufacturers have made equipment capable of non-atomized application. Now it is up to the user to follow the recommended procedures of the equipment manufacturers to gain the advantage of low emissions. At COMPOSITES 2002, you will have the opportunity to learn how to do your part to employ non-atomized application. There will be demonstrations by several equipment manufacturers on how to set up spray equipment to meet the non-atomizing definition. Items to be covered include, tip selection, how to dial in the optimum pressure and proper use of air assist. Also the manufacturers will demonstrate what will happen if the equipment has not been adjusted properly. You will see the results of proper and improper equipment set up and learn how to detect if the operating instructions are not being followed and the equipment is atomizing the resin.

Table 1 Completed Test Design (by run number)

Styrene Content	25	28	29	34	38	44	46	47
Atomized		2	7	4,6,20			16,17	
Non-Atomized A	21	3		19,25	24		18	
Non-Atomized B	11		8	15	12	13		22,23

Table 2 Atomized Application

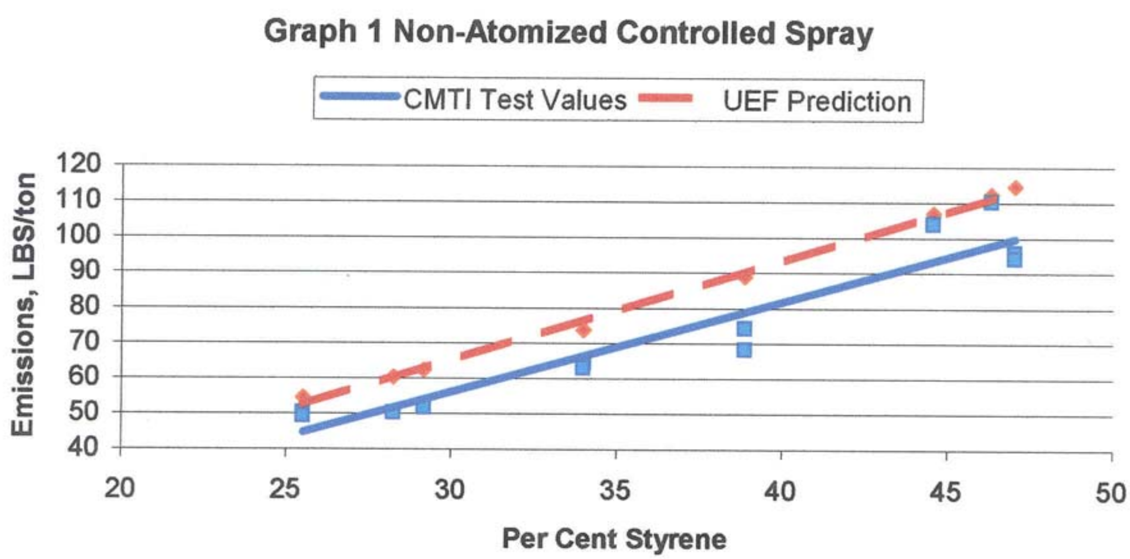
Test #	Pounds of Resin Applied	Percent Styrene	Emissions/ LB Resin
3	13.22	25.25	3.20%
4	13.99	34	3.87%
6	13.44	34	4.47%
7	12.67	29.17	4.35%
16	12.58	46.3	5.94%
17	13.08	46.3	7.59%
20	13.10	34.009	4.47%

Table 3 Excluded Tests

Run	Exclusion Reason
1	Technician did not follow prescribed spray up sequence
5	10 prolonged glass jams
9	Aceton spilled in the chamber
10	Two resins inadvertently mixed yielding unknown styrene content
14	Computer locked up, data lost

Table 4 Non-Atomized Application

Test #	Pounds of Resin Applied	Percent Styrene	Emissions/ LB Resin
2	12.30	28.25	2.52%
8	12.53	29.17	2.59%
11	10.62	25.51	2.52%
12	11.88	38.87	3.42%
13	13.70	44.56	5.20%
15	11.94	34	3.20%
18	12.09	46.3	5.51%
19	13.10	34.009	3.23%
21	11.71	25.51	2.47%
22	12.78	47.03	4.80%
23	12.70	47.03	4.71%
24	11.72	38.87	3.72%
25	13.43	34	3.15%



Unified Emission Factors for Open Molding of Composites

July 23, 2001

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

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 (5)	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
Gelcoat Non-Atomized Application (8)	SEE **Note 9** below	196	205	214	223	232	241	250	259	268	278	287	296	305	314	323	332	341	350	((0.4506 x %styrene) - 0.0505) 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 wt.

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.***

8 SEE the July 17, 2001 EECS report ***Emission Factors for Non-Atomized Application of Gel Coats used in the Open Molding of Composites*** for a detailed description of the non-atomized gelcoat testing.

9 Use the equation **((0.4506 x %styrene) - 0.0505) x 2000** for gelcoats with styrene contents between 19% and 32% by wt.; use the equation **0.185 x %styrene x 2000** for gelcoats with less than 19% styrene content by wt.

UEF unified factors table revised July 23 '01.xls

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