



American Composites
Manufacturers Association

Styrene Emissions Test Protocol

& Facility Certification Procedures

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Test Protocol Revisions 2.2b

Date	Section	Status	Description
3/26/99	2.3	Revised	Measurement Equipment - Optional gas chromatograph added
3/26/99	Table No. 3.1.1	Revised	Optional gas chromatograph added
3/26/99	4.2	Revised	Resin solids determination
3/26/99	Table 4.8.1	Revised	Optional gas chromatograph added
3/26/99	Section 5.2	Added	Optional gas chromatograph procedure added
3/26/99	Section 7.2	Revised	Calibration gas standards procedure
3/26/99	Section 7.5	Deleted	Balance calibration for resin solids determination
3/6/06	Document Attribution	Updated	Changed CFA references to ACMA ¹

¹ The original Test Protocol document was published by the former Composites Fabricators Association (CFA). In 2001 CFA became the American Composites Manufacturers Association (ACMA). This document has been updated to reflect the Association name change.

Forward

It is vitally important for the open molding composites industry to have a unified and standardized test method with which to evaluate styrene emissions. Historically, it has been shown that various test methods, including mass balance testing, “pie pan” evaporation tests, and in-plant stack testing have produced a wide range of results and generally inaccurate data.

The American Composites Manufacturers Association has engaged in the *Open Molding Styrene Emissions Test Project* to enhance the understanding of emissions, and emissions mechanisms. During the course of these multi-year projects, the goal has been to provide “good science” to the quantification of styrene emissions. To this end, the projects have been successful, in that these methods have proven to measure emissions accurately and with repeatability.

This test protocol was initially qualified under an EPA Category II Project Quality Assurance Plan and is the *only* styrene emissions test method to hold that designation. These methods demonstrate the highest levels of quality assurance and data confidence available.

ACMA offers this information for use by the composites industry, materials suppliers, governmental agencies, industry associations, and parties who have an interest in accurately quantifying styrene emissions.

ACMA is willing to assist interested parties in using these test methods, and in understanding the scope, mechanisms, and implications of styrene emissions from the open molding process, provided the information herein is used in context, and within the scope of the body of work developed by the testing project.

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Section 1.0 **INTRODUCTION AND BACKGROUND**

1.0 Introduction

The purpose of the ACMA Open Molding Styrene Emissions Test Protocol is to standardize accurate styrene emissions testing across the industry. This protocol serves as a foundation to compare materials, application equipment or techniques, and source reduction methods.

The use of specific combinations of materials and conditions, and the development of new materials, require definitive data on styrene emissions. A standard test method is necessary to provide uniform industry-wide data, describing the performance of materials systems and application methods. In addition, pollution prevention and source reduction methodologies must be documented and validated by a repeatable comparative method.

The purpose of this protocol is to provide procedures for measuring styrene emissions from molding operations using styrenated resins. While this protocol was developed specifically for determining open molding emissions, the procedures described are applicable to measuring styrene emissions from various molding operations.

1.1 Background

The industries using unsaturated polyester and vinyl ester resins process an estimated 1.4 billion pounds of resin per year.¹ Various industry estimates indicate a range of 40% to 70% of this resin is used in the open molding-processing category. A wide and diverse range of products is produced through open molding. These products include: corrosion control and pollution prevention products; transportation products; marine products; architectural products; sports and leisure products; and custom molded products.

Because of the versatility of composites, including the fact that many companies manufacture composites as a component of other products, it is difficult to ascertain the absolute size and scope of the industry. Recent surveys estimate that between 3,000 and 5,000 companies are engaged in composites production. These operations may range in size from literal “mom and pop” two person operations, to facilities employing nearly 1000 workers. It is estimated that at least 150,000 workers are employed by the U.S. composites industry, and that the industry contributes over \$16 billion annually to the U.S. economy.

¹(Composites Fabrication, April 1996, *Developing the Demographics of the Composites Industry*, Joseph McDermott, Composites Fabricators Association, Arlington, Virginia, 1996.)

As a result of the 1990 Clean Air Act Amendment, the USEPA is mandated to develop a maximum available control technology (MACT) standard for the open molding composites industry. This standard is focused on styrene emissions from the molding process. Historically EPA’s *Compilation of Air Pollutant Emission Factors (AP-42)* has been the

primary source of styrene emission factors for both the agency and the industry. Comprehensive testing conducted by the Composites Fabricators Association, EPA contractors and others have shown a much wider range of emissions than expressed in traditional AP-42 factors. The purpose of the ACMA Open Molding Styrene Emissions Test Protocol is to standardize accurate styrene emissions across the industry.

The open molding industry uses the hand lay-up, spray-up and gel coating processes. Gel coat is used to provide a cosmetic and weatherable exterior surface for composite products. Both the hand lay-up and spray-up processes use thermoset resin and a reinforcement fiber to create the structural laminate. Polyester or vinyl ester resins, and glass fiber reinforcement are most commonly used by a vast majority of the industry.

This test protocol serves as a foundation to compare materials, application equipment or techniques, and source reduction methods, by accurately measuring styrene emissions. Please refer to the CFA Phase I Baseline Study Report, September 1996 for additional information.

1.2 Process Definitions:

Manual Resin Application:

Bucket and tool application, with resin being hand mixed in a container and manually applied to the laminate with a brush, paint roller, squeegee or other tool.

The hand lay-up process is defined as the manual application of resin to roll stock (glass) fiber reinforcement. The resin and initiator are mixed in a container and applied to the laminate using a brush, paint roller, squeegee or similar tool. Following saturation of the fiber reinforcement a “roll out” sequence takes place, where an FRP roller is used to remove entrapped air and consolidate the laminate.

Mechanical Resin Application:

UNCONTROLLED SPRAYING - No spray gun pressure calibration, no mold containment flanges, no specific operator training.

CONTROLLED SPRAYING - Spray gun pressure calibration verified, mold containment flanges in place, and operator training documented as outlined in the ACMA Controlled Spraying Handbook. All three elements must be in place to qualify as Controlled Spray Application.

Resin spray-up application is defined as the use of a “chopper gun” to apply a laminate. The chopper gun dispenses resin,

catalyst and chopped glass fibers. Continuous strand fiberglass roving is fed to a chopper unit mounted on the spray gun and is cut into chopped short fiber lengths. The chopped fiber is ejected from the chopper unit and is captured by the resin fan pattern a short distance from the spray gun. The mixture of the catalyzed resin and chopped fiber is deposited on the mold by the spraying action. Resin dispensed from a spray gun in atomized form, used to saturate roll stock (fiberglass) reinforcement is considered a spray application.

NON-ATOMIZED APPLICATION - Includes flow-coaters, flow choppers, pressure fed rollers, or other non-spray application. Please note – Flow-coaters and flow-choppers are referred to as non-atomized application methods.

Flow-chop application is defined as the use of a non-atomized “chopper gun” to apply a laminate. The chopper gun dispenses non-atomized resin, catalyst and chopped glass fibers. Continuous strand fiberglass roving is fed to a chopper unit mounted on the applicator and is cut into chopped short fiber lengths. The chopped fiber is ejected from the chopper unit and is captured by the resin stream a short distance from the spray gun. The mixture of the catalyzed resin and chopped fiber is deposited on the mold. Resin may be dispensed from a flow applicator and used to saturate roll stock (fiberglass) reinforcement. A pressure fed roller is used to dispense resin on roll stock (glass) fiber reinforcement.

Gel Coat Application:

The application of gel coat products using atomized spray with either controlled or uncontrolled application methods.

Gel coat application uses a spray gun. The gel coat and initiator are mixed during the spraying process, and the “catalyzed” gel coat is deposited on the mold surface in a uniform film. In the fabrication of composites parts using gel coat, the gel coating process is identical for both the manual lay-up and mechanical application laminating process.

UNCONTROLLED SPRAYING - No spray gun pressure calibration, no mold containment flanges, no specific operator training.

CONTROLLED SPRAYING - Spray gun pressure calibration verified, mold containment flanges in place, and operator training documented as outlined in the ACMA Controlled Spraying Handbook. All three elements must be in place to qualify as Controlled Spray Application.

Filament Winding:

The wet wrapping of a continuous filament around a mandrel. Typical filament winding wraps continuous filament around a rotating mandrel, however variants of the process can wrap a stationary mandrel in both the horizontal or vertical position.

1.3 Testing Approach

The molding process is housed in an enclosure which provides 100% air capture to the exhaust stack. A total hydrocarbon analyzer is used to determine styrene concentration in the exhaust stack. Styrene concentrations are measured in parts per million (ppm), and expressed in grams of emissions. Total grams of emissions will be expressed as emissions per weight of available styrene (%AS), emissions per resin weight (%RW), and emissions per unit surface area.

1.4 Test Facility Certification

In order to provide uniformity from facility to facility, and to insure required measurement accuracy, the *Composites Fabricators Association will certify all facilities using this testing protocol*. This certification will verify that all critical elements of the physical test facility are in place, that testing procedures are in conformance with this protocol, and that calibration testing meets required accuracy standards. Periodic re-verification will be required to maintain ACMA endorsement of a test facility.

1.5 Test Set-Up Cost

Depending upon existing laboratory facilities, equipment, and degree of in-house expertise/labor, it is estimated that the cost of installing an approved Styrene Emissions Test Facility will range from ~\$50,000 to \$80,000.

Section 2

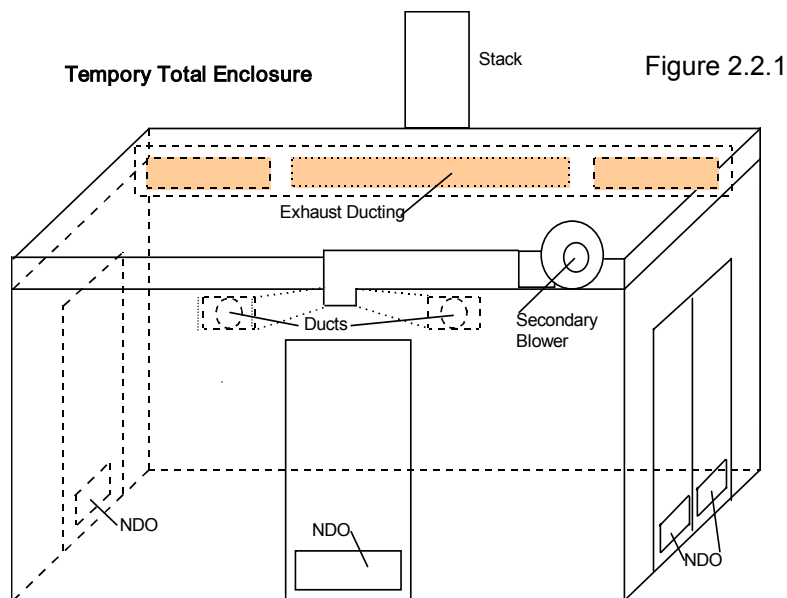
FACILITY AND EXPERIMENTAL SET-UP

2.0 Laboratory Facility

The test chamber must be located in a laboratory that is temperature controlled, and is used exclusively during experimental runs to minimize background VOC concentrations. An analytical laboratory should be located within, or near the test facility. This analytical laboratory should employ equipment and personnel to analyze resin properties and modify resin or gel coat formulations as required. The measurement and analytical equipment used in the project should be maintained under ISO 9001 certification, *or equivalent quality assurance standards*. These equivalent QA standards may be internal procedures, which are at least as stringent as ISO 9001 requirements. The Composites Fabricators Association will certify facilities for conformance to this test protocol.

2.1 Test Enclosure

The test enclosure is a fully enclosed room with an appropriate air exhaust system.. (Figure 2.2.1). Enclosure dimensions will be approximately 8' high x 12.5' wide x 15' long. (The size and shape of the test enclosure may be modified to accommodate specific mold sizes and required working area.) The enclosure is housed within a temperature controlled applications laboratory. Natural draft openings (NDO's) are arranged in accordance with EPA Method 204. (See Figure 2.2.1). The NDO's are baffled to prevent the incoming air from flowing over the mold surface, while still providing the Method 204 required 200 fpm flow through the openings.



2.2 Exhaust System and Enclosure Air Flow

The exhaust system uses a plenum, which is designed to capture air evenly from throughout the test chamber. The plenum is ducted to a single stack delivering exhaust outside the laboratory. The stack exhaust uses a centrifugal blower mounted in an appropriate location outside the laboratory. A total airflow of between 0.933 and 1.066 cfm per cubic foot of enclosure area, will be maintained through the enclosure at all times during testing.

Example:

Enclosure dimensions – 8 ft x 12.5 ft x 15 ft = 1500 ft³ enclosure volume.

1500 ft³ enclosure x .933 cfm = 1400 cfm airflow

1500 ft³ enclosure x 1.066 cfm = 1600 cfm airflow

1500 ft³ Enclosure Airflow Range = 1400 to 1600 cfm Total

Consistent stack airflow is an extremely critical factor in determining emissions based on conversion calculations.

Stack airflow can fluctuate due to atmospheric pressure, the direction and strength of the wind over the stack, voltage anomalies to the blower motor, and the condition of the exhaust hardware. *Because of this, stack airflow must be continuously monitored and controlled in real time, in order to provide an airflow consistency which meets confidence levels in emissions calculations.*

A stack monitoring system will be used, such as the VorTek™ velocity sensing system (or equivalent). This electronic airflow traverse probe reports to the data acquisition system, which monitors and adjusts stack flow on a real time basis. (See Appendix for description of airflow velocity sensor). A manometer is also connected to the exhaust stack as a back-up to the velocity sensor system. This is used as a quality assurance cross-check at the initiation of each experimental run. There is a 100% capture efficiency of air in the temporary total enclosure.

While the airflow into the test enclosure is baffled to prevent direct flow over the mold, a secondary blower provides a measured airflow over the mold surface. This blower is mounted outside of the test enclosure and draws air from within the test area, returning it through two (2) ducts which direct a uniform flow of air across the mold surface. The airflow across the mold is calibrated to high and low velocities of 100 fpm and 50 fpm, respectively.

Baffling of the natural draft openings (NDO's) and using the secondary blower is an innovation of the ACMA Test Method. This allows the use of EPA Method 204, which requires a minimum of 200 fpm through the

enclosure, while retaining the ability to control and adjust the airflow over the mold surface at various rates less than 200 fpm.

2.3 Measurement Equipment

The primary measurement instrument is a total hydrocarbon analyzer, used according to a *modified* EPA Method 25A, as described in the Code of Federal Regulations, Chapter 40, Part 60. Specific modifications to Method 25A are described in this document.

A Gas Chromatograph (GC) may be added as an *optional* measurement instrument, in order to provide the capability to speciate multiple hydrocarbon emissions. This may become useful when examining emissions from resins or gel coats employing dual monomer systems, such as styrene and methylmethacrylate.

The total hydrocarbon analyzer uses a flame ionization detector (FID) that converts hydrocarbons in proportion to the to the number of atoms transiting the detector. The THA provides continuous data output, which in this case is cycled in one-second intervals, with a two-second interval signal output to the data acquisition system. A Thermo Environmental Instruments, Inc. Model 51 heated Total Hydrocarbon Analyzer (THA), or equivalent instrument will be used to measure stack concentrations.

The THA will use a sample probe in the form of a “rake” type pitot tube in the enclosure exhaust duct. The “rake” type pitot tube will have three (3) sample points. The sample points are holes are located in the center of the duct and two holes located 10% of the duct diameter from the edge of the duct.

The optional Gas Chromatograph, equipped with a flame ionizing detector (FID), may be configured to cycle samples every 120 seconds or faster if capable. The GC will sampling point will be a pitot tube located in the exhaust duct. The output signal of the GC will be linked to the data acquisition system.

2.4 Emission Sampling Location

The calibrated pitot tubes for the total hydrocarbon analyzer will be located upstream from the exhaust blower a minimum of six duct diameters from the nearest flow disturbance.

2.5 Data Acquisition System

A computer data acquisition system is used to display real time data inputs, record data and control exhaust airflow. The computer system receives data from the THA at two-second intervals and continually records and adjusts stack exhaust flow; continuously records temperature; records digital output from the resin weight balance; and records output from

the THA. Data is displayed on screen and is written to the internal hard disk and to a floppy disk. The following data streams shall be to be measured and recorded:

- Time
- THA Stack Concentration
- Stack Air Flow
- Enclosure Temperature
- Weight of Resin Being Consumed

2.6 Required Facility and Equipment Elements for Certification

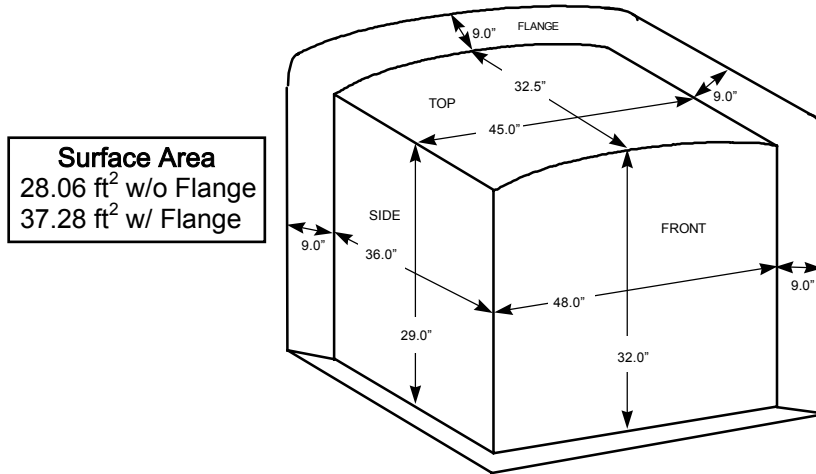
- Temperature controlled lab work area
- Test enclosure complying with (EPA Method 204)
- Test Enclosure exhaust system
- Stack velocity sensor system
- Stack probe
- Blower and re-circulating duct system
- Total hydrocarbon analyzer
- *(Optional) Gas Chromatograph
- Multi-channel computer data acquisition system
- Calibration gas manifold
- Precision balances
- Standardized test mold

2.7 Test Mold Configuration and Size

A standard mold configuration will be used for comparative purposes. Because of the considerable baseline data gathered during previous studies, a standardized mold will allow comparison between test facilities, and application methods.

The mold used for these experiments is a three-sided male mold mounted on a wheeled dolly. The mold has a 9” angular flange on the three primary planes, designed to catch overspray during controlled spraying experiments. Mold dimensions are as follows:

Figure 2.7.1
TEST MOLD

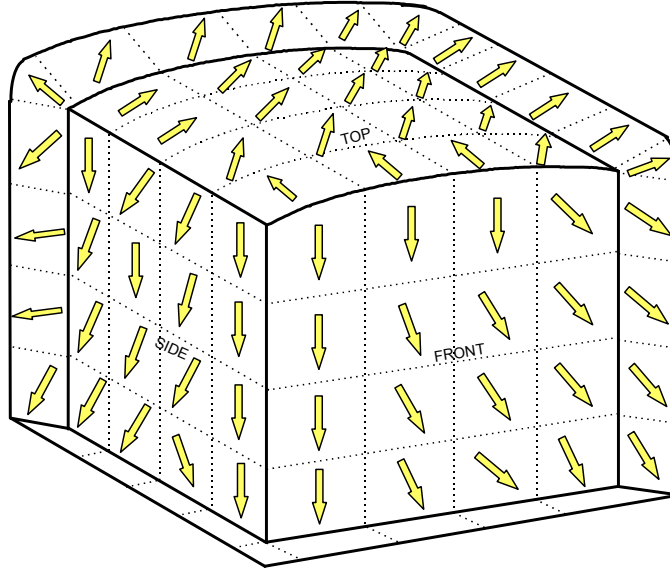


2.8 Air Flow Over Mold Surface

Outside air drawn into the TTE is baffled, to eliminate general exhaust flow over the mold. A secondary blower draws air from within the enclosure, and is ducted to create a direct flow over the mold surface. This airflow can be adjusted to various flow rates. With 50 fpm and 100 fpm used as standard velocities. Air velocity at the mold is measured with a hot wire anemometer to calibrate and document flow rate. Prior to beginning the experiments, a handheld bulb type smoke generator may be used to map the direction of laminar air flow within ¼” (6mm) of the mold surface. The general “aim point” of the airflow is the corner intersecting the front, top and side of the mold.

Figure 2.8.1

Laminar Air Flow Over Mold Surface



Section 3

Experimental Procedure and Measurements

3.0 General Experimental Procedure

1. THA is calibrated. (Optional) GC is calibrated.
2. Baseline measurements are established.
3. Mold, materials and spray unit are moved to test location.
4. Initial weight of resin or gel coat is recorded.
5. Application of resin or gel coat on the mold.
6. Final weight of resin or gel coat is recorded.
7. THA measurements are discontinued when styrene levels reach preceding baseline levels.
8. Data is recovered.
9. A Calibration check is run on the instrumentation
10. Test area, mold and spray unit is prepared for subsequent experiment.

3.1 Critical Measurements

Critical measurements are those which effect or may effect the overall objectives of the measurement process. There are two types of critical measurements in this procedure. First is the direct measurement of styrene emissions, using the total hydrocarbon analyzer and EPA Method 25A. Second are measurements of the process, which must be controlled in order to derive the necessary resolution from the collected data. These measurements include wet laminate/film thickness, resin/gel coat styrene content, gel time, resin/gel flow rate, airflow over mold, and ambient temperature.

Table No. 3.1.1 lists critical measurements and their measurement frequency for this study.

Table No. 3.1.1
Summary of Physical Measurements for
Styrene Emission Testing

Measurement	Measurement Classification	Measurement Designation	Measurement Frequency	Measurement Site
Emissions (THA)	Critical	Stack -EPA Method 25A	Continuous (2 second interval data points)	Exhaust Stack
Emissions (GC) *Optional Equipment*	Critical	Stack - GC Measurement	No longer than 120 second interval	Exhaust Stack
Wet Laminate Thickness	Critical	Wet Mil Gauge	Each Experimental Run	Mold Surface in specified locations
Wet Film Thickness	Critical	Wet Mil Gauge	Each Experimental Run	Mold Surface in specified locations
Resin Solids Determination	Critical	EPA Method 311	Each Material Batch	Laboratory analysis
Cup Gel Time	Critical	Internal Work Instructions	Each Batch of Resin	Laboratory analysis
Resin Flow Rate	Critical	Application Equipment Calibration	Each Experimental Run	Application Equipment
Air Flow Over Mold	Critical	Hot Wire Anemometer	Prior to each test series	Velocity at Mold Surface
Temperature	Critical	Thermocouple	During Each Experiment	Within Enclosure
Mass Balance-Styrene Recovery Check	Critical	EPA Method 25A/ Weight	Weekly or prior to each test series	Within Enclosure
Air Flow Through Enclosure	Critical	Velocity Sensor	Continuous(2 second interval data points)	Vent Hood Stack
Resin/Gel Coat Weight	Critical	Precision Balance	Each Experimental Run	Application Unit Outside Enclosure

Section 4 DATA QUALITY INDICATORS FOR CRITICAL MEASUREMENTS

4.0 Determining QA Objectives

The primary objective is to establish values for styrene emissions under controlled environmental conditions. The THA is the measurement instrument used according to EPA Method 25A. The factor levels for experimental variables have been established under baseline studies, and are necessary in order to produce comparative results from site to site tests. The range of factors is derived from conditions most likely be found in a commercial production setting. Propagation of errors will be taken into consideration in the statistical analysis of variance and lack-of-fit tables.

4.1 Laminate/Gel Coat Thickness

In the spray-up laminate experiments, a chop mil gauge will be used during the application to determine the rate of build-up and distribution of thickness. During the course of spray application the operator will check the thickness at specified locations on the laminate. Laminate thickness will be recorded on the experiment report sheet.

The mean thickness will be calculated from the measurements and compared against each other with a one-tail test at the $\alpha = 0.05$ confidence level for 2 degrees of freedom for which the student's $t_{0.05,2} = 2.760$. The estimated standard deviation required for the hypothesis $H_0:m_1 = m_2$ and either, $H_1:m_1 < m_2$ or $H_1:m_1 > m_2$ is estimated to be $\pm 0.010''$ with the tolerance around the factor levels being $\pm 0.0012''$.

In the hand lay-up laminate experiments, the primary thickness control will be the thickness of the chopped strand mat reinforcement. Typical overlaps and build-ups are expected in corner areas of the mold.

For the gel coat experiments a standard gel coat mil gauge will be used to measure the thickness build-up during the application and to record the final gel coat wet film thickness. Mil gauge readings will be taken at specified locations on the mold surface. The wet film thickness will be recorded on the experiment report sheet. Based on the hypothesis treatment as given above, the specified tolerance (by standard deviation) is $\pm 0.002''$.

The mean thickness will be calculated from the measurements and compared against each other with a one-tail test at the $\alpha = 0.05$ confidence level for 2 degrees of freedom for which the student's $t_{0.05,2} = 2.760$. The estimated standard deviation required for the hypothesis $H_0:m_1 = m_2$ and either, $H_1:m_1 < m_2$ or $H_1:m_1 > m_2$ is estimated to be $\pm 0.002''$ with the tolerance around the factor levels being $\pm 0.002''$.

4.2 Resin Solids Determination

EPA Method 311 will be used to determine resin solids content. This measurement may be made by the material supplier and certified on the resin batch analysis sheet.

4.3 Gel Time

The interval from catalyzation to gelation will be measured using standard gel time procedures. Initiator or promoter levels will be adjusted to obtain the specified gel time within a ± 1.5 min. of the target. The application equipment will then be adjusted to deliver the percentage of initiator required to achieve the specified gel time. The resin/gel coat to initiator ratio of the application equipment will be determined through a standard weight calibration of the dispensed resin.

In the case of the manual resin batch application, the specified amount of initiator will be measured on a calibrated analytical balance. The initiator will then be manually mixed with the resin immediately prior to application.

4.4 Resin Flow

The output of the application equipment will be determined during the standard calibration of the equipment. The output will be controlled by a combination of fluid tip orifice size and pump pressure setting. Standard calibration consists of dispensing into each of 3 containers for 15 seconds and weighing the output. Based on the confidence limit criteria the measured output then requires that the mean of the three measurements are ± 68 g of the target level with any one measurement ± 57 g of the mean value. The mean weight is then converted into a flow rate in pounds per minute (lbs/min).

Flow Rate	Target Mass (15 seconds)	Mean of 3 Samples Must be Within	Measured Values Must be Within
906 g/min (2 lb)	226.5 g	± 68 g	± 59 g
1812 g/min (4 lb)	453 g	± 68 g	± 59 g

4.5 Air Flow

Airflow velocity over the mold surface will be provided by the auxiliary blower and duct system. This system is configured to extract air from within the test enclosure, and return the flow through ducts and outlets that direct a uniform airflow across the mold surface. The airflow over the mold surface will be measured using a hot wire anemometer, such as a Cole-Parmer Trisense Model No. 37000-00 or equivalent. Dampers in the ducts will be adjusted to provide the specified airflow across the mold surface.

4.6 Mass Balance Styrene Recovery Check

A mass balance calibration will be conducted before studies are to be conducted. The THA will be calibrated according to previously described procedures. Styrene will be evaporated from a shallow pan having an absorbent media hanging over the pan and extending down into the liquid styrene. An auxiliary fan may be used to enhance evaporation. The input weight of the styrene will be compared to the calculated weight based on the average ppm recorded by the THA.

4.7 Resin/Gel Coat Weight

Resin/gel coat weight will be recorded immediately before application and upon completion of application. The weight will be measured with a calibrated balance. Required precision of the balance is ± 1.0 g with a capacity greater than 100 pounds.

Table 4.8.1
Quality Assurance Objectives for
Critical and Non-Critical Measurements

Measurement	Measurement Designation	Measurement Frequency	Precision Range	Required Accuracy	Completeness
Emissions (THA)	Stack –EPA Method 25A	Continuous (2 second interval data points)	±2 ppm	± 10%	>1200 data points per run and when measurement reaches original baseline
Emissions (GC) *Optional	Stack GC Measurement	120 second interval or less	±2 ppm	± 10%	>30 data points per run and when measurement reaches original baseline
Wet Laminate Thickness	Wet Mil Gauge	Each Experiment	±0.010”	±0.012”	3 measurements per run
Wet Film Thickness	Wet Mil Gauge	Each Experiment	±0.002”	± 10% Specified Thickness	3 measurements per run
Resin Solids Determination	EPA Method 311	Each Resin/Gel Coat Batch	±0.34% w/w at 95% confidence level	± 1.5% Specified Styrene Content	2 measurements of each resin prior to a study
Gel Time	Internal Work Instructions	Each Resin/Gel Coat Batch	±4% absolute deviation from mean	± 1.5 min. Specified Gel Time	2 measurements of each resin prior to a study
Resin Flow Rate	Fluid Equipment Calibration	Each Experimental Run	±.3 lb/min.	±.3 lb/min. Specified Flow Rate	2 measurements per run
Air Flow	Velocity at Mold Surface	Prior to Each Experimental Study or monthly	± 20 %	± 20% Specified Air Flow	Six Readings per minute for three minutes
Temperature	Within Enclosure	During Each Experiment	±2°F	75±4° F	> 1200 data points per run
Air Flow Through Enclosure	Vent Stack Air Flow	Continuous (1 second interval data points)	± 25 cfm	± 100 cfm	> 1200 data points per run
Mass Balance - Styrene Recovery Check	EPA Method 25A/Weight	Before Each Emission Study or weekly	± 4%	± 10%	Two measurements prior to each study
Resin/Gel Coat Weights	Precision Balance	During Each Experiment	± 0.002 lb	± 0.004 lb	Two Measurements per run

4.8 Mass Balance Styrene Recovery Check

This measurement is critical for calibrating the overall operation of the system and must be performed immediately prior to the initiation of an experimental plan, or at no less than monthly intervals. Styrene is placed in a flat pan and evaporated to establish overall capture efficiency. Using the following procedure:

1. Instrumentation and airflow are calibrated.
2. Total hydrocarbon analyzer is operated according to specifications. Data is collected.
3. A shallow pan is weighted and tared on a balance accurate to .01 g.
4. A measured quantity of styrene is placed in a shallow pan and weighted.
5. Absorbent media is pre-weighted.
6. Absorbent media (such as paper towel) is secured above pan and submerged in the styrene to enhance evaporation. A small fan can be directed on the media to expedite evaporation.
7. When evaporation is complete, pan and absorbent media are weighted. Styrene loss by weight is calculated.
8. Total hydrocarbon analyzer data is compiled and emissions calculated.
9. THA emissions are compared to mass balance emissions loss.

The experimental accuracy is expressed as the result of a mass balance styrene recovery check. The styrene capture efficiency of the enclosure and exhaust system and the accuracy of the analytical equipment *must be greater than 95%*. This is determined through styrene evaporation trials. Following is an example of a series of recovery checks:

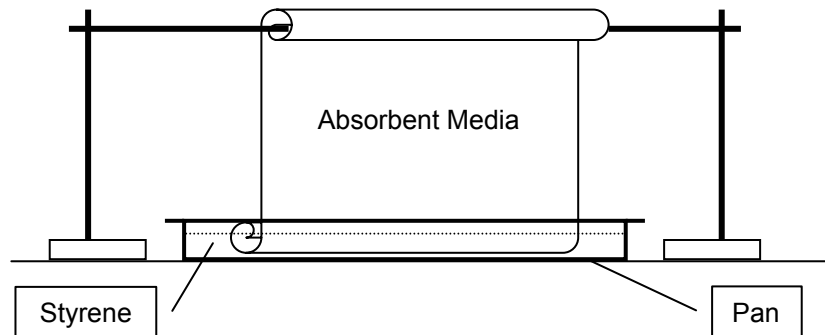


Figure 4.8.1

Table 4.8.1
Example of
Mass Balance Styrene Recovery
Check of Analytical Equipment¹

Run Number	Duration Minutes	Average Emission (ppm)	Weight of Styrene Evaporated (g)	Styrene Emissions Measured - THA (g) ¹	% Styrene Recovery
1	40.7	37.3	278	268.6	96.6
2	34.8	28.8	186	177.3	95.4
3	35.9	32.9	216	209.0	96.8
4	34.1	35.2	220	212.4	96.5
5	57.9	22.3	238	228.3	95.9
6	35.3	34.7	226	216.8	95.9
7	32.6	38.9	231	223.8	96.9
8	31.8	42.4	250	238.6	95.4
9	34.5	35.3	222	215.5	97.1
10	35.2	40.9	267	254.8	95.4
11	37.1	28.4	196	186.4	95.1
12	33.4	35.1	217	207.4	95.6

Overall Styrene Recovery Efficiency	95.9
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¹Based on THA measurements in ppm converted to weight

4.9 Calculation for Total Styrene Emissions

Total Styrene Emissions, lbs. =

$$\frac{\text{TWA styrene emissions in cc/m}^3 \text{ (ppm)} \times \text{Air flow in m}^3/\text{min.} \times \text{Time in min.} \times 104\text{g/mole}}{24.45 \text{ l/mole} \times 1000 \text{ cc/l} \times 454 \text{ g/lb}}$$

Equation is valid at 77°F and 29.92 inches HG, which corresponds to the standard molecular volume of 24.45l/g-mole. The standard volume can vary significantly at different temperatures, barometric pressures, and most importantly, local elevation. The equation should be corrected with a local air density factor.

Section 5 **SAMPLING PROCEDURES**

5.0 Sampling Site

The sampling site will be located in the stack of the Temporary Total Enclosure (TTE) exhaust hood. The sampling probes are to be installed in the exhaust stack as prescribed by EPA Method 40 CFR Ch.1. The airflow through the exhaust ducting is monitored and adjusted in real time by electronic air traverse probe utilizing a VorTek™ velocity sensing system (or equivalent) linked to the data acquisition computer. The method used for calibrating stack airflow is described in EPA 40 CFR Ch. 1, Method 1. A manometer attached to an S type pitot tube installed in the exhaust ducting will be used as a back-up monitor for any change in set flow.

5.1 THA Sampling Procedure

The THA sampling procedure follows EPA Method 25A - Determination of Total Gaseous Organic Concentrations Using a Flame Ionization Analyzer, with the following modifications:

1. The acceptable accuracy for checking calibration with the 80% span gas standard will be $\pm 10\%$ from the predicted response.
2. Calibration checks will not be made during data collection.
3. The calibration of the THA will be verified using the low span, mid-span and the 80% span gas before the first run of the day. The calibration will be checked before the second run of the day using the mid-span calibration gas. The THA will be re-calibrated, if necessary for the second run
4. Only one detection range will be used during a study. The typical detection range is spanned to cover styrene emissions from 0-350 ppm. The detection range may be spanned to cover higher styrene emissions should the need arise.
5. 100% Hydrogen will be used as a fuel gas.

5.2 GC Sampling Procedure

An appropriate gas standard will be used to check GC area response for consistency. The same gas samples used for the THA will be used to verify consistency between the THA and the GC.

1. The GC analysis system will be standardized at the beginning of each day, using calibrated gas samples.

2. The analysis system is placed into the sample mode prior to resin being introduced into the test enclosure. An ambient baseline of emissions is established at this point. Typical baseline readings are <2.0 ppm.
3. The analysis system will take a stack sample every 2 minutes, or at a shorter interval.
4. The analysis system will continue to take air samples throughout the experiment until the emissions level has dropped back to the initial baseline level. Sampling will be terminated at that point.
5. The GC analysis system will then be standardized, using a sample gas, to determine if calibration was maintained during the sampling period.

5.3 Sample Line Leak Checks

Leak checks will be performed at the beginning of each week of testing. All fittings, valves and connections of the THA will be examined. A valve just down stream from each sample port will be closed off while a sample is being drawn to a detector. The in-line flow meter will drop to zero if no leaks are present in the sample line.

Section 6

SAMPLE AND DATA HANDLING

6.0 Sample ID Procedure

Uniform procedures will be used to track all data and information generated from testing. A worksheet will document each experimental run. A data ID designation will be assigned prior to commencing each run. A separate data diskette will be used to record each experimental run. The ID number will be recorded on the data diskette prior to the experimental run.

Physical samples, such as those used in determining non-volatile content, will be assigned a unique sample number, which includes the resin/gel coat batch number, date and experiment for which test is being conducted.

Section 7 CALIBRATION PROCEDURES

7.0 Analytical and Application Equipment Calibration

All application apparatus and analytical equipment must be calibrated within a specified time period or at the start of experimental runs. Calibration procedures are as follows:

7.1 Total Hydrocarbon Analyzer Calibration Procedure

The THA sampling procedure is consistent with EPA Method 25A - Determination of Total Gaseous Organic Concentrations Using a Flame Ionization Analyzer. The following changes will be made to Method 25A:

4. The acceptable accuracy for checking calibration with the 80% span gas standard will be $\pm 10\%$ from the predicted response.
5. Calibration checks will not be made during data collection.
6. The calibration of the THA will be verified using the low span, mid-span and the 80% span gas before the first run of the day. The calibration will be checked before the second run of the day using the mid-span calibration gas. The THA will be re-calibrated, if necessary for the second run
4. Only one detection range will be used during a study. The detection range is spanned to cover styrene emissions from 0-350 ppm. The detection range will be spanned to cover higher styrene emissions should the need arise.
6. 100% Hydrogen will be used as a fuel gas.

7.2 Calibration Gas Standards

Propane may be used as a calibration gas standard with the appropriate conversion factors applied to relate to styrene.

7.3 Enclosure Air Flow Calibration

The airflow through the enclosure will be measured and verified prior to the start of a study, using EPA 40 CFR Method 1, Ch. 1, with a hot-wire anemometer or a pitot tube. The data acquisition system will be calibrated in reference to the stack velocity sensing system.

The airflow will be re-calibrated at the beginning of each study. The manometer reading will be recorded at the beginning and end of each test run. If a change of ± 0.05 inches of water is noted during testing the airflow through the enclosure will be re-calibrated.

7.4 Spray Equipment Calibration

Application equipment will be calibrated before each test run. The flow rate will be calibrated to provide a specific resin and gel coat output as required by the experimental design. In the case of the spray-up application, the glass content will be adjusted to the required resin flow rate. The flow rate calibration will consist of spraying resin into a pre-weighed container for 15 seconds and recording the material weight in lbs/min. The resin pump pressure will be adjusted or spray tip sizes will be changed to achieve the specified flow rate.

For the spray-up experiments the calibration will consist of capturing both resin and chopped glass for 15 seconds, in separate containers, and weighing individually to determine the resin to glass ratio. Once the flow rate is established, the chopper speed will be adjusted to provide the proper glass ratio.

Resin/gel coat to catalyst ratio will be calibrated by means of catalyst volume measurement compared to flow rate. The catalyst ratio will be adjusted by the catalyst delivery unit.

7.4.1 Spray Gun's Flow Rate Calibration

- 1) Spray tip is selected with specific orifice size and fan angle.
- 2) Catalyst pump is disconnected.
- 3) Atomizing air is shut off.
- 4) Spray unit is charged with a specific resin or gel coat. Air is purged from system and material flow is checked to verify cleaning solvent is fully purged from fluid lines.
- 5) Pump pressure is set to anticipated pressure.
- 6) Analytical balance is tared.
- 7) Container tare weight is recorded.
- 8) Resin/gel coat is sprayed into container for a timed 15 seconds.
- 9) Resin/gel coat weight and pressure setting are recorded.
- 10) Pump pressure is adjusted to modify flow rate, if needed.
- 11) Steps 8 -10 are repeated to produce the required flow rate with ± 14 g/min of target flow.
- 12) Two flow rate checks will be made once final adjustments are made.

7.4.2 Catalyst Flow Rate Calibration

- 1) Spray unit is charged and resin/gel coat flow rate calibration is completed as described in 7.4.1.
- 2) The 250-ml graduated cylinder serving as the catalyst reservoir is filled with the catalyst to specified volume.

- 3) The catalyst pump is positioned to the appropriate setting.
- 4) The separator tip is mounted on the spray gun.
- 5) The spray gun is activated for 15 seconds.
- 6) The reduction in catalyst volume in the graduated cylinder is recorded.
- 7) The catalyst pump setting is adjusted to modify flow rate.
- 8) Steps 5-7 are repeated to produce the required flow rate yielding the specific gel time.
- 9) The specific gravity of the catalyst will be used to convert volume to mass. The specific gravity will be obtained from the catalyst supplier specifications.

7.4.3 Chopper Gun Calibration - Resin:Glass Ratio

- 1) Spray gun rate calibration and catalyst calibration are completed.
- 2) Continuous strand roving is fed to the chopper and unit is initialized.
- 3) Chopper unit air pressure is set to anticipated level.
- 4) A pre-weighed plastic bag is placed over the chopper chute and another pre-weighed plastic bag is placed over the spray tip.
- 5) The spray gun is activated for 15 seconds.
- 6) The bag containing dry chopped glass and the bag containing sprayed resin are separately weighed and recorded.
- 7) The chopper unit air pressure is adjusted to modify chopped glass output in relation to resin output.
- 8) Steps 5 - 7 are repeated to produce the specified resin to glass ratio.

7.5 Balance Calibration Check

Balance for Resin Weight During Spray-Up and Hand Lay-Up

- 1) A Sartorius balance model F61S (or equivalent) will be used.
- 2) The balance upon arrival at the test site will be calibrated by an approved vendor utilizing NIST traceable standards and documented procedures.
- 3) Internal adjustments will only be made by a qualified repair technician.
- 5) The balance will be calibrated semi-annually by an approved vendor utilizing NIST traceable standards and documented procedures.

7.6 Gel Timer Calibration Check

- 1) Use a NIST traceable stopwatch.

- 2) Press the “ON” button to the NIST stopwatch and Gel Timer simultaneously.
- 3) Let the NIST traceable stopwatch and gel timer run for 15 minutes \pm 5 seconds.
- 4) When the time is up, simultaneously stop the NIST traceable stopwatch and the gel timer.
- 5) Record the time displayed by the gel timer.
- 6) The time displayed by the gel timer must be 15 minutes \pm 15 seconds in order to meet acceptance criteria.
- 7) The frequency of calibration check is “at the time of use or monthly, whichever is greater.

7.7 Enclosure Thermocouple Calibration Check

The temperature reported by the data acquisition system will be checked against a NIST traceable thermometer on a weekly basis. A type J thermocouple is located approximately three feet above the floor level.

7.8 Water Bath Temperature Calibration Check

- 1) Immerse the probe of a NIST digital thermometer to the same depth as the probe of the thermometer for the constant temperature water bath.
- 2) Wait one minute for temperature readings to stabilize.
- 3) Compare the temperature readings of both thermometers.
- 4) Acceptance criteria is a difference in temperature from the NIST thermometer of no greater than \pm 5 °F.
- 5) Frequency of calibration check is “At time of use or monthly, whichever is greater”.

Section 8 ANALYTICAL PROCEDURES

8.0 Standardized Analytical Procedures

The following standard procedures will be used in the determination of resin properties.

8.1 Percent Resin Solids Determination Procedure (Volatile Content)

Resin solids determination will be made using EPA Method 311.

8.2 Gel Time Procedure

- 1) The promoted resin should be brought to $77 \pm 2^{\circ}\text{F}$ by use of a constant temperature water bath.
- 2) Weigh 100 ± 1.00 grams of the promoted resin into a tared 4 oz. wide mouth bottle.
- 3) Catalyze the promoted resin with the prescribed amount of catalyst. Cap the bottle tightly, turn the Power switch “ON”, and shake the bottle for 45 seconds.
- 4) Immediately uncap the bottle, place the bottle in a foam holder, and position the bottle under the gel timer.
- 5) Attach the glass rod spindle to the gel timer, while centering the glass rod in the 4 oz. glass bottle.
- 6) Turn the Test switch to the “ON” position to activate the gel time alarm.
- 7) When the alarm sounds, immediately turn both the Power and Test switches “OFF”. Record the gel time.

SAMPLE WORKSHEET

Experiment Work Order / Process Data Sheet

Block (Day)	Date	Run No.	Thickness (in)	Resin Batch No.	Resin Flow Rate	Air Flow Rate

Data ID Code:	
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Equipment Set-up

Spray Tip Size:		Air Assist Pressure:	
Spray Tip Angle:		Catalyst Pump Setting:	
Pump Pressure:		Flow Rate:	
Chopper Pressure:			

Resin / Gel Coat Data

Adjusted Gel Time:		@ Catalyst %	
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Temperature

Ambient Temp. Start Run:		Ambient Temp. End Run:	
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Process Times

Data Recording Start:		Batch Start Time:	
Data recording End:		Batch End Time:	
Total Experiment Time:		Total Batch Time:	
Spray Start Time:		Laminating Start Time:	
Spray End Time:		Laminating End Time:	
Total Spray Time:		Total Laminating Time:	

Resin/Gel Coat Weight

Initial Weights:		Final Weights:	
Total Resin/Gel Coat Weight			

Section 9

QUALITY CONTROL CHECKS

9.0 Internal QC Checks

Routine quality control checks shall be carried out, as described, to insure various aspects of experimental control are maintained.

9.1 Materials

Each batch of polyester resin and gel coat will be adjusted to the specified gel time by adjusting the level of initiator and/or promoter to produce the required gel time. Gel times will be determined prior to testing.

9.2 Temperature

The ambient air temperature will be monitored and recorded during the testing by the data acquisition system linked to a thermocouple in the TTE. The accuracy of the thermocouple readings are to be validated by the periodic use of a NIST traceable thermometer.

9.3 Replicate Experiments

Each emission study contains an appropriate number of replicate runs to verify the reproducibility of test runs.

9.4 Air Flow Over Mold Surface

Prior to each emission study, the airflow over the surface of the mold will be checked to verify that no changes have occurred.

9.5 Measurement Equipment

Equipment calibration procedures and work instructions are part of the quality management system, which is certified to ISO 9001 or equivalent internal standards. Equipment requiring calibration includes: balances, gel timer, ovens, etc.

9.6 Air Flow Through Enclosure

The manometer located in the vent hood stack is used to monitor for changes in airflow through the TTE. The vacuum in inches of water determined at the initial calibration of the airflow will be recorded and daily vacuum readings checked against it.

9.7 Blank Readings

Emission blank readings will be obtained by the THA prior to each test run to ensure that extraneous styrene vapors are not present. Blank readings should be less than 1.5 ppm.

Section 10 **DATA QUALITY INDICATORS**

10.0 Determining the Quality of Collected Data

The following data quality analysis will be applied to experimental studies.

10.1 Precision

Calculated from duplicate measurements, the relative percent difference is the measure of precision:

$$RPD = \frac{|C_2 - C_1|}{m} (100\%)$$

Where: RPD = relative percent difference
C₁, C₂ = observed values
m = mean of the two values

Standard deviation will be calculated for multiple duplicate measurements.

10.2 Completeness

Completeness is as follows for all measurements:

$$\%C = \frac{V}{N} (100\%)$$

Where: %C = percent completeness
V = number of measurements executed
N = total number of measurements planned

10.3 Accuracy

Accuracy is expressed as the relative error from a value from a known standard:

$$\%RE = \frac{m - S}{S} (100\%)$$

Where: %RE = percent relative error
μ = measured value
S = standard value

Section 11

FACILITY CERTIFICATION

11.0 Requirement for Certification

In order to qualify new materials, equipment, processes or operational parameters under the MACT Regulation, standardized testing will be used. Additionally, the development or evolution of products or procedures will require “apples-to-apples” quantification to assess the effectiveness or nature of changes.

To provide uniformity and credibility from test facility to facility, and to insure required measurement accuracy, the *American Composites Manufacturers Association will certify all facilities using this testing protocol*. This certification will verify that all critical elements of the physical test facility are in place, that testing procedures are in conformance with this protocol, and that calibration testing meets required accuracy standards. Periodic re-certification will be required to maintain ACMA endorsement of a test facility.

11.1 Facility Certification Requirements

In order to receive ACMA Certification, the following mandatory elements must be in place and operational within the specifications of this test protocol:

- Temperature controlled lab work area
- Test enclosure complying with ACMA/EPA Method 204 specifications
- Test Enclosure exhaust system – Single point stack
- Stack velocity sensor system – VorTek AirFlow Transmitter
- Stack probes linked to THA
- Stack airflow velocity check – detailed stack flow analysis
- Enclosure re-circulating airflow system – blower and ducts
- Total hydrocarbon analyzer using modified Method 25A
- Multi-channel computer data acquisition system
- Calibration gas manifold
- Propane gas standards
- Ambient background hydrocarbon levels within control limits

- Precision balances – digital output to acquisition system
- Resin gel time measurement and adjustment capability
- Standardized ACMA test mold
- Working procedures documented for various processes
- Standardized data recording sheets
- Standardized data handling procedures and emissions calculations
- All equipment and procedures operational to protocol specifications
- Certification trial runs within specification

11.2 Certification Cost

The cost of certification will be based on on-site evaluation of ACMA technical staff and a third party engineering consultant selected by ACMA, such as Dr. Rob Haberlein of Engineering Environmental Consulting Services. It is estimated that certification will require approximately 2-3 days. The certification team costs will be based on standard ACMA consulting rates and the standard rates of the third party auditor. Other than the per diem cost of the certification team, there is *no* charge for certification from ACMA. In addition to auditing the facility, the certification team will provide technical expertise and start-up assistance.

11.3 Emissions Calibration Standards

Once the facility, equipment, and procedures audit has been conducted, actual emissions testing calibrations will be conducted. This testing will involve processing a standardized resin, under specified conditions, with the resulting emissions being measured within a set parameter.

11.4 Emissions Calibration Parameters

Procedures: Audit of test procedures

Recovery Check: Styrene Mass Balance Recovery - >95% Capture Efficiency

Mold: ACMA Standardized Test Mold

Process: Manual – Bucket and Tool (Hand Lay-up)

Calibration Trials: 3 Runs – 1 Pre-certification trial, 2 Certification Trials

Laminate: 1 ply – 1.5 oz. CSM - .041 Thick

Resin Quantity Applied: 2950 g ± 200 g

- Resin: Orthophthalic/Polyester Laminating Resin
- Monomer – 42% Styrene \pm 1.5%
 - No other monomer present
 - Viscosity - 500 cps \pm 50 cps (LVF #3 @ 6 & 60 rpm)
 - Thix Index – 2.3 \pm 0.3
 - Gel Time – 15.0 min. \pm 1.5 min.(100g mass)
 - Interval – 11.0 \pm 2.0 min.
 - Time to Peak – 26.0 \pm 2.0 min.
- Airflow Over Mold: 50 fpm \pm 10 fpm
Enclosure Temperature: 74⁰F \pm 4⁰F

Target Emissions Results – 2 Certification Trials:

THA Measurements & Emissions Calculation:
Average Emission Weight : 220.33 grams \pm 13.21 grams
Upper Control Limit – 233.54 g
Lower Control Limit – 207.12 g
Average Emissions %: 7.40 % Resin Weight \pm 0.44%
Upper Control Limit – 7.84% RW
Lower Control Limit – 6.95% RW

11.5 Certification Approval and Re-Certification Requirements

ACMA will issue a pre-certification upon successful audit of facility, equipment and test procedures. Final certification will be issued upon the completion of successful certification trials. A re-certification audit will be required every 24 months to maintain facility as a ACMA approved testing site.

Section 12 REFERENCES

Testing Methodology

- 1) Composites Fabricators Association Open Molding Styrene Emissions Test Project, Phase I Baseline Study & Phase II Emissions Reduction Study, CFA, Arlington, VA 1996 (This report describes testing methodology in detail)
- 2) USEPA Method 25A – modified to ACMA protocol
- 3) USEPA Method 40CFR Method 1
- 4) USEPA Method 204

Experimental Design and Data Analysis

- 1) JMP User's Guide, Version 2 of JMP, SAS Institute Inc., Cary, NC, 1989. Chapter 14,15.
- 2) Wheeler, Donald J., Understanding Industrial Experimentation, Statistical Process Controls, Inc., Knoxville, TN, 1988.
- 3) Montgomery, Douglas C., Design and Analysis of Experiments, Wiley & Sons, 3rd edition, New York, 1991. pg. 69
- 4) Montgomery, op. Cit., pg. 197ff.
- 5) SAS User's Guide: Statistics, Version 5 edition, SAS Institute inc., Cary, NC, 1985. pg. 464-7.
- 6) Milliken, G.A., Johnson, D.E., Analysis of Messy Data, vol 1; Designed Experiments, Van-Nostrand-Reinhold, New York, 1984.
- 7) Montgomery, op. Cit., pg. 134.
- 8) Box, E.P., William G. Hunter, J. Stuart Hunter, Statistics for Experimenters, An Introduction to Design, Data Analysis, and Model Building, John Wiley & Sons, New York, 1978. pg. 340.
- 9) Deming, Stanley N., and Stephen L. Morgan, Experimental Design for Quality and Productivity in Research, Development, and Manufacturing, Statical Designs, Houston, Texas, 1992. pg. 105ff

APPENDIX

Tek-Air Systems Inc.

43 Beaver Brook Rd., Danbury, CT 06810
Ph: (202)-791-1400
Fax: (203)-798-6534

VorTek – SD

Airflow Transmitter For Smaller Ducts

Tek-Air Systems Inc.

43 Beaver Brook Rd., Danbury, CT 06810
Ph: (202)-791-1400
Fax: (203)-798-6534

General Description –

The Tek-Air *VorTeksm* airflow measurement system consists of one or more duct insertion probes and an electronic transmitter. The VorTek measurement system is capable of *measuring* airflow volume in ducts of all sizes and shapes.

VorTek insertion probes have multiple velocity sensors located along their length. Each sensor measures airflow velocity using a unique, patented (#4,770,035) application of the digital velocity sensing technique called vortex shedding.

Vortex shedding is the generation of eddy currents by an obstruction in an air stream. Airflow through each VorTek sensor creates a succession of eddy currents, which are then sensed as pressure pulses. The frequency at which these pulses are generated is directly proportional to the velocity of airflow around the sensor.

In large ducts, the profile of the air velocity across a duct is often uneven due to the bends and transitions in the ductwork. In-line devices such as dampers, elbows, and transitions also create disturbances in the flow profile. To compensate for these varying velocity profiles, multiple VorTek sensors are utilized within a duct. The frequency outputs of individual sensors are flow averaged to obtain the average duct velocity.

The VorTek transmitter totalizes the frequency signals from the individual sensors to perform true velocity averaging. From this average, an electronic signal (4-20ma) is generated for direct Input to a customers control system.

The VorTek-SD transmitter is specifically designed for application in smaller ducts where one to four sensors are adequate for measurements of the air volume. This manual will cover the operation, installation, startup, and calibration of the VorTek-SD probes and transmitter.

Specifications-Sensors and Probes –

Sensor Type: Vortex shedding
Velocity range: 350 to 7500 FPM
Probe Length: 8" to 24"
Probe Configuration: Rectangular, Round, Oval
Materials of *Construction*; Standard:
 Mounting Plate: Galvanized Steel or Aluminum
 Probe Bar: Extruded Aluminum
 Sensor Assembly: Aluminum, ABS, and Polypropylene
 Miscellaneous: EPDM Finishing Strip
Materials of Construction; Fume Hood:
 Mounting Plate: Stainless Steel or ~VC
 Probe Bar: CPVC
 Sensor Assembly: PVC and ABS
Probe Support Mounting: Flange Plate and Threaded Rod
Sensors Per Probe: 1 to 4 per Bar
Number of Bars per Transmitter: 1 to 2
Operational Temperature: -20 to 200 degrees F
Weight: Function of probe configuration

Transmitter Electronics

Input One to four sensor inputs
Output 4-20ma, isolated
Load Capability: 650 ohms
Voltage: 15-35Vdc
Power: 50 milliamps at 24 Vdc
Calibration: Adjustable from 0-1000 to 0-4000 FPM
Optional to 8000 FPM
Operational Temperature: 40 to 130 deg F
Frequency Conversion Error: less than $\pm 0.25\%$ FS (4 sensors)
Temperature Error: less than ± 0.5 over 25 to 125 deg. F
Low Frequency Cutout; 350 PPM (adjustable)
Time Constant 0.67 seconds, fixed
Housing: NEMA 1 type, use Indoors only
Dimensions: 6" x 6" x V" (WxHxD)
Weight: 5lbs with probes
Mounting: Standard; integral to probe assembly Optional; 24 inch umbilical

Operation of VorTek Sensors -

The VorTek Sensing system measures air Velocity by a physical principle called vortex shedding. The vortex shedding phenomena can be witnessed all around us in everyday life. Swirling Vortices, or eddy currents, are generated whenever air *or* liquids flow around an obstruction in their flow pattern. Common examples are the eddy currents which develop behind rocks in a stream, and in the fluttering of a flag behind a flag pole. The flag and the flag pole provide the most visual example of how vortex shedding works.

The flagpole presents an obstruction in the pattern of the airflow, which is the wind. As the wind passes around the flagpole, vortices (eddies) are created in the wake of the pole. These vortices, in accordance with the laws of nature, are developed and shed in an alternating manner, from one side of the flagpole to the other. The evidence of the shedding of vortices is in the waving *of* the flag itself.

Tek-Airs unique VorTek flow sensors use a trapezoidal shaped obstruction placed in a small tube section to generate stable vortices over a wide range of low velocities. Pressure sensors sense the passing of individual eddies. Multiple VorTek sensors are mounted on probe supports to provide ample coverage of the duct cross section.

ACMA Certification Checklist

- Temperature controlled lab work area within protocol specification
- Test enclosure complying with ACMA/EPA Method 204 specifications
- Test enclosure exhaust system – Plenum and single point stack
- Stack velocity sensor system – VorTek AirFlow Transmitter/Controller
- Stack probes linked to THA
- Stack airflow velocity check – detailed stack flow analysis
- Enclosure re-circulating airflow system – blower and ducts
- Total Hydrocarbon Analyzer using modified Method 25A
- Multi-channel computer data acquisition system - continuous data recording
- Calibration gas manifold
- Propane gas standards
- Ambient background hydrocarbon levels within control limits
- Precision balances – digital output to acquisition system
- Resin gel time measurement and adjustment capability
- Resin solids determination capability
- Standardized ACMA test mold in place
- Working procedures documented for various processes
- Standardized data recording sheets
- Standardized data handling procedures and emissions calculations
- All equipment and procedures operational to protocol specifications
- Certification trial runs within specification