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EVALUATION OF POLLUTION PREVENTION TECHNIQUES TO REDUCE STYRENE EMISSIONS FROM OPEN CONTACT MOLDING PROCESSES

Volume II, Appendixes

Prepared for

Office of Air Quality Planning and Standards

Prepared by

National Risk Management
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Research Triangle Park, NC 27711

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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EPA-600/R-97-018b
March 1997

Evaluation of Pollution Prevention Techniques to Reduce Styrene Emissions from Open Contact Molding Processes

Volume II, Appendixes

By

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Abstract

Pollution prevention options to reduce styrene emissions, such as new materials and application equipment, are commercially available to the operators of open molding processes. However, information is needed about the percent reduction in emissions that is achievable with these options.

To meet this need, several of these pollution prevention options were examined. Options examined were operator techniques, air flow velocities in the spraying area, gel coat and resin formulations, and application equipment. Styrene emission factors calculated from this test result were compared with the existing AP-42 emission factors for gel coat sprayup and resin applications.

The study found that using controlled spraying (i.e., reducing overspray), low-styrene and styrene-suppressed materials, and nonatomizing application equipment can reduce styrene emissions from 11 to 52 percent. Facilities should investigate the applicability and feasibility of these pollution prevention options to reduce their styrene emissions. The calculated emission factors were from 1.6 to 2.5 times the mid-range AP-42 emission factors for the corresponding gel coat and resin application. These results indicate that facilities using existing AP-42 emission factors to estimate emissions in open molding processes are likely to underestimate actual emissions.

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Appendix A

A Category III Quality Assurance Project Plan for the Evaluation of Pollution Prevention Techniques to Reduce Styrene Emissions from Open Contact Molding Processes (minus Appendixes) and RTI's Responses to EPA's Comments on the Category III Quality Assurance Project Plan

POLLUTION PREVENTION TECHNOLOGY DEMONSTRATION

EVALUATION OF POLLUTION PREVENTION TECHNIQUES TO REDUCE STYRENE EMISSIONS FROM OPEN CONTACT MOLDING PROCESSES

CATEGORY III QUALITY ASSURANCE PROJECT PLAN

EPA Cooperative Agreement CR 818419-03
RTI Project No. 96U-5171-016

Submitted to:

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April 28, 1995

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1.0 PROJECT DESCRIPTION

1.1 Background

The Research Triangle Institute (RTI) is under a cooperative agreement with the U.S. Environmental Protection Agency (EPA), Air and Energy Engineering Research Laboratory (AEERL), to evaluate pollution prevention techniques to reduce styrene emissions from open contact molding processes. The open contact molding process is one of the most common production processes used by the reinforced plastics and composites (RP/C) industry. This process is used to manufacture boats, bathtubs, shower stalls, truck body parts, swimming pools, storage tanks, corrosion-resistant equipment, furniture and accessories, electrical and equipment housings and enclosures, duct and air handling equipment, etc. It is one of the RP/C processes that consumes the most polyester resins. It also has the greatest potential of emitting styrene due to the spraying equipment used and the openness of the process.

Styrene is emitted during the application stage when a catalyzed gelcoat or resin is applied to the surface of an open contact mold. Styrene continues to emit from wet gelcoat or resin during gelation and curing. The open contact molding process usually is conducted in a facility with ample ventilation to maintain the ambient styrene concentrations under current Occupational Safety and Health Association (OSHA) standards of 100 ppm. Therefore, styrene emissions from open contact molding process are difficult to capture and control.

The maximum achievable control technology (MACT) standards for the reinforced plastics and composites source category and boat building source category are scheduled to be promulgated by November 15, 1997, and November 15, 2000, respectively. For some open contact molding processes, pollution prevention techniques could be used to reduce styrene emissions. These pollution prevention techniques include changing application equipment and environment and using different gelcoat or resin formulations. Existing information indicates that using nonspraying equipment or low-emitting/high-transfer efficiency spray guns, such as air-assisted airless or high-volume low pressure spray guns, can reduce emissions from the application stage. Gelcoat and resin manufacturers also have developed different gelcoat and resin formulations to reduce emissions. However, the effects of these pollution prevention techniques have not been compared systematically.

The purpose of this evaluation test is to use emission measurements and mass balance calculations to quantify and validate the effects of several pollution prevention techniques, specifically gelcoat/resin formulations and application equipment, on styrene emissions from the open contact molding process. The results of this study will be analyzed and presented to the RP/C industry so that individual facilities can identify

the most effective and practical pollution prevention techniques to reduce styrene emissions.

This Quality Assurance Project Plan (QAPP) describes the scope of the proposed pollution prevention techniques evaluation test and the procedures that will be employed in the evaluation test to ensure that the data collected are of sufficient quality to achieve project objectives.

1.2 Data Quality Objectives

The objective of this testing is to determine the styrene emission reduction for several pollution prevention techniques from the baseline conditions. Pollution prevention techniques will be evaluated for gelcoat and resin applications on open contact molding processes. The baseline emissions will be determined for a regular gelcoat and a regular resin formulation using an air-assisted airless spray gun under a typical environmental condition. Comparison of emissions will be based on styrene emission factors expressed as weight percent of available styrene (% AS) and as mass per unit surface area (g/m^2). The former unit is the unit used in the EPA Compilation of Air Pollutant Emission Factors, AP-42 Document.

Table 1-1 summarizes the anticipated performance of the evaluation in terms of the widths of confidence intervals for differences in mean %AS associated with the primary comparisons of interest. The widths of the intervals depend on the magnitude of the measurement error standard deviation, which is denoted by σ. Results are presented for σ = 1, 3, and 5 percentage points. The prior test results (shown in Table 3-1) suggest that standard deviations in this range should be achievable by mass balance calculation method.

1.3 Intended Use of Data

The test results will be analyzed, summarized, and presented to the RP/C industry in an EPA report. The report will provide quantitative emission reduction potentials for the pollution prevention techniques evaluated, so that a facility owner or operator can identify the most effective and practical pollution prevention techniques to reduce styrene emissions from its operation.

1.4 Scope of Work

This testing will include a pilot experiment and a main experiment. From the pilot experiment, the linear air flow velocity and the spraying technique will be determined for the main experiment. The main experiment will include a gelcoat experiment, which will examine two gelcoat formulations with three pieces of gelcoating equipment, and a resin experiment, which will examine six resin formulations and four pieces of resin

application equipment. The formulations and equipment selected for the testing are representative of current and evolving technologies available to the RP/C industry. Each of the experiments is described in the following subsections.

Table 1-1. Anticipated Performance of Evaluation Test

Difference in mean %AS due to:	Expected half width of 95% confidence interval on difference[a]		
	$\sigma = 1$	$\sigma = 3$	$\sigma = 5$
Alternative gelcoat formulation vs. baseline formulation (based on 12 df)[b]	±1.03	±3.08	±5.14
Alternative gelcoat spray equipment vs. baseline equipment (based on 12 df)[b]	±1.26	±3.77	±6.29
Alternative resin formulation vs. baseline formulation (based on 15 df)[c]	±1.51	±4.52	±7.54
Alternative resin spray equipment vs. baseline equipment (based on 9 df)[c]	±1.60	±4.80	±8.00

[a] Units for σ and the half-widths are in percentage points.

[b] Construction of the interval is not meaningful if there is an interaction of the gelcoat formulations and equipment types.

[c] Half-widths are conservative in that larger numbers of degrees of freedom (df) may be available; this will lead to narrower confidence intervals.

1.4.1 Pilot Experiment

Before these formulations and equipment are examined, we will conduct a pilot experiment to determine the air flow velocity in the spray booth and the spraying method that will be used throughout the entire test. A low and a high air flow velocity in the spray area will be examined. A low air flow velocity in the spraying area will be established by diverting the makeup air away from the spraying area to the sides of the spray booth. A normal and a more careful spraying method will be examined for the application technique. The pilot experiment will be conducted using a low-profile resin or a regular gelcoat catalyzed with methyl ethyl ketone peroxide (MEKP) and by an air-assisted airless (AAA) spray gun. Reichhold Chemicals or Cook Composites and

Polymers will provide the resin or gelcoat, respectively. Magnum Industries will provide the AAA spray gun and an operator to operate it. The results will be analyzed to determine whether there are any differences in styrene emissions resulting from different air flow velocities and spraying methods. Following the pilot experiment, one air flow velocity and one spraying method will be selected for the gelcoat and resin experiments in the evaluation test.

The number of test runs for air flow velocity and spraying method are summarized as follows and presented in Table 1-2.

A. Air flow velocity
   A1. Low air flow velocity (40 to 100 fpm)
   A2. High air flow velocity (100 to 200 fpm)

B. Spraying method
   M1. Normal technique without conscious control of overspray from flanges
   M2. Alternative spraying technique with more conscious control of overspray

Table 1-2. Test Runs for Pilot Experiment

	A1-Low air flow velocity	A2-High air flow velocity
M1-Normal technique	3	3
M2-Alternative technique	3	3

1.4.2 Gelcoat Experiment

The gelcoat formulations selected are one regular gelcoat with isophthalic acid/neopentyl glycol (ISO/NPG®)-based resin and a low volatile organic compound (VOC) gelcoat with the same base resin. Cook Composites and Polymers (CCP) will provide these two gelcoats. For the purpose of this testing, both gelcoats will contain straight styrene without any methyl methacrylate. MEKP catalyst will be used and the catalyst ratios will follow those suggested by CCP.

The gelcoating equipment selected includes: one AAA external catalyst mixing spray gun, one high-volume low-pressure (HVLP) external catalyst mixing spray gun, and one HVLP internal catalyst mixing spray gun. The AAA external mixing spray gun is considered the baseline condition of the industry. The AAA spray gun will be compared with HVLP spray guns. The effects of internal and external catalyst mixing will be evaluated for the HVLP spray guns. Magnum will provide the AAA and the other two HVLP spray guns. A pump ratio of 20:1 will be selected for the gelcoat pump systems. The spray guns will be compared at similar gelcoat delivery rates.

The gelcoat formulations and application equipment are denoted as follows:

a. Formulations
- GF1. a regular (ISO/NPG®) gelcoat containing only styrene monomer (baseline condition)
- GF2. a low VOC styrene-suppressed (ISO/NPG®) gelcoat containing only styrene monomer

b. Equipment
- GE1. an AAA external catalyst mixing spray gun (baseline condition)
- GE2. an HVLP internal catalyst mixing spray gun
- GE3. an HVLP external catalyst mixing spray gun

Table 1-3 shows the number of test runs for each of the gelcoat formulation and equipment combinations in the gelcoat experiment.

Table 1-3. Test Runs for Each of the Gelcoat Formulations and Equipment Combinations

	Equipment type		
Formulation	GE1-AAA(ext)	GE2-HVLP(int)	GE3-HVLP(ext)
GF1-Regular gelcoat	3	3	3
GF2-Low VOC gelcoat	3	3	3

ext=External catalyst mixing.
int=Internal catalyst mixing.

1.4.3 Resin Experiment

The resin experiment will examine six resin formulations with an AAA spray gun and four application equipment with one standard resin.

The resin formulations selected are one dicyclopentadiene (DCPD)-based low-profile resin catalyzed with MEKP, one DCPD-based low-styrene resin, one orthophthalic(ORTHO)-based styrene-suppressed resin, one DCPD-based low-profile resin catalyzed with benzoyl peroxide (BPO), a water-emulsified resin catalyzed with MEKP, and the same ORTHO-based styrene-suppressed resin at a higher suppressant concentration. All the resin formulations will be sprayed by an air-assisted airless spray gun. Reichhold Chemicals, Inc., will provide all resin formulations and catalyst, except the water-emulsified resin. The W.E.T., Inc. will provide the water emulsified resin. The catalyst ratios will follow those suggested by Reichhold and W.E.T., Inc.

The resin application equipment selected are one AAA external catalyst mixing spray gun; an internal catalyst mixing flow coater; a pressure-fed roller; and an AAA

external catalyst mixing spray gun modified for the resin catalyzed with BPO. The AAA, external mixing spray gun is consider the baseline condition of the industry. The AAA spray gun is to be compared with other nonspraying equipment (i.e., the flow coater and the pressure-fed roller). Magnum will provide all the equipment for evaluation. A pump ratio of 11:1 will be selected for the resin pump systems. The equipment will be compared at similar resin delivery rates.

Resin formulations and application equipment are denoted as follows:

a. Formulations
- RF1. a DCPD-based low-profile resin catalyzed with MEKP (baseline condition)
- RF2. a DCPD-based low-styrene resin
- RF3. an ORTHO-based styrene-suppressed resin
- RF4. a DCPD-based low-profile resin catalyzed with BPO
- RF5. a water-emulsified resin
- RF6. the same ORTHO-based styrene suppressed resin at a higher suppressant concentration

b. Equipment
- RE1. an AAA external catalyst mixing spray gun (baseline condition)
- RE2. an internal catalyst mixing flow coater
- RE3. an internal catalyst mixing pressure-fed roller
- RE4. a modified AAA, external catalyst mixing spray gun for the resin catalyzed with BPO

Table 1-4 show the number of test runs for the resin formulation and equipment to be examined in the resin experiment.

Table 1-4. Test Runs for the Resin Formulations and Equipment Types

	Equipment type			
Formulation	RE1-AAA(ext)	RE2-flow coater(int)	RE3-pressure-fed roller(int)	RE4-modified AAA (ext)
RF1-DCPD-based low-profile resin with MEKP	6	3	3	NA
RF2-DCPD-based low-styrene resin	3	NA	NA	NA
RF3-ORTHO-based styrene-suppressed resin	3	NA	NA	NA
RF4-DCPD-based low-profile resin with BPO	NA	NA	NA	3
RF5-water-emulsified resin	3	NA	NA	NA
RF6-the ORTHO-based styrene-suppressed resin at a higher suppressant concentration	3	NA	NA	NA

ext=External catalyst mixing.
Int=Internal catalyst mixing.
NA = Not included in the experiment.

1.5 Schedule/Milestone Chart

The schedule and milestones for this testing are shown in Figure 1-1. The schedule and milestones are determined by the overall project completion date at the end of September. The evaluation test is scheduled to start in the first week of June 1995 and will take 4 weeks to complete. The resin and gelcoat manufacturers and equipment vendors will need to provide the materials and equipment to the test site at Reichhold Chemicals Inc., c/o Mr. Mark Callicutt, 2400 Ellis Road, Durham, North Carolina 27703-5543 by May 26, 1995. RTI will prepare a temporary total enclosure setup at Reichhold's spray booth in late May. RTI will conduct preliminary testing to ensure that the enclosure and emission measurement instrument meet EPA requirements. The preliminary testing will also ensure that the emissions are within the proper concentration ranges of the total hydrocarbon (THC) analyzer prior to the actual testing.

The proposed schedule shows that the testing will take place during the month of June. The testing schedule is based on the assumption that three test runs can be conducted in each working day and 19 working days will be needed to

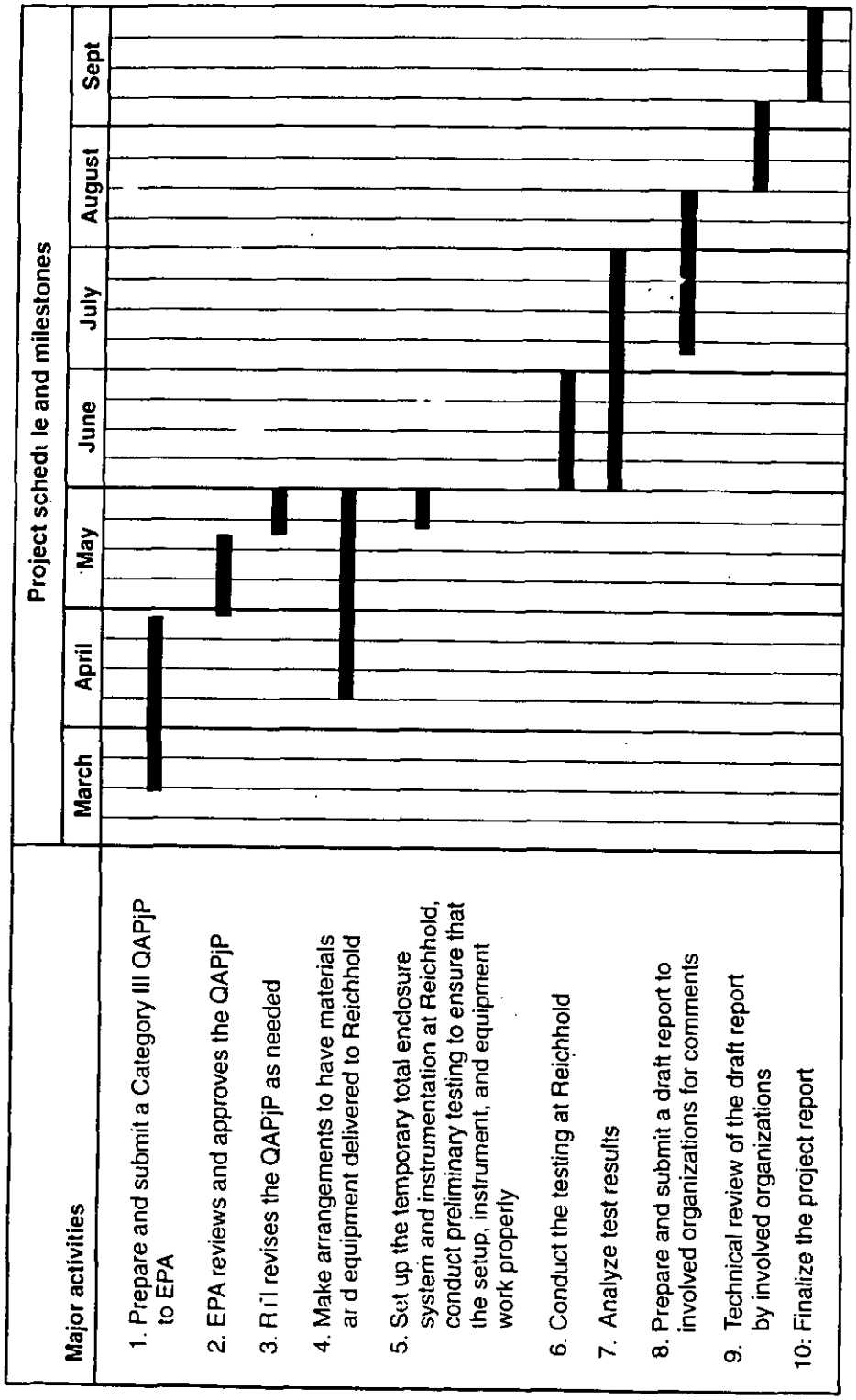


Figure 1-1. Proposed schedule and milestones.

complete the proposed 57 test runs. The final test period may be longer than the proposed duration, if Reichhold needs the spray booth for its own testing or the test team encounters technical difficulties that need to be resolved before the test can be resumed.

1.6 Facility Description

The evaluation test will be conducted in an isolated spray booth in the Reichhold Chemicals' physical testing laboratory, located in Research Triangle Park, North Carolina. This type of spray booth is commonly used in a gelcoating area of an RP/C facility. The Reichhold Chemicals' physical testing laboratory is used to conduct testing for their resin users. It is not a production facility; therefore, the background styrene concentration can be minimized.

1.6.1 Total Enclosure System

The spray booth is situated in an enclosed room with a double door leading to the physical testing laboratory. Figure 1-2 shows the side view of the spray booth. The room is 12 feet wide, 19 feet high, and 15 feet deep, which can be considered a permanent total enclosure. The double door measures 6 feet wide by 7 feet high, which can be consider the natural draft opening to the enclosure.

The spray booth is 7 feet high, 11.5 feet wide, and 7.5 feet deep from the front edge to the filter bank. The filter bank is 6 feet high by 11 feet wide. The distance between the front edge of the spray booth to the double door is 4 feet 10 inches. The conditioned makeup air is provided through a duct (3 feet 9 inches by 4 feet) above the open space between the spray booth and the double door. This duct is considered a forced draft opening to the total enclosure system. The makeup air flows downward, then turns horizontally through the spray booth. The exhaust air flows through the filter bank at the end of the spray booth and is exhausted upward by a duct 34 inches in diameter. The exhaust flow rate from the spray booth is estimated to be 8,000 cfm when the double door is closed. The actual flow rate will be determined in preliminary testing.

Emission measurements and exhaust air flow rate will be monitored from the exhaust duct. The sampling location is 8 diameters downstream of the last bend as shown in Figure 1-2. EPA Methods 1 and 2 will be used to determine the exhaust gas velocity and volumetric flow rate. EPA Method 25A will be used to determine total gaseous organic emissions. EPA Method 204 will be used to ensure that the enclosed room meets the criteria for a total enclosure. The sampling procedures are outlined in Section 4.0.

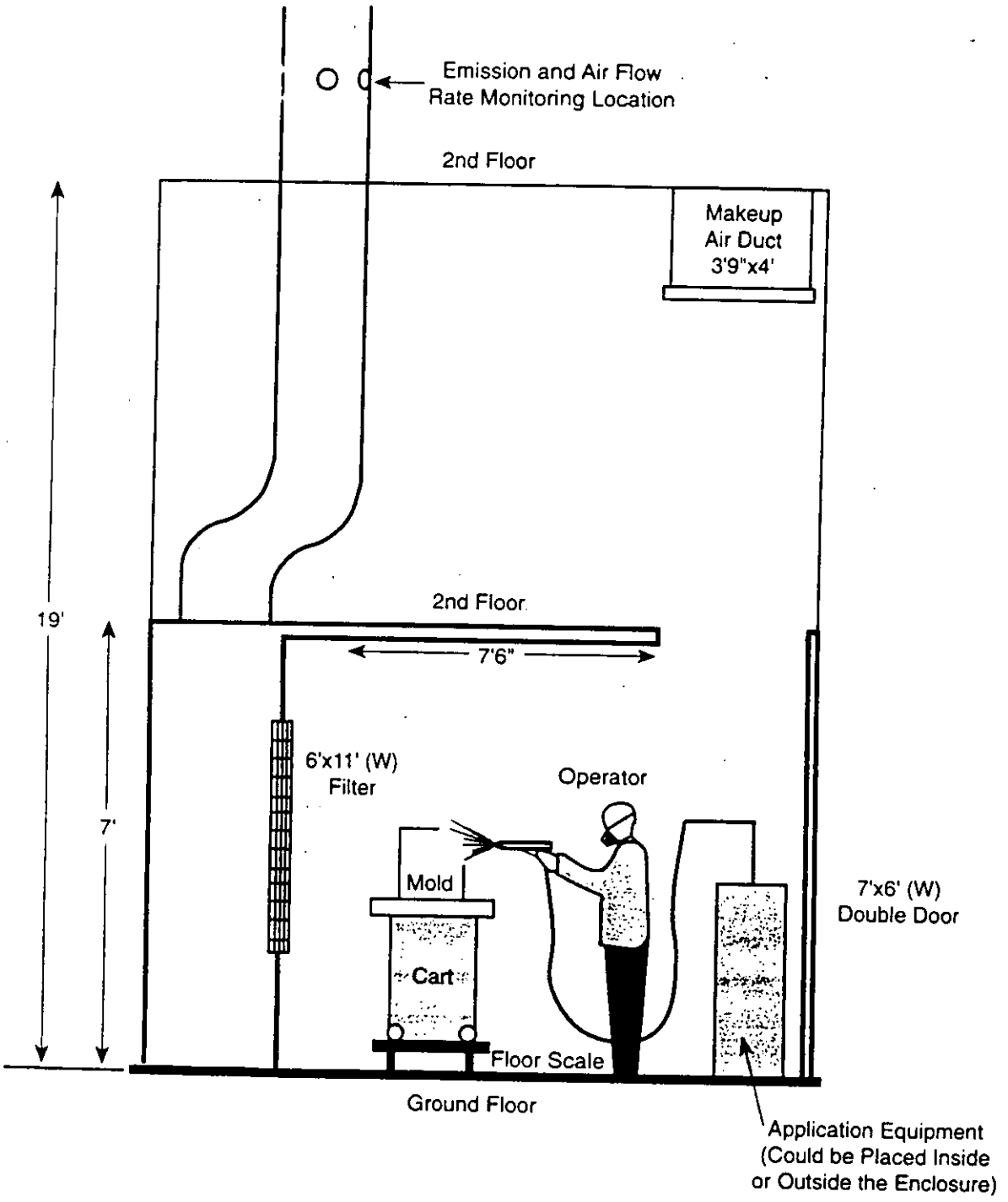


Figure 1-2. Side view of the Reichhold Chemicals spray booth in a permanent total enclosure (19'H x 12'W x 15'L)

1.6.2 Resin Property Testing Laboratory

Reichhold Chemicals has a resin property testing laboratory located in the same building as the spray booth. The laboratory has all the instrument and equipment necessary to determine the styrene contents and curing characteristics for the gelcoat and resin formulations. Reichhold personnel will help the project team examine these properties for every gelcoat and resin formulation. Available instruments include an analytical balance, a forced-air oven, several Brookfield viscometers, a thermocouple, and a temperature recorder.

1.6.3 Open Contact Mold

A male mold will be used for this evaluation test. Figure 1-3 shows a drawing of this mold. The male mold will have five exposed smooth surfaces similar to a rectangular box. The mold will measure 2 feet high, 2.5 feet long, and 2 feet wide. A 2-inch wide flange surrounds the bottom of the mold for ease of part removal. The total surface area, including flange, equals 24.5 ft^2. The shape and surface area of this mold are selected to simulate real conditions in the open contact molding process. The mold is constructed of traditional reinforced plastics material to represent real molds used by the industry. The mold will be placed on a cart with wheels so that the operator can spray on all mold surfaces by turning the cart and without moving his position to the down-wind location.

1.7 Experimental/Test Matrix Design

1.7.1 Critical and Noncritical Measurements

The critical and noncritical measurements, the frequency of measurement, the locations where these measurements are taken, and methods of measurements are shown in Table 1-5. The emission measurements, exhaust air flow rate, and mass balance calculations are critical measurements for this study. The emission rates are to be determined from styrene emissions measured as total hydrocarbon concentration and the exhaust air flow rate monitored over the duration of the test run. Mass balance calculations will be used to determine transfer efficiency of the application equipment and to determine the weight losses from the mold and from the overspray. The styrene contents of the gelcoat and resin formulations are critical measurements; because the information will be used to express the styrene emission factors as the percent of available styrene in the materials.

The linear air velocity over the mold and the ambient temperature are non-critical measurements, but they will be recorded to document actual test conditions. The type of gelcoat or resin materials and the equipment type will be noncritical parameters, but the emission quantities will be compared for different materials and equipment.

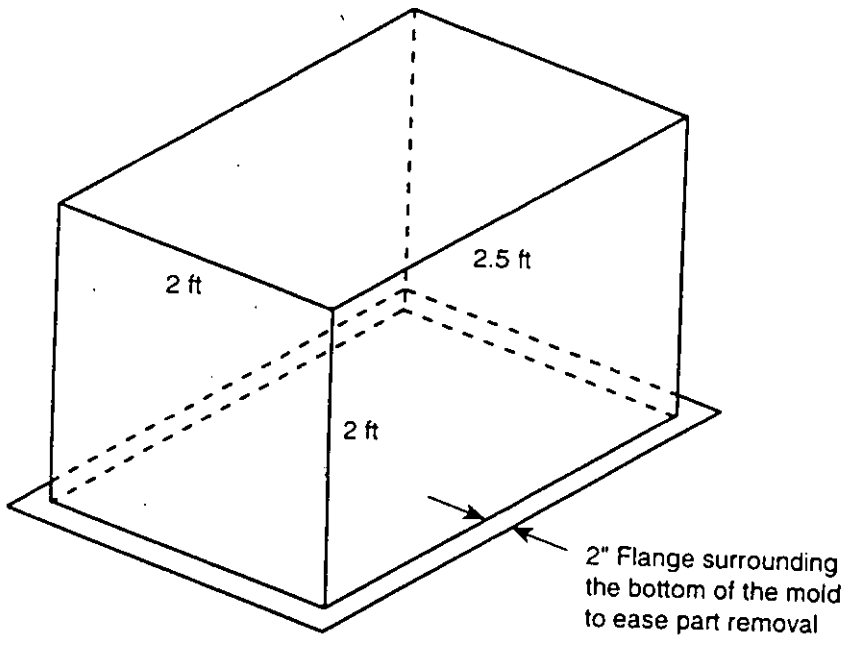


Figure 1-3. Sketch of a male mold.

The equipment setup (such as pump and air pressure, spray tip size and angle, delivery rate, and catalyst ratio setting) are noncritical. The duration of application, gelcoat/laminate thickness, glass/resin ratio, gel time, total time to peak, and peak exotherm are noncritical measurements. However, these equipment conditions and gelcoat/resin parameters are important information that should be documented.

1.7.2 Experimental Design

1.7.2.1 Pilot Experiment

Before executing the main experiment, several preliminary runs are proposed. The primary purpose is to help establish "standard" conditions under which the main experiment will be conducted. A secondary purpose is to gain insight into the magnitude of measurement error variability that might be anticipated in the main experiment. If the pilot experiment indicates major difficulties with the planned approach, this QAPP will be amended to indicate changes to the main experiment. RTI will acquire verbal approval from the EPA Project Office for changes that occur during the test activities and submit a QAPP change as soon as possible. The proposed pilot consists of 12 trials -- namely, three replicates for each of the following conditions:

a. Normal spraying method (M1), low air flow velocity (A1)
b. Alternative spraying method (M2), low air flow velocity (A1)
c. Normal spraying method (M1), high air flow velocity (A2)
d. Alternative spraying method (M2), high air flow velocity (A2)

Resin RF1 or gelcoat GF1 will be used in all cases. The following random ordering of the 12 trials will be used: b,c,d,c,b,a,d,a,d,b,c,a. Since one of the four conditions will be chosen as the standard method for the subsequent trials, it may be possible to use those three pilot trials in the analysis of the main resin experiment (e.g., to provide more degrees of freedom for error variability).

The pilot will provide only a limited amount of information that can be used for statistical purposes. The data can be used, however, to give some idea of the impact of these two parameters on emissions. The analysis of variance for the experiment is as follows:

Table 1-5. Summary of Critical and Noncritical Measurements

Measurement	Classification	Method
THC concentration	Critical	EPA Method 25A
Exhaust air flow rate and velocity head (Δp)	Critical	EPA Methods 1 and 2
Humidity	Noncritical	Sling psychrometer or relative humidity detector
Mass balance calculations 1) gelcoat/resin materials used 2) gelcoat/resin applied on mold 3) cured material on mold 4) cured material on other ground cover	Critical	High precision scales with 150 kg capacity and 1 g readability
Types of gelcoat and resin materials	Noncritical	Manufacturer data
Styrene content	Critical	Reichhold standard test method No. 18-001
Gelcoat/resin properties 1) gel time 2) total time to peak 3) peak exotherm	Noncritical	Reichhold standard test method No. 18-050 and 18-051
Linear air velocity in the spray booth	Noncritical	Hot wire anemometer
Ambient temperature	Noncritical	Thermocouple
Equipment type	Noncritical	Vendor information
Equipment setup 1) pump pressure 2) air pressure 3) spray tip size 4) spray tip angle 5) catalyst ratio setting 6) equipment delivery rate	Noncritical	Vendor information and actual setting on equipment
Gelcoat/Resin data 1) catalyst ratio 2) gelcoat/laminate thickness 3) glass/resin ratio	Noncritical	Mass calculation and mil gauges

Source of variation	Degrees of freedom
M (spraying method)	1
A (air flow velocity)	1
M x A (interaction)	1
Error	8
Total	11

The magnitude of differences in mean %AS that can be detected via the pilot experiment can be expressed in terms of the half-width of confidence intervals (C.I.) on the differences of interest:

Difference in mean %AS	Expected half-width of 95% C.I.
M2 vs. M1	1.331σ
A2 vs. A1	1.331σ
For any two cells	2.306σ

In this table, σ denotes the standard deviation associated with measurement variability of emissions in %AS. The width of the confidence intervals is based on an assumption that the data for a given combination of M and A will be approximately normally distributed with a common measurement error variability (similar assumptions apply to all other confidence intervals described herein). The 95 percent confidence interval half-width on the difference can be related to a pairwise hypothesis test (conducted at a significance level of 0.05) in two ways. First, if the estimated confidence interval does not include zero, then the corresponding test of no difference in mean %AS will be rejected. Second, if the true difference between the means (for A1 and A2, say) is equal to the expected half-width, then we will have a 50 percent chance of detecting a difference in the means. (Of course, if the true difference is larger than the half-width, then there will a higher likelihood that we will be able to detect a difference.) Thus if the underlying error variability of emissions in %AS is 5 percentage points, then we should have about a 50 percent chance of finding a difference in the two flow rates if the true difference between them is about 6.7 (i.e., 1.331 x 5).

A similar statement can be made regarding the methods. Both of these statements assume that there is not a method by air flow interaction (in which case the overall comparisons would not generally be meaningful). It should be noted that the above analysis of variance (ANOVA) and confidence interval statements rely on an assumption of measurement-error variance homogeneity across the four combinations of factors M and A.

1.7.2.2 Gelcoat Experiment

The gelcoat experiment is one of the two major components in the main experiment. This experiment is aimed at evaluating how styrene emissions are affected by type of gelcoat formulation (factor GF) and type of equipment (factor GE). The factor combinations (two formulations and three equipment types) and proposed sample sizes are given in Table 1-3. The 18 trials are to be performed in random order (trials will be interspersed with the trials of the resin experiment, described below).

The ANOVA associated with the design (a completely random design with three replications) has the following structure:

Source of variation	Degrees of freedom
GF (gelcoats)	1
GE (equipment)	2
GF x GE (interaction)	2
Error	12
Total	17

For the gelcoat experiment, the magnitude of differences that can be detected can be expressed in terms of the half-width of confidence intervals on the differences of interest:

Difference in mean %AS	Expected half-width of 95% C.I.
GF2 vs. GF1	1.027σ
GE2 vs. GE1, GE3 vs. GE1, or GE3 vs. GE2	1.258σ
For any two cells	1.779σ

Again, σ denotes the standard deviation associated with measurement error variability. The 95 percent confidence interval half-width on the difference can be related to a pairwise hypothesis test (conducted at a significance level of 0.05) in two ways. First, if the estimated confidence interval does not include zero, then the corresponding test of no difference will be rejected. Second, if the true difference between the means (for GF1 and GF2, say) is equal to the expected half-width, then we will have a 50 percent chance of detecting a difference in the means. Hence if the underlying error variability of emissions in percent available styrene is 5 percentage points, then we should have (1) about a 50 percent chance of finding a difference in the gelcoat formulations if the true difference between them is about 5.1, and (2) about a 50 percent chance of detecting a difference in two pieces of equipment if the true difference between them is about 6.3. Both of these statements assume that no

difference between them is about 6.3. Both of these statements assume that no interactions are present. It should be noted that the above ANOVA and confidence interval statements rely on an assumption of measurement error variance homogeneity across equipment, gelcoat formulations, and levels of percent available styrene. If the variability appears to change with level, then transformations such as logarithms will be considered (for the logarithmic transformation, the σ can then be interpreted as the true underlying relative standard deviation).

1.7.2.3 Resin Experiment

The resin experiment is the other major component of the main experiment. This experiment is aimed at evaluating how styrene emissions are affected by type of resin formulation (factor RF) and type of equipment (factor RE). Table 1-4 shows the proposed combinations and associated test runs. This design consists of 27 trials, which will be run in random order. Separate ANOVAs are used to test for different equipment (REs) and for the different resin formulations (RFs).

The ANOVA for equipment comparisons is as follows:

Source of variation	Degrees of freedom
RE (equipments)	2
Error	9 or 12 or 19 or 22

The various choices for the error degrees of freedom (df) result from which set of data is used for estimation of error variability: If just the 12 observations associated with the different equipment are employed, then 9 df result; if the 3 trials from the pilot are included, then 12 df result; if all trials in the resin experiment (Table 1-4) are used, 19 df are available; and if the 3 pilot trials are added, 22 df are available. If variances across all cells in the experiment appear homogeneous and are also consistent with the variance of the pilot trials, then use of the larger degrees of freedom is warranted.

The expected half-width of confidence intervals on the differences of equipment are as follows:

Difference in mean %AS	Expected half-width of 95% C.I.	
	9 df	19 df
RE2 vs. RE1, RE3 vs.RE1	1.599σ	1.480σ
RE3 vs. RE2	1.847σ	1.709σ

The width of the confidence intervals will be slightly narrower if the same observations from the pilot experiment can be used for estimating measurement error variability (i.e., there will be more df for the error component of the ANOVA). If the underlying error variability of emissions in %AS is 5, then (assuming the 19 df situation) we should have about a 50 percent chance of finding a difference between the baseline spraying equipment and one of the alternatives if the true difference is 7.4 percentage points (i.e., 1.480 x 5).

For resin formulation comparisons, the following ANOVA applies:

Source of variation	Degrees of freedom
RF (resins)	5
Error	15 or 18 or 19 or 22

The various choices for the error df result from which set of data one uses, as previously discussed.

The expected half-width of confidence intervals on the differences of resin formulations are as follows:

Difference in mean %AS	Expected half-width of 95% C.I.	
	15 df	19 df
RF2, RF3, RF4, RF5, or RF6 vs. RF1	1.507σ	1.480σ
All comparisons not involving RF1	1.740σ	1.709σ

It should be noted that any comparison involving RF4 is a comparison not only of resin formulations but also of application methods. The width of the confidence intervals will be slightly narrower if some of the observations from the pilot experiment can be included in the data analysis. If the underlying error variability of emissions in %AS is 5, then (assuming the 19 df situation) we should have about a 50 percent chance of finding a difference between the RF1 and one of the alternative resin formulations if the true difference is 7.4 percentage points (i.e., 1.480 x 5).

1.7.2.4 Combining the Gelcoat and Resin Experiments

The gelcoat and resin experiments can be run effectively if trials of the two experiments are interspersed. In particular, it is desirable if each gelcoat trial is followed by at least one resin trial. To accomplish this and to randomize the ordering of

trials within each separate experiment, a random ordering of the 27 trials in the resin experiment was first determined. Then a list of 27 "pseudo-trials" was created for the gelcoat experiment; the list contained the actual 18 gelcoat trials plus 9 dummy trials. These 27 "trials" were also independently randomly ordered and then the two randomly ordered lists were merged to produce the final composite set of trials, which is shown in Table 1-6.

Table 1-6. Randomly Ordered List of Trials for the Main Experiment

Trial No.	GF	GE	RF	RE
1	.	.	5	1
2	1	3	.	.
3	.	.	6	1
4	1	2	.	.
5	.	.	5	1
6	1	1	.	.
7	.	.	1	2
8	.	.	1	3
9	2	1	.	.
10	.	.	1	3
11	.	.	1	1
12	.	.	3	1
13	1	1	.	.
14	.	.	1	1
15	1	1	.	.
16	.	.	2	1
17	.	.	4	4
18	2	3	.	.
19	.	.	2	1
20	1	3	.	.
21	.	.	6	1
22	1	2	.	.
23	.	.	6	1
24	1	3	.	.
25	.	.	2	1
26	2	2	.	.
27	.	.	1	1
28	.	.	1	1
29	2	2	.	.
30	.	.	1	3
31	.	.	4	4
32	.	.	1	2
33	2	2	.	.
34	.	.	3	1
35	2	1	.	.
36	.	.	3	1
37	.	.	5	1
38	1	2	.	.
39	.	.	1	1
40	2	1	.	.
41	.	.	4	4
42	2	3	.	.
43	.	.	1	1
44	2	3	.	.
45	.	.	1	2

Key :

GF1 = a regular (ISO/NPG®) gelcoat containing only styrene monomer (baseline condition)
GF2 = a low VOC styrene-suppressed (ISO/NPG®) gelcoat containing only styrene monomer

GE1 = an AAA external catalyst mixing spray gun (baseline condition)
GE2 = an HVLP internal catalyst mixing spray gun
GE3 = an HVLP external catalyst mixing spray gun

RF1 = a DCPD-based low-profile resin catalyzed with MEKP (baseline condition)
RF2 = a DCPD-based low-styrene resin
RF3 = an ORTHO-based styrene-suppressed resin
RF4 = a DCPD-based low-profile resin catalyzed with BPO
RF5 = a water-emulsified resin
RF6 = the same ORTHO-based styrene suppressed resin at a higher suppressant concentration

RE1 = an AAA external catalyst mixing spray gun (baseline condition)
RE2 = an internal catalyst mixing flow coater
RE3 = an internal catalyst mixing pressure-fed roller
RE4 = a modified AAA, external catalyst mixing spray gun for the resin catalyzed with BPO

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Figure 2-1 depicts the organizations and personnel involved in this pollution prevention technique evaluation test. Carlos Nunez is the EPA Project Officer for this research project. Nancy Adams is the EPA Quality Assurance Officer.

Emery Kong, the RTI Project Leader, will coordinate the preparation and testing activities. Emery Kong will be responsible for developing the QAPP, all data generated under this study, all corrective action, and the overall technical quality of the evaluation test. Andrew Clayton will assist in the experimental design and data analysis. Mark Bahner is the RTI Testing Crew Chief. He and Keith Leese will conduct the actual testing. Craig Whitaker and Robert Wright will operate the THC analyzer and measure the exhaust air flow rate. Mark Bahner will also be responsible for the data reduction activities, analyzing the test results, and preparing the final report. Cynthia Salmons, the RTI QA Manager, William Yeager, and Shrikant Kulkarni will provide assistance in the QAPP preparation and ensure that the data collected adhere to the quality assurance requirements specified herein. They are independent of the technical activities on this project.

Reichhold will provide technical assistance, resin materials, and catalysts for the testing. Mark Callicutt, Reichhold's Technical Service Supervisor, will be the primary contact at Reichhold. Federico Linares, Manager of Physical Testing and Application, will provide facility support, and Lorenzo Esposito, Reichhold's Senior Technical Service Representative, will provide technical support to the test. Reichhold's technical service personnel will analyze some specific properties of the gelcoat and resin formulations in their laboratory.

Mark Hollenbech of Cook Composites and Polymers (CCP) will provide both the ISO/NPG®-based regular gelcoat and low VOC gelcoat for testing. Casey Herbert of W.E.T. Inc., will provide the water emulsified resin for testing. Tom Hedger of Magnum Industries will provide gelcoat and resin application equipment. Charles Stard from Magnum Industries will be onsite during the test period to operate the equipment.

This testing will not have any off-site sample analysis. All measurements and process data will be collected onsite or analyzed in Reichhold Chemicals' laboratory during the test. Emery Kong will ensure that all testing procedures and quality assurance requirements are correctly followed. Emery Kong will communicate with other contributing organizations that will provide materials, equipment, and support for the test. He will communicate with Reichhold personnel for necessary facility, laboratory, and technical support for the test. If Emery Kong is absent, Mark Bahner will assume all coordination responsibilities.

As the Testing Crew Chief, Mark Bahner will coordinate all activities and on-site personnel during the testing and report to the Project Leader. He will communicate with the application equipment operator and the THC analyzer operator to address any concerns or problems that they might encounter. Decisions to stop or continue testing will be made by the Project Leader.

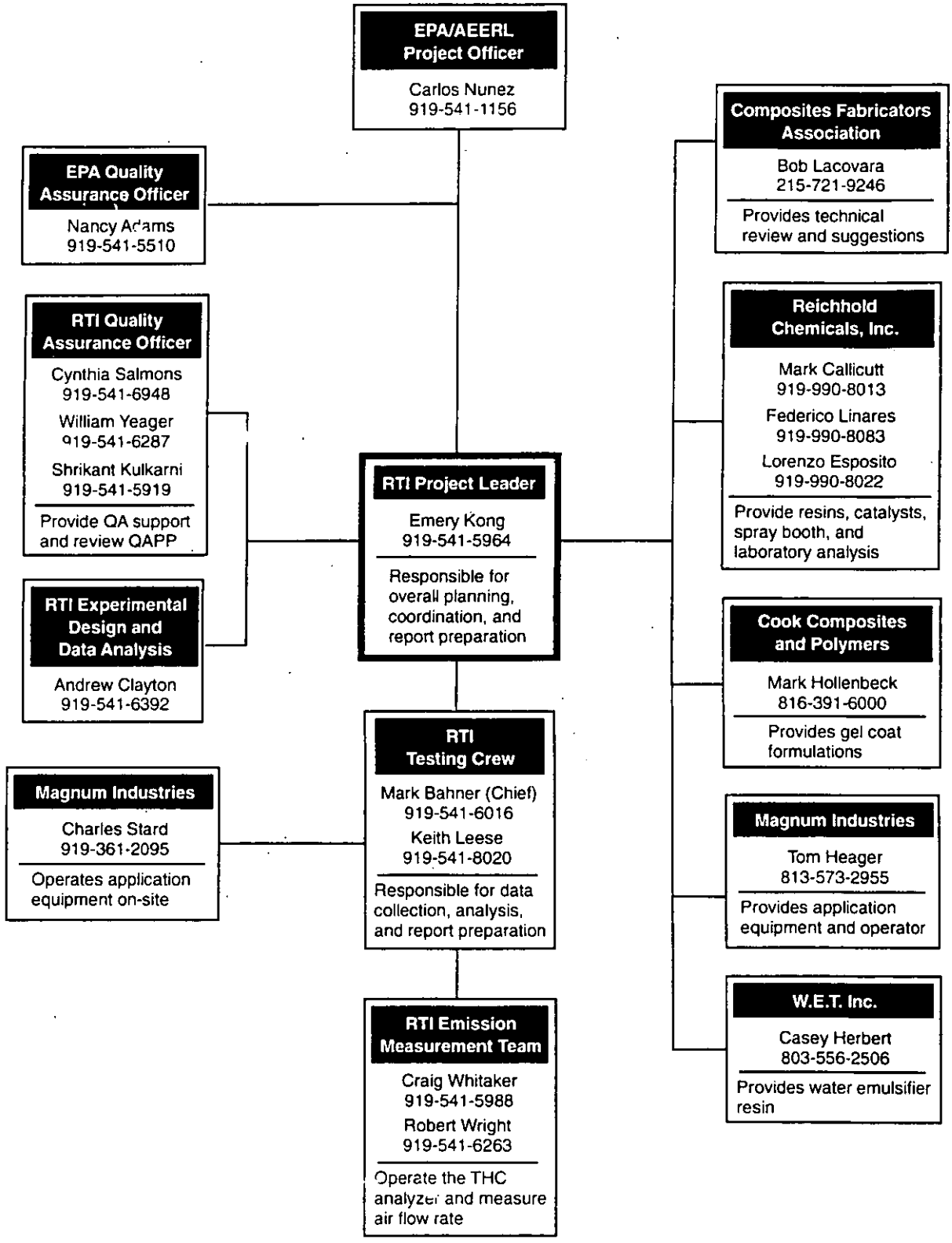


Figure 2-1. Project organization chart.

3.0 DATA QUALITY INDICATOR GOALS FOR CRITICAL MEASUREMENTS

This section presents the qualitative and quantitative descriptors that are used to interpret the degree of acceptability of the test data. The principal data quality indicators are precision, accuracy, detection limits, and completeness.

The primary objectives for this testing are to quantify the emissions from selected pollution prevention techniques and to compare the emissions of these techniques with the baseline conditions. Styrene emissions for baseline conditions and each of the pollution prevention techniques will be expressed as percent of available styrene in the gelcoat and resin formulations. The data quality indicator (DQI) goals specified in this section are based on results obtained from previous tests. If these DQI goals are attained in this testing, sufficient valid data of known quality will be collected to evaluate different pollution prevention techniques.

The results of a recent test conducted by RTI in early March 1995 are summarized in Table 3.1. This table presents the styrene emission data (expressed as %AS) and preliminary statistical analysis of the results measured by mass balance and THC emission measurement methods. In this table, σ denotes the standard deviation associated with measurement variability of emissions in %AS.

Table 3-1. Summary of Styrene Emission Data from a Previous RTI Testing

Formulation	Equipment	Method	No. of test runs	Mean (% of AS)	σ (standard deviation in %AS)	Relative standard deviation (%)
Gelcoat	Spray-up	MB[a]	3	65.0	2.6	4
		THC	3	66.7	4.6	7
Resin	Hand lay-up	MB	3	20.3	1.2	6
		THC	3	19.7	0.7	4
Resin	Chop and spray-up	MB[a]	4	24.5	1.3	5
		THC	4	20.8[b]	5.3[b]	26[b]

MB=mass balance method.
THC=THC emission measurement method.
[a] Mass balance standard deviations for gelcoat and resin spray-up include corrected values.
[b] Includes one chop spray test run that had a known large error.

3.1 Objectives for Quantitative Data Quality Indicators

Quantitative DQIs are typically defined in terms of measurement precision, accuracy, detection limits, and completeness. The DQI objectives for the critical measurements are summarized in Table 3-2. These DQI objectives are based on the results of a recent RTI test and data in Table 3-1. Precision is typically determined from duplicate measurements and is usually expressed as percent difference or standard deviation in either absolute or relative terms. Accuracy is the degree of agreement between an observed value and an accepted reference value. For the THC analyzer and balance, the accuracy will be determined from standard reference styrene gases and weights, respectively. Detection limits are the lowest concentration or amount of weight that can be determined to be different from zero. Completeness is defined as the ratio of the amount of valid data obtained compared to the planned amount. Procedures for determining these quantitative DQIs are discussed in more detail below.

Table 3-2. Objectives for Quantitative Data Quality Indicators

Measurement (unit)	Method	Precision (RPD or RSD)	Accuracy (%)	Detection limit	Completeness (%)
THC conc. (ppm)	EPA Method 25A	10 %	+/- 5	1 ppm	90
Exhaust air flow rate (cfm)	EPA Method 2	10 %	+/- 5	NA	90
Mass balance (g)	Floor-type, high-precision balance	5 %	+/- 1	1 g	90
Styrene content (%)	Reichhold standard test method No. 18-001 and a high-precision analytical balance	0.5 %	+/- 1	0.0001 g	90

RPD = Relative percent difference as calculated from duplicate measurements.
RSD = Relative standard deviation as calculated from three or more replicates

3.1.1 Precision

Precision objectives for all the listed measurements are presented as relative percent difference (RPD) of duplicate measurements or as relative standard deviation (RSD) of three or more replicates. The number of replicates for each test are shown in Tables 1-3 and 1-4. Precision for THC measurement, air flow rate measurement, and mass balance measurement is shown in Table 3-2. The styrene content for each

gelcoat or resin formulation is determination by duplicate samples having an RPD of +/- 0.5 percent. If duplicate samples are not within +/- 0.5 percent, the entire test to determine styrene content will be repeated.

3.1.2 Accuracy

The accuracy of the THC analyzer will be determined following the calibration error test procedures in Section 6.4 of EPA Method 25A. Immediately prior to the test series, a zero gas and high-level calibration gas are introduced at the calibration valve assemble. Then the analyzer output is adjusted to the appropriate levels, if necessary. The predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level responses is calculated. Then low-level and mid-level calibration gases are introduced successively to the measurement system. The analyzer responses for low-level and mid-level calibration gases are recorded and the differences between the predicted responses are determined. These differences must be less than 5 percent of the respective calibration gas values. If not, the measurement system is not acceptable and must be replaced or repaired prior to testing.

The accuracy of the floor-type, high-precision balance (150,000 g capacity with 1 g readability) will be determined using standard reference weights. The balance has an internal calibration weight that is used to calibrate the balance initially. Then the accuracy of the floor-type balance will be checked by placing reference standard weights from 1 g up to 1 kg with and without the cart and empty mold. The accuracy of the analytical balance will be checked using standard weights suitable for its capacity range. The accuracy of the floor-type balance and the analytical balance should be less than 1 percent of the respective standard weights.

3.1.3 Detection Limit

The detection limit is defined as the lowest concentration or amount of the target analyte that can be determined to be different from zero from a single measurement at a stated level of probability. The detection limits for the instruments used for critical measurements are presented in Table 3-2. These instruments include the THC analyzer for emission measurement, the floor-type high-precision balance for material balance determination, and the analytical balance for styrene content determination. The detection limits specified in Table 3-2 provide adequate quantification for the measurements of interest.

3.1.4 Completeness

Completeness is defined as the amount of valid data obtained compared to the planned amount. The completeness objective of 90 percent was selected based on the results of a recent RTI test that compared emission measurement and mass balance

methods to quantify styrene emissions from open contact molding processes. A completeness level of 90 percent ensures that sufficient valid data of known quality are collected to evaluate different pollution prevention techniques for styrene emission reduction. The results from emission measurements and mass balance methods will complement each other, because each method has good precision. In the event that both test methods failed for more than 10 percent of the planned test runs and the completeness level of 90 percent is not met, then those invalid test runs will be repeated.

3.2 Objectives for Qualitative Data Quality Indicators

Qualitative DQIs are typically defined in terms of representativeness and comparability. The representativeness is the degree to which the collected data accurately and precisely represent the population or the actual operations. The comparability is the degree or confidence to which one data set can be compared to another. These qualitative DQIs are described in more detail in the following sections.

3.2.1 Representativeness

The representativeness of this testing is best determined by the materials and equipment used, the environmental conditions of the testing, and the operator techniques. The gelcoat and resin materials, except the water-emulsified resin, and the application selected for testing are currently available to, and used by, the industry. Water-emulsified resin is currently used by the industry to a very limited extent; however, this testing will determine whether this resin can significantly reduce styrene emissions. The environmental conditions (i.e., air flow velocity and ambient temperature) for the testing will be controlled so that they are representative of typical conditions in an operating facility. The person who will operate the equipment is an experienced technical support person from Magnum Industries. His experience will ensure that the operating procedures are consistent between test runs and representative of industry practice.

The emissions in the spray booth will be representative of actual industry practice. As is discussed in more detail in Section 4.1, EPA Method 204 for a total enclosure is to be followed to ensure that 100 percent of the emissions is captured.

3.2.2 Comparability

The baseline emissions of this testing will be compared to the results RTI collected from an early March testing at Dow Chemical that used similar spraying techniques and the same gelcoat and resin materials. Another styrene emission study is planned by Composites Fabricators Association (CFA) to be conducted at Dow Chemicals in a time frame similar to this testing. The same regular gelcoat and low-profile resin materials will be applied by similar spraying techniques in the CFA testing.

The measurement procedures and methods will be similar for the CFA tests and this testing; therefore, results from both testings should be comparable.

4.0 SAMPLING PROCEDURES

4.1 Total Enclosure and Capture Efficiency Test

The open contact molding process will be conducted at a spray booth in a total enclosure setup in Reichhold Chemicals' physical testing laboratory. The spray booth is described in Section 1.6.1. The enclosure will be tested prior to the pilot and main experiments to ensure that the enclosure meets EPA's total enclosure guidelines (EPA Method 204), so that the emissions from the test can be assumed 100 percent captured. The capture efficiency of the enclosure will be examined by (1) evaporating a known quantity of styrene (determined by a high- precision scale) and measuring the total styrene emissions at the exhaust stack and (2) making sure that all air flows at natural draft openings flow inward and the velocity is at least 200 fpm.

4.2 Sampling Location and Duration of Test Run

Emissions from the open contact molding processes will be measured at the exhaust stack of the enclosure. A test run will start when gelcoat or resin material is applied to a mold and finish when the gelcoat or resin material is cured (as determined by a negligible rate of emissions). An earlier RTI test at Dow Chemical Company indicated that a test run may last from 1-1/2 to 2 hours. At the end of a test run, the mold will be removed from the enclosure and the enclosure will be flushed with fresh makeup air for the next test run. The THC analyzer will measure the background concentration before each test run. Any other VOC emission sources will be eliminated from the immediate area to minimize the background VOC concentration.

Table 4-1 shows the locations and frequencies of the measurements for the test.

4.3 Testing Procedures

Procedures for individual test runs are outlined in this section. More detailed descriptions of the procedures are presented in the following sections.

A Before the Test Run
1. Measure and record the gelcoat/resin properties
2. Calibrate the THC analyzer
3. Measure the baseline concentration in the spray booth with the THC analyzer
4. Measure and record initial air temperature, velocity head, and relative humidity

Table 4-1. Summary of Measurement Location and Frequency

Measurement	Classification	Location	Frequency
THC concentration	Critical	Exhaust stack	Continuous
Exhaust air flow rate and velocity head (Δp)	Critical	Exhaust stack	Flow rate (weekly), Δp (every 15 minutes)
Humidity	Noncritical	Spray booth	Before each test run
Mass balance calculations 1) gelcoat/resin materials used 2) gelcoat/resin applied on mold 3) cured material on mold 4) cured material on other ground cover	Critical	Spray booth	Each test run
Types of gelcoat and resin materials	Noncritical	Manufacturer	Each gelcoat and resin formulation
Styrene content	Critical	Laboratory	Each gelcoat and resin formulation
Gelcoat/resin properties 1) gel time 2) total time to peak 3) peak exotherm	Noncritical	Laboratory	Each gelcoat and resin formulation
Linear air velocity in the spray booth	Noncritical	Spray booth	Every week
Ambient temperature	Noncritical	Spray booth	Every test run
Equipment type	Noncritical	Equipment vendor	Each equipment
Equipment setup 1) pump pressure 2) air pressure 3) spray tip size 4) spray tip angle 5) catalyst ratio setting 6) equipment delivery rate	Noncritical	Spray booth	Each equipment
Gelcoat/Resin data 1) catalyst ratio 2) gelcoat/laminate thickness 3) glass/resin ratio	Noncritical	Spray booth	Each test run

5. Calibrate the balance(s) and check the accuracy with standard weights
6. Prepare and adjust the application equipment
7. Measure equipment delivery rate at the setup conditions in a remote location
8. Record the equipment setup conditions
9. Record the initial weights for mold, gelcoat/resin, catalyst, fiberglass reinforcement, protective skirt for cart, and ground cover

B. During the Test Run
1. Initiate the timer as soon as the application starts
2. Record styrene emissions with the THC analyzer continuously
3. Record velocity head (Δp) and air temperature every 15 minutes
4. Record the time and the weight of gelcoat/resin reading as soon as the application is completed (the application equipment can be removed for cleaning)
5. Measure and record wet gelcoat/laminate thickness at the center of each mold surface
6. Remove the protective skirt from the cart and record the weight of the wet mold at the end of application
7. Reattach the protective skirt to the cart
8. Stop the test run when the concentration returns to the baseline concentration or when incremental emissions are negligible
9. Record the time at the end of the test run

C. After the Test Run
1. Record the final weights for mold, catalyst, fiberglass reinforcement, protective skirt for cart, and ground cover immediately
2. Conduct the baseline drift determination for the THC analyzer
3. Remove the mold from the enclosure and flush the enclosure with fresh makeup air until the baseline concentration stabilizes

4.4 Emission Measurement

Styrene emissions will be measured from the exhaust stack of the enclosure using a total hydrocarbon analyzer following the EPA Method 25A. The THC analyzer will provide real-time measurements of the emission concentrations. Any other VOC emission sources will be eliminated from the enclosure, so that the total VOC emissions measured can be assumed to be from styrene emissions. Two to three concentration ranges (0-11 ppm, 0-110 ppm, and 0-1,100 ppm) on the THC analyzer will be used for the emission measurement. If the highest concentration range (0-1,100 ppm) is used, the maximum concentration is not expected to exceed 300 ppm. The following styrene standard reference gases are available to establish the calibration curve for each of the concentration ranges; 5.1, 10.7, 49.5, 81.5, and 237.1 ppm. Exceptions to EPA Method 25A are that the calibration error check for lowest concentration range (0-11 ppm) will be done with one instead of two standard reference gases.

4.5 Exhaust Air Flow Rate Measurement

The exhaust flow rate will be measured using EPA Methods 1 and 2 at least once a week. EPA Method 2 specifies the use of either a standard or S-type pitot tube to traverse the duct. Because the particulate loading of the exhaust air stream is expected to be low for this test series, a standard pitot tube will be used. The exhaust flow rate will be measured at traverse points using a standard pitot tube with a differential pressure gauge that meets the specifications described in EPA Method 2, Section 2.2. The exhaust flow rate will be correlated to the velocity head measured at the center point. The center point velocity head (Δp) will be monitored periodically (every 15 minutes) to ensure that air flow rate is consistent during the test run. The relative humidity of the air in the spray booth will be measured by a sling psychrometer.

4.6 Mass Balance Determination

Weight losses due to styrene emissions will be determined using a floor-type, high-precision balance (Sartorius Corporation, Model F150S) that has a 150,000-g capacity and 1 g readability. The initial and final weights of mold, gelcoat/resin materials, catalyst, fiberglass reinforcement, protective skirt for the cart, and ground cover will be measured by two balances. (A protective skirt will encircle the cart to prevent contamination during the application.) Total emission quantity will be determined from the difference of total materials used and the final weights after curing (see data reduction in Section 6.0). From the weights of materials used and materials applied on the mold, the transfer efficiency can be calculated for each test run.

Weight loss due to emissions will be recorded for each test run and the results will be compared to the emission measurement to determine whether these two methods are comparable.

4.7 Gelcoat and Resin Properties

Roughly a liter of sample will be taken from each of the gelcoat and resin container for analysis. Before sampling, the content in the container will be thoroughly mixed by a hand-held mixer for 2 minutes. The content will be scooped out to a nonreactive container and delivered to the laboratory. The type of material, lot/batch number, and container number will be recorded on the sample container. This information will be recorded on the data sheet in Section 5.0. Analytical procedures used to determine gelcoat and resin properties are presented in Section 5.0. These gelcoat and resin properties will be documented in the report to show the reader what kind of gelcoat materials were examined in the testing.

4.8 Environmental Conditions

Environmental conditions include linear air velocity and the ambient temperature in the spray booth. These conditions will be maintained at constant levels when feasible. The linear air velocity in the spray booth will be maintained at the level selected from the pilot testing. The temperature in the spray booth is affected by the temperature of the makeup air, which is heated or cooled according to the difference in indoor and outdoor temperatures. The actual temperature will be recorded for every test run on the data sheet shown at the end of Section 4.

4.8.1 Linear Air Velocity in Spray Booth

Linear air velocity in the spray booth will be measured with a hot wire anemometer at various traverse points in the spray booth. The spray booth will be divided into three sections (i.e., at front edge, in the middle, and at filter face), two layers (in the middle of top and bottom filter banks), and four divisions from left to right. These (3x2x4) volumetric traverse points will provide 24 readings to characterize the air flow pattern and velocities in the spray booth. Linear air velocities will be verified once every week or whenever the physical setup of the enclosure is changed. The air flow pattern and velocities will be recorded in Table 4-2.

Table 4-2. Air Flow Pattern and Velocity in the Spray Booth

	1/5 width from left wall		2/5 width from left wall		3/5 width from left wall		4/5 width from left wall	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Filter bank (top)								
Filter bank (bottom)								
Middle (top)								
Middle (bottom)								
Front edge (top)								
Front edge (bottom)								

Dir. = Air flow direction expressed by an arrow head.
Vel.= air flow velocity in fpm.

4.8.2 Ambient Temperature

Ambient temperature in the exhaust air and in the spray booth will be monitored with thermocouples. The temperature will be recorded every 15 minutes during the test run.

4.8.3 Relative Humidity

Relative humidity in the spray booth will be measured before each test run by a sling psychrometer or a relative humidity detector. The relative humidity reading will be recorded on the data sheet shown later.

4.9 Equipment Type and Setup

The equipment type and setup will be documented in the report to show the reader what kinds of equipment are examined in the testing.

4.9.1 Equipment Type

The types of equipment to be examined are described in Section 1.4.

4.9.2 Equipment Setup

The equipment setup affects the operation of the equipment and the emission generated. These conditions include pump pressure, air pressure, spray tip size, spray tip angle, catalyst ratio, and equipment delivery rate. These set-up conditions will be adjusted according to the vendors' recommendations by an experienced operator so that the equipment will be operated under their optimum conditions. The setup will be recorded for each equipment in each test run. The same setup will be used for the same equipment and material in the replicate test runs.

The equipment delivery rate will be determined during the standard calibration of the equipment under the same conditions of the testing. The standard calibration procedures consist of spraying the gelcoat or resin materials into a plastic bag for 30 seconds and weighing the amount of output materials. The weight is then multiplied by 2 to convert to a flow rate in pounds per minute.

4.10 Operating Parameters for Parts

The operating parameters for parts include catalyst ratio, gelcoat/laminate thickness, and glass/resin ratio. These parameters will be measured and documented in the report.

4.10.1 Catalyst Ratio

The actual catalyst ratio will follow the catalyst ratio suggested by the gelcoat and resin manufacturers.

4.10.2 Gelcoat/Resin Thickness

In the gelcoating and spray-up laminating tests, the operator will use a gelcoat and chop mil gauge during the application to determine the thickness. The operator will check and build the thickness of the gelcoat or laminate at various locations on the mold surface to the specified thickness. The wet gelcoat thickness is expected to be 18 to 24 mils and is to be achieved by multiple passes of spraying. The spray-up laminate thickness is expected to be 80 to 100 mils and is to be achieved by two passes of 40- to 50-mil thick laminate. Each pass of the spray-up laminate is equivalent to 1.5 oz/ft^2 of glass.

In the flow coating and pressure-fed rolling laminate tests, the primary thickness control will be the thickness of the chopped strand mat reinforcement. Two ply of 1.5-oz/ft^2 mat will be used to build the laminate so that the thickness of the laminates fabricated by the flow coater and pressure-fed roller will be similar to that of the laminates fabricated by spraying equipment.

4.10.3 Glass/Resin Ratio

The glass/resin ratio will be determined from the weights of glass roving or chopped strand mat and the amount of resin used to build the laminate. The glass/resin ratio will be documented for resin laminate only.

The data recording sheet for the measurements described in Section 4.0 is as follows:

Table 4-3. Data Recording Sheet for the Pollution Prevention Technique Evaluation Test

Date/Time span:
Test run No.:
Formulation type (gelcoat/resin):
Equipment type:
Recorded by:

1. Temporary Total Enclosure System
   a. Air flow velocities at natural draft openings (fpm)
   b. Air flow velocity over application area (fpm)

2. Air Temperature, Exhaust Air Flow Rate, and Relative Humidity
   a. Ambient air temperature (°F)

0'	15'(min)	30'	45'	60'
75'	90'	105'	120'	135'

   b. Velocity head (Δp) on the pitot tube (inches)

0'	15'	30'	45'	60'
75'	90'	105'	120'	135'

   c. Exhaust air flow rate (cfm)
   d. Relative humidity (%)

3. Emission Measurement
   a. Readings of THC analyzer calibration check

Range 1	Low	Med	High
Range 2	Low	Med	High
Range 3	Low	Med	High

   b. Reading of zero gas before the test run
   c. Reading of zero gas after the test run
   d. Zero and span potentiometer setting before calibration
   e. Zero and span potentiometer setting after calibration

4. Mass Balance Calculation
   Readings of balance accuracy check with standard weights

1g	5g	10g	50g	100g
200g	500g	1,000g		

   a. Weight of empty mold, g
   b. Weight of empty ground cover, skirt for cart, gloves, and tapes, g

(cont.)

Table 4-3. Data Recording Sheet for the Pollution Prevention Technique Evaluation Test (continued)

c. Initial weight of gelcoat/resin used, g (container No:)
Initial reading, g Final reading, g
d. Weight of catalyst used, g
Initial reading, g Final reading, g
e. Weight of fiberglass reinforcement used, g
Initial reading, g Final reading, g
f. Weight of wet mold at the end of application, g
g. Weight of mold with cured part, g
h. Weight of ground cover, skirt for cart, gloves, and tapes with cured overspray, g

5. Open Contact Molding Processes
a. Type of spray gun
b. Spray gun brand name/model No.
c. Pump brand name/model No.
d. Pump ratio
e. Air supply pressure, psi
f. Pressure at pump assembly, psi
g. Spray tip number/size
h. Catalyst ratio setting
I. Delivery rate, gpm
j. Gelcoat/laminate thickness, mil
top front left right back
k. Glass/resin ratio, %

5.0 ANALYTICAL PROCEDURES

This section describes the analytical procedures that will be used to analyze the gelcoat and resin materials tested. Gelcoat and resin properties include types of materials, styrene contents, and curing characteristics of the materials. Laboratory procedures commonly used by the industry will be followed to measure these properties. The other measurements, such as emission and environmental measurements, are described in Section 4 in conjunction with sampling procedures.

5.1 Types of Gelcoat and Resin Materials

The types of gelcoat and resin materials to be examined are listed in Section 1.4.

5.2 Styrene Content

Styrene content for each of the gelcoat and resin materials will be measured using Reichhold Standard Test Method No. 18-001 (Appendix A) in the Reichhold laboratory. The gelcoat and resin manufacturers will be asked to provide materials that contain only styrene as the monomer. The Reichhold test method determines the nonvolatile content of the materials, and the remainder is considered the styrene content. The styrene content of the water-emulsified resin will be determined for the base resin material before water is added.

5.3 Gel time, Time to Peak, and Peak Exotherm Characteristics of Polyester Resins

The gel time, time to peak, and peak exotherm characteristics of polyester resins will be measured following the Reichhold Standard Test Method No. 18-050 (in Appendix A) for gelcoats and resins catalyzed with MEKP. The Reichhold Standard Test Method No. 18-051 (in Appendix A) will be used for the resin catalyzed with BPO. The catalyst ratio suggested by the gelcoat and resin manufacturers will be used in the curing characteristics determination and in the actual testing.

The data recording sheet for the measurements described in Section 5.0 is presented on the next page.

Table 5-1. Data Recording Sheet for Gelcoat and Resin Properties

Date/Time:
Test run No.:
Formulation type:(gelcoat/resin)
Container No.:
Recorded by:

a. Gelcoat/Resin type
b. Manufacturer, Lot/Batch No.
c. Styrene content (%)
d. Weight percent of water (water-emulsified resin only)
e. Catalyst type
f. Catalyst ratio (wt. %)
g. Geltime (minute/second)
h. Time to peak (minute/second)
I. Peak exotherm (°F)

6.0 DATA REDUCTION, VALIDATION, AND REPORTING

This section describes how data will be reduced, validated, and reported. The data handling, reduction, validation, and reporting procedures are shown in Figure 6-1.

6.1 Data Reduction

After daily sampling is completed, the recording sheets containing sampling and analytical results will be collected, verified, and analyzed by the Testing Crew Chief. If THC analyzer readings are not available on a recorder, they will be entered into a computer spreadsheet. The styrene concentrations will be calculated from the THC analyzer readings and the styrene standard calibration curve for each corresponding concentration range used. An average styrene emission concentration will be calculated for the duration of the test run.

An average exhaust air flow rate will be calculated from the average velocity head monitored during the test run using the equations in EPA Method 2. Styrene emission quantity (Em) for each test run will be calculated by the following equation:

$$Em, lb = 2.6 \times 10^{-9} \times Q \times MW \times C \times T$$
$$Em, g = 1.18 \times 10^{-6} \times Q \times MW \times C \times T$$

where

2.6×10^{-9}, 1.18×10^{-6} = conversion factors to standard conditions (68 °F and 29.92 inches mercury) in English and metric units, respectively
Q = average exhaust air flow rate (dry standard cubic feet per minute)
MW = molecular weight of styrene (104)
C = average styrene emission concentration (ppmv dry)
T = duration of test run (minute).

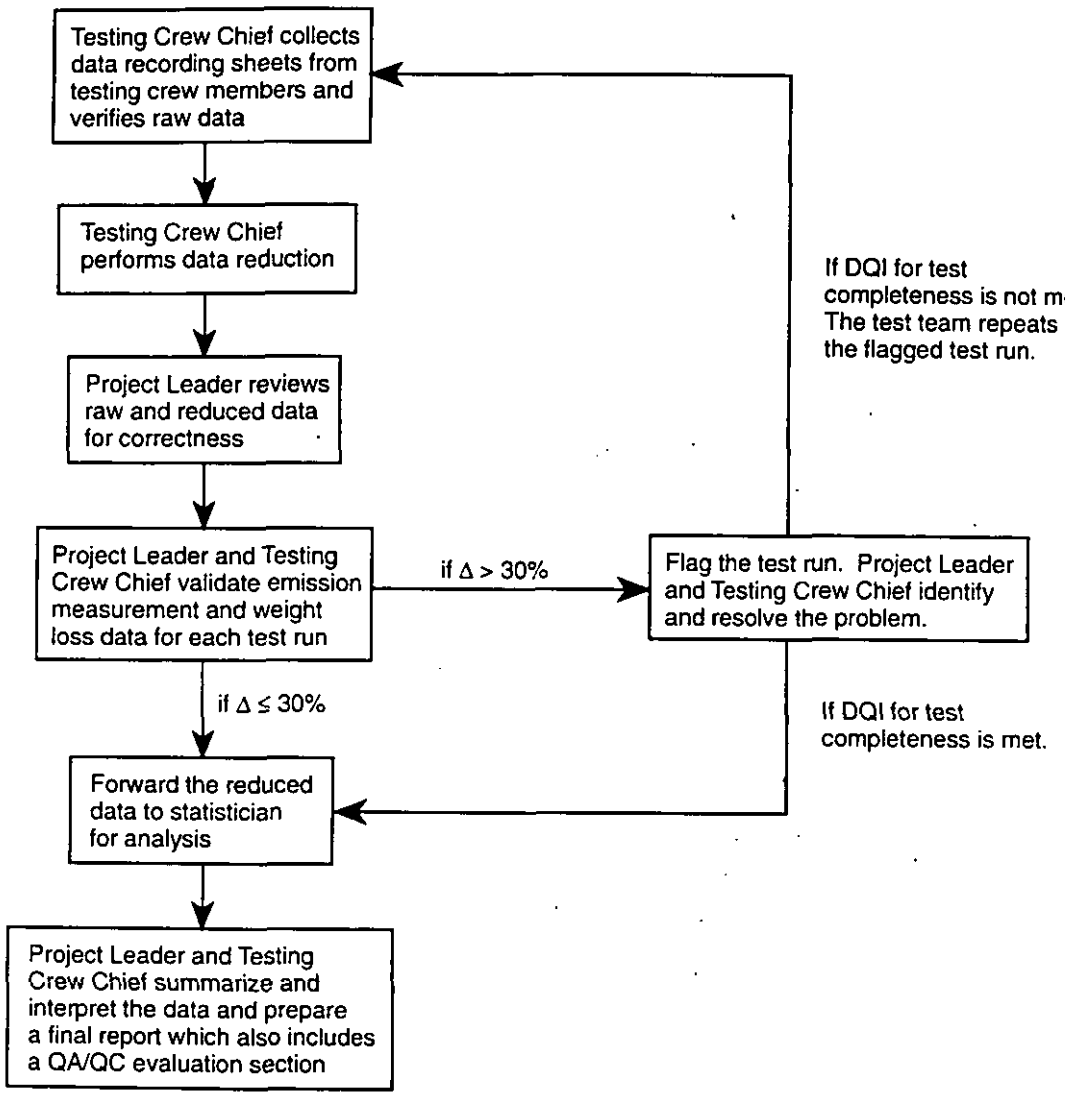
The weight loss due to emissions (Wloss) and the transfer efficiency (TReff) will be calculated by the following equations for each test run:

$$Wloss, g = (Wa+Wb+Wc+Wd+We) - (Wg+Wh)$$

$$TReff, \% = (Wf-Wa) / (Wc+Wd+We) \times 100\%$$

where

Wa = Weight of empty mold (g)
Wb = Weight of empty ground cover, skirt for the cart, gloves, tapes (g)



Note: Δ is the difference between the emission measurement and weight loss results for each test run.

Figure 6-1. The data handling, reduction, validation, and reporting procedures.

Wc = Weight of gelcoat/resin used (g)
Wd = Weight of catalyst used (g)
We = Weight of fiberglass reinforcement used (g)
Wf = Weight of wet mold at the end of application (without the skirt on the cart) (g)
Wg = Weight of cured part with mold (g)
Wh = Weight of ground cover, skirt for the cart, gloves, and tapes with cured overspray (g).

The emission quantity and weight loss data will be expressed as emission factor (Ef) in percent available styrene according to the following formula.

Ef, %AS = (Em or Wloss, g) / (Wc, g x styrene content) x 100%

where styrene content is the weight fraction of styrene in the gelcoat or resin formulation.

The same emission quantity and weight loss data can also be expressed as emissions per unit mold area (Ea) in gram per square meter according to the following formula:

Ea, g/m^2 = (Em or Wloss, g) / (surface area of the mold, m^2).

The field data will be reduced by the Testing Crew Chief as they are generated. At the end of the pilot experiment, these field data and reduced data will be analyzed to establish "standard" conditions under which the main experiment will be conducted. The standard conditions will be selected that best represent the actual operating conditions in the industry.

At the end of the main experiment, the field data and reduced data will be reviewed by the Project Leader for correctness. The reduced data are then passed to an RTI statistician for the analysis of variance as outlined in Section 1.7. The reduced data and the results of the statistical analysis will be included in the final report.

6.2 Data Validation

A key element in assessing data quality and validity is the comparison of emission measurement and the weight loss data for the pure styrene emissions test (described in Section 4.1) and for each test run. The Testing Crew Chief will perform the basic review and audit of the field data sheet for completeness and accuracy. The Testing Crew Chief will also compare the reduced emission measurement with the weight loss data to ensure that these two results are comparable within $\pm$ 30 percent. If these two results are not within $\pm$ 30 percent, the test run will be flagged. The test team will investigate the possible cause of the difference and correct the problem

immediately. At the end of the main experiment, if the data quality indicator for completeness is not met for emission measurement and weight loss determination, then these flagged test runs will be repeated.

6.3 Data Reporting

An RTI statistician will analyze reduced data and prepare the results of the statistical analysis. The Project Leader and the Test Crew Chief will be responsible for data summary, interpretation, and final report preparation. The report will present the effects of air flow velocity, spraying methods, gelcoat formulations, gelcoat application equipment, resin formulations, and resin application equipment on styrene emissions. The emissions from different formulations or equipment will be compared with the emissions from the baseline conditions. The ability to differentiate any emission reduction potential will be determined by the variability of the measurement method and the actual difference between the two compared conditions. The final report will also contain a Quality Assurance/Quality Control (QA/QC) evaluation report to document the QA/QC activities and results. The final report will include a statement indicating whether the data quality objectives were met or not. If the QA objectives were not met, an explanation of the impact of not meeting the project's QA objectives will be included.

7.0 INTERNAL PERFORMANCE AND SYSTEM AUDITS

7.1 Technical Systems Audits

A technical systems audit (TSA) is a qualitative on-site evaluation. A TSA evaluates compliance with the QAPP and any standard operating procedures (SOPs). One internal TSA is planned for this project. The TSA will be conducted by the project QA Manager, Ms. Salmons, or her designee and will cover sampling, analysis, and data handling steps. A written report will be prepared, summarizing the results of the audit and noting any deviations from the QAPP, within one month of completion of the audit. In addition, RTI will cooperate fully with any external audits performed by EPA.

7.2 Performance Evaluation Audits

A performance evaluation audit (PEA) is a quantitative evaluation of a measurement system. No internal performance audits are planned for this project. If EPA provides performance evaluation samples, RTI will analyze them.

7.3 Audits of Data Quality

Audits of data quality (ADQs) involve assessments of the methods used to collect, interpret, and report the information required to characterize data quality. While no formal ADQ is planned for the project, the project QA Manager or her designee will review the data at the end of the project, before the report is finalized. This review will check that reduction and validation, as described in Section 6, have been performed, and that data can be tracked from data forms and notebooks to the summary tables in the report.

8.0 CALCULATION OF DATA QUALITY INDICATORS

The exhaust air flow rate, the THC analyzer readings, and weight loss data are measured and recorded at the test site. These field data are immediately available for data quality review. The field data will be reduced during the testing to the extent possible to provide a means of immediately assessing the field data quality. If it is found during the testing that accuracy, precision, method detection limit, and completeness measurements deviate from the DQI goals indicated in Section 3, the source of error will be identified and the problem corrected as soon as possible. A pure styrene emission test as described in the capture efficiency test for the total enclosure may be used to identify the source of error.

The following calculations will be used for this study.

8.1 Precision

For precision, relative standard deviation will be reported:

$$RSD = (s/\bar{y}) \times 100\%$$

where

RSD = relative standard deviation
s = standard deviation
y = mean of replicate analyses.

Standard deviation is defined as follows:

$$s = \sqrt{\sum_{i=1}^{n} \frac{(y_i - \bar{y})^2}{n - 1}}$$

where

y_i = measured value of the with replicate
n = number of replicates.

8.2 Accuracy

For accuracy, percent recovery will be reported.

When a standard reference material (SRM) is used:

$$\%R = 100\% \; x \left[\frac{C_m}{C_{srm}} \right]$$

where

%R = percent recovery

C_m = measured concentration of SRM

C_{srm} = actual concentration of SRM.

8.3 Method Detection Limit

MDL is defined as follows for all measurements:

$$MDL = t_{(n-1,1-\alpha=0.99)} \; x \; s$$

where

MDL = method detection limit

s = standard deviation of the replicate analyses

$t_{(n-1,1-\alpha=0.99)}$ = students' t-value for a one-sided 99% confidence level and a standard deviation estimate for n-1 degrees of freedom.

8.4 Completeness

Completeness is defined as follows for all measurements:

$$\%C = 100\% \; x \left[\frac{V}{n} \right]$$

where

%C = percent completeness

V = number of measurements judged valid

n = total number of measurements planned

9.0 CORRECTIVE ACTION

The need for corrective action may be identified through internal performance and system audits (described in Section 7); whenever measurement precision, accuracy, detection limit, or completeness deviates from the objectives established in Section 3; or whenever the comparison of emission measurement and weight loss calculation for individual test runs differs by more than 10 percent.

Corrective action begins with identifying the source of the problem. Potential sources of problems include failure to adhere to prescribed test procedures or methods, equipment malfunction, or error in data reduction. Pure styrene emission tests described in Section 4.1 may be used to identify problems related to the THC analyzer. If an instrument calibration check does not meet the specified acceptance criteria, recalibration will be required.

The Testing Crew Chief has the primary responsibility for initiating and completing corrective action required to resolve measurement problems encountered during the testing. The Project Leader and the Testing Crew Chief will determine whether the corrective action has resolved the problem or not and when to resume the testing. The Quality Assurance Manager will be notified of all corrective actions undertaken at the test site. If necessary, the Project Leader will work with the Quality Assurance Manager to resolve major problems such as THC analyzer malfunction and to obtain concurrence from the EPA Project Officer and QA Officer. All corrective actions and the nature of problem will be documented in the QA/QC evaluation in the final report.

RESEARCH TRIANGLE INSTITUTE

RTI

Center for Environmental Analysis

MEMORANDUM

DATE: May 25, 1995

TO: Carlos Nunez, EPA Project Officer

FROM: Emery J. Kong

SUBJECT: Responses to EPA's Comments on the Category III Quality Assurance Project Plan (QAPP)

RE: Evaluation of Pollution Prevention Techniques to Reduce Styrene Emissions from Open Contact Molding Processes
EPA Cooperative Agreement No. CR 818419-03
RTI Project No. 96U-5171-016

Our responses to EPA's comments on the QAPP are presented in the attachment. As I have discussed with Dr. Nancy Adams on May 5, RTI will make the following changes to the QAPP: (1) RTI will calibrate the THC analyzer with propane standards and establish a response factor relationship between the propane and styrene standards, and this relationship will be used to determine the styrene concentrations monitored, and (2) RTI will use hydrogen gas as the fuel for the Ratfisch THC analyzer (as called for in the instrument manual) instead of a hydrogen/nitrogen mixture.

In addition to the above changes, we will separate the gelcoat experiment from the resin experiment because we are able to resolve some technical problems in gelcoat and resin application. This change will not affect the validity of measurements for either gelcoat experiment or resin experiment because data analysis for each experiment is done separately. We will perform the pilot experiment first using the regular gelcoat, then the gelcoat experiment, and finally the resin experiment.

Please forward our responses to Dr. Nancy Adams. If you believe our responses have adequately addressed EPA's concerns in the QAPP, please sign and date the attached signature page and return it to me as soon as possible. Please call me at 541-5964 immediately, if you think the responses are not adequate. Thank you very much.

Attachments

cc: Cynthia Salmons, RTI
Mark Bahner, RTI
Bob Wright, RTI
Andy Clayton, RTI
Jesse Baskir, RTI

3040 Cornwallis Road • Post Office Box 12194 • Research Triangle Park, North Carolina 27709-2194 USA
Telephone 919 541-5816 • Fax 919 541-7155

Attachment

Section	Comment
1. Table 1-4	TEST RUNS FOR THE RESIN FORMULATIONS AND EQUIPMENT TYPES

How will RE-3 (pressure-fed rollers) and RE-4 (modified AAA) be compared when different resin formulations are being used in the testing of these two types of equipment? RE-1, RE-2, and RE-3 are all being tested with the same resin formulation, but RE-4 testing is proposed using a different formulation. A discussion of the way in which the four equipment types (REs) will be compared would add to the plan.

Response:

The resin catalyzed with benzoyl peroxide (BPO) catalyst requires the modification of the air-assisted airless (AAA) spray gun and pump system, so it is not possible to test the BPO system using the conventional AAA spray gun. This means that it will not be possible within the present test design to separate the effects of the BPO catalyst from the effects of the modified spray gun. Therefore, the test report will acknowledge that no separation of these effects can be made. As noted on page 1-18, any comparison of RF-4 with other resin formulations will be confounded with the equipment difference.

2. Table 1-5 SUMMARY OF CRITICAL AND NONCRITICAL MEASUREMENTS

Reichhold Method No. 18-001 is proposed for the measurement of styrene content in the formulations tested. This method (Appendix A) involves weight loss with heating of a small sample on foil. Method 18-001 seems to be a measurement of volatiles and not styrene. This matter is discussed in Section 5.2; the manufacturers will be asked to "provide materials that contain only styrene as the monomer." However, throughout the document, styrene measurement is listed as a critical measurement, and the proposed method is not measuring styrene. Is there any additional data that could be supplied to verify that the proposed method really is an accurate measure of styrene?

Response:

Reichhold Method No. 18-001 is commonly used by the industry to determine the non-volatile (NV) content of polyester resins. Section VI of

the method shows that the % monomer content is calculated using the following formula:

$$\% \text{ monomer} = 100 - \% \text{ NV}.$$

Since the materials used in the testing will contain only styrene monomer, we can use the method as an indirect measurement of styrene content.

3. Section 3.1.2 ACCURACY

These accuracy goals pertain to calibration error only. What about zero and calibration drift (post test checks)?

There is a minor typo noted in the text. The word is "assembly".

Response:

The zero and mid-level calibration drift will be checked according to the procedures outlined in Method 25A section 7.2, at the end of each run (but not hourly during the run). The acceptable drift will be taken to be ± 3 percent of span value. If the drift exceeds the acceptable level, the THC response will be checked for all calibration gases within the range(s) used in the run. The test results will be reported using both sets of calibration data (before and after the run). The THC analyzer will then be recalibrated as described in Method 25A section 6.4, prior to the following run.

4. Table 3-2 OBJECTIVES FOR QUANTITATIVE DATA QUALITY INDICATORS

The accuracy objectives should be clearly defined. Is % bias from full scale or from a known standard? Is the THC detection limit of 1 ppm realistic in the 0 - 1, 100 ppm range? How was the detection limit derived? Does the equation in Section 8.3 apply for non-discrete measurements such as those from CEMs?

Response:

RTI now plans to operate the total hydrocarbon analyzer on instrumental ranges that correspond to 0 to 20 ppm styrene (C8) and 0 to 200 ppm styrene (C8). These ranges are also equivalent to 0 to 53 ppm propane (C3) and 0 to 533 ppm propane (C3). The calibration gases will be 16, 27, 45, 160, 267, and 453 ppm propane. These calibration gases will correspond to 30 percent, 50 percent, and 85 percent of the two full-scale ranges, as called for in EPA Method 25A.

The accuracy data quality objective is being changed from +/- 5 percent to +/- 3 ppm on the 0 to 53 ppm propane range and to +/- 31 ppm on the 0 to 533 ppm propane range. The values are the root-sum-squares of the calibration gas accuracy, the calibration error, and the calibration drift. The following example is for the 0 to 53 ppm propane range:

calibration gas accuracy	= 5 % of 45 ppm	= 2.25 ppm
calibration error	= 5 % of 27 ppm	= 1.35 ppm
calibration drift	= 3 % of 53 ppm	= 1.59 ppm
root-sum-square		= 3.07 ppm

Please note that each of these accuracy components is measurable. The calibration gas accuracy will be determined by comparing the specialty gas producer's certified value with RTI's verification value for the high-level calibration gases. The calibration error and calibration drift will be measured according to the procedures outlined in Method 25A section 7.2, at the end of each run.

The THC detection limit of 1 ppm (as styrene) is quite realistic for the 0-200 ppm (as styrene) range. As shown in the attached figure, the zero gas analysis in a March 1995 testing at Dow (using the same THC analyzer) showed that a detection limit of less than 1 ppm was achieved in a 0-350 ppm (as styrene) range. The equation in Section 8.3 can be used if THC readings are taken at fixed intervals (such as every 15 seconds).

5. Section 4.4 EMISSION MEASUREMENT

How many points will go into the calibration? Based on the gases discussed in the QAPP, only the 1,100 ppm scale can be calibrated per Method 25A. What is the sample line made of? Is it heated? Are the other components of the sample delivery system heated? Are any system bias checks planned? Styrene is very reactive. What will be done to evaluate the bias of the sample delivery system? Where will the probe be located in the stack? Will an emissions profile be performed to assess stratification in the duct? A probe can be built to sample representatively across the duct (see 40 CFR Part 86.310-79).

Response:

In accordance with EPA Method 25, each of the two concentration ranges used in the total hydrocarbon analyzer will be calibrated with zero gas and low-level, mid-level, and high-level calibration gases. The concentrations of these calibration gases are shown in the response to Comment No. 4.

RTI anticipates using PFA Teflon for the sample line. The sampling location will be 5 or 6 stack diameters downstream of the last bend. The sample line will be capped at its end and a number of holes will be drilled along its in-stack length to obtain a sample stream that is representative of the entire stack. In general, RTI will follow the specifications for the sample probe given in 40 CFR, Part 86.310.79 (b) except for the use of PFA Teflon rather than stainless steel.

Method 25 states that the sample line should be heated, if necessary, to prevent condensation in the line. The total hydrocarbon analyzer will be sampling essentially room air at room temperature. As such, there is no need to heat the sample line to prevent condensation. Further, heated sample line may cause styrene polymerization within the sample line.

During a previous gas chromatographic verification study of styrene calibration gases, RTI checked for sample line losses using a calibration gas containing approximately 5 ppm styrene. No differences among unheated stainless steel, heated stainless steel, and unheated Teflon sample lines were found. Any sample line losses would likely be less at the much higher flow rate associated with the total hydrocarbon analyzer.

The bias of the sample delivery system will be tested, before the actual testing, by comparing the instrumental responses to the styrene and propane calibration gases when they are delivered through the analyzer's calibration gas port and through the unheated sample line. If the responses for both styrene and propane gases are the same, the sample line will not be heated. If the response for styrene gas is different and the response for propane gas is the same, then the need for heating the sample line will be evaluated. If responses for both styrene and propane gases are different, then the THC analyzer will be checked and repaired. A THC analyzer rental unit can be arranged if the Ratfisch THC analyzer is not functional.

In addition to the direct sample delivery system bias test, an indirect sample system bias check will be conducted in the preliminary testing using pure styrene evaporation. The pure styrene evaporation test will identify the bias in exhaust flow rate and THC measurements when the emission quantity is compared to the known quantity of styrene evaporated. The pure styrene evaporation test will release styrene at a constant rate; therefore, it can be used to determine the emissions profile and to assess stratification in the exhaust stack. The emission concentrations profile could not be performed during an actual test due to the changing styrene concentrations. Additionally, the multi-point sample probe described above should eliminate bias due to potential stratification.

6. Section 4.5 EXHAUST AIR FLOW MEASUREMENTS

Is the exhaust flow rate stable enough to only measure flows weekly? Why was the center of the duct selected to monitor Δp? Wouldn't the average square root of Δps across the duct be more appropriate? Has an Annubar been considered to determine total flow with a single Δp?

Response:

Prior to the actual testing, several velocity traverse/centerline measurements will be made on different days to determine whether the exhaust flow rate changes over time and whether the centerline Δp measurements accurately correlate with velocity traverse measurements. If the preliminary exhaust flow rate measurements indicate that centerline Δp measurements do no correlate to within $\pm$ 5 percent of the exhaust flow rate as determined by traverse measurements, an Annubar probe will be used for Δp monitoring in the actual testing.

If the exhaust flow rate is relatively stable over time, a velocity traverse will be performed at the beginning of each week to determine the exhaust flow rate, and the Δp (either at centerline or by Annubar) will be monitored every 15 minutes during the test run. The exhaust flow rate during the test run will be calculated according to the following formula:

$$Q_{run} = [avg\ (\Delta p_{run})^{0.5}/(\Delta p_{weekly})^{0.5}] \times Q_{weekly}$$

where

Q_{run} = exhaust flow rate during a test run (scfm)
Q_{weekly} = exhaust flow rate determined by the weekly velocity traverse (scfm)
$avg\ (\Delta p_{run})^{0.5}$ = average square root of the 15-minute Δps recorded during the test run, either at the centerline or by Annubar
$(\Delta p_{weekly})^{0.5}$ = square root of the Δps recorded during the weekly velocity traverse

7. Section 4.7 GELCOAT AND RESIN PROPERTIES

Is the hand-held mixer electric? If so, please be sure the motor is explosion proof since the flash point of styrene is 31°C.

Response:

The hand-held mixer will be powered by compressed air.

8. Section 8.3 METHOD DETECTION LIMIT

Does the definition of s mean the (estimated) standard deviation of a single observation, or the average of the *n*? Presumably the "MDL" refers to a single observation but is based on a variance estimated from multiple observations.

Response:

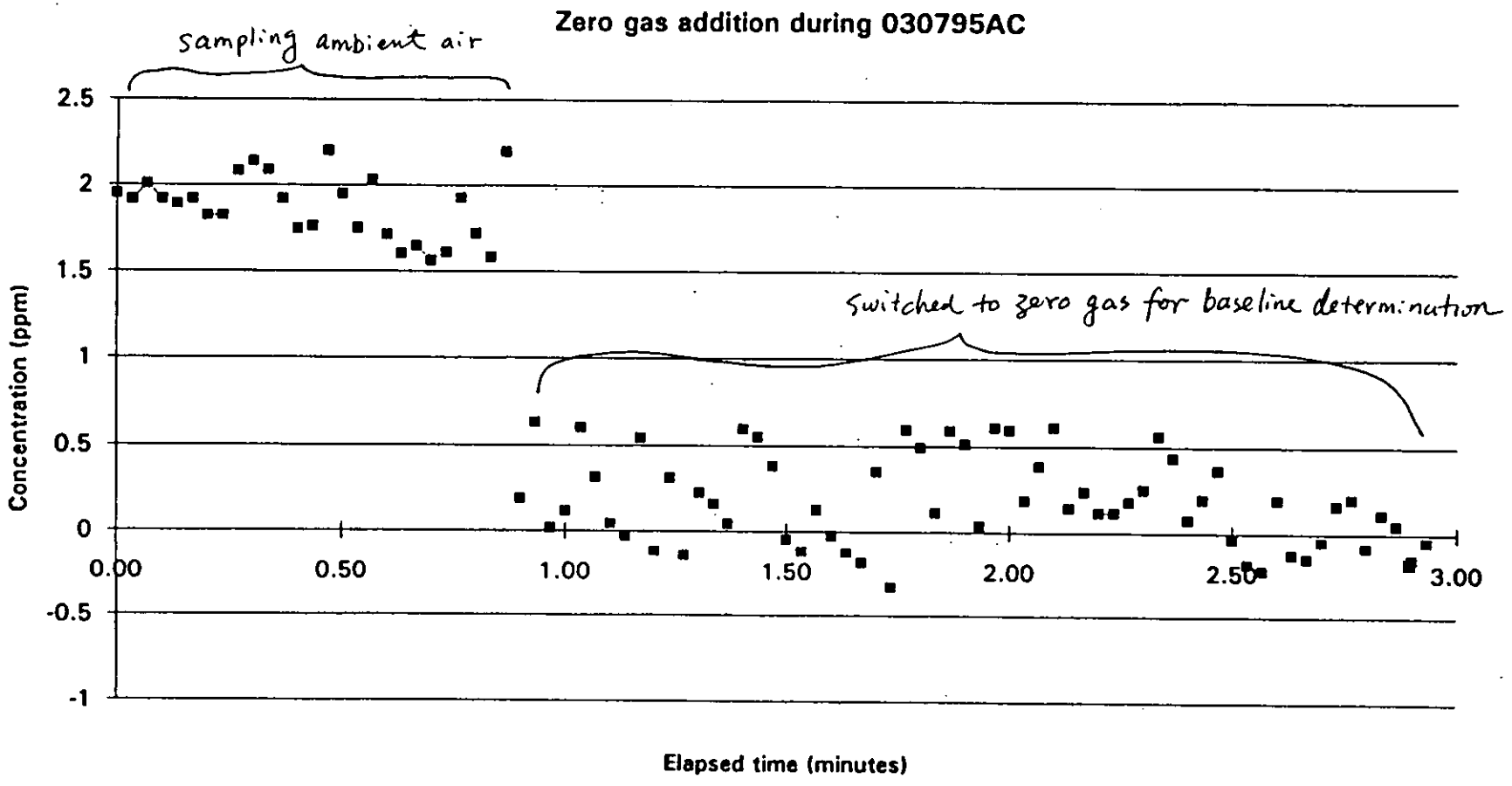
The method detection limit will be calculated using the equation shown with s being determined from n measurements of zero gas taken at 15-second intervals. RTI anticipates that n will equal 20.

9. GENERAL COMMENTS FROM ROSS LEADBETTER

Response:

The entries in Table 1-1 are approximated half widths.

The QAPP was arranged according to the format given in the QA manual; therefore, some of the texts may be disconnected to the reader. Nevertheless, the reader should be able to find the essential information by referring to the table of contents.



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Appendix B

Reichhold Standard Test Methods

Reichhold Standard Test Methods

DETERMINATION OF NON-VOLATILE CONTENT
OF POLYESTER RESINS

METHOD: 18-001
ISSUED: 11/17/87
REVISED: 02/27/89
PAGE: 1 OF 3

I. SCOPE

This method describes a procedure for the rapid determination of the non-volatile content of polyester resin solutions.

II. SAFETY

Safety glasses are recommended for this procedure.

III. EQUIPMENT

1. Aluminum foil - 6" x 12", Thomas Scientific 1086-F27-F32 or equivalent. (Reynolds Wrap Heavy Duty)
2. Paper clips, #1 gem clips or equivalent.
3. Cardboard sheet - 8" x 12" x 0.025".
4. Analytical balance, capable of accurately weighing to +/- 0.0001 grams.
5. Disposable syringe, 3cc capacity, B-D #5586 or equivalent.
6. Oven, forced air, of suitable capacity maintained at 120 +/- 2°C.
7. Thermometer, (1.0°C divisions).
8. Clean glass plates (2) approximately 8" x 8" x 1/4".
9. Stopwatch or timer capable of measuring to one second intervals.

IV. PROCEDURE

1. Fill disposable syringe with polyester resin solution to be tested, cleaning away all excess resin from the exterior of the syringe and removing all excess air from the interior. Immediately replace syringe cap to insure minimal monomer loss due to evaporation.

2. Fold a 6" x 12" aluminum foil sheet in half, shiny surface facing in, and measure its dry weight (without resin) to the nearest 0.0001 gm. Record this weight as "A".

3. Unfold the aluminum foil sheet and rest it shiny side up on one of the 8" x 8" x 1/4" glass plates. Place approximately 0.5 grams (0.5cc) of polyester resin solution in the center of either of the 6" x 6" halves of the aluminum foil sheet. Replace the syringe cap.

4. Carefully fold foil sheet halves together and gently place second glass plate over the folded foil sheet. Press carefully to ensure even distribution of the resin sample into a thin film without exuding from the edges of the aluminum foil.

5. Quickly reweigh the aluminum foil containing the resin sample, to the nearest 0.0001 gram. Record this weight as "B".

6. Unfold the foil sheet and place (resin side up) onto the cardboard sheet. Use the paper clips to carefully secure the foil to opposite corners of the cardboard.

   NOTE: Use care not to tear the aluminum foil sheet or allow the paper clips to come in contact with the resin.

7. Place entire apparatus in 120 +/- 2°C oven, begin timer, and leave in oven for 10 minutes.

8. Repeat steps two (2) through seven (7) for duplicate sample.

9. After 10 minutes, remove the sample apparatus from the oven. Carefully remove the aluminum foil from the cardboard surface and fold several times to avoid the loss of dried resin sample. This will also help to minimize added moisture from condensation. Quickly reweigh the aluminum foil to the nearest 0.0001 gram. Record this weight as "C".

V. CALCULATIONS

Percent non-volatile can then be calculated using the following formula:

$$\% NV = \frac{\text{Weight of Resin Solids}}{\text{Weight of Resin Solution}} \times 100$$

Where: Weight of resin solids = C - A
Weight of resin solution = B - A

Duplicate samples should agree to within +/- 0.5%. If duplicate samples are not within +/- 0.5%, rerun the entire test.

NOTE: Occasionally, high boiling monomers are used in manufacturing polyester resins. Some may not evaporate as quickly as styrene. If samples don't agree on the second run, this may be the cause.

VI. REPORT

The percent non-volatile is reported as an average of the duplicate samples. Round the value to the nearest 0.1%. Once the % NV is known, % Monomer Content may be calculated using the following formula:

% Monomer = 100 - %NV

Author: _____

Approved by: _____

DETERMINATION OF BROOKFIELD VISCOSITY
AND THIXOTROPIC INDEX OF POLYESTER RESINS

METHOD: 18-021
ISSUED: 02/17/84
REVISED: 02/27/89
PAGE 1 OF 5

I. SCOPE

This method describes a procedure for determining the Brookfield viscosity and/or thixotropy of polyester resins.

II. SAFETY

Safety glasses and protective gloves are recommended for this procedure.

III. EQUIPMENT

1. Brookfield Viscometer, Model LVF, (6,12,30 and 60 RPM) with spindles #1 through #4 and without guard.

2. Brookfield Viscometer, Model RVF (2,4,10 and 20 RPM) with spindles #1 through #7 and without guard.

3. Brookfield Viscometer, Model RVT (0.5,1,2.5,5,10,50 and 100 RPM) with spindles #1 through #7 and without guard.

4. Brookfield Laboratory Stand. Model A.

5. Circulating water bath controlled at 25°C +/- 0.2°C.

6. Thermometer, ASTM-17C (19-27°C).

7. Stopwatch or timer capable of measuring to one second intervals.

8. Quart can and lid.

9. Brookfield factor finder or note page 5 of 5.

10. Laboratory monitored at 25+/-1°C or 77+/-2°F.

IV. CALIBRATION

1. Brookfield 500 cps and 2500 cps oil standards are to be used. Each viscometer calibration should be checked once per month using the Brookfield Standardized oils. Select a spindle and RPM that will give a reading in the mid range of the viscometer scale; 40-60 on the dial.

2. Mount the viscometer in air and level it. Deflect the needle lightly from its zero position and let it swing back under its own power. If the needle swings freely and returns to zero it is acceptable.

V. PROCEDURE (NON-THIXOTROPIC RESINS)

1. Pour approximately 800 ml of resin sample into a quart can and adjust to 25 +/- 0.2°C using a thermometer (avoid air entrapment).

2. Place the resin sample into the constant temperature water bath at 25 +/- 0.2°C. Allow sufficient time for the sample to deaerate completely since air bubbles will affect viscosity readings.

3. Select the appropriate viscometer, spindle and spindle speed according to the Master Formula. If unspecified, select spindle and speed which will give a reading in the mid range of viscometer dial.

4. Remove the lid and place the resin sample under the leveled viscometer. Lower the viscometer to a point where the spindle coupling is approximately two (2) inches from the resin surface. Insert the clean, dry spindle into the sample at an angle to avoid air entrapment under the spindle. Lift up on the spindle coupling and attach the spindle. (NOTE: left-hand thread). Avoid putting side or down thrust on the shaft when attaching spindle.

5. Center the spindle, then raise or lower the viscometer housing until the upper surface of the sample is in the middle of the spindle shaft indentation.

6. After selecting the desired viscometer RPM, turn on viscometer motor and simultaneously start the stopwatch.

7. After one (1) minute has elapsed, depress the viscometer clutch, stop the motor and take a dial reading.

Va. CALCULATION

1. Multiply the dial reading by the factor obtained from the factor finder (see page 5 of 5) to obtain a centipoise value. Report results in centipoises (CPS) showing temperature, Brookfield Model, spindle number and RPM.

VI. PROCEDURE (THIXOTROPIC RESINS)

1. Pour approximately 800 ml of resin sample into a quart can and adjust to 25 +/- 0.2°C using a thermometer (avoid air entrapment).

2. Place the resin sample into the constant temperature water bath at 25 +/- 0.2°C, undisturbed for exactly fifteen (15) minutes prior to viscosity determination.

3. Select the appropriate viscometer, spindle and spindle speed. Unless specified, all thixotropic resins will be evaluated using the Brookfield Model LVF viscometer, #3 spindle at 6 RPM and 60 RPM.

4. Follow steps (4) and (5) for non-thixotropic resins. Handle the sample with care to minimize disturbance of the resin.

5. Set the speed to 6 rpm, then start the viscometer simultaneously with the timer. After 60 seconds, increase the speed to 60 rpm. After three (3) minutes depress the viscometer clutch and take a reading. Reduce the speed to 6 RPM and start the viscometer again. Take a final reading at third (3) minutes.

VIa. CALCULATIONS

Multiply the dial reading taken at each speed by the respective factor obtained from the factor finder (see Page 5 of 5) to obtain centipoise values. Report results in centipoises (CPS) showing temperature, Brookfield Model, spindle number and RPM. (NOTE: In most cases the viscosity is reported using the higher RPM value).

VII. THIXOTROPIC INDEX

CALCULATIONS

Divide the viscosity obtained at the slower spindle speed by the viscosity obtained at the higher spindle speed to obtain the thixotropic index. Thixotropic index has no units of measure and is reported to the nearest 0.1.

$$T.I. = \frac{\text{Viscosity @ 6rpm}}{\text{Viscosity @ 60rpm}}$$

Author: _____

Approved by: _____

BROOKFIELD FACTOR FINDER

METHOD: 18-021
ISSUED: 2/17/84
REVISED: 2/27/89

Viscometer Model	RV	RV	RV	RV	RV	RV	RV
Spindle Number	1	2	3	4	5	6	7
.5	200	800	2M	4M	8M	20M	80M
1	100	400	1M	2M	4M	10M	40M
2	50	200	500	1M	2M	5M	20M
2.5	40	160	400	800	1.6M	4M	16M
4	25	100	250	500	1M	26M	10M
Speed RPM 5	20	80	200	400	800	2M	8M
10	10	40	100	200	400	1M	4M
20	5	20	50	100	200	500	2M
50	2	8	20	40	80	200	800
100	1	4	10	20	40	100	400

Factor

Viscometer Model	LV	LV	LV	LV
Spindle Number	1	2	3	4
.3	200	1M	4M	20M
.6	100	500	2M	10M
1.5	40	200	800	4M
3	20	100	400	2M
6	10	50	200	1M
Speed RPM 12	5	25	100	500
30	2	10	40	200
60	1	5	20	100

Factor

To convert viscometer dial reading to centipoise, locate the column which identifies the viscometer model and spindle number used. Locate viscometer speed, RPM'■. The number found at the intersection of viscometer, spindle and speed is the factor. Multiply viscometer dial reading by the factor to determine viscosity in centipoise.

M=1000

DETERMINATION OF ROOM TEMPERATURE GEL, TIME TO PEAK AND PEAK EXOTHERM CHARACTERISTICS OF POLYESTER RESINS

METHOD: 18-050
ISSUED: 2/17/84
REVISED: 2/27/89
PAGE 1 OF 3

I. SCOPE

This method describes a procedure for determining the gel, total-time to peak and peak exotherm of promoted or unpromoted resins when catalyzed with methyl ethyl ketone peroxide.

II. SAFETY

Safety glasses and protective gloves are recommended for this procedure. Use care when handling methyl ethyl ketone peroxide. Read and thoroughly understand the Material Safety Data Sheet provided with this material before its use.

III. EQUIPMENT

1. Temperature recorder with 0 to 500°F range. Type J thermocouple interface. Capable of speeds of 30"/hour and 60"/hour.
2. Type J thermocouple, iron-constantan, 6" sheathed in stainless steel.
3. Constant temperature water bath maintained at 25 +/- 0.2°C with suitable rack.
4. Laboratory balance, 400 gm minimum capacity, capable of weighing to 0.01 grams.
5. ASTM-17C thermometer, (19-27°C).
6. 6" wooden handle stainless steel spatula or wooden tongue depressor (6" X 3/4").

7. Disposable 150 ml polypropylene beaker (VWR Scientific Cat. no. 13915-544 or equivalent).

8. Stopwatch or timer capable of measuring to one second intervals.

9. Laboratory - maintained @ 25 +/- 1°C or 77 +/- 2°F.

10. Repipet dispenser. 5 ml capacity with 0.05 ml graduations (Fisher Scientific-Cat. no. 13-687-54 or equivalent) or Tuberculin Syringe, 1.0 CC capacity with 1/100 graduations (Fisher Scientific-Cat. no 14-820-15 or equivalent.

IV. REAGENTS

1. Methyl Ethyl Ketone Peroxide (Type specified by Master Formula).

2. 12% (metal) cobalt octoate solution (optional).

V. PROCEDURE

1. Weigh 100 +/- 0.1 grams of resin into a 150 ml polypropylene beaker.

2. Insert metal spatula, wooden tongue depressor, or thermometer into beaker. If the wooden tongue depressor is used, it must be coated 1/2 inch above the resin level with previously weighed resin to prevent absorption of cobalt solution, MEKP or any additional additives.

3. Promote resin if necessary for room temperature cure. Unless specifically stated by Master Formula, unpromoted resins are promoted with 0.21 grams of 12% cobalt octoate. Any promoter must be thoroughly mixed into the resin before proceeding.

4. Place the beaker containing resin into a constant temperature water bath at 25 +/- 0.2°C. Allow sufficient time for the resin sample to equilibrate to 25 +/- 0.2°C. If a thermometer is used to facilitate resin temperature adjustment it must remain in the sample until after the MEKP has been added and thoroughly dispersed.

5. Add the type and amount of MEKP specifically stated in the Master Formula into the sample resin; simultaneously start the stopwatch and mix thoroughly for one minute in the water bath. Avoid air entrapment while mixing. Allow the stopwatch to run for the entire test.

6. Check the sample periodically by lifting the spatula or tongue blade to observe the resin flow rate watching for signs of gellation. Do not stir the sample when checking it, but simply lift the spatula or tongue blade straight up and replace it. The point at which the resin ceases to flow and "snaps" off the stick back into the beaker is called the gel point and the elapsed time from catalyst addition to the gel point is called "gel time". Record the gel time. Do not stop the stopwatch.

7. Upon reaching the gel time, immediately remove the beaker from the water bath, place on a non-heat-conductive surface (i.e., wood) and insert the thermocouple. The tip of the thermocouple is to be located 3/16 inch from the beaker's bottom and within the center of the resin sample surface.

8. Observe the recorder and stopwatch. Record the time elapsed from catalyst addition to the peak temperature. This is called, "Total Time to Peak".

9. The maximum temperature reached is reported as the "Peak Exotherm".

NOTE: Some customers require an interval time rather than "Total Time to Peak". The interval (also called Gel-to-Peak) is the Total Time to Peak minus the Gel Time.

Example:

GEL TIME: 13'

TOTAL TIME TO PEAK: 28'

PEAK EXOTHERM: 325°F

Here, the interval (or Gel-to-Peak) is: 28' - 13' = 15'

AUTHOR: _____

APPROVED BY: _____

DETERMINATION OF STATIC STYRENE EMISSIONS
FOR COMPLIANCE WITH SCAQMD RULE 1162

METHOD: 18-152
ISSUED: 06/07/88
REVISED: 11/15/88
PAGE: 1 OF 3

I. SCOPE

This method describes the procedure for determining the weight loss of styrene from a polyester resin during its gel and cure under static conditions. Results are reported in g/m for compliance with Rule 1162's limit of 60 g/m maximum emissions.

II. SAFETY

Safety glasses and protective gloves are recommended for this procedure. Use care when handling methyl ethyl ketone peroxide. Read and thoroughly understand the Material Safety Data Sheet provided with this material before its use.

III. EQUIPMENT

1. Constant temperature water bath maintained at 25 +/- 0.2 deg C.
2. ASTM-17C Thermometer, (19-27 deg C).
3. Laboratory balance, 400 gm minimum capacity, accurate to +/- 0.01 gm.
4. Stopwatch or timer capable of one second intervals.
5. Disposable 400 ml polypropylene beaker.
6. 6" wooden handle stainless steel spatula or wooden tongue depressor (6" x 3/4").
7. Gallon can lid, 14.5 cm diameter, deep form to hold 100 gm resin.

8. Paper clip; bent to 90 deg angle.

9. Relative Humidity Meter, +/- 3% accuracy.

10. Repipet dispenser 5 ml capacity with 0.05 ml graduations (Fisher Scientific Cat. No. 13-687-54 or equivalent). A Tuberculin syringe, 1.0 cc capacity with 1/100 graduations (Fisher Scientific Cat. No. 14-820-15 or equivalent) may also be used.

IV. REAGENTS

1. MEKP (Type specified on Master Formula).

V. PROCEDURE

1. Place bent paper clip on can lid.

2. Weigh can lid to +/- 0.01gm. Record weight.

3. Record relative humidity and ambient temperature.

4. Weigh 200 +/- 0.1gm of resin into polypropylene beaker.

5. Adjust temperature of resin to 25 +/- 0.2 deg C.

6. Insert metal spatula, wooden tongue depressor or thermometer. If the wooden tongue is used the depressor much be coated 1/2 inch above the resin level with presiously weighed resin to prevent absorption of cobalt solution, MEKP or any additional additives. Add the type and amount of MEKP specified in the Master Formula, then start the stopwatch. Mix thoroughly for one (1) minute.

7. Place the gallon lid on the balance then tare. Then pour 100 +/- 0.5gm of catalyzed resin into the lid. Record the weight of resin to +/- 0.01gm.

8. Note the gel time of resin remaining in the beaker. Determine the gel time of the resin in the can lid by cautiously lifting paper clip. Record gel time of resin in the can lid. Avoid excessive movement of the paper clip as this will interfere with the results.

9. Allow the resin to cure in the lid for one (1) hour, or until the resin has cooled to room temperature.

   NOTE I: If balance use is required, remove the can lid from the balance after gel and place the lid on a heat conductive surface until weight back is required.

   NOTE II: A draft-free area is required for the test.

10. Record the final weight of resin in the can lid to +/- 0.01gm, or record the final weight of resin plus the can lid to +/- 0.01gm.

VI. CALCULATION

1. Styrene loss in g/m (E)

   a. Can lid left on balance for duration of test

      $E = (W - W) A$

      Where: W = initial weight of resin

             W = final weight of resin

             A = 60.56 for 14.5cm lid

   b. Can lid removed from balance during test for other balance use

      $E = (W + W - W) A$

      Where: W = initial weight of resin

             W = weight of can lid and paper clip

             W = final weight of resin plus can lid

             A = 60.56 for 14.5cm lid

VII. REPORT

Resin
Batch Number
Gel Time, Catalyst, and Catalyst Level
Relative Humidity
Ambient Temperature
Styrene Loss in g/m

Author: _____

Approved by: _____

Appendix C

Verification and Intercomparison of Compressed Gas Calibration Standards

APPENDIX C. VERIFICATION AND INTERCOMPARISON OF COMPRESSED GAS CALIBRATION STANDARDS

Styrene and propane compressed gas calibration standards used to calibrate the Ratfisch total hydrocarbon analyzer were purchased in 1994 and 1995 from Scott Specialty Gases in Durham, North Carolina. The styrene calibration standards could not be used directly for routine calibrations during styrene emission testing because of cylinder pressure limitations associated with styrene's dew point. Instead, propane calibration standards without such pressure limitations were used for the routine calibrations. Prior to the styrene emission testing at Reichhold Chemical, the certified concentrations of the styrene and propane calibration standards were verified at RTI. Additionally, the styrene and propane calibration standards were intercompared using the total hydrocarbon analyzer to obtain a propane-to-styrene correction factor for the styrene emission testing. This section discusses the verification and intercomparison of the calibration standards.

The styrene in nitrogen calibration standards were verified using a Hewlett Packard Model 5890, Series II gas chromatograph with a flame ionization detector, a gas sampling valve, and a 10-foot long by 1/8-inch OD stainless steel column packed with 10-percent OV-101 on Chromasorb WHP, 80/100 mesh at an oven temperature of 150 degrees Celsius (°C) isothermal. The analytical reference standards were prepared by serial dilution of a primary standard that was prepared by injection of liquid styrene and gaseous nitrogen into a canister. The analytical reference standard concentrations were 249, 25.1, and 2.49 parts per million by volume (ppmv). Each analytical reference standard and calibration standard was analyzed three times in succession before the next standard was analyzed. Styrene concentrations were calculated by linear interpolation between the nearest two analytical reference standard measurements.

The propane in air calibration standards were verified using a Hewlett Packard Model 5890, Series II gas chromatograph with a flame ionization detector, a gas sampling valve, and a 6-foot long by 1/8-inch OD stainless steel column packed with n-octane/Porasil C, 80/100 mesh at an oven temperature of 40 °C isothermal. The analytical reference standards were National Institute of Standards and Technology (NIST) Standard Reference Materials (SRMs) containing propane in air at concentrations of 476, 94.8, 48.6, and 0.99 parts ppmv. Each analytical reference standard and calibration standard was analyzed five times in succession before the next standard was analyzed. Propane concentrations were calculated from a least squares regression line determined from the analytical reference standard measurements.

The results of the styrene and propane calibration standard verifications are given in the following table:

Stamped Cylinder Number	Scott- Certified Concentration	RTI-Verified Concentration (year of RTI verification)	Percent Difference
AAL17461	237.1 ppm styrene(about 175 ppm upon reanalysis)	184 ppm (95)	-22.4
BAL3703	81.5 ppm styrene	85.0 ppm (94) 87.9 ppm (95)	+4.3 +7.9
BAL1361	49.5 ppm styrene	53.4 ppm (94) 53.9 ppm (95)	+7.9 +8.9
ALM036826	10.7 ppm styrene	9.83 ppm (95)	-8.1
BAL4319	5.12 ppm styrene	5.42 ppm (94) 5.33 ppm (95)	+5.9 +4.1
1A009797	454 ppm propane	453.6 ppm (95)	-0.1
ALM044162	275 ppm propane	278.0 ppm (95)	+1.1
ALM019336	150.9 ppm propane	153.4 ppm (95)	+1.7
AAL4968 (1)	95.4 ppm propane	95.77 ppm (93) 96.9 ppm (95)	+0.4 +1.6
A022617	44.8 ppm propane	45.03 ppm (95)	+0.5
A12158	26.9 ppm propane	27.02 ppm (95)	+0.4
A5406	15.95 ppm propane	15.99 ppm (95)	+0.3

(1) This calibration standard was not used for routine calibrations during the styrene emission testing, but was used during the evaluation of the total hydrocarbon analyzer.

In general, the Scott-certified concentrations and the RTI-verified concentrations for four of five styrene calibration standards agreed to within +/- 10 percent. However, the agreement was -22.4 percent for AAL17461. This calibration standard was returned to Scott Specialty Gases for reanalysis and its concentration was found to have shifted since its first analysis. It was judged to be unstable and was not used for routine calibrations. Three other styrene calibration standards (i.e., BAL1361, BAL3703, and BAL4319) had been verified by RTI in 1994. The reasonably good agreement between RTI's 1994 and 1995 values for these three calibration standards supports the beliefs that all styrene calibration standards were measured accurately and that the styrene concentrations are stable over the time period between the verifications.

The Scott-certified propane concentrations and the RTI-verified concentrations agreed to within +/- 2 percent for all seven propane calibration standards. One propane calibration standard (i.e. AAL4968) had been verified by RTI in 1993. The good agreement between RTI's 1993 and 1995 values for this calibration standard supports the beliefs that all propane calibration standards were measured accurately and that the propane concentrations are stable over the time period between the verifications. The 1995 RTI-verified concentrations for the propane calibration standards were used in the routine calibrations during the styrene emissions testing.

The styrene and propane calibration standards were intercompared using the Ratfisch total hydrocarbon analyzer to obtain a propane-to-styrene correction factor for the styrene emission testing. The calibration standards were delivered to the analyzer in a manner very similar to that employed during routine calibrations. The analyzer operating parameters were identical to those used during styrene emission testing. Two styrene calibration standards, four propane calibration standards, and zero air were measured twice on Range 2 (0 to 200 ppmv styrene). Two other styrene calibration standards, three other propane standards, and zero air were measured twice on Range 1 (0 to 20 ppmv styrene). Least squares regression analysis of 2-minute mean voltages yielded the following slopes for the styrene and propane regression lines:

	Range 2	Range 1
Styrene Slope (Volts/ppmv)	0.04928	0.50550
Propane Slope (Volts/ppmv)	0.01834	0.18305
Slope Ratio	2.686	2.762

A styrene molecule has 8 carbon atoms and a propane molecule has 3 carbon atoms. As a first approximation, one would expect the propane-to-styrene correction factor to equal the ratio of the carbon atoms (i.e., 8/3 = 2.667). The measured slope ratios are in good agreement with this theoretical value, particularly for Range 2.

Appendix D

Summary of Calibration Data, Calibration Error Tests, and Drift Checks

APPENDIX D. SUMMARY OF CALIBRATION DATA, CALIBRATION ERROR TESTS, AND DRIFT CHECKS

The total hydrocarbon analyzer was calibrated prior to each test run and a calibration drift check was done at the end of each test run. This section presents a summary of the calibration data, including calibration error tests and drift checks. The calibration requirements of EPA Method 25A were met or exceeded for the styrene emission tests. The method specifies that the calibration error must be less than +/- 5 percent of the calibration standard's concentration. The mid-level calibration error was less than +/- 1 percent for all test runs and the low-level calibration error was less than +/- 2 percent for all test runs. The method specifies that the zero and calibration drifts must be less than +/- 3 percent of scale. The zero and calibration drifts were less than or equal to +/- 1 percent full scale (% FS) for all test runs.

The propane calibration standards that RTI had verified and intercompared with styrene calibration standards were used for routine calibrations. The RTI-verified concentrations were used as the values for these calibration standards. For most test runs, the styrene measurements were made using Range 2 of the analyzer. These measurements were recorded by an Omega Engineering model OM-170 data logger and a Hewlett-Packard model 7132A strip chart recorder. The discussion of calibration error tests and drift checks in this section is based on those data recorded by the strip chart recorder. These data have an approximate resolution of 1/4 % FS.

The total hydrocarbon analyzer's response to the high-level calibration standard throughout the styrene emission testing is summarized in the following table. The analyzer was operated on Range 2 for all test runs, except for those Range 1 test runs marked by asterisks in the table. The analyzer's zero and span pots were not adjusted during the entire 5-week testing period. This table demonstrates that the analyzer's calibration remained very stable during the testing period. All 53 measurements of the high-level calibration standard on Range 2 fell between 87 and 90.5 % FS.

Test Run	High-Level Cal. Std. Response (% FS)	Test Run	High-Level Cal. Std. Response (% FS)	Test Run	High-Level Cal. Std. Response (% FS)
P1	89.75	G1	89.25	R1	88.75
P2	90.50	G2	88.75	R2	89.00
P3	90.00	G3	89.25	R3	88.75
P4	89.50	G4	89.25	R4 *	89.50
P5	89.75	G5	88.50	R5	88.50

Test Run	High-Level Cal. Std. Response (% FS)	Test Run	High-Level Cal. Std. Response (% FS)	Test Run	High-Level Cal. Std. Response (% FS)
P6	88.50	G6	88.75	R6	87.75
P7	89.00	G7	90.00	R7	88.00
P8	89.50	G8	90.50	R8	88.25
P9	88.50	G9	90.00	R9	88.50
P10	89.25	G10	90.00	R10	88.00
P11	89.00	G11	90.25	R11	88.25
P12	89.00	G12	89.75	R12	88.00
		G13	89.50	R13	88.00
		G14	89.50	R14	88.50
		G15	88.50	R15	88.50
		G16	88.75	R16 *	89.00
		G17	88.50	R17	87.00
		G18	88.75	R18 *	88.00
				R19	88.75
				R20	89.00
				R21	87.75
				R22	87.50
				R23	88.00
				R24	88.25
				R25	87.75

* Analyzer operated on Range 1 (0 to 20 ppm styrene).

EPA Method 25A specifies that calibration error tests be conducted immediately prior to each test run. After the analyzer's calibration equation was determined by measurements of the high-level calibration standard and zero air, the linearity of the calibration curve was tested by measurements of the mid-level and low-level calibration standards. The calibration error is

calculated as the difference between the analyzer's actual response to these calibration standards and the response that is predicted from the calibration equation. The method specifies that the calibration error must be less than +/- 5 percent of the calibration standard's concentration. The following table demonstrates that the mid-level calibration error was less than +/- 1 percent for all test runs and that the low-level calibration error was less than +/- 2 percent for all test runs. Other data not reported here supports the belief that the analyzer's calibration curve is a straight line.

Test Run	Mid-Level Cal. Error (percent)	Low-Level Cal. Error (percent)	Test Run	Mid-Level Cal. Error (percent)	Low-Level Cal. Error (percent)
P1	-1.30	-1.71	R1	-0.40	-1.20
P2	-0.35	-0.97	R2	-0.23	-0.70
P3	0.19	0.28	R3	0.22	0.05
P4	-0.60	-0.71	R4 *	0.08	-0.73
P5	0.02	-0.96	R5	0.05	-0.45
P6	0.05	0.31	R6	-0.03	-0.44
P7	-0.50	-0.20	R7	0.15	-0.70
P8	-0.15	-0.71	R8	-0.13	-0.96
P9	0.05	-0.45	R9	-0.40	-1.21
P10	0.12	-0.46	R10	0.60	0.06
P11	-0.50	-1.72	R11	-0.13	-0.96
P12	-0.50	-0.96	R12	-0.03	-1.20
G1	-0.33	-0.46	R13	-0.03	-0.44
G2	-0.23	-0.71	R14	-0.57	-0.95
G3	-0.33	-1.21	R15	-0.13	-0.95
G4	-0.50	-1.70	R16 *	0.71	-0.43
G5	0.05	-0.45	R17	-0.27	-0.94
G6	-0.23	0.05	R18 *	-0.74	-0.39
G7	0.02	-0.96	R19	-0.23	0.05
G8	0.18	0.03	R20	0.39	-0.20

Test Run	Mid-Level Cal. Error (percent)	Low-Level Cal. Error (percent)	Test Run	Mid-Level Cal. Error (percent)	Low-Level Cal. Error (percent)
G9	-0.42	-0.96	R21	-0.03	-1.21
G10	-0.42	-1.70	R22	0.53	-0.69
G11	-0.52	-1.46	R23	0.15	-0.70
G12	-0.59	-1.45	R24	-0.13	-0.96
G13	-0.60	-0.71	R25	-0.48	-1.21
G14	-0.60	-1.46			
G15	-0.40	-0.45			
G16	-0.23	-0.71			
G17	-0.40	-1.21			
G18	-0.23	-0.71			

* Analyzer operated on Range 1 (0 to 20 ppm styrene).

EPA Method 25A specifies that zero and calibration drift checks be conducted immediately following the completion of each test run. The same mid-level calibration standard and zero air that were measured during the calibration are to be remeasured at the end of the test run. The method specifies that the zero and calibration drifts must be less than +/- 3 percent of scale. The following table demonstrates that the zero and calibration drifts were less than or equal to +/- 1 % FS for all test runs.

Test Run	Zero Drift (% FS)	Mid-Level Cal. Drift (% FS)	Test Run	Zero Drift (% FS)	Mid-Level Cal. Drift (% FS)
P1	0.00	0.50	R1	0.00	0.25
P2	0.00	0.25	R2	-0.25	0.00
P3	0.00	0.50	R3	0.00	-0.25
P4	0.00	0.25	R4 *	0.00	0.25
P5	0.00	0.00	R5	0.00	-0.50
P6	0.00	-0.50	R6	0.00	0.50

Test Run	Zero Drift (% FS)	Mid-Level Cal. Drift (% FS)	Test Run	Zero Drift (% FS)	Mid-Level Cal. Drift (% FS)
P7	0.00	0.50	R7	0.00	0.00
P8	0.00	-0.50	R8	0.00	0.00
P9	0.00	0.25	R9	0.00	0.25
P10	0.00	-0.50	R10	0.00	-0.25
P11	0.00	0.00	R11	0.25	0.00
P12	0.00	0.50	R12	0.00	0.25
G1	0.00	-0.25	R13	0.00	0.00
G2	0.00	0.25	R14	0.00	0.25
G3	0.00	0.25	R15	0.00	-0.75
G4	-0.25	-0.25	R16 *	-0.25	-0.25
G5	0.00	0.00	R17	0.00	0.25
G6	0.00	0.25	R18 *	-0.75	0.00
G7	0.00	0.25	R19	0.00	0.50
G8	0.00	-0.50	R20	0.00	-1.00
G9	-0.25	0.50	R21	0.00	0.00
G10	-0.25	0.00	R22	-0.25	0.00
G11	0.25	-0.25	R23	0.00	0.00
G12	-0.25	0.00	R24	0.00	0.25
G13	0.00	0.00	R25	0.00	0.75
G14	0.00	-0.50			
G15	0.00	-0.50			
G16	0.00	-0.25			
G17	0.00	0.25			
G18	0.00	0.00			

* Analyzer operated on Range 1 (0 to 20 ppm styrene).

Appendix E

A Summary of Emission Measurements, Gravimetric Measurements, and Calculated Emission Quantities and Emission Factors for the Test

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Application Method	Air Vel.	Avg. sqrt (delta P)	Exhaust flow rate, cfm	Avg. conc. ppm	Background conc., ppm	Avg. net conc., ppm	Test run duration, min	Total emissions by THC, g
EXPERIMENTAL RUNS													
6/6/95	10:22	RF1-EXP	RF1	RE1	Normal	High	0.3693	9124	6.94	0.59	6.35	88.8	631
6/6/95	14:55	GF1-EXP	GF1	GE1	Normal	High	0.3657	9054	7.54	0.23	7.30	56.2	456
7/7/95	12:19	EXP1	GF1	GE1	Enclosed	Low	0.3376	8510	1.06	0.48	0.58	102.2	62
7/7/95	14:12	EXP2	GF1	GE1	Part. Encl.	Low	0.3464	8681	4.90	0.42	4.48	31.2	149
PILOT EXPERIMENT													
6/7/95	14:50	P1	GF1 #10	GE1	Controlled	Low	0.3582	8909	4.18	0.32	3.85	76.3	322
6/8/95	10:01	P2	GF1 #1	GE1	Normal	High	0.3619	8980	7.60	0.47	7.14	68.2	536
6/8/95	12:11	P3	GF1 #1	GE1	Controlled	High	0.3605	8953	5.39	0.33	5.05	68.8	382
6/8/95	14:40	P4	GF1 #1	GE1	Normal	High	0.3464	8681	7.75	0.36	7.39	66.8	526
6/9/95	10:20	P5	GF1 #1	GE1	Controlled	Low	0.3535	8818	5.14	0.42	4.72	77.8	397
6/9/95	14:45	P6	GF1 #1	GE1	Normal	Low	0.3476	8704	6.62	0.41	6.21	76.3	506
6/12/95	10:36	P7	GF1 #1/#2	GE1	Controlled	High	0.3559	8864	5.28	0.29	4.99	78.7	427
6/12/95	13:47	P8	GF1 #2	GE1	Normal	Low	0.3524	8796	7.85	0.32	7.53	68.2	554
6/12/95	15:44	P9	GF1 #2	GE1	Controlled	High	0.3464	8681	6.57	0.65	5.92	66.9	422
6/13/95	10:37	P10	GF1 #2	GE1	Controlled	Low	0.3647	9034	5.64	0.53	5.11	70.0	396
6/13/95	12:57	P11	GF1 #2	GE1	Normal	High	0.3623	8987	6.49	0.45	6.04	71.9	479
6/13/95	15:21	P12	GF1 #2	GE1	Normal	Low	0.3582	8909	6.61	0.59	6.02	72.3	476
Average (12 runs)							0.3557	8860	6.26	0.43	5.83	71.8	452
M1-Normal spraying (6 runs)							0.3548	8843	7.15	0.43	6.72	70.6	513
M2-Controlled spraying (6 runs)							0.3565	8876	5.37	0.42	4.94	73.1	391
A2-High air velocity (6 runs)							0.3556	8858	6.51	0.43	6.09	70.2	462
A1-Low air velocity (6 runs)							0.3558	8862	6.01	0.43	5.57	73.5	442
M1/A1 (3 runs)							0.3527	8803	7.03	0.44	6.59	72.3	512
M2/A1 (3 runs)							0.3588	8920	4.99	0.43	4.56	74.7	372
M1/A2 (3 runs)							0.3569	8883	7.28	0.43	6.86	69.0	514
M2/A2 (3 runs)							0.3543	8833	5.75	0.42	5.32	71.5	410

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Avg. spraying conc., ppm	Avg. net spraying, ppm	Spraying time, min	Emissions during application (by THC)	Std. Dev. of application emissions (by THC)	Wt. loss from part during curing stage (by MB)	Std. Dev. of curing loss from part (by MB)	Wt. loss during application and from overspray, g (by MB)
EXPERIMENTAL RUNS												
6/6/95	10:22	RF1-EXP	RF1	RE1	65.74	65.14	4.5	328	NA	264	NA	622
6/6/95	14:55	GF1-EXP	GF1	GE1	41.31	41.08	5.0	228	NA	193	NA	285
7/7/95	12:19	EXP1	GF1	GE1	1.05	0.57	2.0	1	NA	44	NA	21
7/7/95	14:12	EXP2	GF1	GE1	45.25	44.83	2.2	103	NA	50	NA	102
PILOT EXPERIMENT												
6/7/95	14:50	P1	GF1 #10	GE1	29.73	29.41	4.2	134	NA	167	NA	213
6/8/95	10:01	P2	GF1 #1	GE1	43.71	43.24	6.5	310	NA	190	NA	417
6/8/95	12:11	P3	GF1 #1	GE1	42.14	41.80	3.0	138	NA	221	NA	221
6/8/95	14:40	P4	GF1 #1	GE1	65.24	64.87	3.7	253	NA	203	NA	212
6/9/95	10:20	P5	GF1 #1	GE1	39.44	39.01	3.2	134	NA	224	NA	188
6/9/95	14:45	P6	GF1 #1	GE1	59.03	58.62	3.5	219	NA	242	NA	264
6/12/95	10:36	P7	GF1 #1/#2	GE1	48.30	48.01	3.0	157	NA	235	NA	231
6/12/95	13:47	P8	GF1 #2	GE1	74.04	73.71	3.4	271	NA	217	NA	282
6/12/95	15:44	P9	GF1 #2	GE1	52.82	52.17	3.2	176	NA	213	NA	176
6/13/95	10:37	P10	GF1 #2	GE1	41.80	41.27	3.2	145	NA	221	NA	236
6/13/95	12:57	P11	GF1 #2	GE1	64.60	64.15	3.0	214	NA	235	NA	300
6/13/95	15:21	P12	GF1 #2	GE1	58.44	57.85	3.2	204	NA	218	NA	224
Average (12 runs)					51.61	51.18	3.6	196	57	216	20	247
M1-Normal spraying (6 runs)					60.84	60.41	3.9	245	37	218	18	283
M2-Controlled spraying (6 runs)					42.37	41.95	3.3	147	15	214	22	211
A2-High air velocity (6 runs)					52.80	52.37	3.7	208	59	216	16	260
A1-Low air velocity (6 runs)					50.41	49.98	3.4	184	51	215	23	235
M1/A1 (3 runs)					63.84	63.39	3.4	231	28	226	12	257
M2/A1 (3 runs)					36.99	36.56	3.5	138	5	204	26	212
M1/A2 (3 runs)					57.85	57.42	4.4	259	39	209	19	310
M2/A2 (3 runs)					47.75	47.33	3.1	157	16	223	9	209

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Total emissions by MB, g	Ratio of two measurement methods (MB/THC)	Material used, g	Transfer eff. %	Styrene content, %	EF, % available styrene by THC	EF, % available styrene by MB	Std. Dev., % AS by THC	Std. Dev., % AS by MB	Total mold surface, m2
EXPERIMENTAL RUNS														
6/6/95	10:22	RF1-EXP	RF1	RE1	886	1.40	9287	90.1	38.33	17.7	24.9	NA	NA	2.28
6/6/95	14:55	GF1-EXP	GF1	GE1	478	1.05	1564	75.5	38.75	75.2	78.9	NA	NA	2.28
7/7/95	12:19	EXP1	GF1	GE1	65	1.05	1732	99.9	38.75	9.2	9.7	NA	NA	0.32
7/7/95	14:12	EXP2	GF1	GE1	152	1.02	1737	94.2	38.75	22.2	22.6	NA	NA	0.45
PILOT EXPERIMENT														
6/7/95	14:50	P1	GF1 #10	GE1	380	1.18	1564	79.8	38.75	53.1	62.7	NA	NA	2.28
6/8/95	10:01	P2	GF1 #1	GE1	607	1.13	2261	66.1	38.75	61.2	69.3	NA	NA	2.28
6/8/95	12:11	P3	GF1 #1	GE1	442	1.16	1695	80.0	38.75	58.2	67.3	NA	NA	2.28
6/8/95	14:40	P4	GF1 #1	GE1	415	0.79	2067	74.0	38.75	65.7	51.8	NA	NA	2.28
6/9/95	10:20	P5	GF1 #1	GE1	412	1.04	1964	85.1	38.75	52.2	54.1	NA	NA	2.28
6/9/95	14:45	P6	GF1 #1	GE1	506	1.00	2204	75.7	38.75	59.2	59.2	NA	NA	2.28
6/12/95	10:36	P7	GF1 #1/#2	GE1	466	1.09	1900	81.2	38.75	58.0	63.3	NA	NA	2.28
6/12/95	13:47	P8	GF1 #2	GE1	499	0.90	2056	73.8	38.75	69.6	62.6	NA	NA	2.28
6/12/95	15:44	P9	GF1 #2	GE1	389	0.92	2064	85.0	38.75	52.7	48.6	NA	NA	2.28
6/13/95	10:37	P10	GF1 #2	GE1	457	1.15	2021	82.6	38.75	50.6	58.4	NA	NA	2.28
6/13/95	12:57	P11	GF1 #2	GE1	535	1.12	2077	74.5	38.75	59.5	66.5	NA	NA	2.28
6/13/95	15:21	P12	GF1 #2	GE1	442	0.93	2049	77.7	38.75	60.0	55.7	NA	NA	2.28
Average (12 runs)					463	1.03	1994	78.0	38.75	58.3	60.0	5.4	6.2	2.28
M1-Normal spraying (6 runs)					501	0.98	2119	73.6	38.75	62.5	60.9	3.8	6.0	2.28
M2-Controlled spraying (6 runs)					424	1.09	1868	82.3	38.75	54.1	59.1	2.9	6.2	2.28
A2-High air velocity (6 runs)					476	1.03	2011	76.8	38.75	59.2	61.1	3.9	8.0	2.28
A1-Low air velocity (6 runs)					449	1.03	1976	79.1	38.75	57.4	58.8	6.5	3.2	2.28
M1/A1 (3 runs)					482	0.94	2103	75.7	38.75	62.9	59.2	4.7	2.8	2.28
M2/A1 (3 runs)					416	1.12	1850	82.5	38.75	52.0	58.4	1.0	3.5	2.28
M1/A2 (3 runs)					519	1.01	2135	71.5	38.75	62.1	62.5	2.6	7.7	2.28
M2/A2 (3 runs)					432	1.06	1886	82.1	38.75	56.3	59.7	2.5	8.0	2.28

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	EF, g/m2 by THC	EF, g/m2 by MB	Std. Dev., g/m2 by THC	Std. Dev., g/m2 by MB	EF, g/g material by THC	EF, g/g material by MB	Std. Dev., g/g by THC	Std. Dev., g/g by MB	Catalyst Ratio, %	Glass/Resin Ratio, %
EXPERIMENTAL RUNS														
6/6/95	10:22	RF1-EXP	RF1	RE1	277	389	NA	NA	0.068	0.095	NA	NA	1.33	NA
6/6/95	14:55	GF1-EXP	GF1	GE1	200	210	NA	NA	0.291	0.306	NA	NA	1.40	NA
7/7/95	12:19	EXP1	GF1	GE1	194	205	NA	NA	0.036	0.038	NA	NA	NC	NA
7/7/95	14:12	EXP2	GF1	GE1	332	339	NA	NA	0.086	0.088	NA	NA	NC	NA
PILOT EXPERIMENT														
6/7/95	14:50	P1	GF1 #10	GE1	141	167	NA	NA	0.206	0.243	NA	NA	1.66	NA
6/8/95	10:01	P2	GF1 #1	GE1	236	267	NA	NA	0.237	0.268	NA	NA	1.68	NA
6/8/95	12:11	P3	GF1 #1	GE1	168	194	NA	NA	0.225	0.261	NA	NA	1.65	NA
6/8/95	14:40	P4	GF1 #1	GE1	231	182	NA	NA	0.254	0.201	NA	NA	1.79	NA
6/9/95	10:20	P5	GF1 #1	GE1	175	181	NA	NA	0.202	0.210	NA	NA	1.63	NA
6/9/95	14:45	P6	GF1 #1	GE1	222	222	NA	NA	0.230	0.230	NA	NA	1.68	NA
6/12/95	10:36	P7	GF1 #1/#2	GE1	188	205	NA	NA	0.225	0.245	NA	NA	1.74	NA
6/12/95	13:47	P8	GF1 #2	GE1	244	219	NA	NA	0.270	0.243	NA	NA	1.75	NA
6/12/95	15:44	P9	GF1 #2	GE1	185	171	NA	NA	0.204	0.188	NA	NA	1.74	NA
6/13/95	10:37	P10	GF1 #2	GE1	174	201	NA	NA	0.196	0.226	NA	NA	1.73	NA
6/13/95	12:57	P11	GF1 #2	GE1	210	235	NA	NA	0.231	0.258	NA	NA	1.69	NA
6/13/95	15:21	P12	GF1 #2	GE1	209	194	NA	NA	0.232	0.216	NA	NA	1.76	NA
Average (12 runs)					199	203	30.2	27.6	0.226	0.232	0.021	0.024	1.71	NA
M1-Normal spraying (6 runs)					225	220	12.6	27.4	0.242	0.236	0.015	0.023	1.73	NA
M2-Controlled spraying (6 runs)					172	186	15.2	14.4	0.210	0.229	0.011	0.024	1.69	NA
A2-High air velocity (6 runs)					203	209	24.8	32.7	0.229	0.237	0.015	0.031	1.72	NA
A1-Low air velocity (6 runs)					194	197	34.2	19.6	0.223	0.228	0.025	0.012	1.70	NA
M1/A1 (3 runs)					225	212	14.2	12.6	0.244	0.229	0.018	0.011	1.73	NA
M2/A1 (3 runs)					163	183	15.6	13.9	0.201	0.226	0.004	0.014	1.67	NA
M1/A2 (3 runs)					226	228	10.9	34.8	0.241	0.242	0.010	0.030	1.72	NA
M2/A2 (3 runs)					180	190	8.8	14.1	0.218	0.231	0.010	0.031	1.71	NA

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Application Method	Air Vel.	Avg. sqrt (delta P)	Exhaust flow rate, cfm	Avg. conc. ppm	Background conc., ppm	Avg. net conc., ppm	Test run duration, min	Total emissions by THC, g
GELCOAT EXPERIMENT													
6/14/95	10:11	G1	GF1 #2	GE3	Controlled	Low	0.3507	8764	5.80	0.55	5.25	70.0	395
6/14/95	13:46	G2	GF1 #2/#3	GE2	Controlled	Low	0.3464	8680	5.89	0.59	5.30	70.0	395
6/14/95	16:06	G3	GF1 #2/#3	GE1	Controlled	Low	0.3403	8563	6.94	0.47	6.46	60.3	409
6/15/95	11:38	G4	GF2 #1	GE1	Controlled	Low	0.3428	8610	3.80	0.39	3.41	75.7	273
6/15/95	14:03	G5	GF1 #3	GE1	Controlled	Low	0.3427	8609	5.92	0.51	5.41	70.4	403
6/15/95	15:59	G6	GF1 #3	GE1	Controlled	Low	0.3440	8633	5.80	0.68	5.13	71.2	387
6/16/95	10:23	G7	GF2 #1	GE3	Controlled	Low	0.3586	8916	3.38	0.31	3.07	80.7	271
6/16/95	12:49	G8	GF1 #3/#4	GE3	Controlled	Low	0.3571	8887	5.60	0.63	4.97	70.5	382
6/16/95	15:33	G9	GF1 #3/#4	GE2	Controlled	Low	0.3536	8819	5.65	0.58	5.07	70.2	386
6/19/95	10:36	G10	GF1 #4	GE3	Controlled	Low	0.3500	8752	5.60	0.46	5.14	69.6	384
6/19/95	12:47	G11	GF2 #1/#2	GE2	Controlled	Low	0.3559	8866	3.77	0.59	3.18	85.1	294
6/19/95	15:23	G12	GF2 #1/#2	GE2	Controlled	Low	0.3473	8700	3.47	0.72	2.74	85.0	249
6/21/95	10:46	G13	GF2 #2	GE2	Controlled	Low	0.3527	8804	3.77	0.55	3.22	83.7	291
6/21/95	13:18	G14	GF2 #2	GE1	Controlled	Low	0.3493	8739	3.36	0.51	2.85	87.5	267
6/21/95	16:27	G15	GF1 #4	GE2	Controlled	Low	0.3452	8660	5.81	0.56	5.25	60.7	339
6/22/95	11:14	G16	GF2 #2/#3	GE1	Controlled	Low	0.3511	8775	3.47	0.47	3.00	85.0	274
6/22/95	13:41	G17	GF2 #2/#3	GE3	Controlled	Low	0.3535	8820	3.80	0.58	3.21	85.7	298
6/22/95	15:55	G18	GF2 #3	GE3	Controlled	Low	0.3484	8722	3.80	0.60	3.19	82.4	282
Average (18 runs)							0.3494	8740	4.76	0.54	4.21	75.8	332
GF1-Regular gel coat (9 runs)							0.3478	8707	5.89	0.56	5.33	68.1	387
GF2-Low VOC gel coat (9 runs)							0.3511	8772	3.62	0.53	3.10	83.4	278
GE1-AAA ext mix gun (6 runs)							0.3450	8655	4.88	0.50	4.38	75.0	336
GE2-HVLP int mix gun (6 runs)							0.3502	8755	4.73	0.60	4.13	75.8	326
GE3-HVLP ext mix gun (6 runs)							0.3530	8810	4.66	0.52	4.14	76.5	335
GF1/GE1 (3 runs)							0.3423	8602	6.22	0.55	5.67	67.3	400
GF1/GE2 (3 runs)							0.3484	8720	5.79	0.58	5.21	67.0	373
GF1/GE3 (3 runs)							0.3526	8801	5.67	0.55	5.12	70.0	387
GF2/GE1 (3 runs)							0.3477	8708	3.54	0.46	3.09	82.7	272
GF2/GE2 (3 runs)							0.3519	8790	3.67	0.62	3.05	84.6	278
GF2/GE3 (3 runs)							0.3535	8819	3.66	0.50	3.16	82.9	284

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Avg. spraying conc., ppm	Avg. net spraying, ppm	Spraying time, min	Emissions during application (by THC)	Std. Dev. of application emissions (by THC)	Wt. loss from part during curing stage (by MB)	Std. Dev. of curing loss from part (by MB)	Wt. loss during application and from overspray, g (by MB)
GELCOAT EXPERIMENT												
6/14/95	10:11	G1	GF1 #2	GE3	48.22	47.66	3.0	154	NA	220	NA	128
6/14/95	13:46	G2	GF1 #2/#3	GE2	44.48	43.89	3.5	164	NA	206	NA	200
6/14/95	16:06	G3	GF1 #2/#3	GE1	50.51	50.04	3.0	158	NA	204	NA	200
6/15/95	11:38	G4	GF2 #1	GE1	21.88	21.50	4.0	91	NA	153	NA	74
6/15/95	14:03	G5	GF1 #3	GE1	49.01	48.50	3.0	154	NA	212	NA	143
6/15/95	15:59	G6	GF1 #3	GE1	45.34	44.66	3.0	142	NA	220	NA	190
6/16/95	10:23	G7	GF2 #1	GE3	23.46	23.14	3.2	80	NA	161	NA	112
6/16/95	12:49	G8	GF1 #3/#4	GE3	44.31	43.68	3.0	143	NA	211	NA	261
6/16/95	15:33	G9	GF1 #3/#4	GE2	45.04	44.46	3.2	155	NA	205	NA	193
6/19/95	10:36	G10	GF1 #4	GE3	43.40	42.94	2.9	134	NA	214	NA	146
6/19/95	12:47	G11	GF2 #1/#2	GE2	28.43	27.84	3.1	94	NA	159	NA	168
6/19/95	15:23	G12	GF2 #1/#2	GE2	29.10	28.37	3.1	94	NA	157	NA	189
6/21/95	10:46	G13	GF2 #2	GE2	34.91	34.35	3.0	112	NA	163	NA	211
6/21/95	13:18	G14	GF2 #2	GE1	30.12	29.61	2.9	92	NA	165	NA	167
6/21/95	16:27	G15	GF1 #4	GE2	48.31	47.75	3.2	162	NA	201	NA	186
6/22/95	11:14	G16	GF2 #2/#3	GE1	26.75	26.28	3.5	99	NA	155	NA	147
6/22/95	13:41	G17	GF2 #2/#3	GE3	31.41	30.83	3.0	100	NA	157	NA	153
6/22/95	15:55	G18	GF2 #3	GE3	29.39	28.79	3.0	93	NA	160	NA	126
Average (18 runs)					37.45	36.90	3.1	123	30	185	26	166
GF1-Regular gel coat (9 runs)					46.51	45.95	3.1	152	9	210	6	183
GF2-Low VOC gel coat (9 runs)					28.38	27.86	3.2	95	8	159	4	150
GE1-AAA ext mix gun (6 runs)					37.27	36.76	3.2	123	29	185	28	154
GE2-HVLP int mix gun (6 runs)					38.38	37.78	3.2	130	31	182	22	191
GE3-HVLP ext mix gun (6 runs)					36.70	36.17	3.0	117	27	187	28	154
GF1/GE1 (3 runs)					48.29	47.73	3.0	151	7	212	7	178
GF1/GE2 (3 runs)					45.94	45.37	3.3	160	4	204	2	193
GF1/GE3 (3 runs)					45.31	44.76	3.0	143	8	215	4	178
GF2/GE1 (3 runs)					26.25	25.80	3.5	94	4	158	5	129
GF2/GE2 (3 runs)					30.81	30.19	3.1	100	9	160	2	189
GF2/GE3 (3 runs)					28.09	27.59	3.1	91	8	159	2	130

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Total emissions by MB, g	Ratio of two measurement methods (MB/THC)	Material used, g	Transfer eff. %	Styrene content, %	EF, % available styrene by THC	EF, % available styrene by MB	Std. Dev., % AS by THC	Std. Dev., % AS by MB	Total mold surface, m2
GELCOAT EXPERIMENT														
6/14/95	10:11	G1	GF1 #2	GE3	348	0.88	1723	84.6	38.75	59.2	52.1	NA	NA	2.28
6/14/95	13:46	G2	GF1 #2/#3	GE2	406	1.03	1808	81.4	38.75	56.4	58.0	NA	NA	2.28
6/14/95	16:06	G3	GF1 #2/#3	GE1	404	0.99	1756	79.0	38.75	60.2	59.4	NA	NA	2.28
6/15/95	11:38	G4	GF2 #1	GE1	227	0.83	1929	88.8	25.35	55.8	46.4	NA	NA	2.28
6/15/95	14:03	G5	GF1 #3	GE1	355	0.88	1765	84.3	38.75	58.9	51.9	NA	NA	2.28
6/15/95	15:59	G6	GF1 #3	GE1	410	1.06	1817	82.9	38.75	54.9	58.2	NA	NA	2.28
6/16/95	10:23	G7	GF2 #1	GE3	273	1.01	1876	87.3	25.35	56.9	57.4	NA	NA	2.28
6/16/95	12:49	G8	GF1 #3/#4	GE3	472	1.24	1891	80.0	38.75	52.1	64.4	NA	NA	2.28
6/16/95	15:33	G9	GF1 #3/#4	GE2	398	1.03	1787	82.4	38.75	55.7	57.5	NA	NA	2.28
6/19/95	10:36	G10	GF1 #4	GE3	360	0.94	1723	84.7	38.75	57.6	53.9	NA	NA	2.28
6/19/95	12:47	G11	GF2 #1/#2	GE2	327	1.11	1940	83.3	25.35	59.8	66.5	NA	NA	2.28
6/19/95	15:23	G12	GF2 #1/#2	GE2	346	1.39	1940	81.9	25.35	50.6	70.4	NA	NA	2.28
6/21/95	10:46	G13	GF2 #2	GE2	374	1.28	2245	81.1	25.35	51.2	65.7	NA	NA	2.28
6/21/95	13:18	G14	GF2 #2	GE1	332	1.24	1933	81.9	25.35	54.6	67.8	NA	NA	2.28
6/21/95	16:27	G15	GF1 #4	GE2	387	1.14	1776	82.0	38.75	49.2	56.2	NA	NA	2.28
6/22/95	11:14	G16	GF2 #2/#3	GE1	302	1.10	2128	87.4	25.35	50.9	56.0	NA	NA	2.28
6/22/95	13:41	G17	GF2 #2/#3	GE3	310	1.04	2275	85.7	25.35	51.7	53.8	NA	NA	2.28
6/22/95	15:55	G18	GF2 #3	GE3	286	1.01	1963	85.4	25.35	56.6	57.5	NA	NA	2.28
Average (18 runs)					351	1.07	1904	83.6	32.05	55.1	58.5	3.4	6.1	2.28
GF1-Regular gel coat (9 runs)					393	1.02	1783	82.4	38.75	56.0	56.8	3.3	3.7	2.28
GF2-Low VOC gel coat (9 runs)					309	1.11	2025	84.8	25.35	54.2	60.2	3.1	7.4	2.28
GE1-AAA ext mix gun (6 runs)					338	1.02	1888	84.1	32.05	55.9	56.6	3.0	6.6	2.28
GE2-HVLP int mix gun (6 runs)					373	1.16	1916	82.0	32.05	53.8	62.4	3.8	5.4	2.28
GE3-HVLP ext mix gun (6 runs)					342	1.02	1909	84.6	32.05	55.7	56.5	2.8	4.0	2.28
GF1/GE1 (3 runs)					390	0.98	1779	82.1	38.75	58.0	56.5	2.2	3.3	2.28
GF1/GE2 (3 runs)					397	1.07	1790	81.9	38.75	53.8	57.2	3.2	0.7	2.28
GF1/GE3 (3 runs)					393	1.02	1779	83.1	38.75	56.3	56.8	3.0	5.4	2.28
GF2/GE1 (3 runs)					287	1.06	1997	86.0	25.35	53.7	56.7	2.1	8.7	2.28
GF2/GE2 (3 runs)					349	1.26	2042	82.1	25.35	53.9	67.5	4.2	2.0	2.28
GF2/GE3 (3 runs)					290	1.02	2038	86.1	25.35	55.1	56.2	2.4	1.7	2.28

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	EF, g/m2 by THC	EF, g/m2 by MB	Std. Dev., g/m2 by THC	Std. Dev., g/m2 by MB	EF, g/g material by THC	EF, g/g material by MB	Std. Dev., g/g by THC	Std. Dev., g/g by MB	Catalyst Ratio, %	Glass/Resin Ratio, %
GELCOAT EXPERIMENT														
6/14/95	10:11	G1	GF1 #2	GE3	174	153	NA	NA	0.229	0.202	NA	NA	1.86	NA
6/14/95	13:46	G2	GF1 #2/#3	GE2	174	178	NA	NA	0.218	0.225	NA	NA	1.88	NA
6/14/95	16:06	G3	GF1 #2/#3	GE1	180	177	NA	NA	0.233	0.230	NA	NA	1.82	NA
6/15/95	11:38	G4	GF2 #1	GE1	120	100	NA	NA	0.141	0.118	NA	NA	1.68	NA
6/15/95	14:03	G5	GF1 #3	GE1	177	156	NA	NA	0.228	0.201	NA	NA	1.92	NA
6/15/95	15:59	G6	GF1 #3	GE1	170	180	NA	NA	0.213	0.226	NA	NA	1.87	NA
6/16/95	10:23	G7	GF2 #1	GE3	119	120	NA	NA	0.144	0.146	NA	NA	1.65	NA
6/16/95	12:49	G8	GF1 #3/#4	GE3	168	207	NA	NA	0.202	0.250	NA	NA	1.80	NA
6/16/95	15:33	G9	GF1 #3/#4	GE2	169	175	NA	NA	0.216	0.223	NA	NA	1.82	NA
6/19/95	10:36	G10	GF1 #4	GE3	169	158	NA	NA	0.223	0.209	NA	NA	1.80	NA
6/19/95	12:47	G11	GF2 #1/#2	GE2	129	144	NA	NA	0.152	0.169	NA	NA	1.86	NA
6/19/95	15:23	G12	GF2 #1/#2	GE2	109	152	NA	NA	0.128	0.178	NA	NA	1.75	NA
6/21/95	10:46	G13	GF2 #2	GE2	128	164	NA	NA	0.130	0.167	NA	NA	1.87	NA
6/21/95	13:18	G14	GF2 #2	GE1	117	146	NA	NA	0.138	0.172	NA	NA	1.86	NA
6/21/95	16:27	G15	GF1 #4	GE2	149	170	NA	NA	0.191	0.218	NA	NA	1.89	NA
6/22/95	11:14	G16	GF2 #2/#3	GE1	120	132	NA	NA	0.129	0.142	NA	NA	1.80	NA
6/22/95	13:41	G17	GF2 #2/#3	GE3	131	136	NA	NA	0.131	0.136	NA	NA	1.71	NA
6/22/95	15:55	G18	GF2 #3	GE3	124	125	NA	NA	0.144	0.146	NA	NA	1.78	NA
Average (18 runs)					146	154	25.1	25.1	0.177	0.186	0.041	0.038	1.81	NA
GF1-Regular gel coat (9 runs)					170	173	8.4	15.7	0.217	0.220	0.013	0.014	1.85	NA
GF2-Low VOC gel coat (9 runs)					122	135	6.4	17.9	0.137	0.152	0.008	0.019	1.77	NA
GE1-AAA ext mix gun (6 runs)					147	149	28.4	27.5	0.180	0.181	0.045	0.042	1.83	NA
GE2-HVLP int mix gun (6 runs)					143	164	23.2	12.4	0.172	0.196	0.038	0.026	1.85	NA
GE3-HVLP ext mix gun (6 runs)					147	150	23.1	29.1	0.179	0.181	0.040	0.042	1.77	NA
GF1/GE1 (3 runs)					176	171	4.2	10.8	0.225	0.219	0.009	0.013	1.87	NA
GF1/GE2 (3 runs)					164	174	10.9	3.5	0.208	0.222	0.012	0.003	1.86	NA
GF1/GE3 (3 runs)					170	173	2.5	24.5	0.218	0.220	0.012	0.021	1.82	NA
GF2/GE1 (3 runs)					119	126	1.3	19.3	0.136	0.144	0.005	0.022	1.78	NA
GF2/GE2 (3 runs)					122	153	9.1	8.4	0.137	0.171	0.011	0.005	1.83	NA
GF2/GE3 (3 runs)					124	127	4.8	6.6	0.140	0.142	0.006	0.004	1.71	NA

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Application Method	Air Vel.	Avg. sqrt (delta P)	Exhaust flow rate, cfm	Avg. conc. ppm	Background conc., ppm	Avg. net conc., ppm	Test run duration, min	Total emissions by THC, g
RESIN EXPERIMENT													
6/23/95	11:06	R1	RF6 #1	RE1	Controlled	Low	0.3478	8710	3.21	0.35	2.86	103.1	316
6/23/95	14:30	R2	RF1 #3	RE2	Controlled	Low	0.3464	8683	3.97	0.45	3.52	81.3	305
6/23/95	16:35	R3	RF1 #3	RE3	Controlled	Low	0.3316	8399	4.15	0.46	3.70	75.0	286
6/26/95	10:42	R4	RF1 #4	RE3	Controlled	Low	0.3401	8563	3.63	0.45	3.17	83.8	279
6/26/95	13:27	R5	RF1 #5	RE1	Controlled	Low	0.3366	8495	6.66	0.39	6.27	67.3	440
6/26/95	16:05	R6	RF3 #1	RE1	Controlled	Low	0.3366	8495	4.08	0.43	3.65	78.0	296
6/27/95	10:46	R7	RF1 #5/#6	RE1	Controlled	Low	0.3427	8613	5.83	0.77	5.05	75.7	404
6/27/95	13:14	R8	RF2 #1	RE1	Controlled	Low	0.3391	8543	5.59	0.43	5.16	71.8	389
6/27/95	15:51	R9	RF4 #1	RE4	Controlled	Low	0.3295	8358	5.21	0.46	4.76	152.4	743
6/28/95	10:21	R10	RF1 #6	RE1	Normal	Low	0.3369	8501	7.95	0.46	7.49	81.5	636
6/28/95	12:45	R11	RF6 #1/2	RE1	Controlled	Low	0.3354	8471	3.22	0.42	2.81	91.3	267
6/28/95	15:20	R12	RF6 #1/2/3	RE1	Controlled	Low	0.3369	8501	2.55	0.36	2.18	95.2	217
6/29/95	10:22	R13	RF2 #2	RE1	Controlled	Low	0.3403	8566	5.28	0.27	5.01	76.5	403
6/29/95	12:20	R14	RF2 #2	RE1	Controlled	Low	0.3366	8495	5.43	0.40	5.04	75.1	394
6/29/95	14:36	R15	RF1 #6/7	RE1	Controlled	Low	0.3438	8633	5.97	0.37	5.59	76.5	453
6/30/95	10:14	R16	RF1 #4/8	RE3	Controlled	Low	0.3366	8495	4.51	0.49	4.03	79.1	332
6/30/95	13:13	R17	RF4 #2	RE4	Controlled	Low	0.3380	8521	7.61	0.51	7.10	102.6	762
6/30/95	15:51	R18	RF1 #4/8	RE2	Controlled	Low	0.3346	8457	4.52	0.44	4.07	69.3	293
7/5/95	11:53	R19	RF3 #2	RE1	Controlled	Low	0.3440	8637	3.92	0.29	3.63	75.6	291
7/5/95	14:02	R20	RF3 #2/3	RE1	Controlled	Low	0.3354	8471	3.91	0.41	3.51	74.7	272
7/5/95	16:19	R21	RF1 #8/7	RE1	Controlled	Low	0.3327	8419	6.32	0.45	5.87	77.2	468
7/6/95	10:12	R22	RF1 #8/#9	RE1	Controlled	Low	0.3415	8589	6.15	0.41	5.74	75.9	459
7/6/95	14:34	R23	RF4 #3	RE4	Controlled	Low	0.3452	8661	5.85	0.30	5.55	88.9	524
7/6/95	16:41	R24	RF1 #8/#9	RE2	Controlled	Low	0.3364	8492	4.38	0.43	3.96	78.0	322
7/7/95	10:10	R25	RF4 #4	RE4	Controlled	Low	0.3451	8658	6.15	0.62	5.53	85.1	500
Average (25 runs, w "Normal" run R10)							0.3388	8537	5.04	0.43	4.61	83.6	402
Average (24 runs, w/o "Normal" run R10)							0.3389	8539	4.92	0.43	4.49	83.7	392
RE1/RF1-AAA ext mix gun (6 runs, w/ run R10)							0.3391	8542	6.48	0.48	6.00	75.7	477
RE1/RF1-AAA ext mix gun (5 runs, w/o run R10)							0.3395	8550	6.18	0.48	5.71	74.5	445
RE2-Flow coater (3 runs)							0.3392	8544	4.29	0.44	3.85	76.2	306
RE3-Pressure-fed roller (3 runs)							0.3361	8486	4.10	0.46	3.63	79.3	299
RE4-AAA ext mix gun for BPO system (see RF4)													
RF2-Low styrene Resin (3 runs)							0.3387	8535	5.44	0.37	5.07	74.5	395
RF3-Styrene suppressed resin (3 runs)							0.3387	8534	3.97	0.38	3.59	76.1	286
RF4-BPO-Catalyzed Resin (4 runs)							0.3395	8550	6.20	0.47	5.73	107.2	632
RF4-BPO-Catalyzed Resin (2 runs, slow gel)							0.3338	8440	6.41	0.48	5.93	127.5	752
RF4-BPO-Catalyzed Resin (2 runs, fast gel)							0.3452	8659	6.00	0.46	5.54	87.0	512
RF5-Water emulsified resin (Not tested)							NA	NA	NA	NA	NA	NA	NA
RF6-Styrene suppressed resin plus wax (3 runs)							0.3400	8561	2.99	0.38	2.62	96.5	266

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Avg. spraying conc., ppm	Avg. net spraying, ppm	Spraying time, min	Emissions during application (by THC)	Std. Dev. of application emissions (by THC)	Wt. loss from part during curing stage (by MB)	Std. Dev. of curing loss from part (by MB)	Wt. loss during application and from overspray, g (by MB)
RESIN EXPERIMENT												
6/23/95	11:06	R1	RF6 #1	RE1	40.88	40.53	4.5	196	NA	71	NA	213
6/23/95	14:30	R2	RF1 #3	RE2	7.36	6.91	23.0	169	NA	92	NA	243
6/23/95	16:35	R3	RF1 #3	RE3	7.31	6.86	19.2	136	NA	135	NA	132
6/26/95	10:42	R4	RF1 #4	RE3	6.77	6.32	21.4	142	NA	107	NA	173
6/26/95	13:27	R5	RF1 #5	RE1	58.52	58.13	3.5	212	NA	193	NA	241
6/26/95	16:05	R6	RF3 #1	RE1	56.47	56.04	3.3	193	NA	97	NA	205
6/27/95	10:46	R7	RF1 #5/#6	RE1	65.93	65.16	3.0	207	NA	187	NA	237
6/27/95	13:14	R8	RF2 #1	RE1	56.12	55.69	3.3	195	NA	162	NA	199
6/27/95	15:51	R9	RF4 #1	RE4	73.79	73.34	3.5	266	NA	451	NA	243
6/28/95	10:21	R10	RF1 #6	RE1	88.66	88.20	3.4	310	NA	250	NA	357
6/28/95	12:45	R11	RF6 #1/2	RE1	44.67	44.26	3.3	153	NA	85	NA	162
6/28/95	15:20	R12	RF6 #1/2/3	RE1	32.34	31.98	2.9	97	NA	76	NA	127
6/29/95	10:22	R13	RF2 #2	RE1	52.43	52.16	3.5	192	NA	175	NA	199
6/29/95	12:20	R14	RF2 #2	RE1	51.23	50.83	3.6	191	NA	174	NA	192
6/29/95	14:36	R15	RF1 #6/7	RE1	60.23	59.86	3.6	228	NA	204	NA	238
6/30/95	10:14	R16	RF1 #4/8	RE3	8.08	7.60	27.9	221	NA	121	NA	215
6/30/95	13:13	R17	RF4 #2	RE4	56.67	56.16	6.1	356	NA	314	NA	418
6/30/95	15:51	R18	RF1 #4/8	RE2	9.21	8.77	13.9	126	NA	166	NA	99
7/5/95	11:53	R19	RF3 #2	RE1	53.18	52.89	3.0	166	NA	78	NA	184
7/5/95	14:02	R20	RF3 #2/3	RE1	57.64	57.24	3.0	180	NA	85	NA	188
7/5/95	16:19	R21	RF1 #8/7	RE1	57.03	56.58	3.7	216	NA	210	NA	218
7/6/95	10:12	R22	RF1 #8/#9	RE1	58.25	57.83	3.4	207	NA	216	NA	215
7/6/95	14:34	R23	RF4 #3	RE4	50.51	50.21	3.6	192	NA	262	NA	226
7/6/95	16:41	R24	RF1 #8/#9	RE2	8.82	8.39	15.3	134	NA	189	NA	100
7/7/95	10:10	R25	RF4 #4	RE4	58.01	57.39	3.2	193	NA	262	NA	226
Average (25 runs, w "Normal" run R10)					44.81	44.37	7.5	195	55	174	87	210
Average (24 runs, w/o "Normal" run R10)					42.98	42.55	7.7	190	55	171	87	204
RE1/RF1-AAA ext mix gun (6 runs, w/ run R10)					64.77	64.29	3.4	230	36	210	20	251
RE1/RF1-AAA ext mix gun (5 runs, w/o run R10)					59.99	59.51	3.4	214	8	202	11	230
RE2-Flow coater (3 runs)					8.46	8.02	17.4	143	19	149	41	147
RE3-Pressure-fed roller (3 runs)					7.39	6.93	22.8	166	39	121	11	173
RE4-AAA ext mix gun for BPO system (see RF4)												
RF2-Low styrene Resin (3 runs)					53.26	52.90	3.5	192	2	170	6	197
RF3-Styrene suppressed resin (3 runs)					55.77	55.39	3.1	180	11	87	8	192
RF4-BPO-Catalyzed Resin (4 runs)					59.74	59.27	4.1	252	67	322	77	278
RF4-BPO-Catalyzed Resin (2 runs, slow gel)					65.23	64.75	4.8	311	45	383	69	331
RF4-BPO-Catalyzed Resin (2 runs, fast gel)					54.26	53.80	3.4	193	0	262	0	226
RF5-Water emulsified resin (Not tested)					NA	NA	NA	NA	NA	NA	NA	NA
RF6-Styrene suppressed resin plus wax (3 runs)					39.30	38.92	3.6	149	41	77	6	167

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	Total emissions by MB, g	Ratio of two measurement methods (MB/THC)	Material used, g	Transfer eff. %	Styrene content, %	EF, % available styrene by THC	EF, % available styrene by MB	Std. Dev., % AS by THC	Std. Dev., % AS by MB	Total mold surface, m2
RESIN EXPERIMENT														
6/23/95	11:06	R1	RF6 #1	RE1	284	0.90	7712	92.7	43.29	9.5	8.5	NA	NA	2.28
6/23/95	14:30	R2	RF1 #3	RE2	335	1.10	5445	96.2	38.33	14.6	16.1	NA	NA	2.28
6/23/95	16:35	R3	RF1 #3	RE3	267	0.93	4919	97.2	38.33	15.2	14.2	NA	NA	2.28
6/26/95	10:42	R4	RF1 #4	RE3	280	1.00	5041	97.3	38.33	14.5	14.5	NA	NA	2.28
6/26/95	13:27	R5	RF1 #5	RE1	434	0.99	5978	90.8	38.33	19.2	18.9	NA	NA	2.28
6/26/95	16:05	R6	RF3 #1	RE1	302	1.02	5663	91.7	43.45	12.0	12.3	NA	NA	2.28
6/27/95	10:46	R7	RF1 #5/#6	RE1	424	1.05	6160	91.0	38.33	17.1	18.0	NA	NA	2.28
6/27/95	13:14	R8	RF2 #1	RE1	361	0.93	5979	91.4	35.34	18.4	17.1	NA	NA	2.28
6/27/95	15:51	R9	RF4 #1	RE4	694	0.93	6116	88.7	42.61	28.5	26.6	NA	NA	2.28
6/28/95	10:21	R10	RF1 #6	RE1	607	0.95	6133	80.5	38.33	27.1	25.8	NA	NA	2.28
6/28/95	12:45	R11	RF6 #1/2	RE1	247	0.93	5152	89.9	43.29	12.0	11.1	NA	NA	2.28
6/28/95	15:20	R12	RF6 #1/2/3	RE1	203	0.94	4872	92.7	43.29	10.3	9.6	NA	NA	2.28
6/29/95	10:22	R13	RF2 #2	RE1	374	0.93	6566	91.4	35.34	17.4	16.1	NA	NA	2.28
6/29/95	12:20	R14	RF2 #2	RE1	366	0.93	6870	93.2	35.34	16.2	15.1	NA	NA	2.28
6/29/95	14:36	R15	RF1 #6/7	RE1	442	0.98	7000	92.6	38.33	16.9	16.5	NA	NA	2.28
6/30/95	10:14	R16	RF1 #4/8	RE3	336	1.01	5328	96.7	38.33	16.3	16.5	NA	NA	2.28
6/30/95	13:13	R17	RF4 #2	RE4	732	0.96	7467	79.5	42.61	23.9	23.0	NA	NA	2.28
6/30/95	15:51	R18	RF1 #4/8	RE2	265	0.90	5371	97.7	38.33	14.2	12.9	NA	NA	2.28
7/5/95	11:53	R19	RF3 #2	RE1	262	0.90	6689	92.9	43.45	10.0	9.0	NA	NA	2.28
7/5/95	14:02	R20	RF3 #2/3	RE1	273	1.00	6423	92.9	43.45	9.8	9.8	NA	NA	2.28
7/5/95	16:19	R21	RF1 #8/7	RE1	428	0.91	6958	92.2	38.33	17.5	16.0	NA	NA	2.28
7/6/95	10:12	R22	RF1 #8/#9	RE1	431	0.94	7256	93.5	38.33	16.5	15.5	NA	NA	2.28
7/6/95	14:34	R23	RF4 #3	RE4	488	0.93	5606	91.7	42.61	21.9	20.4	NA	NA	2.28
7/6/95	16:41	R24	RF1 #8/#9	RE2	289	0.90	6040	97.9	38.33	13.9	12.5	NA	NA	2.28
7/7/95	10:10	R25	RF4 #4	RE4	488	0.98	5698	91.9	42.61	20.6	20.1	NA	NA	2.28
Average (25 runs, w "Normal" run R10)					384	0.96	6098	92.2	39.87	16.5	15.8	4.9	4.7	2.28
Average (24 runs, w/o "Normal" run R10)					375	0.96	6096	92.7	39.93	16.1	15.4	4.9	4.7	2.28
RE1/RF1-AAA ext mix gun (6 runs, w/ run R10)					461	0.97	6581	90.1	38.33	19.1	18.5	3.7	3.5	2.28
RE1/RF1-AAA ext mix gun (5 runs, w/o run R10)					432	0.97	6670	92.0	38.33	17.5	17.0	0.9	1.3	2.28
RE2-Flow coater (3 runs)					296	0.97	5619	97.3	38.33	14.2	13.8	0.3	1.6	2.28
RE3-Pressure-fed roller (3 runs)					294	0.98	5096	97.1	38.33	15.3	15.0	0.7	1.0	2.28
RE4-AAA ext mix gun for BPO system (see RF4)														
RF2-Low styrene Resin (3 runs)					367	0.93	6472	92.0	35.34	17.3	16.1	0.9	0.8	2.28
RF3-Styrene suppressed resin (3 runs)					279	0.97	6258	92.5	43.45	10.6	10.4	1.0	1.4	2.28
RF4-BPO-Catalyzed Resin (4 runs)					601	0.95	6222	88.0	42.61	23.7	22.5	3.0	2.6	2.28
RF4-BPO-Catalyzed Resin (2 runs, slow gel)					713	0.95	6792	84.1	42.61	26.2	24.8	2.3	1.8	2.28
RF4-BPO-Catalyzed Resin (2 runs, fast gel)					488	0.95	5652	91.8	42.61	21.3	20.3	0.7	0.2	2.28
RF5-Water emulsified resin (Not tested)					NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RF6-Styrene suppressed resin plus wax (3 runs)					245	0.92	5912	91.8	43.29	10.6	9.7	1.0	1.1	2.28

Emission Measurements, Gravimetric Measurements, and Calculated Emissions and Factors

Date	Time	Test run #	Material/ container #	Equip.	EF, g/m2 by THC	EF, g/m2 by MB	Std. Dev., g/m2 by THC	Std. Dev., g/m2 by MB	EF, g/g material by THC	EF, g/g material by MB	Std. Dev., g/g by THC	Std. Dev., g/g by MB	Catalyst Ratio, %	Glass/Resin Ratio, %
RESIN EXPERIMENT														
6/23/95	11:06	R1	RF6 #1	RE1	138	125	NA	NA	0.041	0.037	NA	NA	1.50	29.2
6/23/95	14:30	R2	RF1 #3	RE2	134	147	NA	NA	0.056	0.062	NA	NA	1.45	32.0
6/23/95	16:35	R3	RF1 #3	RE3	125	117	NA	NA	0.058	0.054	NA	NA	1.65	33.6
6/26/95	10:42	R4	RF1 #4	RE3	123	123	NA	NA	0.055	0.056	NA	NA	1.61	33.8
6/26/95	13:27	R5	RF1 #5	RE1	193	190	NA	NA	0.074	0.073	NA	NA	1.46	33.0
6/26/95	16:05	R6	RF3 #1	RE1	130	132	NA	NA	0.052	0.053	NA	NA	1.45	34.6
6/27/95	10:46	R7	RF1 #5/#6	RE1	177	186	NA	NA	0.066	0.069	NA	NA	1.46	32.4
6/27/95	13:14	R8	RF2 #1	RE1	170	158	NA	NA	0.065	0.060	NA	NA	1.47	33.2
6/27/95	15:51	R9	RF4 #1	RE4	326	304	NA	NA	0.122	0.113	NA	NA	1.67	34.3
6/28/95	10:21	R10	RF1 #6	RE1	279	266	NA	NA	0.104	0.099	NA	NA	1.45	32.2
6/28/95	12:45	R11	RF6 #1/2	RE1	117	108	NA	NA	0.052	0.048	NA	NA	1.44	33.4
6/28/95	15:20	R12	RF6 #1/2/3	RE1	95	89	NA	NA	0.044	0.042	NA	NA	1.48	33.3
6/29/95	10:22	R13	RF2 #2	RE1	177	164	NA	NA	0.061	0.057	NA	NA	1.42	34.8
6/29/95	12:20	R14	RF2 #2	RE1	173	161	NA	NA	0.057	0.053	NA	NA	1.41	32.9
6/29/95	14:36	R15	RF1 #6/7	RE1	199	194	NA	NA	0.065	0.063	NA	NA	1.47	32.6
6/30/95	10:14	R16	RF1 #4/8	RE3	146	147	NA	NA	0.062	0.063	NA	NA	1.69	32.4
6/30/95	13:13	R17	RF4 #2	RE4	334	321	NA	NA	0.102	0.098	NA	NA	2.50	35.4
6/30/95	15:51	R18	RF1 #4/8	RE2	129	116	NA	NA	0.055	0.049	NA	NA	1.51	32.7
7/5/95	11:53	R19	RF3 #2	RE1	127	115	NA	NA	0.043	0.039	NA	NA	1.44	30.0
7/5/95	14:02	R20	RF3 #2/3	RE1	119	120	NA	NA	0.042	0.043	NA	NA	1.46	31.9
7/5/95	16:19	R21	RF1 #8/7	RE1	205	188	NA	NA	0.067	0.062	NA	NA	1.45	32.7
7/6/95	10:12	R22	RF1 #8/#9	RE1	201	189	NA	NA	0.063	0.059	NA	NA	1.47	31.1
7/6/95	14:34	R23	RF4 #3	RE4	230	214	NA	NA	0.094	0.087	NA	NA	3.12	37.5
7/6/95	16:41	R24	RF1 #8/#9	RE2	141	127	NA	NA	0.053	0.048	NA	NA	1.52	30.6
7/7/95	10:10	R25	RF4 #4	RE4	219	214	NA	NA	0.088	0.086	NA	NA	3.09	38.1
Average (25 runs, w "Normal" run R10)					175	167	62.0	58.8	0.065	0.062	0.020	0.019	1.67	33.1
Average (24 runs, w/o "Normal" run R10)					172	165	62.0	58.8	0.064	0.061	0.020	0.019	1.67	33.1
RE1/RF1-AAA ext mix gun (6 runs, w/ run R10)					209	202	32.5	28.7	0.073	0.071	0.014	0.013	1.46	32.3
RE1/RF1-AAA ext mix gun (5 runs, w/o run R10)					195	189	9.8	2.7	0.067	0.065	0.004	0.005	1.46	32.4
RE2-Flow coater (3 runs)					134	130	5.1	12.7	0.055	0.053	0.001	0.006	1.49	31.8
RE3-Pressure-fed roller (3 runs)					131	129	10.3	13.1	0.059	0.058	0.003	0.004	1.65	33.3
RE4-AAA ext mix gun for BPO system (see RF4)														
RF2-Low styrene Resin (3 runs)					173	161	2.7	2.3	0.061	0.057	0.003	0.003	1.43	33.6
RF3-Styrene suppressed resin (3 runs)					126	122	4.5	7.4	0.046	0.045	0.004	0.006	1.45	32.2
RF4-BPO-Catalyzed Resin (4 runs)					277	263	52.9	49.7	0.101	0.096	0.013	0.011	2.60	36.3
RF4-BPO-Catalyzed Resin (2 runs, slow gel)					330	313	4.0	8.3	0.112	0.106	0.010	0.008	2.09	34.9
RF4-BPO-Catalyzed Resin (2 runs, fast gel)					225	214	5.4	0.0	0.091	0.086	0.003	0.001	3.11	37.8
RF5-Water emulsified resin (Not tested)					NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RF6-Styrene suppressed resin plus wax (3 runs)					117	107	17.7	14.5	0.046	0.042	0.004	0.005	1.47	32.0

Appendix F

Statistical Analyses of Test Results

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F.1 Pilot Experiment.

Before executing the main experiment, a pilot study was conducted to help establish "standard" conditions under which the subsequent experiments should be conducted. A secondary purpose was to gain insight into the magnitude of measurement error variability that might be anticipated in the main experiment. The pilot study was run as a factorial experiment involving two factors: M = spraying method, and A = air velocity. The experiment consisted of 12 trials -- namely, three replicates for each of the following conditions:

(a) Normal spraying method (M1), low air velocity (A1)
(b) Controlled spraying method (M2), low air velocity (A1)
(c) Normal spraying method (M1), high air velocity (A2)
(d) Controlled spraying method (M2), high air velocity (A2)

A single gelcoat formulation (GF1) and a single application equipment (GE1) were used throughout the pilot experiment. The 12 trials were run in a random order.

Although it was recognized that the pilot study would provide only a limited amount of statistical information, the resultant data were subjected to statistical analysis in order to get some idea of the impact of the two factors on percent available styrene (%AS) and other related measures. The specific outcome measures that were analyzed are the following:

Variable	Description
X	Transfer Efficiency (%) (standardized to have mean 0)
Z1	Total Emissions (g), by THC
Z2	Total Emissions (g), by MB
Y1	Emissions during the application stage (g), by THC
Y2	Curing Loss from Part (g), by MB
Y3	EF (% Available Styrene), by THC
Y4	EF (% Available Styrene), by MB
Y5	EF (g/m^2), by THC
Y6	EF (g/m^2), by MB
Y7	EF (g/g), by THC
Y8	EF (g/g), by MB

The x variable was considered a possible coovariate for the Z1 and Z2 variables; as a result, the X variable was standardized to have a zero mean.

For each variable, an initial analysis of variance (ANOVA) of the following form was performed:

SOURCE OF VARIATION	DEGREES OF FREEDOM
M (methods)	1
A (air flow)	1
M x A (interaction)	1
Error	8
Total	11

In each case, the interaction term appeared statistically nonsignificant; hence the interaction term was dropped to produce an ANOVA as follows:

SOURCE OF VARIATION	DEGREES OF FREEDOM
M (methods)	1
A (air flow)	1
Error	9
Total	11

The results of the above analyses are summarized in Table 1 for the X variable and each of the Ys (the two Z variables are considered subsequently). The upper portion of the table gives means of the pertinent variables for each combination of the M and A factors. These rows are followed by rows giving the means separately for each level of each factor. The lower portion of the table provides information relating to the statistical tests. The first row gives the root mean squared error (RMSE); this is equivalent to the pooled within-cell variance. This is used to test whether there is a METHOD by AIR VELOCITY interaction. The test results, summarized in the next row, show these interactions to be statistically nonsignificant (n.s.). Consequently, a new RMSE for testing the main effects of the factors is constructed (by pooling of the former RMSE and the interaction mean square); these RMSEs, based on 9 degrees of freedom (df), are displayed in the next row of Table 1. Results of the tests for main effects are given in the last two rows of the table. The effect of AIR VELOCITY is statistically nonsignificant, although the low velocity exhibited lower estimated values than the high velocity for each of the Y variables. For the METHOD effect, statistically signficant differences were found for several of the variables: the controlled spraying, as contrasted with the normal spraying, yielded a higher transfer efficiency (0.01 level), and lower average spraying emissions, percent available styrene,

TABLE 1. Analysis of Variance Results for Pilot Study: Variables X, Y1, Y2, . . ., and Y8

Application method	Air velocity	n	Means, by variable: X[a]	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
Controlled	High	3	4.1	157.0	223.0	56.3	59.7	180.3	190.0	0.218	0.231
Controlled	Low	3	4.5	137.7	204.0	52.0	58.4	163.3	183.0	0.201	0.226
Normal	High	3	-6.4	259.0	209.3	62.1	62.5	225.7	228.0	0.241	0.242
Normal	Low	3	-2.2	231.3	225.7	62.9	59.2	225.0	211.7	0.244	0.229
Controlled	-	6	4.3	147.3	213.5	54.1	59.1	171.8	186.5	0.210	0.229
Normal	-	6	-4.3	245.2	217.5	62.5	60.9	225.3	219.8	0.242	0.236
-	High	6	-1.2	208.0	216.2	59.2	61.1	203.0	209.0	0.229	0.237
-	Low	6	1.2	184.5	214.8	57.5	58.8	194.2	197.3	0.223	0.228
Hypothesis Testing Results											
RMSE for testing interaction (8 df):			3.16	31.50	21.74	3.71	7.34	15.76	25.85	0.014	0.028
Test for interaction:			n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s	n.s
RMSE for testing main effects (9 df):			3.17	29.79	22.89	3.80	6.95	15.59	24.52	0.015	0.027
Test for METHOD:			**	***	n.s.	**	n.s.	***	*	*	n.s
Test for AIR VELOCITY:			n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* = statistically significant at the 0.05 level
** = statistically significant at the 0.01 level
*** = statistically significant at the 0.001 level
[a] Overall mean for X prior to standardization was 79.96.

and emission factor (EF), as measured by THC. When measured via the mass balance (MB) approach, only the EF variable appeared statistically significant (at the 0.05 level).

Point estimates and confidence interval estimates for the differences due to application methods and air velocities are shown in Tables 2 and 3, respectively.

In Tables 2 and 3, the construction of the confidence intervals is based on an assumption that the data for a given combination of METHOD and AIR VELOCITY are approximately normally distributed with a common measurement error variability (the same assumption applies to the hypothesis tests previously described, and similar assumptions apply to all other confidence intervals described herein). Cell-specific estimates of the measurement error variablity (or standard deviations) are shown in Table 4. The 95 percent confidence interval on the difference is related to a pairwise hypothesis test (conducted at a significance level of 0.05) in that if the estimated confidence interval does not include zero, then the corresponding test of no difference in mean %AS will be rejected.

TABLE 2. Estimated Mean Differences and 95% Confidence Interval Estmates for Normal Vs. Controlled Application Methods in the Pilot Experiment

Variable and comparison	Lower 95% confidence limit	Esitmated mean difference	Upper 95% confidence limit	Significant
X - Transfer efficiency (%)	-12.79	-8.65	-4.51	**
Z1 - Total emissions by THC (g)	76.40	121.83	167.27	***
Z2 - Total emissions by MB (g)	3.88	76.33	148.79	*
Y1 - Application emissions by THC (g)	58.92	97.83	136.75	***
Y2 - Curing loss from part by MB (g)	-25.90	4.00	33.90	n.s
Y3 - EF as % AS by THC	3.44	8.40	13.36	**
Y4 - EF as % AS by MB	-7.29	1.78	10.86	n.s
Y5 - EF as g/m^2 by THC	33.14	53.50	73.86	***
Y6 - EF as g/m^2 by MB	1.31	33.33	65.35	*
Y7 - EF (g/g) by THC	0.0134	0.0325	0.0516	*
Y8 - EF (g/g) by MB	-0.0282	0.0069	0.0420	n.s.

* = Statistically significant at the 0.05 level.
** = Statistically significant at the 0.01 level.
*** = Statistically significant at the 0.001 level.
n.s. = Not statistically significant at the 0.05 level.

TABLE 3. Confidence Limits for Pilot Study: High Vs. Low Air Velocity

Variable and comparison	Lower 95% confidence limit	Esitmated mean difference	Upper 95% confidence limit	Significant
X - Transfer efficiency %	-6.45	-2.32	1.82	n.s.
Z1 - Total emissions by THC (g)	-25.27	20.17	65.60	n.s.
Z2 - Total emissions by MB (g)	-46.12	26.33	98.79	n.s.
Y1 - Application emissions by THC (g)	-15.41	23.50	62.41	n.s.
Y2 - Curing loss from part by MB (g)	-28.56	1.33	31.23	n.s.
Y3 - EF as % AS by THC	-3.20	1.77	6.73	n.s.
Y4 - EF as % AS by MB	-6.73	2.35	11.43	n.s
Y5 - EF as g/m^2 by THC	-11.53	8.83	29.20.	n.s.
Y6 - EF as g/m^2 by MB	-20.35	11.67	43.69	n.s.
Y7 - EF (g/g) by THC	-0.0122	0.0069	0.0260	n.s.
Y8 - EF (g/g) by MB	-0.0260	0.0091	0.0442	n.s

n.s = Not statistically significant at the 0.05 level.

TABLE 4. Within-cell Standard Deviations - Pilot Study Data

METHOD	AIRVEL	X	Z1	Z2	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
Controlled	High	2.6	24.7	39.4	19.0	11.1	3.1	9.8	10.8	17.3	0.012	0.038
Controlled	Low	2.7	43.0	38.7	6.4	32.1	1.3	4.3	19.3	17.1	0.005	0.017
Normal	High	4.7	30.4	97.0	48.3	23.2	3.2	9.4	13.8	42.9	0.012	0.036
Normal	Low	2.0	39.3	35.1	35.2	14.2	5.8	3.5	17.7	15.4	0.022	0.013

For the two total emission variables (Z1 and Z2), an initial analysis of covariance (ANACOVA) of the following form was performed:

SOURCE OF VARIATION	DEGREES OF FREEDOM
X (transfer efficiency)	1
M (methods)	1
A (air flow)	1
M x A (interaction)	1
Error	7
Total	11

Since in each case the interaction term appeared statistically nonsignificant, that term was dropped to produce the following:

SOURCE OF VARIATION	DEGREES OF FREEDOM
X (transfer efficiency)	1
M (methods)	1
A (air flow)	1
Error	8
Total	11

The results are summarized in Table 5. The format of the table is similar to that of Table 1 in that the upper portion shows means by cells and factor levels and the lower portion gives RMSEs and results of hypothesis tests. In this case, the hypothesis tests are performed on means of the Z variables after adjustment for the covariate X (assuming a linear relaionship between a Z and X). (The ANOVA results for the Z variables (i.e., ignoring adjustments for X) are shown in the lower left portion of the table while the ANACOVA results are given in the lower right portion.) The adjusted means are given in the upper righthand part of the table. Total emissions by THC (variable Z1) appear to be affected (0.05 significance level) by spraying method, while AIR VELOCITY and X appear to have nonsignificant effects on Z1. Neither factor A or M nor the covariate X appears to affect variable Z2. As noted previously (see Table 1), the METHOD factor appears to affect the covariate X and this situation can lead to problems with interpretation. For instance, it is not clear whether METHOD affects X only, which in turn induces differences in the Z1 variate, or whether (at least part of) the effect of METHOD on Z1 a direct effect (i.e., not related to the difference in X levels).

TABLE 5. Analysis of Covariance Results for Pilot Study: Variables Z1 and Z2

				MEANS		MEANS ADJUSTED FOR X	
METHOD	**AIRVEL**	**N**	**X**	**Z1**	**Z2**	**Z1**	**Z2**
Controlled	High	3	4.1	410.3	432.3	413.7	477.9
Controlled	Low	3	4.5	371.7	416.3	375.4	466.8
Normal	High	3	-6.4	513.7	519.0	508.4	447.7
Normal	Low	3	-2.2	512.0	482.3	510.2	457.6
Controlled	-	6	4.3	391.0	424.3	389.1	469.5
Normal	-	6	-4.3	512.8	500.7	514.7	455.5
-	High	6	-1.2	462.0	475.7	462.5	463.6
-	Low	6	1.2	441.8	449.3	441.3	461.4

Hypothesis Testing Results:

RMSE for testing interaction (8 df):	35.1	58.5		
(7 df):			37.4	50.1
Test for interaction:	n.s.	n.s.	n.s.	n.s.
RMSE for testing main effects (9 df):	4.8	55.5		
(and covariate) (8 df):			36.9	47.2
Test for METHOD:	***	*	*	n.s.
Test for AIR VELOCITY:	n.s.	n.s.	n.s.	n.s.
Test for covariate X:			n.s.	n.s.

* = statistically significant at the 0.05 level
** = statistically significant at the 0.01 level
*** = statistically significant at the 0.001 level

F.2 Gelcoat Experiment.

This experiment is aimed at evaluating how styrene emissions are affected by gelcoat formulation (factor GF) and type of equipment (factor GE). The factor combinations (two formulations and three equipment types) were each run in triplicate, with trials run in a random order (i.e., a 2x3 factorial experiment with three replications embedded in a completely random design). The analysis, which was conducted for the X variate and each of the previously defined Y variates, entailed conducting an analysis of variance (ANOVA) having the following structure:

SOURCE OF VARIATION	DEGREES OF FREEDOM
GF (gelcoats)	1
GE (equipments)	2
GF x GE (interaction)	2
Error	12
Total	17

In each case, the interaction term appeared statistically nonsignificant; hence the interaction term was dropped to produce an ANOVA as follows:

SOURCE OF VARIATION	DEGREES OF FREEDOM
GF (gelcoats)	1
GE (equipments)	2
Error	14
Total	17

The results are summarized in Table 6. The format of this table is similar to that described for Table 1: the upper portion gives means of the pertinent variables for each combination of the GF and GE factors, the middle portion shows the means separately for each level of each factor, and the lower portion gives the pertinent RMSEs and hypothesis testing results. With one exception (a difference in variable Y1 for GE2 and GE3, at the 0.05 level of significance), the effect of EQUIPMENT is statistically nonsignificant. For the gelcoat FORMULATIONS effect, statistically signficant differences were found for the X variable (0.05 level) and for several of the Y variables (Y1, Y2, Y5, and Y6, all highly significant). Statistically significant differences for the GF and GE factors were not found for the percent available styrene variables (Y3 and Y4).

Point estimates and confidence interval estimates for the differences due to two gel coat formulations and three spray guns are shown in Tables 7 and 8, respectively. The with-in cell standard deviations for gel coat experiment are shown in Table 9.

TABLE 6. Analysis of Variance Results for Gelcoat Experiment: Variables X, Y1, Y2, . . ., Y8

				MEANS							
GF	**EQUIP**	**N**	**X[a]**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**
GF1	GE1	3	-1.5	151.3	212.0	58.0	56.5	175.7	171.0	0.225	0.219
GF1	GE2	3	-1.6	160.3	204.0	53.8	57.2	164.0	174.3	0.208	0.222
GF1	GE3	3	-0.5	143.7	215.0	56.3	56.8	170.3	172.7	0.218	0.220
GF2	GE1	3	2.5	94.0	157.7	53.8	56.7	119.0	126.0	0.136	0.144
GF2	GE2	3	-1.5	100.0	159.7	53.9	67.5	122.0	153.3	0.137	0.171
GF2	GE3	3	2.6	91.0	159.3	55.1	56.2	124.7	127.0	0.140	0.142
GF1	-	9	-1.2	151.8	210.3	56.0	60.2	170.0	172.7	0.217	0.220
GF2	-	9	1.2	95.0	158.9	54.2	56.8	121.9	135.4	0.137	0.152
-	GE1	6	0.5	122.7	184.8	55.9	56.6	147.3	148.5	0.180	0.181
-	GE2	6	-1.5	130.2x	181.8	53.8	62.4	143.0	163.8	0.179	0.196
-	GE3	6	1.1	117.3x	187.2	55.7	56.5	147.5	149.8	0.172	0.181
Hypothesis Testing Results:											
RMSE for testing interaction (12 df):			2.26	8.39	4.95	3.62	5.58	7.94	17.33	0.012	0.017
Test for interaction:			n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
RMSE for testing main effects (14 df):			2.28	7.97	5.41	3.51	5.88	8.15	17.31	0.011	0.017
Test for FORMULATIONS:			*	***	***	n.s.	n.s.	***	***	***	***
Test for EQUIPMENT:			n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* = statistically significant at the 0.05 level
** = statistically significant at the 0.01 level
*** = statistically significant at the 0.001 level
[a]Overall mean for X prior to standardization was 83.56

TABLE 7. Confidence Limits for Gelcoat Study: Regular Vs. Low Voc Gelcoats

Variable and comparison	Lower 95% confidence limit	Esitmated mean difference	Upper 95% confidence limit	Significant
X - Transfer efficiency %	-4.70	-2.39	-0.08	*
Z1 - Total emissions by THC (g)	90.44	109.00	127.56	***
Z2 - Total emissions by MB (g)	46.63	86.78	126.93	***
Y1 - Application emissions by THC (g)	48.72	56.78	64.83	***
Y2 - Curing loss from part by MB (g)	45.98	51.44	56.91	***
Y3 - EF as % AS by THC	-1.76	1.79	5.34	n.s.
Y4 - EF as % AS by MB	-9.27	-3.32	2.62	n.s.
Y5 - EF as g/m^2 by THC	39.87	48.11	56.36	***
Y6 - EF as g/m^2 by MB	19.72	37.22	54.73	***
Y7 - EF (g/g) by THC	0.0680	0.0796	0.0912	***
Y8 - EF (g/g) by MB	0.0505	0.0678	0.0851	***

* = Statistically significant at the 0.05 level.
** = Statistically significant at the 0.01 level.
*** = Statistically significant at the 0.001 level.
n.s. = Not statistically significant at the 0.05 level.

TABLE 8. Confidence Limits for Gelcoat Study: Different Spray Guns

Variable and comparison	Lower 95% confidence limit	Esitmated mean difference	Upper 95% confidence limit	Significant
Comparison between AAA vs. HVLP (internal mix)				
X - Transfer efficiency %	-0.79	2.03	4.86	n.s.
Z1 - Total emissions by THC (g)	-12.90	9.83	32.56	n.s.
Z2 - Total emissions by MB (g)	-83.84	-34.67	14.50	n.s.
Y1 - Application emissions by THC (g)	-17.37	-7.50	2.37	n.s.
Y2 - Curing loss from part by MB (g)	-3.69	3.00	9.69	n.s.
Y3 - EF as % AS by THC	-2.28	2.07	6.41	n.s.
Y4 - EF as % AS by MB	-13.05	-5.77	1.51	n.s.
Y5 - EF as g/m^2 by THC	-5.76	4.33	14.43	n.s.
Y6 - EF as g/m^2 by MB	-36.77	-15.33	6.11	n.s.
Y7 - EF (g/g) by THC	-0.0063	0.0080	0.0222	n.s.
Y8 - EF (g/g) by MB	-0.0363	-0.0151	0.0062	n.s.
Comparison between AAA vs. HVLP (external mix)				n.s.
X - Transfer efficiency %	-3.39	-0.57	2.26	n.s.
Z1 - Total emissions by THC (g)	-22.56	0.17	22.90	n.s.
Z2 - Total emissions by MB (g)	-52.34	-3.17	46.00	n.s.
Y1 - Application emissions by THC (g)	-4.53	5.33	15.20	n.s.
Y2 - Curing loss from part by MB (g)	-9.03	-2.33	4.36	n.s.
Y3 - EF as % AS by THC	-4.15	0.20	4.55	n.s.
Y4 - EF as % AS by MB	-7.18	0.10	7.38	n.s.
Y5 - EF as g/m^2 by THC	-10.26	-0.17	9.93	n.s.

(cont.)

TABLE 8. Continued

Variable and comparison	Lower 95% confidence limit	Esitmated mean difference	Upper 95% confidence limit	Significant
Y6 - EF as g/m^2 by MB	-22.77	-1.33	20.11	n.s.
Y7 - EF (g/g) by THC	-0.0127	0.0016	0.0158	n.s
Y8 - EF (g/g) by MB	-0.0212	0.0000	0.0213	n.s.
Comparison between HVLP (int) vs. HVLP (external mix)				
X - Transfer efficiency %	-5.43	-2.60	0.23	n.s.
Z1 - Total emissions by THC (g)	-32.40	-9.67	13.06	n.s.
Z2 - Total emissions by MB (g)	-17.67	31.50	80.67	n.s.
Y1 - Application emissions by THC (g)	2.97	12.83	22.70	*
Y2 - Curing loss from part by MB (g)	-12.03	-5.33	1.36	n.s.
Y3 - EF as % AS by THC	-6.21	-1.87	2.48	n.s.
Y4 - EF as % AS by MB	-1.41	5.87	13.15	n.s.
Y5 - EF as g/m^2 by THC	-14.60	-4.50	5.60	n.s.
Y6 - EF as g/m^2 by MB	-7.44	14.00	35.44	n.s.
Y7 - EF (g/g) by THC	-0.0206	-0.0064	0.0078	n.s.
Y8 - EF (g/g) by MB	-0.0061	0.0151	0.0363	n.s.

* = Statistically significant at the 0.05 level.
n.s. = Not statistically significant at the 0.05 level.

TABLE 9. Within-cell Standard Deviations - Gelcoat Experiment

GF	EQUIP	X	Z1	Z2	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
GF1	GE1	2.7	11.4	30.2	8.3	8.0	2.8	4.0	5.1	13.1	0.010	0.016
GF1	GE2	0.5	30.1	9.5	4.7	2.6	4.0	0.9	13.2	4.0	0.015	0.003
GF1	GE3	2.7	7.0	68.4	10.0	4.6	3.7	6.6	3.2	29.8	0.014	0.026
GF2	GE1	3.6	3.8	54.1	4.4	6.4	2.6	10.7	1.7	23.6	0.007	0.027
GF2	GE2	1.1	25.2	23.6	10.4	3.1	5.1	2.5	11.3	10.1	0.013	0.006
GF2	GE3	1.0	13.6	18.8	10.1	2.1	2.9	2.1	6.0	8.2	0.008	0.005

For the two Z variables, an initial analysis of covariance (ANACOVA) of the following form was performed:

SOURCE OF VARIATION	DEGREES OF FREEDOM
X (transfer efficiency)	1
GF (gelcoats)	1
GE (equipments)	2
GF x GE (interaction)	2
Error	11
Total	17

Since in each case the interaction term appeared statistically nonsignificant, that term was dropped to produce the following:

SOURCE OF VARIATION	DEGREES OF FREEDOM
X (transfer efficiency)	1
GF (gelcoats)	1
GE (equipments)	2
Error	13
Total	17

Table 10 provides the ANOVA and ANACOVA results for the two Z variables. Type of gelcoat FORMULATION appears to have a significant effect on both variables. Neither Z1 nor Z2 exhibits differences attributable to types of EQUIPMENT.

TABLE 10. Analysis of Covariance Results for Gelcoat Experiment: Variables Z1 and Z2

				MEANS		MEANS ADJUSTED FOR X	
GF	**EQUIP**	**N**	**X**	**Z1**	**Z2**	**Z1**	**Z2**
GF1	GE1	3	-1.5	399.7	389.7	399.7	368.1
GF1	GE2	3	-1.6	373.3	397.0	373.4	373.5
GF1	GE3	3	-0.5	387.0	393.3	387.0	386.7
GF2	GE1	3	2.5	271.3	287.0	271.3	322.7
GF2	GE2	3	-1.5	278.0	349.0	278.0	327.9
GF2	GE3	3	2.6	283.7	289.7	283.6	326.8
GF1	-	9	-1.2	386.7	393.3	385.3	375.9
GF2	-	9	1.2	277.7	308.6	279.0	326.0
-	GE1	6	0.5	335.5	338.3	336.1	345.5
-	GE2	6	-1.5	325.7	373.0	323.9	350.4
-	GE3	6	1.1	335.3	341.5	336.6	356.9

Hypothesis testing results:

RMSE for testing interaction (12 df):	17.9	39.8		
(11 df):			18.7	23.9
Test for interaction:	n.s.	n.s.	n.s.	n.s.
RMSE for testing main effects (14 df):	18.4	39.7		
(and covariate) (13 df):			18.9	22.4
Test for FORMULATIONS:	***	***	***	**
Test for EQUIPMENT:	n.s.	n.s.	n.s.	n.s.
Test for covariate X:			n.s.	***

* = statistically significant at the 0.05 level.
** = statistically significant at the 0.01 level.
*** = statistically significant at the 0.001 level.

F.3 Resin Experiment.

This experiment was aimed at evaluating how styrene emissions are affected by type of resin formulation (factor RF) and type of equipment (factor RE). The factor combinations used in the experiment and the associated sample sizes were as follows:

Treatment	Level of RE	Level of RF	n
1	RE1	RF1	5
2	RE1	RF2	3
3	RE1	RF3	3
4	RE1	RF6	3
5	RE2	RF1	3
6	RE3	RF1	3
7	RE4	RF4FG	2
8	RE4	RF4SG	2

This design deviates slightly from the orignally planned design. Resin RF4 was modified to shorten gel time after two test runs had shown that resin drains to the flange before it cures. These two RF4 test runs are noted with SG for slow gel. The modified RF4 resin has a faster gel time that allows resin to cure before it drains. RF 5 resin was not tested because the resin manufacturer decided to drop out from the testing. The actual runs yield 16 degrees of freedom for error. Separate analyses are used to test for equipment differences and for different resin formulations.

The ANOVA for equipment comparisons among RE1, RE2, and RE3 (for resin RF1) is as follows:

SOURCE OF VARIATION	DEGREES OF FREEDOM	
RE (equipments)	2	
Error	16	(assumes pooling of variances from within all treatments)

For resin formulation comparisons (i.e., excluding treatments 5 and 6) the following ANOVA applies:

SOURCE OF VARIATION	DEGREES OF FREEDOM	
RF (resins)	5	
Error	16	(assumes pooling of variances from within all treatments)

It should be noted that any comparison involving RF4SG or RF4FG versus one of the other treatments is not only a comparison of resin formulations but also of application method.

Table 11 presents the ANOVA results for the X and all of the Y variables. The upper portion of the table gives means for each treatment (combination of equipment and formualtion) while the lower portion shows the results of testing hypotheses. Nonsignificant results were obtained for X and Y1 with regard to differences due to resin formulations (while using a fixed type of equipment, RE1); the remaining Y variables all exhibited highly significant effects due to these formulations. Type of equipment appeared to be a significant factor for all of seven of these variables. Point estimates of mean differences and 95 percent confidence interval estimates are given in Table 12 for EF in percent available styrene (% AS) as measured by THC and MB. Similar information is presented in Table 13 for EF in g/m^2 as measured by THC and MB. Similar information is presented in Table 14 for EF in g/g as measured by THC and MB. The with-in cell standard deviations for resin experiment are shown in Table 15.

For the two Z variables, an initial analyses of covariance were run by incorporating the transfer efficiency variable X into the ANOVA model. The results are given in Table 16. Both type of resin formulation and type of equipment appears to have a significant effect on both variables.

TABLE 11. Analysis of Variance Results for Resin Experiment: Variables X, Y1, Y2, . . ., Y8

TREATMENT		N	MEANS X[a]	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
1 RE1	RF1	5	-0.6	214.0	202.0	17.4	17.0	195.0	189.4	0.067	0.065
2 RE1	RF2	3	-0.7	192.7	170.3	17.3	16.1	173.3	161.0	0.061	0.057
3 RE1	RF3	3	-0.2	179.7	86.7	10.6	10.4	125.3	122.3	0.046	0.045
4 RE1	RF6	3	-0.9	148.7	77.3	10.6	9.7	116.7	107.3	0.046	0.042
5 RE2	RF1	3	4.6	143.0	149.0	14.2	13.8	134.7	130.0	0.055	0.053
6 RE3	RF1	3	4.4	166.3	121.0	15.3	15.1	131.3	129.0	0.059	0.058
7 RE4	RF4FG	2	-0.9	192.5	262.0	21.3	20.3	224.5	214.0	0.091	0.086
8 RE4	RF4SG	2	-8.6	311.0	382.5	26.2	24.8	330.0	312.5	0.112	0.106
Hypothesis Testing Results:											
RMSE for testing effects (16 df):			1.90	30.82	31.50	1.28	1.52	11.14	11.17	0.0053	0.0061
Test for Treatments			***	***	***	***	***	***	***	***	***
Test for Resin Formulations (Trt 1 vs. 2 vs. 3 vs. 4):			n.s.	n.s.	***	***	***	***	***	***	***
Test for Equipments (Trt 1 vs. 5 vs. 6):			**	*	**	**	*	***	***	*	*

* = statistically significant at the 0.05 level.
** = statistically significant at the 0.01 level.
*** = statistically significant at the 0.001 level.
[a]Overall mean for X prior to standardization was 92.65.

TABLE 12. Estimated Mean Differences and Confidence Interval Estimates for Percent Available Styrene (% AS): Resin Experiment

Variable and comparison	Lower 95% confidence limit	Estimated mean difference	Upper 95% confidence limit	Significant
Y3 - EF, % AS (by THC)				
Equipment Comparisons				
RE1RF1 - RE2RF1	1.220	3.207	5.194	**
RE1RF1 - RE3RF1	0.120	2.107	4.094	*
RE2RF1 - RE3RF1	-3.322	-1.100	1.122	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	-1.880	0.107	2.094	
RE1RF1 - RE1RF3	4.853	6.840	8.827	***
RE1RF1 - RE1RF6	4.853	6.840	8.827	***
RE1RF2 - RE1RF3	4.512	6.733	8.955	***
RE1RF2 - RE1RF6	4.512	6.733	8.955	***
RE1RF3 - RE1RF6	-2.222	0.000	2.222	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG				
RE1RF1 - RE4RF4SG	-6.086	-3.810	-1.534	**
	-11.036	-8.760	-6.484	***
Y4 - EF, % AS (by MB)				
Equipment Comparisons				
RE1RF1 - RE2RF1	0.796	3.147	5.497	*
RE1RF1 - RE3RF1	-0.437	1.913	4.264	
RE2RF1 - RE3RF1	-3.322	-1.100	1.122	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	-1.470	0.880	3.230	
RE1RF1 - RE1RF3	4.263	6.613	8.964	***
RE1RF1 - RE1RF6	4.896	7.247	9.597	***
RE1RF2 - RE1RF3	3.105	5.733	8.361	***
RE1RF2 - RE1RF6	3.739	6.367	8.995	***
RE1RF3 - RE1RF6	-1.995	0.633	3.261	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG	-5.963	-3.270	-0.577	*
RE1RF1 - RE4RF4SG	-10.513	-7.820	-5.127	***

Comparisons significant at the 0.05 level are indicated by '*'

* = statistically significant at the 0.05 level.

** = statistically significant at the 0.01 level.

*** = statistically significant at the 0.001 level.

TABLE 13. Estimated Mean Differences and Confidence Interval Estimates for Emission Factor (g/m^2): Resin Experiment

Variable and comparison	Lower 95% confidence limit	Estimated mean difference	Upper 95% confidence limit	Significant
Y5 - EF, g/m^2 (by THC)				
Equipment Comparisons				
RE1RF1 - RE2RF1	43.094	60.333	77.572	***
RE1RF1 - RE3RF1	46.428	63.667	80.906	***
RE2RF1 - RE3RF1	-15.940	3.333	22.607	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	4.428	21.667	38.906	*
RE1RF1 - RE1RF3	52.428	69.667	86.906	*
RE1RF1 - RE1RF6	61.094	78.333	95.572	***
RE1RF2 - RE1RF3	28.726	48.000	67.274	***
RE1RF2 - RE1RF6	37.393	56.667	75.940	***
RE1RF3 - RE1RF6	-10.607	8.667	27.940	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG	-49.250	-29.500	-9.750	**
RE1RF1 - RE4RF4SG	-154.750	-135.000	115.250	***
Y6 - EF, g/m^2 (by MB)				
Equipment Comparisons				
RE1RF1 - RE2RF1	42.104	59.400	76.696	***
RE1RF1 - RE3RF1	43.104	60.400	77.696	***
RE2RF1 - RE3RF1	-18.338	1.000	20.338	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	11.104	28.400	45.696	**
RE1RF1 - RE1RF3	49.771	67.067	84.363	***
RE1RF1 - RE1RF6	64.771	82.067	99.363	***
RE1RF2 - RE1RF3	19.329	38.667	58.004	***
RE1RF2 - RE1RF6	34.329	53.667	73.004	***
RE1RF3 - RE1RF6	-4.338	15.000	34.338	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG	-44.415	-24.600	-4.785	*
RE1RF1 - RE4RF4SG	-142.915	-123.100	-103.285	***

Comparisons significant at the 0.05 level are indicated by '*'.

* = Statistically significant at the 0.05 level.
** = Statistically significant at the 0.01 level.
*** = Statistically significant at the 0.001 level.
n.s. = Not statistically significant at the 0.05 level.

TABLE 14. Estimated Mean Differences and Confidence Interval Estimates for Emission Factor (g/g): Resin Experiment

Variable and comparison	Lower 95% confidence limit	Esimtated mean difference	Upper 95% confidence limit	Significant
Y7 - EF, g/g (by THC)				
Equipment Comparisons				
RE1RF1 - RE2RF1	0.004	0.012	0.020	**
RE1RF1 - RE3RF1	0.000	0.008	0.016	*
RE2RF1 - RE3RF1	-0.013	-0.004	0.005	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	-0.003	0.006	0.014	
RE1RF1 - RE1RF3	0.013	0.021	0.029	***
RE1RF1 - RE1RF6	0.013	0.021	0.029	***
RE1RF2 - RE1RF3	0.006	0.015	0.024	**
RE1RF2 - RE1RF6	0.006	0.015	0.025	**
RE1RF3 - RE1RF6	-0.009	0.000	0.009	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG	-0.033	-0.024	-0.014	***
RE1RF1 - RE4RF4SG	-0.054	-0.045	-0.035	***
Y8 - EF, g/g (by MB)				
Equipment Comparisons				
RE1RF1 - RE2RF1	0.003	0.012	0.022	*
RE1RF1 - RE3RF1	-0.002	0.007	0.017	
	-0.015	-0.005	0.006	
Resin Formulation Comparisons				
RE1RF1 - RE1RF2	-0.001	0.008	0.018	
RE1RF1 - RE1RF3	0.011	0.020	0.030	***
RE1RF1 - RE1RF6	0.014	0.023	0.032	***
RE1RF2 - RE1RF3	0.001	0.012	0.022	*
RE1RF2 - RE1RF6	0.004	0.015	0.025	**
RE1RF3 - RE1RF6	-0.008	0.003	0.013	
Comparison of MEKP and BPO systems				
RE1RF1 - RE4RF4FG	-0.032	-0.021	-0.010	***
RE1RF1 - RE4RF4SG	-0.051	-0.041	-0.030	***

Comparisons significant at the 0.05 level are indicated by '*'.

* = Statistically significant at the 0.05 level.

** = Statistically significant at the 0.01 level.

*** = Statistically significant at the 0.001 level.

n.s. = Not statistically significant at the 0.05 level.

TABLE 15. Within-treatment Standard Deviations - Resin Experiment

TRT	N	X	Z1	Z2	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
RE1RF1	5	1.1	25.0	6.8	8.7	11.9	1.0	1.4	11.0	3.0	0.004	0.005
RE1RF2	3	1.0	7.1	6.6	2.1	7.2	1.1	1.0	3.5	3.0	0.004	0.004
RE1RF3	3	0.7	12.7	20.7	13.5	9.6	1.2	1.7	5.7	8.7	0.005	0.007
RE1RF6	3	1.6	49.5	40.6	49.6	7.1	1.3	1.3	21.5	18.0	0.006	0.006
RE2RF1	3	0.9	14.6	35.6	22.9	50.7	0.4	2.0	6.0	15.7	0.001	0.008
RE3RF1	3	0.3	28.8	36.7	47.4	14.0	0.9	1.3	12.7	15.9	0.004	0.005
RE4RF4FG	2	0.1	17.0	0.0	0.7	0.0	0.9	0.2	7.8	0.0	0.004	0.001
RE4RF4SG	2	6.5	13.4	26.9	63.6	96.9	3.3	2.5	5.7	12.0	0.014	0.011

TABLE 16. Analysis of Covariance Results for Resin Experiment: Variables Z1 and Z2

			MEANS	MEANS ADJUSTED FOR X			
TREATMENT		**N**	**X[a]**	**Z1**	**Z2**	**Z1**	**Z2**
1 RE1	RF1	5	-0.6	444.8	431.8	444.4	428.7
2 RE1	RF2	3	-0.7	395.3	367.0	394.9	363.8
3 RE1	RF3	3	-0.2	286.3	279.0	286.2	278.2
4 RE1	RF6	3	-0.9	266.7	244.7	266.0	240.3
5 RE2	RF1	3	4.6	306.7	296.3	309.9	319.0
6 RE3	RF1	3	4.4	299.0	294.3	302.1	316.0
7 RE4	RF4FG	2	-0.9	512.0	488.0	511.4	483.8
8 RE4	RF4SG	2	-8.6	752.5	713.0	746.5	671.0
Hypothesis Testing Results:							
RMSE for testing effects (16 df):				25.46	25.44		
(and covariate) (15 df):						26.26	24.45
Test for Treatments:				***	***	***	***
Test for Resin Formulations (Trt 1 vs. 2 vs. 3 vs. 4):				***	***	***	***
Test for Equipments (Trt 1 vs. 5 vs. 6):				***	***	***	***

* = statistically significant at the 0.05 level
** = statistically significant at the 0.01 level
*** = statistically significant at the 0.001 level
[a] Overall mean for X prior to standardization was 79.96.

F.4 Summary

Table 17 provides a summary of the hypothesis testing results.

TABLE 17. Summary of Results of Specific Hypothesis Tests

Comparison	X	Z1	Z2	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
M1 vs. M2	**	***	*	***		**		***	•	*	
A1 vs. A2											
GF1 vs. GF2	•	***	***	***	***			***	***	***	***
GE1 vs. GE2 GE1 vs. GE3 GE2 vs. GE3				*							
RF1 vs. RF2 | RE1		•	**					*	**		
RF1 vs. RF3 | RE1		***	***		***	***	***	***	***	***	***
RF1 vs. RF6 | RE1		***	***	*	***	***	***	***	***	***	***
RF2 vs. RF3 | RE1		***	***		**	***	***	***	***	**	*
RF2 vs. RF6 | RE1		***	***		**	***	***	***	***	**	**
RF3 vs. RF6 | RE1											
RE1 vs. RE2 | RF1	**	***	***	**	*	**	*	***	***	**	•
RE1 vs. RE3 | RF1	**	***	***		**	*		***	***	*	
RE2 vs. RE3 | RF1											
RE1RF1 vs. RE4RF4FG		**	*		*	**	*	**	•	***	***
RE1RF1 vs. RE4RF4SG	***	***	***	***	***	***	***	***	***	***	***
RE4RF4FG vs. RE4RF4SG	***	***	***	***	***	***	***	***	***	**	**

* = statistically significant at the 0.05 level.
** = statistically significant at the 0.01 level.
*** = statistically significant at the 0.001 level.

Appendix G

THC Analyzer Evaluation: Sampling Line Loss and Pressure Effect

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G.1 Sampling Line Loss

At the beginning of the project, questions were raised about whether styrene would be lost in the sampling line due to its reactive nature. RTI investigated potential sampling line losses prior to the styrene emission testing at Reichhold Chemical. Styrene and propane calibration standards were delivered through various sampling lines connected to the analyzer's calibration and sample ports in a manner very similar to that employed during routine calibrations. The analyzer operating parameters were identical to those used during styrene emission testing. The results of this study indicate that there are no significant pressure effects or styrene losses associated with the sampling line.

In an initial test, two different lengths (4 feet versus 25 feet)of 1/8-inch ID PFA Teflon tubing were compared. In a second test, 4 feet of 1/8-inch ID PFA Teflon tubing was compared to 12 feet of 1/4-inch ID tetrafluoroethylene (TFE) Teflon tubing.

In the initial test, two styrene calibration standards, four propane calibration standards, and zero air were measured on Range 2 (0 to 200 ppmv styrene) after being delivered through the 4-foot and 25-foot lengths of 1/8-inch ID sampling lines. Two other styrene calibration standards, three other propane calibration standards, and zero air were measured on Range 1 (0 to 20 ppmv styrene) after being delivered through the two sampling lines. Least squares regression analysis of 2-minute mean voltages yielded slopes for the 25-foot data regressed against the 4-foot data. The results of this test are given in the following table:

	Range 2	Range 1
Styrene Slope (Volts/Volt)	1.0697 (+/- 0.0070)	1.1115 (+/- 0.0266)
Propane Slope (Volts/Volt)	1.0485 (+/- 0.0150)	1.0430 (+/- 0.0032)
Styrene-to-Propane Slope Ratio	1.0203	1.0657

A styrene or propane slope equal to 1.0000 would indicate equal or no losses for propane or styrene in the two different sampling lines. The measured slopes are greater than 1.0000, which could mean that the 25-foot sampling line had lower losses than the 4-foot sampling line. This possible conclusion is counterintuitive. Instead, it was hypothesized that the higher total hydrocarbon analyzer responses in the 25-foot sampling line were associated with some pressure effect in the analyzer.

A styrene-to-propane slope ratio of 1.0000 would indicate that any styrene losses in the sampling lines were equal to any propane losses. No conclusions were drawn from these data concerning styrene losses due to questions about possible pressure effects.

The sampling line loss measurements were repeated in a second test using a different sampling line. A 12-foot length of 3/16-inch ID TFE tubing, which more realistically simulates the actual sampling line, was compared to the 4-foot length of 1/8-inch ID PFA tubing. This test used the same calibration standards as was used in the previous test. The results of the least squares regression analysis of these test data are given in the following table:

	Range 2	Range 1
Styrene Slope (Volts/Volt)	0.9972 (+/- 0.0186)	1.0326 (+/- 0.0072)
Propane Slope (Volts/Volt)	1.0134 (+/- 0.0020)	1.0228 (+/- 0.0064)
Styrene-to-Propane Slope Ratio	0.9840	1.0095

These results indicate that there are no significant pressure effects associated with the two sampling lines that were tested and that there is no significant styrene losses in the longer sampling line.

G.2 Pressure Effect

During routine calibrations of the total hydrocarbon analyzer, RTI observed that the analyzer's response is very sensitive to changes in the sample pressure at the inlet of the FID's capillary. The analyzer's operating manual states that it is very critical to maintain exactly the same sample pressure during calibrations as during analysis of actual samples. It may be necessary to adjust the back-pressure regulator to maintain the sample pressure.

RTI carefully maintained the sample pressure at 3.0 psig during calibrations and routine sampling and noted that the sample pressure shifted by approximately 0.1 psig when the analyzer was switched between these two operating modes. The back-pressure regulator was adjusted as needed. RTI found that a +/- 0.1 psig sample pressure shift during a calibration produced an approximately +/- 6.5 percent shift in the analyzer's response.

Some questions remained concerning possible residual pressure effects. The sample pressure gauge is connected to the inlet of the back-pressure regulator, which is about 9 inches downstream of the inlet of the FID capillary. Differences in sampling line pressure drops upstream of the sampling pump may produce pressure differences at the FID inlet even though the sample pressure was maintained at 3.0 psig.

RTI investigated these questions by delivering three propane calibration standards and zero air through three different sampling lines to the analyzer in a manner similar to that used during routine calibrations. The analyzer was operated on Range 2. The three following sample lines were connected to the analyzer's three inlet ports:

(A) 8-feet x 1/8-inch ID PFA Teflon tubing with gas pressure maintained at 5 psig by an in-line pressure regulator (normal calibration configuration);
(B) 4-feet x 1/8-inch ID PFA Teflon tubing with gas pressure maintained at 0 psig by an atmospheric- pressure sampling manifold; and
(C) 12-feet x 3/16-inch ID TFE Teflon tubing with gas pressure maintained at 0 psig by an atmospheric-pressure sampling manifold.

Least squares regression analysis of 2-minute mean voltages yielded the following slopes for the regression lines associated with the three sampling lines:

Sampling Line	Regression Slope (Volts/ppmv)	Slope Ratio relative to Normal Calibration Configuration
A	0.01845	- - -
B	0.01792	0.971
C	0.01969	1.067

These results indicate that residual pressure effects exist even when the sample pressure is maintained at 3.0 psig. Although Sampling Lines B and C were operating at atmospheric pressure, the slopes differed by approximately 11 percent. It is hypothesized that the pressure drops across the sampling lines are the cause of the difference. The theoretical pressure drop across Sampling Line B is 0.47 psig at a flowrate of 7 liters per minute. The corresponding pressure drop across Sampling Line C is 0.20 psig.

It is unclear how these results can be extrapolated to the 12-foot long by 1/4-inch ID PFA Teflon tubing used as the sampling line in the styrene emission tests. The theoretical pressure drop for this sampling line is 0.053 psig.

Immediately following the EPA performance evaluation, RTI conducted an additional pressure effects test using the 153 ppm propane calibration standard and various sampling lines. The results of this test is given in the following table.

Sampling Line and Configuration	Analyzer Response to 153 ppm Propane (Volts)	Analyzer Response Ratio Relative to Normal Calibration Configuration
8-feet x 1/8-inch ID PFA Teflon tubing with pressure maintained at 5 psig by an in-line pressure regulator (normal calibration configuration)	2.782	- - -
12-feet x 3/16-inch ID TFE Teflon tubing with pressure maintained at 0 psig by an atmospheric pressure sampling manifold	2.809	1.010
12-feet x 1/4-inch ID PFA Teflon tubing with pressure maintained at 0 psig by an atmospheric pressure sampling manifold (normal sampling line)	2.968	1.067

These results are somewhat different from the previous set of results. The 3/16-inch tubing produced an analyzer response 1 percent greater than the normal calibration configuration whereas it was 6.7 percent greater in the previous set of results. This difference may be due to either a variation in the magnitude of the pressure effect during the two sets of measurements or to a variation in the concentration in the sampling lines. Nevertheless, the general trend of these results is the same (i.e., larger-bore sampling lines at atmospheric pressure produce greater responses than the normal pressurized calibration line).

Based on these limited measurements and those obtained during the performance evaluation, the following conclusions may be drawn:

- despite careful control of the analyzer's sample pressure, variations of the gas pressure in the sampling line and the calibration line produce changes in the analyzer's response;
- the results of the pressure effects measurements are inconsistent and more measurements would be required to quantify definitively the magnitude of the pressure effect; and
- the observed magnitude of the pressure effect ranged between 1 and 7 percent.

The impact of the pressure effects on the total hydrocarbon measurements is not excessive relative to the +/- 5 percent accuracy objective that is given in the quality assurance project plan. Consequently, the total hydrocarbon measurements should not be corrected for pressure effects of unquantified magnitude.

(Reference: F. Caplan, "Finding Air Pressure Drop Through Smooth Tubes", Plant Engineering, January 6, 1977, pp. 74-75.)

Appendix H

An RTI Technical System Audit Report

MEMORANDUM

TO: Emery Kong, RTI Project Leader

FROM: Cynthia Salmons, RTI QA Officer CAS

DATE: July 20, 1995

SUBJECT: Technical Systems Audit of Evaluation of Pollution Prevention Techniques to Reduce Styrene Emissions From Open Contact Molding Processes

On June 9, Dr. William Yeager and I conducted a technical systems audit (TSA) of the styrene emissions project. Pre-audit activities included preparation of an audit checklist based on the quality assurance project plan (QAPP, see attachment) and an informal walkthrough on June 2. This memorandum summarizes the audit findings.

We generally found that the activities were conducted in accordance with the QAPP. The scales and total hydrocarbon analyzer (THA) were calibrated. The actual THA calibration procedure was more extensive than that described in the QAPP and Method 25A. Originally, use of two concentration ranges on the THA was planned so adequate cylinders to calibrate both were obtained. Through June 9, for all test runs involving spray guns, the higher concentration range (0-200 ppm) was used, but all of the cylinders (seven all together) were used to calibrate and/or check the calibration of the one range before each run. In addition, the calibration drift test was performed after each run. When the flow coater or pressure-fed roller was used in the test run, the lower concentration range (0-20 ppm) on the THA was used for better resolution. On days with three or four runs, this approach involved many checks with the same calibration gases. If a calibration is performed before each run, using two of the cylinders from the series of calibration gases for the calibration drift check immediately before, for nine analyses of the seven cylinders, is probably not necessary. While it seems reasonable to perform the seven point calibration at the start of the day, a four point calibration, as called for in the method, should be sufficient before the other runs of the day. While Method 25A is explicit about which concentrations should be used (80-90%, 45-55%, and 25-35% of the span value, and a zero) for the four point calibration, with this many calibrations taking place, it would seem reasonable to switch around the cylinders used for the four point calibration, appropriate for the high or low concentration range, in the course of the day. After June 9, when we discussed this issue, seven point calibrations were performed at the start of each day. Then, four point calibrations were performed before each test run.

The scale calibrations consisted of adding 9 weights sequentially. This

procedure was then repeated with something heavy, such as the mold, on the scale. Both scales (i.e., inside the enclosure and outside the enclosure) were linear.

The measurement point for the exhaust flow rate (i.e., where the pitot tube is placed) is approximately 5-6 diameters downstream from a bend. Thus, the measurement point satisfies the requirement that there not be a disturbance less than 2 diameters upstream of the measurement point, but is not consistent with the recommendation of not having a disturbance less than 8 diameters upstream of the measurement point. There is not a reasonable way of achieving the recommended 8 diameters. Method 1 requires at least 16 points for a velocity traverse; 24 points were used for this project. Mark Bahner checked for off-axis flow by rotating the pitot tube in the duct and making velocity head (Δ P) measurements. This check did not indicate a problem with off-axis flow.

The demonstration that the spray booth meets the criteria for total enclosure was not observed, but the notes from this were reviewed. A few of the hot-wire anemometer readings at the natural draft openings were slightly less than 200 fpm, and there was considerable fluctuation in the hot wire anemometer readings. Smoke tubes were used to check the natural draft at the door, and the air was always observed to be flowing into the spray booth. Calculating the duct flowrate by dividing the duct flow rate, which averaged 8,674 cfm, by the open area (42 square feet) indicates a natural draft opening velocity of 206 fpm. The results of the styrene evaporation experiments indicate that the styrene emissions were captured.

We did not observe the sampling and analysis of the gelcoat and resin because this was not performed on the day of our visit. We understand that a Reichhold laboratory will perform the gelcoat property measurements. We also did not observe the styrene evaporation experiment or the weekly traverse measurements, but we reviewed results from these activities. We also did not see the measurement of the equipment delivery rate. We understand that this was performed once per day, at the end of the day, during the early tests. Later, this was done after each test run, except for the pressure-fed roller, for which this determination was difficult to make and inaccurate.

The manufacturer's specifications for the gelcoat and resin indicate that styrene is the only volatile component. The 55 gallon drum was mixed and then split into 5 gallon cans. One quart samples were taken for the laboratory measurements from the first 5 gallon cans when the material was used the first time. Small samples (approximately 30 grams) were taken when the material was last used for the analysis of non-volatile content.

The baseline in the spray booth was measured with the THA for approximately 5 minutes before each run. For the purposes of ending a test, baseline was defined as a reading of less than 1 ppm styrene on the THA. Typically, the pre-test background was between 0.4 and 0.6 ppm, and tests were not ended until the readings reached this level. The data logger records every 2 seconds. At the end of each run, the data were downloaded to a computer, but there was a computer software problem with this step during the period we observed. This computer software problem was resolved later, and all data were

smoothly transferred to a computer.

Bob Wright recorded the pitot tube measurements and temperature every 15 minutes on data recording sheets and in his notebook. There is a NIST-traceable thermometer for checking these temperature measurements, but this had not been performed yet.

We have reviewed the materials that Mark Bahner provided on June 20 in response to Bill Yeager's electronic mail request of June 12. This included results from the styrene evaporation experiment, the weekly traverse measurements, the checks for off-axis flow in the duct, and the tests that we observed during our audit. These results did not indicate any problems with the project activities.

cc: Shri Kulkarni
Bill Yeager
Bob Wright
Mark Bahner
Keith Leese

File: 5171-016

TECHNICAL SYSTEMS AUDIT CHECKLIST

Audit Subject: Styrene Emissions Date: June 9, 1995
Auditee: RTI Auditors: Salmons, Yeager
Location: Reichhold Chemical Auditor Affil.: RTI
Personnel Present During Audit: Emery Kong, Mark Bahner, Bob Wright

GENERAL

1. Is a written and approved QA Project Plan (QAPP) available to field personnel for this project?

Yes.

2. Are all deviations from the QAPP and methods properly documented?

The data logger is using a 2 second interval, which is more frequent than discussed in the QAPP. This still needs to be formally documented.

3. How are corrective action procedures implemented?

None needed so far.

INITIAL AND PERIODIC PROCEDURES

4. Are there records of the comparison between the propane and styrene standardizatons? When was the comparison performed? What were the results?

Yes. May 26, 1995. Experimental and theoretical results are in good agreement.

5. Are there records for the comparison of direct injection and unheated sample lines? When was this performed? What were the results?

Yes. May 30, 1995? The agreement is good when the pressure is steady. When the pressure fluctuates, introducing gas through the sample line leads to higher, not lower, values. A larger diameter sample line was also used and seemed to improve agreement.

6. Was EPA Method 204 used to demonstrate that the spray booth meets the criteria for a total enclosure?

Yes. Some hot-wire anemometer measurements at the natural draft openings were less than 200 fpm (approx. 175). Considerable fluctuation in

the hot-wire anemometer readings.

7. Was the capture efficiency of the booth determined by evaporating a known amount of pure styrene? Was this test replicated? Within days? Among days?

Yes. Five tests on 6/5; repeated on 6/7 and on 6/29.

8. Is the measurement location for exhaust flowrate consistent with the EPA recommendation (8 diameters downstream of bend or disturbance and 2 diameters upstream)? Was the flow direction parallel to the axis of the duct at all points on the traverse? Was a 3D pitot tube used to check for turbulence?

The measurement location is 5 or 6 diameters downstream of the bend so it meets the 2 diameter criteria but not the 8 diameter recommendation. A 3D pitot tube was not used. At a later time, a check for off-axis flow was performed by rotating the pitot tube in the duct. Off-axis flow does not seem to be a problem.

9. Does the flowrate derived from centerline Δ P accurately predict the flowrate determined by the traverse? How does the pitot tube Δ P at the center of the duct compare with the Δ Ps on the traverse? How much does this Δ P vary during a run? Are there any acceptance criteria for this variation? The precision goal for the exhaust flow rate is RPD less than or equal to 10%.

Yes, within approximately 1 percent. Approx. 0.14 at center, approx. 0.10 at side of the traverse. Velocity varies by approx. 18%. Δ P is slightly asymmetric across the duct.

10. When was the hot wire anemometer calibrated? Has it recently been checked against a pitot tube?

Calibration on April 14, 1995. Will check again after June. Not checked against a pitot tube.

11. Were the linear air velocities in the spray booth consistent with the exhaust flow rate measurements?

Approx. 7700 cfm versus 9000 in the duct. There were considerable fluctuations in the hot-wire anemometer used to measure flow rate at the filter face in the booth.

12. Was the exhaust flow rate determined at least once per week?

Yes. A traverse of both the spray booth and the stack was performed each week. The exhaust flowrate was calculated based on the center line Δ P measurements, which were taken every 15 minutes.

13. Were the air flow velocities determined and recorded for the natural draft openings and over the application area?

Yes.

14. Were the contents of the gelcoat or resin container mixed for 2 minutes before sampling?

Not observed, but discussed this with technical staff.

15. How was the 1 liter sample of gelcoat or resin taken from the container to assure that it was representative? Was each container sampled? Were these determinations replicated? Within days? Among days? Does the manufacturer's invoice indicate that styrene is the only volatile component of the material?

Not observed. Manufacturer's specification indicates that styrene is the only volatile component. 55 gallon drums are broken down into 5 gallon cans. 1 quart samples will be taken from the first 5 gallon can and a 30 gram sample will be taken from the last 5 gallon can. The gelcoat samples will be sent to a Reichhold laboratory for analysis.

16. Were the material type, lot or batch number, and container number recorded on the gelcoat or resin container delivered to the laboratory?

Yes.

17. Was styrene content for the gelcoat and resin materials determined with Reichhold Standard Test Method No. 18-001?

Not observed.

18. Were the gel time, time to peak, and peak exotherm characteristics of polyester resins measured following Reichhold Standard Test Method No. 18-050 and 18-051?

Not observed.

PROCEDURES FOR EACH RUN

19. Was the THC calibrated before each run?

Yes.

20. Was the calibration error test procedure for the THC followed (i.e., introduction of the zero and high-level gases, adjustment, analysis of the low and mid-level gases)? If so, were the results within 5% of expected? What were the

predicted and observed readings?

During the project, the zero and span pots were not adjusted so that the instrument drift could be monitored. As is described in the memorandum to which this is attached, more standards were analyzed than are described in the method. The calculated calibration was based on the high span gas and the zero gas, which was assumed to be zero. The other standards functioned as linearity and calibration checks. The predicted and observed values were generally within 5%. Background, as determined from the instrument reading prior to the start of the test, was subtracted.

21. Were the balances checked with standard reference weights? If so, how many and what size weights were used?

Yes. Nine weights, ranging from 2 kg to 1 g. Also a box of fiberglass or a mold was added to the scale and the weights added again to check for linearity.

22. Was the baseline in the spray booth measured with the THC before and after each run? For how long?

Yes. The baseline is indicated by a THC reading of less than 1 ppm. Approx. 5 minutes.

23. Were the initial air temperature, velocity head, and relative humidity measured and recorded?

Yes.

24. Was the equipment delivery rate measured in a remote location?

Not observed, but told this was done at the end of the day during the early testing. Later, this was done after each test, except for the pressure-fed roller.

25. Were the equipment setup conditions recorded?

Not observed.

26. Were the initial weights for the mold, gelcoat/resin, catalyst, fiberglass reinforcement, protective skirt for cart, and groundcover recorded?

Yes.

27. Was the time initiated as soon as application started?

Yes.

28. Were the velocity head and air temperature recorded every 15 minutes?

Yes. Recorded on a data recording sheet and in Bob Wright's notebook except during lunch breaks.

29. Were the time and weight of gelcoat or resin recorded as soon as application was completed?

Yes.

30. Was the weight of the wet mold at the end of application without the protective skirt recorded?

No. Recorded with the skirt on. The skirt was not removed until gel had cured and THC returned to baseline.

31. Are the equipment delivery rates consistent with the before and after mass measurements for the mass balance calculations?

Not observed.

32. Was the run stopped when the THC indicated that the concentration returned to baseline? Was the time at which this happened recorded?

Yes.

33. Was the baseline drift for the THC determined at the end of the run?

Yes.

34. Was the enclosure flushed with fresh makeup air until the baseline stabilized?

Yes.

35. At the end of the day, were the recording sheets with sampling and analytical results collected, verified, and analyzed by the Testing Crew Chief?

Not observed, but Mark Bahner had the results from the previous days and was able to show comparisons, etc.

Appendix I

EPA Performance Evaluation of Total Hydrocarbon Analyzer

APPENDIX I. EPA PERFORMANCE EVALUATION OF TOTAL HYDROCARBON ANALYZER

EPA personnel conducted a performance evaluation of the total hydrocarbon analyzer on July 7, 1995. The purpose of the performance evaluation was to assess the accuracy of the analyzer and to compare this assessment with the accuracy data quality objective that was given in the quality assurance project plan. The assessment was accomplished by measurement of a styrene perforfance evaluation sample whose certified concentration was unknown to RTI. The measurements were performed on Range 2 of the analyzer. RTI's predicted concentration for this sample differed by 2 percent from its certified concentration. This result meets the data quality objective of +/- 5 percent for calibration gas accuracy that was given in the quality assurance project plan. Additional measurements showed that pressure effects did not exceed 3 percent during the performance evaluation. The styrene loss in the sampling line was found to be less than 2 percent. A more detailed discussion of the EPA performance evaluation is presented below.

Discussions between RTI and EPA personnel resulted in agreement that three components of accuracy needed to be assessed during the performance evaluation:

(1) the accuracy of RTI's calibration standards (especially in light of the use of propane to calibrate for styrene measurements);
(2) pressure effects associated with calibration line/sampling line differences; and
(3) styrene sampling line losses.

EPA and RTI personnel agreed that these three accuracy components would be assessed by measurement of RTI's propane calibration standards and EPA's performance evaluation sample through RTI's calibration line from the cylinders directly and through RTI's sampling line from an EPA heated sampling manifold.

The accuracy of RTI's propane calibration standards was determined from measurements in RTI's normal calibration configuration. RTI measured its propane calibration standards and the performance evaluation sample. RTI calculated a calibration equation from the propane measurements and predicted a concentration for the styrene sample based on this equation. This accuracy component was calculated as the percentage difference between the predicted and certified concentrations.

Pressure effects were determined by comparing measurements of RTI's propane calibration standard through the normal calibration line and through the sampling line from an EPA heated sampling manifold. This accuracy component was calculated as the percentage difference between the two sets of analyzer responses.

Styrene sampling losses were determined from measurements of EPA's styrene performance evaluation sample in the normal calibration configuration and through the EPA heated sampling manifold/ RTI sampling line. This accuracy component was calculated as the percentage difference between the two predicted styrene concentrations.

The EPA performance evaluation sample was a compressed gas calibration standard that was prepared in June 1995 by Scott Specialty Gases. Its certified styrene concentration is 31.0 ppm as measured by Scott, but this value was not independently verified by EPA. RTI did not know the certified concentration until after the evaluation had been completed.

EPA's sampling manifold was constructed from a 28-inch length of 2-inch OD stainless steel tube. Stainless steel tubing fittings were welded to the tube. RTI's sampling line was inserted into the manifold along the tube's long axis. The manifold was heated to approximately 130 oC. The static pressure inside the manifold was measured by RTI's Magnehelic® differential pressure gauge and was maintained at 0.01 inches of water to ensure that it was at near-atmospheric conditions.

The results of the evaluation are given in the following table:

Parameter	RTI 45.03 ppm Propane Calibration Standard	RTI 153.37 ppm Propane Calibration Standard	EPA Styrene Performance Evaluation Sample	RTI Zero Air
Equivalent Styrene Concentration	16.88	57.51	Unknown during analysis	0.00
THC Analyzer Response via Cal Port (Volts)	0.844	2.848	1.511	0.008
THC Analyzer Response via EPA Manifold (Volts)	0.863	2.765	1.469	0.035
Predicted Styrene Concentration (Cal Port)	- - -	- - -	30.39	-0.08
Predicted Styrene Concentration (EPA Manifold)	- - -	- - -	29.82	-0.81

Parameter	RTI 45.03 ppm Propane Calibration Standard	RTI 153.37 ppm Propane Calibration Standard	EPA Styrene Performance Evaluation Sample	RTI Zero Air
Response Change due to Pressure Effects (percent)	+2.23	-2.92	-2.76	- - -
Styrene Loss in Sampling Line (percent)	- - -	- - -	-1.87	- - -

Using measurements in RTI's normal calibration configuration, the predicted concentration of the styrene performance evaluation sample is 30.39 ppm. This value differs by -2.0 percent from the certified value of 31.0 ppm.

The results of the pressure effects measurements are inconsistent. The analyzer's response for one propane calibration standard increased by 2.2 percent, but response decreased by 2.9 and 2.8 percent for the other propane calibration standard and for the styrene performance evaluation sample, respectively. It is hypothesized that stabilization problems or some unknown problem were biasing the EPA manifold results. In any case, pressure effects do not appear to exceed +/- 3 percent.

The styrene loss in RTI's sampling line were less that 2 percent if one accepts all the propane and styrene measurements as being correct.

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16. ABSTRACT The report gives results of a study to evaluate several pollution prevention techniques that could be used to reduce styrene emissions from open molding processes in the fiberglass-reinforced plastics/composites (FRP/C) and fiberglass boat building industries. Styrene emissions using standard industry techniques, materials, and equipment were evaluated in a controlled environment and compared to a basline condition to determine the effects of these pollution prevention techniques on styrene emissions. The study found that using controlled spraying (i.e., reducing overspray), low-styrene and styrene-suppressed materials, and nonatomizing application equipment can reduce styrene emissions by from 11 to 52%. Facilities should investigate the applicability and feasibility of these pollution prevention options to reduce their styrene emissions. The calculated emission factors were from 1.6 to 2.5 times the mid-range AP-42 emission factors for the corresponding gel coat and resin application. These results indicate that facilities using AP-42 emission factors to estimate emissions in open molding processes are likely to underestimate actual emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Prevention	13B
Styrene Resins	Stationary Sources	11I, 11J
Emission	Boat Building	14G
Molding Techniques		13H
Fiberglass-reinforced Plastics		11D
Boats		13J
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