

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Draft Report for

AQMD GEL COAT TESTING PROGRAM

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AQMD GEL COAT TESTING PROGRAM

Executive Summary

The South Coast Air Quality Management District (AQMD), in cooperation with American Composite Manufacturers Association (ACMA), spray equipment manufacturers, gel coat manufacturers, and major composite fabricators developed the AQMD Gel Coat Testing Program. The objective of the testing program was to determine the minimum range of pressure values at the tip of the nonatomizing spray gun that produces gel coat sprayed products with surface quality that is no less than the surface quality achieved when using an atomizing spray gun in accordance with the composite industry standards and achieves the emissions rates stated in the Unified Emission Factors table (Composites Fabricators Association (CFA) 2001) for composite manufacturers operating in the AQMD. The information from the testing program would be the basis to develop a more appropriate and enforceable definition for the nonatomizing spray application technique of gel coats. The testing program also implements the AQMD Governing Board directive to conduct testing of equipment used in the nonatomizing spray application of gel coats (AQMD Board Resolution 04-5).

Four (4) major spray equipment manufacturers participated in the testing program, which was conducted from August through October 2004. The testing program included volatile organic compound (VOC) emission and surface quality measurements (porosity, gloss, orange peel and water resistance) of gel coat sprayed materials. VOC emissions were measured by AQMD staff. Surface quality analyses were conducted by California Polytechnic State University, San Luis Obispo.

The Gel Coat Testing Program verified that the gel coat pressure at the tip of the spray gun is an appropriate method to define the nonatomizing spray application technique for gel coats. However, the testing data also demonstrated that there were no significant differences in both the VOC emission and the surface quality measurements of the nonatomizing application and the atomizing application technique using a conventional air-assisted airless spray gun.

BACKGROUND

Rule 1162 – Polyester Resin Operations requires open molding composite fabricators in the AQMD to use a nonatomizing spray application technique in applying gel coats by July 1, 2005. The VOC emission reductions resulting from the use of the nonatomizing spray application technique were documented in several studies; in particular, the CFA and Clean Manufacturing Technology and Safe Materials Institute (CMTI) testing program. The CFA/CMTI studies include emissions data for resins and gel coats using both atomizing and nonatomizing spray applications. The results were most recently published in the Unified Emissions Factor (UEF) 2001 table, expressed as pounds of VOC per ton of sprayed gel coat or resin. Based on the UEF table emission rates, the VOC emission reduction for the nonatomizing spray application technique of gel coats is approximately 40 percent by weight (as compared to the atomized application equipment). On April 11, the CFA became the ACMA. Any reference to CFA or ACMA is to maintain a historical perspective.

Rule 1162 (b) (19) defines the nonatomizing spray application technique as “any application technique in which resin or gel coat flows from the applicator, in a steady and observable coherent flow, without droplets, for a minimum distance of three (3) inches from the applicator orifices”.

During the implementation of Rule 1162 (2001 amendments), composite manufacturers encountered difficulties in achieving the required three (3) inches coherent flow, as specified in the definition of nonatomizing spray technique for gel coat applications. Staff confirmed the same difficulties as part of the Rule 1162 Technical Assessment study (January 2003) that addressed the feasibility of gel coat nonatomizing application.

On July 11, 2003, the AQMD Governing Board amended the effective date for nonatomizing spray application for gel coats in Rule 1162 from July 1, 2003, to July 1, 2004, to allow for additional testing of the gel coat nonatomizing spray application technique. The Gel Coat Testing Program was scheduled to be completed in March 2004. However, on February 12, 2004, the spray equipment manufacturers unexpectedly withdrew from the program and the testing was suspended.

On July 9, 2004, the AQMD Governing Board amended the effective date for the gel coat nonatomizing spray application requirement in Rule 1162 from July 1, 2004, to July 1, 2005, to allow for additional time to implement the Gel Coat Testing Program and develop an appropriate definition of the nonatomizing spray application technique of gel coat.

Throughout 2004, staff in cooperation with Rule 1162 Testing Subgroup, which included the American Composite Manufacturers Association (ACMA), spray equipment manufacturers, gel coat manufacturers and several composite fabricators, developed and conducted the AQMD Gel Coat Testing Program. Testing was conducted from August through October 2004 and samples analyses were completed December 2004.

PROGRAM OBJECTIVES

The objective of the Gel Coat Testing Program was to determine the minimum range of pressure values at the tip of the nonatomizing spray gun that produces gel coat sprayed products with

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surface quality that is no less than the surface quality achieved when using an atomizing spray gun in accordance with the composite industry standards and achieves the emissions rates stated in the Unified Emission Factors table (CFA, 2001) for composite manufacturers operating in the AQMD. The testing program also implements the AQMD Governing Board directive to conduct testing of equipment used in the nonatomizing spray application of gel coats (AQMD Board Resolution 04-5).

PROGRAM OVERVIEW

The Gel Coat Testing Program is the culmination of numerous meetings with composite manufacturers, spray equipment manufacturers, gel coat manufacturers, ACMA and AQMD staff, and several pilot studies. The key elements of the Gel Coat Testing Program are listed below:

- ✓ Develop a testing protocol that would yield results that are representative of gel coat spray applications at composite manufacturing operations in the AQMD;
- ✓ Use the CFA Styrene Emissions Test Protocol & Facility Certification Procedures Revision 2.2 (March 1999) as the basis for developing the AQMD Test Protocol for Nonatomizing Spray Application Techniques for Gel Coats [Attachment 1];
- ✓ Select gel coat materials for the testing program that represent the major usage categories of the composite industry, which include clear, white, pigmented and filled gel coats;
- ✓ Use the same gel coat materials for each spray equipment manufacturer testing to eliminate the possible impact of gel coat performance on the testing results;
- ✓ Use the same mold for testing the spray equipment to eliminate the impact of the testing mold variation (mold configuration and dimension) on the testing results;
- ✓ Utilize optimum performance of the spray equipment by requiring the spray equipment manufacturers to operate their own equipment to eliminate the “learning curve” impact on the testing results;
- ✓ Measure the gel coat (liquid) pressure at the tip of the spray gun and utilize the tip pressure data to revise the definition of the nonatomizing spray application technique. Staff conducted field evaluations of the tip and the pump pressure of the gel coat spray equipment and found that while changes in the spray hose length and diameter affected the pump pressure, they showed no impact on the tip pressure;
- ✓ Maintain the spray gun flow rates in a range between 2.5 and 3.5 pounds per minute for all the tested gel coats with the exception of the clear gel coat where the flow rates should range between 1.5 to 2.5 pounds per minute. These gel coat flow rates are based on typical composite industry standards;
- ✓ Determine the efficiency of the nonatomizing spray application technique in reducing VOC emissions by comparing the VOC emission rates, in pounds of VOC emissions per ton of sprayed gel coat materials, for the conventional air-assisted airless and the nonatomizing spray application equipment;

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- ✓ Evaluate the surface quality of the sprayed gel coat materials for both nonatomizing spray application conventional air-assisted airless equipment. Surface quality measurements include porosity, gloss, orange peel and water resistance; and
- ✓ Keep all VOC emissions data and the surface quality analyses as it relates to specific spray equipment manufacturers anonymous and confidential.

AQMD GEL COAT TESTING PROGRAM PROTOCOL

The AQMD determined that in order to meet the objective of the Gel Coat Testing Program, it was critical to develop a testing protocol that would yield results and subsequent conclusions that are representative of gel coat spray applications at composite manufacturing operations in the AQMD. With this objective in mind, the AQMD worked with the Rule 1162 Testing Subgroup from July 2002 through June 2004 to develop the AQMD Test Protocol for Nonatomizing Spray Application Techniques for Gel Coats to be used for the Gel Coat Testing Program [Attachment 1]. The AQMD protocol incorporated key elements of the CFA Styrene Emissions Test Protocol & Facility Certification Procedures Revision 2.2 (March 1999), except for the following modifications:

Test Facility - Temperature of the Working Area

The CFA protocol states that the test chamber must be located in a temperature controlled environment. Previous CFA tests applied gel coat materials in a temperature controlled laboratory where the temperature ranged from 69 to 80 °F. The AQMD test applied gel coat in ambient temperatures, which ranged from 74 to 85 °F because that temperature range is representative of the conditions in the work areas for composite fabricators operating in the AQMD.

Test Enclosure

The cross sectional area of the spray booth doorway was reduced using 12 mil thick clear plastic in order to meet U.S. EPA Test Method 204 requirements for a temporary permanent enclosure. The CFA test protocol specified the use of a second blower to maintain laminar air flow at the surface of the test mold, with the air velocity ranging from 50 to 100 feet per minute. Instead of using a second blower, the AQMD Gel Coat Testing Program used a baffle which was placed in front of the mold to divert the air flow to maintain the specified range of air velocity at the surface of the test mold. (for a detailed description regarding the test spray booth dimensions and modifications, and laminar flow air measurements, please see Attachment 2).

Test Mold Configuration and Size

The testing mold was similar in dimensions and configuration to the CFA test mold (for more detailed information concerning the test mold and the air flow over its surface, please see Attachment 2).

Gel Coat (Liquid) Tip Pressure Measurement

The CFA test protocol does not specify the measurement of application pressure (pump or gun tip). The CFA test report contains pump pressure measurements (exit pump pressure equals pump gauge pressure multiplied by pressure ratio). The composite industry expressed concern regarding the use of pump pressure in developing a definition for the nonatomizing spray application technique for gel coats. Their concern included length of the hose and pump ratios and how they can differ between composite manufacturing facilities. Staff believed that the pressure at the tip of the gun, as applied, would be a valid method to define nonatomizing spray application technique for gel coats. Staff conducted field studies to compare the exit pump and tip pressure measurements. These studies indicated that while changes in the spray hose length and diameter changed the exit pump pressure, they showed no impact on the tip pressure of the gel coat spraying application equipment. Accordingly, staff chose to implement the tip pressure measurement in the AQMD Gel Coat Testing Program.

To implement the tip pressure measurements as required under the Gel Coat Testing Program, all spray guns tested were modified to include an adaptor installed before the tip of the gun to attach a liquid pressure gauge. The adaptor and the gauge were used only during the tip pressure measurements immediately prior to spraying/testing. The pressure gauges were precision, compact liquid pressure measurement units, and were calibrated according to the National Institute of Standard and Testing (NIST) standards.

Gel Coat Application Temperature

The composite industry in the AQMD typically operates at ambient outdoor temperatures; most facilities are not well insulated and are not air conditioned. To address the diurnal temperature changes throughout the year, most operators are heating their gel coat materials to maintain more consistent spray applications. Field surveys conducted by the AQMD during August and September 2002 determined that applying heat to gel coat materials reduces viscosity, minimize porosity, enhance materials coverage/wetting and improve adhesion to the substrate. The Gel Coat Testing Program protocol requires the application temperature of the gel coat material be maintained between 80 and 90 °F.

VOC Emissions Measurement Equipment - Test Methods

In addition to the U.S. EPA Test Method 25A, the AQMD Gel Coat Testing Program included additional, simultaneous VOC emissions sampling, as per SCAQMD Test Method 25.1. The AQMD protocol requires VOC emissions testing in triplicate. The average of the two test methods results are represented in this report.

Some gel coat materials contained both styrene and methyl methacrylate. During the spraying/testing of these gel coats, additional gas samples were collected into evacuated canisters and were analyzed for both styrene and methyl methacrylate using U.S. EPA Test Method 18.

Gel Coat Film Samples and Analyses

The CFA protocol did not include a requirement for qualitative or quantitative analyses for surface quality. The AQMD protocol required duplicate samples to be collected simultaneously with the VOC emissions testing. A discussion of the sampling procedure, sample recovery and surface quality analyses can be found under Surface Quality Testing Methods of this report.

PROGRAM PARTICIPANTS

The Gel Coat Testing Program participants included representatives from spray equipment manufacturers, gel coat and catalyst suppliers, testing facility, ACMA, surface quality testing laboratory, and AQMD staff.

Spray Equipment Manufacturers:

- ✓ GS-Manufacturing
- ✓ Glas-Craft, Inc.
- ✓ ITW Industrial Finishing
- ✓ Magnum Venus Products

Gel Coat and Catalyst Suppliers

Rule 1162 Testing Subgroup, as identified in the acknowledgements section of this report, selected Ashland as the gel coat manufacturer to provide the gel coat materials for the Gel Coat Testing Program. The gel coat materials included clear, midnight blue, and san bright white and gray sandable gel coats. Gel coat material of each type was supplied in fifty-five (55) gallon drums. The VOC/monomer contents of the testing gel coat materials were measured by the AQMD laboratory and were found to be comparable to the VOC data listed in the Material Safety Data Sheet (MSDS) for these gel coats. The gel coat materials sprayed, their product names and monomer contents are listed in Table 1:

**Table 1
Gel Coat Materials Tested**

GEL COAT	PRODUCT NAME	MONOMER CONTENT (%)*
Clear	CG-40-02145 HAP 40 Clear	40.9
Pigmented	LG-33LE-2049 Midnight Blue	32.9
White	WG-30X-2181 San Bright White	30.8
Filled	AG-27PR-72315 Gray Sandable	27.3

*Monomer content measured by AQMD Laboratory using EPA Method 18

Catalyst is added to the gel coat prior to spraying to facilitate timely curing of the sprayed gel coat. The percentage of catalyst used in the gel coat tests ranged from 1.8 to 2 percent by weight. The catalyst used in the Gel Coat Testing Program was Norox MEKP 925H, a methyl ethyl ketone peroxide, manufactured by Norox Incorporation.

Testing Facility

The Gel Coat Testing Program was conducted at LASCO Bathware located at 3255 Miraloma Avenue, Anaheim, California. LASCO Bathware is one of the major composite manufacturers in the AQMD and is a member of Rule 1162 Testing Subgroup. Testing was conducted in the research and development building at LASCO Bathware, which includes two spray booths. The two spray booths are located within 20 feet of each other. One of the spray booths was used as the test enclosure to collect the VOC emissions resulting from the atomized and nonatomized spray applications of gel coat materials. The other spray booth was used for spray gun equipment maintenance, changing gel coat materials between testing runs and general clean up. During the testing runs, the maintenance spray booth was operated to minimize any potential VOC background in the testing area.

American Composite Manufacturers Association (ACMA)

The ACMA actively participated in the development of the AQMD Gel Coat Testing Program protocol. Dr. Robert Haberlein, an ACMA consultant, also observed eight testing runs.

Surface Quality Testing Laboratory

The surface quality samples were analyzed by California Polytechnic State University, San Luis Obispo, California. Surface quality analyses included porosity, gloss, orange peel and water resistance.

AQMD Testing and Laboratory Analysis Team

The AQMD testing team included rule development, source testing, and laboratory staff.

TESTING METHODS

The testing methods include VOC emission and surface quality testing methods.

Emission Testing Methods

Emission testing methods include the following:

- ✓ USEPA Test Method 204-Temporary/Permanent Enclosure with 100% Capture Efficiency,
- ✓ USEPA Test Method 1- Sample and Velocity Traverse for Stationary Sources,
- ✓ USEPA Test Method 25A-Determination of Total Gaseous, Organic Concentration Using Flame Ionization Detector,
- ✓ USEPA Test Method 18 – Measurement of Gaseous Organic Compound Emissions By Gas Chromatography, and

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- ✓ SCAQMD Test Method 25.1-Determination of Total Gaseous Non-Methane Organic Emissions as Carbon.

The VOC emissions were collected, measured, and analyzed using U.S. EPA Test Method 25 A and SCAQMD Test Method 25.1. The emission results presented in this report represent the average of the two testing methods. The results of the emissions mass recovery tests provided correction factors for the VOC emission results of both testing methods.

The clear and midnight blue gel coats contained both styrene and methyl methacrylate, which will evaporate at different rates during the VOC emission testing. To address this issue, canister samples were collected simultaneously with the SCAQMD Test Method 25.1 samples and analyzed for both styrene and methyl methacrylate using U.S. EPA Test Method 18.

To reduce the possible degradation of styrene (VOC) emissions in the sample line from the stack sampling port to the total hydrocarbon concentration analyzer due to ultra violet (UV) light, the Teflon tubing sample line was wrapped with heat resistance fiberglass tape. Furthermore, additional tests were conducted to verify that air temperature, UV radiation and residence time had no impact on the styrene emissions measured. These additional tests compared the VOC concentration of gas samples taken simultaneously at the stack (in evacuated cylinders) and at the point where the sampling line entered the total hydrocarbon concentration analyzer.

For more detailed information concerning the implementation of U.S. EPA Test Method criteria, the spray gel coat usage and gel coat film thickness, the stack flow rate measurement, and the emission testing methods and analytical procedures, please see the Attachment 2.

Surface Quality Testing Methods

Background

Surface quality is critical to the appearance and structural integrity of the manufactured composite products. During the implementation of Rule 1162, the composite industry expressed concern regarding the surface quality of the composite products when using the nonatomizing spray application techniques for gel coats; in particular, the porosity of the gel coat surface of the composite products. To address this concern, the Gel Coat Testing Program included the collection and analyses of triplicate, sprayed gel coat samples (films) for surface quality.

Sampling and Sample Recovery Procedure

Gel coat film/surface quality samples were generated concurrently with the VOC emission tests during the spraying of each of the four different gel coat materials. Gel coat materials were sprayed using both the nonatomizing and air-assisted airless applications. The samples were collected on 12 inch by 12 inch by ¼ inch clear glass plates, which were pretreated with a mold release agent. The mold release agent, Prekote 508 56A PA manufactured by Henkel Loctite Corporation, includes synthetic isoparafinic hydrocarbon, hydrotreated heavy naphtha and a proprietary resin solution. It is a colorless, mild odor liquid with a high boiling point (>235 °F). The volatility of the mold release agent is 99.5 percent and its VOC content is 6.12 pounds per gallon.

The glass plate preparation and gel coat recovery procedure is as follows:

1. Apply a thin film of mold release on the surface of the glass plate to be sprayed;

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2. Place the glass plate in an oven for thirty (30) minutes at 150°F;
3. Remove the glass plate from the oven and apply a second thin film coat of mold release (the glass plate is now ready for collecting the gel coat sample);
4. Spray the gel coat onto the glass plate (and mold) and allow the gel coat to cure overnight before the recovery of the gel coat film;
5. Recover/demold the gel coat film by carefully sliding a long, thin spatula between the gel coat film and the glass plate; and
6. Wrap the gel coat film in wax paper and support with a hard/stiff material for shipment.

Analytical Laboratory

The AQMD contracted with California Polytechnic State University, San Luis Obispo to perform the surface quality testing on the gel coat film samples produced during the Gel Coat Testing Program using the following testing procedures:

1. Porosity test : American National Standard Institute (ANSI Z124), Test Method 3.3 and Test Method 3.4;
2. Gloss test: American Standard Test Methods (ASTM D523) using BYK-Gardner gloss measuring equipment;
3. Orange Peel test: ACT- Distinctness of Image (DOI) Panels; and
4. Water Resistance test: ANSI Z124, Test Method 6.1.

Porosity Test

The porosity tests were comprised of both surface and subsurface measurements. Surface porosity tests were conducted using ANSI Z124, Method 3.3, which includes:

1. Prepare the test surface (wash the test areas with liquid detergent, rinse with clear water and dry);
2. Apply ink or soil the test surface; and
3. Inspect the test surface with the unaided eye for voids (pinholes).

Subsurface porosity tests were conducted using ANSI Z124, Method 3.4, which includes:

1. Prepare two test areas (same procedure used in the surface porosity tests);
2. Rub the two test areas for at least 25 cycles with 600-grit wet silicone carbide abrasive paper (each test area is approximately 16 square inches);
3. Rinse the test areas with tap water and dry;
4. Soil the test areas with standard dirt (see ANSI Z124, Test Method 3.4.2 for the Standard Dirt Specification), apply 0.2 ounces of the standard dirt to each test area and rub with dampened a chamois and heavy thumb pressure in a circular motion for about 25 cycles; and

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5. Allow the dirt to dry for one (1) hour, wash with clean a dampened chamois and liquid detergent before visual inspection.

Porosity voids (pinholes) include small and large voids with diameters of less than 1/16 and more than 1/16 of an inch, respectively. Based on ANSI Z124, Methods 3.3 and 3.4, the maximum allowable small voids in the two test areas are 8 and no large voids are allowed.

Gloss Test

Gloss describes the capability of a surface to reflect more light in certain directions. Gloss measurements are obtained by comparing the specular reflectance from the gel coat sample to that from a standard polished black glass. The assigned specular gloss value of the standard polished black glass is 100 for each geometry. The sample surface needs to be thoroughly prepared for the gloss test.

Gloss tests were performed on the whole gel coat sample (approximately one square foot gel coat film) as originally produced from the Gel Coat Testing Program using ASTM D 523 and BYK-Gardner gloss measuring equipment. The gloss measurement process includes an incandescent light source furnishing an incident light beam on the, surface of the specimen and a photosensitive receptor. Gloss measurements were taken at 20° and 60° geometry. The 60° geometry is used for intercomparing specimens. The 20° geometry is advantageous for specimens having 60° gloss values higher than 70.

The gloss measuring instrument is calibrated according to the manufacturer's specification and the instrument zero is verified in each gloss measurement (any variation which is not within ± 0.1 or zero is subtracted algebraically from subsequent readings).

Orange Peel

An orange peel surface is a wavy, slightly lumpy surface similar to the skin of an orange. Gel coat flow and viscosity are greatly impacting the roughness/texture of the gel coat surface and the degree of its orange peel.

The orange peel of the gel coat samples was determined using the Distinctness of Image (DOI) Panels method. The panels represent different degrees of orange peel on a surface. The orange peel of the gel coat samples were determined by visually comparing the surface of the gel coat samples with the surface of the DOI panels.

Water Resistance

The Hot Water Resistance test was conducted using ANSI Z124, Test Method 6.1. Three specimens of each gel coat sample were analyzed. Surface preparation of the specimens includes:

1. Rub the test surface with a scoring compound and cheesecloth for a minimum of 20 scrub cycles and wash with tap water;
2. Place the test surface against the portholes (6 square inch each) of a non-reactive vessel and use silicon rubber gaskets between the tank and specimen;

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3. Boil specimens in distilled water for $100 \pm \frac{1}{2}$ hour and keep the test areas submerged; and
4. Remove specimens and visually examine within four (4) hours from the test completion.

The water resistance rating of the gel coat samples is based on comparing the rating of the tested and the untreated (control) specimens. The water resistance rating involved five (5) major defects: blisters, color change, change in surface profile, cracks, and loss of visible gloss. The numerical scale for the water resistance rating is zero (0) for no change, one through four (1-4) for increasing gradation of change, and five (5) for extreme change or approaching maximum possible change. The water resistance rating was determined by totaling, for each specimen, the numerical designation for each of the five gradations of change, then totaling the value for all three specimens and dividing by three. ANSI Z124, Method 6.1, states that the water resistance rating shall not exceed nine for the five major defects and four for any one of them.

RETESTING

Prior to the start of the Gel Coat Testing Program, the AQMD conducted preliminary testing to calibrate testing equipment and familiarize AQMD staff with sample collection and recovery methods and techniques. In particular, staff conducted trials to improve the technique of recovering the sprayed gel coat film from the sampling glass plates. Staff did not experience any difficulty in recovering the gel coat film samples that were sprayed two to three days prior to the recovery.

Surface quality samples consisting of gel coat sprayed onto the glass sample plates collected during the first week of the testing program were packaged and shipped to the surface quality testing laboratory for analyses the following week. The second week of testing proceeded as scheduled. The testing laboratory could not recover/demold the sprayed gel coat films from the glass plates. Apparently, the gel coat film had fully cured prior to receipt and attempted recovery by the surface quality testing laboratory. To address this problem, staff, in cooperation with the LASCO laboratory, conducted laboratory tests to develop a procedure to properly prepare and recover the gel coat film off the glass plate. These tests included the following:

1. Apply laminate resin to support and recover/demold gel coat film;
2. Apply mold release agent on the side of the glass plate which will be sprayed with gel coat, place the glass plate in an oven for 30 minutes at 150 °F, remove the glass plate from the oven and allow them to cool to the ambient temperature, and reapply mold release agent two or three times and let the mold release completely dry before spraying; and
3. Determine the appropriate time to recover/demold the gel coat film off the glass plate by recovering/demolding different gel coat films at three (3) hours, six (6) hours and overnight after the curing time.

Staff observed shrinkage in the laminate surface which will adversely impact the gloss and the orange peel of the gel coat film and concluded that the glass plate treatment and overnight gel

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coat recovery/demold is the optimum procedure to recover/demold gel coat films and assure the integrity of the surface quality tests.

Based on these tests, the AQMD changed the procedures for preparing the glass plates to collect the liquid gel coat materials and removing/recovering the cured gel coat film from the glass plates.

Since the gel coat film samples could not be recovered for those samples collected during the first two weeks of the testing program, two nonatomizing spray guns and the air-assisted airless spray gun needed to be tested a second time in order to collect data to correlate the VOC emissions with surface quality for those spray guns. This retesting was conducted during the first two weeks of October 2004 after the other two nonatomizing spray gun manufacturers were tested. The additional VOC emissions data collected for the retested spray guns also provided data to investigate the temporal effects on the testing.

CONFIDENTIALITY

During the development off the Gel Coat Testing Program, the AQMD stated that it was not the objective of the Gel Coat Testing Program to compare the performance of the four spray equipment manufacturers. Accordingly, the four participant spray equipment manufacturers will be referred to as Gun Manufacturer I, Gun Manufacturer II, Gun Manufacturer III, and Gun Manufacturer IV. The AQMD intends to keep the performance of the participant spray equipment manufacturers anonymous and confidential.

TEST RESULTS AND DISCUSSION

The AQMD conducted seventy-nine source tests at the testing facility during the test period August 24 through October 14, 2004. The source testing consisted of simultaneous VOC emissions testing, as per USEPA Test Method 25A and SCAQMD Test Method 25.1. Concurrent with the VOC emissions testing, the AQMD also collected gel coat film samples (gel sprayed onto 12 inch square glass plates). All VOC testing and analysis was completed by the AQMD. The gel coat films were analyzed for four surface quality characteristics by the California Polytechnic State University, San Luis Obispo, from October 4 through December 10, 2004. The complete data, results, and sampling and analytical methods are in the attached VOC emissions report [Attachment 2] and surface quality report [Attachment 3].

VOC Emissions Testing Results

The AQMD conducted seventy-nine source tests. However, the results presented in this report exclude data from seven source tests that were rejected for cause. For two of the tests, catalyst was not added to the sprayed gel coat. For two other tests, the gel coat material was found to have unusually low viscosity and contamination was suspected. Finally, three other tests were determined to be statistical outliers, based on the U.S. EPA Dixon test. The results of the VOC emissions tests are summarized in the following sections.

(a) Average Tip Pressure of the Nonatomizing and Air-Assisted Airless Gel Coat Spray Applications Equipment

The AQMD measured the air pressure at the tip of the spray gun using an attached liquid pressure gauge, which was calibrated and certified according to the National Institute of Standards and Testing (NIST) standards. The tip pressure was measured approximately in the middle of the spray application/VOC emission testing period.

The average tip pressure, in pounds per square inch (psi), for each spray gun manufacturer for the tested gel coat materials sprayed with the nonatomizing application equipment and the air-assisted airless application equipment are listed in Table 2.

Table 2
Average Tip Pressure
Nonatomizing and Air-Assisted Airless Gel Coat Spray Application Equipment

EQUIPMENT MANUFACTURER	GEL COAT MATERIAL AVERAGE TIP PRESSURE (PSI)			
	Clear	Midnight Blue	San Bright White	Gray Sandable
I. Nonatomizing Application				
Spray Gun Manufacturer I	460	440	470	550
Spray Gun Manufacturer II	275	300	425	550
Spray Gun Manufacturer III	400	350	700	590
Spray Gun Manufacturer IV	340	350	390	420
Average Application Pressure	370	360	500	530
II. Air-Assisted Airless Application	970	980	970	970

(b) Average VOC Emission Rates of Nonatomizing and Air-Assisted Airless Gel Coat Spray Application Equipment

The VOC emission rates of the nonatomizing and air-assisted airless applications were determined using U.S. EPA Test Method 25A and SCAQMD Test Method 25.1. Stack emission rates were calculated in pounds of VOC per ton of sprayed gel coat materials. The average VOC emission rates of the nonatomizing and air-assisted airless spray applications are listed in Table 3. The VOC emission data indicates that there were no significant differences between the emission rates of the nonatomizing and air-assisted airless spray applications. Furthermore, the VOC emission rates show no significant difference between the emission rates of the spray applications of the four (4) participant equipment manufacturers.

Table 3
Average VOC Emission Rates
Nonatomizing and Air-Assisted Airless Gel Coat Spray Application Equipment

EQUIPMENT MANUFACTURER	GEL COAT EMISSION (LB/TON)			
	Clear (40.9 %)	Midnight Blue (32.9%)	San Bright White (30.8%)	Gray Sandable (27.3%)
I. Nonatomizing Application				
Spray Gun Manufacturer I	524	233	290	221
Spray Gun Manufacturer II	402	161	277	185
Spray Gun Manufacturer III	411	204	328	225
Spray Gun Manufacturer IV	492	236	329	195
Average Emission Rate	457	209	306	207
II. Air-Assisted Airless Application	438	233	373	223

Table 3 also indicates that except for the san bright white, the average VOC emission rates of the gel coat tested materials are a function of their monomer content. The relatively higher VOC emission rates of the san bright white (30.8 percent monomer content), as compared to the VOC emission rates of the midnight blue (32.9 percent monomer content) may be attributed to the higher VOC content of the san bright white (440 g/l) as compared to the VOC content of the midnight blue (390 g/l).

(c) Examples of the Emission Profiles of the Gel Coat Nonatomizing and Air-Assisted Airless Spray Applications

Typical emission profiles of the nonatomizing and air-assisted spray application equipment of the clear, midnight blue, san bright white and gray sandable gel coat are shown in Figures 1, 2, 3 and 4, respectively.

The emission profiles of the clear, midnight blue, san bright white and gray sandable all illustrate that during the application phase, the emission rates of the air-assisted airless spray application represent 77 percent, 57 percent, 76 percent and 71 percent, of the total emission profiles, respectively. During the same phase, the emission rates of the nonatomizing spray application were 23 percent, 43 percent, 24 percent and 29 percent of the total emission profiles, respectively. The opposite trend was observed during the curing phase where the emission rates of the nonatomizing spray application equipment

were higher than the emission rates of the air-assisted airless spray application equipment.

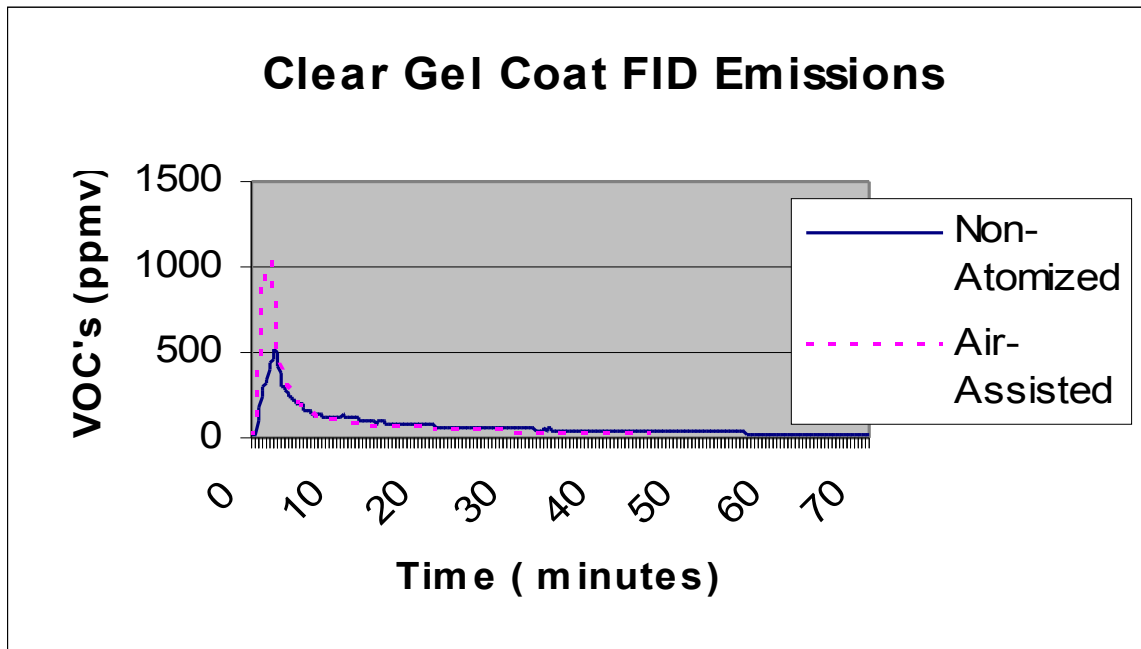


Figure 1

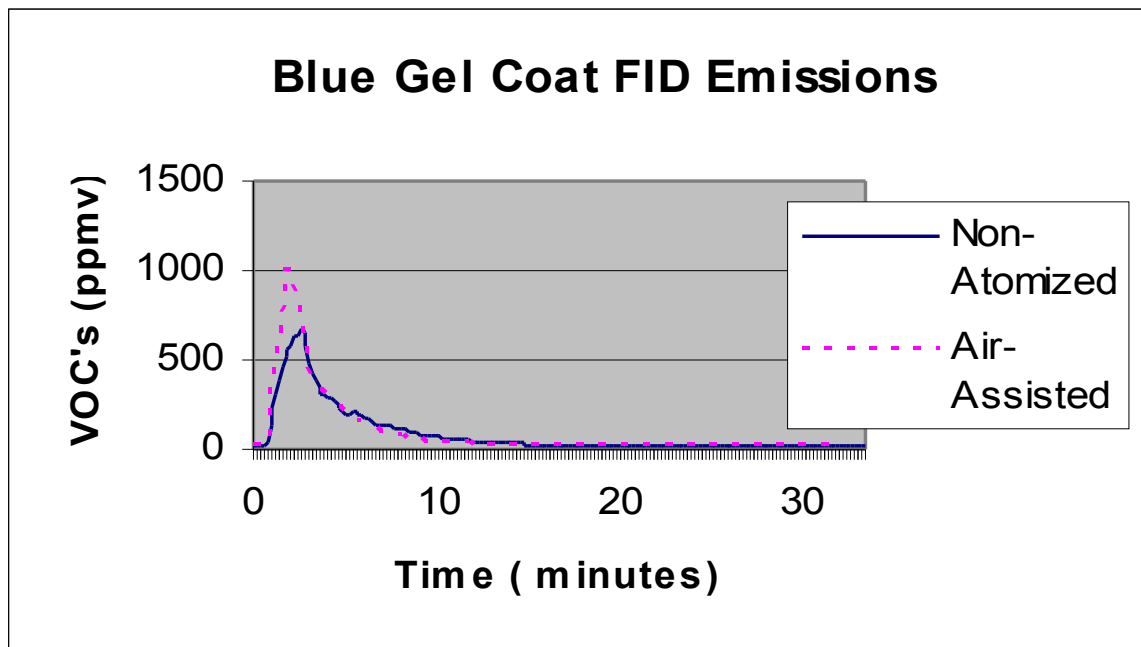


Figure 2

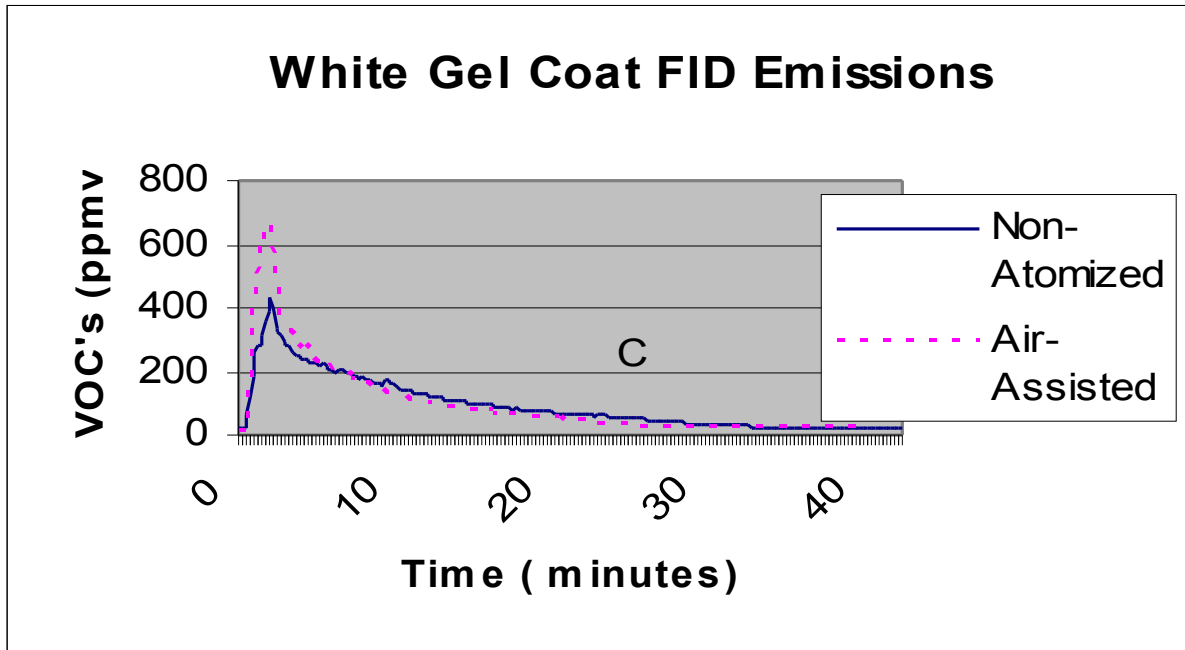


Figure 3

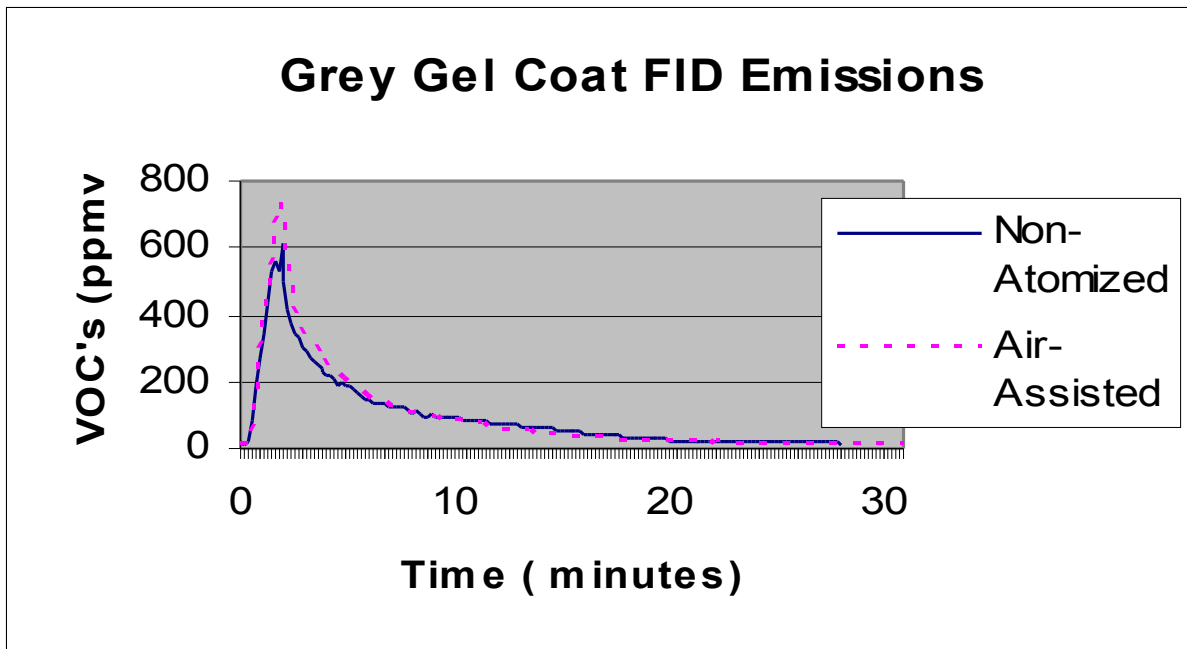


Figure 4

d) Average VOC Emission Peak Concentration (ppm) of the Gel Coat Nonatomizing and Air-Assisted Airless Spray Application Equipment

The average VOC emission peak (ppm) of the gel coat nonatomizing and air-assisted airless spray application equipment of all gel coat sprayed materials are shown in Table 4. The results indicate that the overall average VOC emission peak of the of the nonatomizing application equipment represent 44 percent of the air-assisted airless spray application equipment VOC emission peak.

Table 4
Average VOC Emission Peak (ppm)
Nonatomizing and Air-Assisted Airless Gel Coat Spray Application Equipment

GEL COAT	VOC EMISSION PEAK (PPM)		PERCENT OF A/B
	(A) Nonatomized Spray Equipment	(B) Air-Assisted Airless Spray Equipment	
Clear	380	1065	36
Midnight Blue	415	1040	40
San Bright White	420	780	54
Gray Sandable	380	730	52

(e) Average Curing Time for Gel Coat Sprayed Using Nonatomizing and Air-Assisted Airless Application Equipment

The average curing time, in minutes, for the gel coat sprayed using nonatomizing and air-assisted airless spray application equipment are shown in Table 5. The test results indicate that the overall average curing time of the air-assisted airless spray application equipment represent 76.8 percent of the nonatomizing spray application equipment overall average curing time.

Table 5
Average Curing Time (Minutes)
Nonatomizing and Air-Assisted Airless Gel Coat Spray Application Equipment

GEL COAT	CURING TIME (MINUTES)		PERCENT OF A/ B
	(A) Air-Assisted Airless	(B) Nonatomized	
Clear	47.3	73.0	64.8
Midnight Blue	26.5	27.0	98.1
San Bright White	35.3	39.7	88.9
Sandable Gray	27.7	38.3	72.3

(f) Reproducibility of the VOC Emission Rates of the Gel Coat Testing Program- Comparison of the Initial and the Retest Results

To determine the temporal variations of the VOC emission rates of the Gel Coat Testing Program, the initial and the retest VOC emission rates of the nonatomizing and air-assisted airless spray application equipment are listed in Table 6 and Table 7, respectively. The initial VOC emission rates were collected during late August and early September 2004, and the retest data were obtained during early October 2004. The results illustrate the reproducibility of the VOC emission rates despite the changes in the viscosity of the gel coat tested materials.

Furthermore, samples of each gel coat tested were collected near the beginning and at the end of the Gel Coat Testing Program and analyzed by the AQMD laboratory. The analyses of the VOC content of the clear, midnight blue, white and gray sandable gel coats show that the VOC content, 440, 390, 440, 370 grams per liter (g/l), respectively, did not change over the duration of the testing program.

Table 6

**Reproducibility of the VOC Emission Rates
Nonatomizing Spray Application Equipment
Comparison between the Initial and Retest VOC Emission Rates**

EQUIPMENT MANUFACTURER	GEL COAT MATERIAL	MONOME R CONTENT PERCENT	VOC EMISSION RATES*	
			Initial Tests Average (lb/ton)	Retest Average (lb/ton)
Spray Gun Mfg I	White	30.8	341	307
Spray Gun Mfg I	Gray	27.3	197	190
Spray Gun Mfg II	Clear	40.9	522	531
Spray Gun Mfg II	White	30.8	287	298
Spray Gun Mfg II	Gray	27.3	214	239
Spray Gun Mfg II	Blue	32.9	216	283

* VOC Emission Rates Measured in Pounds of VOC Emissions per Ton of Gel Coat Sprayed Materials

Table 7

**Reproducibility of the VOC Emission Rates
Air-Assisted Airless Spray Application Equipment
Comparison between the Initial and Retest VOC Emission Rates**

SPRAY EQUIPMENT	GEL COAT MATERIAL	MONOME R CONTENT PERCENT	VOC EMISSION RATES*	
			Initial Tests Average (lb/ton)	Retest Average (lb/ton)
Air-Assisted Airless	Clear	40.9	446	421
Air-Assisted Airless	Blue	32.9	216	266
Air-Assisted Airless	White Clear	30.8	365	389

Air-Assisted Airless	Gray	27.3	206	257
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* VOC Emission Rates Measured in Pounds of VOC Emissions per Ton of Gel Coat Sprayed Materials

Surface Quality Testing Results

The results surface quality testing on the gel coat film samples produced during the Gel Coat Testing Program are summarized below.

(g)(1) Summary of the Porosity Testing Results

Table 8 summarizes the total number of porosity samples tested and the number of samples with porosity for both the nonatomizing and air-assisted airless spray application equipment. The results indicate that there were no significant differences between the porosity of the nonatomizing and air-assisted airless spray application equipment and the percentage of porosity in all the tested samples is less than 4 percent.

Table 8
Summary of the Porosity Test Data

<i>Equipment Manufacturer</i>	<i>Porosity Samples</i>	
	Number of Samples	Number of Samples With Porosity
Nonatomizing Application		
Spray Gun Manufacturer I	38	0
Spray Gun Manufacturer II	96	0
Spray Gun Manufacturer III	64	2
Spray Gun Manufacturer IV	32	4
Air-Assisted Application	32	4
Total Number of Samples	262	10

(g)(2) Maximum Porosity of Different Gel Coat Tested Materials

Table 9 lists the maximum porosity measured for the gel coat materials tested for each spray equipment manufacturer. The results showed that the maximum allowable voids are less than eight (8) which in compliance with ANSI Z124 standard; the maximum

allowable count of small voids in the two test areas are 8 and no large voids are allowed. Furthermore, no large porosity voids (> 1/16 “diameter) were observed (except for the clear gel coat nonatomizing spray application equipment of spray equipment manufacturer IV where three (3) large voids were observed).

Table 9
Maximum Porosity of Gel Coat Materials Tested

EQUIPMENT MANUFACTURER	POROSITY							
	Clear		Midnight Blue		San Bright White		Sandable Gray	
	Voids <1/16	Voids >1/16	Voids <1/16	Voids >1/16	Voids <1/16	Voids >1/16	Voids <1/16	Voids >1/16”
I. Nonatom. Appl. Spray Gun Mfg I	0	0	0	0	0	0	0	0
Spray Gun Mfg II	0	0	0	0	0	0	0	0
Spray Gun Mfg III	0	0	0	0	0	0	3	0
Spray Gun Mfg IV	2	3	0	0	0	0	1	0
II. Air-Assisted Airless Appl.	0	0	0	0	3	0	1	0

(h)(1) Summary of the Gloss Testing Results

Table 10 is a summary of the gloss testing results. The results indicate that 20 percent of the samples tested did not meet the acceptable gloss standard required by the majority of the composite industry, which is equal or greater than 80.

Table 10
Summary of the Gloss Testing Results

Equipment Manufacturer	Gloss Samples	
	Number of Samples	Number of Samples With Gloss (≤ 80)
I. Nonatomizing Application		
Spray Gun Manufacturer I	48	9
Spray Gun Manufacturer II	144	29
Spray Gun Manufacturer III	96	13

Spray Gun Manufacturer IV	48	7
II. Air-Assisted Airless Appl.	48	7
Total Number of Samples	384	65

(h)(2) Gloss Values of Gel Coat Tested Materials at 20° and 60° Geometry.

Table 11 lists the average gloss values of the gel coat tested measured at 20° and 60° geometry. The results indicate that the average gloss values of the gel coat tested materials were within or above the composite industry standard for all gel coat types, except for the white gel coat gloss values at 20° geometry for both nonatomizing and air-assisted airless application equipment.

Table 11
Average Gloss Values
Gel Coat Tested Materials at 20° and 60° Geometry

EQUIPMENT MANUFACTURER	GEL COAT MATERIAL							
	Clear		Midnight Blue		San Bright White		Sandable Gray	
	20 ⁰	60 ⁰	20 ⁰	60 ⁰	20 ⁰	60 ⁰	20 ⁰	60 ⁰
I. Nonatomizing Application								
Spray Gun Manufacturer I	88	93.3	80.8	89.9	71	87.6	82.5	91.1
Spray Gun Manufacturer II	78.9	95	80.9	91	66.9	85.5	82.2	91
Spray Gun Manufacturer III	79.3	92	83	93.4	76.7	89.9	84.6	94
Spray Gun Manufacturer IV	85.4	93.8	--*	--*	78.8	91.5	83	91.9
II. Air-Assisted Airless Appl.	86.6	93.3	81.5	90.3	75	90.1	77	89.2

*Surface quality samples of the midnight blue of the spray gun manufacturer IV were not available for analyses as the midnight blue gel coat was sprayed without a catalyst.

(i)(1) Summary of Orange Peel Testing Results

Table 12 represents the orange peel testing results which showed that none of gel coat samples exceeded the composite industry standard for orange peel (rating equal to or less than 10).

(i)(2) Average Orange Peel Ratings Using Distinctness of Image (DOI) Panels

Table 13 illustrates that the orange peel ratings of the nonatomizing and air-assisted spray application equipment did not exceed the composite industry standard of equal to or less than 10).

Table 12
Summary of the Orange Peel Testing Results

<i>Equipment Manufacturer</i>	<i>Orange Peel Samples</i>	
	Number of Samples	Number of Samples With Orange Peel (>10)
I. Nonatomizing Application		
Spray Gun Manufacturer I	24	0
Spray Gun Manufacturer II	72	0
Spray Gun Manufacturer III	48	0
Spray Gun Manufacturer IV	24	0
II. Air-Assisted Airless Appl.	24	0
Total Number of Samples	192	0

Table 13
Average Orange Peel Rating of Tested Gel Coats

EQUIPMENT MANUFACTURER	GEL COAT MATERIALS			
	Clear	Midnight Blue	San Bright White	Gray Sandable
I. Nonatomizing Application				
Spray Gun Manufacturer I	8.4	9.9	8.8	9.0
Spray Gun Manufacturer II	8.1	9.3	7.9	8.8
Spray Gun Manufacturer III	7.7	8.5	8.8	8.9
Spray Gun Manufacturer IV	9.0	*	9.1	9.0
II. Air-Assisted Airless Appl.	9.9	9.5	10	9.0

Draft Report

*Surface quality samples of the midnight blue of the spray gun manufacturer IV were not available for analyses as the midnight blue gel coat was sprayed without a catalyst.

(j)(1) Summary of Water Resistance Rating Results

Table 14 includes the total number of water resistance samples tested and the number of samples that failed to meet the ANSI Z124 standard which states that the water resistance rating shall not exceed nine for the five major defects and four for any one of them. The results illustrate that no gel coat samples tested failed the standard.

Table 14
Summary of Water Resistance Rating Results

<i>Equipment Manufacturer</i>	<i>Water Resistance Rating Samples</i>	
	Number of Samples	Number of Samples Failed Test
I. Nonatomizing Application		
Spray Gun Manufacturer	80	0
Spray Gun Manufacturer II	440	0
Spray Gun Manufacturer III	360	0
Spray Gun Manufacturer IV	160	0
II. Air-Assisted Airless Application	80	0
Total Number of Samples	1,120	0

(j)(2) Average Water Resistance Rating of Gel Coats

Table 15 represents the average water resistance rating of gel coat samples tested of both the nonatomizing and air-assisted airless application equipment. The results showed that the water resistance ratings of gel coat samples were within the range of ANSI Z124 standard.

Table 15
Average Water Resistance Ratings of Tested Gel Coats

EQUIPMENT MANUFACTURER	GEL COAT MATERIAL			
	Clear	Midnight Blue	San Bright White	Gray Sandable
I. Nonatomizing Application				
Spray Gun Manufacturer I	5.5	4.8	5.0	6.6
Spray Gun Manufacturer II	4.5	5.0	3.2	6.0
Spray Gun Manufacturer III	3.5	5.0	3.0	8.2
Spray Gun Manufacturer IV	2.8	*	4.0	6.0
II. Air-Assisted Airless Application	4.0	5.0	4.0	6.0

*Surface quality samples of the midnight blue of the spray gun manufacturer IV were not available for analyses as the midnight blue gel coat was sprayed without a catalyst.

CONCLUSIONS

Based on the VOC emissions and surface quality results from the Gel Coat Testing Program, the AQMD has concluded the following:

- ✓ Pressure measurement at the tip of the gun is feasible and enforceable. For each gel coat tested, the tip pressures of the four spray equipment manufacturers were similar. The tip pressures of the four tested gel coats were different and related to the viscosity of the gel coat material.
- ✓ Stack emissions indicate that the nonatomizing spray application equipment in most instances resulted in equivalent or lower emission rates compared to air-assisted airless spray application equipment. However, the difference between the VOC emission rates of the nonatomizing and air-assisted airless spray application equipment was not significant. Furthermore, there were no significant differences between the VOC emission rates of the spray application equipment of the four participant spray equipment manufacturers.
- ✓ The VOC emission profile of the gel coat spray application equipment consists of two phases, the application phase and the curing phase which represent 55 percent and 45 percent of the total emission profile, respectively. During the application phase, the emission rate of the air-assisted airless spray application equipment was higher than the nonatomizing spray application equipment. However, the opposite was observed during the curing phase. Interestingly, the total VOC emissions for both the air-assisted airless and the nonatomizing spray application equipment were approximately the same.
- ✓ The Gel Coat Testing Program started on August 23 and continued through October 14, 2004. Regardless of some changes in the viscosity of the testing gel coat materials during the testing period, the VOC emission rates for the same gel coat materials were reproducible at the end of the testing period.

In conclusion, the Gel Coat Testing Program results demonstrate that the pressure at the tip of the gun is a feasible and an enforceable measure to define the nonatomizing spray application technique of gel coats; however, the test results also show that this is very little difference in the measured VOC emission reductions between the use of the nonatomizing spray application equipment and the air-assisted airless spray application equipment.

REFERENCES

CFA Styrene Emissions Test Protocol & Facility Certification Procedures Revision 2.2 (March 1999)

R.A. Haberlein, "Technical Discussion of the United Emission Factors for Open Molding Composite," Engineering Environmental, July 17, 2001.

South Coast Air Quality Management District, "Final Staff Report For Proposed Amended Rule 1162-Polyester Resin Operations," July 9, 2004.

South Coast Air Quality Management District, "Final Staff Report For Proposed Amended Rule 1162-Polyester Resin Operations," July 11, 2003.

South Coast Air Quality Management District, "Final Staff Report For Proposed Amended Rule 1162-Polyester Resin Operations," November 9, 2001.

ATTACHMENT 1:

**AQMD TEST PROTOCOL
FOR NONATOMIZING SPRAY APPLICATION TECHNIQUES FOR GEL COATS
(JULY 2004)**

FINAL
TESTING PROTOCOL OF THE NONATOMIZING SPRAY APPLICATION
TECHNIQUE (NSAT) OF GEL COATS

Objective

Determine the minimum applicable pressure values that produce surface qualities in accordance with the composite industry standards and measure the associated emission rates.

Testing Criteria

- The stack emission rate of each gel coat application.
- The performance of gel coat applications/surface quality of the sprayed composite part shall comply with industry standards listed under “Application Performance”.
- The pressure values at the tip of the spray gun for each gel coat application.

Testing Methods

- USEPA Method 204 (Temporary/Permanent Enclosure) - 100% capture efficiency).
- USEPA Method 1 (Sample and Velocity Traverse for Stationary Sources).
- USEPA Method 25 A (Determination of Total Gaseous, Organic Concentration Using Flame Ionization Detector).

Testing Location

Testing will be conducted in LASCO Bathware research and development facility at 3255 E. Miraloma Street, Anaheim, CA 92806.

Testing Guidelines

Flow Rate

The gel coat flow rate shall be calibrated each spraying application and shall be kept within the average flow rate of the majority of composite operations (2.5 to 3.5 pounds per minute).

Gel Time

Gel coat materials shall be adjusted to a specific gel time by adjusting the level of initiators to produce the required gel time within ± 1.5 minute. Gel time will be determined prior to testing.

Film Thickness

The gel coat film thickness shall be maintained within 20 ± 2 mils which represents the average industry gel coat film thickness.

Application Temperature

The application temperature of the gel coat material shall be maintained within 80 to 90 °F and measured at the outlet of the spraying application. The testing will be conducted at the ambient air temperature of the spraying facility.

Application Performance

For each sprayed gel coat, an air- assisted airless application shall be used to compare the performance and the emissions of the nonatomizing and atomizing spray application techniques. Application performance shall be evaluated based on the gel coat sprayed onto two (2) horizontally positioned “12 inches by 12 inches” formica plates using the following surface quality tests:

1. Gloss test using ASTM D 523
2. Orange Peel test using BYK- Gardner
3. Porosity test using ANSI Z 124
4. Water Resistance using ANSI Z 124

Number of Tests

To verify the reproducibility of the testing data, each spray equipment manufacturer will conduct twelve (12) tests including three (3) runs of clear, white, navy and sandable gel coats using the nonatomizing spray application technique. In addition twelve (12) tests of the same gel coats will be conducted using air-assisted airless spray application technique by one manufacturer.

Mold Configuration

Each gel coat shall be sprayed onto a mold that is identical in dimensions and configuration to the mold used to develop the gel coat emissions rates of the UEFs (CFA, 1999).

Shaping Air/Air Assist

If a gel coat spraying application utilizes shaping air to improve its spraying pattern, the air pressure shall be recorded.

ATTACHMENT 2:

**VOC EMISSIONS FROM GEL COAT SPRAYING USING
FOUR NON-ATOMIZING AND TWO AIR ASSISTED AIRLESS SPRAY GUNS (2004)**

SOURCE TEST REPORT

04-0229 through 04-0236

VOC Emissions from Gel Coat Spraying Using Four Non-Atomized and Two Air Assisted Airless Spray Guns

TESTED: August 24 - October 14, 2004

ISSUED:

REPORTED BY: Wayne A. Stredwick
Air Quality Engineer II

REVIEWED BY:

Michael Garibay
Supervising Air Quality Engineer

SOURCE TEST ENGINEERING BRANCH

MONITORING AND ANALYSIS DIVISION



Source Test No. 04-229 – 04-236

-2-

Dates 8/24/04 – 10/14/04

BACKGROUND

a. Host Test Facility.....Lasco Bathware

b. Test Location.....3255 E. Miraloma Ave., Anaheim, CA 92806

c. Unit Tested.....Experimental Spray Booth and Gel Coat Spraying

d. Test Requested by.....Laki Tisopulos, Asst. DEO Planning & Rules

e. Reason for Test Request.....Measure Gel Coat Emissions / Spray Quality

f. Date of Test.....August 24 through October 14, 2004

g. Source Test Performed by.....Michael Garibay, Ron Lem,
Carey Willoughby, Wayne Stredwick, Glenn Kasai

h. Test Arrangements Made Through.....Ricardo Gutierrez, Environmental Manager
Lasco Bathware, (714) 961-9735

- Laki Tisopulos, SCAQMD
- Larry Bowen, SCAQMD
- Ed Muehlbacher, SCAQMD
- Helmy Sultan, SCAQMD
- Stacy Farley, Lasco
- Victor Prismantas, Lasco
- Ricardo Gutierrez, Lasco
- Manny Gonzalez, Lasco
- Terry Pe, Lasco
- Robert Haberlein, ACMA
- Dewey Smith, ITW
- Paul Rossi, ITW
- Brad Walter ITW
- Chad Macer, GlasCraft
- Gary Smith, GS Manufacturing
- Gary Smith Jr., GS Manufacturing
- Rod Dean, MVP
- Lee Lesrcer, MVP
- Denny Fink, Norac
- Chris Kelly, Norac
- Steve Saul, Ashland Chemical

i. Source Test Observed by.....Dan Riley, Ashland Chemical



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RESULTS

VOC Average Emissions Comparison by Gun Type and Gel Coat Color

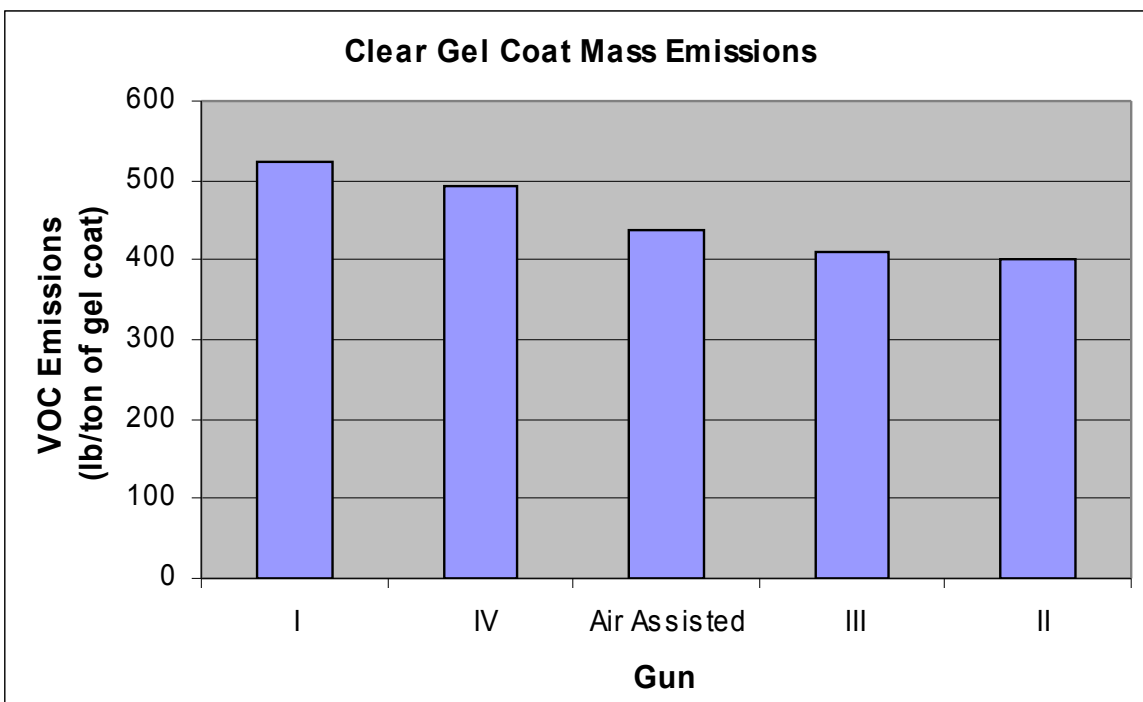
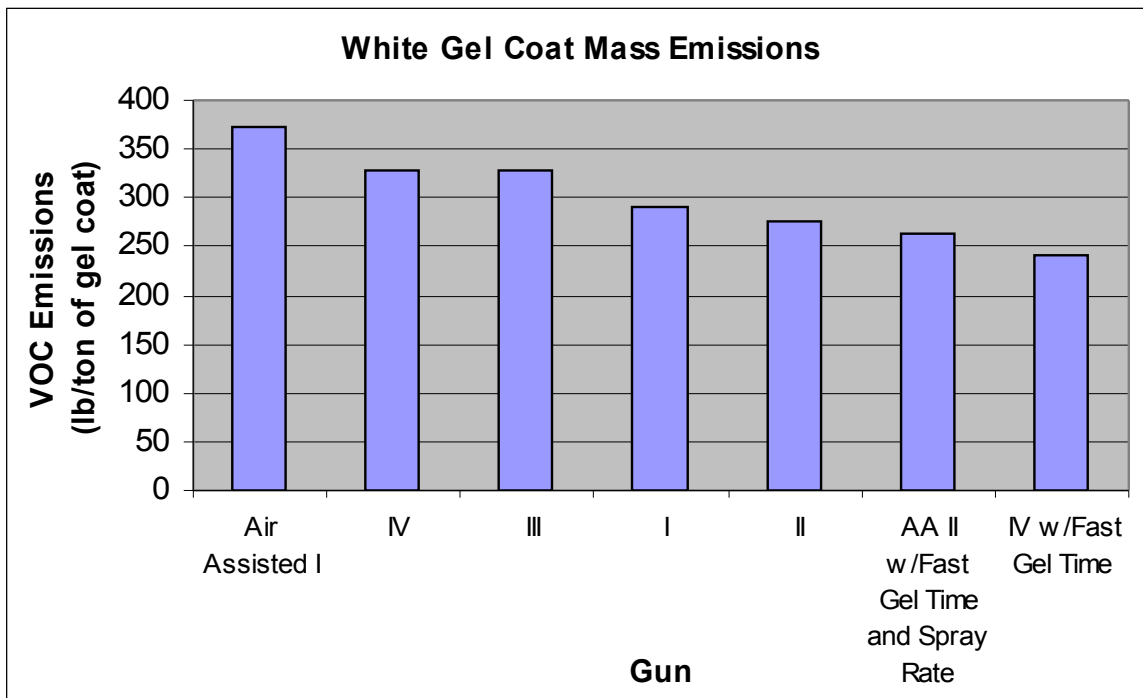
Gel Coat Spray Gun	Gel Coat VOC Emissions (lb/ton)				
	Clear	Bright White	Blue	Gray	Fast Gel Time White
Non-Atomized Application					
Gun I	524	290	233	221	
Gun II	402	277	161	185	
Gun III	411	328	204	225	
Gun IV	492	329	236	195	241
Non-Atomized Average	457	306	209	207	
Atomized Application					
Air-Assisted-Airless I	438	373	233	223	
Air Assisted Airless II with High Spray Rate					263

For a complete set of individual test results for all 79 test runs and operating data during testing, see results table in Appendix A.



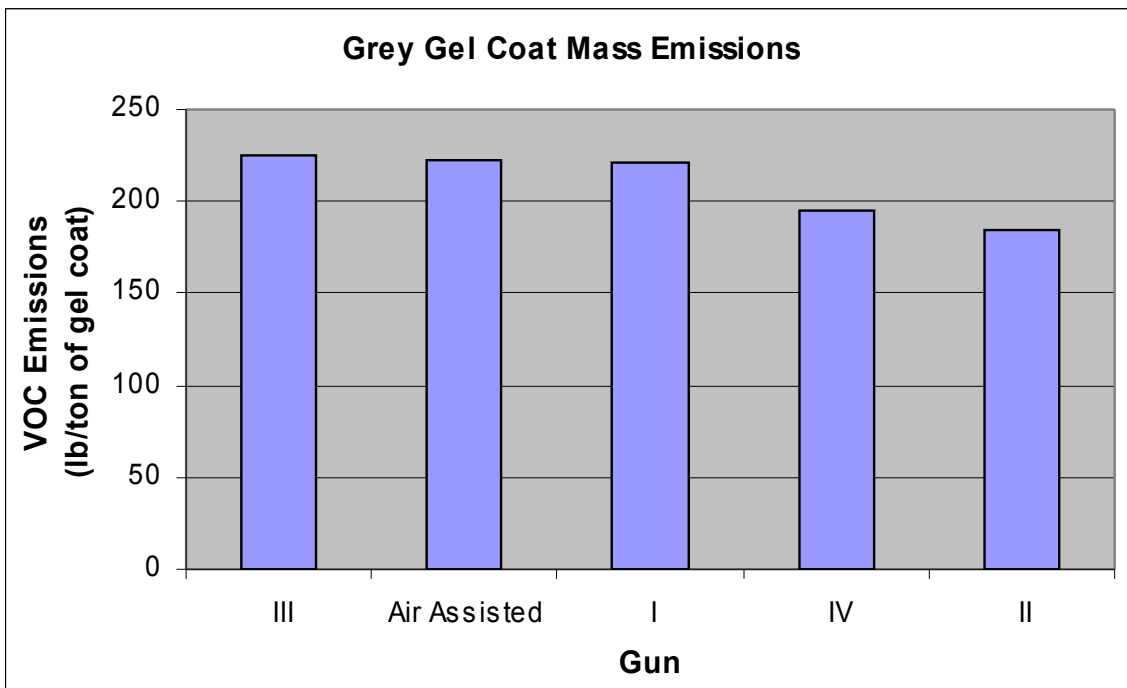
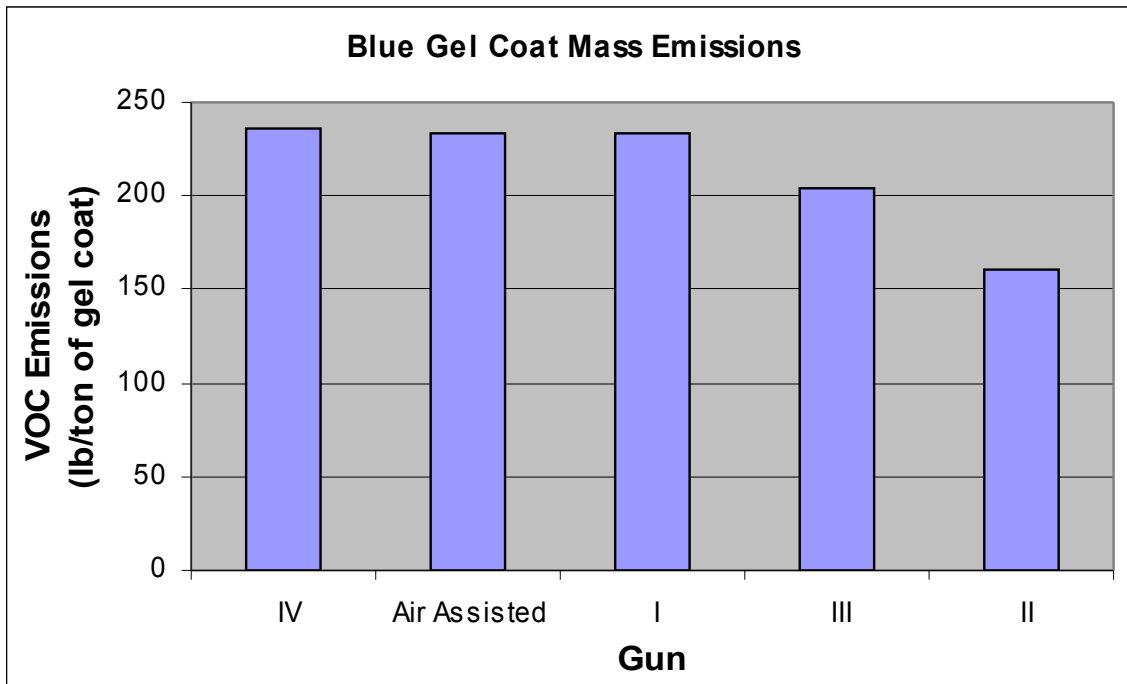
RESULTS (continued)

Bar Graph Representation of VOC Emissions Sorted by Gel Coat Color





RESULTS (continued)





INTRODUCTION

During the Summer and Fall of 2004, personnel from the South Coast Air Quality Management District (SCAQMD) Source Test Engineering (STE) Branch conducted source tests at a host fiberglass composite facility in the local area. The objective of the testing was to measure Volatile Organic Compound (VOC) emissions from Non-Atomized (NA) gel coat spray applications. The testing follows a previous study dated September 1996 conducted by the Composite Fabricators Association (CFA), now known as the American Composite Manufacturers Association (ACMA). The results of the testing will be used by the SCAQMD Planning and Rules group as information for the purpose of amending Rule 1162 which is currently in progress.

The testing was intended to address concerns regarding developing an enforceable means to assure that in practice, Non-Atomized gel coat spray guns are being operated in a manner that achieves the emission reductions as represented by the existing emission factors, which were based on the previous CFA testing. According to the CFA/ACMA, monitoring pressure at the spray gun tip by a gauge, as supplied by the gun manufacturer, may be utilized as this enforceable means. The current testing effort, therefore, was intended to verify whether spray gun tip pressure may be used to ensure the emission reductions as indicated by existing emission factors. Additionally, the gel coat product performance and surface quality were to be measured. As such, each of the gun manufacturers and operators was asked to configure and operate their gun in a manner which would minimize emissions, provide an acceptable surface quality, and simulate “real world” conditions. To monitor the performance and surface quality, sample plates were placed on top of the test mold prior to each test run for evaluation.

The testing was conducted using Non-Atomized spray guns from four manufacturers. As a comparison, an Air-Assisted Airless spray gun was also tested. Multiple test runs were conducted for each of these five guns, and for each of four gel coat colors: Bright White, Clear, Sandable Grey, and Midnight Blue. Two of the Non-Atomized guns and the Air Assisted gun were retested at the completion of the project to collect additional surface quality samples, and to investigate temporal effects on the testing. Additionally, a test of a faster setting gel coat, with an Air Assisted Airless spray gun and high volume application practices was also conducted. This faster setting gel coat was also tested with one Non-Atomized gun. Other than this emphasis on product spraying quality and the sampling for coating performance and surface quality, the testing was conducted much in the same manner as the previous CFA testing. At the request of the gun manufacturers, the individual spray guns are labeled generically with Roman numerals, so that the guns remain anonymous with respect to the test results.



PROCESS DESCRIPTION

Process Overview

The host facility operates an open molding process to manufacture composite bathtub and shower units in the local Southern California area. Gel coats, resins, fiberglass, and other composite materials are applied on an open mold using spray-up applications.

During the gel coat application stage, polyester resins are atomized and sprayed onto a mold. The gel coats contain styrene or styrene and methyl methacrylate, which participate in cross-linking the resin molecules. The cross linking process is initiated by mixing the gel coat with an initiator (referred to as a catalyst) at the spray tip as the gel coat is applied. The catalyst is most often an organic peroxide, in this case methyl ethyl ketone peroxide (MEKP), which is a strong oxidizer that removes an inhibitor present in the gel coat formulation. Once the inhibitor is removed, the cross-linking process initiates. After spraying, the wet resin material polymerizes on the mold. Overspray emissions from the application step, and styrene emissions not cross-linked in polymerization during curing, are captured in the spray booth and emitted into the atmosphere.

Background

For years, the composites industry relied on EPA Table AP-42 emission factors for determining emissions from open molding operations. In 1999, the then CFA and National Marine Manufacturers Association (NMMA) conducted testing that developed new emission factors. Consequently, the EPA withdrew the AP-42 emissions factors in favor of the CFA and NMMA merged data which became known as the Unified Emission Factors (UEF).

In the summer of 2004, the SCAQMD Source Test Engineering (STE) branch was asked to review the CFA open mold styrene emissions report, and to incorporate the CFA testing protocol, using CFA testing procedures and methods for the current effort. Subsequently, open mold styrene testing was performed from August to October of that year.



TESTING METHODOLOGY

The testing quantified VOC emissions from test runs while applying the gel coats using standard industry practices, materials, and equipment. Commercially available gel coat was supplied by Ashland Chemical and Cook Composites and Polymers Co. Five gel coats were tested (See Appendix B for Material Safety Data Sheets). MEKP was used as the gel coat catalyst for all testing. The catalyst ratio to gel coat was 2% by volume, with the exception of the fast setting gel coat tests which used 1.8% catalyst. The mold used for testing was a three sided male mold constructed by Gruber Systems of Valencia, CA. The mold was a replica of the mold used for the *1996 CFA Phase I Baseline Study*. The outside 3 inches of the mold perimeter were taped with an approximate 10 inch width of paper for each run, which had the effect of excluding the mold edge overspray in the project.

Four different spray gun manufacturers supplied the Non-Atomized gel coat spray guns. Two Air-Assisted Airless spray guns were also tested.

Testing was conducted in an isolated spray booth supplied by the host facility. Emissions in the spray booth were exhausted through a stack on the building's roof to the outside. Emissions resulting from the gel coat spraying were quantified by approved EPA and SCAQMD test methods, as specified in the following *SAMPLING AND ANALYTICAL PROCEDURES* Section. The emissions reported in the *RESULTS* section of the report are the average of those as determined by SCAQMD Method 25.1 and EPA Method 25A.

The testing was initiated after a stable background VOC concentration was achieved. The spray gun operator then sprayed the gel coat on the test mold and glass plates at a prescribed flow rate. An application flow rate of 2.5 – 3.5 lb/min was used for the tests, with the exceptions of the clear gel coat tests which were sprayed at lower rates (at the gun manufacturer's recommendation), and the fast gel time gel coat tests, which were sprayed at higher rates. These flow rates were intended to act as representative of "real world" practices. Gel coat film thickness and usage were recorded. The gel coat sprayed glass plates placed on the top of the mold surface for each run were used to determine gel coat surface quality. VOC emissions were monitored during the application and curing stages. The testing started just prior to when gel coat was applied to the mold surface, and ended when the gel coat was completely cured and the monitored concentration returned to a baseline concentration.

All tests were conducted in triplicate to permit statistical analysis of the results. Emission results are presented in pounds of VOC per ton of gel coat sprayed (lb VOC/ton of gel coat).



SAMPLING AND ANALYTICAL PROCEDURES

EPA Method 204 – Criteria for a Temporary Total Enclosure (TTE)

At the courtesy of the host facility, an existing spray booth was used to isolate, capture and convey the gel coat emissions to the exhaust stack to facilitate emissions measurements. The spray booth used for testing was 9 feet high, 20 feet wide and 24 feet long (See Figure 1). The booth was located inside a separate building from the host facility's main operations. Although the building was not temperature controlled, the ambient temperature inside the building during testing ranged from 74 to 85°F. The spray booth exhausted out the back of the booth, through filter media, to a 30 inch duct. The duct went through the building's roof and exhausted all fumes outside the building.

The spray booth's doorway was modified, and the test mold was placed inside the booth to meet EPA Method 204's criteria for a Temporary Total Enclosure. According to EPA Method 204, a Temporary Total Enclosure must meet all of the criteria as specified on the following page. An explanation of the manner in which each criteria was satisfied follows each criteria in italics.



Criteria for Temporary Total Enclosure

- Any natural draft opening (NDO) shall be at least four equivalent diameters from each VOC emitting point.

*The single NDO measured 39" x 67.5" for an equivalent diameter of 49.4".
The mold was placed 16 ft (four diameters) from the NDO.*

- Any exhaust point from the enclosure shall be at least four equivalent duct diameters from each NDO.

The exhaust point was 24' (5.8 diameters) from the NDO.

- The total area of all NDO's shall not exceed 5% of the surface area of the enclosure's four walls, floor and ceiling.

The NDO's area (18.3 ft²) was 1.0% of the surface area of the enclosure (1,752 ft²).

- The average facial velocity (FV) of air through all NDO's shall be at least 200 fpm. The direction of air flow through all NDO's shall be into the enclosure.

The average face velocity was 280 ft/min as measured at several points in a cross sectional matrix by a calibrated hot wire anemometer.

- All access doors and windows not used in calculating the NDO surface area shall be closed during routine operation of the process.

There were no access doors other than the NDO.



Figure 1 – Photographs of Spray Booth as a Temporary Total Enclosure



Stack Flow Rate

The gas velocity profile within the sampling duct was measured each day before, after, or between sampling runs using a 16 point traverse and measured at a reference point during sampling, as according to SCAQMD Methods 1.1 and 2.1. This was performed simultaneously with the pollutant sampling using a calibrated S-type Pitot tube with a calibrated differential pressure gauge, and a calibrated type "K" thermocouple with a calibrated potentiometer (See Figure 2). The apparatus was checked for leaks both before and after use by introducing a pressure head and blocking the flow at the Pitot tip. An observation of the resulting stabilization in pressure at the manometer verified the absence of leaks in the system. The stack's access ports were located using the approach of SCAQMD Method 2.1 for stacks greater than 12 inches in diameter. Using this approach, the sampling access ports were located approximately eight stack diameters downstream and greater than two stack diameters upstream from flow disturbances. This configuration meets the most preferred SCAQMD Method 1.1 requirements for measurement site location.

The volumetric flow rate was calculated for each sampling run using the stack's cross sectional area, average gas velocity during the traverse, and average reference point velocity during sampling. The flow rate was corrected to standard conditions by using the stack temperature and pressure, along with the barometric pressure measured with a calibrated aneroid barometer. Since there was no combustion involved in the process, ambient air conditions were used to determine the moisture in the gas stream. Ambient air conditions during testing were obtained from the SCAQMD air monitoring station located in Anaheim, CA.

The stack flow was also measured for cyclonic flow conditions on each test day according to SCAQMD Source Test Manual, Chapter 10. Since cyclonic flow was present in the stack, the individual velocities for each traverse were corrected to non-cyclonic conditions using the cosines of the average individual cyclonic angles, as prescribed by the method in Chapter 10.

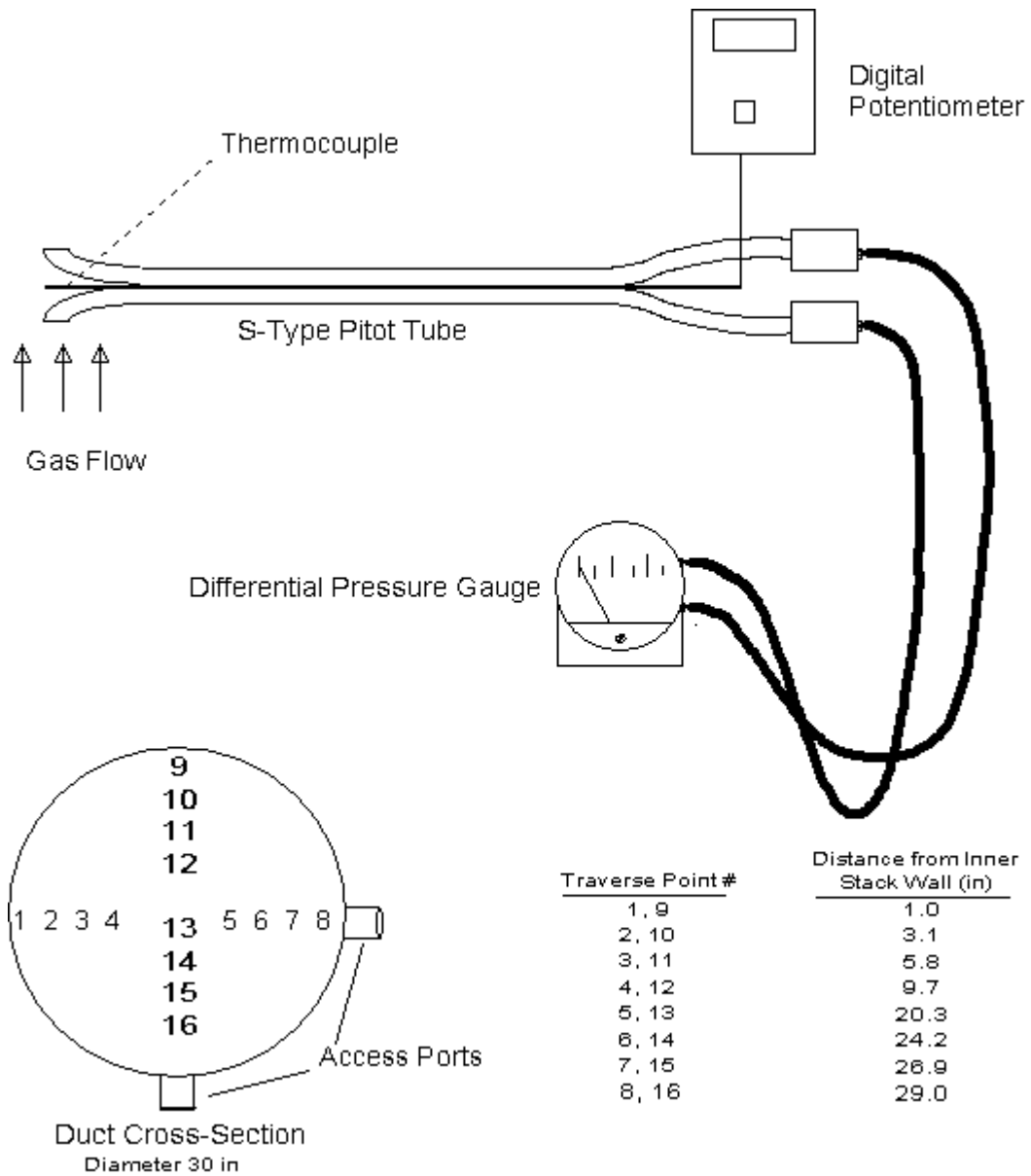


Figure 2 – Apparatus for Stack Flow Rates



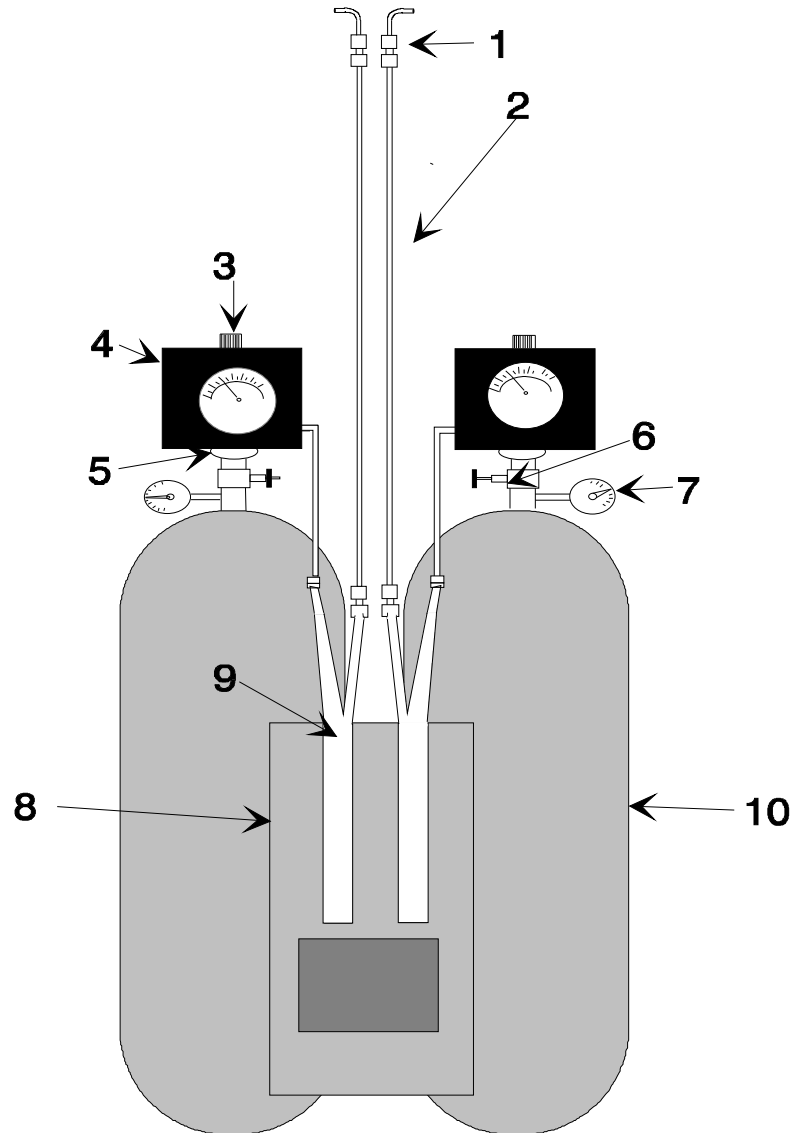
VOC Stack Concentration by SCAQMD Method 25.1

For each run, the average exhaust stack VOC concentrations were determined from duplicate integrated gas samples collected simultaneously for the period beginning just before initiating spraying until the return to background levels. The gas samples were collected in dry ice cooled condensate traps followed by nine liter evacuated tanks (Figure 3). A constant sampling rate was maintained by regulating the pressure drop across the 0.125 inch o.d. sampling probes. This method is used for VOC concentrations above 25 ppm and is reported as Non-Methane Non-Ethane Organic Compounds (NMNEOC).

The sample tanks were checked for leaks before each sampling run by observing the internal vacuum gauges over a period of several hours. An observation of a zero loss in vacuum indicated an acceptable tank leak check. The sampling apparatus was checked for leaks both before and after sampling by blocking the flow at the probe tip with a clean tubing cap and introducing a portion of the tank vacuum into the remainder of the sampling system. An observation of the resulting stabilization in the gauge for a period of ten minutes indicated an acceptable leak check.

The contents of the traps and the tanks were analyzed at the SCAQMD laboratory for methane, ethane, and NMNEOC. Methane, ethane, and NMNEOC concentrations were analyzed by the total combustion analysis (TCA) technique using a flame ionization detector (FID) as in SCAQMD Method 25.1.

This method reports the NMNEOC as carbon. A molecular weight per carbon (for example 13.0 lb/lb-molC for styrene) must therefore be determined in order to convert the ppm volume concentration to a mass emission rate. (See Appendix I for calculations) For the white and grey gel coats, the 13.0 lb/lb-molC molecular weight per carbon was used since the volatile formulation of the gel coats contained styrene only. The clear and blue gel coats are considered as “acrylic modified”, and contained a mixture of styrene and methyl methacrylate. The ratio of the two compounds in the emissions was determined and used to calculate the resulting molecular weight to carbon ratio. The gel coat formulations could not be used for this ratio due to the differing volatilities of styrene and methyl methacrylate. The ratio was determined by taking a few canister samples simultaneous with the Method 25.1 samples, and analyzing the samples for styrene and methyl methacrylate by EPA Method 18.



- | | |
|--------------------------------|-----------------------------------------|
| 1. Nozzle (pointed downstream) | 6. Shut-off Valve |
| 2. Stainless Steel Probe | 7. Tank Vacuum Gauge |
| 3. Control Valve | 8. Dry Ice Container |
| 4. Differential Pressure Gauge | 9. Stainless Steel Condensate Traps |
| 5. Flow Controller | 10. Nine-liter Stainless Steel Canister |

Figure 3 - Method 25.1 Sampling Apparatus



VOC Stack Concentration by EPA Method 25A

Continuous measurements were taken during each sampling run from the exhaust stack using a Rafisch Model RS-55 heated Total Carbon Analyzer equipped with a Flame Ionization Detector (FID). Using EPA Method 25A, the gas sample was extracted through a three-point steel probe, glass fiber filter, and unheated 1/4" Teflon tubing to the FID.

The FID was calibrated at the probe tip before and after each sampling run as specified in EPA Method 25A using a methane in air mixture. A zero and span two point calibration of the FID was conducted for each test run in the 0-1000 ppm analyzer range. A low and mid concentration gas was also tested to verify analyzer accuracy. When the gas concentration reached 10% of the analyzer range, the analyzer was changed to the 0-100 ppm range. At the lower range, a mid and high concentration gas was injected without adjusting the calibration to verify that the analyzer was still reading correctly.

Specific FID operating parameters recorded during testing may be found in Appendix C. The calibration records are located in Appendix D, and the raw data for the test runs are located in Appendix E.

Because of a concern that styrene could degrade in the tubing from temperature, UV light, and residence time, the Teflon tubing was wrapped in heat resistant fiberglass tape. To verify that there was no styrene being lost in the sample line, a Tedlar bag sample was taken at the stack during one of the sample runs. Immediately after sampling, the bag contents were sampled through the probe and full length of sampling line. The bag contents were then sampled directly into the FID analyzer and compared to the gas sample taken from the probe tip. An additional reading was also taken at the analyzer 10 minutes later. Since all three measurements were identical, it was concluded that styrene was not being lost from temperature, UV light, or residence time in the sampling line.



Mass Balance- VOC Recovery Check

Three mass recovery tests were performed using the same Ashland gel coats (clear, white and grey) that were used for testing. The gel coat was evaporated from a shallow pan after it was mixed with 2% catalyst (see Figure 4). After the catalyst addition, the gel coat was continuously mixed while a fan was used to enhance evaporation until the gel coat hardened and the baseline was re-established. The pan was weighed with a calibrated high precision scale to determine the weight loss which was assumed to be the true VOC emissions in pounds per run. Aside from the deviations discussed in this section, the mass recovery check runs were conducted in the same manner as all the other sampling runs in this project. The true VOC emissions were compared to the calculated weight based upon the measurement techniques employed in all of the other test runs using the average concentrations (ppm) obtained separately from each of Methods 25.1 and 25A. The average percent recoveries were then used to obtain a correction factor for each method.

The mass recovery tests determined that when using SCAQMD Method 25.1, the measured emissions were 109% of the true VOC emissions on average. Similarly, when using Method 25A, the measured emissions were 65% of the true VOC emissions on average. To arrive at a corrected emissions rate for all of the other test runs, a correction factor of $(1 / 1.09)$ was applied to all of the mass emissions as measured by Method 25.1 and a correction factor of $(1 / 0.65)$ was applied to all mass emissions as measured by EPA Method 25A. By employing this correction factor approach based on the mass recovery check, the test results that are reported in this report have been corrected to a true VOC emissions basis that accounts for all potential biases in the test methods and testing methodologies.

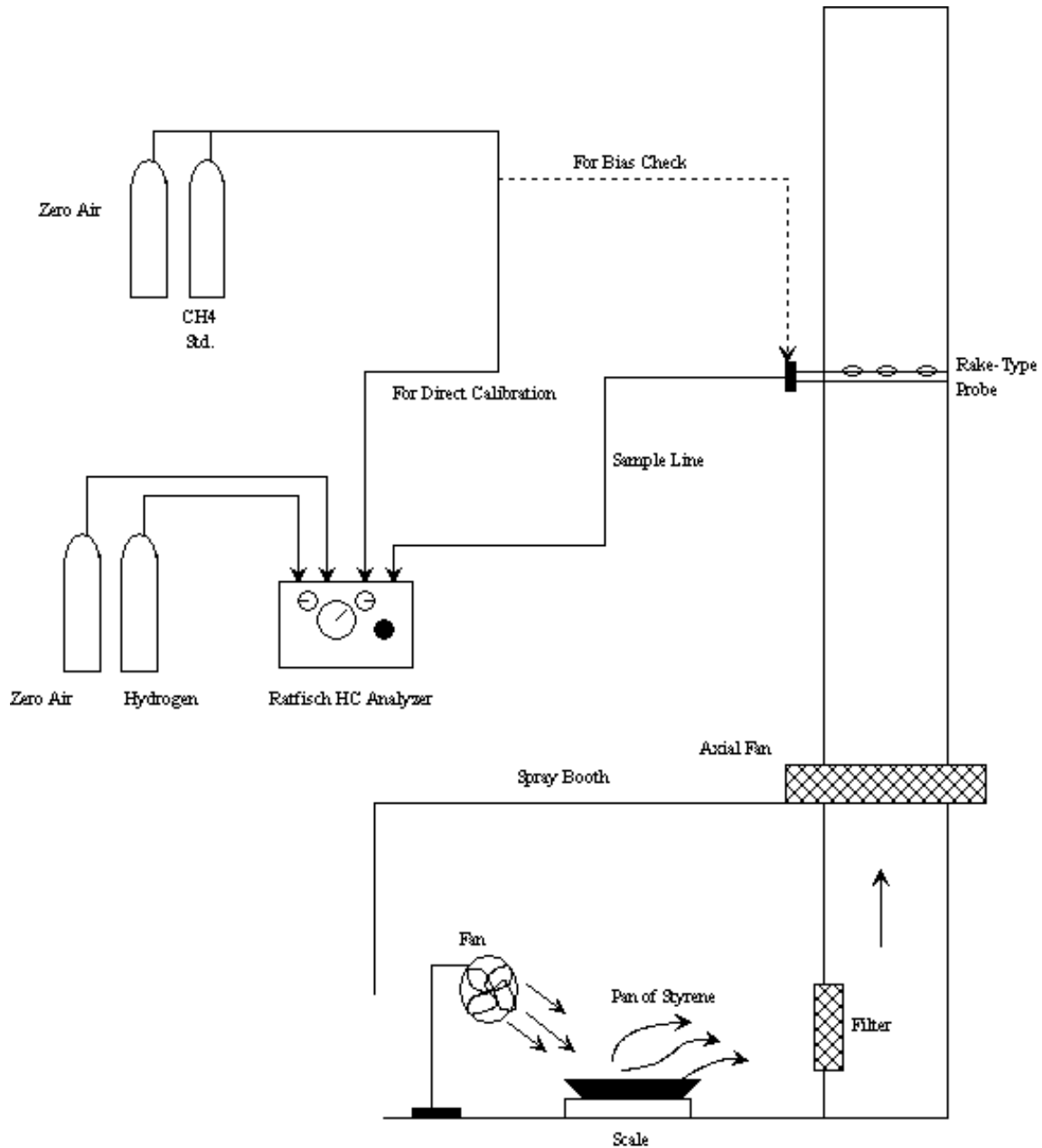


Figure 4 – Mass Recovery Check



Spray Gun Gel Coat Usage

The gel coat consumption for each test run was measured with a high precision ($\pm 0.5\text{g}$) calibrated scale placed under a covered five gallon bucket containing the gel coat. The pump pick up for each spray gun was suspended so that it did not touch the bottom of the bucket as to avoid interference with the weight measurements. The gel coat consumption weights and also the reported emissions per ton gel coat are in terms of gel coat only (excluding catalyst).

The gel coat was sprayed at a target rate of 2.5 to 3.5 lb/min of gel coat for all colors except clear. Clear was sprayed at a 1.5 to 2.5 lb/min rate. The output was controlled by adjusting the spray tip size and pump pressure. The gun operators calibrated their equipment by one of two methods. The gun output was sprayed into a cup, and either the cup was weighed for increase in weight, or the gel coat five gallon bucket was weighed for weight loss. Both methods showed equivalency. In addition to adjusting the gel coat flow, the operators also adjusted their guns to obtain the proper spray pattern. Pictures of the gel coat being sprayed on the mold showing spray patterns may be seen in Appendix F.

Gel Coat Thickness

For the tests, a standard gel coat mil thickness gauge was used. The wet film thickness target was 18-22 mils (1 mil = 0.001”). The thickness was measured on the top and sides of the mold and recorded on the Test Spray Data Sheets located in Appendix G.

Gel Coat Samples

A set of samples of each color gel coat were taken near the beginning and at the end of the project. The samples were analyzed for weight percent volatiles, water, and solids by SCAQMD Method 304. The results of the analyses as shown in the following Table I were used to show that the composition of the gel coat stored in the drums did not significantly change over the project.

Table 1 – Comparison of Pre and Post Test VOC Content

Gel Coat	Pre-Test VOC Content (g/L)	Post-Test VOC Content (g/L)
White	440	440
Grey	370	370
Blue	390	390
Clear	440	440
White w/Fast Gel Time	-	420



Spray Quality Samples

Two spray quality samples were taken for each run. The samples were taken from 12” x 12” x ¼” thick glass plates placed on the top of the mold as shown below in Figure 5. The plates were prepared by cleaning and applying multiple coats of mold release. The samples that could be removed from the glass plates were analyzed for porosity using ANSI Z124, gloss using ASTM D523, orange peel using ACT DOI, and water resistance using ANSI Z124. The results are included in Appendix H. A discussion of the surface quality results is not included in this report which will be left to discussion after the report’s issue. Please refer to the document, *AQMD Gel Coat Testing Program* which is to be included as part of the upcoming Rule 1162 board package for a discussion of the surface quality testing.

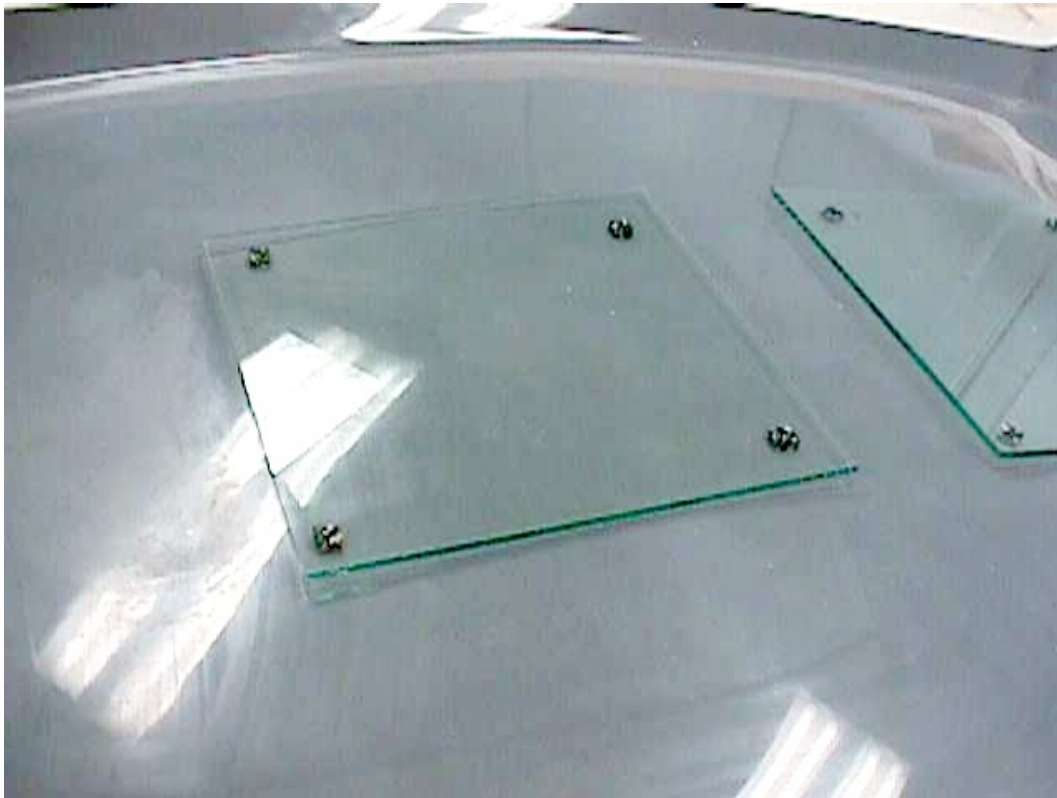
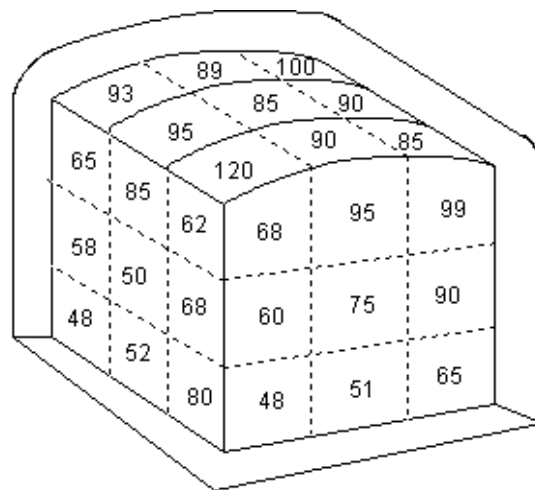


Figure 5 – Glass Sample Plates for Surface Quality

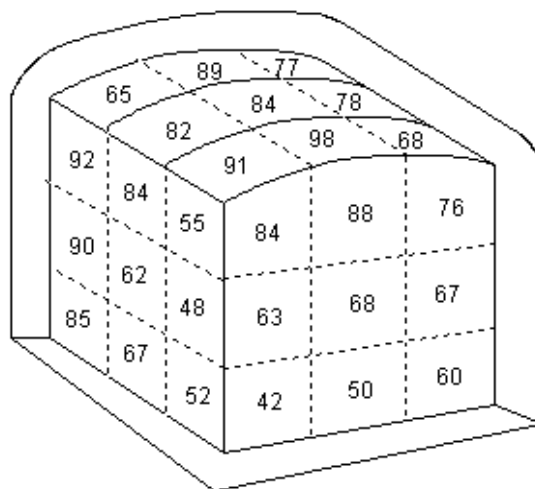


Air Flow Over the Test Mold Surface

The air flow over the mold surface was measured with a hot wire anemometer. The air flow over the mold was adjusted to range between 50 and 100 fpm as to meet the specifications of the CFA protocol. This was done by adjusting the baffle (pictured in Figure 1), located just inside the booth, to adjust the air flow from the NDO. The resulting air velocity over the mold as measured during the testing is shown below in Figure 6.



Average Air Velocity Over Mold Surface on 8/25/04 - 77 ft/min



Average Air Velocity Over Mold Surface on 9/9/04 - 73 ft/min

Figure 6 – Air Flow Over the Mold Surface



Test Procedure

The testing procedure was as follows:

- 16 point traverse and cyclonic flow angles measured to determine stack flow rate
- FID - Ratfisch Model RS 55 CA pre-calibration
- Mold masked and release agent applied
- Spray gun adjusted for gel coat usage and spray pattern
- Baseline measurements established using FID
- Ambient conditions recorded
- SCAQMD Method 25.1 testing started
- Gel coat sprayed on mold and glass plates for surface quality testing
- Gel coat usage and other operational data recorded
- Velocity reference point monitored and recorded
- FID data captured and recorded
- Test stopped after gel coat is cured and emissions return to baseline conditions
- FID post-calibration
- Equipment prepared for next test



TEST CRITIQUE

Seventy-nine (79) test runs were conducted at the host facility. Twelve (12) of the runs used an Air Assisted Airless spray gun, three (3) runs used an Air Assisted Airless spray gun with a fast gel time gel coat, three (3) runs were conducted for mass recovery check, and the remainder of the runs were Non-Atomized applications. Two (2) of the runs were rejected because of unusual gel coat viscosity, two (2) runs were rejected for lack of catalyst, and three (3) runs were considered statistical outliers by the EPA Dixon test.

The test mold had a 9 inch angular flange on six sides of its three primary planes. This flange was designed to catch overspray and may not be representative of a typical industrial mold. Additionally, following the advice of a gun manufacturer, each of the six sides of the mold was taped with an additional >10 inch width of paper (as shown in Figure 7) for each run to be consistent with past testing. Overspray produced during the test would be expected to be less than in normal production operations due to this extensive flanging and masking. As such, the reported emissions would only represent applications that are flanged and masked as pictured below. It is thought that applications which do not employ these flanging and taping practices may have significantly higher emissions, due to increased overspray effects at the mold edges, which were largely negated in this project.



Figure 7 – Mold Flanges and Masking



Cyclonic flow conditions were encountered in the exhaust stack, and calculations were made to correct to actual net flow conditions. Although ideally, cyclonic flow and correcting for cyclonic flow conditions are not desirable test conditions, the correction techniques were considered adequate and did not introduce a bias in the testing. Any potential error introduced by the cyclonic flow would have been corrected by the mass recovery correction factor approach that was used, since the same cyclonic flow techniques were used in the mass recovery determination. Furthermore, the emissions comparison based on the gun type and gel coat should not be affected, since the same techniques were involved in all calculations.

Each gun contained proprietary information and was therefore operated by each manufacturer. It is unknown how much, if any, error can be attributed to the different gun operator's spray techniques. However, each gun manufacturer optimized their gun to minimize emissions with product quality in mind.

Results using both SCAQMD Method 25.1 and EPA Method 25A gave concurring values, and the average of both methods was used in the final results. The EPA Dixon test was used to determine outliers, which were removed from the final results. The results from the initial and make-up testing phases showed generally good reproducibility as shown in the following Table II.

Table II – Reproducibility Between Initial and Make-Up Test Phases

Gun Manufacturer	Gel Coat Color	Monomer Content	Initial Average lb/ton	Make-Up lb/ton
IV	White	30.8	340	307
IV	Gray	27.3	197	190
I	Clear	40.9	522	531
I	White	30.8	287	298
I	Gray	27.3	214	239
I	Blue	32.9	216	283



CONCLUSION

A primary objective of the testing was to verify whether spray gun tip pressure could be used to indicate the Non-Atomized emission performance as indicated by existing emission factors. In the end, this objective was not achieved. Since the emissions reductions as indicated by existing emissions factors were not achieved when monitoring product quality, the evaluation of using spray pressure as an enforcement tool to achieve an emissions reductions could not be performed.

Most of the discussion of the comparison of Non-Atomized versus Air Assisted Airless emissions will be left to outside of the scope of this source test report, which is intended to present the findings and the means by which the findings were arrived. It is anticipated, however, that much of this discussion will take place over the issue that the two spraying techniques resulted in emissions much closer than those in previous findings. While the potential error of the testing is not known, it is thought that most of the measured emissions fall within the potential error range of the average for all guns for a given gel coat. It is also thought that the main reason for the closeness of the Non-Atomized and Air Assisted Airless emissions as compared to previous findings is the emphasis placed on product quality, in the current effort, resulting in an increase in Non-Atomized spray pressures.

Despite the closeness in emissions, it was observed that the Non-Atomized guns generally resulted in lower peak emission concentrations during spraying. This would suggest that at the spray pressures encountered, the Non-Atomized guns resulted in slightly decreased emissions during spraying, but slightly higher emissions during curing. The following example in Figure 8 illustrates this occurrence.

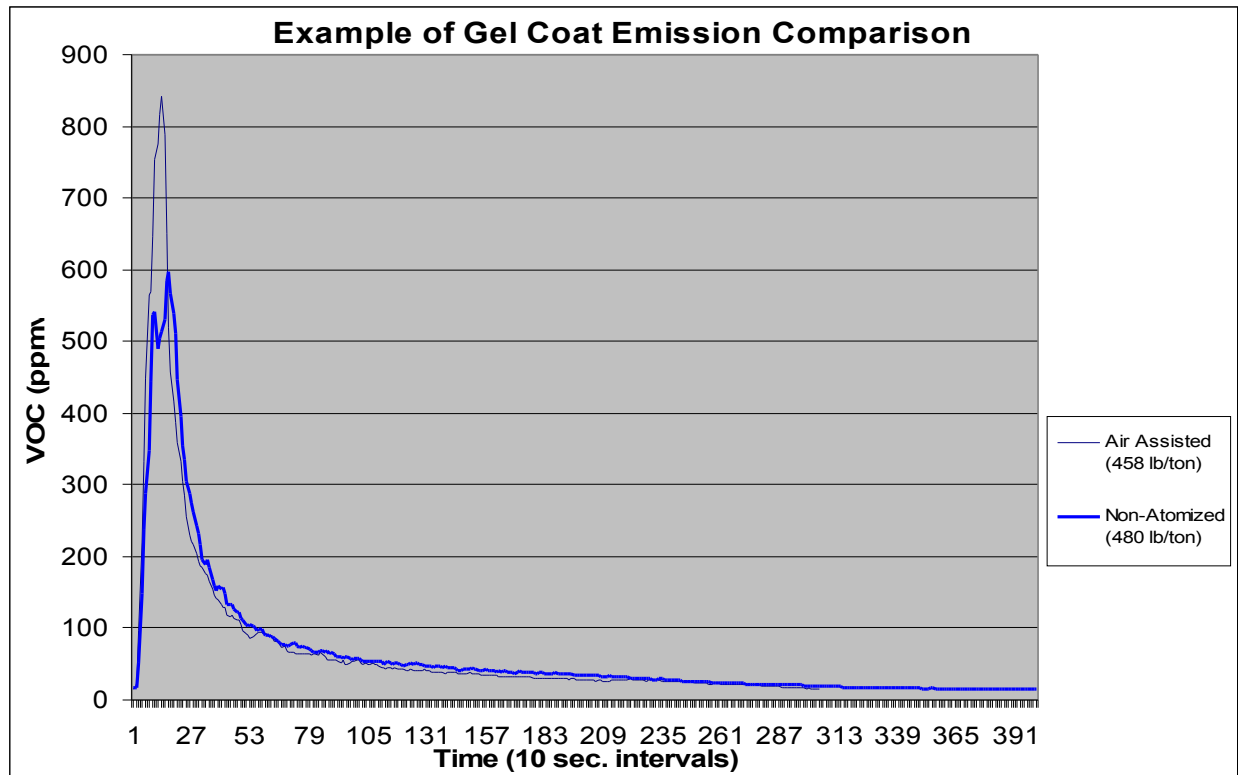


Figure 8 – Gel Coat VOC Emissions Profile

The Non-Atomized spray gun is intended to reduce overspray compared to the Air Assisted Airless gun. However, it appears that the styrene that was not lost in the application stage was subsequently lost in the cure stage, thereby negating some or much of the emission reductions. If the VOC emissions can be reduced in the curing stage, then a true VOC reduction using Non-Atomized spray guns may be more realistic. This can be seen during testing where VOC emissions were reduced by 27% (328 lb/ton Bright White gel coat versus 241 lb/ton Arctic White) when a faster setting gel coat was used with the same Non-Atomized spray gun (Gun IV).



APPENDICES

**Equipment Information, Field Data, Calibration Data, Calculations, Pictures,
and Laboratory Results**

ATTACHMENT 3:

SURFACE QUALITY TESTING OF GEL COAT NON-ATOMIZING AND AIR-ASSISTED AIRLESS APPLICATIONS (DECEMBER 27, 2004)

Surface Quality Testing of Gel Coat Non-atomizing Applications

**Testing Project Sponsored by South Coast Air Quality Management District
(SCAQMD)**

Contract No. 04198

Test Report Submitted by,

**Ray Fernando, PhD
Polymers and Coatings Program
Department of Chemistry and Biochemistry
California Polytechnic State University
San Luis Obispo, CA**

December 27, 2004

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Scope of Work

To compare the performance and surface quality of gel coat samples supplied by AQMD. The following four tests were used for the comparison.

1. Porosity Test (using ANSI Z124)
2. Gloss Test (using ASTM D523 and a BYK-Gardner Tri-gloss Meter)
3. Orange Peel Test (using ACT DOI-Distinctness of Image panels)
4. Water Resistance Test (using ANSI Z124)

The dimensions of the sample panels received were approximately 12" x 12". Gloss and Orange Peel (DOI) tests were performed on whole panels as originally received. Care was taken not to take measurements at or near the edge of those panels. Porosity and Water Resistance Tests required that the panels be cut into approximately 4" x 4" samples. This was achieved by use of a razor blade and a straight edge.

More details can be found within the SCAQMD Contract No. 04198.

Porosity Test

All porosity samples shown in Table 1 resulted in passing scores as described by ANSI Z124. Samples were evaluated by Ryan Garcia and Bryce Floryncic.

Table 1 Porosity test data. All panels obtained a passing score.

Sample	Date	color	Voids < 1/16"		Voids > 1/16"	
			sample #1	sample #2	sample #1	sample #2
50	11/23/2004	gray	0	0	0	0
51	11/23/2004	gray	0	0	0	0
52	11/23/2004	gray	0	0	0	0
53	11/23/2004	gray	1	0	0	0
54	11/23/2004	gray	0	0	0	0
55	11/23/2004	gray	0	0	0	0
56	11/23/2004	white	3	0	0	0
57	11/23/2004	white	0	0	0	0
58	11/23/2004	white	0	0	0	0
62	11/23/2004	blue	0	0	0	0
63	11/23/2004	blue	0	0	0	0
64	11/23/2004	blue	0	0	0	0
65	11/23/2004	blue	0	0	0	0
66	11/23/2004	blue	0	0	0	0
72	11/23/2004	clear	0	0	0	0
73	11/23/2004	clear	0	0	0	0
75	11/18/2004	white	0	0	0	0
76	11/18/2004	white	0	0	0	0
77	11/18/2004	white	0	0	0	0
78	11/18/2004	white	0	0	0	0

79	11/18/2004	white	0	0	0	0
80	11/18/2004	white	0	0	0	0
81	11/18/2004	gray	0	0	0	0
82	11/18/2004	gray	0	0	0	0
83	11/18/2004	gray	0	0	0	0
84	11/18/2004	gray	0	0	0	0
85	11/18/2004	gray	0	0	0	0
86	11/18/2004	gray	0	0	0	0
87	11/18/2004	blue	0	0	0	0
88	11/18/2004	blue	0	0	0	0
89	11/18/2004	blue	0	0	0	0
90	12/7/2004	blue	0	0	0	0
91	12/7/2004	blue	0	0	0	0
92	12/7/2004	blue	0	0	0	0
93	12/7/2004	clear	0	0	0	0
94	12/7/2004	clear	0	0	0	0
95	12/7/2004	clear	0	0	0	0
96	12/7/2004	clear	0	0	0	0
97	12/7/2004	clear	0	0	0	0
98	12/7/2004	clear	0	0	0	0
101	12/7/2004	white	0	0	0	0
104	12/7/2004	white	0	0	0	0
106	12/7/2004	white	0	0	0	0
110	12/7/2004	white	0	0	0	0
150	12/7/2004	clear	2	0	3	0
151	12/7/2004	clear	0	0	0	0
153	12/7/2004	white	0	0	0	0
155	12/7/2004	white	0	0	0	0
156	12/7/2004	white	0	0	0	0
157	12/7/2004	white	0	0	0	0
158	12/7/2004	gray	1	0	0	0
159	12/7/2004	gray	1	0	0	0
160	12/7/2004	clear	0	0	0	0
161	12/7/2004	clear	0	0	0	0
162	12/7/2004	clear	0	0	0	0
163	12/7/2004	clear	0	0	0	0
164	12/7/2004	white	0	0	0	0
165	12/7/2004	white	0	0	0	0
166	12/7/2004	white	0	0	0	0
167	12/7/2004	white	0	0	2	0
168	12/7/2004	blue	0	0	0	0
169	12/7/2004	blue	0	0	0	0
170	12/7/2004	blue	0	0	0	0
171	12/7/2004	blue	0	0	0	0
172	12/7/2004	gray	0	0	0	0
173	12/7/2004	gray	0	0	0	0
174	12/7/2004	gray	0	0	0	0
175	12/7/2004	gray	0	0	0	0

Gloss Test

All of the clear samples shown in Table 2 had paper shipping material adhered to the back side of each panel. This is likely to cause significant error in their gloss measurements. It should also be noted that measurements on these panels were made with the samples resting on a black surface in an attempt to minimize potential effects of the background. These same measurements were also gathered using a white background, and the results are provided in Appendix A.

Table 2 Gloss Measurements (20/60).

sample #	Date measured	sample color	Gloss Value (20/60)							
			Trial 1		Trial 2		Trial 3		average	
			20	60	20	60	20	60	20	60
50	10/4/2004	gray	84.1	96.2	85.9	94.3	86.3	95.0	85.4	95.2
51	10/4/2004	gray	86.2	94.5	84.6	93.9	84.9	94.1	85.2	94.2
52	10/4/2004	gray	83.6	93.8	82.5	93.1	81.8	92.9	82.6	93.3
53	10/4/2004	gray	86.1	93.7	84.5	93.7	84.0	91.9	84.9	93.1
54	10/4/2004	gray	86.5	94.6	85.4	93.2	84.3	93.2	85.4	93.7
55	10/4/2004	gray	84.5	94.2	82.2	93.9	87.6	94.7	84.8	94.3
56	10/4/2004	white	75.1	89.1	75.2	90.1	71.8	88.9	74.0	89.4
57	10/4/2004	white	77.1	91.7	76.2	89.2	77.2	89.7	76.8	90.2
58	10/4/2004	white	79.1	86.2	78.6	91.7	80.1	92.8	79.3	90.2
62	10/4/2004	dark blue	88.8	95.3	89.0	94.7	87.4	94.1	88.4	94.7
63	10/4/2004	dark blue	83.8	93.7	80.1	93.8	89.2	95.6	84.4	94.4
64	10/4/2004	dark blue	86.9	94.5	73.0	93.0	84.8	94.5	81.6	94.0
65	10/4/2004	dark blue	84.0	91.4	78.9	91.9	85.7	93.4	82.9	92.2
66	10/4/2004	dark blue	79.2	90.5	70.4	92.6	82.8	92.1	77.5	91.7
72*	10/4/2004	clear	79.5	102.2	78.3	94.0	80.1	91.6	79.3	95.9
73*	10/4/2004	clear	42.1	93.2	71.9	95.2	23.6	76.2	45.9	88.2
75	10/14/2004	white	74.5	89.2	67.5	86.2	73.3	88.4	71.8	87.9
76	10/14/2004	white	71.6	87.3	65.3	87.5	72.9	87.6	69.9	87.5
77	10/14/2004	white	68.3	87.4	62.7	83.1	71.2	88.6	67.4	86.4
78	10/14/2004	white	64.9	85.3	67.8	85.7	68.8	86.6	67.2	85.9
79	10/14/2004	white	64.2	82.7	66.6	85.2	61.9	82.4	64.2	83.4
80	10/14/2004	white	59.8	81.7	61.1	80.8	61.9	82.8	60.9	81.8
81	10/14/2004	gray	83.5	93.5	83.3	93.4	81.6	92.1	82.8	93.0
82	10/14/2004	gray	84.7	92.8	84.5	92.9	85.2	93.5	84.8	93.1
83	10/14/2004	gray	79.5	90.2	79.4	90.7	79.5	90.3	79.5	90.4
84	10/14/2004	gray	79.5	89.8	83.4	92.7	81.2	91.5	81.4	91.3
85	10/14/2004	gray	82.5	91.1	81.4	90.7	82.2	92.2	82.0	91.3
86	10/14/2004	gray	82.8	93.2	82.2	92.2	82.9	93.1	82.6	92.8
87	10/14/2004	blue	80.6	89.0	84.6	91.9	77.4	88.6	80.9	89.8
88	10/14/2004	blue	80.4	90.4	79.8	90.7	78.2	89.4	79.5	90.2
89	10/14/2004	blue	77.9	89.7	78.8	89.9	82.5	91.7	79.7	90.4
90	10/14/2004	blue	83.5	92.6	78.4	93.3	82.8	92.3	81.6	92.7
91	10/14/2004	blue	81.8	91.5	82.3	91.1	80.8	90.7	81.6	91.1
92	10/14/2004	blue	80.5	91.1	80.7	91.2	85.0	92.7	82.1	91.7
93*	10/14/2004	clear	84.1	95.1	20.7	95.6	78.7	100.4	61.2	97.0
94*	10/14/2004	clear	77.4	93.0	80.2	93.6	92.4	110.8	83.3	99.1
95*	10/14/2004	clear	70.8	94.5	78.6	92.8	86.5	93.0	78.6	93.4
96*	10/14/2004	clear	55.1	94.2	73.0	94.4	84.6	92.5	70.9	93.7

97*	10/14/2004	clear	41.8	83.0	35.9	87.8	85.6	101.3	54.4	90.7
98*	10/14/2004	clear	86.2	98.3	82.2	93.7	79.7	96.3	82.7	96.1
101	11/2/2004	white	87.8	94.4	86.5	93.7	84.9	92.9	86.4	93.7
104	11/2/2004	white	84.2	92.8	83.1	92.2	85.5	93.5	84.3	92.8
106	11/2/2004	white	79.5	92.3	82.1	93.1	74.0	89.4	78.5	91.6
110	11/2/2004	white	86.8	94.7	87.2	95.0	87.1	94.6	87.0	94.8
150*	11/2/2004	clear	94.2	96.8	81.7	89.1	63.6	91.1	79.8	92.3
151*	11/2/2004	clear	90.4	93.9	92.7	97.6	89.5	94.4	90.9	95.3
153	11/2/2004	white	85.5	94.7	86.3	94.7	87.0	93.5	86.3	94.3
155	11/2/2004	white	87.9	94.8	87.0	94.5	87.5	93.9	87.5	94.4
156	11/2/2004	white	68.9	88.0	71.1	89.3	62.3	85.1	67.4	87.5
157	11/2/2004	white	75.7	90.1	72.0	89.6	74.0	89.5	73.9	89.7
158	11/2/2004	gray	83.5	91.8	85.8	93.1	84.2	91.8	84.5	92.2
159	11/2/2004	gray	81.1	90.8	80.5	91.9	83.1	91.8	81.6	91.5
160*	11/2/2004	clear	89.9	93.8	87.5	92.9	84.4	93.8	87.3	93.5
161*	11/2/2004	clear	87.3	93.4	88.9	94.3	89.7	95.3	88.6	94.3
162*	11/2/2004	clear	90	93.8	89.1	93.1	88.6	94.6	89.2	93.8
163*	11/2/2004	clear	73	87.4	89.1	93	89.7	98.1	83.9	92.8
164	11/2/2004	white	64.8	89.9	73.2	88.2	68.9	86.1	69.0	88.1
165	11/2/2004	white	73.0	88.9	73.0	85.5	73.1	86.6	73.0	87.0
166	11/2/2004	white	74.2	89.9	77.4	91.1	75.6	90.3	75.7	90.4
167	11/2/2004	white	74.5	90.2	76.0	90.2	72.8	89.0	74.4	89.8
168	11/2/2004	blue	77.2	88.9	84.1	91.2	80.8	89.8	80.7	90.0
169	11/2/2004	blue	82.7	90.3	79.8	89.4	80.0	89.5	80.8	89.7
170	11/2/2004	blue	86.0	91.2	82.8	90.9	83.3	91.0	84.0	91.0
171	11/2/2004	blue	78.6	89.5	78.6	89.4	79.9	89.8	79.0	89.6
172	11/2/2004	gray	85.3	92.0	81.1	90.5	85.0	91.8	83.8	91.4
173	11/2/2004	gray	79.7	89.8	84.1	92.0	79.7	90.6	81.2	90.8
174	11/2/2004	gray	85.0	92.4	85.5	92.4	86.4	92.1	85.6	92.3
175	11/2/2004	gray	76.6	89.2	66.4	85.4	62.2	83.5	68.4	86.0

*Clear samples were stuck to the paper backing resulting in erroneous gloss measurements. The values listed above were gathered by placing a dark background behind these samples.

Orange Peel Test

Panels were evaluated by Ryan Garcia, Bryce Floryncic, and Ray Fernando.

Table 3 Orange Peel/Distinctness of Image (DOI) Ratings.

sample #	Date measured	sample color	Ratings			
			observer 1	observer 2	observer 3	average
50	10/4/2004	gray	8	9	9	8.7
51	10/4/2004	gray	9	9	9	9.0
52	10/4/2004	gray	8	9	9	8.7
53	10/4/2004	gray	9	9	9	9.0
54	10/4/2004	gray	9	9	9	9.0
55	10/4/2004	gray	9	9	9	9.0
56	10/4/2004	white	9	9	8	8.7
57	10/4/2004	white	9	9	9	9.0
58	10/4/2004	white	9	9	8	8.7
62	10/4/2004	dark blue	9	7	9	8.3
63	10/4/2004	dark blue	8	7	9	8.0
64	10/4/2004	dark blue	9	8	9	8.7
65	10/4/2004	dark blue	9	9	9	9.0
66	10/4/2004	dark blue	9	8	9	8.7
72	10/4/2004	clear	8	7	8	7.7
73	10/4/2004	clear	8	7	8	7.7
75	10/14/2004	white	8	7	8	7.7
76	10/14/2004	white	8	7	8	7.7
77	10/14/2004	white	8	8	8	8.0
78	10/14/2004	white	8	8	8	8.0
79	10/14/2004	white	8	8	8	8.0
80	10/14/2004	white	8	8	8	8.0
81	10/14/2004	gray	9	8	9	8.7
82	10/14/2004	gray	9	9	9	9.0
83	10/14/2004	gray	9	8	9	8.7
84	10/14/2004	gray	9	8	9	8.7
85	10/14/2004	gray	9	8	9	8.7
86	10/14/2004	gray	9	8	9	8.7
87	10/14/2004	blue	10	9	10	9.7
88	10/14/2004	blue	9	8	9	8.7
89	10/14/2004	blue	10	9	10	9.7
90	10/14/2004	blue	9	8	9	8.7
91	10/14/2004	blue	9	9	9	9.0
92	10/14/2004	blue	10	10	10	10.0
93	10/14/2004	clear	9	7	8	8.0
94	10/14/2004	clear	9	8	8	8.3
95	10/14/2004	clear	9	8	8	8.3
96	10/14/2004	clear	8	7	8	7.7
97	10/14/2004	clear	8	8	8	8.0
98	10/14/2004	clear	9	8	8	8.3

101	11/2/2004	white	10	10	10	10.0
104	11/2/2004	white	10	9	9	9.3
106	11/2/2004	white	10	9	9	9.3
110	11/2/2004	white	10	9	10	9.7
150	11/2/2004	clear	9	9	9	9.0
151	11/2/2004	clear	9	9	9	9.0
153	11/2/2004	white	10	10	10	10.0
155	11/2/2004	white	9	9	10	9.3
156	11/2/2004	white	8	9	8	8.3
157	11/2/2004	white	8	9	9	8.7
158	11/2/2004	gray	10	9	9	9.3
159	11/2/2004	gray	9	8	9	8.7
160	11/2/2004	clear	8	8	8	8.0
161	11/2/2004	clear	9	8	9	8.7
162	11/2/2004	clear	9	9	9	9.0
163	11/2/2004	clear	9	9	9	9.0
164	11/2/2004	white	8	9	9	8.7
165	11/2/2004	white	9	9	9	9.0
166	11/2/2004	white	10	10	10	10.0
167	11/2/2004	white	10	10	10	10.0
168	11/2/2004	blue	10	10	10	10.0
169	11/2/2004	blue	10	9	10	9.7
170	11/2/2004	blue	10	10	10	10.0
171	11/2/2004	blue	9	9	9	9.0
172	11/2/2004	gray	9	9	9	9.0
173	11/2/2004	gray	9	9	9	9.0
174	11/2/2004	gray	9	9	9	9.0
175	11/2/2004	gray	9	9	9	9.0

Water Resistance

A stainless steel test tank was fabricated as specified in ANZI Z124. Exposed samples were evaluated by Ryan Garcia and Bryce Floryncic

Table 4 Water resistance test results.

Batch #1 start date/time: 10/14/2004 8:00am end date/time: 10/18/2004 12:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
50-1	1	0	0	3	3	3	3	0	0	2	2	8	8	8
50-2	2	0	0	3	3	3	3	0	0	2	2	8	8	8
50-3	3	0	0	3	3	2	3	0	0	2	2	7	8	7.5
51-1	4	0	0	3	3	3	3	0	0	2	2	8	8	8
51-2	5	0	0	3	3	3	3	0	0	2	2	8	8	8
51-3	6	0	0	3	3	3	3	0	0	2	2	8	8	8
52-1	7	0	0	3	3	3	3	0	0	2	2	8	8	8
52-2	8	0	0	3	3	3	3	0	0	2	2	8	8	8
52-3	9	0	0	3	3	3	3	0	0	2	2	8	8	8
53-1	10	0	0	3	3	3	3	0	0	2	2	8	8	8
53-2	11	0	0	3	3	2	3	0	0	2	2	7	8	7.5
53-3	12	0	0	3	3	3	3	0	0	2	2	8	8	8

Batch #2 start date/time: 10/18/2004 2:00pm end date/time: 10/22/2004 6:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
54-1	11	0	0	3	3	3	3	0	0	3	3	9	9	9
54-2	12	0	0	3	3	3	3	0	0	3	3	9	9	9
55-1	5	0	0	3	3	3	3	0	0	3	3	9	9	9
55-2	6	0	0	3	3	3	3	0	0	3	3	9	9	9
56-1	3	0	0	1	2	1	2	0	0	1	1	3	5	4
56-2	4	0	0	1	2	1	2	0	0	1	1	3	5	4
57-1	1	0	0	1	2	0	0	0	0	1	1	2	3	2.5
57-2	2	0	0	1	2	0	0	0	0	1	1	2	3	2.5
58-1	7	0	0	1	2	0	0	0	0	1	1	2	3	2.5
58-2	8	0	0	1	2	0	0	0	0	1	1	2	3	2.5
62-1	10	0	0	2	2	1	1	0	0	2	2	5	5	5
62-2	9	0	0	2	2	1	1	0	0	2	2	5	5	5

Batch #3

start date/time: 10/23/2004 12:00pm

end date/time: 10/27/2004 4:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
63-1	7	0	0	3	2	1	1	0	0	1	2	5	5	5
63-2	8	0	0	3	2	1	1	0	0	1	2	5	5	5
64-1	9	0	0	3	2	1	1	0	0	1	2	5	5	5
64-2	10	0	0	3	2	1	1	0	0	1	2	5	5	5
65-1	11	0	0	3	2	1	1	0	0	1	2	5	5	5
65-2	12	0	0	3	2	1	1	0	0	1	2	5	5	5
66-1	1	0	0	3	2	1	1	0	0	1	2	5	5	5
66-2	2	0	0	3	2	1	1	0	0	1	2	5	5	5
72-1	3	0	0	2	1	1	1	0	0	1	1	4	3	3.5
72-2	4	0	0	2	1	1	1	0	0	1	1	4	3	3.5
73-1	5	0	0	2	1	1	1	0	0	1	1	4	3	3.5
73-2	6	0	0	2	1	1	1	0	0	1	1	4	3	3.5

Batch #4

start date/time: 10/28/2004 12:00pm

end date/time: 11/1/2004 4:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
75-1	1	0	0	1	1	1	1	0	0	1	1	3	3	3
75-2	2	0	0	1	1	1	1	0	0	1	1	3	3	3
76-1	3	0	0	1	1	1	1	0	0	1	1	3	3	3
76-2	4	0	0	1	1	2	2	0	0	1	1	4	4	4
77-1	5	0	0	1	1	1	1	0	0	1	1	3	3	3
77-2	6	0	0	1	1	2	2	0	0	1	1	4	4	4
78-1	7	0	0	1	1	1	1	0	0	1	1	3	3	3
78-2	8	0	0	1	1	1	1	0	0	1	1	3	3	3
79-1	9	0	0	1	1	1	1	0	0	1	1	3	3	3
79-2	10	0	0	1	1	1	1	0	0	1	1	3	3	3
80-1	11	0	0	1	1	1	1	0	0	1	1	3	3	3
80-2	12	0	0	1	1	1	1	0	0	1	1	3	3	3

Batch #5

start date/time: 11/2/2004 10:00am

end date/time: 11/6/2004 2:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
81-1	1	0	0	2	2	2	2	0	0	2	2	6	6	6
81-2	2	0	0	2	2	2	2	0	0	2	2	6	6	6
82-1	3	0	0	2	2	2	2	0	0	2	2	6	6	6
82-2	4	0	0	2	2	2	2	0	0	2	2	6	6	6
83-1	5	0	0	2	2	2	2	0	0	2	2	6	6	6
83-2	6	0	0	2	2	2	2	0	0	2	2	6	6	6
84-1	7	0	0	2	2	2	2	0	0	2	2	6	6	6
84-2	8	0	0	2	2	2	2	0	0	2	2	6	6	6
85-1	9	0	0	2	2	2	2	0	0	2	2	6	6	6
85-2	10	0	0	2	2	2	2	0	0	2	2	6	6	6
86-1	11	0	0	2	2	2	2	0	0	2	2	6	6	6
86-2	12	0	0	2	2	2	2	0	0	2	2	6	6	6

Batch #6

start date/time: 11/6/2004 2:00pm

end date/time: 11/10/04 6:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
87-1	1	0	0	2	2	1	1	0	0	2	2	5	5	5
87-2	2	0	0	2	2	1	1	0	0	2	2	5	5	5
88-1	3	0	0	2	2	1	1	0	0	2	2	5	5	5
88-2	4	0	0	2	2	1	1	0	0	2	2	5	5	5
89-1	5	0	0	2	2	1	1	0	0	2	2	5	5	5
89-2	6	0	0	2	2	1	1	0	0	2	2	5	5	5
90-1	7	0	0	2	2	1	1	0	0	2	2	5	5	5
90-2	8	0	0	2	2	1	1	0	0	2	2	5	5	5
91-1	9	0	0	2	2	1	1	0	0	2	2	5	5	5
91-2	10	0	0	2	2	1	1	0	0	2	2	5	5	5
92-1	11	0	0	2	2	1	1	0	0	2	2	5	5	5
92-2	12	0	0	2	2	1	1	0	0	2	2	5	5	5

Batch #7

start date/time: 11/11/2004 8:00am

end date/time: 11/15/04 12:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
93-1	1	0	0	0	1	1	2	0	0	3	2	4	5	4.5
93-2	2	0	0	0	1	1	1	0	0	3	2	4	4	4
94-1	3	0	0	0	1	2	2	0	0	3	2	5	5	5
94-2	4	0	0	0	1	1	1	0	0	3	2	4	4	4
95-1	5	0	0	0	1	3	2	0	0	3	2	6	5	5.5
95-2	6	0	0	0	1	1	1	0	0	3	2	4	4	4
96-1	7	0	0	0	1	1	1	0	0	3	2	4	4	4
96-2	8	0	0	0	1	2	2	0	0	3	2	5	5	5
101-1	9	0	0	0	1	0	0	0	0	1	1	1	2	1.5
101-2	10	0	0	1	1	0	0	0	0	1	1	2	2	2
104-1	11	0	0	3	2	0	0	0	0	2	2	5	4	4.5
104-2	12	0	0	3	2	0	0	0	0	2	2	5	4	4.5

Batch #8

start date/time: 11/16/04 8:00am

end date/time: 11/20/04 12:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
106-1	1	0	0	1	1	1	1	0	0	1	1	3	3	3
106-2	2	0	0	1	1	1	1	0	0	1	1	3	3	3
110-1	3	0	0	1	1	1	1	0	0	1	1	3	3	3
110-2	4	0	0	1	1	0	0	0	0	1	1	2	2	2
150-1	5	0	0	1	1	1	0	0	0	1	2	3	3	3
150-2	6	0	0	1	1	1	0	0	0	1	2	3	3	3
151-1	7	0	0	1	1	1	1	0	0	1	1	3	3	3
151-2	8	0	0	1	2	0	0	0	0	2	2	3	4	3.5
153-1	9	0	0	1	1	0	1	0	0	1	1	2	3	2.5
153-2	10	0	0	1	1	1	0	0	0	1	2	3	3	3
155-1	11	0	0	1	1	1	1	0	0	1	2	3	4	3.5
155-2	12	0	0	1	1	1	0	0	0	1	1	3	2	2.5

Batch #9

start date/time: 11/20/04 2:00pm

end date/time: 11/24/04 6:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
156-1	1	0	0	2	2	2	2	0	0	1	1	5	5	5
156-2	2	0	0	2	2	2	2	2	1	1	1	7	6	6.5
157-1	3	0	0	2	2	2	2	0	0	1	1	5	5	5
157-2	4	0	0	2	2	2	2	0	0	1	1	5	5	5
158-1	5	0	0	2	2	2	2	0	0	2	2	6	6	6
158-2	6	0	0	2	2	2	2	0	0	2	2	6	6	6
159-1	7	0	0	2	2	2	2	0	0	2	2	6	6	6
159-2	8	0	0	2	2	2	2	0	0	2	2	6	6	6
160-1	9	1	0	2	2	1	1	0	0	2	2	6	5	5.5
160-2	10	1	0	2	2	1	1	0	0	2	2	6	5	5.5
161-1	11	1	0	2	2	1	1	0	0	2	2	6	5	5.5
161-2	12	1	0	2	2	1	1	0	0	2	2	6	5	5.5

Batch #10

start date/time: 11/26/04 8:00am

end date/time: 11/30/2004 12:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
162-1	1	0	0	1	1	1	1	0	0	2	2	4	4	4
162-2	2	0	0	1	1	1	1	0	0	2	2	4	4	4
163-1	3	0	0	1	1	1	1	0	0	2	2	4	4	4
163-2	4	0	0	1	1	1	1	0	0	2	2	4	4	4
164-1	5	0	0	1	1	2	2	0	0	2	2	5	5	5
164-2	6	0	0	1	1	2	2	0	0	2	2	5	5	5
165-1	7	0	0	1	1	2	2	0	0	2	2	5	5	5
165-2	8	0	0	1	1	2	2	0	0	2	2	5	5	5
166-1	9	0	0	1	1	1	1	0	0	2	2	4	4	4
166-2	10	0	0	1	1	1	1	0	0	2	2	4	4	4
167-1	11	0	0	1	1	1	1	0	0	2	2	4	4	4
167-2	12	0	0	1	1	1	1	0	0	2	2	4	4	4

Batch #11

start date/time: 11/30/2004 1:00pm

end date/time: 12/4/04 5:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
168-1	1	0	0	2	3	1	1	0	0	1	1	4	5	4.5
168-2	2	0	0	2	3	1	1	0	0	1	1	4	5	4.5
169-1	3	0	0	2	3	1	1	0	0	1	1	4	5	4.5
169-2	4	0	0	2	3	2	2	0	0	1	1	5	6	5.5
170-1	5	0	0	2	3	1	1	0	0	1	1	4	5	4.5
170-2	6	0	0	2	3	2	2	0	0	1	1	5	6	5.5
171-1	7	0	0	2	3	1	1	0	0	1	1	4	5	4.5
171-2	8	0	0	2	3	2	2	0	0	1	1	5	6	5.5
172-1	9	0	0	2	3	2	2	0	0	2	2	6	7	6.5
172-2	10	0	0	2	3	2	2	0	0	2	2	6	7	6.5
173-1	11	0	0	2	3	3	2	0	0	2	2	7	7	7
173-2	12	0	0	2	3	2	2	0	0	2	2	6	7	6.5

Batch #12

start date/time: 12/6/2004 11:00am

end date/time: 12/10/2004 3:00pm

sample	port-hole	blisters		color change		surface profile		cracks		loss of gloss		total		observer average
		obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	obs 1	obs 2	
174-1	1	0	0	2	2	2	2	0	0	2	2	6	6	6
174-2	2	0	0	2	2	2	2	0	0	2	2	6	6	6
175-1	3	0	0	2	2	2	2	0	0	2	2	6	6	6
175-2	4	0	0	2	2	2	2	0	0	2	2	6	6	6

Appendix A

Table 5 Gloss Measurements (20/60) for Clear Samples Using White Background.

sample #	Date measured	sample color	Gloss Value (20/60)							
			Trial 1		Trial 2		Trial 3		average	
			20	60	20	60	20	60	20	60
72*	12/17/2004	clear	83.5	94.0	80.7	91.0	75.2	89.0	79.8	91.3
73*	12/17/2004	clear	76.4	93.7	79.7	95.4	87.2	95.6	81.1	94.9
93*	12/17/2004	clear	84.9	93.8	80.2	96.2	82.7	95.7	82.6	95.2
94*	12/17/2004	clear	61.6	93.9	55.2	93.8	54.5	92.1	57.1	93.3
95*	12/17/2004	clear	82.5	93.2	65.6	93.2	65.2	95.8	71.1	94.1
96*	12/17/2004	clear	70.8	95.3	70.5	93.3	69.9	93.3	70.4	94.0
97*	12/17/2004	clear	35.4	86.1	22.2	74.0	20.9	66.5	26.2	75.5
98*	12/17/2004	clear	76.0	96.4	63.7	93.9	56.2	97.6	65.3	96.0
150*	12/17/2004	clear	90.8	95.9	92.3	97.1	90.3	95.1	91.1	96.0
151*	12/17/2004	clear	92.8	98.4	90.9	96.2	89.7	95.7	91.1	96.8
160*	12/17/2004	clear	88.8	94.8	87.5	95.3	90.2	96.1	88.8	95.4
161*	12/17/2004	clear	90.5	98.0	90.9	97.1	88.7	96.5	90.0	97.2
162*	12/17/2004	clear	90.3	96.9	86.7	95.1	84.2	100.3	87.1	97.4
163*	12/17/2004	clear	81.9	92.7	73.1	96.3	86.9	96.4	80.6	95.1

These clear samples were stuck to the paper backing resulting in erroneous gloss measurements. The values listed above were gathered by placing a white background behind these samples

The following porosity data was gathered on 11/2/04 as a group of expedited samples, in response to a request by SCAQMD. All of these panels were tested again within the original matrix as shown in Table 1.

Table 6 Porosity Test.

Sample	Date	color	Voids < 1/16"		Voids > 1/16"	
			sample #1	sample #2	sample #1	sample #2
162	11/2/2004	clear	0	0	0	0
163	11/2/2004	clear	0	0	0	0
166	11/2/2004	white	0	0	0	0
167	11/2/2004	white	0	3	0	0
170	11/2/2004	blue	0	0	0	0
171	11/2/2004	blue	0	0	0	0
174	11/2/2004	gray	0	1	0	0
175	11/2/2004	gray	0	0	0	0

ENGINEERING ENVIRONMENTAL

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July 27, 2005

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phone (734) 622-0162
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RE: Report on the SCAQMD NAGA Testing at Lasco and SCAQMD Test Report

John:

The report on the SCAQMD non-atomized gelcoat application (NAGA) testing at the Lasco Bathware R&D facility in Anaheim, California is attached to this cover letter. This report is based on the following five sources of information:

- observations made during my visit to the site from September 20 - 23, 2004, which included the third test trial period.
- test data and test reports made available by SCAQMD.
- statements made by SCAQMD personnel and gun manufacturer participants.
- information provided by Lasco Bathware staff.
- EPA reference methods and other scientific and test references.

Please call me if you have any questions.

Best regards



Robert A. Haberlein, Ph.D., QEP

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**Assessment of the
South Coast Air Quality Management District
Non-atomized Gelcoat Application Test Program at the
Lasco Bathware R&D Facility in
Anaheim, California**

prepared for

American Composites Manufacturers Association
1010 N. Glebe Road
Suite 450
Arlington, VA 22201

by



Robert A. Haberlein, Ph.D., QEP
Engineering Environmental
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July 27, 2005

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Persons involved with this Assessment

The following SCAQMD personnel were present at the Lasco site during my visit:

Helmy Sultan, Air Quality Specialist
Michael Garibay, Senior Air Quality Engineer (technical lead for testing)
Glenn Kasai, Air Quality Engineer
Ron Lem (technician on roof)
Carrey Willoughby (technician on roof)
Wayne Stredwick (FID operator)
Ed Muehlbacher, Program Supervisor

The following gun manufacturer personnel were also present at the Lasco site during my visit:

Brad Walter, R & D Project Engineer
Paul Rossl, Industrial Finishing Specialist
Dewey Smith, FRP Market Specialist

The following Lasco personnel were present during the testing:

Viktor Prismantas, Corporate Environmental
Syd Pe, Corporate Engineering
Terry Pe, Anaheim Chemist

The following ACMA staff and consultants assisted in the preparation and review of this report:

Chuck Elkins
David Lipiro
Bob Lacovara
John Schweitzer

Schedule of Events during the Test Site Visit

Date	Activity
Monday, September 20	Equipment arrived at site after noon Applicator setup by manufacturer personnel Initial runs to verify performance of applicator
Tuesday, September 21	Gray gelcoat runs (3) White gelcoat run (1)
Wednesday, September 22	White gelcoat runs (2) Blue gelcoat runs (3)
Thursday, September 23	Clear gelcoat runs (3) Sample line loss test (after 1 st run of the day)

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Gelcoat Materials

The MSDS information and SCAQMD analyses for the four gelcoats sampled during the SCAQMD test are listed below:

Table 1 – Summary of the Gelcoat Material Data

Gelcoat Description	Identification Codes	Lot Number	Mix Date	Specific Monomer Contents (per MSDS data)	Monomer Content (per SCAQMD analysis)
Clear	CG-40-02145	0012836	7/26/04	29.3% styrene 10% MMA	40.9%
San Bright White	WG-30X-2181	0012871	8/9/04	28.0 - 30.0% styrene	30.8%
Midnight Blue	LG-33LE-2049	0013049	8/10/04	23.0 - 27.0% styrene 1.0 - 3.0% MMA	32.9%
Gray Sandable	AG-27PR-72315	S421501	undated	23.0 - 27.0% styrene	27.3%

Test Facility and Test Setup

The SCAQMD reports provided complete and accurate descriptions of the test facility and test setup. Please refer to the SCAQMD reports for these descriptions.

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Section 1 - Overview of Emission Factor Testing

The non-atomized gelcoat application (NAGA) emission factor reported by SCAQMD was determined by dividing the VOC emissions by the amount of gelcoat used during the NAGA process:

$$\text{Emission factor (lb VOC emitted per ton gelcoat)} = \frac{\text{Emissions (lb VOC)}}{\text{Material Usage (ton gelcoat)}}$$

The SCAQMD NAGA factor has different units than the original UEF NAGA emission factor developed by the Composite Fabricators Association (CFA), which is now known as the American Composites Manufacturing Association (ACMA). The UEF NAGA emission factor only applies to gelcoat materials that contain styrene monomer, so the UEF factor has units of “pound styrene emitted per ton gelcoat.” Gelcoat materials that contain MMA or other monomer species instead of styrene do not have UEF NAGA factors. Federal EPA adopted the ACMA UEF factors as Table 1 of Subpart WWWW in the Composites MACT rule. These adopted factors included the UEF NAGA factor. However, the Composites MACT rule intentionally treats all HAP monomers like styrene, so while the MACT NAGA emission factors are numerically identical to the UEF NAGA factors, the MACT NAGA factor has units of “lb HAP emissions per ton gelcoat.” Gelcoat that contains both styrene and MMA HAP monomers would likely have a significantly greater HAP emission rate than gelcoat with an equivalent amount of styrene only. However, federal EPA does not recognize this difference in the MACT rule as a matter of regulatory expediency.

The differences between the emission factor units used by SCAQMD (lbs VOC per ton), federal EPA (lbs HAP per ton), and UEF (lbs styrene per ton) are important, and underscore a common misconception regarding the applicability of the UEF factors. The NAGA UEF was devised to estimate styrene emissions only, and does not estimate HAP or VOC emissions from NAGA operations. For this reason, the NAGA UEF cannot be used to estimate HAP or VOC emissions, unless the only HAP or VOC present in the gelcoat material is styrene.

The emissions value used in the emission factor calculation is determined by multiplying the exhaust airflow and the organic concentration in the exhaust airflow (with the proper conversion factors). Thus, the emission factor result is calculated using the fundamental relationship:

$$\text{Factor} = \frac{\text{Exhaust Airflow} \times \text{Concentration}}{\text{Material Usage}}$$

All measurements collected during emission factor testing are eventually used to compute one or more of these three fundamental factors:

- exhaust airflow (total airflow – not just the airflow rate)
- average stack concentration
- material usage

These three fundamental factors will appear many times in the following assessment.

Section 2 - Assessment of the SCAQMD Test Results

2.1 Data Plots

The SCAQMD test data is summarized in **Table 2** on the next page. One of the best ways to understand such experimental data is simply to plot the data.

The SCAQMD baseline air-assisted airless spray (AAS) test results are plotted in **Figure 1**. The plot is organized to show the different gelcoats by different plot shapes (blue gelcoat – “square,” clear gelcoat – “triangle,” white gelcoat – “circle,” and grey gelcoat – “diamond”). The linear regression fit through this data is shown as a bold red line, and the regression statistics are shown in bold red text.

The SCAQMD NAGA test results are plotted in **Figure 2**. The plot shows the different equipment manufacturers by color (I – green, II – orange, III – yellow, and IV – magenta) and the different gelcoats by different plot shapes as above. For example, a data point for blue gelcoat applied by equipment type IV would be shown as magenta square. The linear regression fit through this data is shown as a bold cyan line, and the linear regression statistics are shown in bold cyan text. The previous SCAQMD AAS linear regression line is included as a bold red line.

A comparison between the SCAQMD baseline AAS test results for grey and white gelcoat and the UEF factors for NAGA and atomized gelcoat is shown in **Figure 3**. Blue and clear gelcoat results are not included in this plot, because gelcoats that contain MMA cannot be compared to the UEF. The plot shows the white and grey gelcoat data as red and orange diamonds. The mean white and mean grey results are shown as pink and yellow circles. The UEF NAGA data is plotted as turquoise circles and the UEF NAGA factor equation is drawn as a bold blue line. The UEF factor equation for atomized gelcoat application is drawn as a bold red line.

A comparison between the SCAQMD NAGA test results for grey and white gelcoat and the UEF factors for NAGA and atomized gelcoat is shown in **Figure 4**. As mentioned above, blue and clear gelcoat results are not included in this plot, because gelcoats that contain MMA cannot be compared to the UEF. This plot uses the same coding scheme for the SCAQMD data as in the earlier plots. The UEF NAGA data is plotted as turquoise circles and the UEF NAGA factor equation is drawn as a bold blue line. The UEF factor equation for atomized gelcoat application is drawn as a bold red line.

The test results for the two different concentration methods used by SCAQMD (denoted “25.1” and “FID” in **Table 2**) are plotted separately. This illustrates the true scatter in the test results, which was partially obscured when SCAQMD elected to average the two different method results together in its reports.

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Table 2 – Summary of SCAQMD Test Data

Run #	Manuf.	Color	Gel	Amb.	Spray	Spray	Spray	Gel Coat	Test time (min)	Rate (lb/ton)	
			Temp. (F)	Temp. (F)	Press (psi)	Rate (lb/min)	Time (sec)	Used (lb)		25.1	FID
1	IV	Clear		78		2.5	120	4.20	60.0	360.95	334.76
2	IV	Clear		79		2.5	120	3.40	56.0	471.61	473.80
3	IV	Clear		80		2.5	142	3.60	70.0	506.20	514.63
4	IV	White	90.0	77	390		120	5.00	34.0	259.31	249.56
5	IV	White		79	390		90	4.00	42.0	367.15	316.40
6	IV	White		80	390		99	4.00	42.0	354.20	322.70
7	IV	White	86.0	77	1050		102	3.80	35.0	337.11	322.68
8	IV	White		78	1550		81	4.40	43.0	284.39	280.15
9	IV	Grey		80	325		113	5.00	31.0	197.57	184.76
10	IV	Grey		77	400		105	5.00	34.0	233.01	195.16
11	IV	Grey	88.0	77	400		117	5.10	37.0	190.08	182.82
12	IV	Blue	86.0	78	300	2.7	92	3.90	30.0	225.64	251.28
13	IV	Blue	100.0	79	400	2.7	95	4.00	24.0	260.60	207.20
14	IV	Blue	89.0	79	440	2.7	94	4.50	22.0		151.07
15	I	Clear	87.0	78	425	1.7	140	3.60	56.0	613.41	508.15
16	I	Clear	87.0	80	425	1.7	130	3.58	50.0	516.76	467.41
17	I	Clear	89.0	82	500	1.7	115	2.97	48.0	595.82	428.28
18	I	White	87.0	83	425	2.8	112	4.60	30.0	309.35	242.83
19	I	White	84.0	80	410	2.8	101	4.75	35.0	293.69	287.80
20	I	White	89.0	81	450	2.8	106	4.47	34.0	293.35	294.87
21	I	Grey	87.0	82	575	3.1	90	4.33	29.0	233.52	228.38
22	I	Grey	85.0	83	575	3.1	96	4.48	33.0	232.03	212.63
23	I	Grey	90.0	79	550	3.1	121	5.75	29.0	186.78	192.32
24	I	Blue	90.0	80	400	3.1	115	4.93	37.0	192.63	197.13
25	I	Blue	90.0	82	400	3.1	107	4.56	27.0	198.36	211.58
26	I	Blue	85.0	83	400	3.1	124	4.65	34.0	262.01	232.03
27	AAS	Blue	83.0	82	1000	3.3	120	6.33	27.0	196.49	195.64
28	AAS	Blue	83.0	83	1000	3.3	89	4.04	32.0	236.57	234.72
29	AAS	Grey	82.0	85	950	3.3	126	6.11	28.0	188.35	187.74
30	AAS	Grey	83.0	85	950	3.3	87	4.30	31.0	230.94	216.28
31	AAS	White	88.0	81	950	3.1	93	4.08	42.0	389.46	371.96
32	AAS	White	83.0	82	950	3.1	83	3.71	40.0	351.48	346.09
33	AAS	Clear	80.0	83	950	2.8	113	4.98	53.0	488.49	425.70
34	AAS	Clear	80.0	85	950	2.8	87	3.96	46.0	441.80	428.25
35	III	Grey	90.0	76	590	2.7	156	6.18	44.0	210.98	219.53
36	III	Grey	87.0	77	590	2.7	128	5.22	50.0	254.79	216.79
37	III	Grey	88.0	79	590	2.7	136	5.21	36.0	224.34	224.11
38	III	White	92.0	80	700	2.5	151	5.37	49.0	347.35	308.72
39	III	White	87.0	78	700	2.5	152	4.68	44.0	369.49	346.30
40	III	White	82.0	80	700	2.5	165	3.94	38.0	372.93	432.40
41	III	Blue	89.0	82	350	2.7	134	4.15	37.0	199.71	203.87
42	III	Blue	90.0	83	350	2.7	116	4.12	28.0	212.27	209.09
43	III	Blue	89.0	85	350	2.7	134	5.06	31.0	205.24	195.43
44	III	Clear	90.0	79	400	1.8	173	4.89	71.0	390.57	401.70
45	III	Clear	90.0	81	400	1.8	143	3.70	67.0	434.59	413.47
46	III	Clear	84.0	85	400	1.8	156	3.66	62.0	412.20	412.20
47	II	White	86.0	78	425	3.4	112	4.46	41.0	284.06	274.56
48	II	White	84.0	79	430	3.4	112	4.61	44.0	259.29	257.70
49	II	White	82.0	80	420	3.4	105	4.24	43.0	314.72	269.09
50	II	Grey	84.0	80	450	3.2	107	5.22	40.0	184.67	172.67
51	II	Grey	87.0	76	575	3.2	90	4.43	42.0	192.46	200.99
52	II	Grey	87.0	77	590	3.2	88	4.62	42.0	183.94	174.55
53	II	Blue	87.0	79	300	2.7	110	4.64	30.0	176.72	147.84
54	II	Blue	82.0	78	300	2.7	105	4.10	30.0	196.83	153.66
55	II	Blue	87.0	79	300	2.7	104	4.18	30.0	146.17	142.58
56	II	Clear	81.0	76	275	1.5	133	3.37	69.0	422.55	376.13
57	II	Clear	82.0	76	275	1.5	144	2.58	85.0	414.02	418.41
58	II	Clear	83.0	76	275	1.5	137	2.61	74.0	393.15	389.37
68	IV	Clear	91.0	76	395	2.5	87	3.59	92.0	569.77	542.43
70	IV	White	94.0	82	400	2.8	87	4.16	40.0	317.63	296.47
71	IV	Grey	88.0	81	400	3.2	94	5.06	31.0	198.28	181.13
72	I	Clear	95.0	76	475	2.1	104	3.11	66.0	589.26	473.25
73	AAS	Clear	95.0	78	1000	2.0	114	3.78	52.0	424.51	417.63
74	I	White	95.0	81	600	2.8	113	4.71	40.0	293.56	302.34
75	AAS	White	93.0	81	1000	3.2	82	4.10	33.0	470.05	308.00
76	I	Blue	88.0	74	550	2.9	92	4.50	47.0	278.87	287.57
77	AAS	Blue	92.0	76	950	3.0	80	3.97	44.0	256.02	276.71
78	I	Grey	92.0	80	500	2.8	78	3.32	31.0	225.65	253.04
79	AAS	Grey	90.0	80	1000	3.0	70	3.23	33.0	254.74	259.85

Figure 1 – Plot of SCAQMD Baseline AAS Data

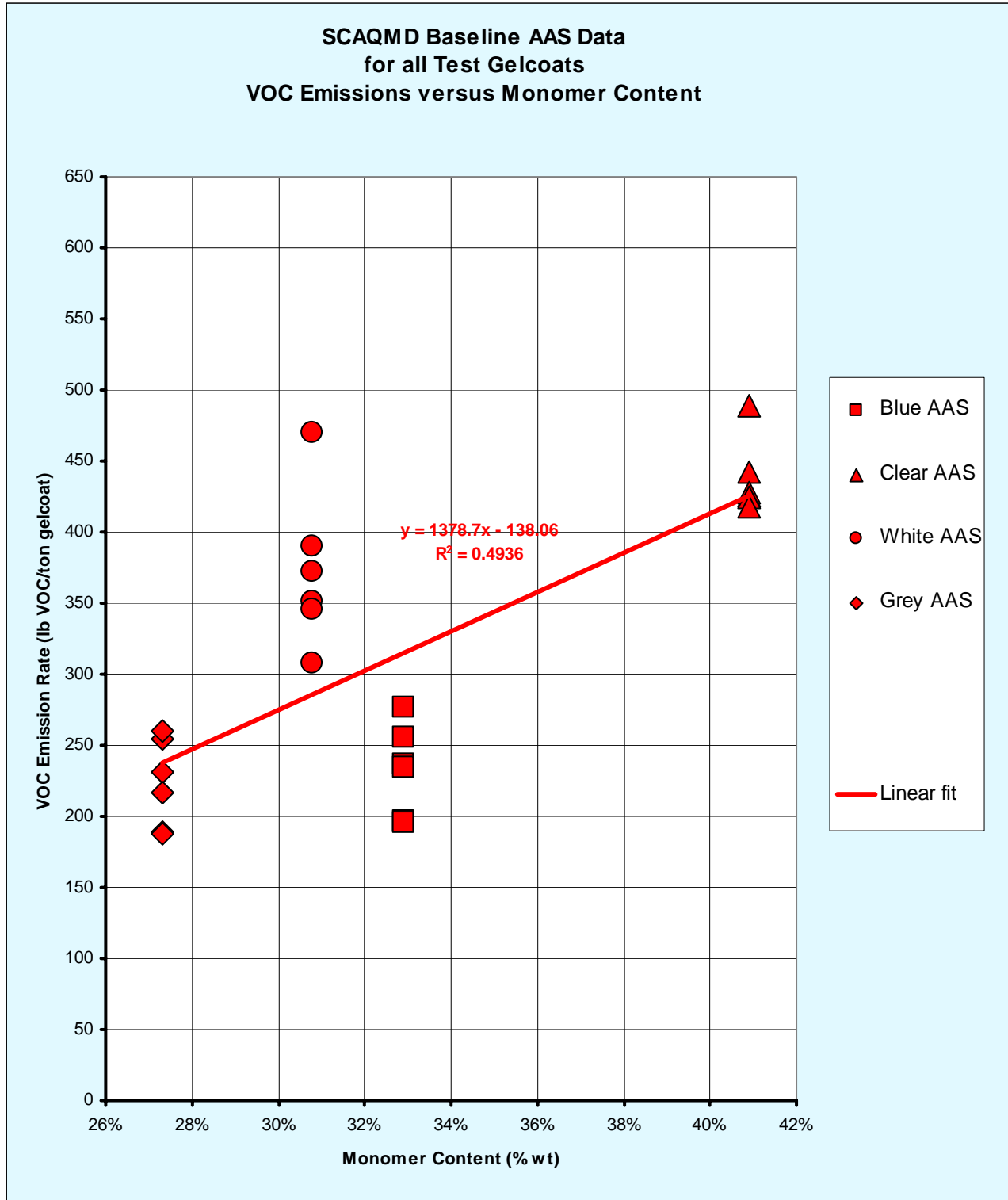
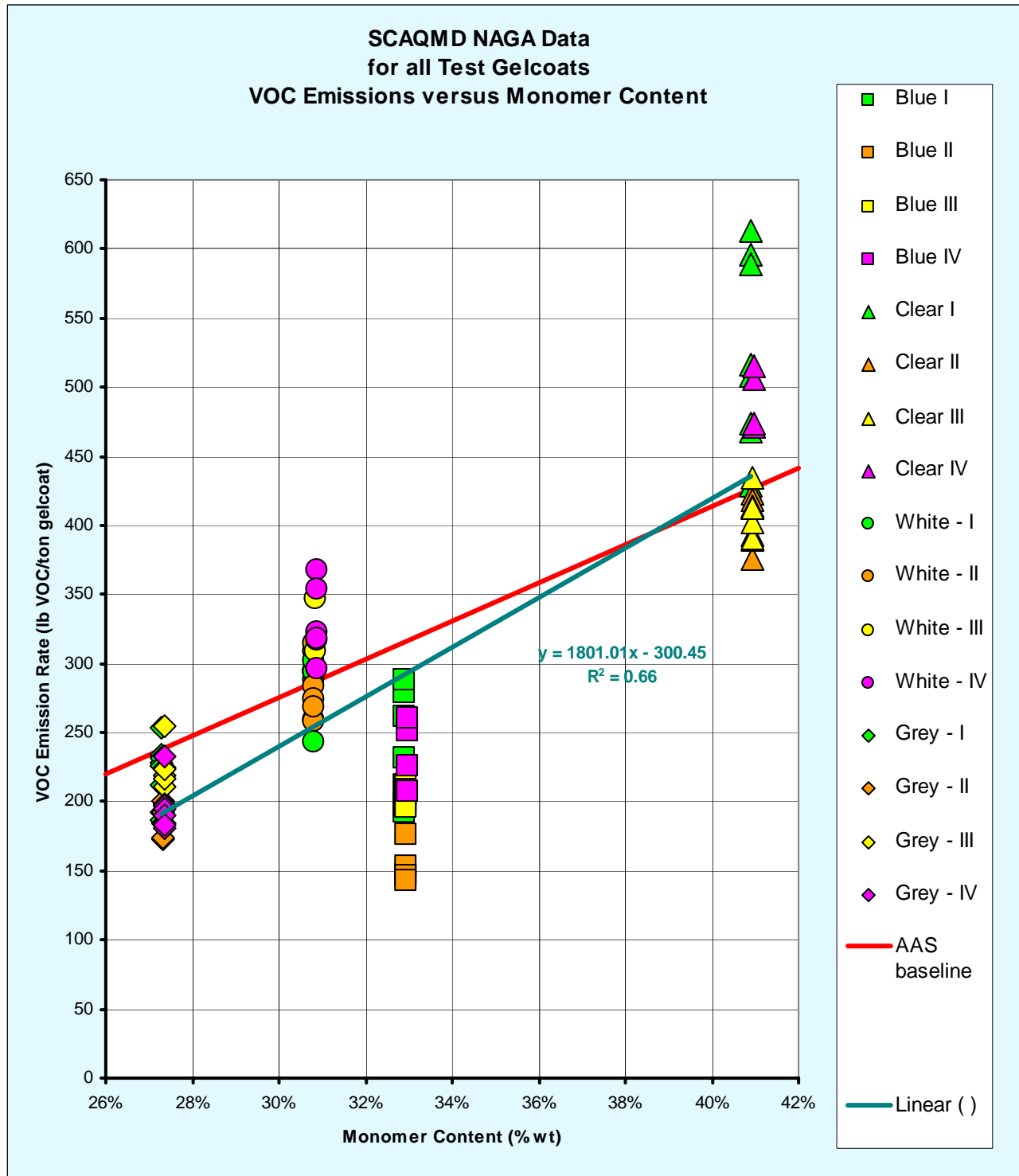
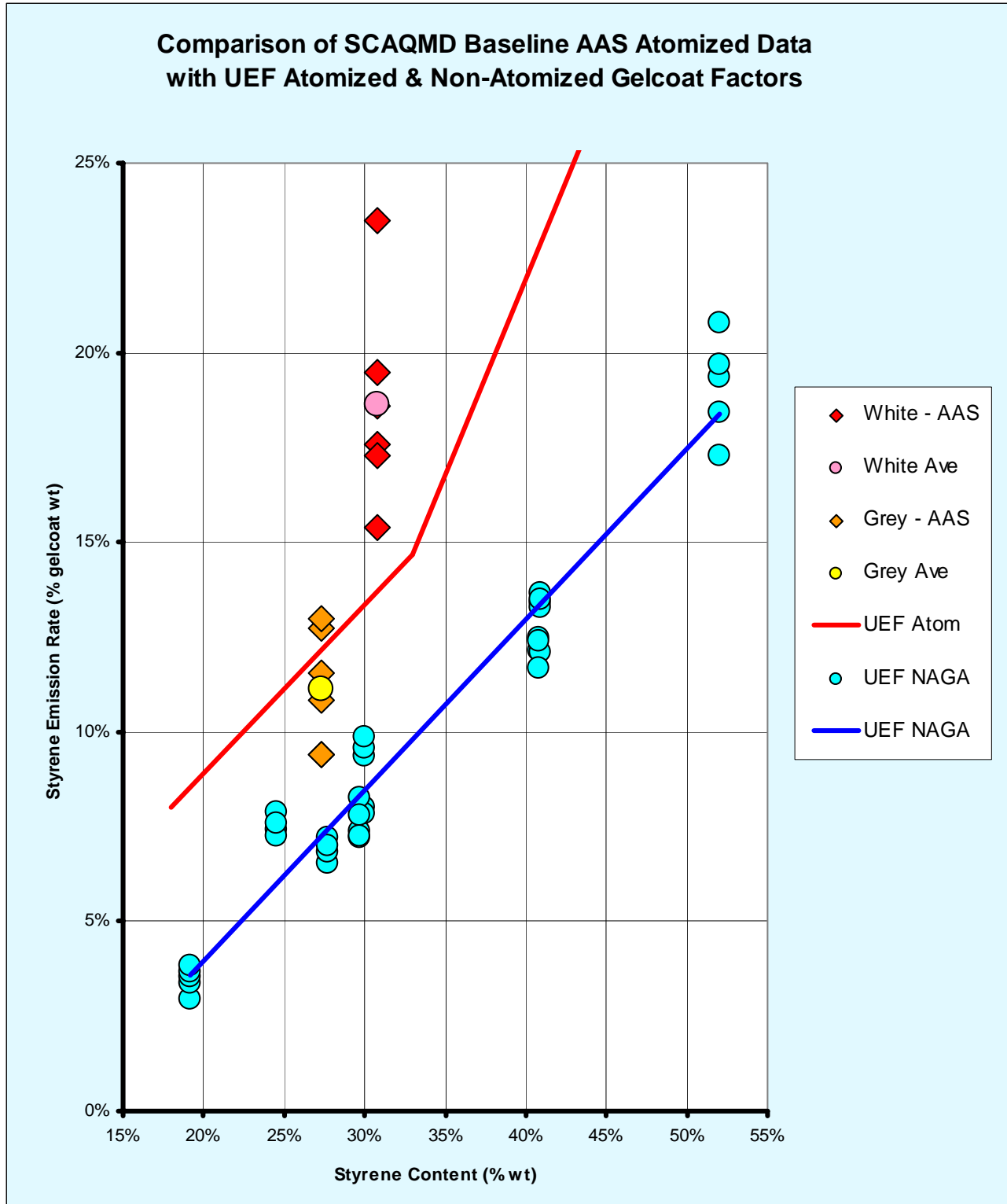


Figure 2 - Plot of SCAQMD Baseline NAGA Data



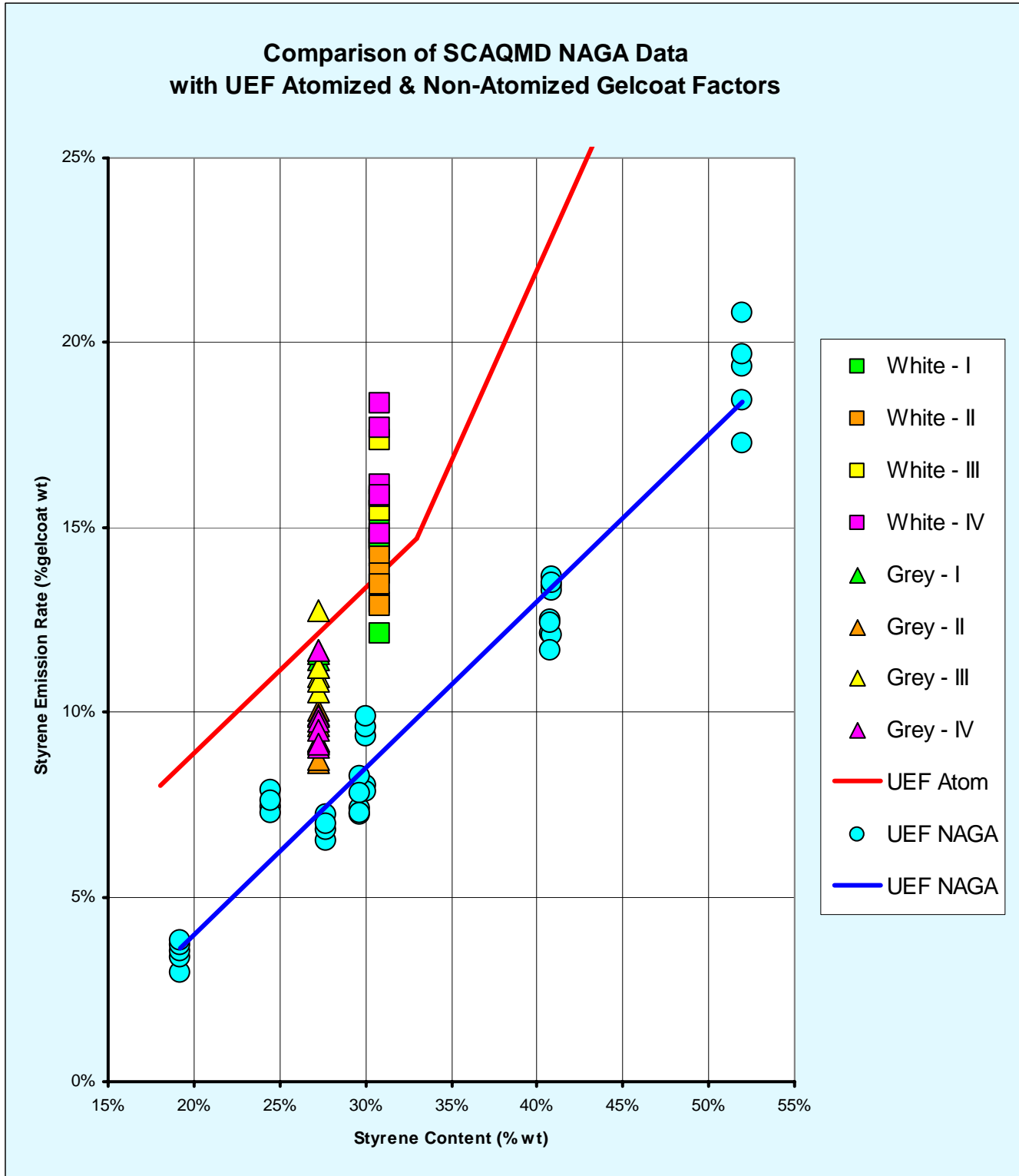
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Figure 3 – Comparison of Baseline AAS with UEF Atomized and Non-Atomized Gelcoat



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Figure 4 - Comparison of NAGA with UEF Atomized and Non-Atomized Gelcoat



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2.2 Problems with the SCAQMD Test Results

The test results alone reveal inexplicable anomalies that indicate fundamental problems with the testing.

Anomalies in the AAS Results

The average blue gelcoat AAS emission rate should have been greater than the white gelcoat rate, yet all white gelcoat AAS test data values were greater than all blue gelcoat data values. This defies explanation and indicates a serious problem with the SCAQMD test procedure. The white gelcoat had a monomer content of 30.8% by weight, which was styrene only, while the blue gelcoat had a total monomer content of 32.9%, which was about 1 to 3% MMA. All previous emissions testing had shown that emissions are directly proportional to monomer content, yet this data showed the opposite. This is particularly hard to explain, because the MMA monomer in the blue gelcoat should have emitted at a higher relative rate.

The average clear gelcoat AAS emission rate should have been significantly greater than the white gelcoat rate, yet the white gelcoat AAS data values were nearly the same as the clear gelcoat data values. This also suggests problems with the SCAQMD test procedure. The clear gelcoat had a total monomer content of 40.9% by weight, which was about 10% MMA. If the SCAQMD testing was conducted properly, then the clear gelcoat should have had significantly greater emissions than the white gelcoat.

A linear regression of the AAS data (emission rate versus monomer content) yielded a R^2 statistic of only 0.49, which showed a very poor fit to the data. Thus, the AAS data show no meaningful relationship between emission rate and monomer content, which is contrary to prior experience. Again, this suggests problems with the SCAQMD test procedure.

Anomalies in the NAGA Results

The average blue gelcoat NAGA emission rate should have been greater than the white gelcoat rate, yet the mean white gelcoat NAGA result was significantly greater than the mean blue gelcoat NAGA result. Most of the individual white gelcoat NAGA test data values were greater than the greatest blue gelcoat data value. As discussed above, this is especially difficult to explain, because the MMA monomer in the blue gelcoat should have emitted at a higher relative rate.

Further confounding the situation, the average blue gelcoat NAGA emission rate should have been greater than the grey gelcoat rate, yet the mean grey gelcoat NAGA result was slightly greater than the mean blue gelcoat NAGA result. Some of the individual blue gelcoat test data

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values were much less than the smallest blue gelcoat data value. The grey gelcoat had a total monomer content of 27.3% by weight, which was all styrene. The blue gelcoat should have had significantly greater emissions than the grey gelcoat. This is also difficult to explain, because the MMA monomer in the blue gelcoat should have emitted at a higher relative rate.

A linear regression of the NAGA data (emission rate versus monomer content) yielded a R^2 statistic of only 0.66, which showed a poor fit to the data. The scatter in the data was also excessive. For example, within the white NAGA results, the greatest individual white gelcoat test data values were two times larger than the smallest values. The other gelcoat types also showed excessive scatter. This degree of scatter is particularly troubling, because this much scatter is still present after SCAQMD had manipulated and “adjusted” the results to smooth out the scatter (please see the following discussion on the test procedure used by SCAQMD)

The clear gelcoat test results for Manufacturer I (plotted as green triangles) were unbelievably high at 589, 595, and 613 lb/ton. The clear gelcoat only contained about 800 lb/ton of monomer, so these emission results were 74 to 77% of the total monomer content. Atomized gelcoat application should have emissions less than 50% of the monomer content, so these results must be in error. The clear gelcoat test results for the other manufacturers were much lower; almost one-half in some cases (please see the other plot triangles in **Figure 2**).

2.3 Results that Defy Explanation

Several test results defy rational explanation:

- Reported differences in gelcoat cure times for AAS and NAGA depended on the color of the gelcoat. Such behavior has never been previously reported, and is contrary to the original test results used to develop the UEF.
- Gelcoat cure times were greater for some gelcoats applied with NAGA equipment than for gelcoat applied with AAS equipment, but not for all gelcoats. This has no physical explanation.
- AAS and NAGA process emissions were not proportional to the monomer content in the gelcoat materials. This contradicts all previous emissions testing results.
- Some test results had monomer emissions approaching 80% of the total monomer content. According to the gelcoat suppliers, this is not physically possible.

2.4 Results that Contradict SCAQMD Conclusions

High-pressure NAGA test result was less than the associated low-pressure NAGA results – the initial hypothesis developed by SCAQMD before the start of testing was that higher gun tip pressure would result in greater emissions. However, SCAQMD did not directly test this hypothesis by varying the tip pressure for NAGA equipment. This would have required too many test runs. Instead, SCAQMD asked manufacturers to “optimize” their NAGA equipment to the lowest feasible pressure and then compared this NAGA equipment to higher-pressure AAS equipment. Thus, SCAQMD never actually tested its initial hypothesis.

Fortunately, SCAQMD accidentally tested NAGA equipment that was operating at a very high gun tip pressure. The reported value was the result for test run #7. The gun tip pressure was listed as 1,050 psi, which was much greater than the gun tip pressure in the baseline AAS equipment, and even greater than the other NAGA test runs for this equipment and gelcoat material. The other low-pressure NAGA runs associated with this high-pressure value are for test runs #5 and #6. If increased tip pressure causes greater emissions, then this high-pressure NAGA test run should have shown greater emissions than the low-pressure “optimized” NAGA runs. However, the exact opposite occurred. As shown in **Table 3**, the high-pressure NAGA result was significantly less than low-pressure results. This contradicted the SCAQMD hypothesis that NAGA emissions increase at higher tip pressures!

Table 3 – High-pressure versus Low-pressure NAGA results

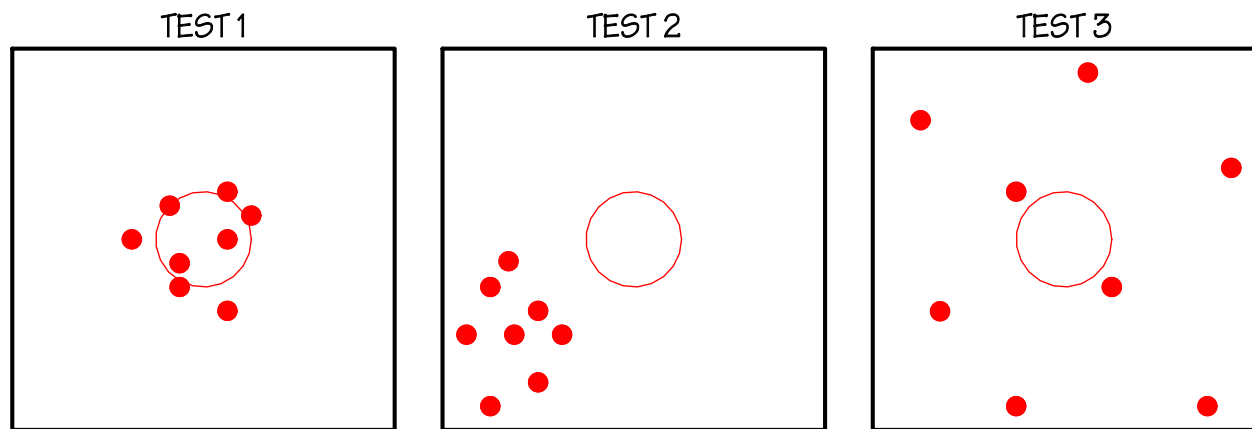
Test Run	Equipment Maker	Gelcoat Color	Gun Pressure psi	Test Results		
				25.1	25 A	Average
5	IV	White	390	367.15	316.40	341.78
6	IV	White	390	354.20	322.70	338.45
7	IV	White	1050	337.11	322.68	329.89

At this point, SCAQMD should have suspended testing and reexamined its basic experimental hypothesis and experimental plan. After all, if NAGA emissions are independent of gun tip pressure, which these results suggested, then further testing would be pointless.

Section 3 - Assessment of the SCAQMD Test Procedure

The test procedure used by SCAQMD was judged on both the precision and accuracy of its many test measurements. An ideal test procedure is both precise and accurate, as shown in the example data for Test 1 in the illustration below. The eight red dots represent individual test measurements, and the red circle is centered at the true measurement value. The data values are slightly spread apart, which is called “scatter,” but are still relatively close together. The mean value of these measurements is dead center inside the target ring, so the procedure is accurate.

A precise test procedure might have inaccurate results. The example data for Test 2 is very precise, but the data is offset from the target. This offset from the true value is known as “bias.” Ironically, an imprecise test procedure could still provide accurate test results. This could happen if the procedure has little to no bias, and many replicates are sampled to develop a representative mean result. The example data shown for Test 3 is very imprecise, but the mean result is dead center inside the target ring. Technically, the procedure is accurate, but the scatter is so great that little confidence can be ascribed to the results.



In the case of the emission factor testing conducted by SCAQMD, the overall accuracy of the baseline AAS and experimental NAGA test results is proportional to the accuracies of the procedures used to measure the exhaust airflow and concentration (the factor numerator) and the material usage (the factor denominator). Likewise, the overall precision of the test results is proportional to the precision of these measurements.

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3.1 Exhaust Airflow

Summary of the Exhaust Airflow Measurement Procedure

The following procedure was used by SCAQMD to determine the exhaust airflow:

1. EPA Methods 1 and 2 were used to measure the average exhaust velocity in the test booth exhaust stack.
2. The average exhaust airflow rate in the stack was computed by multiplying the average exhaust air velocity by the cross sectional area of the stack.
3. The total test run time was determined by observing the start and stop background concentration for each test run. The test was stopped when the stop concentration reached the start concentration.
4. The total exhaust airflow during each test run was computed by multiplying the average exhaust airflow rate by the test run time.
5. The total exhaust airflow was corrected to dry standard temperature and pressure conditions (68° F, 14.69 psia, and 0% moisture). The exhaust temperature, local barometric pressure, and humidity measurements from a nearby weather station were used to make this correction.

Problems with the Exhaust Airflow Measurements

The exhaust airflow measurement suffered from three serious problems:

Unacceptable stack vorticity – extremely excessive vorticity was measured in the test booth stack. During my visit, Lem (SCAQMD roof technician) reported an average 50-degree resultant angle, which indicates extreme cyclonic flow (also known as “vorticity”) in the stack airflow. Lem stated that he had never tested an axial fan before and was surprised at the severity of the cyclonic flow.

According to EPA Method 2, the average resultant angle must be less than 20 degrees. Given the excessive amount of vorticity, federal EPA and most state EPA agencies would consider the stack traverse measurements collected during the testing to be invalid. The field data for the twenty-one vorticity traverses performed by SCAQMD revealed an even greater degree of unacceptable vorticity in the stack. The null angle measured at the individual pitot points varied from minus 93 degree to plus 78 degree. The range of null angle variation for the vorticity runs is listed in **Table 4** on the next page.

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Table 4 – Deviations in Stack Vorticity Measurements for Each Test Run

Date of run	Deviation from null angle	
	minus	plus
8/24/04	- 59°	+ 76°
8/25/04	- 72°	+ 77°
8/26/04	- 66°	+ 75°
8/27/04	- 79°	+ 67°
8/31/04	- 93°	+ 58°
9/1/04	- 77°	+ 70°
9/2/04	- 67°	+ 55°
9/8/04	- 90°	+ 53°
9/19/04	- 85°	+ 45°
9/21/04	- 90°	+ 45°
9/22/04	- 74°	+ 57°
9/23/04	- 75°	+ 68°
9/28/04	- 90°	+ 55°
9/29/04	- 82°	+ 71°
9/30/04	- 64°	+ 64°
10/5/04	- 80°	+ 69°
10/6/04	- 90°	+ 40°
10/7/04	- 90°	+ 40°
10/12/04	- 89°	+ 50°
10/13/04	- 88°	+ 50°
10/14/04	- 83°	+ 66°

This data showed extreme vorticity in the exhaust stack. When an exhaust airflow stream has this amount of excessive vorticity, three acceptable options are recommended in EPA Method 2:

1. Add flow straighteners to the upstream stack section
2. Move the traverse to a location with acceptable vorticity
3. Use a special 3-D pitot instrument capable of measuring the swirling flow

The first alternative was feasible at Lasco, and would have practically eliminated the vorticity. However, SCAQMD faced a difficult dilemma. The stack could not be modified in the middle of the test program without compromising the consistency of the earlier readings for the first and second test trials. This was unfortunate, because the flow straighteners would have cost less than \$100 and taken less than two hours to install at the site. Flow straighteners could still be added to the R&D Booth exhaust stack, and the actual exhaust flow rate could be measured without vorticity and compared to the

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SCAQMD flow rate measurements. The other two alternatives were not feasible at Lasco.

Instead of adding flow straighteners, SCAQMD decided to use a cosine correction approach discussed in Chapter 10 of the District Source Test Manual to adjust the pitot readings. The cosine correction procedure typically includes the following four steps:

1. measure the null point angle at each individual traverse point
2. rotate the pitot normal to the different null point angles measured at each point
3. measure the velocity pressure at the rotated angle for each point
4. adjust the rotated velocity pressure measurement by the cosine of the rotation angle to determine the “actual” velocity pressure

Due to the excessive degree of vorticity present in the test booth exhaust stack, the cosine correction procedure would not be acceptable to most EPA authorities. The cosine procedure is not applicable for angles greater than 90 degree ($\cosine\ 90^\circ = 0.00$), and is questionable for angles greater than 60 degree ($\cosine\ 60^\circ = 0.50$).

Questionable accuracy of the S-type pitot coefficient – the excessive amount of vorticity also affected another test assumption. The 0.84 pitot coefficient used by SCAQMD to correct the S-type pitot assumed smooth parallel airflow conditions. S-type pitot readings are known to over-predict exhaust airflow measurements (when compared to standard pitot readings) in flow streams with significant vorticity, so the 0.84 factor assumed by SCAQMD probably over-predicted the exhaust airflow and measured emission rates during testing. The degree of over prediction is unknown, but could have been estimated by comparing simultaneous S-type and standard pitot readings in the stack at each traverse point.

Again, failure to anticipate the excessive vorticity that was present in the exhaust stack, and then to take the proper steps to correct this condition before starting or continuing the testing also underscored a lack of proper planning and field procedure.

Questionable measurement of the true test run time period – SCAQMD had no way to document that each test run actually measured the true period of NAGA process emissions during the run. Please refer to Section 3.2 for a discussion of this problem.

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3.2 Concentration

Summary of the Exhaust Concentration Measurement Procedure

Two different methods were used by SCAQMD to measure the average organic concentration in the test booth exhaust for each test run:

SCAQMD 25.1 – gas samples were collected in dry ice cooled condensate traps followed by nine liter evacuated tanks. The organic concentrations in the condensate and tanks were analyzed by the total combustion analysis (TCA) technique that oxidizes all carbon compounds to carbon dioxide gas, which is then quantified using infra red absorption spectroscopy.

EPA Method 25A – continuous measurements of the organic concentration were taken using a Rafisch Model RS-55 TCA equipped with a FID. The gas sample was extracted through a three-point steel probe, glass fiber filter, and unheated 1/4" Teflon tubing connected to the FID. The FID was calibrated at the probe tip before and after each sampling run using a series of certified methane-in-air calibration gas standards.

Three mass balance tests were conducted using three different test gelcoats. A mass balance test was not conducted using the blue gelcoat, so only one gelcoat containing MMA (clear gelcoat) was used in the mass balance tests. The mass balance tests had the following average results:

- Method 25.1 slightly overpredicted the expected result – about 109% of the mass loss
- Method 25A greatly underpredicted the expected result – only 65% of the mass loss

SCAQMD did not provide ACMA with any mass balance test data, so an evaluation of the three mass balance runs cannot be offered. However, if subsequent inspection of this data reveals significant variation between the individual mass balance results, then the entire basis of the correction approach used by SCAQMD would be suspect.

All subsequent concentration measurements for the two methods were adjusted by applying the following equipment-specific correction factors:

SCAQMD 25.1 correction factor $(1/1.09) = \mathbf{0.917}$

EPA Method 25A correction factor $(1/0.65) = \mathbf{1.538}$

The reported average organic concentration was then computed for each test run by averaging together the “corrected” results of the two concentration methods.

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Problems with the Exhaust Concentration Measurements

The procedure used to measure the average stack concentration was very problematic. Any of the following problems could seriously compromise the test results.

Inappropriate use of “correction” factors to compensate for excessive variation between methods – SCAQMD should have suspended the testing and determined the root cause of the unacceptably large difference between the two concentration methods. However, SCAQMD decided instead to “adjust” all subsequent concentration measurements for the two methods by applying the aforementioned equipment-specific “correction” factors. Such over reliance on correction factors would not be acceptable to most EPA authorities.

Inappropriate use of averaging to obscure significant deviations between the methods – the differences between the concentration measurements were profoundly significant. SCAQMD should have reported the two different concentration results separately.

Insufficient mass balance testing was performed – the average results of only three mass balance tests were used to adjust over 70 sets of concentration measurements. Only three of the four gelcoats were used in this mass balance test, and only one mass balance test was performed on a gelcoat that contained MMA. Given the differences between the gelcoats and the excessive variation between the two concentration measurements, additional mass balance tests should have been performed.

Excessive variations existed between concentration measurements, even after “correction” – even after “adjusting” the concentration measurements, the two different methods did not show agreement during the subsequent test runs. The average difference in concentration readings between the two methods was about 9%, and the standard deviation of the differences was almost 10%. None of these “adjusted” measurements should have had more than a 5% difference. Yet, thirty-five of the seventy-eight measurement pairs exceeded a 5% difference, twenty pairs exceeded a 10% difference, seven pairs exceeded a 20% difference, and one pair differed by over 50%! Such excessive variation in the measurement of a primary test factor during a compliance test would not be acceptable to most EPA authorities.

MMA monomer emissions were measured as an afterthought – MMA monomer was contained in two of the four test gelcoats materials, the clear and the blue gelcoats. According to the corresponding MSDS data, a range of 1 - 3% MMA was contained in the blue gelcoat and 10% MMA was in the clear gelcoat. The presence of MMA monomer greatly complicated the interpretation of the Method 25A carbon concentration

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readings and the SCAQMD Method 25.1 THC measurements. On the second day of the third test trial, Garibay (SCAQMD lead test coordinator) reported that he had not yet reviewed the MSDS data for the gelcoat materials being tested. Further, he was surprised to learn that the test gelcoats contained MMA monomer and he had assumed that only styrene was present in the test gelcoat. He did not know the relative amounts of MMA in the gelcoats, and could not speculate on the relative ratio of MMA to styrene emissions from the clear or blue gelcoats. The MSDS information was only then provided to Garibay late that morning. These observations are reported to underscore the lack of adequate planning and proper test preparation regarding MMA content in the gelcoats. This should not detract from the diligent efforts made by SCAQMD personnel to complete the test program. However, the failure to plan and compensate for the "mixed monomer" emission streams from the clear and blue gelcoats essentially invalidated the test data for the clear and blue gelcoat materials. Further, the results for the blue and clear gelcoats should not be compared to the UEF NAGA factors, because UEF NAGA factors are only valid for gelcoats that contain just styrene.

Background concentration was not measured during each test run - SCAQMD only had one FID instrument at the site during the testing. For this reason, only the exhaust concentration leaving the test booth was measured during each test run. Thus, SCAQMD has no direct measurements of the background concentrations flowing into the test booth during any of the test runs.

Left without a means of measuring the background concentration, the SCAQMD personnel were forced to use their judgment to decide when to stop each test run. The procedure used by SCAQMD was rudimentary. The exhaust stack concentration was noted at the beginning of the test run, and then the test was supposed to terminate when the concentration reached the beginning level. Unfortunately, this was not the case for many of the test runs.

Please refer to the appendices to the SCAQMD reports, which contain the FID traces for all 79 runs. For some test runs, the concentration reached an apparently stable level at the end of the test that was higher than the beginning value. For some runs, the concentration value was still dropping when the test was stopped because test personnel had decided that the gelcoat had gelled and was no longer emitting. A few test runs showed spikes and periods of increased emissions during curing, which can only be explained by increases in the background concentration.

Basically, SCAQMD had no way to document that each test run period actually measured the true period of NAGA process emissions during the run. If SCAQMD personnel terminated the test too soon, then the test result would under predict, because some emissions would not be measured and included in the results. If the test run was stopped

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too late, then the test result would overpredict, because some background emissions would be falsely measured and included as NAGA emissions. Human perception tends to lag observed events, so SCAQMD probably waited too long to end many test runs. Hence, the curing emissions were probably exaggerated for some test runs. Since the curing emissions are a larger portion of the total NAGA emissions, this flaw in the test procedure would result in the illusion of longer cure times for NAGA. In my opinion, this procedural flaw is the most plausible explanation for the longer NAGA cure times claimed by SCAQMD.

The start and stop of each test run was a critical test decision that could greatly affect the precision and accuracy of the test results. SCAQMD should have placed a second FID instrument on the inlet air stream to the test booth, as recommended in the CFA Test Protocol and as practiced at CMTI where the UEF testing was first conducted.

Variable background concentration compromised a fundamental test assumption – Several sources of fugitive emissions that could cause variable background concentration were observed that included:

- Non-VOC fugitives – acetone clean solvent
- Non-HAP fugitives – cyclohexane, MEK, other organic solvents
- Styrene fugitives – emitted from a loosely covered test pail

During the third trial, I observed other VOC-emitting operations taking place inside the R&D Building during test runs. For example, Lasco personnel were assembling PVC pipe manifolds using a substantial amount of PVC primer and adhesive in a location directly behind the test booth. These materials contain highly volatile organic solvents that were released into the building, and presumably drawn into the test booth exhaust stream. In fact, the odor of cyclohexane and MEK (components in the primer and adhesive) in the vicinity of the test booth alerted me to the PVC assembly operation. I also observed Lasco personnel cleaning some process equipment with a substantial quantity of organic solvent during a test run. Some styrene evaporated from the loosely covered supply pail on the platform balance; this emission reduced the styrene content of the gelcoat during the test period and added to the background concentration.

Test results were not consistently reproduced – SCAQMD placed great reliance upon a claim that the test results were reproduced, therefore the overall measurement procedure must be accurate and precise. However, closer scrutiny of the data shows that this claim is not supported. In fact, the NAGA test data actually contradicts this claim. While three of the six before-and-after test run pairs showed good agreement with the earlier runs, three of these pairs differed by more than 10% and one pair differed by 31%,

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which is almost the size of the experimental effect! These test pair comparisons are listed in **Table 5** below:

Table 5 – Retest Results for the NAGA Test Runs

Color	Equipment	Initial (lb/ton)	Retest (lb/ton)		Difference (%)
Blue	II	216	283	-31%	31%
Clear	II	522	531	-2%	2%
Grey	I	197	190	4%	4%
Grey	II	214	239	-12%	12%
White	I	341	307	10%	10%
White	II	287	298	-4%	4%
				-6%	10%

The NAGA data does not show evidence of reproducibility – just the opposite. This data actually shows that SCAQMD was not able to reproduce the NAGA results for blue gelcoat, and could only reproduce the NAGA results for white and grey gelcoats twice in four attempts. Further, the wide scatter in the before-and-after test data demonstrates a serious lack of precision in the test procedure discussed elsewhere in this report. If the test results were truly reproducible, then the average difference in the before-and-after test data should be less than 5% and none of the results should exceed 10% of the mean. For example, the CMTI lab can routinely reproduce Method 25A test results with no before-and-after data pair exceeding a 5% difference.

The baseline AAS results also suffered from the same lack of reproducibility. Half of these AAS pairs differed by more than 20%, which is almost two-thirds the amount of the experimental effect!

Table 6 – Retest Results for the Baseline AAS Test Runs

Color	Equipment	Initial (lb/ton)	Retest (lb/ton)		Difference (%)
Clear	AAS	446	421	6%	6%
Blue	AAS	216	266	-23%	23%
White	AAS	365	389	-7%	7%
Grey	AAS	206	257	-25%	25%
				-12%	15%

The AAS data actually shows that SCAQMD was not able to reproduce the baseline AAS results for blue and grey gelcoats, and could only reproduce the AAS results for clear and white with some difficulty (between 5% and 10%).

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3.3 Material Usage

Summary of the Material Usage Measurement Procedure

The following procedure was used by SCAQMD to determine the gelcoat material usage:

1. A small quantity of gelcoat was transferred from the 55-gallon steel storage drum to an open five-gallon pail located just outside the test booth enclosure
2. The open pail was placed on a digital platform scale.
3. The NAGA equipment supply line was suspended into the pail from a overhead support bar to compensate for the weight of the line.
4. A piece of polyethylene film was loosely placed over the top of the open pail.
5. The gelcoat usage used during the test run was directly weighed by the digital scale (before and after weights)

Problems with the Material Usage Measurement and Material Handling Procedures

Excessive variation in gelcoat usage – SCAQMD took exceptional care to hold the gelcoat application rate to within relatively tight tolerances. However, the test procedure did not control the amount of gelcoat material actually used during each test run. An analysis of the actual amount of gelcoat used during each test run shows a surprisingly large variation in this critical variable:

Table 7 – Deviations in Material Usage for Each Gelcoat Type during the Test Runs

SCAQMD NAGA Test Data - Gelcoat Material Usage (thickness surrogate)								
(pounds gelcoat applied per test run)								
Gelcoat	Impact of Outliers	Usage Range			Tolerance		Usage	
		minimum	to	maximum	minus /	plus	Mean	Std Dev
Blue	included	3.90	-	6.33	-13%	41%	4.48	0.61
	not included	3.90	-	6.33			4.48	0.63
Clear	included	2.58	-	4.98	-29%	37%	3.62	0.65
	not included	2.58	-	4.98			3.59	0.68
Grey	included	3.23	-	6.18	-33%	27%	4.86	0.81
	not included	3.23	-	6.18			4.86	0.81
White	included	3.71	-	5.37	-15%	23%	4.37	0.43
	not included	3.71	-	5.37			4.38	0.42

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The test mold had a fixed surface area, so the same amount of deposited gelcoat should have formed the same thickness on the mold during each test run. However, the test data shows that this was not the case – significantly different amount of gelcoat were deposited. If each test run had the same gelcoat thickness, then where did the missing gelcoat come from or where did the extra gelcoat go? Three possible explanations for these material differences are:

1. **Measurement of material usage may have been imprecise** – although I did not observe any problems with measurement of the gelcoat material during the third test trial, problems may have existed that I did not see or material measurements for the other test trials may have been sloppy. If the material measurement procedure was so imprecise as to allow a plus or minus 30% variation, then the test procedure was severely flawed.
2. **Applied thickness of gelcoat could have varied** – SCAQMD took steps to ensure consistent gelcoat thickness by measuring the thickness at several locations on the mold. However, I observed problems with blue and clear gelcoat application during the third test trial. The blue gelcoat sagged on the mold, and the clear gelcoat thickness was difficult to judge. Gelcoat thickness is a critical test variable. After monomer content, gelcoat thickness is the second most important test variable that accounts for almost 30% of the variation in emissions (please see the CFA Model report for a complete discussion). The material usage data reported suggests a possible lack of thickness control. If the gelcoat thickness varied by plus or minus 30%, then the test procedure was flawed.
3. **Amount of gelcoat overspray and wasted gelcoat could have varied** – perhaps some gelcoat was sprayed on the floor or in a bucket during the individual test runs. However, if plus or minus 30% of the gelcoat material used during the test run was wasted in this fashion, then this practice would significantly alter the emission rate and invalidate the test run.

Based upon the limited information, I cannot determine which of these explanations is most likely, or if the usage variation was a combination of two or three causes. SCAQMD should have monitored the amount of gelcoat used during each test run instead of focusing on the rate of gelcoat delivery. After the first few usage measurements were recorded, SCAQMD should have suspended testing and carefully investigated the cause of the variation in gelcoat usage and corrected the problem before resuming testing.

The following problem involves the gelcoat material and could have affected the test results, but does not concern the measurement of the material usage.

Deviation in viscosity and improper gelcoat agitation – the drums containing the test gelcoats stood at the site without agitation before the third test trial. Following my

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inquiry, manufacturer personnel rolled the drums before dispensing the test quantities of gelcoat. Rolling the drums is not effective at agitating the gelcoat, but this was the only possible action that could be taken since proper agitation equipment was not available. Instead, the gelcoat materials should have been continuously agitated with a low-speed low-shear drum mixer during the entire test period. The gelcoat handling practice during the first and second trials is not known. According to other reports, the test gelcoats were not agitated during these trials. The impact of this could be significant. Gelcoat viscosity is believed to affect significantly the performance of the NAGA equipment, but this effect cannot be quantified at present with any certainty. The deviations between the original material analyses and the viscosity and thixotropic properties of the test gelcoats measured during the third trial are listed below:

Table 8 – Deviations in Gelcoat Viscosity and Thixotrophy

Gelcoat	Original Certificate of Analysis Values	Measured Values (third trial)	Percentage Change
Clear	Date – 7/28/04 Viscosity @ 77°F 20 rpm – 2,500 cP thix 5/50 – 4.9	Date – 9/23/04 Viscosity @ 76°F 5 rpm – 6,080 cP 20 rpm – 2,290 cP 50 rpm – 1,312 cP thix 5/50 – 4.63	- 8.4% - 5.5%
San Bright White	Date – 8/9/04 Viscosity @ 77°F 20 rpm – 4,990 cP thix 5/50 – 3.83	Date – 9/22/04 Viscosity @ 76°F 5 rpm – 8,200 cP 20 rpm – 3,770 cP 50 rpm – 2,332 cP thix 5/50 – 3.52	- 24% - 8.8%
Midnight Blue	Date – 8/10/04 Viscosity @ 77°F 20 rpm – 4,960 cP thix 5/50 – 6.7	Date – 9/22/04 Viscosity @ 75°F 5 rpm – 10,920 cP 20 rpm – 3,230 cP 50 rpm – 1,612 cP thix 5/50 – 6.77	- 35% + 1.0%
Gray Sandable	Date – 9/10/04 Viscosity @ 77°F 20 rpm – 5,100 cP thix 2/20 – 6.3	Date – 9/21/04 Viscosity @ 76°F 2 rpm – 24,200 cP 20 rpm – 4,160 cP thix 2/20 – 5.82	- 18% - 7.6%

As shown in **Table 8**, all of the gelcoats show a marked change in viscosity. Three of the four gelcoats showed a reduction in thixotropic index.

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Section 4 - Conclusions

Many of the reported test results defy explanation or contradict the test hypothesis, and raise serious doubts about the validity of the test:

- Reported differences in gelcoat cure times for the AAS and NAGA processes depended on the color of the gelcoat.
- Some of the NAGA results for clear gelcoat were unbelievably high.
- Unlike the results from all previous gelcoat testing, the measured emission rate was not proportional to gelcoat monomer content.
- The test result for a high-pressure NAGA test run was less than the associated low-pressure NAGA results, contradicting the test hypothesis.

The test procedure used by SCAQMD suffered from a pronounced lack of accuracy and precision. All three of the fundamental test factor measurements (exhaust airflow, concentration, and material usage) had problems that could cause unacceptable scatter and bias in the results.

Excessive scatter and pronounced bias was apparent in the data.

At least five critical flaws in the test procedure compromised the validity of the test results.

- Unacceptable vorticity in the exhaust airflow – introduced potential bias and scatter in the exhaust airflow measurements.
- Unacceptable variation in the gelcoat usages between test runs – caused scatter in the factor computation.
- Unknown background concentration during the test run – caused scatter and bias in the concentration measurements.
- Indeterminate test run times – scatter and bias in the concentration measurement and factor computation.
- Mixed monomers (styrene and MMA) with substantially different vapor pressures and unknown relative emissions rates – scatter and bias is a common problem for mixed monomer concentration measurements

The test results were not reproduced by SCAQMD.

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Section 5 - Critique of SCAQMD NAGA Test Report

Two draft reports were produced by SCAQMD concerning the NAGA test program conducted at Lasco:

- Report (no date) entitled “*VOC Emissions from Gel Coat Spraying Using Four Non-Atomized and Two Air Assisted Airless Spray Guns*” by Wayne Stredwick (henceforth called the “**Stredwick Report**”)
- March 2005 report entitled “*AQMD Gel Coat Testing Program*” by Helmy Sultan (henceforth called the “**Sultan Report**”)

The following section provides a critique of the Sultan Report. This critique proceeds through the pages of the associated report from start to finish. Where a statement or section requires comment, that statement or section is first quoted verbatim, and then the comment and information supporting the comment immediately follows the quotation.

The Stredwick Report was practically identical to the Sultan Report, so a separate critique of that report is not included in this assessment.

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Critique of the Sultan Report

page 2

“The results were most recently published in the Unified Emissions Factor (UEF) 2001 table, expressed as pounds of VOC per ton of sprayed gel coat or resin. Based on the UEF table emission rates, the VOC emission reduction for the nonatomizing spray application technique of gel coats is approximately 40 percent by weight (as compared to the atomized application equipment).”

This statement is incorrect in two ways. First, the UEF 2001 table does not express the emissions from NAGA equipment as “pounds of VOC per ton of sprayed gelcoat or resin.” Second, the average styrene emission reduction for NAGA versus atomized gelcoat application in the UEF is not approximately 40%. The amount of reduction varied with the styrene content in the gelcoat and ranged from 33% to 41% across the range of gelcoat contents used in the NAGA test program.

page 3

“Utilize optimum performance of the spray equipment by requiring the spray equipment manufacturers to operate their own equipment to eliminate the “learning curve” impact on the testing results;”

Optimum performance involves substantial working experience with the combination of equipment and gelcoat material, not just knowledge of the equipment. The “learning curve” referred to by SCAQMD was not eliminated. To the contrary, the manufacturers did not have sufficient time to optimize their equipment for four different test gelcoats in the short time period allotted before each test trial.

page 4

“The AQMD protocol incorporated key elements of the CFA Styrene Emissions Test Protocol & Facility Certification Procedures Revision 2.2 (March 1999), except for the following modifications:”

SCAQMD failed to mention several critical modifications to the CFA Test Protocol that seriously compromised the test procedure. These critical modifications included:

- Only one FID instrument was available at the test site to measure just the test booth exhaust concentration – the background concentration flowing into the test booth was not measured during the test run.
- Gelcoats that contained MMA monomer were tested.
- Exhaust airflow measurements failed EPA Method 2 vorticity requirements.

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page 7

“During the testing runs, the maintenance spray booth was operated to minimize any potential VOC background in the testing area.”

The Maintenance Spray Booth was not operated continuously during all four trials. Equipment cleaning with acetone reportedly occurred outside this booth during the first test trial. Several other sources of VOC were observed in the R&D Building during the third trial, and were probably also present during the second and fourth trials. The background VOC was significant and varied during the test runs. The impact of background VOC in the testing area was not minimized as suggested here. In fact, the failure of SCAQMD to measure the background concentration entering the test booth with a second FID instrument was one of five serious flaws in the test procedure.

“Emission testing methods include the following:”

SCAQMD listed several emission testing methods that were part of the NAGA test procedures. However, one of the key test methods, EPA Test Method 2 – “Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube),” was conspicuously absent from the list of these emission testing methods. Perhaps this method was not mentioned here, because the test booth exhaust stack failed to meet the minimum conditions specified in section 1.2 of Method 2 regarding the unacceptable cyclonic flow conditions present in the stack. Further, SCAQMD failed to implement any of the three alternative procedures listed in section 1.2 of Method 2. As detailed in Section 3.1 of this assessment, the first alternative (install straightening vanes) could have eliminated the cyclonic flow and could have been implemented in a few hours at a cost of less than \$100.

page 8 through page 11 – surface quality test procedures

This assessment does not address surface quality.

page 12

“...the results presented in this report exclude data from seven source tests that were rejected for cause.”

Eight data points were actually discarded instead of seven values as stated by SCAQMD. The eighth value was a very high-pressure NAGA result that was inadvertently measured by SCAQMD. As discussed in Section 2.4, the high-pressure NAGA result was significantly less than the associated low-pressure results. Thus, the data actually

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contradicted the SCAQMD hypothesis that high tip pressure affects the NAGA emission rate and that NAGA emissions increase at higher tip pressures!

page 13

“The VOC emission data indicates that there were no significant differences between the emission rates of the nonatomizing and air-assisted airless spray applications.”

Given the amount of scatter in the data and the other procedural flaws in the testing, the test data cannot support any definitive comparison. Still, the data shows significant differences between the baseline AAS results and NAGA for some manufacturers and some gelcoats, which is contrary to this claim. Please refer to the discussions in Section 2.

“Furthermore, the VOC emission rates show no significant difference between the emission rates of the spray applications of the four (4) participant equipment manufacturers.”

This is simply not true. Please refer to the discussion in Section 2 and see **Figure 2**.

page 14

“Table 3 also indicates that except for the san bright white, the average VOC emission rates of the gel coat tested materials are a function of their monomer content.”

SCAQMD is asking us ignore one-quarter of the data. Even if the white gelcoat results were discarded, the other gelcoat results do not support this claim (please see **Figure 2**).

“The relatively higher VOC emission rates of the san bright white (30.8 percent monomer content), as compared to the VOC emission rates of the midnight blue (32.9 percent monomer content) may be attributed to the higher VOC content of the san bright white (440 g/l) as compared to the VOC content of the midnight blue (390 g/l).”

This explanation has no physical basis, and is contrary to the results for all past emissions testing. Why does SCAQMD believe that volumetric content would have any bearing on the emission rate?

“Typical emission profiles of the nonatomizing and air-assisted spray application equipment of the clear, midnight blue, san bright white and gray sandable gel coat are shown in Figures 1, 2, 3 and 4, respectively [page 15 through page 16]”

These ideal profiles downplay the problems that are evident in other profiles.

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page 17

“The test results indicate that the overall average curing time of the air-assisted airless spray application equipment represent 76.8 percent of the nonatomizing spray application equipment overall average curing time.”

The data presented by SCAQMD is not consistent with this claim. Moreover, the reported average curing time for all four gelcoats was misleading. Table 5 on page 18 of the report lists the individual average AAS and NAGA cure times for the four different gelcoat types. According to these individual results, the average cure time for blue gelcoat was the same for both the AAS and NAGA processes. The average cure time for white gelcoat was nearly the same for both processes, and was probably statistically the same at 89%. The gray and clear gelcoat were the only two gelcoats that show different average cure times. Thus, the data presented by SCAQMD indicates that curing time is a function of gelcoat color, which makes no sense at all!

pages 18 and 19

“The results illustrate the reproducibility of the VOC emission rates despite the changes in the viscosity of the gel coat tested materials.”

As detailed in Section 3.2, the data presented by SCAQMD actually contradicts this claim. While three of the six before-and-after NAGA test run pairs showed good agreement with the earlier runs, three of these pairs differed by more than 10% and one pair differed by 31%, which is almost the size of the experimental effect. The baseline AAS results also suffered from the same lack of reproducibility. Half of these AAS pairs differed by more than 20%, which is almost two-thirds the amount of the experimental effect. SCAQMD was not able to reproduce the baseline AAS results for blue and grey gelcoats, and could only reproduce the AAS results for clear and white with some difficulty (between 5% and 10%).

pages 20 through 25 - Surface Quality Testing Results

Surface quality test results are not a subject of this assessment.

page 26

“Furthermore, there were no significant differences between the VOC emission rates of the spray application equipment of the four participant spray equipment manufacturers.”

The data actually supports the opposite conclusion. Please refer to the SCAQMD NAGA data plotted in **Figure 2**. Equipment from Manufacturer II (orange plot points) consistently outperformed all other equipment for all four gelcoats types. Equipment

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from Manufacturer I (green plot points) consistently underperformed all other equipment for the application of blue and clear gelcoats (both containing MMA monomer). Equipment from Manufacturer IV (magenta plot points) consistently underperformed all other equipment for the application of white gelcoat. Other equipment specific performances are evident, but these three examples really stand out.

“During the application phase, the emission rate of the air-assisted airless spray application equipment was higher than the nonatomizing spray application equipment. However, the opposite was observed during the curing phase. Interestingly, the total VOC emissions for both the air-assisted airless and the nonatomizing spray application equipment were approximately the same.”

No rational physical explanation is available to explain the increase in curing emissions from NAGA claimed by SCAQMD. This was more likely caused by problems with the test procedure.

Further, the scatter in the SCAQMD data was so great that the second claim has no real meaning. Indeed, any comparison of average results would look the same for a test procedure that lacks precision.