September 2003

Environmental Technology Verification Report

Evermore Paints and Coatings, Inc. Formula 5 Coating

Prepared by
National Defense Center for Environmental Excellence
Operated by
Concurrent Technologies Corporation

for the
U.S. Environmental Protection Agency
Under Contract No. DAAE30-98-C-1050
with the U.S. Defense Contract Command – Washington (DCC-W)
via EPA Interagency Agreement No. DW2193939801

Notice

This document was prepared by Concurrent Technologies Corporation (*CTC*) under Contract No. DAAE30-98-C-1050 with the U.S. Defense Contract Command – Washington (DCC-W), Task N.306, SOW Task 4. The U.S. Environmental Protection Agency (EPA) and the U.S. Army are working together under EPA Interagency Agreement No. DW2193939801. This document has been subjected to EPA's technical peer and administrative reviews and has been approved for publication. Mention of corporation names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products.

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Evermore Paints and Coatings, Inc.
Formula 5 Coating

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Foreword

The Environmental Technology Verification (ETV) Program has been established by the U.S. Environmental Protection Agency (EPA) to verify the performance characteristics of innovative environmental technologies across all media and to report this objective information to the states, buyers, and users of environmental technology, thus accelerating the entrance of these new technologies into the marketplace. Verification organizations oversee and report verification activities based on testing and quality assurance protocols developed with input from major stakeholders and customer groups associated with the technology area. ETV consists of six technology centers. Information about each of these centers can be found on the Internet at http://www.epa.gov/etv/.

EPA's ETV Program, through the National Risk Management Research Laboratory, Air Pollution Prevention and Control Division has partnered with Concurrent Technologies Corporation, through the National Defense Center for Environmental Excellence, to verify innovative coatings and coating equipment technologies for reducing air emissions from coating operations. Pollutant releases to other media are considered, but in less detail.

The following report describes the verification of the performance of the Evermore Paints and Coatings Inc. Formula 5 Coating for industrial/architectural/institutional applications.

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Formula 5 Coating Data Notebook (Available from *CTC* upon request)

Acknowledgments

CTC acknowledges the support of all those who helped plan and implement the verification activities and prepare this report. In particular, a special thanks to Michael Kosusko, EPA ETV CCEP Project Manager, and Shirley Wasson, EPA ETV CCEP Quality Assurance Manager, both of EPA's National Risk Management Research Laboratory in Research Triangle Park, North Carolina.

CTC also expresses sincere gratitude to Evermore Paints and Coatings Inc., the manufacturer of the Formula 5 coating, for their participation in, and support of, this program and their ongoing commitment to improve organic finishing operations. In particular, *CTC* would like to thank Dr. Patrick Herd, President. Evermore Paints and Coatings Inc. is based in Tulsa, Oklahoma.

SI to English Conversions

SI Unit	English Unit	Multiply SI by factor to obtain English
°C	°F	1.80, then add 32
L	gal (U.S.)	0.2642
m	ft	3.281
kg	lbm	2.205
kPa	psi	0.14504
cm	in.	0.3937
mm	mil (1 mil = 1/1000 in.)	39.37
m/s	ft/min	196.9
kg/L	lbm/gal (U.S.)	8.345

List of Abbreviations and Acronyms

APPCD	Air Pollution Prevention and Control Division
ASTM	American Society for Testing and Materials
avg.	average
CCEP	Coatings and Coating Equipment Program
CTC	Concurrent Technologies Corporation
DFT	dry film thickness
DI	deionized
DOI	distinctness-of-image
EPA	U.S. Environmental Protection Agency
ETF	Environmental Technology Facility
ETV	Environmental Technology Verification
HAP	hazardous air pollutant
MEK	methyl ethyl ketone
NDCEE	National Defense Center for Environmental Excellence
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NIST	National Institute for Standards and Technology
NRMRL	National Risk Management Research Laboratory
P2	pollution prevention
PEA	performance evaluation audit
PLC	programmable logic controller
QA/QC	quality assurance/quality control
SAE	Society of Automotive Engineers
SD	standard deviation
TQAPP	Testing and Quality Assurance Project Plan
TSA	technical system audit
VOC	volatile organic compound

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Section 1
Introduction

1.1 ETV Overview

Through the Environmental Technology Verification (ETV) Pollution Prevention (P2) Innovative Coatings & Coating Equipment Program (CCEP) of the P2, Recycling, and Waste Treatment Center, the U.S. Environmental Protection Agency (EPA) is assisting manufacturers in selecting more environmentally acceptable coatings and equipment to apply coating materials. The ETV program, established by the EPA as a result of former President Clinton's environmental technology strategy, *Bridge to a Sustainable Future*, was developed to accelerate environmental technology development and commercialization through third-party verification and reporting of performance. Specifically, this program targets coating technologies that are capable of improving organic finishing operations while reducing the quantity of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) generated by coating applications. The overall objective of the ETV CCEP is to verify P2 and performance characteristics of coatings and coating equipment technologies and to make the results of the verification tests available to prospective technology end users. The ETV CCEP is managed by Concurrent Technologies Corporation (*CTC*), located in Johnstown, Pennsylvania. *CTC,* under the National Defense Center for Environmental Excellence (NDCEE) program, was directed to establish a demonstration factory with prototype manufacturing processes that are capable of reducing or eliminating materials that are harmful to the environment.

The ETV CCEP is a program of partnerships among the EPA, *CTC*, the vendors of the technologies being verified, and a stakeholders group. The stakeholders group comprises representatives of end users, vendors, industry associations, consultants, and regulatory permitters.

The purpose of this report is to present the results of verification testing of the Evermore Paints and Coatings Inc.'s Formula 5 coating, hereafter referred to as Formula 5, which is intended for use in industrial, architectural, and institutional coating applications. The application equipment recommended by Evermore Paints and Coatings Inc. was the Graco Silver Plus airless spray gun. Where possible, analyses performed during these tests followed American Society for Testing and Materials (ASTM) methods, or other standard test methods.

1.2 Potential Environmental Impacts

VOCs are emitted to the atmosphere from many industrial processes, as well as through natural biological reactions. VOCs are mobile in the vapor phase, enabling them to travel rapidly to the troposphere where they combine with nitrogen oxides in the presence of sunlight to form photochemical oxidants. These photochemical oxidants are precursors to ground-level ozone or photochemical smog.[1] Many VOCs, HAPs, or their reaction products are mutagenic, carcinogenic, or teratogenic (i.e., cause gene mutation, cancer, or abnormal fetal development).[2] Because of these detrimental effects, Titles I and III of the Clean Air Act Amendments of 1990 were established to control ozone precursors and HAP emissions.[2,3]

Painting operations contribute approximately 20% of stationary source VOC emissions. These operations also contribute to HAP emissions, liquid wastes, and solid wastes. End users and permitters often overlook these multimedia environmental effects of coating operations. New technologies are needed and are being developed to reduce the generation of pollutants from coating operations. However, the emerging technologies must not compromise coating performance and finish quality.

CTC is serving as the verification organization for the ETV CCEP because of their commitment to environmental excellence and helping the U.S. industrial base achieve world-class agility and competitiveness. *CTC*'s equipment is located in a demonstration factory that was established under the NDCEE program. This equipment includes full-scale, state-of-the-art organic finishing equipment, as well as the laboratory equipment required to test and evaluate organic coatings. The equipment and facilities have been made available for this program for the purpose of testing and verifying the abilities of finishing technologies.

1.3 Formula 5 Technology Description

The Formula 5 coating is manufactured by Evermore Paints and Coatings Inc. The Formula 5 coating is a polyamide-epoxy-silicone modified coating. The Formula 5 coating was developed as a high performance coating for industrial, architectural, and institutional applications. The Formula 5 coating is a water-reducible coating that is low in VOCs and HAPs. The coating is a two-component epoxy, consisting of the base and an activator. The coating is mixed at a volumetric ratio of 1 part activator to 2 parts base. The coating can be reduced by up to 15% with deionized (DI) water to reduce viscosity and improve sprayability. Test #1 was completed in March 2001, and Test #2 was completed in September 2002. For these tests, the coating sample used in Test #1 was reduced with DI water by 10% by volume, and the new coating sample used in Test #2 was reduced with DI water by 15% by volume.

1.4 Technology Testing Process

CTC developed a technology-specific Testing and Quality Assurance Project Plan (TQAPP) for the Formula 5 coating with significant input from the vendor.[4] This was based on the Generic Verification Protocol for liquid coatings.[5] After the vendor concurred with, and the EPA and *CTC* approved, the TQAPP, *CTC* performed the verification test. The Verification Statement, which is produced as a result of this test, may be used by Evermore Paint and Coatings Inc. for marketing purposes or by end users of the Formula 5 coating. The Verification Statement for the Formula 5 coating is included on pages v–ix of this report. A Data Notebook has been compiled by *CTC*, which includes a more detailed discussion of the test conditions, the test results, and the data analyses. The Data Notebook is available from *CTC* upon request.

1.4.1 Technology Selection

Organic finishing technologies that demonstrated the ability to provide environmental advantages were reviewed and prioritized by the ETV CCEP stakeholders group. The stakeholders group is composed of coating industry end user and vendor association representatives, end users, vendors, industry consultants, and state and regional technical representatives. The stakeholders group reviewed the P2 potential of each candidate technology and considered the interests of industry. The Formula 5 coating was found to have P2 potential and can be utilized by many applications that traditionally use epoxy polyamide type coatings, but the end user must consider the performance characteristics when evaluating Formula 5 as an alternative to higher VOC coatings.

1.4.2 Rationale for Multiple Tests

The results of Test #1 were considerably different from previous testing of the Formula 5 coating by reputable testing firms, raising questions about the representativeness of the coating sample used. *CTC* had manufactured the Test #1 coating sample for Evermore and the vendor blamed *CTC* for the coating's failure. In order to ensure the unbiased integrity of the program and its results, ETV CCEP agreed to a retest and allowed Evermore to submit a new batch of Formula 5 for Test #2.

1.5 Test Objectives and Approach

The testing was performed according to the Formula 5 coating TQAPP. This project was designed to verify the performance of the Formula 5 coating and its capability to provide the end user with a P2 benefit while maintaining or improving the expected finish quality of the applied coating. This project supplies the end users with the best available, unbiased technical data to assist them in determining whether the Formula 5 coating meets their needs.

The quantitative P2 benefit will result from an analysis of the coating's VOC and HAP content. For this verification test, a specific combination of test factors was selected by *CTC,* EPA, Evermore Paints and Coatings Inc., and the ETV CCEP stakeholders. The data presented in this report are representative only of the specific conditions tested; however, the test design represents an independent, repeatable evaluation of the P2 benefits and performance of the technology.

All processing and laboratory analyses were performed at *CTC*'s Environmental Technology Facility (ETF) by ETV CCEP staff, with the exception of the VOC and HAP content analyses, which were performed by Advanced Technologies of Michigan Inc. The VOC and HAP contents were determined to quantify the P2 benefit of the technology. The following analyses were performed on the coated test panels to verify the coating's finish quality: dry film thickness (DFT), gloss, visual appearance, color, color difference, MEK (methyl ethyl ketone) rub, tape adhesion, mandrel bend, pencil hardness, direct impact, abrasion resistance, weather resistance, salt spray, and humidity resistance.

Table 1. Verification Factors for the Formula 5 Coating

Factor	Test #1 Results	Test #2 Results
VOC Content[a], g/L	212	226
HAP Content[a], g/L	160	165
Dry Film Thickness (mils)	Average/SD[b]: 2.3 / 0.4	Average/SD: 1.8 / 0.2
Gloss, gloss units (at a 60° angle)	Average/SD: 40 / 17	Average/SD: 75 / 5
Visual Appearance	No major defects. Coating was uniform from rack to rack and from run to run.	Slight striping effect and slight dimples. Coating was uniform from rack to rack and from run to run.
Color, ΔE units	Average/SD: 0.75 / 0.39	Average/SD: 0.50 / 0.08
Color Difference[c]	Average/SD: 4 / N/A[d]	Average/SD: 4 / N/A
MEK Rub[e]	Average/SD: 5 / N/A	Average/SD: 5 / N/A
Tape Adhesion[f]	Average/SD: 4A / N/A	Average/SD: 4A / N/A
Mandrel Bend	Average/SD: Fail	Average/SD: Fail
Pencil Hardness (Gouge/Scratch)	Average: 6H / N/A	Average: 9H / 2H
Direct Impact, J	Average/SD: 4.7 / 0.1	Average/SD: 3.1 / 0.2
Abrasion Resistance, mg	Average/SD: 100.7 / 6.4	Average/SD: 95.9 / 5.1
Weather Resistance		
Gloss Retention, gloss units	Average/SD: 12% / 3%	Average/SD: 1.8% / 0.1%
Color Change, ΔE units	Average/SD: 3.22 / 0.59	Average/SD: 6.83 / 0.34
Salt Spray[g] **(1000 hrs.)**	Average/SD: 0 / N/A	Average/SD: 0 / N/A
Humidity Resistance[h]	Average/SD: 6 / N/A	Average/SD: 0 / N/A

[a] Less water and exempt solvents.
[b] SD = Standard Deviation.
[c] A score of 4 indicates good color match to AATCC Gray Scale (ACT #1004) panel.
[d] N/A = Not applicable.
[e] A score of 5 indicates little to no effect on the coating.
[f] A score of 4A indicates slight coating removal at the scribe.
[g] A score of 0 indicates complete removal of the coating.
[h] A score of 0 indicates >75% blistering on unscribed panels.

1.6 Performance and Cost Summary

This verification has quantitatively shown that the Formula 5 coating is capable of providing an environmental benefit based on VOC and HAP contents below the current regulatory limits established for architectural coatings, as shown in Table 1. This verification test has also shown that the Formula 5 coating provides the end user with a finish quality characterized by the data shown in Table 1. The end user should review these data carefully to ascertain the applicability of Evermore Formula 5 to their application.

Evermore has declined to supply the retail prices of the Formula 5 base and activator components. The only special requirements that the Formula 5 coating may have for application are stainless steel components on the spray gun and a pneumatic mixer on the fluid delivery system. The operating costs of the Formula 5 coating include only routine maintenance and cleanup. The economic advantage of the Formula 5 coating is realized after consideration of the reduced VOC and HAP emissions generated by the coating application process. The National VOC Emissions Standards for Architectural Coatings identifies VOC content limits for several types of coatings. The lowest limit identified for this type of coating is 350 g VOC/L of coating, minus water and exempt solvents. The VOC content of Formula 5 was determined to be 212 g/L and 226 g/L for Tests #1 and #2, respectively, which is 35 to 40% below the regulatory limit. There are currently no regulations on the HAP content of architectural coatings. However, by comparison, the National Emissions Standard for Hazardous Air Pollutants (NESHAP) for Shipbuilding and Ship Repair (Surface Coating) Operations identifies volatile organic HAP content limits for marine coatings. The lowest limit identified for coatings similar to Formula 5 is 340 g of HAP/L of coating, minus water and exempt solvents. The HAP content of Formula 5 was determined to be 160 g/L and 165 g/L for Tests #1 and #2, respectively, which is approximately 52% below the Shipbuilding NESHAP limit.

During Test #1, the coating was allowed to sit for 30 minutes (induction time) prior to spraying each run. As time progressed, it became evident that continuous stirring of the pot was needed to maintain a homogeneous coating. As the time after mixing approached one hour, the components separated more rapidly and readily once the stirring stopped. Test #2 did not incorporate an induction time after mixing. Each run was then completed in less than an hour after mixing. Separation of the components still occurred, and continuous stirring was again utilized. Separation of the coating components during spraying resulted in poor atomization characteristics and a yellowing of the applied coating due to the color of the component that came to the surface of the applied film.

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Section 2
Description of the Technology

2.1 Technology Performance, Evaluation, and Verification

The overall objectives of this verification study are to verify P2 characteristics and performance of the Formula 5 coating and to make the results of the verification tests available to the coating vendor and prospective end users. The Formula 5 coating is designed for use in architectural, industrial, and institutional coating applications. The Formula 5 coating is a polyamide-epoxy-silicone modified coating that is a two-component, water-reducible epoxy coating, low in VOCs and HAPs.

CTC, the independent, third-party evaluator, worked with Evermore Paints and Coatings Inc. and the EPA throughout the verification test. *CTC* personnel conducted all portions of the verification test with the exception of the VOC and HAP content analyses. *CTC* prepared this verification report and was responsible for performing the data review and analyses associated with this verification.

2.2 The Formula 5 Coating Test

This verification test is based on the ETV CCEP Formula 5 Coating TQAPP. Evermore Paints and Coatings Inc. worked with *CTC* to identify the optimum performance measures for this test. The TQAPP was drafted using the vendor-supplied information and was submitted to EPA for review of content. Following the initial EPA review and incorporation of comments, the vendor was given the opportunity to comment on the specifics of the TQAPP. Any information pertinent to maintaining the quality of the study was incorporated into the TQAPP. The final draft of the TQAPP was reviewed by the vendor and technical peer reviewers and then approved by the EPA and *CTC* prior to the start of verification testing.

CTC staff associated with the ETV CCEP conducted both Tests #1 and #2. All information gathered during verification testing was analyzed, reduced, and documented in this report. VOC/HAP content and finish quality measurements of the Formula 5 coating were the primary objectives of this report. The data highlight the P2 benefit of the Formula 5 coating, as well as the coating's finish quality. A randomly selected portion of at least 10% of the test data has been quality audited by the ETV CCEP Quality Assurance (QA) Officer to ensure the validity of the data.

2.3 Formula 5 Coating

This section contains information on Formula 5 coating, potential applications in the target industry, the advantages and benefits of the coating, and information on coating deployment.

2.3.1 Applications of the Technology

The Formula 5 coating can be used in a broad range of coating applications. Evermore developed the Formula 5 coating to be used on metal, wood, concrete, and plastic surfaces. These could include interior walls, equipment, and surfaces that are not exposed to direct sunlight or sea (salt) air and require an extremely hard finish.

2.3.2 Advantages of the Technology

The Formula 5 coating reduces emissions by virtue of VOC and HAP contents below regulatory limits. Reduced emissions can help end users add new equipment or meet future regulations.

2.3.3 Disadvantages of the Technology

The primary disadvantage to the Formula 5 coating is that it may require a mixer for the fluid delivery system. However, constant mixing aids in delivering a uniform coating across large surfaces. Constant mixing was required to apply the coating to avoid separation of the coating components. Results of laboratory testing indicate that the cured coating is inflexible and has little resistance to salt spray and humidity.

2.3.4 Technology Deployment and Costs

The Formula 5 coating could be a drop-in replacement for existing higher VOC/HAP coatings. The coating may be cost effective because its material and operating costs are paid back through reduced VOC and HAP emissions.

Section 3
Description and Rationale for the Test Design

3.1 Description of Test Site

The testing of the Formula 5 coating was conducted at the Organic Finishing Line, in *CTC*'s Environmental Technology Facility Demonstration Factory. The layout of the Organic Finishing Line is shown in Figure 1.

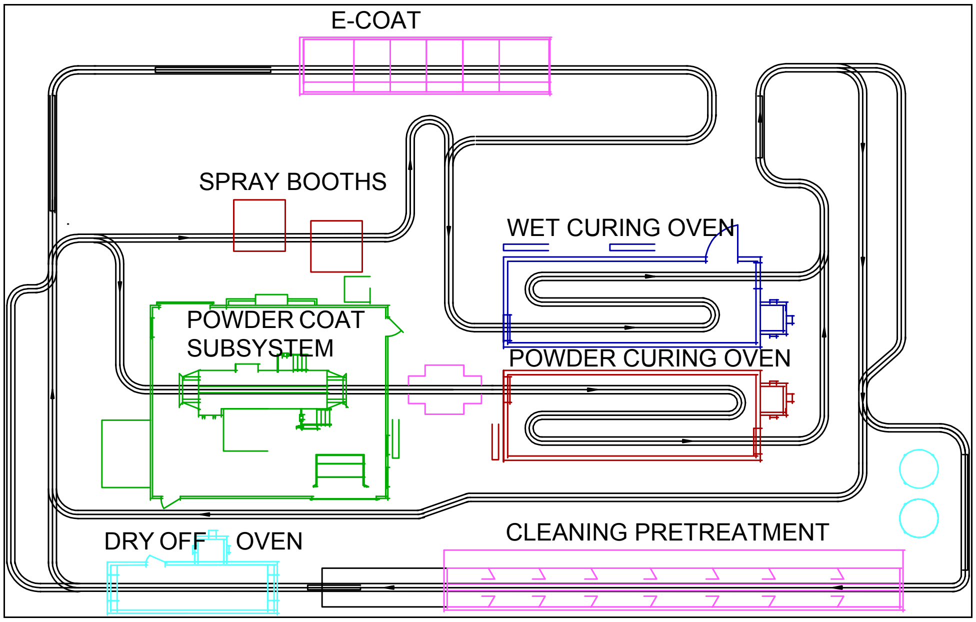

Figure 1. Organic Finishing Line at *CTC*

Coating application involves transporting test panels through the Organic Finishing Line using an automatic conveyor. Pretreated test panels were received, weighed, and stored until needed for testing. When testing was ready to begin, the panels were placed on the racks and then transported through the Organic Finishing Line to the wet spray booth. The spray booths are capable of producing air velocities of up to 0.63 m/s (125 ft/min). The three stages of dry filters are equipped with a gauge that monitors the pressure drop across the filter bank. Air supply lines for operating the pump and gauge readouts are located at the spray booth and were used for this test. A linear translator was procured to move the spray guns vertically and horizontally when applying the coating. The translator, operated through a programmable logic controller (PLC), was used to remove any operator bias. The rack setup is shown in Figure 2. Figure 2 shows the location of the two support bars that were positioned behind the test panels. These support bars helped to minimize the motion of the test panels during the application of the test coating.

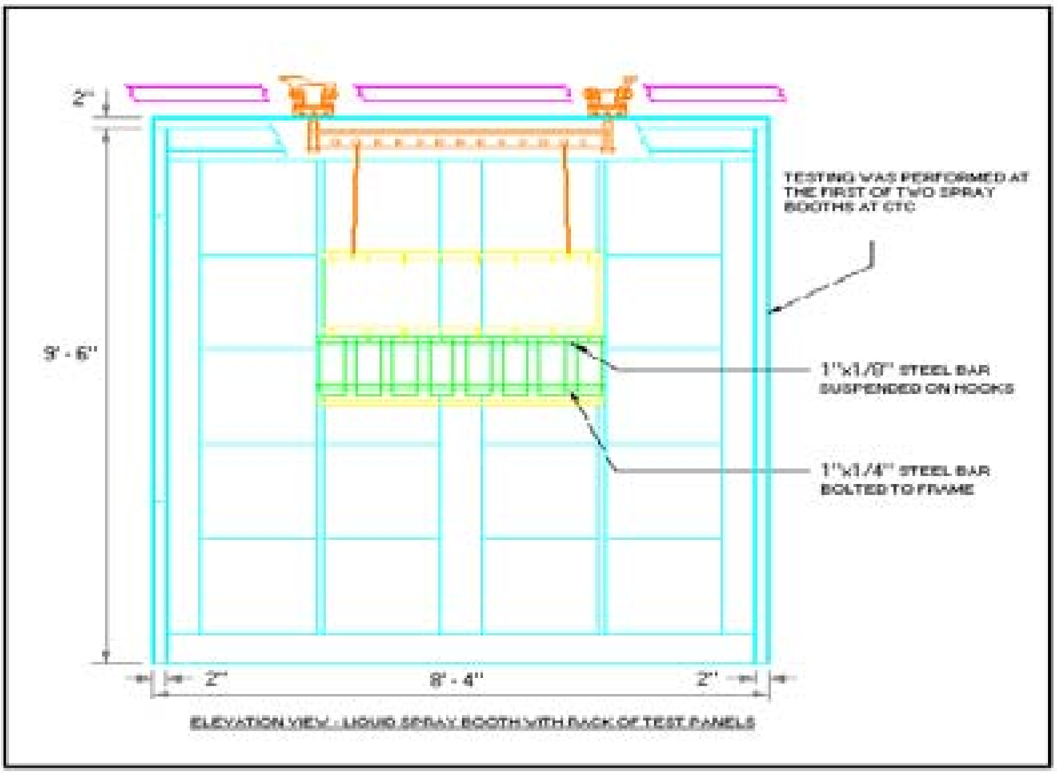

Figure 2. Rack Setup Diagram

3.2 Evaluation of Formula 5's Performance

The overall objectives of this verification test were to establish the P2 benefit of the Formula 5 coating and to determine the effectiveness of the Formula 5 coating at providing a surface protection layer of sufficient finish quality. Finish quality cannot be compromised in most applications, despite the environmental benefit that may be achieved; therefore, this study has evaluated both of these performance aspects. Results from the Formula 5 coating verification testing will benefit prospective end users by enabling them to better determine whether the Formula 5 coating will provide a P2 benefit while meeting the finish quality requirements for their application. Unless otherwise noted, coatings were applied during Test #2 under the same conditions as during Test #1.

3.2.1 Test Operations at CTC

The TQAPP for the Formula 5 coating identified that testing would consist of coating eight panels per rack, two racks per run, and five runs per test. This enabled both total and run-to-run variation to be determined for each response factor. The statistical analyses for all response factors were performed using a statistical software package.

The standard test panels used for verification testing were flat, cold-rolled 22-gauge steel with a 0.6-cm (1/4-in.) hole in one end that meets Society of Automotive Engineers (SAE) 1008 specifications. The panel dimensions were 30.5 cm by 10.2 cm (12 in. x 4 in.). The panels were received pretreated. Five random test panels were removed for pretreatment analysis prior to testing. All panels were suspended on the racks by placing them on hooks attached to the rack. Two bars were fixed to the rack, one near the top of the panels and one near the bottom of the panels. The bars were used to minimize movement during paint application.

The application method used for this verification test was chosen based on the Formula 5 coating's product data sheet. The Formula 5 coating was applied using a Graco Silver Plus airless spray gun. Prior to testing, *CTC*, in conjunction with Evermore Paints and Coatings Inc., conducted setup trials to determine the appropriate fluid tip/fluid pressure configuration to apply the Formula 5 coating. It was determined that the test should be performed with the spray gun equipped with a 0.33 mm (0.013 in.) RAC IV fluid tip, the dynamic fluid pressure set to approximately 2900 psig [Test #1 was applied at 2800 psig], and the spray gun operated at 30.5 cm (12 in.) from the panels, which yielded a fan pattern of 21.6 cm (8.5 in.). The spray gun product data sheet is shown in Appendix B of the Formula 5 Coating Data Notebook.

Prior to each run, the test coating was prepared in the laboratory according to the manufacturer's instructions. The exact coating preparation procedures were recorded and are listed in Appendix C of the Formula 5 Coating Data Notebook. To ensure comparability among tests, the test coating was prepared using the same procedures for each run. In order to minimize pot life effects of the coating, one batch was mixed for each run. Viscosity and temperature measurements were taken before each run. Samples were taken at the beginning of each run for weight percent solids, density, and VOC and HAP content analyses (all data are listed in the Formula 5 Coating Data Notebook). After the coating was mixed, it was connected to the fluid pump that delivered the coating to the spray gun. The coating was continuously stirred during the application process.

Once the racks were in the spray booth, a mechanical stop mechanism aligned the racks of test panels in the proper position relative to the spraying mechanism. The rack of panels remained stationary during spraying. The Graco Silver Plus airless spray gun was mounted on a nylon arm extending from the carrier plate of the robotic translator, which was controlled by a remote PLC. The PLC also controlled the pneumatic cylinder that triggered the gun. The coating was applied in a single coat. The horizontal traverse speed of the gun/translator system was set so that the gun traveled at 68.1 cm/s (26.8 in./s) while in front of the panels [Test #1 was applied at 66.4 cm/s (26 in./s)]. Each coat required four passes of the gun. The vertical drop between passes was set at 10.2 cm (4.0 in.), and the gun-to-target distance was set at 30.5 cm (12 in.).

New, clean spray booth filters were installed before testing the Formula 5 coating. The booth air velocity was measured in close proximity to the panels. The air velocity through the booth was between 0.4 and 0.7 m/s (80 and 140 ft/min). The velocity measured near the panels may vary greatly because of the disruption of the air currents by the rack and panels. The pressure drop across the filters was also checked prior to each run and at the end of the test. The pressure drop across the filter bank system was monitored to ensure that the system was functioning properly, and a pressure drop across the filter bank greater than 1.0 cm of water indicated that the system required service.

The dynamic fluid pressure at the spray gun was set during the setup phase to obtain the desired atomization of the coating. A dynamic fluid pressure of approximately 2900 psig [2800 psig for Test #1] was used for the test. The coating traveled from the pump through a 100-µm screen filter, to a fluid pressure gauge, and then to the inlet of spray gun. All fluid hoses had a 9.5-mm (3/8-in.) inside diameter.

Once the racks were in position, all pertinent measurements taken, and equipment adjustments made, the PLC activated the motors that drove the linear motion translators and the pneumatic cylinder that triggered the gun. The translator traveled 139.7 cm (55 in.) [142.2 cm (56 in.) for Test #1] horizontally and dropped a total of 30.5 cm (12 in.) vertically during the four passes on each rack. The panels were automatically sprayed using vertical overlap of the fan pattern. The target DFT requirement was 1.0–2.0 mils. Four passes and one coat were used to achieve the required thickness. A dwell time of 2 minutes was used between passes, during which time the paint flow was interrupted to minimize paint usage. Once each rack was completed, the PLC released the mechanical stop maintaining the position of the rack on the overhead conveyor. During Test #1 at the vendor’s suggestion, the processed rack was moved to the cure oven and force-cured at 65.5 °C (150 °F) for 8 hr/day for 3 days and then air-dried at ambient conditions for at least 4 additional days prior to initiating any laboratory analyses. During Test #2, the processed rack was moved to the cure oven where the panels were air-dried at ambient conditions for at least 7 days prior to initiating laboratory analysis.

Sixteen panels were coated during each of five runs during each of the two tests. Coated test panels were analyzed for DFT, visual appearance, gloss, color, color difference, MEK rub, tape adhesion, mandrel bend, pencil hardness, direct impact, abrasion resistance, weather resistance, salt spray, and humidity resistance.

3.2.2 *Test Sampling Operations at* CTC*'s ETF*

CTC staff recorded the date and time of each run and the time at which each measurement was taken. The DFT measurements were taken at approximately the same location on each panel. Gloss of the coated parts was assessed in a manner similar to the DFT measurements. Visual appearance was checked while the panels were laying on a large flat surface. The remaining finish quality tests were performed according to their respective ASTM methods. The data from these measurements can be found in Appendix C of the Formula 5 Coating Data Notebook.

3.2.3 *Sample Handling and Quality Assurance/Quality Control Procedures*

After the test coating components were mixed, temperature, viscosity, density, VOC/HAP sampling, and percent solids analyses were performed. Data were logged on bench data sheets, precision and accuracy data were evaluated, and results were recorded on laboratory data sheets. Another *CTC* staff member reviewed the data sheets before sending them for QA review and statistical analysis by ETV CCEP personnel.

Each apparatus used to assess the quality of a coating on a test part was set up and maintained according to the manufacturer’s instructions and/or the appropriate reference methods. Actual sample analyses were performed only after setup was verified per the appropriate instructions. As available, samples of known materials, with established product quality, were used to verify that a system was working properly.

3.3 Data Reporting, Reduction, and Verification Steps

3.3.1 Data Reporting

Raw data were generated and collected manually and electronically by the analysts at the bench and/or process level. Process data were recorded on process log sheets during factory operations. The recorded data included original observations, printouts, and readouts from equipment for sample, standard, and reference QC analyses. The analyst processed raw data and was responsible for reviewing the data according to specified precision, accuracy, and completeness policies. Raw data bench sheets, calculations, and data summary sheets for each sample batch were kept together.

3.3.2 Data Reduction

CTC laboratory staff assembled a preliminary data package. The data package was submitted to ETV CCEP personnel for review to ensure that tracking, sample treatment, and calculations were correct.

3.3.3 Data Verification

A preliminary data report was prepared and submitted to the *CTC* Laboratory Manager, who then reviewed all final results for adequacy in meeting project QA objectives. The ETV CCEP Technical Project Manager was notified of the results of the review and statistical analysis. After the ETV CCEP Technical Project Manager reviewed the results and conclusions, the Verification Statement/Verification Report was written by the ETV CCEP, sent to the vendor for comment, passed through technical peer review, and submitted to EPA for approval. The Verification Statement will be disseminated only after agreement by the Evermore Paints and Coatings Inc.

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Section 4
Results and Discussion

This section presents an overview of the verification test results, including an analysis of environmental benefits of the Formula 5 coating, a summary of panel finish quality, and a summary of data quality. The VOC and HAP contents of Evermore Formula 5 coating were determined to quantify the P2 benefit of the technology. The following analyses were performed on the coated test panels to verify the coating's finish quality: DFT, gloss, visual appearance, color, color difference, MEK rub, tape adhesion, mandrel bend, pencil hardness, direct impact, abrasion resistance, weather resistance, salt spray, and humidity resistance. Subsequently, the actual tabulation, assessment, and evaluation of the data are presented. The accuracy, precision, and completeness data as well as the process and laboratory bench sheets, raw data tables, and calculated data tables are included in Section 5 of the Formula 5 Coating Data Notebook.

4.1 Potential Environmental Benefits and Vendor Claims

The primary purpose of this test is to verify that the Formula 5 Coating has a VOC and HAP content below current regulatory limits and that the applied coating's finish quality is sufficient to meet end users' needs, which would lead to reduced VOC and HAP emissions.

4.2 Selection of Test Methods and Parameters Monitored

CTC performed the laboratory testing required for this verification test. Test procedures, process conditions, and parameters to be monitored were selected based on their correlation to, or impact on, VOC/HAP content or finish quality.

4.2.1 Process Conditions Monitored

The conditions listed below were documented to ensure that there were no significant fluctuations in conditions during the verification test. No significant differences were recorded. A more detailed discussion of the data is presented in Section 3 of the Formula 5 Coating Data Notebook. Table 2 shows the average and standard deviation variation observed for the process conditions.

Table 2. Average and Standard Deviation of Process Conditions

	Test #1 (Avg. / SD)	Test #2 (Avg. / SD)
Factory Relative Humidity (%)	15 / 3	36 / 3
Spray Booth Relative Humidity (%)	16 / 3	36 / 3
Factory Temperature (°C)	22.4 / 0.1	22.8 / 1.0
Spray Booth Temperature (°C)	22.4 / 0.2	22.9 / 0.5
Spray Booth Air Velocity (m/s)	0.5 / 0.1	0.6 / 0.1
Part Temperature (°C)	Not measured	23.4 / 0.3

4.2.2 Operational Parameters

A number of operational parameters were also monitored because they could vary slightly from run to run. A more detailed discussion of the data is presented in Section 3 of the Formula 5 Coating Data Notebook. Table 3 shows the average and standard deviation variation observed for the operational parameters.

Table 3. Average and Standard Deviation of Operational Parameters

	Test #1 (Avg. / SD)	Test #2 (Avg. / SD)
Pretreatment Weight (g/m^2)	2.8 / 0.1	2.8 / 0.1
Input Air Pressure to Fluid Pump (psig)	105 / 1	107 / 2
Inlet Fluid Pressure to the Spray Gun (psig)	2822 / 92	2894 / 60
Average Coating Viscosity, as applied (seconds, Ford #4 Cup)	60 / 1	49 / 3
Average Coating Temperature, as applied (°C)	24.4 / 0.8	21.8 / 0.4
Average Weight Percent Solids (%)	54.5 / 0.5	51.2 / 0.1
Average Coating Density (g/L)	1190 / 5	1175 / 7
Paint Flow Rate (g/s)	12.3 / 0.3	12.6 / 0.4
Total Paint Flow per Run (g)	305 / 3	298 / 8

4.2.3 Parameters/Conditions Monitored

Other parameters and conditions were monitored to ensure that they remained relatively constant throughout the verification test. Constancy was desired in order to reduce the number of factors that could significantly influence the evaluation of finish quality. All of these parameters were relatively constant. A more detailed discussion of these parameters is presented in Section 3 of the Formula 5 Coating Data Notebook.

4.3 Overall Performance Evaluation of the Formula 5 Coating

The test results indicate that the Formula 5 coating is able to provide an environmental benefit in terms of lower VOC and HAP contents and can provide the end user with an acceptable finish quality depending upon its end application.

4.3.1 Response Factors

Responses to the process conditions and parameters were considered to be important due to their effect on, or ability to evaluate, finish quality; therefore, these responses were documented and the appropriate tests required to identify these characteristics were performed. Any response that was characterized using laboratory equipment followed accepted industrial and ASTM standards. Table 4 presents the average results for the response factors. A more detailed discussion of the data is presented in Section 3 of the Formula 5 Coating Data Notebook.

Table 4. Formula 5 Coating Response Factor Results

	Test #1 (Avg. / SD)	Test #2 (Avg. / SD)
VOC Content (g/L, less water and exempt solvents)	212 / N/A	226 / N/A
HAP Content (g/L, less water and exempt solvents)	160 / N/A	165 / N/A
Average DFT (mils)	2.3 / 0.4	1.8 / 0.2
Visual Appearance	No major defects. Coating was uniform from rack to rack and from run to run	Slight striping. Coating was uniform from rack to rack and from run to run
Average Gloss (gloss units, 60° angle)	40 / 17	75 / 5
Color (ΔE value)	0.75 / 0.39	0.50 / 0.08
Color Difference	4 / N/A	4 / N/A
MEK Rub	5 / N/A	5 / N/A
Tape Adhesion	4A / N/A	4A / N/A
Mandrel Bend	Fail	Fail
Pencil Hardness (Gouge/Scratch)	6H/----- / N/A	9H/2H / N/A
Direct Impact (J [in.-lbs])	4.7 [41] / 0.1 [1]	3.1 [28] / 0.2 [2]
Abrasion Resistance (mg)	100.7 / 6.4	95.9 / 5.1
Weather Resistance		
Gloss Retention, gloss units	12% / 3%	1.8% / 0.1%
Color Change, ΔE units	3.22 / 0.59	6.83 / 0.34
Salt Spray (1000 hrs.)	0 / N/A	0 / N/A
Humidity Resistance	6 / N/A	0 / N/A

N/A = not applicable.
----- = not available.

4.3.2 Assessment of Laboratory Data Quality

The Formula 5 coating response factor results are considered to be statistically valid and significant such that the verification of the Formula 5 coating under these test conditions could be identified with a high degree of confidence. It can be stated with greater than 95% confidence that the Formula 5 coating has a VOC content below current regulatory limits for the architectural industry.

4.3.3 Other Observations

The components of the coatings in both Tests #1 and #2 required continuous stirring to prevent separation. Separation of the components resulted in poor atomization of the coating as it left the spray gun nozzle and reduced finish quality on the test panels. In addition, coating that was allowed to separate in the fluid lines prior to spraying resulted in a finish that exhibited a yellowish tint in the applied coating. As the time after mixing approached one hour, the components separated more rapidly and readily once the stirring stopped.

4.4 Technology Data Quality Assessment

Accuracy, precision, and completeness goals were established for each process parameter and condition of interest as well as for each test method used. The goals are outlined in the TQAPP.

All laboratory analyses and monitored process conditions/parameters met the accuracy, precision, and completeness requirements specified in the TQAPP, except for the deviations listed in Section 2 of the Formula 5 Coating Data Notebook. None of these deviations were found to have a significant effect on the results. The definition of accuracy, precision, and completeness, as well as the methodology used to maintain the limits placed on each in the TQAPP, are presented below. The actual accuracy, precision, and completeness values, where applicable, are presented in Section 5 of the Formula 5 Coating Data Notebook.

4.4.1 Accuracy, Precision, and Completeness

Accuracy is defined as exactness of a measurement (i.e., the degree to which a measured value corresponds with that of the actual value). To ensure that measurements were accurate, standard reference materials traceable to the National Institute of Standards and Technology (NIST) were used for instrument calibration and periodic calibration verification. Accuracy was determined to be within the expected values listed in the TQAPP. Accuracy results are located in Table 32 of the Formula 5 Coating Data Notebook.

Precision is defined as the agreement of two or more measurements that have been performed in exactly the same manner. Ensuring that measurements are performed with precision is an important aspect of verification testing. The exact number of test parts coated is identified in the TQAPP, and the analysis of replicate test parts for each coating property at each of the experimental conditions occurred by design. Precision was determined to be within the expected values listed in the TQAPP. All precision data are listed in Tables 34 to 41 of the Formula 5 Coating Data Notebook.

Completeness is defined as the number of valid determinations and expressed as a percentage of the total number of analyses conducted, by analysis type. The goal for these tests was at least 90% completeness. Completeness is ensured by evaluating precision and accuracy data during analysis. All laboratory results for finish quality were 100% complete. All results were reviewed and considered usable for statistical analysis. Completeness results are shown in Table 33 of the Formula 5 Coating Data Notebook.

4.4.2 Audits

The ETV CCEP QA Officer conducted an internal technical systems audit (TSA) and a performance evaluation audit (PEA) of the Formula 5 Coating verification test. Also, prior to the certification of the data, the ETV CCEP QA Officer audited a portion of the data generated during the Formula 5 coating test.

The TSAs verified that *CTC*'s personnel were adequately trained and prepared to perform their assigned duties and that routine procedures were adequately documented. The ETV CCEP QA Officer examined copies of test data sheets that recorded information such as process conditions, spray booth conditions, equipment setup, and coating preparation and also reviewed laboratory bench sheets showing data for coating pretreatment weights, densities, and percent nonvolatile matter.

The ETV CCEP QA Officer audit found that the Formula 5 coating test was conducted in a manner that provides valid data to support this Verification Statement/Report. Several deviations from the original TQAPP were identified by the TSA and PEA and are discussed in Section 2 of the Formula 5 Coating Data Notebook.

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Section 5
Vendor Forum

[Evermore Paints and Coatings Inc. has been offered the opportunity to comment on the findings of this report. However, the vendor chose not to comment upon the contents of this report.]

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Section 6
References

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2. Clean Air Act Amendments of 1990, Title III - Hazardous Air Pollutants, November 15, 1990.

3. Clean Air Act Amendments of 1990, Title I - Attainment/Maintenance of National Ambient Air Quality Standards (NAAQS), November 15, 1990.

4. Environmental Technology Verification Coatings and Coating Equipment Program (ETV CCEP): Evermore Paints and Coatings Formula 5 Coating – Testing and Quality Assurance Project Plan (TQAPP), Revision No. 0, August 4, 2000, http://www.epa.gov/etv/pdfs/testplan/06_tp_liquid.pdf.

5. Environmental Technology Verification Coatings and Coating Equipment Program (ETV CCEP): Liquid Coating – Generic Testing and Quality Assurance Protocol, Rev. No. 0, February 16, 2000, http://www.epa.gov/etv/pdfs/vp/06_vp_liquid.pdf.