September 2003

Environmental Technology Verification Report

Allied PhotoChemical KrohnZone 7014 UV-Curable 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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Environmental Technology Verification Report

Allied PhotoChemical KrohnZone 7014 UV-Curable Coating

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Operated by
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Johnstown, PA 15904

Under Contract No. DAAE30-98-C-1050 (Task N.306, SOW Task 4)
with the U.S. Defense Contract Command – Washington (DCC-W)
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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 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's 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 Allied PhotoChemical KrohnZone 7014 UV-curable coating for automotive manufacturing applications.

Table of Contents

List of Tables

List of Associated Documents

KrohnZone 7014 Data Notebook (Available from *CTC* upon request)

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV JOINT VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**ULTRAVIOLET (UV) CURABLE LIQUID COATING**
APPLICATION:	**LIQUID ORGANIC COATING FOR AUTOMOTIVE MANUFACTURING**
TECHNOLOGY NAME:	**KrohnZone™ 7014**

COMPANY: **Allied PhotoChemical**
POC: **Roy Krohn, Founder & CSO**
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The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; with stakeholder groups consisting of buyers, vendor organizations and states; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The ETV Coatings and Coating Equipment Program (CCEP), one of seven technology areas under the ETV Program, is operated by Concurrent Technologies Corporation (*CTC*) under the National Defense Center for Environmental Excellence (NDCEE) in cooperation with EPA's National Risk Management Research Laboratory. The ETV CCEP has recently evaluated the performance of an innovative liquid coating intended for automotive manufacturing applications. This verification statement provides a summary of the test results for the KrohnZone 7014 UV-curable coating manufactured by Allied PhotoChemical.

VERIFICATION TEST DESCRIPTION

The ETV CCEP evaluated the pollution prevention capabilities of the KrohnZone 7014 UV-curable coating. The coating application phase and a portion of the laboratory analyses were conducted at Allied PhotoChemical's facility in Marysville, MI. The remaining testing was completed at *CTC*'s facility in Johnstown, PA. The test was designed to verify the environmental benefit of the UV-curable coating by determining the total volatile content per ASTM D 5403. The test also verified the coating's finish quality characteristics.

In this test, the KrohnZone 7014 UV-curable coating was tested under conditions recommended by Allied PhotoChemical, the coating's vendor. The test panels were 15.2 cm long and 10.2 cm wide. Allied PhotoChemical recommended the ITW Automotive Refinishing GTi high-volume, low-pressure spray gun equipped with a 1.4 mm fluid tip and a #2000 air cap. The test consisted of five runs. During each run, one set of ten panels was sprayed manually.

The total volatile content of the KrohnZone 7014 UV-curable coating was determined using ASTM D 5403. This method determines the processing volatiles generated during the UV-cure phase and the potential volatiles generated by heat curing the UV-cured coating. Total volatiles are determined by adding the processing and potential results.

The details of the test, including a summary of the data and a discussion of results, may be found in Section 4 of the "Environmental Technology Verification Report: Allied PhotoChemical – KrohnZone 7014 UV-Curable Coating," which is available at http://www.epa.gov/etv/verifications/verification-index.html. A more detailed discussion of the test conditions, test results, and data analyses can be found in "Environmental Technology Verification Data Notebook: Allied PhotoChemical – KrohnZone 7014 UV-Curable Coating," which is available from *CTC*.

QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

The EPA ETV CCEP QA manager conducted a technical systems audit to assure that testing conducted at Allied PhotoChemical's facility was performed in compliance with the approved test plan, and the ETV CCEP QA officer conducted a performance evaluation audit of the laboratory analyses conducted in Johnstown, PA, to assure that the measurement systems employed were adequate to produce reliable data. Also, prior to the certification of the data, the ETV CCEP QA officer and the EPA ETV QA manager both audited at least 10% of the data generated during the KrohnZone 7014 test to assure that the reported data represented the data generated during testing. In addition, the EPA ETV CCEP QA manager has conducted a quality systems audit of the ETV CCEP Quality Management Plan and onsite visits during previous tests.

TECHNOLOGY DESCRIPTION

The KrohnZone 7014 UV-curable coating was tested as received from Allied PhotoChemical to assess its capabilities. The coating was manually applied using the ITW Automotive Refinishing GTi HVLP spray gun equipped with a 1.4 mm fluid tip and #2000 air cap and was set to obtain a fan pattern of 10.2 cm (4 in.) 15.2 cm (6 in.) from the gun. The KrohnZone 7014 UV-curable coating is marketed to automotive manufacturers as a single layer clearcoat.

VERIFICATION OF PERFORMANCE

The performance characteristics of the KrohnZone 7014 UV-curable coating include the following:

Environmental Factors

- Total volatile content: The KrohnZone 7014 UV-curable coating exhibited 1.6% processing volatiles and 1.0% potential volatiles, for a total volatile content of 2.6%. The standard deviation for the total volatile content was 0.9%.

- Energy Usage: The coating was UV-cured under a medium mercury vapor lamp followed by an iron-doped lamp. Both lamps were tubes 76.2 cm in length and rated for 157.5 watts/cm. The panels were passed under the lamps on a conveyor belt moving at 16.7 cm/s. Assuming that each panel passes through a 15.2 cm cure zone for each lamp, it can be calculated that 8.1×10^{-4} kWh is required to cure one panel. This value does not include the energy required to warm up the lamps or the energy expended by the length of the lamps that are idle.

Performance Factors

- Dry Film Thickness (DFT): The DFTs for all runs were determined from six points measured on each panel. The DFT averaged 3.1 mils with a standard deviation of 0.2 mil.

- Visual Appearance: *CTC* personnel assessed the visual appearance of all 50 coated panels. The intent of this analysis was to identify any obvious coating abnormalities that could be attributed to the application equipment. No defects were found, and the coating was uniform from panel to panel and run to run.

- Gloss: The gloss was measured per ASTM D 523 Test Method at three points on one panel per run at both 20° and 60°. The test method has a range of 0 to 100 gloss units. The 20° analyses yielded an average of 80.8 gloss units with a standard deviation of 4.4 gloss units. The 60° analyses yielded an average of 92.3 gloss units with a standard deviation of 2.1 gloss units.

- Salt Spray Resistance: The salt spray resistance was determined per ASTM B 117 from one coated panel per run exposed to 2000 hours of salt spray. Corrosion appeared on the scribed areas between 120 and 240 hours and on the unscribed areas between 120 and 1508 hours. The creepage at the scribe ranged from 0 to 1.6 cm. After the full 2000 hours, the scribed panels obtained an average rating of 6 (10 being no corrosion and 0 being total corrosion), and the unscribed panels obtained an average rating of 4.

- Humidity Resistance: The humidity resistance measurements were determined per ASTM D 1735 from one coated panel per run. The panels were placed in the humidity chamber unscribed and were subjected to 2000 hours in the chamber. Three of the five panels developed between 7 and 30 small blisters of 0.1 cm or less in size. The panels obtained an average rating of 9 (10 being no corrosion) after the full 2000 hours.

- Tape Adhesion: Two tape adhesion tests were conducted according to ASTM D 3359, one per Method A and one per Method B. Method A uses a scribe in the shape of an 'X'. Method B uses a scribe in a crosshatch shape. The rating scale for both methods ranges from 1 to 5, with 5 meaning no visible loss of adhesion or removal of coating. The coated panels were rated 5A and 5B, which means that no visible loss of adhesion or coating removal was present using Methods A and B, respectively.

- Direct Impact: The direct impact measurements were determined per ASTM D 2794 from one coated panel per run. The measurements for all panels averaged 3.1 J (27 in.-lbs) with a standard deviation of 0.1 J (1.0 in.-lbs).

- Mandrel Bend: The mandrel bend measurements for flexibility were determined per ASTM D 522 on a conical mandrel from one coated panel per run. The coating on all panels cracked and/or separated from the panels the entire 15.2 cm length of the sample panels.

- MEK (Methyl Ethyl Ketone) Rub: The MEK rub measurements were determined per ASTM D 5402 from one coated panel per run. The measurements for all panels rated a 4 out of 5, indicating minor effects on the coating.

- Abrasion Resistance: The abrasion resistance measurements were determined per ASTM D 4060 from one coated panel per run. All panels were subjected to 1000 cycles using a CS-10 wheel and 1000 g weight. The weight loss measurements for all panels were 92.6 mg with a standard deviation of 8.8 mg.

Original signed on

September 30, 2003

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Lee A. Mulkey
Acting Director
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency

Original signed on

September 30, 2003

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Brian D. Schweitzer
Manager
ETV CCEP
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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 Allied PhotoChemical, the manufacturer of the KrohnZone 7014 UV-curable 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 Roy Krohn, Founder and Chief Science Officer (CSO) and Scott Howe, Vice President, Operations. Allied PhotoChemical is based in Marysville, MI.

SI to English Conversions

SI Unit	English Unit	Multiply SI by factor to obtain English
°C	°F	1.80, then add 32
L	gal, liq (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, liq (U.S.)	8.345

List of Abbreviations and Acronyms

APC	Allied PhotoChemical
APPCD	Air Pollution Prevention and Control Division
ASTM	American Society for Testing and Materials
CCEP	Coatings and Coating Equipment Program
CSO	Chief Science Officer
CTC	Concurrent Technologies Corporation
DFT	dry film thickness
EPA	U.S. Environmental Protection Agency
ETF	Environmental Technology Facility
ETV	Environmental Technology Verification
HAP	hazardous air pollutant
HVLP	high-volume, low-pressure
ID	identification
MEK	methyl ethyl ketone
NDCEE	National Defense Center for Environmental Excellence
NIST	National Institute for Standards and Technology
NRMRL	National Risk Management Research Laboratory
OSHA	Occupational Health and Safety Administration
P2	pollution prevention
PEA	performance evaluation audit
PEL	permissible exposure limit
QA/QC	quality assurance/quality control
RFU	ready-for-use
SAE	Society of Automotive Engineers
TQAPP	Testing and Quality Assurance Project Plan
TSA	technical systems audit
UV	ultraviolet
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) pilot, 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 pilot 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 demonstration factory finishing equipment was made available for this project.

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 consists of 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 Allied PhotoChemical (APC) KrohnZone 7014 UV-curable coating, hereafter referred to as the KrohnZone 7014, which is designed for use in automotive manufacturing. The test spray gun chosen by APC was the ITW Automotive Refinishing GTi high-volume, low-pressure (HVLP) 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 total 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, and their 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 UV-Curable Coating Technology Description

KrohnZone 7014 is manufactured by APC. It is an UV-curable coating utilizing free-radical chemistry. This product was developed as a high performance coating for automotive manufacturing applications. KrohnZone 7014 is reported to be low in VOCs and HAPs. The coating is a one-component clearcoat.

1.4 Technology Testing Process

The ETV CCEP developed a technology-specific Testing and Quality Assurance Project Plan (TQAPP) for KrohnZone 7014, with significant input from the vendor[4]. After the vendor concurred with, and the EPA and *CTC* approved, the TQAPP, the ETV CCEP performed the verification test. The Verification Statement, which is produced as a result of this test, may be used by APC for marketing purposes or by end users of the KrohnZone 7014 UV-curable coating. The Verification Statement for KrohnZone 7014 is included on pages v–viii of this report. A Data Notebook has been compiled by the ETV CCEP, which includes a more detailed discussion of the test conditions, the test results, and the data analyses. The Data Notebook is available from the ETV CCEP 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. UV-curable coatings were found to have a large P2 potential and were being considered by industry in organic finishing replacement activities.

1.5 Test Objectives and Approach

The testing was performed according to the Allied PhotoChemical KrohnZone 7014 TQAPP. This project was designed to verify the performance of KrohnZone 7014 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 KrohnZone 7014 meets their needs.

The quantitative P2 benefit will result from an analysis of the coating's total volatile content per ASTM D 5403. For this verification test, a specific combination of test factors were selected by the ETV CCEP, EPA, APC, 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.

Representatives of APC, under supervision of the ETV CCEP, completed the coating application and curing. The EPA ETV CCEP QA Manager was on site to observe verification testing. ETV CCEP staff performed all processing and laboratory analyses. The total volatile content was 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), visual appearance, gloss, salt spray, humidity resistance, tape adhesion, direct impact, mandrel bend, MEK (methyl ethyl ketone) rub, and abrasion resistance.

1.6 Performance Summary

This verification has quantitatively shown that the KrohnZone 7014 UV-curable coating is capable of providing an environmental benefit and an acceptable coating finish (see Table 1). The environmental benefit was quantified through the total volatile content of the UV-curable coating. The end user should review these data carefully to ascertain the applicability of APC Krohnzone 7014 for its process.

Table 1. Verification Factors for KrohnZone 7014

	Average	Standard Deviation
Total Volatiles (%) [Processing + Potential]	2.6	0.9
Cure Oven Line Speed (cm/s)	16.7	0.0
Calculated Energy Usage per Panel (kWh)	8.1×10^{-4}	N/A
Average DFT (mils)	3.1	0.2
Visual Appearance	No major defects. Coating was uniform from rack to rack and from run to run.	
Average Gloss (gloss units, 20° angle)	80.8	4.4
Average Gloss (gloss units, 60° angle)	92.3	2.1
Salt Spray (2000 h) **Scribed (out of 10)** **Unscribed (out of 10)**	 6 4	N/A
Humidity Resistance	9	N/A
Tape Adhesion (X-Cut)	5A	N/A
Tape Adhesion (Cross Hatch)	5B	N/A
Direct Impact (J [in.-lb])	3.1 [27]	0.1 [1.0]
Conical Mandrel Bend	Adhesion loss or cracking across sample width	N/A
MEK Rub (Average DFT = 3.0 mils)	4 out of 5	N/A
Abrasion Resistance (mg)	92.6	8.8

N/A – Not applicable

The KrohnZone 7014 requires UV-curing equipment, but the coating can be cured via direct sunlight, but the process takes several minutes to several hours, depending on the UV light intensity, the wet film thickness and the pigmentation of the coating. The calculated energy usage in Table 1 represents only the energy required to cure one 10.2 cm by 15.2 cm panel. This value does not include the energy required to warm up the lamps or the energy expended by the length of the lamps that are idle (i.e., not directly over a panel being cured). The operating costs of KrohnZone 7014 include the UV oven, maintenance, and cleanup. The economic advantage of KrohnZone 7014 is realized after consideration of the reduced volatile emissions and reduction in coating wastes due to the ability to recycle the uncured material.

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 UV-curable coating technologies and to make the results of the verification tests available to the technology vendor and to prospective technology end users. KrohnZone 7014 is designed for use in automotive manufacturing applications. For this verification study, the spray gun used to apply KrohnZone 7014 was a gravity-feed GTi HVLP spray gun, manufactured by ITW Automotive Refinishing. The spray gun was equipped with a 1.4 mm fluid tip and a #2000 air cap.

CTC, the independent, third party evaluator, worked with the vendor of the technology and the EPA throughout verification testing. *CTC* prepared this verification report and was responsible for performing the testing associated with this verification.

2.2 The KrohnZone 7014 Test

This verification test is based on the ETV CCEP UV-Curable Coatings – Generic Verification Protocol, which was reviewed by the ETV CCEP stakeholders.[5] Allied PhotoChemical (APC), the manufacturer of KrohnZone 7014, worked with *CTC* to identify the optimum performance settings for the coating/gun combination. APC had determined the parameters through tests that their personnel conducted at their facility in Marysville, MI. A preliminary TQAPP was generated using the vendor supplied information and was submitted to EPA for review of content. Following the initial EPA review and incorporation of their 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. A final draft of the TQAPP was reviewed by the vendor and technical peer reviewers then approved by the EPA and *CTC* prior to the start of verification testing.

Testing was conducted under the direction of ETV CCEP personnel, with representatives from APC assisting with the coating application and curing phase. All information gathered during verification testing was analyzed, reduced, and documented in this report. Total volatile content and finish quality measurements of KrohnZone 7014 were the primary objectives of this test. The data highlight the P2 benefit of the KrohnZone 7014 coating as well as its ability to provide the required finish quality. A randomly selected portion of at least 10% of the test data has been quality audited by EPA and the ETV CCEP QA officer to ensure the validity of the data.

2.3 UV-Curable Coating Technology

This section contains information on KrohnZone 7014, its current applications in industry, the advantages and benefits of the technology, and information on technology deployment.

KrohnZone 7014 is a UV-curable coating that was developed for automotive applications and other metal coating applications that require only one-coat applications, (such as lawnmowers and metal coil). KrohnZone 7014 is a one-component, ready-to-spray, or ready-for-use (RFU), coating with a manufacturer recommended shelf life of 1 year. The coating can be tailored to a specific viscosity range as designated by the customer. The standard KrohnZone materials are RFU in the 300 to 1000 cps range, which can be applied by a HVLP spray gun.

The KrohnZone 7014 UV-curable coating is reported to meet the following specifications:

- 100% UV-curable
- contains 100% solids with no VOCs or HAPs
- one-component, RFU coating
- shelf life of 1 year with no prolonged exposure to light
- theoretical coverage of 1020 ft^2/gal (at 65% transfer efficiency and 1 mil thickness)
- curable up to 6 mils with a cure energy greater than 0.35 J/cm^2

2.3.1 Applications of the Technology

KrohnZone 7014 can be used in many applications, such as automotive, plastics, and wood finishing; however, an automotive manufacturing application was the subject of this verification test. Automotive manufacturers may use the KrohnZone 7014 because it is low volatile content material capable of being recycled and produces a durable, corrosion resistant finish.

2.3.2 Advantages of the Technology

The KrohnZone 7014 UV-curable coating has a very small percentage of VOCs, significantly reducing the VOC emissions that typically result from spray painting operations. It does not depend on solvents to transport the coating solids to the target surface, only to require volatilization in later steps. The coating can be applied by traditional means (conventional, HVLP, brush, roller, etc). The cure process requires significantly less space than traditional thermal curing methods, allowing for multiple coatings to be applied wet on dry in a shorter period of time.

2.3.3 Limitations of the Technology

For some applications, KrohnZone 7014 may exhibit incomplete curing due to the complexity of the shape to be coated. The UV radiation is line-of-sight and may not be able to contact all of the coated areas. The UV lamps require special protection eyewear for operators. Also, the UV lamps generate ozone, especially during the lamp warm-up period. Workers must be protected from ozone concentrations exceeding Occupational Health and Safety Administration (OSHA) standards. The permissible exposure limit (PEL) for an 8-hour, time-weighted average value of 0.1 ppm.

Also, the coating fractured and/or lost adhesion during the conical mandrel bend testing. The end user should note that the direct impact test result was 3.1 J (27 in.-lb) and that the abrasion resistance test result was 92.6 mg. Also, please note that the DFT of 3 mils was thicker than planned, which may have impacted the results of some of these analyses.

2.3.4 Technology Deployment and Costs

KrohnZone 7014 has many applications, with few limitations on its distribution throughout the various finishing industries. One area of concern is the efficient curing of complex shapes. The coating is cost effective because of its capability to be recycled, the ease of removing the uncured coating from painted surfaces, and the high solids content of the material. KrohnZone 7014 is similar in operating costs to standard solvent coatings; however, initial capital cost of switching from thermal to UV-cure ovens may be significant.

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Section 3
Description and Rationale for the Test Design

3.1 Description of Test Site

The testing of KrohnZone 7014 was conducted at Allied PhotoChemical's (APC's) facility in Marysville, MI and at *CTC*'s Environmental Technology Facility (ETF) in Johnstown, PA. APC applied the coating to the test panels under the ETV CCEP's supervision. The spray booth is a tabletop model approximately 5 ft wide by 2.5 ft deep by 5 ft tall, with a 2.5 ft by 2.5 ft opening. The back wall of the booth contained booth filters, and the exhaust was ducted into the factory because of the small amount of VOCs emitted. Coating application involved manually positioning the test panels lying flat in the spray booth. After being coated, the panels were placed on a conveyor that passes the panels under two UV light sources, a medium mercury vapor lamp and an iron-doped lamp. The panels were then packaged and shipped to *CTC*'s facility for further testing.

3.2 Evaluation of KrohnZone 7014's Performance

The overall objectives of the verification study were to establish the P2 benefit of KrohnZone 7014, and to determine the effectiveness of KrohnZone 7014 in providing an acceptable coating finish. Finish quality cannot be compromised in most applications, despite the environmental benefit that may be achieved; therefore, this study has evaluated both of these factors. Results from the KrohnZone 7014 verification testing will benefit prospective end users by enabling them to better determine whether KrohnZone 7014 will provide a P2 benefit while meeting the finish quality requirements for their application.

3.2.1 Test Operations at Allied PhotoChemical and CTC

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 15.2 cm by 10.2 cm (6 in. x 4 in.). The panels were received treated with a zinc phosphate pretreatment by ACT Laboratories, Inc. Five random test panels were removed prior to the test for pretreatment analysis. All panels were manually coated while lying flat on a cardboard sheet. The whole sheet was positioned on the UV-curing oven conveyer to cure the coated test panels.

The test spray gun chosen by APC was the ITW Automotive Refinishing GTi HVLP gun. The spray gun product data sheet is shown in Appendix B of the KrohnZone 7014 Data Notebook. Prior to each run, temperature measurements were taken of the coating, panel, and spray booth. The relative humidity of the spray booth was also measured. Samples were taken at the beginning of each run for weight percent solids, density, and volatile content measurements (all data are provided in the KrohnZone 7014 Data Notebook). One batch of coating was used to complete this test. A small container of material was used to fill the gravity cup on the spray gun. As the panels were coated, the level of coating in the gravity cup dropped. The small container was then used to refill the gravity cup before each run. The cup was refilled to maintain a consistent fluid flow rate from the gravity cup.

Ten panels were coated during each run. Five additional panels from the same batch as the coated panels were used for zinc phosphate coating weight determination. Total volatile content was determined using circular pans and 15.2 cm x 10.2 cm aluminum foil dishes. Coated standard test panels were also analyzed for DFT, gloss, and visual appearance in addition to other performance characteristics analyses.

3.2.2 Test Sampling Operations at CTC's ETF

Standard test panels were used in this project, and each panel was labeled with a unique alphanumeric identifier. The experimental design used 50 samples for the test (5 runs with 1 set per run and 10 panels per set).

The panels were processed under the supervision of *CTC* personnel. The *CTC* laboratory analyst recorded the date and time of each run and the time at which each measurement was taken. Once coated and cured, the panels were stacked, each being separated by a layer of packing material, and transported to the *CTC* laboratory by ETV CCEP personnel.

3.2.3 Sample Handling and Quality Assurance/Quality Control Procedures

Prior to performing the required analyses, the laboratory analyst logged panels, giving each a unique laboratory identification (ID) number. The analyst who delivered the test panels to the laboratory completed a custody log that indicated the sampling point IDs, sample material IDs, quantity of samples, time and date of testing, and the analyst's initials. The product evaluation tests were also noted on the custody log, and the laboratory's sample custodian verified this information. The analyst and the sample custodian both signed the custody log, indicating the transfer of the samples from the processing area to the laboratory analysis area. The laboratory sample custodian logged the test panels into a bound record book, stored the test panels under the appropriate conditions (ambient room temperature and humidity), and created a work order to initiate testing.

The temperature of the coating, as applied, was measured during the test by ETV CCEP personnel. APC provided the ETV CCEP with a sample of the coating batch, which was transported to Johnstown, PA, for analysis. The viscosity, density, VOC content, and percent solids analyses were completed by ETV CCEP personnel in the ETF laboratory. Data were logged on bench data sheets, precision and accuracy data were evaluated, and results were recorded on the ETV CCEP Quality Assurance/Quality Control (QA/QC) Data forms. Another laboratory staff member reviewed the data sheets for QA.

Each apparatus used to assess the quality of a coating on a test panel is set up and maintained according to the manufacturer's instructions and/or the appropriate reference methods. Actual sample analysis was 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 and Verification

The primary analyst(s) assembled a preliminary data package. The data package was reviewed by a different analyst to ensure that tracking, sample treatment, and calculations were correct. A preliminary data report was prepared and submitted to the ETV CCEP laboratory leader, who then reviewed all final results for adequacy to project QA objectives. After the EPA reviewed the results and conclusions from the ETV CCEP project manager, the Verification Statement/Verification Report was written, 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 vendor.

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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 KrohnZone 7014, a summary of panel finish quality, and a summary of data quality. Data generated during this test are being evaluated in order to establish the environmental benefit and the finish quality characteristics of the product. An explanation of the manner in which the data were gathered is provided. Subsequently, the tabulation, assessment and evaluation of the data are presented. The accuracy, precision, and completeness data; the process and laboratory bench sheets; raw data tables; and calculated data tables are included in Section 5 of the KrohnZone 7014 Data Notebook.

4.1 Potential Environmental Benefits and Vendor Claims

The primary purpose of this test is to verify that KrohnZone 7014 is a low volatile content coating that offers a finish quality suitable for automotive manufacturing applications.

4.2 Selection of Test Methods and Parameters Monitored

CTC, the ETV CCEP partner organization, performed the laboratory testing required for this verification test. The ETV CCEP selected test procedures, process conditions, and parameters to be monitored based on their correlation to, or impact on, volatile 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. A more detailed discussion of the data is presented in Section 3 of the KrohnZone 7014 Data Notebook.

- Spray booth relative humidity ranged from 16.7% to 18.1%.
- Cure area relative humidity ranged from 16.5% to 19.0%.
- Spray booth temperature ranged from 19.3 to 21.1 °C.
- Cure area temperature ranged from 20.4 to 21.2 °C.
- Panel temperature ranged from 20.1 to 20.8 °C.

4.2.2 Operational Parameters

The conditions listed below were documented to ensure that there were no significant fluctuations in conditions during the verification test. A more detailed discussion of the data is presented in Section 3 of the KrohnZone 7014 Data Notebook.

- Zinc phosphate weight ranged from 2.3 to 3.0 g/m^2.
- Coating density was 1031 g/L.
- Weight percent solids ranged from 25.01% to 25.16%.
- Coating temperature ranged from 20.0 to 21.0 °C.
- Coating viscosity ranged from 23.9 to 24.1 seconds using a #4 Ford cup.

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 total volatile content calculations and the evaluation of finish quality. A more detailed discussion of these data is presented in Section 3 of the KrohnZone 7014 Data Notebook.

4.3 Overall Performance Evaluation of KrohnZone 7014

The verification factors for KrohnZone 7014 are listed in Table 1 of this report. The test results indicate that the KrohnZone 7014 UV-curable coating provided an environmental benefit and maintained the required finish quality of the applied coating.

4.3.1 Assessment of Laboratory Data Quality

The KrohnZone 7014 data results were subjected to an internal data quality audit by the ETV CCEP QA officer. The information gathered was considered to be statistically valid and significant such that the advantages and limitations of KrohnZone 7014, per these test conditions, could be identified to 95% confidence.

4.4 Technology Data Quality Assessment

Accuracy, precision, and completeness goals were established for each process parameter and condition of interest as well as 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 KrohnZone 7014 Data Notebook. 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 KrohnZone 7014 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 26 of the KrohnZone 7014 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 28 to 32 of the KrohnZone 7014 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. *CTC*'s laboratory was striving for at least 90% completeness. Evaluating precision and accuracy data during analysis ensures completeness. 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 27 of the KrohnZone 7014 Data Notebook.

4.4.2 Audits

The EPA ETV CCEP QA manager conducted a technical systems audit (TSA) and a performance evaluation audit (PEA) of the KrohnZone 7014 verification test. Also, prior to the certification of the data, the ETV CCEP QA manager audited a portion of the data generated during the KrohnZone 7014 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 EPA ETV CCEP QA manager examined copies of process conditions data sheets during the coating application process.

The EPA ETV CCEP QA manager audit found that the KrohnZone 7014 test was conducted in a manner that provides valid data to support this Verification Statement/Report. Several deviations from the original TQAPP were made and are discussed in Section 2 of the KrohnZone 7014 Data Notebook.

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Section 5
Vendor Forum

[Allied PhotoChemical has been offered the opportunity to comment on the findings of this report. Its comments are presented in this section of the report and reflect their opinions. *CTC* and EPA do not necessarily agree or disagree with the vendor's comments and opinions.]

The Manufacturer's Suggested Retail Price of the KrohnZone 7014 UV-curable coating at the time of this verification test was $100/gal. Significant volume discounts were available.

The KZ 7014 UV-curable coating has been tested in an industrial application. A paint line for real manufacturing is being developed for future production. Allied Photochemical cannot disclose the name of the company at this time.

Utilizing Allied's 100% UV-curable paint system has allowed an automotive parts manufacturer to paint parts with Allied's UV paint at a much faster speed and lower costs than the current standard water-based paint.

Allied's paint system has reduced the size of the paint line and capital investment by 65%. This includes, but is not limited to, less square footage for the actual paint line because of some of the processing steps that could be omitted and still produce quality parts. For example with the water-based coating currently in use, the parts must be sand blasted to take of the slag to get a good, final finish. Allied's paint covered the roughness of the slag. The phosphating process has been deleted. Some of the washing steps are deleted. The energy costs of the water-based paint line are $2,000,000 per month for gas and electricity. The estimated combined costs are to be less than $100,000 per month with the UV process, a huge energy savings. This particular company had to run a 9-inch gas line for 2 miles to have enough energy to run their current single water based line. The water-based line had an initial capital investment of approximately $10,000,000. The UV line using Allied's paint is estimated to have an initial cost of less than $1,000,000.

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Section 6
References

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