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Final Report

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ZERO-VOC INDUSTRIAL MAINTENANCE METAL COATING

Prepared for

California Air Resources Board
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ABSTRACT

Hydrocarbon emissions generated from stationary sources are a significant environmental problem in California. One of the largest stationary emission sources is the evaporation of solvents used in paints, coatings, inks, and other products. Local air pollution control districts in California have passed rules to limit the volatile organic compounds (VOC) content in these products. Air emissions can be reduced through a gradual shift from high- to low-/no-VOC coatings. By phasing in low-/no-VOC coatings, industries will be able to reduce energy use and air emissions without installation of add-on controls.

Under California Air Resource Board (ARB) sponsorship, AeroVironment Environmental Services, Inc. (AVES), Adhesive Coatings Co. (ADCO), and Compliance Engineering Technology, Inc. (CET) are teamed to develop and demonstrate a metal coating, which contains no volatile organic compound (VOC) and no hazardous air pollutant (HAP). This two-part system consists, in general, of an epoxy resin emulsion and an aqueous solution of a reaction product of certain polyamines. This new technology can help the coating industry reduce emissions of VOC and HAP. At the same time, this technology has the potential of affecting a sizable reduction in energy consumption in: (1) heat curing end products coated with paint made with the new polymer, and (2) thermal oxidizing VOCs from solvent-based coating operations.

The objectives of this project are to develop a new metal coating system that is sufficiently mature for demonstration and to develop a technology transfer plan to get the product into public use. The coating system was first fully tested in the laboratory. Hundreds of panels were prepared and tested, and many engineering hours were spent to develop the coating theory and fine tune the coating performance characteristics. The performance characteristics of this new coating system are excellent in terms of adhesion, drying times, hardness, and rust and chemical resistance.

Field demonstrations were conducted at two selected manufacturing facilities. The field demonstrations provide valuable information on how the coating performs in a full-scale application. In addition, the field demonstrations provide the information required for converting from conventional metal coating to the new metal coating system.

This report summarizes the research and development of this metal coating system. Topics presented in this report include: product performance data, application techniques, ease of use, and field demonstration results. A cost analysis was conducted for this new system and included costs of materials, capital outlay, and disposal expenses. An environmental impact study was also included in this project to address emissions benefits, disposal cost saving, and energy conservation based on data gathered during the in-plant, full-scale demonstrations.

Substantial progress has been made to identify market opportunities in California for new environmentally-sound products—specifically the need for a no-/low- VOC finishing coating system for metal furniture and industrial maintenance coatings. The complete absence of

organic solvents means that this new coating is not only less hazardous to use but emits no volatile organic compounds; therefore, it does not contribute to air pollution. The self-contained manufacturing process emits no significant air pollutants.

For example, it is estimated that companies in California use over 300-million liters or 10-million gallons of industrial maintenance, primer, and other architectural coatings each year in California alone. The potential to reduce emissions is very significant if all such coatings contained no solvents. Eliminating approximately three pounds per gallon of solvent by employing the no-VOC coating technology, would be equivalent to eliminating over 30-million pounds of emissions each year. Because this new water-borne metal finish coating dramatically reduces the level of VOCs, it has excellent potential for long-term emission compliance. It does not contain HAPs, which are specifically beneficial to a worker's health.

The environmental benefits of this project and the cost-effective solution for VOC reduction in California would be achieved with the continuous VOC reduction capability of this product and thereby help the California Air Resources Board (ARB) meet clean air goals.

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SECTION 1.0

INTRODUCTION

Under California Air Resource Board (ARB) sponsorship, AeroVironment Environmental Services, Inc. (AVES), Adhesive Coatings Co. (ADCO), and Compliance Engineering Technology, Inc. (CET) are teamed to develop and demonstrate a metal coating, which contains no volatile organic compound (VOC) and no hazardous air pollutant (HAP). This two-part system consists, in general, of an epoxy resin emulsion and an aqueous solution of a reaction product of certain polyamines.

The objectives of this project are to develop a new metal coating system that is sufficiently mature for demonstration and to develop a technology transfer plan to get the product into large scale. The performance characteristics of this new coating system are excellent in terms of adhesion, drying times, gloss, hardness, mar resistance, level of solvents, and stain resistance.

This report summarizes the research and development of this metal coating system. Topics presented in this report include: product performance data, application techniques, ease of use, and field demonstration results. A cost analysis was conducted for this new coating system and included costs of materials, capital outlay, and disposal expense.

An environmental impact study was also included in this project to address emissions benefits, disposal cost saving, and energy conservation based on data gathered during the in-plant, full-scale demonstrations.

AVES and ADCO has developed coatings and resins which comply and/or exceed the emissions standards. ADCO holds patents on some of these formulations. AVES, by working jointly with ADCO, has developed and evaluated this new promising technology which is sufficiently mature and has the potential for commercialization of industrial maintenance metal coatings for use by furniture manufacturers and industrial companies.

ADCO ENVIROPOLYMER is an epoxy emulsion with an increased molecular weight range designed to enhance the properties of air dry, force dry, and baked coatings systems. In the past, products have been developed and marketed which try to increase epoxy emulsion molecular weight in order to enhance film properties. Prior to ADCO's invention, however, any significant increase in molecular weight required solvents to help the polymer to coalesce. Further, the current competitive offerings in the marketplace which are represented to be water-borne epoxies are odoriferous and contain significant amounts of solvents or coalescing agents.

The innovation of ENVIROPOLYMER alters the resin's molecular weight and its distribution. This new product possesses five unique properties: (1) the emulsion polymerization of an epoxy latex; (2) a unique distribution of molecular weights; (3) the presence of a unique high polymer which is insoluble in many strong organic solvents yet is soluble in the mixture of molecular weights of this polymer; (4) when added to other water-borne polymers, allows these polymers to coalesce at temperatures below their normal glass transition temperature; and (5) it acts as a superior binder system for the formation of a high performance metal coating.

ENVIROPOLYMER was engineered as the next step beyond the conventional water-based epoxy emulsion systems. ADCO's technology provides a solvent-free water-borne epoxy polymer that exhibits, in a final paint film, better film properties (hardness, flexibility, chemical resistance, and overall durability) than even some of the newest epoxy emulsions on the market. In addition, ADCO's polymer does not have some of the weak points that most epoxy systems exhibit. For example, tests reported by customers to ADCO document this polymer as having much better ultraviolet radiation resistance and better flexibility while maintaining superior hardness. ENVIROPOLYMER is colorless, odorless, and is VOC- and HAP-free. ENVIROPOLYMER can be used as a resin system alone, or it can be used as an enhancer in latex paint formulations to provide greater durability.

This no-VOC coating technology has been developed and undergone successful preliminary tests and demonstrations for applications on metal surfaces by AVES and ADCO in this project.

1.1 EMISSION BENEFITS

The complete absence of organic solvents means that this new coating is not only less hazardous to use but emits no volatile organic compounds (VOCs); therefore, it does not contribute to air pollution. The self-contained manufacturing process emits no significant air pollutants. AVES believes that this new two-component, water-based epoxy technology, when used as a metal maintenance coating, has the potential of setting a new standard and therefore replacing a very significant share of current solvent systems now in use.

In the past, the Federal Clean Air Act has focused on reducing VOC emissions from mobile sources (cars, etc.) and stationary sources (power plants, factories, etc.). However, regulating consumer and commercial products may prove to be a more cost-effective way of substantially reducing VOC emissions nationwide.

In March 1995, the EPA issued a report to Congress entitled, "Study of Volatile Organic Compound Emissions from Consumer and Commercial Products." Architectural coatings are in the first group of products to be regulated. The EPA’s proposed rule set a VOC content level for each of the 55 categories of architectural coatings with 36 established in 1996.

Consumer and commercial products (such as surface coatings) contribute about six-million tons or approximately 30 percent annually of VOC emissions nationwide. The proposed regulation (if it is enforced) would reduce emissions of VOCs by 104,000 tons annually representing a 20% reduction from current levels.

Substantial progress has been made to identify market opportunities in California for new environmentally-sound products—specifically the need for a no-/low- VOC finishing coating system for metal furniture and industrial maintenance coatings.

For example, it is estimated that companies in California use over 300-million liters or 10-million gallons of industrial maintenance, primer, and other architectural coatings each year in California alone. The potential to reduce emissions is very significant if all such coatings contained no solvents. Eliminating approximately three pounds per gallon of solvent by employing the no-VOC coating technology, would be equivalent to eliminating over 30-million pounds of emissions each year. Because ADCO's water-borne metal finish coating dramatically reduces the level of VOCs, it has excellent potential for long-term emission compliance. It does not contain HAPs, which are specifically beneficial to a worker's health.

The environmental benefits of this project and the cost-effective solution for VOC reduction in California would be achieved with the continuous VOC reduction capability of this product thereby meeting the California Air Resources Board's (ARB) requirements. The goal of the project was to develop and demonstrate a metal coating that would set new industry standards for no VOCs.

SECTION 2.0

BACKGROUND

Hydrocarbon emissions generated from stationary sources are a significant environmental problem in California. One of the largest stationary emission sources is the evaporation of solvents used in paints, coatings, inks, and other products. Local air pollution control districts in California have passed rules to limit the volatile organic compounds (VOC) content in these products. For example, the South Coast Air Quality Management District (SCAQMD) has passed rules to limit the VOC content in coatings. These rules generally establish VOC limits based on the materials to which the coatings are applied. For example, Rule 1107 sets limits on metal coatings and Rule 1136 sets limits on furniture coatings.

The goal of this project was to demonstrate a zero-VOC and zero-HAP (hazardous air pollutants) coating technology for metal. This new technology can help the coating industry reduce emissions of VOC and HAP. At the same time, this technology has the potential of affecting a sizable reduction in energy consumption in: (1) heat curing end products coated with paint made with the new polymer, and (2) thermal oxidizing VOCs from solvent-based coating operations.

Traditional industrial maintenance coating technologies emit large quantities of pollutants into the air and consume energy in drying processes and air pollution abatement. Air emissions can be reduced through a gradual shift from high- to low-/no-VOC coatings. By phasing in low-/no-VOC coatings, industries will be able to reduce energy use and air emissions without installation of add-on controls.

2.1 CURRENT VOC REDUCTION TECHNOLOGIES FOR METAL COATINGS

With currently available coating technologies, there are several compliant coatings on the market for the industries of interest. Coating formulators have made tremendous progress in developing low-VOC products. Paints and coatings with lower VOCs (for example, high solids, water-based coatings, and powder coatings) become substitutes or alternatives for conventional coatings in a wide range of applications.

The coating industry, as a whole, has been very responsive with respect to regulatory requirements. In anticipation of stricter rules, manufacturers are developing and marketing products that exceed regulatory requirements. More importantly, the coating industry has been trying to introduce products that are better, safer, and more convenient for the end-user. Individual companies are also taking the initiative to reduce or eliminate the use of coatings that contain VOCs. Following is a summary of current metal coating system with low-/no-VOC content.

Water-borne Technologies

Water-borne technologies have been widely accepted by the overall metal-coating market. However, water-borne coatings may not be applied as successfully at lower temperatures as solvent-borne coatings, and require more thorough surface preparation for adhesion (sometimes requiring more than one coat). For some applications, multiple coats of paint may be necessary to achieve sufficient film hardness and to overcome wearability problems. Water-borne coatings may require painting more often than solvent-borne coatings because of wearability problems. Also, poor adhesion due to improper surface preparation is more prominent to water-borne coatings.

High Solids Coatings

High solids coatings are available with VOC content typically between that of water-borne- and solvent-based materials; but there are some catalyzed coatings at the low end of the water-borne VOC content range. There are both water-borne- and solvent-based catalyzed coatings. The solids content is also between that of water-borne- and solvent-based materials. There is an epoxy protective coating that was evaluated in our previous study with a solids content of 100% solids and zero-VOC content.

Powder Coatings

Powder coatings are an environmentally superior alternative to high-VOC liquid paints, and have become more attractive to large facilities. High solids and water-based coatings produce overspray and result in a higher loss than do powder coatings, which have a 96 to 99% transfer efficiency. Powder coatings are a proven compliance technology, with negligible overspray loss, no waste, and are recyclable.

In summary, the increasing popularity of powder coatings is due to low- or no-VOC emissions, high application yields, less energy required for curing than with liquid paints, no residual paint sludge, etc. New chemistries and technical progress continue to improve the quality and properties of powder coatings.

Powder painted parts or assemblies must be capable of being baked at the powder paint's cure temperature. Cure temperatures range from about 250 to 400°F depending on the powder's formulations. Since powder paints usually have excellent abrasion resistance, powder painted parts usually require little or no touch-up after typical assembly processes. These abrasion characteristics allow components to be powder painted prior to assembly, thus avoiding thermal damage to sensitive components or assemblies. Although there are a lot of advantages to using powder coatings (e.g., its performance limitations as mentioned above), they cannot be applied to some nonconductive materials, some geometry may be difficult to be painted, and powder coatings have limited color selections compared to liquid products. In addition, powder coatings cannot be effectively removed using solvents or paint removers. Removal usually requires some form of media blast. Media blast must be carefully evaluated before using in applications where nondestructive testing techniques are used, since it may obscure cracks, corrosion, or signs of metal fatigue.

Ultraviolet Coatings

Ultraviolet coatings (UV) have significant applications for exterior coating on galvanized steel pipe for fence posts, highway guard rails, road signs, and parking meters. Advancements in UV absorbers, light stabilizers, and a broader selection of aliphatic urethanes have enabled exterior, weatherable UV coatings to become a commercial reality. However, compared with powder coatings, UV coatings have yet to impact the general metal coatings market.

2.2 NEW NO-VOC/NO-HAP METAL COATINGS

Performance features of this new no-VOC metal coating are:

- Requires no solvents
- Delivers hardness with flexibility
- Versatile - compatible with most lattices
- Increases toughness/scrub resistance
- Increases chemical resistance
- Increases dry times in slow dry systems
- Aids in coalescence to allow reduction or elimination of solvents

The no-VOC coating system differs with all current compliant coating systems in several ways:

- ADCO's resin formulation contains no VOCs and no HAPs.

- Drying time of this coating (typically less than 30 minutes) is faster than conventional coatings.

- This coating demonstrates excellent adhesion and corrosion resistance.

- This technology has the potential of affecting a sizable reduction in energy consumption in: (1) heat curing the end products coated with paint made with the new polymer, and (2) thermal oxidizing VOCs from solvent-based coating operations.

SECTION 3.0

PERFORMANCE CHARACTERISTICS

Testing has been conducted to demonstrate the performance characteristics of this no-VOC coating system.

3.1 PERFORMANCE TESTING

Two curing agents were tested in formulations with each of the polymers tested in various stoichiometric amounts.

- ADCO's RESILINK^{TM} 2003, an aliphatic polyamine
- A commercially available modified aliphatic polyamine

These two amines are not only compatible with the RESILEX^{TM} polymer system but also impart good metal coating characteristics. Staff performed various tests (hardness, flexibility, etc.) to determine what effect this had on the polymerization. Various latex emulsions were added to the formulations to enhance the performance of the finished paint. We have found that by combining RESILEX^{TM} polymer with a specific latex emulsion we can tailor the characteristics of the finished coating to the end use more easily. Among the types of latex we tested were:

Standard Acrylics
Styrene Acrylics
Acrylonitrile Acrylics
Carboxyl Functional Acrylics

All of these lattices contained nonionic and anionic stabilizers, had pH values between 6.0 and 8.5, and were 30 to 55% solids. The selected four polymers were formulated with the above curing agents and acrylics in various combinations. This required over 250 separate formulations. Further, each formulation required applying the film, curing the film, and testing each of the 120+ samples.

For developing a metal primer coating, we have chosen the following system as the best candidate for further testing.

- RESILEX^{TM} polymer:
  - Epoxide Equivalent Weight - 1300
  - Average Molecular Weight - 530
  - Solids Content - 55.0% by weight
  - Insoluble Homopolymer - 35-40%
  - Average Particle Size - 0.25 microns

– Amine Curative:

  - System #1 - RESILINK™ 2003-35 polyamine used at 1:0.9 stoichiometry
    Used with a standard acrylic latex at a level of 25% resin solids based on the RESILEX™ polymer at 75%.

  - System #2 - Modified Aliphatic Polyamine diluted to 17.5% in water and used at 1:0.9 stoichiometry.

Laboratory Tests

The following performance characteristics were extensively tested. Results are summarized in Appendix A.

– Dry time
  Oven Bake - Air Flash at 25ºC for 5 minutes then bake at 125ºC for 20 minutes
  Air Dry - 2 weeks @ 25ºC and 50% Relative Humidity ASTM D-1640

– Flexibility - ASTM D-522
  Blend coated metal panel over 1.4" mandrel without it cracking.

– Level of Solvents - ASTM D-4457
  These were prepared to send to AVES.

– Corrosion - ASTM B-117
  Salt spray tests were done in a Singleton Salt spray cabinet.

– Rub resistance - We looked for 200 double rubs with no loss of film.

– Chemical resistance - ASTM D-1308 - Spot tests - One hour covered exposure
  Isopropyl Alcohol
  Acetone
  Sodium Hydroxide
  Hydrochloric Acid
  Acetic Acid
  De-ionized Water

– Ultraviolet Light Resistance - ASTM D-4587
  This test was done in a QUV cabinet. Exposure was 4 hours UV-B light then 4 hours condensing humidity at 60 degrees Celsius.

– Hardness - Pencil Hardness according to ASTM D-3363

3.2 SMALL-SCALE TESTING

In-Plant Testing Procedures

The following procedures were developed for the in-plant testing of the metal coatings. When conducting in-plant testing, all individual parameters were altered somewhat to conform to specific manufacturer's needs and operating procedures.

1. The number of pieces were between 10 to 20, depending on their size and complexity. This gave the Team (AV and ADCO) enough pieces to run in the field, test, and put into actual use.

2. Surface preparation was some kind of washing and subsequent phosphatizing pretreatment. Usually large metal products were washed on-line in a washer that used soap and hot water to remove mill oil and other impurities. Then the metal was rinsed with a sequence of chemicals to deposit corrosion inhibiting metal phosphates on the surface prior to painting. Hot air was employed to dry the part before painting. Some operations simply used a hand-applied corrosion inhibitor; others used a dip tank system.

3. The application guns depended entirely on the manufacturer and the Team used whatever the manufacturer used. The metal coating was applied using a myriad of guns including: conventional air guns, airless spray, air-over-airless spray, disks, bells, electrostatic or not. In any case, the adjustments of pressures, tip sizes, and fluid flow rates was done during the "dry run" stage. This was necessary in any new application. The one caution was if the manufacturer used only solvent-based coatings. In this case, modifications were made to the fluid hoses in the system. It has been our experience that new hoses should be employed when solvent has been used prior to water-based paints. It is best to replace the fluid hoses to avoid any of these problems.

4. Prior to any spraying on site, the Team attempted to match the color, gloss, and look of the manufacturer's current system as closely as possible. Nonetheless, the Team tried to have the manufacturer approve the color, gloss, etc., prior to the dry run. Another factor was that the Team may match the color exactly in the laboratory but when sprayed with other equipment and cured in other ovens, the color may be slightly different.

5. Mixing of the two components were done either by hand or with an electrical or air powered paint mixer, depending on the size of the mixed batch.

6. Since this material can either be air dried or force dried, the Team followed the manufacturer's procedures as well as possible. However, the Team demanded some modification with the cure method depending on the conditions. For instance, the Team needed auxiliary heaters or air movers when humid or cold conditions existed at the time of application. Or, adjustments to the temperature of the ovens or the air flash time

were necessary. In any case, the Team attempted to make any changes to highlight the benefits of this coatings' quick drying character.

7. Cleanup was done with hot or warm water to the manufacturer's specifications.

InfraTech Testing

Date: April 17, 1997

Place: Infratech Corp.
1684 W. Industrial Park
Covina, California

The small-scale testing consisted of spraying panels supplied by Infratech. The panels were cold-rolled steel approximately 12-inches square. Four of these panels were painted with the No-VOC Metal Primer (MPR-97-14) to about 1.5 mils thickness. Then two of the primed panels were sprayed with the No-VOC White Metal Top Coat and two were sprayed with ADCO's Blue Metal Top Coat. In addition, two bare metal panels were sprayed with white and blue topcoat. Also, one of the same bare metal panels was painted with Cardinal's Catalyzed Polyurethane enamel (VOC content: 420 g/l) which was used by Infratech for their own products. The Cardinal panel and two of the ADCO panels were dried via infrared heaters. All of the primers were dried by air only. Air dry time for the no-VOC products averaged 15 minutes.

SECTION 4.0

FIELD DEMONSTRATIONS

Demonstrations of this new metal coating system were conducted at two manufacturing facilities. The purpose of the demonstration was to show that this new coating system could be used successfully in a commercial metal finishing operation. AeroVironment Environmental Services, Inc. (AVES), Adhesive Coatings Co. (ADCO), and CET Engineering, Inc. (the Team) conducted the demonstrations. The following sections summarizes the demonstration processes.

4.1 DEMONSTRATIONS AT FACILITY A

Facility A manufactures motor homes. The operations at that facility include wood and metal coatings, metal fabrication, wood and metal cutting, drywall fabrication, engine mounting, etc. One metal coating operation involves the coating of metal chassis and structural beams of motor homes. The metal chassis provides the motor home frame on which other components are mounted; e.g., wheels and engines. The structural beams are referred to as Paco beams. The metal Paco beam is mounted on top of the chassis, forming the sides and bottom of the motor home.

Facility A coated the chassis and Paco beam to provide rust protection. The coating operation is conducted inside a large spray booth (48' L x 22' W x 12' H). The current coating system used is a compliant coating with a VOC content of 1.2 lbs/gal. Approximately half a gallon is used for a singe chassis. The coating is applied using a high volume low pressure (HVLP) gun. Four 5-HP fans exhaust the coating fumes from the spray booth.

Because a motor home is manufactured through an assembly line process, dry time is a critical parameter. The current coating system dry time is approximately half of an hour. Depending on ambient temperature, the dry time for the Cardinal product could vary substantially (from 30 minutes on a dry day to two days on a high humidity day).

First Demonstration, 14 July 1997

The new coating was used on two chassis. The coating demonstration was conducted on a dry, hot day. Similar coating equipment was used; e.g., spray booth and HVLP gun. ADCO personnel performed the coating process.

For the first chassis, the coating time was 20 minutes, comparable to the compliant coating the facility currently uses. Dry time was approximately 30 minutes. Approximately half a gallon was used. Facility A expressed the concerns that too much orange peel was revealed on the coating surface. The Team evaluated the concern and concluded that the orange peel was due to too much coating. For the second chassis, the over-coating was reduced and the results improved. The coating time was 13 minutes and dry time was, again, approximately 30 minutes. The Team believed that the coating should work even better if minor adjustments are made to the coating and Facility A concurred. A large piece of metal chassis was provided to ADCO for further tests at ADCO's laboratory.

Second Demonstration, 20 August 1997

The purpose of the second demonstration was to evaluate a reformulated coating which was developed specially for the Facility A product. The reformulated coating was to reduce surface orange peel. The coating was applied on a single chassis. The result was not satisfactory. Facility A staff expressed that the orange peel effects were still visible and the Team concurred. After in-depth evaluation, the Team believed that the orange peel effects were due to the following:

1. The chassis surface was not adequately cleaned. Dirt remaining on the surface to which coating was applied can contribute to "orange peeling."

2. The first layer of coating was applied by a Facility A personnel, who has never used the new coat. Thus, the operator was not familiar with the new coating system. The coating took only 15 minutes. The Team believed that the Facility A personnel applied insufficient coating. After the first coating, the orange peel effects were significant due to lack of coating applied. After evaluation, ADCO personnel recoated the chassis. ADCO personnel applied a second layer when the first layer was still wet. The recoating did result in less orange peels. However, the effects were still visible.

Lessons learned from the second demonstration provided valuable experience, which was applied in the third demonstration.

Third Demonstration, 23 September 1997

The purpose of the third demonstration was to continue the evaluation of a newly reformulated coating which was developed specially for the Facility A product. The reformulated coating was to reduce surface orange peel. This coating was used in the second demonstration. However, the result of the second demonstration was not satisfactory.

The third demonstration was conducted on a dry, hot day. The coating was applied on a single chassis and PACO beam. The chassis surface was not cleaned in the second demonstration which resulted in a large amount of orange peel. Thus, the chassis and PACO surface were adequately cleaned for the third demonstration. The setting was similar to the second demonstration. The result was satisfactory. Orange peel affect was substantially reduced.

Fourth Demonstration, 15 October 1997

The purpose of the demonstration was to evaluate an in-situ mixing spray gun for the new metal coating. The in-situ spraying gun was developed for in-time mixing of the two-component coating system. In-time mixing reduces labor time required to mix the coating, and also reduces material usage due to the fact that after mixing, the coating has a finite pot life.

This demonstration was conducted on a dry, hot day. The coating was applied on a single chassis and PACO beam. The chassis and PACO beam surface were adequately cleaned. The setting was similar to previous demonstration. For the first several minutes of coating, the coating on the chassis seemed to be contaminated with oil, since tiny bubbles were shown on the coating surface. The demonstration was stopped and investigation was initiated to identify the source of oil. Source of oil could be from the pumps driving the air gun. When the oil-based compliant coating was used, the oil leakage from the pump would not cause incompatibility problem. However, when the water-based no-VOC coating was used, the pump oil could cause coating bubbles since water and oil do not mix. This incompatibility problem can be easily solved by installing an air filter in the spray gun. The air filter takes out the oil mist if released from the pump. Although an air filter was not available at the time, it was decided that the coating should be continued. After several minutes of coating, the bubbles were not visible. The probable reason was that the oil leakage from the pump was not significant. The coating lasts 26 minutes and the result was satisfactory. Orange peel effect was insignificant and the in-situ spraying gun worked as planned.

Fifth Demonstration, 17 October 1997

The purpose of the demonstration was to continue the evaluation of an in-situ mixing spray gun for the new metal coating. The coating was applied on a single chassis and PACO beam. The chassis surface was cleaned. An air filter was installed in the in-situ spray gun. Two-thirds of the chassis was coated with the no-VOC system, and the remaining chassis was coated with the compliant coating system. Comparison of the two coatings on the same chassis provided coating performance data. The new coating system performance compared satisfactorily with the compliant coating system in terms of adhesion and appearance.

Sixth Demonstration, 17 October 1997

The purpose of the demonstration was to evaluate an in-situ spray gun. The demonstration was shown to Facility A's production personnel. Facility A staff expressed that the new coating system and the in-situ spraying gun met their specifications.

Seventh Demonstration, 20 January 1998

AVES, a Sierra Performance Coatings representative, a GRACO Equipment Manufacturer representative, and a Butler Compressor & Spray Equipment Co. representative conducted testing at Facility A. Two sets of regular RV chassis platform and several metal pieces were coated with this no-VOC metal coating. The chassis surfaces dried quickly. However, the Production Supervisor of Facility A suggested that the painting be done by a professional painter.

The Team took Facility A's advice and a professional painter from Fairway Painting Associates came to Facility A on January 28, 1998. Two sets of Paco-Beam RV chassis platforms were coated. The first set of Paco-Beam RV chassis platforms was coated within 40 minutes and took one-and-a-half gallons of coating. The painter of Fairway Painting Associates changed the air pressure of the spray gun which reduced overspray from the second set of the Paco-Beam RV chassis platforms. One-and-a-quarter gallons of coating were used for the second set of RV chassis. At 65^0F and 78% relative humidity, the coated chassis surface dried in less than 30 minutes. Facility A staff expressed that a Space Ray overhead radiant gas heater could be used if it was necessary to expedite the dry time (during raining days or extremely cold days). Facility A staff was satisfied with the demonstration results. They were in the process of conducting their own cost effectiveness study.

4.2 DEMONSTRATIONS AT FACILITY B

Facility B manufactures motor homes. The process is very similar to the process at Facility A. Facility B is planning a large expansion, and is thus expressing high interest in a non-VOC coating like the ADCO system.

Facility B currently does not coat the whole chassis and Paco beam. Only the metal weld joints on the chassis and Paco beams are coated using aerosol cans. The joints are coated for rust protection. The coating is conducted outdoors with no confinement. The current coating system has a VOC content of 2 lbs/gal. Facility B staff expressed that rust protection was a major issue. Another critical parameter is dry time. Thirty minutes is an acceptable dry time for the coating process.

First Demonstration, 15 July 1997

The new coating was used on a single Paco beam. The Team performed the demonstration using a HVLP gun. Coating time was approximately one hour. Dry time was approximately 30 minutes. Approximately one gallon of the new coating was used. The surface was smooth and there was no orange peel. Facility B staff was satisfied with the new coating. Plant personnel asked the Team if the two-component new coats could be applied in-situ (e.g., mixed at the HVLP gun). The new coats require the operator to mix the two component coats before application. This extra effort increases labor hours. Also, after the coating is mixed, it has a limited shelf life. Therefore, if the two-component coat can be applied in-situ, it will be more cost effective for the operator.

Second Demonstration, 16 October 1997

The purpose of the demonstration was to evaluate an in-situ spray gun. The demonstration was shown to Facility B production personnel. Facility B expressed that the new coating system and the in-situ spray gun met their specifications.

Third Demonstration, 12 January 1998

AVES, Sierra Performance Coatings (licensee of ADCO's no-VOC coating technology), GRACO Equipment Manufacturer representative, and Butler Compressor & Spray Equipment Co. conducted testing at Facility B. The purposes of this testing were: (1) to test the feasibility of the in-situ mixing spray gun based on the final specification from December 4 meeting, and (2) to coordinate with Facility B personnel to expand the no-VOC metal coating application (both RV chassis and trailer chassis). Two sets of power-structure RV chassis platform were coated with ADCO's no-VOC metal coatings. The first set of power-structure RV chassis platforms was slightly overcoated and resulted in dripping. The representative from Butler Compressor & Spray Equipment Co. changed the tip size of the spray gun and reduced dripping from the second set of power-structure RV chassis platform. About a gallon to a gallon and a quarter of coating was used for each set of RV chassis. Even though it was a cold day (temperature less than 55^0F outdoors), the coated chassis surfaces dried in about 30 minutes. After completion of these two sets of power-structure RV chassis platforms, the Engineering Services Manager of Facility B asked staff to coat a rusted trailer chassis to see whether this new no-VOC metal coating could be applied to rusted surfaces and protect it from further corrosion. About a gallon and a half of coating was used to cover this big trailer chassis. Facility B was satisfied with the demonstration results. Facility B has installed a new spray booth and is ready to convert to this new no-VOC coating system.

4.3 OPERATIONAL ADJUSTMENT

In-Situ Mixing Spray Gun Specification

AVES, ADCO, and Butler Compressor & Spray Equipment Co. (representative of GRACO Equipment Manufacturer) visited Facility B on December 4, 1997. The purposes of the meeting were: (1) to finalize the specification of the in-situ spray gun, and (2) to coordinate with Facility B personnel to incorporate the in-situ spray equipment with the newly built spray booth. The in-situ spray gun is designed for real-time mixing of the two-component ADCO zero-VOC coating system. Real-time mixing reduces labor time required to mix the coating, and also reduces material usage because after mixing, the coating has a limited pot life.

Laboratory Testing of In-Situ Mixing Spray Gun

ADCO staff sent 10 gallons of zero-VOC metal coating to Butler Compressor & Spray Equipment Co. for their laboratory testing with the two-component coating mixing ratio. Facility B personnel expressed an interest in getting a loan unit (spray gun) from Butler Compressor & Spray Equipment Co. until they feel comfortable purchasing one.

4.4 COMPARISON OF THE ZERO-VOC COATING AND THE COMPLIANT COATING

This no-VOC coating and the compliant coating (VOC 333 g/l) were sprayed on metal panels and put in salt spray cabinet using ASTM Method B117 for corrosion resistance testing. The compliant coating failed after 192 hours (showed crack and blister on coating surface) and the zero-VOC coating passed 1000 hours already (still under ongoing testing). Table 4-1 is a list of comparisons between the compliant coating and this no-VOC metal coating.

TABLE 4-1. Coating Comparisons

	Compliant Coating	**No-VOC Metal Coating**
VOC Content	333 g/l	0 g/l VOC
Solid Content	40%	65%
Applying Time	30 minutes	30 minutes
Drying time	30 minutes	30 minutes
Impact of Humidity[1]	Major Impacts	Minor Impacts
Corrosion Resistance	Failed after 192 hours (showed crack and blister on coating surface)	Passed 1000 hours (still under ongoing testing).
Equipment Requirement[2]		May need to purchase plural component spray gun
Equipment Cleaning	Use solvent to clean up the equipment	Use water to clean up the equipment within coating pot life.
Facility Emission Ceiling	The facility's production is limited by its VOC emission ceiling.	By switching over to No-VOC coatings, the facility's production is no longer limited by the coating process.
Coating Methodology[3]		No significant differences
Workers' Health	Hazard Air Pollutants (HAPs)	No-HAPs

1 Typical drying process for conventional solvent-/water-based coating proceeds as follows: (a) the water molecules first evaporate, (b) solvent remaining in the coating promotes the curing agent to link various coating components forming the final cured coating film, and (c) the solvent then evaporates. These three processes define the drying time of a coating system. On a humid day, ambient air is saturated with water molecules; thus water molecules in the coating do not readily evaporate. Solvent molecules actually evaporate before the water component in a humid environment. Water components remaining in the coating delays the curing agents from performing their work. Thus, on a humid day, it takes longer for a typical solvent-/water-based coating to dry. This new metal coating does not have this problem on a humid day because only water evaporates from the surface.

2 The plural component spray gun is needed if no premixing of two components is desired.

3 No significant difference other than the compliant coating. There is no need to retrain on its application.

SECTION 5.0

COST EFFECTIVE ANALYSES

5.1 COST-EFFECTIVE ANALYSIS USING DATA FROM DEMONSTRATIONS AT FACILITY A - MOTOR HOMES

Table 5-1 presents the compliant coating data used at Facility A. The compliant coating was applied on a motor home's metal chassis and structural beams. (The structural beam is referred to as a PACO beam.) Facility A coated the chassis and PACO beam to provide rust protection. The coating operation was conducted inside a large spray booth (48' L x 22' W x 12' H). Four 5-HP fans exhausted the coating fumes from the spray booth. Approximately two gallons were used for a singe chassis with structural beams. The compliant coating was delivered to the facility in 55-gallon drums. Coating was pumped from a single 55-gallon drum to the regular spray gun via a hose. No mixing of the coating was required. The compliant coating cost is approximately $15 per gallon.

TABLE 5-1. Current compliant coating in use at Facility A.

Ingredients	CAS Number
2-butoxyethanol	111-76-2
sec-butyl alcohol	78-92-4
n-propoxypropanol	1569-01-3
butyl alcohol	71-36-3
VOC Content	333 g/l excluding water, 146 g/l including water

The new metal water-based coating contains zero-VOC material and comes in two parts: Part A and Part B. The coating is applied via an in-situ mixing spray gun system built by either BINKS or GRACO. The system mixes the two coating components near the spray gun nozzle; therefore, premixing of the two components is not required. This new no-VOC coating costs approximately $25 per gallon. During eight demonstrations conducted at Facility A, the following were found:

1. Drying times for the compliant coating and this new no-VOC coating were similar—30 minutes—if applied on a hot day.

2. Coating consumption amounts for the compliant coating and this new no-VOC coating differed (for a single chassis with PACO beams, two gallons of compliant coating versus 1.25 gallons of the no-VOC coating). Coating quantity can differ with painters. An experienced painter will use a consistent amount of paint.

3. Time required to apply the compliant coating and ADCO coatings were both 30 minutes. Coating application time varies with painters' experience.

4. The ADCO coating performance is currently being monitored. Corrosion resistance was found to be better with the no-VOC coating than with the compliant coating.

5. One painter stated that there were no significant differences in using this no-VOC coating in terms of coating methodology (e.g., no need to learn something new).

If Facility A replaces the compliant coating with this new no-VOC coating, the costs listed in Table 5-2 will apply.

TABLE 5-2. Cost Comparisons.[1]

	Compliant Coating	**No-VOC Metal Coating**
Price Difference (Estimated)[2]	$15/gallon	$25/gallon
Usage Per Chassis[3]	2 gallons	1.25 gallons
Emission Fee[4]	$0.94/gallon of coating used	None
Disposal Fee[5]	$0.55/gallon of coating	None
Throughput[6]	Limited by VOC Ceiling	Unlimited
Control Equipment	May be needed ($100,000-$450,000)	None
Spray Equipment	$1,000 for a typical high-volume low pressure (HVLP) gun	$1,000 - $18,000[7]

1 This cost estimate does not include the benefit of increased productivity.
2 Cost is estimated.
3 Current compliant coating use is two gallons/chassis. Based on field demonstrations, the new no-VOC coating use is 1.25 gallons per chassis. The no-VOC coating has a higher solid content.
4 Emission Fee: based on $669/ton of VOC and 4 tons/year of emissions (equivalent to 2857 gallons of compliant coating used), the total is $2,676 per year.
5 Disposal Fee: typical disposal of a 55-gallon drum is $300/drum; compliant coating use estimated = 12 gallons/day * 260 days/year = 3,120 gals/year. Assuming 10% residue from leftover paint, washing solution, etc., the disposal cost is 3,120 gals x 10%/55 gal * $300/drum = $1,702/yr.
6 The productivity is limited by a facility's VOC emission ceiling. By switching to no-VOC coatings, the productivity is no longer limited by the coating process, since the maximum number of chassis sets sprayed per day can increase.
7 A HVLP gun can be used. However, the plural component spray gun may be needed if no premixing of two components is desired.

Generally speaking, this new coating system price (cost per gallon) is higher than the compliant coating on the market. However, this no-VOC coating showed superior performance. For example, the corrosion resistance of this no-VOC coating passed 1000 hours of salt spray testing compared to the compliant coating, which failed after 192 hours. One of the facilities conducted its own field corrosion testing, and there was no sign of coating failure six months after the demonstration.

There will be other long-term cost savings: no need for control equipment when using this no-VOC coating, no emission fees, and no disposal fees. In addition, productivity can be increased due to unlimited no-VOC coating usage (no VOC emissions for this new coating system).

SECTION 6.0

ENVIRONMENTAL IMPACT ASSESSMENT

Traditional metal surface coating technologies emit large quantities of air pollutants through the volatilization of organic solvents and carriers. These air pollutants include volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and ozone depleting compounds. Volatile organic compounds react photochemically with oxides of nitrogen to form ozone, a reactive compound which irritates human tissue and causes damage to plant life. Hazardous air pollutants emitted from metal surface coatings affect health and safety to workers in the workplace and in surrounding areas. Ozone-depleting compounds deplete the stratosphere ozone layer which protects life from sun radiation. Since traditional metal surface coating is widely used in many manufacturing industries, the environmental impact is significant, especially in localized industrial areas in California, such as the South Coast Air Basin.

The preferred pollution prevention method is to reduce the need for surface coating and eliminate or control the emission of VOCs. For example, American Airlines flies unpainted aircraft. There are also many commercially available alternative coating systems that generated less air emissions, such as water-based coating, super-critical carbon dioxide coating, UV-cured primer, and powder coating. In addition, alternative coating application methods can also reduce air emissions, including the uses of high-transfer efficiency spray guns, rotary atomizers, roll coating, autodeposition, and electroplating. Each of these alternative coating systems and application methods is applicable for all of the industrial coating operations. Roll coating cannot reach small nonflat areas. Powder coating requires high capital costs and must be electroplated. Each surface coating operation requires study to determine the most appropriate and cost effective alternative method for practical application and minimal environmental impact.

The non-VOC, non-HAP, water-based metal coating technology presented in this study is an alternative coating to traditional organic solvent based coating system. By using this new, promising no-VOC water-based coating technology, significant air emission reductions, hazardous waste reductions, and energy savings could be achieved without installation of pollution control systems. As a result, cost savings will be achieved from eliminating VOC control equipment and hazardous waste disposal, and from energy savings. Therefore, commercialization of the proposed technology will provide an alternative technology for metal coating which is a cost-effective way to comply with current and future VOC emissions standards for metal coating operations imposed by federal, state, and local government agencies.

There are two major environmental impacts (benefits) and some potential minor benefits to replacing traditional organic solvent and combined solvent/water-based metal coatings with this new ADCO non-VOCs and non-HAPs containing metal coating. First, the emission of VOCs and HAPs is eliminated, and secondly, the risks of VOC/HAP containing metal coatings is eliminated. Risks associated with VOC/HAP containing metal coatings include both human health risks of toxic VOCs and HAPs, as well as the risk of fire and explosion associated with the coating in storage and perhaps more importantly during application and handling of the spray booth filters and debris.

In addition to the environmental benefits, the ADCO metal coating is in compliance with the most recent South Coast Air Quality Management District (SCAQMD) amendment to Rule 1107, which severely limits emissions of VOC from metal coating operations. Compliance is achieved without the cost of installation and operation of pollution control equipment.

The following sections focus primarily on the major environmental impacts (benefits) from replacing standard solvent containing coatings to the ADCO non-VOC containing coating system. Whenever possible, emission data available from the Air Resources Board and/or South Coast Air Quality Management District are used to quantify the relative magnitude of these primary environmental benefits resulting from employing this new non-VOC and non-HAPs coating technology.

6.1 VOC AIR EMISSION REDUCTIONS

The ADCO coatings do not contain VOC or HAP compounds. Thus, replacement of traditional metal organic solvent-containing coatings to the ADCO non-VOCs and non-HAPs coatings will result in significant reduction in VOC air emissions in California. A California Air Resources Board study (CARB Study, "Coatings & Related Process Solvents Industrial Coatings" Section 3.5, Reissued October 1997, Page 3.5-1) estimated that 26 percent of all VOC coating emissions are derived from metal parts and products coating operations. There are other categories in which metal is coated, but for comparison purposes, only this Metal Parts and Products Coating category will be used. The study results are shown in Figure 6-1. The VOC emission data (tons per day) is presented for eight California categories in Table 6-1. It shows that VOC emissions from all coating categories are approximately 286 tons per day, of which 86 tons per day are from Metal Parts and Products coatings category. Metal Parts and Products coating, with the exception of the general Industrial Coatings category, is the largest single source for VOC emissions for all coating operations in California. Even if a small portion of the metal coating industry switched to the ADCO coating system, VOC emissions would be significantly reduced. For example, it is estimated that 450 tons of VOC emission reductions can be achieved per year by replacing 300,000 gallons of the current compliant coating (VOC content 3 lbs/gal) with this no-VOC system .

Figure 6-1 Excel spreadsheet File: Figure1&tables *(Figure 1)*

Table 6-1 and 6-2 Excel Spread sheet File: Figure1&tables, *(Table)*

VOC emissions from Metal Parts and Products coating operations in the South Coast Air Basin represent nearly one half of the metal coating derived VOC emissions in the state of California (Table 6-2). The South Coast Air Quality Management District (SCAQMD) estimates that 30.05 tons per day of VOC (21 percent of the total) was emitted from Metal Part and Products coating operations in 1987 (SCAQMD Report, "Air Quality Management Plan, 1991 Revision" December 1990, Page T-21). The 1987 VOC emissions for all categories in the South Coast Air Basin once again showed that Metal Parts and Products coating is the single largest source, except for the general Industrial Coatings category, of VOC emissions for coating operations in the South Coast Air Basin. If only a portion of the traditional metal coatings were placed with the non-VOC ADCO coatings, a significant reduction in VOC emissions would be realized in the South Coast Air Basin. For example, a 10 percent replacement would realized a reduction in VOC emissions of over three tons each day.

The regulation governing metal surface coating in the South Coast Air Basin is the SCAQMD Rule 1107. Rule 1107 classifies metal coating operations into 19 categories, such as coatings for heat-resistant protection, coatings for silicone-release (nonsticking baking pan), coatings for military products. VOC limits for these 19 coatings ranges from 2.8 pounds per gallon (lb./gal) to 6.7 lb./gal for air-dried coatings and from 2.3 lb./gal to 6.7 lb./gal for bake-dried coatings. A recent amendment to Rule 1107 reduces the VOC limit from 6.7 lb./gal to 3.5 lb./gal for all metal coatings. SCAQMD estimates that 30 pounds of VOCs per day per facility emission reduction is expected to occur as a result of these new VOC limits (SCAQMD Report, "1995 Staff Report for Rule 1107 Amendment," May 1995, Page 2).

Companies throughout the South Coast Air Basin have been impacted by the new metal coating VOC emission limits and will be required to change their current metal coating, coating application methodology, or install emission control equipment to comply with the amended Rule 1107. Since the ADCO metal coating contains no VOCs, it can be used by these companies to comply with the amended Rule 1107.

6.2 EMISSION CONTROL EQUIPMENT

The use of emission control equipment is one of the alternative methods that may be employed to comply with the new VOC emission limits for metal coating operations. The two primary emission control technologies available for the control VOC emissions are destruction in a thermal oxidizer and recovery via adsorption onto activated carbon or liquefied in a refrigerated recovery unit. In both cases the coating must be applied in a containment booth or house, where the volatile compounds are contained, collected, and directed through the emission control equipment. Typically the coating process is conducted in a spray booth, in which a negative pressure has been applied to draw the volatile compounds and particulate matter (overspray) through particulate filters into the emission control equipment. Spray booth blowers must be explosion/fire proof in design and are usually high volume low pressure. Spent particulate filters (exceed partial pressure drop criteria across the filter) must be dried thoroughly and changed periodically. The spent filters may contain entrapped VOCs from VOC organic solvent coatings and are potentially a fire hazard as well as may be considered a hazardous waste, which requires disposal in accordance with applicable hazardous waste disposal regulations.

For example, a spray booth large enough to hold a vehicle or small truck would typically have two exhaust blowers, approximately 5 horsepower each, for a total flow of approximately 7,000 cubic feet per minute (cfm). The VOC laden exhaust air would be drawn through particulate filters, where any coating solids would be removed and then be directed to the pollution control equipment. For calculation purposes it is assumed the system will operate one shift (8 hours) a day for 260 days a year.

Thermal Oxidizer *(BACT in the SCAQMD)*

A typical thermal oxidizer to destroy VOCs in an air-stream at 7,000 cfm. would have a rating of 6 million Btu per hour (mmBtu/hr). Destruction efficiencies of 95 to 98 percent are achievable in a thermal oxidizer. The thermal oxidizer will emit air pollutants, such as NO_x, SO_x, CO, PM_{10}, VOC and other combustion products from natural gas, resulting in adverse air quality impacts. The estimated combustion products for the example thermal oxidizer are shown in Table 6-3.

Thermal incinerator with a rating of 6 mmBtu/hr, controlling a VOC-laden exhaust flow rate of 7,000 cfm. Natural gas consumption rate is based on gas heating value of 1,050 mmBtu/cf. Operating schedule is 8 hr/day and 260 days/year.

TABLE 6-3 - Natural gas combustion products using thermal incineration.

Criteria Pollutants	Emission Factors* (natural gas combustion), lb./mmcf	Emissions, lb./day	Emissions, lb./year
Nitrogen oxides (NO_x)	120	5.49	1426
Sulfur oxides (SO_x)	0.83	.04	9.9
Carbon monoxide (CO)	20	.91	238
Particulate Matters (PM_{10})	0.2	.01	2.6
Reactive Organic Gas (ROG) or (VOC)	5.3	.24	63

***** Emission Factors: AQMD CEQA Handbook, April 1993, Table A9-12-02

The calculation for the total VOC emissions of a spray booth/thermal oxidizer operation, which uses 50 gallons of compliant coating per day, with a VOC content of 333 gm/l (2.78 lb./gal) results in 7.19 lb./day VOC.

- Coating VOC: 2.78 X 50 = 139 lb. VOC
- Thermal oxidizer (95% efficient): 139 X .05 = 6.95 lb. VOC

- Combustion product VOC: 0.24 lb.
- Total VOC emissions = 7.19 lb. per day

Carbon Adsorption Unit

Another pollution control system to reduce VOC emissions is based on activated carbon adsorption. The spray booth exhaust is directed through canisters of activated carbon, where organic compounds are adsorbed onto the granulated carbon. When the carbon reaches maximum adsorption capacity, for the design efficiency, it must be replaced. The spent carbon may either be regenerated or thermally destroyed, which represents additional cost. In addition there are risks associated with handling, storage, and shipment of hazardous materials/wastes.

A carbon adsorption system can be designed to attain 90 to 95 percent efficiency. The design (size of the canisters and residence time) is based on the VOCs to be adsorbed, capture efficiency of the carbon/VOC, VOC concentration in the process stream, temperature of the process stream and other factors to a lesser extent. The system would include a series of canisters with indictors of breakthrough, which necessitates removal of the spent canister and rotation/installation of additional canisters. Regeneration or destruction of the VOC laden carbon is not approved with the SCAB and any VOC emissions that may result during the regeneration process would not be in the SCAB. Operation of a carbon adsorption unit is quite simple, but it is anticipated that additional space will be required for a 95 percent efficient system to process 7,000 cfm flow with a total of 139 lb. of VOC.

Both VOC pollution control systems can attain 95% control efficiency, thus either system could potentially be used and both would emit approximately 7 lb. of VOCs per day of operation. Each project should be evaluated for optimum system design, operation and cost, both capital cost and operational cost.

The use of the non-VOC coatings, like the ADCO coating, would eliminate the compliance requirement for control equipment, emission of VOCs even with the control equipment, and the capital and operational cost of the control system. In addition, it may be possible to use the eliminated VOC emissions for offset, bank the eliminated emissions for credit in the future, or sell the credits.

6.3 RISKS

Use of traditional solvent-containing coating may have the potential to expose workers and the surrounding community to health and environmental risks. This is primarily due to the concentration of volatile gases in the air-stream resulting from the coating application and/or during the handling, storage and disposal of the waste material. In addition, if pollution control equipment is installed in the workplace to control VOC emissions from traditional coating, it could pose similar environmental risks, The risks include human exposure to HAPs and VOCs and potential fire/explosion of the VOC vapor streams and waste material, e.g., spray booth filters. In addition, the handling, storage, and disposal of hazardous material (coating) and hazardous waste (filters, rags, masking material).

Human Health Risk

The traditional organic solvent-based coatings contain VOCs of which many are HAPs. Human exposure to these HAPs are a potential human health risk. The greatest risk, based on potential exposure, would be to the coating application workers, followed by the plant workers, and finally the surrounding community. The potential human health risk can be determined following identification of HAPs in each coating and the estimate of potential exposure using the appropriate air dispersion models. Specialized personal protection equipment (PPE) may be necessary to protect application workers and anyone else with a potential exposure to a concentrated VOC/HAP stream, e.g., spray booth exhaust stream. This human health risk to VOCs/HAPs can be completely mitigated by replacing the solvent-based coating with non-VOC coatings such as the ADCO coatings.

Explosion/Fire Risk

Traditional solvent-based coatings contain flammable VOCs and pose a potential explosion/fire hazard. During application and drying, in an enclosure, the risk is significantly greater due to the volatilization of the flammable solvents. In addition, waste material which contains residual VOCs, e.g., spray booth filters, remain a potential explosion/fire hazard and must be handled, stored, and disposed according to flammable hazardous waste regulations. Business Plans must be prepared and submitted to the local Fire Department, which identify all flammable and hazardous materials, show their location in the facility, and the maximum estimated quantity.

Mitigation of these health and environmental risks can be achieved with careful planning and adherence to strict operating protocols. These risks can be eliminated by replacement of solvent-based coatings with non-VOC/HAP coatings, such as the ADCO metal coatings.

6.4 ENVIRONMENTAL BENEFITS

Energy Savings

1.Compliance with the amended SCAQMD Rule 1107, which limits VOC emission from traditional organic solvent based metal coatings, will require the current metal coatings operators to change their coating process. The three potential options of change are:

1. Reduce operations (production) to reduce VOC emissions below the daily limit
2. Install Pollution (VOC) control equipment, or
3. Change the coating process to a lower- or non-VOC coating

The first option is not acceptable in most cases. The second option, installation of pollution control equipment (PCE), may be necessary for some coating facilities. This would primarily be due to the lack of non-VOC coatings to meet their specific requirements. The installation of PCE will impact the cost of the product in two ways capital cost of the equipment and increased operations cost. One portion of the operational cost increase is due to an increase in energy usage, both electrical and natural gas. This increase in energy usage also represents an indirect environmental impact. The two PCE examples described above are representative of the typical energy usage that would be necessary for each device.

1. Thermal Oxidizer (medium size)
   - Natural Gas: Annual usage - 12 mmcf/yr. (See Table 6-3 for combustion emissions per year)
   - Electrical Energy: Two each 5 hp blowers - 7,176 kWh./yr.
   - Support/Control Electrical Energy: 1,000 kWh /yr.
2. Carbon Adsorption Unit (medium Size)
   - Electrical Energy: Two each 10 hp blowers - 12,896 kWh/yr.
   - Support/Control Electrical Energy: 1,000 kWh /yr.
   - Regeneration/Destruction Gas Energy: 12 mmcf/yr. (Estimated: equivalent to thermal oxidizer energy usage)

This estimate of energy usage is for one medium size PCE unit and if only 10 to 20 percent of the existing coating facilities installed PCE units, the environmental impact of the energy usage and its associated emission of air pollutants could be significant.

The third option, coating material change to non-VOC coatings, would eliminate the air emissions associated with PCE. It would also eliminate all VOC emissions, even those reduced emissions from the PCE Units.

Solid Waste Disposal Impacts

The installation of PCE to mitigate VOC emissions from traditional coating would not reduce the generation of hazardous waste, i.e. the spray booth filters would still be hazardous. Disposal of spent carbon from carbon adsorption units results in an increase in demand for hazardous waste disposal facilities. A regenerative carbon unit has a life of over 10 years. Spent carbon is considered a hazardous waste and must be disposed in a Class 1 site. The non-VOC, ADCO system does not require installation of pollution control equipment, and the spent spray booth filters do not contain VOC; thus, hazardous waste disposal would be eliminated.

Fire Protection

Use of traditional coating would have an impact on local fire departments in the event of a fire emergency. This is primarily due to the concentration of volatile gases in the air-stream and presence of a heat sources from pollution control equipment. Facilities are required to maintain an emergency response management plan (such as Fire Department Business Plan), and are also required to observe and maintain safety procedures in the work area. This could be eliminated if the non-VOC ADCO coating is used to replace the traditional organic solvent based coating.

Transportation Impact

Use of traditional coatings in combination with PCE has the potential to increase the transportation of hazardous waste to distant Class 1 disposal sites, because of the additional wastes which would be generated by the PCE. Increased traffic for transportation of hazardous wastes on roads to distant Class I disposal sites would raise the risk of spills and potential exposure of nearby communities to environmental and health risks. Because the non-VOC ADCO coatings do not generate VOC laden hazardous waste, the traffic associated with transportation of hazardous waste from traditional coatings to Class I disposal sites would be eliminated.

SECTION 7.0

TECHNOLOGY TRANSFER

In order to accelerate the spread of this new zero-VOC metal coating technology to manufacturers, staff from AeroVironment Environmental Services, Inc. (AVES) attended the "Emerging Solutions to VOC and Air Toxics Control" Specialty Conference held in San Diego for technology transfer. The conference was sponsored by the Air and Waste Management Association (A&WMA) and the U.S. Environmental Protection Agency on February 26-28, 1997. Approximately 100 people were in attendance. Topics included: Emerging and Innovative Technologies, Regulatory Issues and Hybrid Technologies, Compliance for Coatings Operations, Air Management for Least-Cost Abatement, and Case Histories.

A paper entitled "Evaluation of Volatile Organic Compound Reduction Technologies for Metal Coatings" was presented by AVES staff on February 27, 1997 (see Appendix C). Our evaluation criteria for low-VOC products include VOC content, availability, and applicability. Some of the current available coating products were presented with their properties and applications. The metal baking enamel and air dry epoxy enamel formulated using ADCO's zero-VOC technology were also presented as new emerging technologies. The properties and performance testing data were summarized and discussed in detail. The metal panels coated with ADCO's metal baking enamel and air dry epoxy enamel were exhibited and the technical coating data sheets (see Appendix B) were handed out to the interested parties. We also solicited manufacturers for the participation of full-scale demonstration of this zero-VOC metal coating.

In addition, the following efforts were made for technology transfer:

- AVES staff member, Dr. Eddy Huang, was invited to present "No-VOC Coating Technologies" on "Pollution Prevention 2000 Conference and Exhibition" held at the Southern California Gas Company Energy Resources Center, Downey, August 7, 1997.

- AVES and ADCO staff prepared new information on no-VOC/no-HAP coatings. This information was presented at the "New Technologies for Clean Air" symposium from September 29 through October 1, 1997 at U.C. Irvine, California. This symposium was sponsored by the ARB, the California Air Pollution Control Officers Association, the U.S. Environmental Protection Agency, and the California Environmental Dialogue. This was a good opportunity for community outreach and technology transfer.

- AVES staff member Dr. Eddy Huang was invited as a conference speaker to present new information on no-VOC/no-HAP coatings at the "Emerging Low-Emission Technologies and Innovative Approaches to Air Pollution Control" symposium on

December 5, 1997 at the SCAQMD. In addition to the new coating performance characteristics, cost analysis and environmental impact analysis data were also included in the presentation.

SECTION 8.0

CONCLUSION AND RECOMMENDATIONS

1. Substantial progress has been made to identify market opportunities in California for this new coating technology. There is a need for a low-/zero-VOC metal coating system for metal furniture, recreational vehicles, motor homes, and other industrial maintenance applications. It has been successfully demonstrated that this no-VOC metal coating system can be used in a commercial metal finishing operation.

2. Some water-based compliant coatings are available on the market. However, they work well only in some applications, and do not provide sufficient corrosion resistance.

3. The physical characteristics of this new metal coating (in terms of adhesion, toughness/scrub resistance, chemical and stain resistance, corrosion resistance, dry times) are excellent. It has successfully passed all tests. Laboratory analysis confirmed that this new coating has no VOCs.

4. The keys to successful conversion to new water-based coatings are staff training and technical support from the coating manufacturers. Personnel may need retraining on spraying techniques for water-based metal coating applications.

5. If premixing of two-component coatings is not desired due to limited pot life, plural component spray guns can be used to apply this coating system. If a plural component spray gun is used, the painter may need to be retrained due to changes in the spray nozzle, gun weight, and coating deposition rate.

6. By using this new, promising no-VOC water-based coating technology, significant air emissions reduction, hazardous waste reduction, energy savings and health risk reduction could be achieved without installing add-on controls. Therefore, commercialization of the proposed technology will provide an alternative to comply with current and future emissions standards for coating operations imposed by federal, state, and local government agencies.

Appendix A

LABORATORY TEST DATA

TABLE A-1. Salt spray testing on seventy-eight panels.

PNL #	Description	RATIO/NTS	Substrate	Color	Cure	HOURS TO FAIL	FAIL BY
9	3203.3A	3205B	B1000P60	White	SB	160	SC FB
10	3203.3A	3205B	B1000P60	White	SB	160	SC
14	3203.3A	3205B	B1000P95	White	SB	96	SC
20	ENM	41/11	B1000P95	White	RT	160	FB
73	3203/81	50/12.5	B1000P60	White	RT	48	FB
79	3203 W/850	35521	B1000P60	White	RT	48	FB
80	3203/850	50/12.5	CRS RUST	White	RT	48	SC
63	3203.3	120/50	B1000P95	Yellow	RT	72	FB
13	ENA-A	0	B1000P60	White	SB	96	FB
32	CLX2	0	B1000P60	Clear	RT	186	SC
12	SW A60	B 16	B1000P60	White	RT	160	SC
16	3203		B1000P60	White	SB	160	FB
22	3203.3		B1000P60	White	SB	96	FB
56	3204.3	-.15B	CRS	White	SB	72	SC
58	3203.3	+.15B	B1000P60	White	SB	72	SC
59	3204.3		B1000P60	White	RT	72	SC
61	3203.3		B1000P60	White	RT	72	SC
66	3203.3	+.15A	B1000P60	White	RT	72	FB
68	3204.3	+.15B	B1000P95	Red	RT	48	FB
69	3204.3	-.15B	B1000P95	Red	RT	48	FB
70	3205	0	B1000P60	Red	RT	48	FB
74	3203.3		B1000P60	White	RT	48	FB
65	3203.3	-.15A	B1000P60	White	RT	72	SC
24	3203.3		B1000P60	White	RT	96	SC
64	3203.3	0+2%JW26	B1000P60	White	SB	72	FB
77	3203.3 MINUS WL81	0	B1000P60	White	SB	48	FB
3	1/1 STOC 2005-55/8290	1-30	B1000P60	Clear	SB	300	FB
4	2003	4-30	B1000P60	Clear	RT	325	SC
18	37-680	2-30	B1000P60	Clear	RT	207	SC
27	COMB 37-680/2003	6-30	B1000P60	Clear	RT	160	SC
28	S8290	1-30	B1000P60	Clear	RT	515	SC
29	AP 401	3-30	B1000P60	Clear	RT	325	SC
67	2003	4-30	B1000P60	Clear	SB	48	SC
30	AP401	5-30	B1000P60	Clear	RT	325	SC
31	COMB 37-680/2003	6-30	B1000P60	Clear	SB	600	SC
33	AP 401	5-30	B1000P60	Clear	SB	300	SC
34	AP 360	3-30	B1000P60	Clear	SB	254	SC
35	37-680	2-30	B1000P60	Clear	SB	300	SC
7	ENA-A -0-	4/1	CRS	White	SB	160	SC
37	CLX3	58/0	CRS	Clear	SB	160	SC
36	CLX5 OR 3	58/42	CRS	Clear	SB	254	SC
38	CL-X3		CRS	Clear	SB	160	FB
1	CL-X3		CRS	Clear	RT	186	SC2
2	CLX3		CRS	Clear	RT	160	SC

5	CLX3	66.4/42	CRS	Clear	RT	160	FB

6	2005-55/2003 WT RATIO	8/1	CRS	Clear	RT	160	SC
19	2005-55/2003 WT RATIO	12/1	CRS	Clear	RT	186	SC
26	2005-55/2003 WT RATIO	9/1	CRS	Clear	RT	160	SC
42	2005-55/2003 WT RATIO	11/1	CRS	Clear	RT	186	SC
43	2005-55/2003 WT RATIO	8/1	CRS	Clear	RT	160	SC
44	2005-55/2003 WT RATIO	7/1	CRS	Clear	RT	160	SC
45	2005-55/2003 WT RATIO	11/1	CRS	Clear	SB	186	SC
47	2005-55/2003 WT RATIO	10/1	CRS	Clear	RT	160	SC
48	2005-55/2003 WT RATIO	12/1	CRS	Clear	SB	160	SC
51	2005-55/2003 WT RATIO	12/1	CRS	Clear	RT	160	SC
52	2005-55/2003 WT RATIO	6/1	CRS	Clear	RT	160	SC
53	2005-55/2003 WT RATIO	10/1	CRS	Clear	SB	160	SC
72	2005-55/2003 WT RATIO	6/1	CRS	Clear	SB	48	SC FB
75	2005-55/2003 WT RATIO	9/1	CRS	Clear	SB	48	SC FB
76	2005-55/2003 WT RATIO	7/1	CRS	Clear	SB	48	SC
78	2005-55/2003 WT RATIO	8/1	CRS	Clear	SB	48	FB
71	3204.5	40/30	CRS	Red	RT	48	FB
15	3203		CRS	White	SB	160	FB
17	2005-55/401-35	1/1 STOC	CRS	Clear	RT	325	FB
39	2005-55/401-35	1/1 STOC	CRS	Clear	RT	186	SC
40	2005-55/401-35	1/1 STOC	B1000P60	Clear	RT	325	SC
49	B2005-55(50GR)401-35(1.4GR)	1/1 STOC	B1000P60	Clear	RT	325	SC
50	B2005-55(50GR)401-35(13.4GR)	1/.085STOC	B1000P60	Clear	RT	457	SC
8	WHA ENA-A	4/1	B1000P60	White	SB	160	FB
11	SW (2005 SUB FOR A STOC)	4/1	B1000P60	White	RT	160	SC
21	ENA-A=.1		B1000P60	White	RT	160	FB
25	WHENA-A	+.1	B1000P60	White	SB	96	SC
60	SW	4/1 VOL	B1000P60	White	RT	72	FB
55	3203 W/850		B1000P60	White	SB	72	SC
57	3204.3	+.15B	CRS	Red	RT	72	FB
62	3203.3A 3205B	01 6	B1000P60	White	SB	72	SC

TABLE A-2. Physical properties testing data on seventy-eight panels.

PNL #	Description	RATIO/NTS	Substrate	Color	Cure	Pen Hrd	200 MEK 2X
9	3203.3A	3205B	B1000P60	White	SB	H	PASS
10	3203.3A	3205B	B1000P60	White	SB	H	PASS
14	3203.3A	3205B	B1000P95	White	SB	2H	PASS
20	ENM	41/11	B1000P95	White	RT	3H	PASS
73	3203/81	50/12.5	B1000P60	White	RT	H	100
79	3203 W/850	35521	B1000P60	White	RT	H	150
80	3203/850	50/12.5	CRS RUST	White	RT	H	PASS
63	3203.3	120/50	B1000P95	Yellow	RT	H	PASS
13	ENA-A	0	B1000P60	White	SB	HB	PASS
32	CLX2	0	B1000P60	Clear	RT	HB	150
12	SW A60	B 16	B1000P60	White	RT	HB	PASS
16	3203		B1000P60	White	SB	2H	PASS
22	3203.3		B1000P60	White	SB	2H	PASS
56	3204.3	-.15B	CRS	White	SB	2H	PASS
58	3203.3	+.15B	B1000P60	White	SB	2H	PASS
59	3204.3		B1000P60	White	RT	2H	PASS
61	3203.3		B1000P60	White	RT	2H	PASS
66	3203.3	+.15A	B1000P60	White	RT	2H	PASS
68	3204.3	+.15B	B1000P95	Red	RT	3H	PASS
69	3204.3	-.15B	B1000P95	Red	RT	H	PASS
70	3205	0	B1000P60	Red	RT	HB	PASS
74	3203.3		B1000P60	White	RT	H	PASS
65	3203.3	-.15A	B1000P60	White	RT	H	100
24	3203.3		B1000P60	White	RT	H	100
64	3203.3	0+2%JW26	B1000P60	White	SB	H	100
77	3203.3 MINUS WL81	0	B1000P60	White	SB	H	150
3	1/1 STOC 2005-55/8290	1-30	B1000P60	Clear	SB	H	130
4	2003	4-30	B1000P60	Clear	RT	H	120
18	37-680	2-30	B1000P60	Clear	RT	3H	PASS
27	COMB 37-680/2003	6-30	B1000P60	Clear	RT	3H	PASS
28	S8290	1-30	B1000P60	Clear	RT	2H	PASS
29	AP 401	3-30	B1000P60	Clear	RT	4H	PASS
67	2003	4-30	B1000P60	Clear	SB	2H	PASS
30	AP401	5-30	B1000P60	Clear	RT	3H	PASS
31	COMB 37-680/2003	6-30	B1000P60	Clear	SB	2H	PASS
33	AP 401	5-30	B1000P60	Clear	SB	H	80
34	AP 360	3-30	B1000P60	Clear	SB	H	90
35	37-680	2-30	B1000P60	Clear	SB	H	90
7	ENA-A -0-	4/1	CRS	White	SB	H	100
37	CLX3	58/0	CRS	Clear	SB	HB	PASS

36	CLX5 OR 3	58/42	CRS	Clear	SB	HB	PASS
38	CL-X3		CRS	Clear	SB	HB	PASS
1	CL-X3		CRS	Clear	RT	HB	PASS
2	CLX3		CRS	Clear	RT	2H	PASS
5	CLX3	66.4/42	CRS	Clear	RT	2H	PASS
6	2005-55/2003 WT RATIO	8/1	CRS	Clear	RT	H	PASS
19	2005-55/2003 WT RATIO	12/1	CRS	Clear	RT	H	PASS
26	2005-55/2003 WT RATIO	9/1	CRS	Clear	RT	H	PASS
42	2005-55/2003 WT RATIO	11/1	CRS	Clear	RT	F	PASS
43	2005-55/2003 WT RATIO	8/1	CRS	Clear	RT	F	PASS
44	2005-55/2003 WT RATIO	7/1	CRS	Clear	RT	HB	PASS
45	2005-55/2003 WT RATIO	11/1	CRS	Clear	SB	HB	PASS
47	2005-55/2003 WT RATIO	10/1	CRS	Clear	RT	H	PASS
48	2005-55/2003 WT RATIO	12/1	CRS	Clear	SB	H	PASS
51	2005-55/2003 WT RATIO	12/1	CRS	Clear	RT	2H	PASS
52	2005-55/2003 WT RATIO	6/1	CRS	Clear	RT	2H	PASS
53	2005-55/2003 WT RATIO	10/1	CRS	Clear	SB	2H	PASS
72	2005-55/2003 WT RATIO	6/1	CRS	Clear	SB	2H	PASS
75	2005-55/2003 WT RATIO	9/1	CRS	Clear	SB	2H	PASS
76	2005-55/2003 WT RATIO	7/1	CRS	Clear	SB	2H	PASS
78	2005-55/2003 WT RATIO	8/1	CRS	Clear	SB	2H	100
71	3204.5	40/30	CRS	Red	RT	2H	100
15	3203		CRS	White	SB	H	100
17	2005-55/401-35	1/1 STOC	CRS	Clear	RT	H	180
39	2005-55/401-35	1/1 STOC	CRS	Clear	RT	H	PASS
40	2005-55/401-35	1/1 STOC	B1000P60	Clear	RT	HB	PASS
49	B2005-55(50GR)401-35(1.4GR)	1/1 STOC	B1000P60	Clear	RT	HB	PASS
50	B2005-55(50GR)401-35(13.4GR)	1/.085STOC	B1000P60	Clear	RT	HB	PASS

8	WHA ENA-A	4/1	B1000P60	White	SB	H	PASS
11	SW (2005 SUB FOR A STOC)	4/1	B1000P60	White	RT	H	PASS
21	ENA-A=.1		B1000P60	White	RT	HB	PASS
25	WHENA-A	+.1	B1000P60	White	SB	HB	PASS
60	SW	4/1 VOL	B1000P60	White	RT	2H	PASS
55	3203 W/850		B1000P60	White	SB	2H	100
57	3204.3	+.15B	CRS	Red	RT	2H	PASS
62	3203.3A 3205B	01 6	B1000P60	White	SB	3H	PASS

TABLE A-3. Salt spray testing data on forty-four panels.

PANEL #	DESCRIPTION	CURE	SUB	90 hrs	139 hrs	150 hrs
1	HB-96-1	350 20 M	B1000P95	XX		
2	HB-96-1	350 20 M	B1000P60	XX		
3	3205 SPAR(20%)	RT	B1000P60	XX FB		
4	3203.3A / 3205B	SB	B1000P60	XX FB		
5	EM-96-2C-1	RT	B1000P60			XX FB
6	HB-96-1	180C 20M	B1000P95	XX FB		
7	RP-96-2	RT	B1000P95		XX FB	
8	RP-96-2	RT	B1000P95	XX FB		
9	3205 S	RT	B1000P60	XX FB		
10	duPont 2 PT POLYYRE	RT	CRS			XX FB
11	CLEAR -2CB	RT	B1000P95	XX SC		
12	CLEAR -2CC	RT	B1000P95			XX FB
13	CLEAR -2CA	RT	B1000P95	VG		
14	CLEAR -1CC	RT	B1000P95			
15	CLEAR -1CB	RT	B1000P95			
16	CLEAR -1CA	RT	B1000P95			
17	1:1 CLR 2005/401 1HPL	RT	B1000P95	VG		
18	2CA	RT	CRS			XX FB
19	2CC	RT	CRS			XX FB
20	2CB	RT	CRS		XX SC	
21	1CA	RT	CRS		XX SC	
22	1CB	RT	CRS		XX SC	
23	1CC	RT	CRS	XX SC		
24	1:.85 2005/401 3HPL	RT	B1000P60			XX FB
25	3203.3 .25HPL	SB	B1000P60	XX FBSC		
26	3203.3 .25HPL	SB	B1000P95	XX FB		
27	3203.3 4HPL	SB	B1000P95	XX FB		
28	3205 SPAR(20%)	RT	B1000P60	XX FB		
29	WTC-96-RT-1	50C 18HR	B1000P60		XX FB	
30	CLR 7:1 2005/2003 WT	SB 1HPL	CRS	XX FBSC		
31	CLR 8:1 2005/2003 WT	SB 1HPL	CRS		SC	
32	CLR 9:1 2005/2003 WT	SB 1HPL	CRS		SC	
33	CLR 10:1 2005/2003 WT	SB 1HPL	CRS		SC	
34	CLR 11:1 2005/2003 WT	SB 1HPL	CRS		SC	
35	CLR 12:1 2005/2003 WT	SB 1HPL	CRS		SC	
36	EM-96 1.1	RT	B1000P60	VG	FB	
37	EM-96 0.9	RT	B1000P60		GOOD	XX FB
38	EM-96 1.0	RT	B1000P60	XX FB		
39	RED 3204.3 -15B	RT	AL 303	VG		
40	RED 3204.3 0B	RT	AL 303	VG		
41	RED 3204.3 +15B	RT	AL 303	VG		
42	CLEAR 50:18.1	RT	CRS	XX FB		
43	CLEAR 50:16.3	RT	CRS	XX FB		

44	CLEAR 50:14.5	RT	CRS	XX FB		

TABLE A-4. Physical properties testing data on forty-four panels.

DESCRIPTION	CURE	SUB	Pencil Hardness	MEK	1/4" Mandrel
HB-96-1	350 20 M	B1000P95	H	200 PASS	PASS
HB-96-1	350 20 M	B1000P60	H	200 PASS	PASS
3205 SPAR(20%)	RT	B1000P60	H	200 PASS	PASS
3203.3A / 3205B	SB	B1000P60	2H	200 PASS	PASS
EM-96-2C-1	RT	B1000P60	2H	100	PASS
HB-96-1	180C 20M	B1000P95	2H	200 PASS	PASS
RP-96-2	RT	B1000P95	2H	200 PASS	PASS
RP-96-2	RT	B1000P95	2H	150	PASS
3205 S	RT	B1000P60	H	200 PASS	PASS
duPont 2 PT POLYYRE	RT	CRS	3H	200 PASS	FAIL
CLEAR -2CB	RT	B1000P95	2H	200 PASS	PASS
CLEAR -2CC	RT	B1000P95	2H	200 PASS	PASS
CLEAR -2CA	RT	B1000P95	3H	100	PASS
CLEAR -1CC	RT	B1000P95	2H	100	PASS
CLEAR -1CB	RT	B1000P95	2H	100	PASS
CLEAR -1CA	RT	B1000P95	3H	150	PASS
1:1 CLR 2005/401 1HPL	RT	B1000P95	4H	200 PASS	PASS
2CA	RT	CRS	H	200 PASS	PASS
2CC	RT	CRS	H	200 PASS	PASS
2CB	RT	CRS	H	200 PASS	PASS
1CA	RT	CRS	H	200 PASS	PASS
1CB	RT	CRS	2H	200 PASS	PASS
1CC	RT	CRS	HB	150	PASS
1:.85 2005/401 3HPL	RT	B1000P60	2H	200 PASS	FAIL
3203.3 .25HPL	SB	B1000P60	2H	200 PASS	PASS
3203.3 .25HPL	SB	B1000P95	H	200 PASS	PASS
3203.3 4HPL	SB	B1000P95	H	200 PASS	PASS
3205 SPAR(20%)	RT	B1000P60	H	50	PASS
WTC-96-RT-1	50C 18HR	B1000P60	2H	200 PASS	PASS
CLR 7:1 2005/2003 WT	SB 1HPL	CRS	H	200 PASS	PASS
CLR 8:1 2005/2003 WT	SB 1HPL	CRS	H	200 PASS	PASS
CLR 9:1 2005/2003 WT	SB 1HPL	CRS	H	200 PASS	PASS
CLR 10:1 2005/2003 WT	SB 1HPL	CRS	H	200 PASS	PASS
CLR 11:1 2005/2003 WT	SB 1HPL	CRS	2H	200 PASS	PASS
CLR 12:1 2005/2003 WT	SB 1HPL	CRS	HB	200 PASS	PASS
EM-96 1.1	RT	B1000P60	2H	100	FAIL
EM-96 0.9	RT	B1000P60	2H	100	PASS
EM-96 1.0	RT	B1000P60	2H	150	PASS
RED 3204.3 -15B	RT	AL 303	2H	200 PASS	PASS
RED 3204.3 0B	RT	AL 303	H	200 PASS	PASS
RED 3204.3 +15B	RT	AL 303	H	200 PASS	PASS
CLEAR 50:18.1	RT	CRS	HB	200 PASS	PASS
CLEAR 50:16.3	RT	CRS	HB	200 PASS	PASS
CLEAR 50:14.5	RT	CRS	HB	200 PASS	PASS

TABLE A-5. Salt spray and physical properties testing data on fifty-seven panels.

P#	ID	COMPOSITION			PH	PH	MEK 2X	BEND 1/4"	166 HRS	500 HRS
1	1	2005/8290Y60 1:1.15	CLR	B-1000P60	HB	H	200 SM	PASS	SC	XX SC
2	1	2005/8290Y60 1:1.15	CLR	CRS					XX SC	
3	2	2005/8290Y60 1:1	CLR	B-1000P60	F	HB	200 MAR	PASS	SC	XX SC
4	2	2005/8290Y60 1:1	CLR	CRS					XX SC	
5	3	2005/8290Y60 1.15:1	CLR	B-1000P60	F	HB	60 MAR	PASS		XX SC
6	3	2005/8290Y60 1.15:1	CLR	CRS					XX SC	
7	4	2005/419 1:1.15	CLR	B-1000P60	HB	2H	50 MAR	PASS	VG	XX SC
8	4	2005/419 1:1.15	CLR	CRS						XX SC
9	5	2005/419 1:1	CLR	B-1000P60	F	HB	28 MARR	PASS	VG	SC MARG<---
10	5	2005/419 1:1	CLR	CRS						XX SC
11	6	2005/419 1.15:1	CLR	B-1000P60	F	H	20 MARR	PASS	VG	SC MARG<---
12	6	2005/419 1.15:1	CLR	CRS					VG	XX SC
13	7	2005/37-681 1:1.15	CLR	B-1000P60	F	HB	33 MAR	SL CRK	VG	XX FB
14	7	2005/37-681 1:1.15	CLR	CRS						XX SCFB
15	8	2005/37-681 1:1	CLR	B-1000P60	F	HB	80 RO	SL CRK	VG	FB <----
16	8	2005/37-681 1:1	CLR	CRS						XX SCFB
17	9	2005/37-681 1.15:1	CLR	B-1000P60	B	HB	40 RO	SL CRK	VG	SFB<---
18	9	2005/37-681 1.15:1	CLR	CRS						XX SCFB
19	10	5522-55/8290Y60 1:1.15	CLR	B-1000P60	3H	3H	200 SM	PASS	SC	XX SC
20	10	5522-55/8290Y60 1:1.15	CLR	CRS					XX SC	
21	11	5522-55/8290Y60 1:1	CLR	B-1000P60	H	4H	200 SM	PASS		SC MARG
22	11	5522-55/8290Y60 1:1	CLR	CRS					SC	XX SCFB
23	12	5522-55/8290Y60 1.15:1	CLR	B-1000P60	H	2H	200 MAR	PASS	VG	SFB
24	12	5522-55/8290Y60 1.15:1	CLR	CRS					SC	XX SCFB
25	13	2005/2003 W/W 8.5:1	CLR	B-1000P60	3H	3H	200 PERF	PASS	VG	XX SC
26	13	2005/2003 W/W 8.5:1	CLR	CRS					SC	XX SC
27	14	2005/2003 W/W 10.0:1	CLR	B-1000P60	2H	2H	200 PERF	PASS	VG	XX SC
28	14	2005/2003 W/W 10.0:1	CLR	CRS						XX SC
29	15	2005/2003 W/W 11.5:1	CLR	B-1000P60	3H	4H	200 PERF	PASS	GOOD	XX SC
30	15	2005/2003 W/W	CLR	CRS						XX SC

		11.5:1								
31	1	2005/419	RPRI	B-1000P60	F	HB	5 RO	PASS	FB	XX SCFB
32	1	2005/419	RPRI	CRS					XX FB	
33	2	2005/419	RPRI	B-1000P60	F	B	5 RO	PASS	FB	XX SCFB
34	2	2005/419	RPRI	CRS					XX FB	
35	3	2005/419	RPRI	B-1000P60	B	B	8 RO	PASS	FB	XX FB
36	3	2005/419	RPRI	CRS					XX FB	
37	4	2005/419	RPRI	B-1000P60	HB	2H	11 RO	PASS		XX SCFB
38	4	2005/419	RPRI	CRS					XX FB	
39	5	2005/37-681	RPRI	B-1000P60	3H	4H	90 RO	PASS		XX SC
40	5	2005/37-681	RPRI	CRS						XX SC
41	6	2005/37-681	RPRI	B-1000P60	HB	3H	90 RO	PASS		XX SC
42	6	2005/37-681	RPRI	CRS					XX FBSC	
43	7	2005/37-681	RPRI	B-1000P60	2H	2H	55 RO	PASS		XX SC
44	7	2005/37-681	RPRI	CRS					XX FB	
45		:1 2005/401 3HPL 01046 CLR			5H	4H	200 PERF	PASS	SC	XX SC
46		1 CA 5/24 CLR P95			2H	3H	200 PERF	PASS	SC	XX SC
47		1 CB 5/24 CLR P95							SC	XX SC
48		1 CC 5/24 CLR P95							SC	XX SC
49		2CA 5/24 CLR P95			4H	4H	200 PERF	FAIL 1/2"		XX SC
50		2 CB 5/24 CLR P95			4H	4H	200 SM	PASS		XX SC
51		2 CC 5/24 CLR P95			4H	4H	200 PERF	PASS		XX SC
52		1 CA 5/24 CLR CRS			5H	5H	200 PERF	PASS	XX SC	
53		1 CB 5/24 CLR CRS			3H	4H	200 PERF	PASS	XX SC W/BLACK BLIST	
54		1 CC 5/24 CLR CRS			5H	5H	200 PERF	PASS	XX SC	
55		2 CA 5/24 CLR CRS			4H	4H	200 PERF	PASS	SC	XX SC
56		2 CB 5/24 CLR CRS			5H	4H	200 PERF	PASS	SC	XX SC
57		2 CC 5/24 CLR CRS			3H	4H	200 PERF	FAIL 1/2"	XX SC	

KEY
XX FAILED / REMOVED
SC SCRIBE CREEP FAILURE-LITTLE IF ANY FIELD BLISTERS
FB FIELD BLISTERS-LITTLE IF ANY SCRIBE CREEP
SSC SOME SCRIBE CREEP IN SPOTS
SFB SOME FIELD BLISTERS
SCFB SCRIBE CREEP AND FIELD BLISTERS
MAR LOSS OF SURFACE GLOSS
SM SLIGHT MAR
PERF PERFECT-NO EFFECT

RO COATING COMPLETELY RUBBED OFF
SL CRK SLIGHT CRACKING AT BEND

TABLE A-6. Salt spray testing data on twenty panels.

All Room Temp Dry

P#	COMPOSITION			100 HRS	150 HRS
1	EPE-96-4 1:1.05 08196	WHT	B-1000P95		FAILED
2	EPE-96-4 1:0.75 08196	WHT	B-1000P95		FAILED
3	EPE-96-4 1: 0.9 08196	WHT	B-1000P95		FAILED
4	EPE-96-4 1:0.75	WHT	CRS		FAILED
5	EPE-96-4 1:0.9	WHT	CRS	XX FB	
6	EPE-96-4 1:1.05	WHT	CRS	XX FB	
7	2005/3 11.5:1 06025	CLR	B-1000P95	XX FB	
8	2005/3 10:1 06025	CLR	B-1000P95		FAILED
9	2005/3 8.5:1 06025	CLR	B-1000P95		FAILED
10	2005/3 11.5:1 08066	CLR	B-1000P95		FAILED
11	2005/3 10:1 08066	CLR	B-1000P95		FAILED
12	2005/3 8.5:1 08066	CLR	B-1000P95		FAILED
13	2005/3 11.5:1 07176	CLR	B-1000P95		FAILED
14	2005/3 10:1 07176	CLR	B-1000P95		FAILED
15	2005/3 8.5:1 07176	CLR	B-1000P95		FAILED
17	BMC-96-1 41/9	CLR	B-1000P95		FAILED
18	BMC-96-1 41/9.9	CLR	B-1000P95		FAILED
19	BMC-96-1 41/10.8	CLR	B-1000P95		FAILED
20	2005/3 10:1	CLR	B-1000P95		FAILED

TABLE A-7. Physical properties testing data on twenty panels.

All Room Temp Dry

COMPOSITION			1W PH	2W PH	MEK 2X	BEND 1/4"
EPE-96-4 1:1.05 08196	WHT	B-1000P95	HB	H	90	PASS
EPE-96-4 1:0.75 08196	WHT	B-1000P95	H	H	100	PASS
EPE-96-4 1: 0.9 08196	WHT	B-1000P95	HB	H	130	PASS
EPE-96-4 1:0.75	WHT	CRS	HB	2H	200	PASS
EPE-96-4 1:0.9	WHT	CRS	HB	2H	150	PASS
EPE-96-4 1:1.05	WHT	CRS	H	H	80	PASS
2005/3 11.5:1 06025	CLR	B-1000P95	HB	H	200	PASS
2005/3 10:1 06025	CLR	B-1000P95	HB	H	200	PASS
2005/3 8.5:1 06025	CLR	B-1000P95	HB	H	200	PASS
2005/3 11.5:1 08066	CLR	B-1000P95	HB	H	200	PASS
2005/3 10:1 08066	CLR	B-1000P95	HB	H	200	PASS
2005/3 8.5:1 08066	CLR	B-1000P95	F	HB	200	PASS
2005/3 11.5:1 07176	CLR	B-1000P95	HB	H	200	PASS
2005/3 10:1 07176	CLR	B-1000P95	HB	H	200	PASS
2005/3 8.5:1 07176	CLR	B-1000P95	HB	H	200	PASS
BMC-96-1 41/9	CLR	B-1000P95	H	H	200	PASS
BMC-96-1 41/9.9	CLR	B-1000P95	H	H	200	PASS
BMC-96-1 41/10.8	CLR	B-1000P95	H	H	200	PASS
2005/3 10:1	CLR	B-1000P95	H	H	200	PASS

TABLE A-8. Salt spray testing data on thirty-one panels for intercoat adhesion.

P#	COMPOSITION (wt ratios)	CURE	CLR	SUBSTR	INTERCOAT ADHESION
1	MPR-96-1 1/1.2	BAKE #1	GRY	CRS	PASS
4	MPR-96-1 1/1.2	BAKE #1	GRY	B1000P60	PASS
7	MPR-96-1 1/1.0	BAKE #1	GRY	CRS	PASS
10	MPR-96-1 1/1.0	BAKE #1	WHT	B1000P60	PASS
13	MPR-96-1 1/0.8	BAKE #1	WHT	CRS	PASS
16	MPR-96-1 1/0.8	BAKE #1	WHT	B1000P60	PASS
19	MPR-96-1 1/1.2+MTC-96-2	BAKE #1	WHT	CRS	PASS
22	MPR-96-1 1/1.2+MTC-96-2	BAKE #1	WHT	B1000P60	PASS
25	MPR-96-1 1/1.0+MTC-96-2	BAKE #1	WHT	CRS	PASS
28	MPR-96-1 1/1.0+MTC-96-2	BAKE #1	WHT	B1000P60	PASS
31	MPR-96-1 1/0.8+MTC-96-2	BAKE #1	WHT	CRS	PASS
34	MPR-96-1 1/0.8+MTC-96-2	BAKE #1	WHT	B1000P60	PASS
37	MTC-96-2	BAKE #1	WHT	CRS	PASS
40	MTC-96-2	BAKE #1	WHT	B1000P60	PASS
41	BMC-96-7 1/.6	RT 3wks	BLK	CRS	PASS
42	BMC-96-7 1/.75	RT 3wks	BLK	CRS	PASS
43	BMC-96-7 1/.9	50C/15M	BLK	CRS	PASS
44	BMC-96-7 1/.9 W/3205b	RT 3wks	BLK	CRS	PASS
45	BMC-96-7 1/.9	RT 3wks	BLK	CRS	PASS
46	BMC-96-9 2HPL	RT 10 days	BLK	B1000P95	PASS
47	BMC-96-9 2HPL	RT 10 days	BLK	CRS	PASS
48	DTM-1 7/16	RT	CLR	B1000P60	PASS
49	DTM-2 7/16	RT	CLR	B1000P60	PASS
50	DTM-3 7/16	RT	CLR	B1000P60	PASS
51	MTC-96-2 1:.9 11206	RT	GRY	CRS	PASS
52	MPR961(1:.9)+MTC962	RT	WHT	CRS	PASS
53	MPR961 (1:.9)	RT	GRY	CRS	PASS
53	MPR961 (1:.75)+MTC962	RT	WHT	CRS	PASS
54	MPR961 (1:.75)	RT	GRY	CRS	PASS
55	MPR961 (1:.64)+MTC962	RT	WHT	CRS	PASS
56	MPR961 (1:.64	RT	GRY	CRS	PASS

NOTE: MTC-96-2 (11206) MPR-96-1 (11196)

TABLE A-9. Physical properties testing data on fifty-one panels.

PNL #	Description	Substrate	Color	Cure	PH	MEK
80	11L -.5h	CRS	Clear	87C, 20M	2H	200
81	11M -.5h	CRS	Clear	87C, 20M	2H	200
82	11H -.5h	CRS	Clear	87C, 20M	3H	200
83	12L -.5h	CRS	Clear	87C, 20M	H	100
84	12M -.5h	CRS	Clear	87C, 20M	H	200
85	12H -.5h	CRS	Clear	87C, 20M	2H	200
86	13L -.5h	CRS	Clear	87C, 20M	H	200
87	13M -.5h	CRS	Clear	87C, 20M	H	200
88	13H -.5h	CRS	Clear	87C, 20M	H	200
89	22L -.75h	CRS	Clear	87C, 20M	2H	150
90	22M -.75h	CRS	Clear	87C, 20M	2H	130
91	22H -.75h	CRS	Clear	87C, 20M	2H	100
92	31L -.5h	CRS	Clear	87C, 20M	H	200
93	31M -.5h	CRS	Clear	87C, 20M	H	200
94	31H -.5h	CRS	Clear	87C, 20M	H	200
95	32L -.5h	CRS	Clear	87C, 20M	2H	200
96	32M -.5h	CRS	Clear	87C, 20M	2H	200
97	32H -.5h	CRS	Clear	87C, 20M	2H	200
98	33L -.5h	CRS	Clear	87C, 20M	3H	200
99	33M -.5h	CRS	Clear	87C, 20M	H	150
100	33H -.5h	CRS	Clear	87C, 20M	H	200
101	11L -.5h	CRS	White	87C, 20M	H	200
102	11M -.5h	CRS	White	87C, 20M	H	200
103	11H -.5h	CRS	White	87C, 20M	H	200
104	12L -.5h	CRS	White	87C, 20M	H	200
105	12M -.5h	CRS	White	87C, 20M	2H	200
106	12H -.5h	CRS	White	87C, 20M	2H	200
107	13L -.5h	CRS	White	87C, 20M	3H	200
108	13M -.5h	CRS	White	87C, 20M	3H	200
109	13H -.5h	CRS	White	87C, 20M	3H	200
110	14L	CRS	White	87C, 20M	2H	200
111	14L w/3% Z6040	CRS	White	87C, 20M	2H	200
112	14L w/3% Z6040 2%DiAcAl	CRS	White	87C, 20M	2H	180
113	14M	CRS	White	87C, 20M	H	150
114	14m w/5%DiAcAl	CRS	White	87C, 20M	H	200
115	14m w/7.5%DiAcAl	CRS	White	87C, 20M	H	200
116	14m w/7.5%DiAcAl	CRS	White	87C, 20M	HB	200
117	14H	CRS	White	87C, 20M	H	150
118	MPR-97-5 02137	B1000/P60	Red	87C, 20M	2H	200

119	MPR-97-1 1/27 1:0.7 stoc	CRS	Red	87C, 20M	2H	200

120	MPR-97-6 02257 1:2.4 wt	CRS	Red	87C, 20M	3H	200
121	MPR-97-6 02257 1:2 wt	CRS	Red	87C, 20M	3H	200
122	MPR-97-6 02257 1:2 wt+348	CRS	Red	87C, 20M	2H	200
123	MPR-97-6 02257 1:1.6 wt	CRS	Red	87C, 20M	2H	200
124	MPR-97-1 1:.7 stoc + MTC-96-2 01287	CRS	White	RT	H	200
125	ARG-97-1 02277	B1000P60	White	RT	H	200
126	MTC-96-2 01227 1:.9 stoc	B1000P60	White	RT	H	200
127	MCL-97-2 03137	CRS	Clear	50C18Hrs	2H	200
128	MCL-97-1 03137 3%	CRS	Clear	87C20M	2H	200
129	MCL-97-4 03137 3%	CRS	Clear	87C20M	2H	200
130	MCL-97-2 03137 1%	CRS	Clear	87C20M	3H	200
131	MCL-97-3 03137 1%	CRS	Clear	87C20M	3H	200
	MPR-97-8 03277 .5H	CRS	RED	87C20M	2H	200
	MPR-97-6B/8A 03277 .5H	CRS	RED	87C20M	2H	200
	MPR-97-6 03277 .5 H	CRS	RED	87C20M	2H	200
	MPR-97-7 03277 .5H	CRS	RED	87C20M	2H	200
	FS-96-104 03277 .5H	CRS	RED	87C20M	H	200

Code:
10 R2005
20 S5522
30 C3901
1 AP 401
2 S8290
3 C3801
L "1:.85 stoc
M "1:1 stoc
H "1:1.15 stoc

TABLE A-10. Physical properties testing data on twenty-nine panels.

PNL #	Description	Substrate	Color	Cure	Pen Hrd	200 MEK 2X
132	MCL-97-1 3%	CRS	Clear	RT 2 wks	2H	NE
133	MCL-97-2 1%	CRS	Clear	RT 2 wks	2H	NE
134	MCL-97-3 1% FOGGY	CRS	Clear	RT 2 wks	2H	NE
135	MCL-97-4 3%	CRS	Clear	RT 2 wks	H	NE
136	11L - .5H	CRS	Clear	RT 3 wks	3H	NE
137	11M - .5H	CRS	Clear	RT 3 wks	3H	NE
138	11H - .5H	CRS	Clear	RT 3 wks	3H	NE
139	12L - .5H	CRS	Clear	RT 3 wks	2H	DES
140	12M - .5H	CRS	Clear	RT 3 wks	H	SM
141	12H - .5H	CRS	Clear	RT 3 wks	2H	SM
142	13L - .5H	CRS	Clear	RT 3 wks	H	DES
143	13M - .5H	CRS	Clear	RT 3 wks	2H	114 DES
144	13H - .5H	CRS	Clear	RT 3 wks	H	MAR
145	22L - .75H	CRS	Clear	RT 3 wks	HB	MAR
146	22M - .75H	CRS	Clear	RT 3 wks	HB	MAR
147	22H - .75H	CRS	Clear	RT 3 wks	2H	SM
148	31L - .5H	CRS	Clear	RT 3 wks	2H	DES
149	31M - .5H	CRS	Clear	RT 3 wks	2H	MAR
150	31H - .5H	CRS	Clear	RT 3 wks	3H	DES
151	32L - .5H	CRS	Clear	RT 3 wks	3H	MAR
152	32M - .5H	CRS	Clear	RT 3 wks	HB	SM
153	32H - .5H	CRS	Clear	RT 3 wks	2H	VSM
154	33L - .5H	CRS	Clear	RT 3 wks	2H	150 DES
155	33M - .5H	CRS	Clear	RT 3 wks	3H	146 DES
156	33H - .5H	CRS	Clear	RT 3 wks	2H	MAR
157	MPR-97-8 03277 .5H	CRS	RED	87C20M	>5H	
158	MPR-97-6B/8A 03277 .5H	CRS	RED	87C20M	H	
159	MPR-97-6 03277 .5 H	CRS	RED	87C20M	4H	
160	MPR-97-7 03277 .5H	CRS	RED	87C20M	H	
161	FS-96-104 03277 .5H	CRS	RED	87C20M	HB	

Code:
10 R2005 L 1: 0.85 stoc
20 S5522 M 1.1.0 stoc
30 C3901 H 1:1.5 stoc
1 AP 401
2 S8290
3 C3801

Appendix B

TECHNICAL DATA SHEETS

Appendix C

LABORATORY RESULTS

Appendix D

TECHNICAL PAPER