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ACRONYMS

AL	Aluminum Substrate
ASTM	American Standard Test Methods
CPVC	Chlorinated Poly-Vinyl Chloride Substrate
JSC	Johnson Space Center
MEK	Methyl Ethyl Ketone
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
QUV	Accelerated Weathering Tester
SOW	Statement of Work
SS	Stainless Steel Substrate
SSPC	Steel Structures Painting Council
VOC	Volatile Organic Content
WETF	Weightless Environment Training Facility

DEFINITIONS

Coupled	Fastened aluminum and stainless steel panel substrate
Repair	Test panel exposed and subject to spot touch-up and coating followed by additional exposure
Cathode	Aluminum and stainless steel panels exposed in immersion service and connected to a sacrificial zinc anode

ABBREVIATIONS

c	Abbreviation sometimes employed in tables for Coupled Panels.
p	Abbreviation sometimes employed in tables for CPVC (plastic) Panels.
mils	Unit of measure, one-one thousandths of an inch (.001")
mg	Milligram, unit of weight.
lbs	Pounds, unit of weight.

System No. Product(s)	Coating System Manufacturer	Contact	Houston, TX Area Office or Distributor
1 PF112	Plastic Flamecoat Systems, Inc 3400 W. Seventh Big Spring, TX 79720 915-263-5263	Doug Horton Big Spring Craig Dorsey Dickinson	Plastic Flamecoat Systems, Inc 2817 Belmont Dickinson, TX 77539 713-337-3082
2 NSP 120	NSP Specialty Products P.O. Box4690 Pinehurst, NC 28374-4690 800-248-8907	Pinehurst L. J. Guillory Jr. Mavor-Kelly (dist.)	Mavor-Kelly (dist.) 10422 West Gulf Bank Houston, TX 77040-3128 713-937-6060
3 Devran 230	Devoe Coatings Company 4000 Dupont Circle Louisville, KY 40207 502-897-9861	Andy House Louisville Dennis Harris Houston	Devoe Coatings Company 4555 Homestead Rd. Suite 606 Houston, TX 77028 713-675-5115
4 Carbomastic 15M500 Carboline 890	Carboline Company 350 Hanley Ind. Ct. St. Louis, MO 63144 314-644-1000	Bill Smith Bob Fredrick Houston	Carboline Company 1221 North PostOak Rd. Houston, TX 77055 713-682-1206
5 Hi-Solids Catalyzed Epoxy	The Sherwin-Williams Company 101 Prospect Ave. NW Cleveland, OH 44115 216-566-2897	Todd Hart Cleveland Micheal Heuer Humble	The Sherwin-Williams Company 2106 FM 1960 By-Pass Humble, TX 77338 713-540-1600
6 UTPlast Super	UTP Welding Technology P.O. Box 721678 Houston, TX 77272-1678 713-499-1212	Rocco Corvelli Johnny Hunnicut Houston	
7 Exobond 1020 (Al) UTPlast Extra	UTP Welding Technology P.O. Box 721678 Houston, TX 77272-1678 713-499-1212	Rocco Corvelli Johnny Hunnicut Houston	
8 Exobond 1020 (Al) Elite 8844	Elite Coatings Company P.O. Box 130 Gordon, GA 31031 912-628-2111	UTP Welding Tech. (Al) Elite Coatings Paul Brantley Gordon	
9 Plasite 7122	Wisconsin Protective Coatings, Corp. 614 Elizabeth St. P.O. Box 8147 Green Bay, WI 54308-8147 414-437-6561	Green Bay Pete Rossy Harry Meyers Chandelle Co. (Dist)	Chandelle Co. (Dist) 1050 N Post Oak Rd Houston, TX 77055 713-680-0805
10 Aquatapoxy A6	American Chemical Corporation 5231 Northrup Ave St. Louis, MO 63110 314-664-2403	Doug Elliott/Bill Taylor ST. Louis Ray Vickers Vickers Ind.. Coat. (dist)	Vickers Indust. Coatings (dist) 16537 Shady Lane Channnelview, Tx 77530 713-452-5040

Product Data and Material Safety Data Sheets for the above Coatings are provided in Appendix A.

SECTION II

Executive Summary

The Program Test Plan for the evaluation of candidate coatings was submitted in final form on November 29, 1993. The final test plan, briefly described below, was designed to address the objectives of the Statement of Work (SOW) as presented in KTA-Tator Inc. response to RFP 9BE3-55-3-35P.

The content of the SOW included a presentation of the testing program to be conducted and solicitation of candidate coating systems. Substrate materials were identified, the manner of surface preparation described and exposure environments defined. Test panel evaluation criteria were established and manner of grading performance identified. Fundamental to program execution was the basic understanding that the program proceed in general accordance with industry standards.

Candidate Coating Systems

A minimum of 20 standard and new technology high performance coating systems were to be identified for consideration. A listing of nearly thirty (30) potential systems was ultimately developed. Candidate systems were solicited from major US. coating manufacturers.

Manufacturers, contacted directly and/or expressing interest in submission of candidate systems, were provided with a description of substrate/service environment information in writing. In addition, the search for candidate systems was advertised in the Research News section of the Journal of Protective Coatings and Linings. Coating systems submitted by manufacturers in response to the solicitation consisted of organic coating systems. Systems were also sought to include thermally sprayed coatings. Response was limited to plastic coating systems applied by thermal spray or fluidized bed techniques. Thermally applied metals were not freely nominated by manufacturers or applicators. It was believed that inclusion of thermally sprayed coating systems would be of benefit to the study. A thermally applied aluminum powder coating was ultimately identified and included.

Coating manufacturer published data, including that for volatile organic content were reviewed and summarized. A list of recommended systems was developed from the candidates and ten (10) systems selected in conjunction with the NASA-JSC Technical Representative.

Information regarding the basic coating system properties, including Product Data and Material Safety Data Sheets, were obtained for coatings selected for testing. Sufficient quantities of each of the ten (10) selected candidate system materials to coat the quantity of specimens required for testing was obtained from the manufacturer or an authorized local product distributor. A fourier transform infrared spectrographic fingerprint has been obtained for each organic coating component and mixed coating system for characterization purposes.

Exposure Environments

The test protocol was designed to represent most environmental conditions anticipated by NASA, to which coated equipment for use in the WETF pool, and storage in the rotunda and outdoor (laydown) area would be exposed.

Exposure environments included immersion exposure, cyclic exposure and field exposure. Immersion included test panels placed in the WETF pool at Johnson Space Center (JSC) and simulated pool immersion, carried out at the KTA-Tator Humble (Houston), Texas facility. The simulated pool immersion consisted of immersion in non-conductive tanks, at approximately 34°C. About 2-4 ppm chlorine concentration was maintained in the tank water.

Accelerated weathering testing included KTA Envirotest exposure, an automatic cyclical test, and QUV (ASTM G-53) weatherometer exposure which was operated with cycles of four (4) hours of UV (60°C) and four (4) hours of condensing humidity (50°C).

Test panels fastened to test racks in the rotunda storage, and outdoor lay-down area adjacent to Building 36 were the field exposures used in the study. The laydown exposure environment was atmospheric with prevailing normal outdoor elements typical of the Houston ambient conditions. The WETF rotunda storage area was an interior environment adjacent to the WETF pool.

Test Panel Substrates

Nominal 3/16" - 1/4" - 4" x 6" test panels of three (3) different substrates were employed for application of selected coatings. The substrates included 6061-T6 aluminum (Al); 304 series stainless steel (SS) and chlorinated polyvinyl chloride (CPVC). In addition to the three material panels, a "coupled" test panel was prepared by assembly of an aluminum test panel fastened to a stainless steel test panel. The Coupled panels were fastened with 304 stainless steel bolts and nuts. Due to potential corrosion associated with dissimilar metal contact, the coupled panels were employed. It was felt that use of dissimilar metals, in contact, may help in discrimination between coating systems based on evaluation of corrosion product formation.

Preparation included the grinding of sharp edges and corners, solvent cleaning with methyl ethyl ketone (MEK) in accordance with Steel Structures Painting Council SSPC-SP1 "Solvent Cleaning." Subsequently, test panels were blast cleaned with aluminum oxide abrasive by KTA personnel, or prepared by the manufacturer / applicator for the thermally applied coatings. Candidate coating systems were applied in general accordance with the manufacturers' recommendations.

Test panels were scribed with an "X-scribe" on the lower one-third of their front surface, and one of each panel pair (duplicate) was subject to direct and reverse impact at 90 inch-pound. CPVC test panels were scribed and one of each panel pair given a direct and reverse impact at approximately 60 inch-pounds.

One (1) set of metallic panels was exposed for over 3000 hours in WETF immersion while electrically connected to sacrificial zinc anode cathodic protection. Included in the WETF pool were "Repair panels". The Repair panels consisted of duplicate panels placed in immersion. After 2,000 hours exposure the Repair panels were removed for spot repair and touch-up then returned to the WETF pool for an additional 1000 hours exposure.

Test Evaluations

Physical tests were conducted on the selected candidate coating systems as follows. Abrasion resistance by ASTM D 4060 "Abrasion Resistance of Organic Coatings by the Taber Abrasor" was conducted to provide an indication of coating durability. Weight loss and film thickness decrease were recorded. Impact resistance was assessed by ASTM D 2794 " Resistance of Organic Coatings to the Effects of Rapid Deterioration (Impact)". Direct and reverse impact values were obtained. Adhesion testing employed ASTM D 3359 "Standard Test Methods for Measuring Adhesion by Tape Test" both Method A (X-cut) and Method B (cross-cut). The ratings from both methods reflect the proportion of coating removed subsequent to scribing and tape testing. This procedure assists in assessing coating system bonding to the substrate, within and between coats and relates to the ability to fulfill the function of protecting the substrate. The method is not sensitive to small differences in adhesion.

Tabor abrasion and impact testing was performed on specifically prepared test panels for comparison between coating systems. Adhesion testing was conducted on prepared panels (unexposed) and exposed panels from each of the exposure environments.

Control and "test" panels were stamped with a unique letter/number designation, however, due to potential loss of identity due to coating application, each panel was also tagged with a stainless steel number tag. The numbers so affixed were documented for substrate, coating system and exposure environment. Photographs were taken which included unexposed control panels to illustrate the effects of testing.

Subsequent to test panel exposure periodic evaluations of the specimens were performed. Each panel was examined for signs of film deterioration/degradation and graded accordingly. Grading included assessment of the following: chalking, according to ASTM D-4214 (Method A, D659); blistering, in accordance with ASTM D-714; and rusting in accordance with ASTM D-610. ASTM D1654 was also employed for rating scribed and unscribed panel surfaces. Not originally included among the evaluation criteria, ASTM D1654 proved to be appropriate for two conditions encountered. Blister rating by ASTM D714 does not provide for relative comparison of the rating scale values. Assessment of corrosion at panel scribes was found to be of importance for panels subject to WETF immersion. Each of these evaluation methods include specific rating systems.

Rating values determined for each panel were recorded by coating system, exposure environment and substrate. Comparison of coating system performance was conducted based upon calculating "system" scores from individual evaluation ratings.

Findings

Cyclic exposures, specifically QUV-Weatherometer and the KTA Envirotest were found to be the most aggressive of the environments included in the study when all three evaluation criteria are considered. This was found to result primarily from chalking of the coatings under ultraviolet (UV) light exposure.

WETF pool and simulated pool exposures, both immersion, contributed primarily to the general occurrence of blistering and formation of corrosion product. The importance of the immersion environments and their relative "aggressiveness" is evident when chalking is discounted during evaluation.

Dissimilar metals in contact, the "Coupled" panels (aluminum-stainless steel), exhibited a greater degree of overall effect than aluminum, stainless steel or CPVC test panels. This was associated with immersion exposure. The aluminum panels component was more affected than stainless steel.

Coating systems #6 (plastic), #2, #10 and #4 (epoxies) were found to be the leading candidates for consideration as coating systems. This results from exhibiting greater relative scores for blistering and corrosion in immersion service. System #1 , a plastic coating, performed well in all environments except the simulated pool, however, chalk resistance was the principal reason.

Results of the project have shown that thermally applied plastic coatings exhibit superior overall performance compared to epoxy systems. However, when considered by exposure environment, the plastic coatings do not appear to perform better in immersion than some of the epoxy systems.

Use of thermally applied coatings over heat sensitive substrates is not recommended. Although performance in exposure is not significantly affected, use of thermal application distorted the CPVC substrates .

Application of an aluminum metal powder, thermally applied over prepared substrates, did not lead to improved system performance. The metal powder coating, as applied, was porous and non-uniform. This contributed to difficulties in over coating.

Tabor abrasion testing found a wide range of weight loss for the systems included in the study. Plastic coating systems were generally low in weight loss, 25-45 mg, while epoxy systems ranged from 50 mg to 200 mg weight change from Tabor abrasion testing.

Adhesion testing results found that , in general, adhesion for all systems was good on each of the substrates employed. The exposure environment did appear to play a role in the observed adhesion values for a limited number of Coating/Substrate pairs. Adhesion of the plastic coatings was good with two occurrences of bad ratings.

Impact resistance testing, ASTM D 2794, generally found comparable resistance between coatings with the exception of two (2) thermally applied plastics. Systems #1 and #7 exceeded 176 in-lb. by direct and indirect impact.

The costs associated with use of the coating systems under evaluation range from a high of $\$2.40/ft^2$ (at the manufacturer's recommended film thickness) to a low of $\$0.50/ft^2$. Thermally applied materials tend to be more costly, however, epoxy systems were as high as $\$1.10/ft^2$. Pretreatment of aluminum, as recommended by the manufacturer of System #9, has not been included in the general cost comparison but would add material costs of about $\$0.02$-$0.03/ft^2$ for aluminum substrate.

Application equipment for flame spray application ranges from as low as $1,600 up to $14,300.00. Equipment costs are approximately $1,500.00 for conventional application and $3,800.00 for airless application.

Epoxy coating systems were found to be less costly based on material and equipment costs.

Section III

NASA Study Design

The testing program undertaken included three (3) Phases of effort.

Phase I entailed a review, revision and submission of a final Statement of Work (SOW). This was then submitted for review and final approval. The content of the SOW included a final presentation of the testing program to be conducted. Basically, substrate materials were identified, the manner of surface preparation described, and exposure environments defined. In addition, test panel evaluation criteria was established and manner of grading coating system performance was identified. Fundamental to program execution was that the program proceed in general accordance with industry standards.

Phase II addressed the approach employed for selection of candidate coating systems, test panel preparation protocols and testing of the candidate coating systems as outlined in the SOW. Phase III included evaluation of the coating systems and reporting. Key elements of Phase III included description of procedures employed during execution of Phase II, compilation and presentation of the data collected and concluding with coating system recommendations based on data resulting from the study. A summary of the testing program for each of the three Phases is provided below.

PHASE I - TEST PLAN

The Program Test Plan for the evaluation of candidate coatings was submitted in final form on November 29, 1993. The final test plan is outlined below and was designed to address the objectives of the Statement of Work (SOW) as presented in KTA-Tator, Inc.'s response to Solicitation No. 9BE3-55-3-35P.

The SOW included laboratory testing, simulated and actual Weightless Environment Training Facility (WETF) pool immersion tests, accelerated laboratory exposure; and outdoor field testing. The test protocol was designed to represent environmental exposure conditions, identified by NASA, to which coating systems would normally be subjected. The objective was to assess which of the coating systems, among those selected for evaluation, would best protect to-scale equipment and mock-up substrates subject to use in the WETF pool, storage in the WETF rotunda and long-term storage out of doors in the "laydown area".

SUBSTRATES

Based upon identification of the construction materials frequently employed by NASA for fabrication of equipment and mock-ups, nominal 1/8 - 3/16", 4" x 6" test panels of three (3) different substrates were employed for application of selected coatings. The substrates included 6061-T6 aluminum (Al); 304 series stainless steel (SS) and chlorinated polyvinyl chloride (CPVC). In addition to the three material panels, a "combination" test panel was prepared by assembly of an aluminum test panel fastened to a stainless steel panel. The resulting assembled combination is identified as a "Coupled panel." The Coupled panels were fastened with 304 stainless steel bolts and nuts. The purpose of the Coupled panels was to determine whether corrosion effects which might occur due to dissimilar metal contact between aluminum and stainless steel might help to discriminate between the performance of the coating systems under test. In addition to these test substrates, one (1) set of stainless steel panels and one (1) set of aluminum, panels were exposed in WETF immersion while electrically connected to a zinc anode.

Coated test panels, single and coupled, were scribed with an "X-scribe" to the panel substrate on the lower one-third of their surfaces. One of each metal panel pair (duplicate) was subjected to 90 inch-pound direct impact. CPVC test panels received a direct impact at approximately 60 inch-pounds.

EXPOSURE ENVIRONMENTS

Immersion Testing

Weightless Environment Training Facility (WETF) Test Pool

Prepared and coated test panels were placed on mounting racks for immersion in the WETF pool at Johnson Space Center (JSC). These included a set of "standard panels", one (1) set of "repair panels" and one set of metal substrate panels attached to a zinc anode. The "repair panels" were removed after 2,000 hours exposure to effect touch-up work on each coating system as discussed below. These were returned to the pool for an additional 1000 hours exposure after touch-up work was completed and cure times observed. Touch up included hand tool cleaning of the lower half of each panel over X-scribed and impacted surfaces. Repair of System 6 and system 7 panels included additional abrasive blast cleaning (spot) and full overcoat. Instructions were to conduct touch-up work as judged necessary to repair the exposed test panels. The extent of repair conducted is described in Section IV-C "WETF Repair Systems." System 6 and System 7 panels had touch-up repairs performed by Thermal Systems, Inc. of Freeport, Texas, a manufacturer approved applicator.

Simulated Pool

Simulated pool immersion was carried out at the KTA-Tator Humble (Houston), Texas facility. The simulated pool immersion consisted of immersion of coated test panels in non conductive tanks, maintained at approximately 34°C (an elevated temperature increases the rate of corrosion reaction). Approximately 2-4 ppm chlorine concentration was maintained in the tank water. The water was continually recirculated to permit reaeration (diffusion stones), mixing and even distribution of heat and chlorine. The simulated pool system was operated approximately one week prior to immersion of test panels to verify flow and heat balance. Chlorine, pH, temperature and conductance of the tank water were periodically monitored. A cumulative period of 2,000 hours exposure was performed, including an examination after roughly 800 hours exposure. During removal for examination the system water was replaced.

Accelerated Weathering Testing

KTA Envirotest

The KTA Envirotest (Draft ASTM Standard) is an automatic cyclical test. Duplicate test panels were exposed to an immersion phase, consisting of facility supply water (recycled), and an atmospheric phase of heat (125°F) and ultraviolet light. Panels were rotated through 420° at 4 hour intervals at 0.5 rpm. Panels would rotate a full 360° passing through the immersion phase and pause 4 hours, 60° beyond their prior location. The test duration was 2,000 hours. Chlorine was introduced to the immersion water and monitored, however, maintaining chlorine levels was stopped due to the rapid loss of chlorine from solution in the system. The source of water, including make-up, was public supply water as supplied to the KTA facility.

QUV (ASTM G-53)

Duplicate test panels were subjected to QUV testing, in accordance with ASTM G53 "Recommended Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials", The exposure regime included a cycle of four (4) hours of UV (60°C) and four (4) hours of condensing humidity (50°C). The total cumulative test duration was 2,000 hours.

Field Exposure

Test panels were fastened to test racks at an outdoor "lay-down area" adjacent to Building 36 at the Johnson Space Center and in the WETF building rotunda. The laydown area test panels were mounted on test racks placed on a concrete slab angled approximately 30° and facing South. The exposure environment was atmospheric with prevailing normal outdoor elements, such as wind, moisture, direct sunlight, and temperature variations of Houston, TX conditions. The WETF rotunda storage area was an interior environment. Panels were placed within forty (40) feet of the WETF pool. The normal interior building environment at the test location included humidity and possible chlorine in the atmosphere due to proximity to the WETF pool. An "indoor swimming pool" environment indicates the type exposure anticipated. The duration of exposure for both the WETF rotunda storage and the outdoor laydown exposures were in excess of 3000 hours.

Final panel evaluation and grading was accomplished for test panels maintained at the NASA JSC facility subsequent to completion of one thousand hours exposure to repair panels had occurred. It was anticipated that both the rotunda storage and exterior storage would be relatively benign compared to the WETF pool immersion and accelerated laboratory tests. Therefore, if a candidate coating system were to perform poorly in either exterior environment, such poor performance would probably disqualify the candidate coating system. Thus, while it was possible that the exposures in both the WETF rotunda and outside exposure sites would not be long enough for differential failure between candidate coating systems, if any one of the candidate coating systems were to perform poorly, such poor performance should eliminate it from further consideration.

PHYSICAL TESTING

Three (3) physical tests were conducted on each candidate coating system. Physical test panels were prepared and coated at the same time of preparation and coating of the exposed test panels for each system. This minimized the potential for variance in surface preparation and coating application conditions, procedures and materials . The physical tests included abrasion resistance, adhesion and impact resistance. These are briefly described below.

Abrasion Resistance

Abrasion resistance of coating was performed in accordance with ASTM D4060, "Abrasion Resistance of Organic Coatings by the Taber Abraser." Duplicate Taber abrasion test plates, measuring 4" x 4" with a 1/4" diameter center hole were prepared for each of the candidate coatings. All taber panels were coated and cured in accordance with the manufacturer's instructions. Dry film thickness was measured and the specimens weighed to the nearest 0.1 mg. Specimens were then subjected to 1,000 cycles using a 1,000 gram load and CS-10 abrasion wheels. The weight loss in milligrams and coating thickness decrease (in mils) was obtained.

Impact Resistance

The impact resistance of coatings was assessed in accordance with ASTM D2794, "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)." The test panels were 24 gage 4" x 6" steel as supplied by the Q-Panel Company, Westlake, Ohio. Both direct and reverse impact test were performed to determine the minimum impact load, inch-pounds (in-lbs), at which cracking or fracturing of the coating films occurred.

Coating Adhesion

The relative adhesion of the coating systems to the underlying substrates was assessed on unexposed test panels as well as test panels after exposure. Adhesion was determined in accordance with ASTM D3359 "Measuring Adhesion by Tape Test," Method A (X-cut) and Method B (cross-cut). Each of the selected test coating systems was evaluated.

Testing of Repainted or Touched-Up Areas

Actual immersion in the WETF pool was expected to represent the most severe exposure environment among those employed in this study. Therefore, an additional set of duplicate panels was prepared for each of the candidate coating systems for WETF immersion. Designated as "Repair panels", these panels were removed after approximately 2,000 hours of exposure in the WETF pool. The lower third of each panel, which had been scribed prior to exposure , was subject to surface preparation and touch-up coating was applied. Spot surface preparation methods included solvent cleaning (SSPC SP-1) and hand tool cleaning by wire brush (SSPC SP-2) to remove accumulations of surface corrosion and/or contaminants. It should be noted that test panels for Systems #6 & #7 were brush blast cleaned by the applicator, Thermal Systems, Inc. Freeport, Texas, prior to recoating the entire panel face. System #1, System #6 and System #7 were recoated by flame spray application of the respective thermoset plastic coatings. System #1 was prepared by KTA-Tator but application was by Plastic Flamecoat at the KTA-Tator facility. System #10 had one of each repair panel pair touched-up underwater, the second panel of each pair was touched up under normal laboratory conditions. The underwater repair procedure, recommended by the manufacturer, involved mixing the coating (in air) and application of the mixed coating underwater by troweling onto the panels with a wooden blade (popsicle stick). All other coatings were applied by brush after appropriate mixing of the coatings. The repair panels were re-immersed in the WETF pool for an additional 1000 hours exposure.

PROGRAM TESTING (PHASE II)

Coating System Selection

A minimum of 20 standard and new technology high performance coating systems were to be presented for consideration by the JSC Technical Monitor. A listing of thirty (30) potential systems was ultimately developed. Candidate systems were solicited from major U.S. coating manufacturers. Manufacturers, contacted directly and/or expressing interest in submission of candidate systems, were provided with a description of substrate/service environment information in writing. It was anticipated that many of the system recommendations would consist of organic coating systems (epoxy, urethane, zinc-rich, etc.). This was found to be true for candidates submitted. Additional systems were sought to include thermally sprayed coatings. Manufacturer/ Applicator response was limited to plastic coating systems applied by thermal spray or fluidized bed techniques. Thermally applied metals, such as zinc, aluminum, or other alloys, were not freely nominated by manufacturers or applicators. It was believed that inclusion of thermally applied metal coating system would be of benefit to the study. A thermally applied aluminum powder coating was identified and included. Gloss white coatings were solicited.

A listing of candidates submitted for consideration is provided in Appendix F, Table F-1, "Candidate Coating Systems".

Coating manufacturer published data, including that for volatile organic content (VOC) (compared to requirements of the Texas Air Control Board regulations) are summarized for each potential candidate product. Examples of pertinent correspondence and solicitation advertising are also provided.

Coating Systems Acquisition

KTA acquired information regarding the basic coating system properties including Product Data and Material Safety Data Sheets for the coatings selected for testing. These are provided in Appendix A. Sufficient quantities of each of ten (10) selected candidate system materials to coat the quantity of specimens required for the testing were obtained directly from the manufacturer or an authorized distributor. It should be noted that, although white coatings were requested, two coatings, System #6 and System #7 (topcoat) were black in color.

Coating Material Composition

A formulation description of each coating as provided by the manufacturer product data sheets, established a "label" analysis (percent by weight compositions of pigments, resins, and solvents) for all organic coatings. A Fourier transform infrared spectrographic fingerprint was obtained for each organic coating component comprising each coating system. For characterization purposes, a fingerprint of each component of the coating and an additional fingerprint of the mixed and applied coating was obtained. The spectra obtained are presented in Appendix B.

Test Panel Preparation

Test panels of stainless steel (grade 304), aluminum (grade 6061 T6) and CPVC were cleaned and prepared prior to coating application. Preparation included the grinding of sharp edges and corners, and solvent cleaning employing methyl ethyl ketone (MEK) in accordance with Steel Structures Painting Council SSPC-SP1 "Solvent Cleaning." Subsequently, test panels were blast cleaned with aluminum oxide abrasive by KTA personnel, or prepared by the manufacturer / applicator for the thermally applied coatings. Candidate coating systems were applied in general accordance with the manufacturers' recommendations for conventional spray application for liquid coatings. The ambient conditions (air temperature, relative humidity, dew point, surface temperature) during surface preparation, coating mixing, and application were recorded and are provided in Appendix A.

Coating materials were verified for manufacturer, product number and batch or lot number then mixed, thinned (if required), and applied. Wet film thickness was monitored during application. Upon sufficient drying, the thickness of each coat was measured on each specimen, generally in accordance with SSPC-PA2, "Measurement of Dry Paint Thickness with Magnetic Gages" prior to use. Coating thickness gages were calibrated using shims of plastic over uncoated test panel substrates rather than the National Institute of Standards and Technology (NIST; formerly NBS) calibration plates. Coatings on certain types of stainless steel and aluminum substrates cannot be measured using magnetic gages. NIST Standards are designed for calibration of magnetic gages only. Plastic shim thickness was verified using a calibrated micrometer to ensure accuracy. Dry film thickness of CPVC panels, because they are non conductive, was determined by micrometer measurement and calculation of average thickness for uncoated, prepared test panels. The average was then subtracted from micrometer measured thickness. Dry film coating thickness data were recorded and are appended.

Specimens were air dried/cured at intervals in excess of manufacturers' recommended minimums. Panels were then evaluated for pinholes by low voltage holiday tester (Tinker-Rasor) and visually examined for runs, sags, or other surface defects. Prepared and coated test panels were inspected by the JSC Technical Monitor prior to testing and approved for project use. System #1, as initially applied by the manufacturer, was rejected due to excessive film thickness. System 1 was reapplied to prepared panels by the manufacturer at a lower film thickness and subsequently employed in the study.

Test Panel Identification/Photography

Each control and "test" panel was stamped with a unique letter/number designation prior to surface preparation and coating application. The markings corresponded to substrate type and panel number. For example, the stamped designation S100 being stainless steel panel #100. Due to potential loss of identity during coating application, each panel was tagged with a stainless steel number tag. The tag numbers affixed were documented for substrate, coating system and exposure environment. Photographs were taken prior to and subsequent to exposure. Control panels were included with the exposed panels to illustrate the effects of testing. Photographs are provided in "Photographs," Appendix C.

PROGRAM TEST EVALUATIONS/REPORTING (PHASE III)

Test Panel Performance Evaluations

Subsequent to initiation of test panel exposure, periodic evaluations of the specimens were performed. Each panel was examined for signs of film deterioration/degradation and graded accordingly. Grading included assessment of chalking, according to ASTM D-4214 "Evaluating Degree of Chalking of Exterior Paints" (Method A, D659); blistering, in accordance with ASTM D-714 "Evaluating Degree of Blistering of Paints"; and rusting in accordance with ASTM D-610 "Evaluating Degree of Rusting on Painted Steel Surfaces". Each of these evaluation methods include specific rating systems and are accompanied by pictorial standards. The evaluation methods are briefly described below. In addition, ASTM D1654 "Standard Method for Evaluation of Coated Specimens Subjected to Corrosive Environments" was employed to assess undercutting at the panel X-scribes.

A. ASTM D 610 "Evaluating Degree of Rusting on Painted Steel Surfaces"

Definition - The ability of a coating to protect the substrate of iron or its alloys from rusting. Typically, rust is a reddish/brown product, primarily hydrated iron oxide, formed on iron or its alloys resulting from exposure to humid atmosphere or chemical attack. Corrosion products formed on aluminum, evaluated in the same manner were based on visible, white/gray colored corrosion products.

Pictorial Standard - Three sets of pictorial standards are available for the evaluation of rusting. Set I of black and white photographic standards includes rusting without blistering (1) and rusting with blistering (2). The degree of rusting is rated on a scale of 10 to 0. Set II of black and white photographic standards represents a rust grade scale of area percent of rust. Set III of colored photographic reference standards shows degrees of rusting not accompanied by blistering on painted steel (or iron) surfaces.

B. ASTM D 714 "Evaluating Degree of Blistering of Paints"

Definition -The ability of a coating to resist the formation, in the film, of dome-shaped, liquid-, or gas-filled projections resulting from local loss of adhesion and lifting of the film from the previously applied coating or the substrate.

Pictorial Standard - The pictorial standards for size have been selected on the basis of a numerical rating of 10 through 0 in four steps. With 10 the rating for no blisters, sizes 8, 6, 4 and 2 represent increasing blister size (0 representing greater than #2 in size).

Frequency standards include steps of four blister frequencies rated as Dense (D), Medium Dense (MD), Medium (M), and Few (F).The panel being evaluated is compared to the pictorial standards for blister size and frequency. When the distribution of blisters has a non uniform pattern, an additional phrase may be employed to describe the distribution such as small clusters or large patches.

C. ASTM D 659 "Evaluating Degree of Chalking of Exterior Paints"

Definition - The ability of a pigmented coating to resist the formation of a friable powder on its surface caused by the disintegration of the binding medium by degradative weather factors. The chalking of a coating can be considerably affected by the choice and concentration of pigment and binding medium.

Pictorial Standards - The pictorial standards represent four degrees of chalking rated 8, 6, 4 and 2 on a scale of 10, with 10 representing no evidence of chalking.

To evaluate a film's degree of chalking failure, an ASTM procedure is to wrap a piece of felt around the index finger, rotate the finger through an angle of 180 degrees holding the felt so it rotates. The spot of chalk on the felt is compared with the standards. A rating value of "9" was adopted for project use. The rating of "9" indicating that no observed chalk transfer was noted but the test point on the panel exhibited a change in color or gloss as a result of testing.

Physical Tests

Physical tests were conducted on the selected candidate coating systems and were as follows. Abrasion resistance by ASTM D 4060 "Abrasion Resistance of Organic Coatings by the Taber Abraser" was conducted to provide an indication of coating durability. Weight loss and film thickness decrease, were recorded. Impact resistance was assessed by ASTM D 2794 " Resistance of Organic Coatings to the Effects of Rapid Deterioration (Impact)". Direct and reverse impact values were obtained Adhesion testing employed ASTM D 3359 "Standard Test Methods for Measuring Adhesion by Tape Test" both Method A (X-cut) and Method B (cross-cut). The ratings from both methods reflect the proportion of coating removed subsequent to scribing and tape testing. This procedure assists in assessing coating system bonding to the substrate, within and between coats and relates to its ability to fulfill the function of protecting the substrate. The method is not sensitive to small differences in adhesion.

Abrasion and impact testing were performed on test panels specifically prepared for conducting these physical tests. This allowed for comparison between coating systems. Adhesion testing was conducted on specifically prepared carbon steel panels (unexposed) as well as exposed panels after termination of exposure.

Evaluation data, due to the semi quantitative and qualitative nature of the evaluation methods, was not subject to detailed statistical or sophisticated analytical evaluation. Ranking of coatings was achieved through ordering evaluation "scores" which employed the grading and rating scales associated with the evaluation methods employed. In general, the gradings are not discriminating on a quantitative basis. Rather, the values recorded are semi-quantitative and based upon relative performance. Emphasis has been placed on data obtained for specific characteristics that reflect the desired performance. Thus, rusting, blistering and chalking gradings have been considered more important and relevant to performance than items such as material costs or ease of application. When candidate coating systems were found to exhibit similar performance characteristics, secondary considerations such as costs and availability were evaluated. Influence of substrate did not necessarily play a role in ranking coating systems, however, coating systems that exhibited similar performance on steel or aluminum performed differently when evaluated on CPVC. Significantly, by way of example, thermally applied systems exhibited extremely poor application performance on CPVC substrates.

Rankings obtained as a result of exposure of the coating systems are presented in Section V.

Final Report

This final report includes all appropriate information as outlined in the SOW, and a KTA recommendation as to the preferred coating system(s) for NASA's use. This has been based on the results of testing performed.

The test results and evaluation outcomes are described in text and displayed in tabular format in Section IV.

Section IV

Introduction

Results of Exposure Evaluations

Evaluation of coated panel performance as a result of exposure included evaluation of signs of film deterioration/degradation and grading (rating). The manner of evaluation and grading included: "Rusting" (corrosion) per ASTM D-610 "Evaluating Degree of Rusting on Painted Steel Surfaces"; "Blistering" per ASTM D-714 "Evaluating Degree of Blistering of Paints"; and "Chalking" per ASTM D-4214 (Method A, D659) "Evaluating Degree of Chalking of Exterior Paints". Each of these evaluation methods contain specific rating systems and are accompanied by pictorial standards. The evaluation methods, briefly described below, are provided in Appendix D. In addition to the three (3) ASTM Methods identified above, ASTM D1654 "Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was employed for specific exposure environments. This was necessary to address the occurrence of film defects at the scribed surface of panels and provide a scale for rating blistering based on surface area affected. Tables presenting the results of grading for each test panel, by exposure environment and coating system are presented at the end of this section.

A. ASTM D 610 "Evaluating Degree of Rusting on Painted Steel Surfaces"

The ability of a coating to protect the substrate of iron or its alloys from rusting (corrosion) can be determined on a relative basis by comparison of the degree of corrosion product (rusting) present on coated surfaces. The linear, numerical rust grade scale is an exponential function of the area exhibiting corrosion.

The degree of rusting is rated on a scale of 10 to 0. Photographic standards represent a rust grade scale of area percent of rust. A grade of 10 represents no rusting or less than 0.01% of surface rusted. A grade of 5 represents 3% of the area rusted and grade of 1 approximately 50% of the surface rusted. Figure 1 and Table 1 of ASTM D610 were employed to assess the degree of corrosion present on each test panel.

B. ASTM D 714 "Evaluating Degree of Blistering of Paints"

The ability of a coating to resist the formation in the film of dome-shaped, liquid-, or gas-filled projections resulting from local loss of adhesion and lifting of the film from the previously applied coating or the substrate.

The pictorial standards for size have been selected on the basis of a numerical rating of 10 through 0 in four steps. With 10 rating for no blisters, sizes 8, 6, 4 and 2 are represented in increasing blister size (0 representing greater than #2 in size).

Frequency standards include steps of four blister frequencies rated as Dense (D), Medium Dense (MD), Medium (M), and Few (F).The panel being evaluated was compared to the pictorial standards for blister size and frequency. When the distribution of blisters has a non uniform pattern, an additional phrase may be employed to describe the distribution. Blister size and frequency were recorded as described in ASTM D714, however, to rate the occurrence of blistering for comparison purposes Table 2 of ASTM D1654 was employed. The numeric scale is analogous to that of ASTM D610 although each rating number reflects a percent range of area exhibiting blistering. This is more fully described below.

C. ASTM D 659 "Evaluating Degree of Chalking of Exterior Paints"

Chalking assesses the ability of a pigmented coating to resist the formation of a friable powder on its surface. Typically the formation of chalk is caused by the disintegration of the binding medium by degradative weather factors. The chalking of a coating can be considerably affected by the choice and concentration of pigment and binding medium.

The pictorial standards employed represent four degrees of chalking rated 8, 6, 4 and 2 on a scale of 10. 10 represents no evidence of chalking and a rating of 2 the greatest amount of chalk transferred to the test cloth on the reference standard.

To evaluate a film's degree of chalking failure, the ASTM procedure is to wrap a piece of felt around the index finger, rotate the finger through an angle of 180 degrees holding the felt so it rotates. The spot of chalk on the felt is compared with the standards. Although a rating of 9 is not provided for in ASTM D659 a value of 9 was employed for the purpose of inter system comparison. When no visual evidence of chalking was present on the test cloth but the test surface of the panel exhibited a change in gloss a rating of 9 was employed.

D. ASTM D1654 "Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments"

ASTM D1654 "Standard Method for Evaluation of Painted or Coated Specimens Subjected Corrosive Environments", Table 1 provides for rating film undercutting and creepage along a scribe placed through the coating film to the substrate. Panels exposed in the WETF Pool included several systems for which scribe evaluation was judged significant. Lifting of the coating or creepage of corrosion products under the applied coating system did not lend itself to rating panel performance by the methods described above thus, Table 1 was employed for panels in specific environments when the occurrence of film undercutting was noted.

The scribed surface of test panels was examined for creepage and the rating number recorded. The rating number, divided by ten, provided a "factor" to apply to the corrosion grade obtained per ASTM D610. Thus a rating of 10 for creepage/undercutting resulted in a factor of "1.0" and a rating of 8 a factor of "0.8." This factor multiplied by the ASTM D610 grade provided an adjusted value which was then employed to obtain system ratings and rankings.

ASTM D714 provides for the size and frequency distribution of blisters but does not provide for a manner to assess the relative comparison between size and frequency combinations. Therefore, ASTM D1654 Table 1 "Rating of Unscribed Areas" was employed to assign a rating number based upon the estimated percent of surface area exhibiting blister formation. The scale ranges from "10", no failure to "0" over 75% of the area failed. This eliminated a need to attempt to establish a scale encompassing size and frequency of blisters observed on the test panels.

SYSTEM RATING AND EVALUATION

All panels for each system substrate, and exposure environment were individually rated employing the methods described above. A "score" was calculated for each system in each environment by obtaining the individual sums of ratings for chalk, blistering and corrosion and dividing by the number of panels. The three values were then added to obtain the "system score". A "perfect" score would be 30. The ordered scores of the exposed systems were then ranked 10 through 1 with the rank of 10 assigned to the highest system score and rank of 1 to the lowest. A comparative performance system score for each system in each of the exposure environments was thus obtained. Within sets of data, system scores were converted to "relative scores" as follows. The highest system score in the data set was divided into each system score of the set. Thus, the relative score maximum would be 1.00 and all other relative scores would be less than 1.00.

Employing the same procedure, sums for all chalk, blister and corrosion ratings were determined for all coated panels in each exposure environment and scores calculated. This resulted in a relative value for the "aggressiveness" of the exposure environment. A more "aggressive" environment would result in a lower system score (and relative score) than a less "aggressive" environment. This occurs simply as the result of the ratings obtained for chalk blister formation and corrosion formation being lower. The "aggressive" environment results in lower overall system scores since evaluation ratings are lower.

The same approach was employed for the substrate materials to obtain a relative comparison of substrate susceptibility to "attack".

All test panels were visually examined and system observations described for each of the exposure environments. The information obtained from these observations are provided in Section IV B for "KTA-Tator Laboratory Exposures" and Section IV C for "NASA-Johnson Space Center Field Exposures". The rating and ranking values for coated panels in each environment are presented in Tables IV D-1 through Table IV C D-8 at the end of Section IV.

Section IV A

Physical Testing of Coating Systems

PHYSICAL TESTING

Physical Testing of coatings applied to test panels included ASTM D4060, "Abrasion Resistance of Organic Coatings by the Taber Abrasor.", ASTM D2794, "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact), and ASTM D3359 "Measuring Adhesion by Tape Test," Both Method A (X-cut) and Method B (cross-cut) adhesion of ASTM D3359 were assessed. The methods employed are briefly described and a summary of results for each of the physical tests is provided below. Test methods are appended.

ABRASION RESISTANCE

Abrasion resistance of coating was performed in accordance with ASTM D4060, "Abrasion Resistance of Organic Coatings by the Taber Abrasor." Duplicate Taber abrasion test plates, measuring 4" x 4" with a 1/4" diameter hole drilled through the center, were coated at the same time as all other system test panels and cured in accordance with the manufacturer's instructions. Subsequently, the dry coating thickness was measured, recorded, and the specimens weighed to the nearest 0.1 mg. Each specimen was subjected to 1,000 cycles using a 1,000 gram load and CS-10 abrasion wheels. The weight loss in milligrams and coating thickness decrease (in mils) were recorded and are presented in Table "IV A-1".

Coatings with greater abrasion resistance lose less coating mass when subjected to abrasion testing. Thus, weight loss was employed to provide an index of abrasion resistance. System 1, a flame applied plastic coating demonstrated the lowest change in weight, followed by Systems 7 and 6, also flame applied plastics. High volume solids content of coatings systems appears to play a role in abrasion resistance. Five (5) of the ten (10) systems evaluated were identified by the manufacturer's to be 100% solids materials and, when ranked by abrasion resistance (based upon weight loss) were the five highest ranked. The average weight loss for these five (5) systems was less than 70 milligrams (mg), range 24.8-65.5 mg. The remaining systems exhibited average weight loss ranging from 85.4 mg to 207.0 mg. and included coatings with volume solids content of 56% to 75%. No clear relationship between the volume solids content and weight loss was noted for this latter group of coating materials.

ADHESION

The relative adhesion of the coating systems to the underlying substrates were assessed, before and after exposure testing. Control panels were employed to assess unexposed adhesion and the results compared to post exposure adhesion results. Adhesion was evaluated in accordance with ASTM D3359 "Measuring Adhesion by Tape Test," Method A (X-cut) and Method B (cross-cut). Each of the selected test coating systems was tested. Results obtained are presented in Table "IV A-2".

Adhesion result rankings for applied and cured coatings employed the rating scale provided for in the method (ASTM D3359). This allows for a "Best" to "Worst" rating from 5 to 0, a rating with 5 being excellent, no adhesion loss. Significantly, all coating systems with exceptions as noted, were rated 5 or 4, both indicating very good adhesion.

Since rating of adhesion is not a strictly quantitative scale, results of adhesion testing should be viewed with knowledge of its limitations. A rating of 5 represents no coating loss as a result of testing while a rating of 4 requires only a small amount be removed. The coating adhesion rating for any system, when summed for all tests conducted, would provide for a maximum rating of 230. This includes a total of 160 from all "5's" on metal test panels and 70 on CPVC test panels. On metal panels the thermally applied plastic coating systems, #1, #6 and #7 all scored 160. No other systems resulted in ratings of all "5's". System #6 also scored a 70 on the CPVC panel tests. However, System #7 scored only 51 and for the CPVC panels ranked lowest. The low adhesion score for System #7 on CPVC is probably associated with substrate degradation resulting from thermal application of aluminum powder as well as the plastic coating. System #1, overall rated second, scored 60 on CPVC test panels. Systems #3 and #4 scored least for adhesion resulting in rating totals of 188 and 200 respectively. However, these values are equivalent of a rating of "4A" or "4B", as indicated above, good adhesion ratings. ASTM D3359 Method B is not normally employed on films in excess of 5 mils thickness and employs cut spacing of 2 mm for films between 2.0 mils and 5 mils thick. The systems evaluated exceeded 5 mils in thickness. Thus, although not strictly applicable, use of Method B was considered appropriate for comparative purposes. Since the coating systems under study all exceeded 5 mils dry film thickness, the ASTM D3359 Method B adhesion test employed 5 millimeter spacing.

IMPACT RESISTANCE

The impact resistance of the coatings was assessed in accordance with ASTM D2794, "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)." Both direct and reverse impact values were determined. Separate test panels were employed for direct impact and reverse impact resulting in cracking. Results are reported in inch-pounds and reflect the minimum impact, separation or loss of film continuity. Measured results are presented in Table "IV A-3".

Impact resistance of the coatings applied to test panels resulted in ranking of "most resistant" to "least resistant" as inch-pounds. Direct and reverse impact ranks were evaluated separately.

Assessment of impact resistance was evaluated based upon the lowest impact load, in inch-pounds, that would result in a cracked coating film. The impacted coating surface film, for both direct impact or indirect impact, was examined with and without the aid of magnification. The maximum impact which could be employed was 176.0 inch-lbs. Both Systems #1 and #7 reached 176 inch-lbs direct and indirect impact without detection of coating rupture or cracking. The next highest direct impact values were System #3 and System #9 at 24 inch-lbs each. The brittleness of the coating was noted to be related to performance. As previously described, the coated test panels were subject to 90 inch-lbs impact prior to exposure in the test environments. It was observed that System #10 exhibited more damage from pre exposure impact than the remaining systems. It was not suprising therefore that System #10 also exhibited the lowest tolerance to direct impact, 4 inch-lbs. Reverse impact results, with the exception of Systems #1 and #7 were no greater than 3 inch-lbs. System #6 exhibited damage at 1 inch-lb. Although a thermally applied "plastic", System 6 is a hard, low elongation type material.

TABLE IV A-1
Taber Abrasion Test Results

System #	Panel #	Weight, g Before	Weight, g After	Weight Change, g	Average Change, mg	DFT,mils Before	DFT, mils After	Average Change, DFT	System Rank
1	79	77.8814	77.8487	0.0327		21.5	23.2		
1	80	78.0711	78.0542	0.0169	24.8	25.1	22.0	-0.7	10
2	161	78.3744	78.3078	0.0666		13.7	15.4		
2	162	79.7206	79.6562	0.0644	65.5	21.0	18.8	-0.3	6
3	245	75.1777	74.9533	0.2244		7.4	5.7		
3	246	75.5501	75.3605	0.1896	207.0	7.7	7.1	-1.1	1
4	325	77.2374	77.1392	0.0982		11.0	10.8		
4	326	77.9770	77.8287	0.1483	123.2	12.8	12.3	-0.4	2
5	407	78.1808	78.0756	0.1052		13.2	13.1		
5	408	78.3980	78.2936	0.1044	104.8	16.7	14.2	-1.3	4
6	489	76.8634	76.8114	0.0520		20.3	20.9		
6	490	75.3410	75.3072	0.0338	42.9	14.7	12.9	-0.6	8
7	571	89.8013	89.7914	0.0099		35.1	35.3		
7	572	93.2682	93.2172	0.0510	30.4	49.2	45.7	-1.6	9
8	653	79.0999	79.0323	0.0676		14.2	12.4		
8	654	79.8975	79.7943	0.1032	85.4	14.5	13.8	-1.3	5
9	735	78.4553	78.3494	0.1059		14.7	14.9		
9	736	78.4981	78.3854	0.1127	109.3	18.0	16.6	-0.6	3
10	817	76.6412	76.5882	0.0530		10.6	11.2		
10	818	78.2365	78.1903	0.0462	49.6	13.9	13.2	-0.1	7

ASTM D4060 "Abrasion Resistance of Organic Coatings by the Taber Abaser

Tape Adhesion Results Summary*

System #	Stainless Steel Method A	Stainless Steel Method B	Aluminum Method A	Aluminum Method B	CPVC Method A	CPVC Method B	Score Sum	System Rank
1	40	40	40	40	30	30	220	9
Average*	5.0	5.0	5.0	5.0	4.3	4.3	4.8	
2	36	36	38	36	33	31	210	4
Average*	4.5	4.5	4.8	4.5	4.7	4.4	4.6	
3	37	30	36	29	32	24	188	1
Average*	4.6	3.8	4.5	3.6	4.6	3.4	4.1	
4	39	30	39	31	34	27	200	2
Average*	4.9	3.8	4.9	3.9	4.9	3.9	4.3	
5	37	36	37	36	32	31	209	3
Average*	4.6	4.5	4.6	4.5	4.6	4.4	4.5	
6	40	40	40	40	35	35	230	10
Average*	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
7	40	40	40	40	30	21	211	5
Average*	5.0	5.0	5.0	5.0	4.3	3.0	4.5	
8	38	37	37	38	34	32	216	7
Average*	4.8	4.6	4.6	4.8	4.9	4.6	4.7	
9	40	36	39	36	35	32	218	8
Average*	5.0	4.5	4.9	4.5	5.0	4.6	4.7	
10	39	35	39	35	34	30	212	6
Average*	5.0	4.5	4.9	4.5	4.9	4.3	4.7	

Substrate Adhesion Test	Stainless Steel Method A	Stainless Steel Method B	Aluminum Method A	Aluminum Method B	CPVC Method A	CPVC Method B	All Method A	All Method B
Average*	4.8	4.5	4.8	4.5	4.7	4.2	4.8	4.4
	A&B	4.7	A&B	4.7	A&B	4.5	A&B	4.6

ASTM D3359 "Standard Test Methods for Measuring Adhesion by Tape Test"

*The values reflect averages of a scale ranging from 5 to 0 in units of one (1). Averaging of results is for comparison purposes. Actual ratings are appended.

TABLE IV A-3

Impact Resistance, Rapid Deformation of Coatings

Direct Impact				Reverse Impact			
System #	Height Inches	Load lbs.	Impact in-lbs	System #	Height Inches	Load lbs.	Impact in-lbs
1	44	4.0	176.0	1	44.0	4.0	176.0
2	2	4.0	8.0	2	1.5	2.0	3.0
3	6	4.0	24.0	3	1.5	2.0	3.0
4	4	4.0	16.0	4	1.5	2.0	3.0
5	4	4.0	16.0	5	1.5	2.0	3.0
6	4	4.0	16.0	6	0.5	2.0	1.0
7	44	4.0	176.0	7	44.0	4.0	176.0
8	4	4.0	16.0	8	1.5	2.0	3.0
9	6	4.0	24.0	9	1.5	2.0	3.0
10	1	4.0	4.0	10	1.5	2.0	3.0

ASTM D2794 "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)"

ASTM D3359 Adhesion Test Results

	QUV- Weatherometer						Simulated Pool					
Substrate	SS		AL		CPVC		SS		AL		CPVC	
System	A	B	A	B	A	B	A	B	A	B	A	B
1	5	5	5	5	5	5	5	5	5	5	5	5
2	5	4	5	4	5	4	5	4	5	4	5	4
3	5	3	5	2	5	2	5	3	5	3	5	2
4	5	2	5	3	5	3	5	2	5	2	5	2
5	5	4	5	4	5	4	5	4	5	4	5	4
6	5	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	5	1	5	5	5	5	5	0
8	5	4	5	4	5	4	5	5	5	5	5	5
9	5	4	5	4	5	4	5	4	5	4	5	4
10	5	3	5	3	5	3	5	4	5	4	5	4

SS		AL		CPVC	
A	B	A	B	A	B
40	40	40	40	30	30
36	36	38	36	33	31
37	30	36	29	32	24
39	30	39	31	34	27
37	36	37	36	32	31
40	40	40	40	35	35
40	40	40	40	30	21
38	37	37	38	34	32
40	36	39	36	35	33
39	35	39	35	34	30
4.8	4.5	4.8	4.5	4.7	4.2
386	360	385	361	329	294
	all		all		all
	4.7		4.7		4.5

A	B
4.8	4.4

	KTA-Envirotest						WETF Pool					
Substrate	SS		AL		CPVC		SS		AL		CPVC	
System	A	B	A	B	A	B	A	B	A	B	A	B
1	5	5	5	5	5	5	5	5	5	5	5	5
2	4	4	5	4	5	4	5	5	5	5	5	5
3	5	4	5	4	5	4	5	4	4	4	4	4
4	5	3	5	3	5	3	5	4	5	3	5	4
5	5	4	5	4	5	4	4	4	4	4	4	4
6	5	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5	5	5	5	5
8	5	4	5	5	5	5	5	5	5	5	5	5
9	5	5	5	5	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	5	5	5	5	5

	Laydown Area						Rotunda					
Substrate	SS		AL		CPVC		SS		AL		CPVC	
System	A	B	A	B	A	B	A	B	A	B	A	B
1	5	5	5	5	5	5	5	5	5	5	5	5
2	4	5	5	5	4	5	5	5	5	5	5	5
3	4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	5	4	5	5	5	5	5	5	5
5	4	5	4	5	4	5	4	5	4	5	4	5
6	5	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	0	0	5	5	5	5	5	5
8	5	4	5	4	5	4	5	5	4	5	5	4
9	5	4	5	4	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	4	5	4	5	4

	Repaired Systems						Zinc Anode				Standard	
Substrate	SS		AL		CPVC		SS		AL		Panels*	
System	A	B	A	B	A	B	A	B	A	B	A	B
1	5	5	5	5	0	0	5	5	5	5	5	5
2	4	4	4	4	4	4	4	5	4	5	5	5
3	5	4	5	4	5	4	4	4	4	4	5	5
4	5	5	5	5	5	5	5	5	5	5	5	4
5	5	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5	5	5	5	5
8	4	5	4	5	4	5	4	5	4	5	not found(?)	
9	5	5	4	5	5	5	5	4	5	4	5	5
10	4	4	4	4	4	4	5	5	5	5	5	5

*not used in summary data

Section IV B

KTA-Tator Laboratory Exposures

With the exception of System #1, all test panels were placed in the exposure environments on May 11 and 12, 1994. System #1 was placed in exposure May 16, 1994. System #1 exposure was begun late due to a need for the manufacturer to recoat panels to a lower film thickness than originally applied.

Exposed test panels were removed from exposure August 4, 1994 and August 5, 1994. Nine (9) of the ten (10) coating systems had reached 2,000 hours cumulative exposure on these dates. System #1required additional exposure to reach 2,000 hours total exposure time. The System #1 panels were removed August 12, 1994.

SIMULATED POOL EXPOSURE - 2999 HOURS

System 1 - PF 112. The test panels were evaluated for chalking and rated "9". No transfer of coating to the test cloth was evident. The rating of "9" was assigned due to slight change in surface gloss at the test point. When compared to an unexposed control the panels were slightly duller. Little color change was noted. Examination of the test panels for blistering found none to be present on any of the panels including stainless steel, aluminum, coupled (stainless and aluminum) and CPVC. When examined for corrosion, both coupled panels and one aluminum panel (#33) were found to exhibit corrosion in the vicinity of the scribe. The scribed aluminum substrate of the coupled panels, where corrosion was noted, also exhibited a small amount of undercutting of the applied film.

System 2 - NSP120. The panels, when evaluated for chalking exhibited none. Visually compared to a control panel, the gloss of exposed panels does not appear to have changed significantly although there has been a change in color. The exposed panels appeared more yellow than the unexposed control. The exposed panels did not exhibit blistering nor was there any indication of corrosion on the panels on edges, at X-scribes or at the seams of the coupled panels. The direct impact area of the aluminum panel does exhibit some corrosion on the exposed aluminum substrate. It should be noted that the impact areas of the stainless steel, aluminum and coupled panels exhibit cracking and fracturing of the paint in a circular pattern. This indicates the coating to act brittle on these substrates. The point of impact shows no effect on the face of the CPVC panel but exhibited some minor cracking on the reverse side of the impact.

System 3 - Devran 230. Test panels were evaluated for chalking and resulted in rating six panels "9". A rating of "9" indicates little or no transfer to the test cloth, however, a change of gloss was visible where tested. The coupled panels exhibited chalk transfer and were rated "8". When visually compared to controls, the exposed panels exhibited a decrease in gloss and a slight yellowing in color. The coupled panels appeared to have changed slightly more in hue than the steel, aluminum, or CPVC panels. When tested for chalking the test locations exhibited an increase in gloss. The panel faces did not exhibit blistering, however, the coupled panels exhibited blisters in the vicinity of the scribe along edges, and one at the seam of coupled panel 219. Typically the blisters were few, 1/16 to 1/8 inch in size. All blisters were limited to edges and the vicinity of the scribe. When examined for the presence of corrosion, at the scribe, none was visually evident. Minor corrosion was noted along the seams and edges of the coupled panels including minute red spots. The direct impact areas on the stainless steel, aluminum and coupled panels exhibited small dots due to damage at the time of impact. This resulted in slight crumbling of the coating, approximately the diameter of the impact ball. There was no visible impact damage on the CPVC panel.

System 4 - Carboline 890. None of the panels exhibited chalking, however, a slight change in gloss was evident where the chalk test was conducted. Compared to the control panel, gloss appears to be similar. The color of the coating yellowed compared to a control panel. None of the panels exhibited blistering on the face, along edges nor in the vicinity of scribes, and all panels were rated "10". When examined for corrosion products, none of the panels exhibited visual evidence of corrosion on the scribes, seams or edges and were rated "10's". Examination of the direct impact areas did not reveal evidence of corrosion. The impacted areas are approximately the diameter of the impact ball. The reverse impact side of the panel coating was fractured, the cracked has coating within the circumference of the impact was adhered. The CPVC panel exhibited a slight circular impact dot but no dent. The coating within the circle of reverse impact was cracked in a pie shaped fashion and lifted from the surface.

System 5 - Sherwin-Williams epoxy. Chalking of all the panels were rated "9", meaning no chalk transfer to the test cloth, however, at the test location there was an increase in the gloss of the coating. When visually compared with a control panel, the panels under exposure exhibited a decrease in gloss. There was also a color change, the exposed panels more yellow than the control panel which is white. When examined for blistering, the stainless steel panels exhibited no blistering on the panel face nor around the scribe. One aluminum panel exhibited blisters, approximately 1/4" in diameter, around the panel hole and through the panel. No blisters were found around the scribe. Coupled panel #383 exhibited blistering along the seam, predominately on the aluminum substrate. This included one blister being approximately 1/2" in diameter with several #2F blisters along the seam. One #2 blister is noted along the edge of the stainless steel panel and two #2 blisters on the reverse side of the aluminum panel. The companion coupled panel #384 exhibited one blister approximately 1/2" in diameter, a second approximately 1/4" in diameter on the aluminum panel at the bolt. No blisters were noted on the coated CPVC panels. When examined for corrosion products none of the panels exhibited visible corrosion product at the scribes nor was any corrosion product noted around the edges. Coupled panel #383 exhibited corrosion product at the seam between the stainless steel and aluminum panels. Coupled panel #384 exhibited corrosion product along the seam and, in the vicinity of the blisters at bolt through the aluminum panel with slight red staining. At the areas of direct impact, the stainless steel panel substrate is exposed approximately the diameter of the impact ball. The aluminum panel shows a dent from the impact but the coating remains in place. The coupled stainless steel panel exhibits a loss of coating at the impact, approximately the diameter of the ball. On the CPVC panel, a slight mark can be seen. However, there is no dent in the panel or fracturing of the coating on the front side. The reverse side of the CPVC panel does not exhibit any cracking or separation of the coating on the reverse side of impact.

System 6 - UTPlast Extra. When tested for chalking, results of chalking were rated "10", no transfer to the test cloth. The point of testing can be seen when viewed at an acute angle. When visually compared to an unexposed control the exposed panels do exhibit some dulling but do not exhibit a change in the color of the panel. It should be noted that the application pattern can be seen when viewed at an angle, probably due to texture associated with the manner of application. Examination of the exposed panels for blistering revealed that the panels did not exhibit blistering on the panel faces nor in the vicinity of the scribes. Examination of the coupled panels at the seams and bolts did not exhibit evidence of blistering. Examination of the exposed panels for corrosion showed no evidence of corrosion of the stainless steel panels. The aluminum panels exhibited a slight amount of corrosion near the hole and a slight amount of white corrosion product within the scribes. The corrosion product did not extend beyond the scribe. There was no indication of undercutting. Both of the coupled panels exhibited white corrosion product on the bottom edge of each panel and a slight amount along the lower seam of panel 466. The bottom edge of aluminum panel 446 exhibited areas of white corrosion product. It is believed that the corrosion product visible on the bottom edges was associated with poor coverage. No evidence of lifting or corrosion product was noted for the coated CPVC panels. Examination of the areas of direct impact showed the paint to exhibit a circular fractured pattern on the stainless steel panel with a dimple where the coating was pushed away from the impact area. The coating was cracked and separated in a circular pattern. The aluminum panel exhibited a dent in the coating at the impact. Visually, a small amount of corrosion product, or perhaps, substrate could be seen through the impact area. The impact on the coupled panel revealed substrate but the coating appeared to have been pushed aside in a crater-like formation and no evidence of cracking or separation was present. Impact of the plastic CPVC panel (which was curved) did not exhibit damage on the front side or any on the reverse side. The reverse impact side of the stainless steel panel, (#423), exhibited a small, 1/4" area with a star pattern crack.

System 7 - UTPlast Ultra over Aluminum. Evaluation for chalking resulted in a rating of 2 for stainless steel and aluminum panels. The coupled panels exhibited a chalking rating of 8 while the CPVC panels were rated "6". The degree of discoloration of the panel surfaces is consistent with the chalking scale. The aluminum and stainless steel panels exhibited a white surface deposit to a greater extent than the coupled or CPVC panels. When visually compared with an unexposed control panel, all exposed panels exhibited a gray-white surface deposit which had a waxy-like feel as opposed to a dry powder as customarily observed. The stainless steel panels and aluminum panels almost appeared as if they were coated light gray. The coupled panels exhibited localized discoloration, particularly the edge on panel #548, which exhibited more white surface deposit than elsewhere on the panel. The CPVC panel surface deposits appeared to be more blue in color than the other panels. When examined for blistering no blisters were present on the panel faces, in the vicinity of the scribes, edges or seams of coupled panels. Examination of the CPVC panels revealed a #2 blister on panel #564 but, due to edge undercutting, may simply reflect an area of corrosion between the plastic coating. Examination of the panels for corrosion products revealed corrosion products along portions of scribes on stainless steel, aluminum and coupled panels. Distribution of corrosion products was noted to be as follows: stainless steel panel #505 principally in the center of the "X"; stainless steel panel #506, through the lower right-hand area of the scribe; aluminum panel #527, lower right-hand portion of the scribe; and aluminum panel #528, principally in the vicinity of the center of the scribe. Each of these areas of corrosion extend at least 1 1/2" in length. Coupled panel #547 exhibited one spot of corrosion at the center of the X-scribe, about a 1/4" in diameter. White corrosion product was noted around bolt heads (stainless steel side) and a portion of the panel seam. One the reverse side of the panel, white corrosion product had formed at the seam between the aluminum and stainless steel panels and bolt hole through the aluminum panel. Coupled panel #548 exhibited some corrosion products along the bottom edge, however, did not exhibit corrosion products at the scribes. A minor amount of white corrosion was noted at the fastener on the backside. CPVC panel #563, exhibited corrosion, lifting and curling of the thermally applied aluminum from the substrate in the vicinity of the scribe. Undercutting along edges was significant. It should be noted that CPVC panel edges were not sealed. Corrosion products resulted from corrosion of thermally applied aluminum powder. Apparent blisters appear to have developed as a result of corrosion of applied aluminum. Panel #564 exhibited minor undercutting along edges and evidence of corrosion product at the scribe with some lifting of the coating. Generally, coating at edges was relatively adhered, not freely delaminated. Impact areas of the coupled and stainless steel aluminum panels simply exhibited a crater at the point of impact. A minute amount of corrosion, visible as small white flecks at the bottom of crater, were noted although the base of the crater is predominately black (coating). The crater of an aluminum panel exhibits a white ring of surface discoloration previously described. In all cases, the coating material was in place, simply deformed and relatively adherent. The CPVC panel, did not show evidence of an impact area on the face of the panel. The back of the panel was not coated. This was due to deformation of CPVC during flame application.

The extent of surface discoloration of all panels may be associated with the aluminum substrate. This has not been established. The majority of corrosion product observed and described above was believed to be related to corrosion of thermally applied aluminum powder rather than panel substrates. Deformation of the CPVC panels of this coating system as well as coating systems #1 and #6, indicated use of thermally applied systems over plastic type materials is not appropriate. The required heat to achieve appropriate application temperatures resulted in softening of CPVC panels and the possibility of compromised adhesion. In addition, on formed pieces, such application will deform the plastic-like materials, making subsequent assembly and design out of tolerance.

System 8 - Elite 8844, over aluminum. When evaluated for chalking, none of the panel tests resulted in chalk transfer to the test cloth. There was a slight change in panel sheen at the test point areas. Overall, the coating system appeared to have retained much of its gloss, although, as a result of chalk testing, some flat spots at the point of test were noted. When visually compared to an unexposed control, the exposed specimens were observed to have yellowed, the color in some panel locations panels being darker than in other areas. Thus, discoloration was not evenly distributed and included yellowish and darker yellow/brown shades. The gloss of the exposed panels does, however, seem to be quite similar to the gloss of an unexposed control. Exposed panels, when viewed at an angle, exhibited a luster similar to "mother-of-pearl". This was not evident when panels were viewed perpendicular to their planes.

When examined for blistering none of the exposed panels exhibited blistering on the panel face. However, the stainless steel panels exhibited some blistering in the vicinity of the scribe, associated with corrosion product. Stainless steel panel #587 exhibited small blisters at the bottom edge of the panel. This was probably associated with the aluminum outer undercoat. The aluminum panels also exhibited small blisters, perhaps 2 mm, in the vicinity of scribes. The coupled panels did not exhibit blistering in the vicinity of scribes of either stainless steel or the aluminum substrate. There was no evidence of blistering on CPVC panels. None of the panel faces, away from the areas of scribes, exhibited blistering. Examination of the panels for corrosion product revealed white corrosion product at the scribes of stainless steel panels and along the bottom edge of stainless steel panel #587. Aluminum test panels exhibited slight areas of corrosion along scribes. The coupled panels did not exhibit areas of corrosion at scribes, however, edges of the stainless steel and aluminum coupled panels did exhibit areas of white corrosion product, associated with minute blisters. Coupled panel #630 had small blister-like areas near bolt heads and nut on the reverse side of the panel. No evidence of white corrosion product was apparent on the plastic CPVC panels. Examination of the impact areas on the stainless steel panels showed a dimple, approximately the diameter of the impact ball, and small cracks in the coating within. The aluminum panel exhibited a dent from the impact of the ball. However, the coating was smooth, uniform and noncracked. The reverse side of the aluminum panel, however, exhibited a star-shaped crack with corrosion product within. The starburst crack was less than 1/2" in diameter. Corrosion product appeared to be present at the impact area of the coupled panel. The CPVC panel direct impact showed no effect, however, the reverse side exhibited a 5-pointed star-like crack approximately the diameter of the support ring. No corrosion product was observed to be present. It should be noted that during the application of the Elite 8844 over the thermally applied aluminum that what appeared to be gas bubbles migrated through the coating film leaving what appeared to be small fisheyes and pinholes in the coating. This is believed to be associated strictly with the application of thermally applied aluminum powder prior to application of a coating system itself. It is speculated that use of the Elite 8844 without the coat of aluminum beneath would have shown better evidence of corrosion resistance in the areas of the scribes and along edges and that inconsistencies with the surface film are associated with the thermally applied aluminum powder.

System 9 - Plasite 7122. When evaluated for chalking, the exposed test panels were rated "9", indicating no transfer of chalk to the test cloth, however, a slight change in gloss at the point of testing was noted. When visually compared to a nonexposed control, the coating was found to have yellowed slightly and had exhibited slight decrease in relative gloss. When examined for blistering, none of the test panels exhibited blistering on the face and, with the exception of one coupled panel, no evidence of blistering or undercutting was apparent in the area of the scribes. Coupled panel #711 did exhibit slight areas which might be construed as blisters adjacent to the scribe. These are probably associated with underfilm corrosion. Of four scribes placed on coupled panels, only one scribe area exhibited this pattern.

Evaluation of the panels for corrosion revealed no evidence of corrosion at the scribes of the stainless steel or aluminum panels. As noted above, there was minor corrosion along the scribe on the aluminum side of panel #711, 4 locations approximately 1/4" in diameter, exhibiting circular, blister-like patterns which appear to contain white corrosion product. Corrosion products were noted to be along the seam.

Coupled panel #712 also exhibited corrosion at the interface of the stainless steel and aluminum panel with slight corrosion around fasteners on the aluminum panels side. When examining impact areas, coating on the stainless steel panel was observed to be deformed with a slight fracture around the diameter of the impact. Although intact, the coating could be peeled free with a thumbnail. A slight amount of surface corrosion was visible underneath. The impact area of the aluminum panel was slightly deformed by the tip of the impact ball. The reverse side exhibited a star-type fracture with corrosion product around the cracks. Examination of the impact area of the coupled panel showed the circular pattern of impact with a slight lifting of the coating. Although cracked around the perimeter, the coating could not be gently lifted with a thumbnail. Examination of the CPVC impact panel showed no evidence of direct impact other than a slight discoloration. The reverse side, however, showed cracking with slight separation within the circular pattern of the support ring.

System 10 - Aquatapoxy A6. When evaluated for chalking, the panels were rated "9" due to a slight change in gloss at the point of chalk test. When visually compared to a nonexposed control, the exposed panels showed a slight change in color resulting in a "mother-of-pearl" luster to the surfaces. When viewed at an angle, it appeared almost like oil on water. The discoloration of the color pattern varied and, when viewed from above, had a yellow hue, light orange tinge and white areas. When examined for blistering none of the panels exhibited evidence of blistering along edges, the face of the panels or in the vicinity of scribes. Examination for corrosion revealed no evidence of corrosion in the vicinity of the scribes on stainless steel, aluminum, or at scribes on coupled panels. The coupled panels, however, did show evidence of corrosion along the outer edge of the aluminum panel (away from the point of connection). This system, applied by brush, exhibited creepage away from sharp corners which contributed to occurrence of corrosion on exposed edges. There was no evidence of coating failure, except for separation on the CPVC panels. Examination of impact areas on stainless steel panels, revealed the impact area to be somewhat oval-shaped, extending beyond the immediate area of impact, associated with coating brittleness. Where cracked due to impact, the coating separated from the substrate, however, beyond the crack, the coating appeared well adhered. A similar pattern was observed on the aluminum panel, however, where cracked the coating remained in place, and when picked, was loose but did not lift freely. An egg-shaped, circular pattern, due to impact on the coupled panel, was lifted from the substrate. On probing, coating separated from the substrate. The edges however, were well adhered. The face of the CPVC impact panel showed no evidence of impact. The reverse side, exhibited a starburst crack which remained adhered to the surface. It should be noted that the reverse side of the aluminum panel also had a starburst crack, but no evidence of corrosion.

KTA ENVIROTEST EXPOSURE - 2000 HOURS

Panels exposed in the KTA Envirotest were evaluated subsequent to 2000 hours of exposure.

System 1 - PF112. The tested panels were all found to exhibit a rating of "8" when tested for chalk; slight transfer to the test cloth was noted. Compared to an unexposed control the test panels were more dull, having a reduced gloss. Color change of the test panels did not appear to have occurred. Each panel was examined for evidence of blister formation. No blisters were observed on any of the test panels. Both of the coupled panels exhibited slight formation of corrosion product along the seam of the stainless steel, aluminum panel interface. No other occurrence of corrosion was observed on any of the test panels.

System 2 - NSP 120. When evaluated for chalking, all panels exhibited a chalk rating of "6". A slight, grayish mark was left on the test cloth. When visually compared to a nonexposed control the exposed panels were shown to have changed in color from a near white to light tan or beige color. Examination of the panel faces and scribe areas for blister formation revealed no blistering present on panel faces nor in the vicinity of scribes. This observation was true of stainless steel, aluminum, coupled, and CPVC panels. Examination of the panels for evidence of corrosion showed no evidence of corrosion visible on stainless steel, aluminum panels or scribes of the coupled panels. Minor corrosion was noted at the points where fastener clips held panels in the test apparatus. For purposes of evaluation these areas were not considered as part of the evaluation. No evidence of coating delamination, separation, or corrosion was noted on CPVC panels. Examination of the areas of impact of stainless steel panels revealed circular impact area with coating raised around the perimeter. In the crater-like center, the coating was cracked with lifting from the substrate. There was no evidence of film separation around the perimeter. The reverse side of the panel showed no results or evidence of impact. The aluminum panel exhibited a similar pattern, however, the fractured paint in the circular pattern was free of the panel. The reverse side of the aluminum panel showed a small, star-like crack with no evidence of corrosion. The coupled panel impact area also exhibited a raised perimeter with a crater like center. The paint was cracked and lifted from the surface, however, no evidence of undercutting was apparent. The reverse side of the panel had no impact effect. The impact area of the CPVC panel exhibited no effect from direct impact. The reverse side of the direct impact face did, however, show a star fracture approximately twice the diameter of the circular reverse impact mandrel.

System 3 - Devran 230. When test panels were evaluated for chalking, the stainless steel, aluminum and coupled panels were rated "8", indicating slight transfer to the cloth. The CPVC panels were rated "6", indicating a greater amount of transfer. Locations of the chalk test were somewhat skinnier than untested surfaces. When visually compared to an unexposed control, the panels all had yellowed in color to a light tan. In addition, gloss had dulled to a flat finish. When examined for blistering panel faces, in areas of the scribe, did not exhibit evidence of blistering. However, on the stainless steel panels, below apparatus fastening clamps #2, blisters were present. A similar pattern was present on aluminum panels and coupled panels. Generally these were less than #2 blisters, medium to medium dense. Such blisters on the CPVC panels were minute and barely visible. When evaluated for corrosion, there was no visual indication of corrosion on the panel faces or the x-scribes of the stainless steel or aluminum panels. On coupled panels, the x-scribes were free of corrosion product, however, white corrosion product was noted along the seam between the aluminum and stainless steel panel on panel #216. In addition, there is slight corrosion product around the fastener nut of the aluminum side of this panel. Separation of coating was apparent on the CPVC panels. Examination of the impact area of the stainless steel panel revealed a slight dent at the area of raised paint around its perimeter, coating absent for an area the diameter of the tip of the impact ball. The panel showed very minor cracking at the center of the reverse impact area. Examination of the aluminum panel impact area also showed exposed substrate directly at the impact site. The reverse side of the panel showed minor circular cracking with a minute amount of corrosion product associated with the crack. The crack pattern is less than 1/2" in diameter. The impact area of the coupled panel revealed the substrate with intact paint around it and no indication of defect on the reverse impact face. The direct face of the CPVC panel shows no evidence of impact. However, the reverse side does show a starburst crack within the circumference of the reverse impact mandrel.

System 4 - Carboline 890. When evaluated for chalking all panels, except one, were assigned a chalk rating of "6". One stainless steel panel had a chalk rating of "8". Small, dark, circular smudges were apparent at the point of chalk testing. When visually compared to an unexposed control, panels appeared to be slightly yellowed to a pale tan or off-white. The gloss of the panels changed from a white, glossy surface to a flat and dull finish. When examined for blistering, the stainless steel panels did not exhibit blistering in the vicinity of the scribe or the face of the panel, however, they did exhibit less than #2 size blisters under the fastener clips. Aluminum panels, likewise, exhibited less than #2 blisters, under fastening clip surfaces. There was no other indication of blistering on panel faces or scribes, including coupled panels. No evidence of blistering was present on the CPVC panels. This included surfaces beneath clips holding the panel in the test apparatus. When examined for corrosion, stainless steel aluminum panels and coupled panels, likewise, exhibited no evidence of corrosion in the vicinity of the scribes, panel faces, or areas of the clips. There was a slight indication of corrosion at attachment clips of panel 298 as well as evidence of corrosion undercutting along the seam between the coupled stainless steel aluminum panel. No lifting or separation of the coating from CPVC panels was noted. Examination of the impact area of the stainless steel panel showed the center impact area to expose the substrate due to a loss of coating. This was true on the aluminum panel as well. The reverse side of the stainless steel panel exhibited a small star-like crack as did the reverse side of the aluminum panel. Neither panel had evidence of corrosion. The impact area of the coupled panel revealed a loss of coating at the area of impact with no significant evidence of corrosion. The impact area of the CPVC panel revealed a portion of the impact area circumference as a crack due to direct impact and starburst crack with coating lifted from the surface on reverse impact. One piece of the pie-shaped crack was free from the substrate. The immediately adjacent coating was adherent.

System 5 - Sherwin-Williams. When evaluated for chalking, all test panels exhibited a rating of "8", a slight removal of chalk from the coating surfaces. Examination of the areas of test found there to be a slight increase in gloss at the points of test. When visually compared to an unexposed control, exposed panels were shown to have had a change in color to a light tan/yellow and panels exhibited a flat finish compared to the semi gloss finish of the unexposed control. When examining for blisters, no evidence of blisters was noted on any of the panel faces or in the vicinity of scribes. This included all system #5 panels. Examination of the panel surfaces held by clips found no visual indication of blistering where the panels were fastened in place. Additionally, no evidence of blistering existed near the fasteners or edges of coupled panels. Examination of the panels for corrosion found there to be no evidence of corrosion at scribes nor on edges of stainless steel, aluminum or coupled panels. There was, however, a slight amount of corrosion product on the ends of the fasteners of the coupled panels. CPVC panels, when examined, showed there to be no indication of separation or lifting of the coating. The impact area on the stainless steel panel showed a fractured coating, approximately the diameter of the impact area, on the face and a very small crack, slightly more than 1/4", on the reverse side. The aluminum panel impact left a slight dent in the panel with no fracture of the coating. The reverse face contained a starburst crack at the center of impact. Examination of the coupled panel revealed a loss of coating at the point of impact. There was no evidence of coating damage on the reverse face. The CPVC panel direct impact left a slight mark with no evidence of damage to the coating. There was, however, a starburst fracture on the reverse.

System 6 - UTPlast Extra. When evaluated for chalking, all panels were rated "9" indicating there was no visible transfer of chalk to the test cloth. There was, however, a slight change of gloss at the point tested. Comparison of an unexposed control to exposed panels, found the exposed to exhibit a loss of gloss. The exposed panels were more dull and exhibited a white discoloration where support clips held panels. When examined for blistering, no evidence of blistering was observed on the faces of the stainless steel or aluminum panels. In addition, there was no indication of blistering at scribes. The coupled panels, also, did not exhibit blistering on faces, at scribes. In addition, no blisters were observed at the seam between the stainless steel and aluminum panel. There was indication of blistering or lifting of coating on CPVC panels. Examination of panels for corrosion, found no evidence of corrosion at the "X" scribes on the stainless steel or aluminum panels. Examination of the coupled panels found there to be evidence of corrosion along the panel top edge at the interface between the aluminum and stainless steel panel and, to lesser extent, on the lower edge. The face did not exhibit evidence of corrosion. A white surface deposit in the vicinity of the clips was discounted from the evaluation as associated with the support clips. Examination of the plastic CPVC showed no indication of separation or lifting of the coating. Examination of the impact area on the stainless steel panel shows a lifted crater perimeter exhibiting cracks. The coating within was cracked but still resisted removal, being stuck to itself. The reverse impact area contained a small star-like fracture, no more than about 1/4" in diameter. The aluminum panel impact area did not expose substrate nor was there a fracture in the coating, although the coating dimpled. The reverse side of the impact area did not exhibit any evidence of damage. There is no evidence of impact on the direct or reverse face of the CPVC panel.

System 7 - UTPlast Ultra, over aluminum. Evaluation of test panels for chalking rated the aluminum and stainless steel a "2", significant chalk transfer to the test cloth. The coupled panels exhibited a chalking rating of "8" and "6". The CPVC plastic exhibited a chalking rating of "4". When compared with an unexposed control, the exposed panels exhibited a significant amount of light gray surface film on aluminum and stainless steel panels, a lesser extent on one coupled panel. The second coupled panel like the CPVC, showed a generalized distribution of this light blue-gray material, however, not as heavy as on the stainless steel or aluminum panels. The panels exhibited a loss of gloss in the areas of discoloration, however, the test areas from chalk testing appeared to return the panel to its original color and gloss. It should be noted that in the case of the coupled and CPVC panels texture of spray application and texturing from the thermally applied aluminum powder beneath were evident. Examination of the test panels for blistering found an indication of blistering at the X-scribes but not faces of stainless steel and aluminum panels. In addition, examination of areas of the scribe, edges and faces of coupled panels showed no indication of blistering. Examination of the CPVC panels, which were coated on one side only, did not give indications of blistering. However, there was some lifting of the applied aluminum film to which the plastic coating was adherent. When evaluated for evidence of corrosion the stainless steel and aluminum panels showed no indication of corrosion along the scribed areas or edges. The coupled panels did show evidence of corrosion along the aluminum and stainless steel interface and edges of the interface. Slight corrosion was noted on nuts on the aluminum side of the panels. The CPVC panels exhibited delamination of the aluminum film from the panel face. Examination of a curled edge revealed white corrosion product associated with the thermally applied aluminum. It should be noted that the thermally applied plastic material remained adhered to the lifted aluminum film. Examination of the areas where clips held panels in the apparatus found the aluminum panels to exhibit small blisters, less than #8 in size. No such indications were present on the stainless steel, coupled panels, or the CPVC panels. The impact area of the stainless steel panel had a dimple at the point of impact, revealing the substrate, but no fracture of the coating. The reverse side of impact had no evidence of damage. Examination of the aluminum panel yielded similar observations. The impact point on the coupled panel also had similar results. The impact on the CPVC panel was not visible on the direct side. The reverse side of the panel contained a circular black spot which appeared to have discolored.

System 8 - Elite 8844 over aluminum. Evaluation for chalking on all of the panels resulted in a rating of "8" indicating a transfer of chalk to the test cloth. At locations where the tests were performed there was an increase in gloss. The panels, when visually compared to an unexposed control, have yellowed significantly to a tan color and a dull, flat finish. Where clamps held the panels in the test apparatus the color changed from slight to nearly none. When examined, there was no indication of blistering on the panel faces or at scribes on stainless steel or aluminum panels. Examination of the coupled panels revealed minute blisters along one edge of a stainless steel panel (#625) and small blisters along the interface of aluminum/stainless steel panel (#626). In addition, small blisters were noted on the bottom of panel edges and around fasteners. The blisters appear to result from corrosion of the applied aluminum film beneath the coating. The CPVC panels, did not reveal evidence of separation or delamination of coating. There were, however, indications of small blisters beneath the areas where the clips held stainless steel and CPVC panels in the apparatus. These were not visible on the aluminum panels. Examination of panels for evidence of corrosion found no corrosion evident at scribed areas of the stainless steel, aluminum or coupled panels. This is true on the coupled panels whether the scribe was in the stainless steel or the aluminum. Likewise, no evidence of corrosion existed on scribes of CPVC panels. However, edges of coupled panels, revealed evidence of corrosion associated with the blisters described above and are probably corrosion related blisters (rather than osmotic). The white corrosion product is associated with the thermally applied aluminum film. Distribution was on seams and edges of both coupled panels. Examination of the impact area of the stainless steel panel shows there to be a slight dimple with a minor crack in the very center. There was no evidence of coating damage on the reverse side. The aluminum panel direct impact exhibited a dent with no fracturing of the coating. However, on the reverse side a small circular spot of corrosion product and blister was noted. Slight rubbing of the spot found no visible cracking. The CPVC panel, direct impact, did not exhibit damage to the coating, however, a star-like fracture was present on the reverse side.

System 9 - Plasite 7122. Evaluation of the panels for chalking resulted in a rating of "6" for all of the panels. The areas of testing, when viewed at an angle, exhibited a slight increase in gloss. When viewed at 90 degrees the test area was not clearly visible. When visually compared to unexposed control, the exposed panels had a flat, lusterless finish. In addition, the color of the panels faded to a light tan with the only exception being surfaces beneath support clips. The exposed panels when evaluated for blistering, exhibited no evidence of blistering on panel faces or at scribes of stainless steel, aluminum, coupled and CPVC panels. However, examination of the coupled panels along the interface edge found small, less than #4, blistering believed to be the result of corrosion along the substrate edges. Areas beneath support clips found the stainless steel panels to show evidence of minor blistering (less than #6 size, medium dense). These were not visually apparent on aluminum panels but were present on one coupled panel. The area under support clips of CPVC panel did not exhibit blistering. When examined for evidence of corrosion, the stainless steel panels and aluminum panels were free of corrosion product at scribes and on panel faces and edges. The coupled panels exhibited evidence of corrosion along the seam between the stainless steel and aluminum panel. There was no evidence of corrosion product on the edges, top or bottom. Examination of the CPVC panels found coating to be adherent and continuous with no evidence of separation or delamination. Examination of the impact areas shows the stainless steel panel to have a slight dimple and a crushed coating at the point of direct impact. The reverse side of the panel did not exhibit any impact effect. Examination of the aluminum panel on direct impact revealed a dent in the coating, a slight dimple with fractured paint at the center of the impact area. The reverse side of the panel exhibited a star-like fracture pattern, approximately 1/3" in diameter. The impact area on the coupled panel contained a dent from direct impact with no evidence of effect on the reverse. The CPVC panel, when examined at the area of direct impact, revealed no visual effect. However, on the reverse face a circular area of star-like cracking was present. The coating was cracked but in place.

System 10 - Aquatapoxy A6. The stainless steel panels, when evaluated for chalking exhibited a rating of "6". Aluminum panels exhibited a "6", and "8", coupled panels, a rating of "8", and the CPVC panels a rating of "6". Examination of the test sites show there to be a slight discoloration but no visual indication of change in gloss. The test areas appeared slightly more yellow than untested areas. When visually compared to a nonexposed control the exposed samples have changed in color to a yellow-brown. The gloss of panels was reduced to a flat finish, with an exception in areas beneath the support clips where gloss and color were not changed. A variation in color of exposed panel surfaces was significant. The dark yellowing on coupled panels seemed to be greater than that on stainless steel, aluminum, or CPVC panels. Examination of the panels for blistering revealed no indication of blistering on panel faces or scribes on any of the panels examined. There were locations on coupled panels which appeared to be large blisters, but were droplets from coating application. Examining the panels for evidence of corrosion found stainless steel and aluminum panels to be free of evidence of corrosion, including the scribe and edges. The coupled panels did not exhibit evidence of corrosion at the scribes, however, the reverse side of one panel (#789) contained a slight spot of corrosion along a sharp edge. The second coupled panel (#790) also had a small spot of white corrosion product along a sharp edge. There was no evidence of lifting, corrosion or separation of the coating from CPVC panels. It should be noted that during coating and recoating of test panels, the System #10 coating Aquatapoxy, flowed to provide a relatively good seal between coupled panels. However, in all cases where there was a sharp edge, there was creepage of coating away from such edges. The observed pattern suggests that the system will require attention at sharp edges.

QUV WEATHEROMETER (ASTM G-53) EXPOSURE

QUV weatherometer testing included exposure to ultraviolet radiation for 6 hours followed by exposure to condensing humidity for 6 hours. The observations are reported after 2000 hours cumulative exposure, employing the cyclic expose.

System 1 - PF112. The test panels when tested for chalk exhibited none. In addition the test location did not exhibit evidence of testing. All were rated "10". Compared to an unexposed control, the test panels exhibited little change in gloss and the color was essentially the same as the control. Examination of the tested panels for blistering revealed none to be present on any of the test panels. Corrosion product was absent from all panel surfaces including scribes, edges, holes and seams and fasteners of the coupled panels. It should be noted that edges of the panels, although not exhibiting effects of exposure did show the area of contact with the apparatus supporting frame.

System 2 - NSP120. When evaluated for chalking a rating of "4" resulted for all panels, including stainless steel, aluminum, coupled and CPVC plastic. When visually compared to an unexposed control, exposed panels exhibited a decrease in gloss to a dull finish. Examination of chalk test locations, found no increase in gloss. It was possible to discriminate at which points the chalk testing was accomplished. Comparison to the control, found panels to have changed to a light brown color. In addition, the panels exhibited a white, streakish pattern on surfaces. Examination of the panels for blistering, found no indication of blistering present at the scribes of the stainless steel and aluminum panels. This was true for the edges and sides as well. The coupled panels did not exhibit blistering nor did CPVC panels. Examination of the panels for corrosion found the stainless steel , aluminum, and coupled panels to be free of substrate corrosion. One minor observation was a slight red discoloration at the substrate of coupled panel #136. There was no evidence of corrosion development. The CPVC panels contained no indication of lifting or separation of coating at scribes or edges. Examination of panel impact areas, found the stainless steel panel to exhibit a circular pattern with cracks and approximately 40% of the impact area void of coating. The exposing substrate did not exhibit corrosion. The reverse side of the impact showed no effect. The impact area of the aluminum panel contained a circular pattern with approximately 70% of the coating separated but adhered around the edges. The reverse side exhibited a starburst pattern, less than 1/2" in diameter. Examination of the impact area on CPVC did not show any evidence of impact on the direct impact face. However, the reverse side showed a starburst fracture from the center extending up to 3" in diameter. The coating did not demonstrate any indication of lifting or loss of adhesion. A general observation was that the bottom and top edges of panels exhibited yellowing with less of the white, streaky, chalk-like surface deposits. This was due to the support rack in the QUV cabinet, partially protecting those portions of the panel from exposure. Patterns of streaky, white material result from condensation rundown on panel faces.

System 3 - Devran 230. Examination of the panels for chalking resulted in a rating of "6" for all of the panels tested. When compared to an unexposed control, all panels were shown to have lost gloss to a flat finish. Visual examination of chalking test locations were barely discernible at an angle. On close inspection a small pattern was noted where the chalk test was conducted. A color change in the panels, compared to the control, was noted. The panels yellowed to a light tan color exhibiting some streaks a darker brown due to run-down from the condensation. This was also evident along the scribes. Examination of the test panels for blistering found that no blistering had occurred on stainless steel aluminum or coupled panels. This included examination of seams, edges, panel faces, and scribed areas. The CPVC panels did not exhibit any blistering at the scribes or edges. Examination of the panels individually for corrosion showed there to be no visible corrosion at the scribes, edges, corners, or the seams of the coupled panels. The CPVC panels did not exhibit separation or lifting of the coating along scribes. The coating at these locations was adherent. General observations on these panels are similar to those noted for System #2, the edges protected by the support racks in the QUV cabinet were protected from chalking, however, they yellowed to a deep yellow. The pattern of staining on the panel faces left a dark brown stain associated with the distribution of moisture from the condensing humidity exposure.

System 4 - Carboline 890. Evaluation of each of the test panel pairs resulted in a rating of "2" for chalking. Chalk test areas were visible and resulted in a darker pattern than the white chalked surface. When visually compared to an unexposed panel the exposed panels exhibited a dull finish. The surface discoloration, although dull and flat, was slightly more yellow that the unexposed panel. The protected edges of the panels exhibited minor discoloration, still being predominately white in color with some gloss along the bottom edges. The top edges were more yellow although they retained a higher amount of the original gloss. The color of exposed panels was a dull, slightly off-white color, slightly more yellowed at locations where the chalk test was performed. The chalking material was a whiter color than the film beneath. Examination of the panels for blistering found no indications of blistering at the scribes or panel edges of the stainless steel panels. The aluminum panels did not exhibit blistering at the scribes or edges. Additionally, there was no evidence of blistering on coupled or CPVC panels, at scribes or edges. When examined for corrosion it was found that none of the test panels exhibited evidence of substrate corrosion along edges, seams, or in the vicinity of the holes or scribes. Examination of the CPVC panels did not indicate any loss of coating at the scribes or edges, the coating being adherent. Examination of the impact areas on the stainless steel panel found a dent, less than 1/2" in diameter. Although the coating was cracked, the majority was in place and appeared relatively firm. The film could be separated when picked at with a thumb nail. The reverse side showed a three line starburst crack, approximately 1/3" in diameter. The aluminum test panel impact area contained a dot near the center, less than 1/2" in diameter. The coating, which fractured from impact, had separated from the panel and was no longer present. The reverse side of the panel contained starburst crack pattern, approximately 1/3" in diameter. The impact area of the coupled panel exhibited damaged coating, less than 1/2" in diameter. At the center a slight amount of the substrate was revealed and the coating within is cracked. The reverse side of the panel showed no effect. The impact area on the CPVC panel resulted in a circular crack on the direct impact face. A slight dent can be seen in the coating where the impact ball struck. The circular crack arc was through 160 degrees and the internal edge of the crack was lifting. The coating seemed adherent as the circular piece could not be lifted from the panel easily. The reverse side of the impact contained a starburst pattern. The coating within the support circle lifted from the surface. As noted on previously examined systems, there was dark staining around the perimeter of the exposed faces due to the collection of condensation. This was noted on the exposed faces of coupled panels although the pattern was not clearly evident on the stainless steel, aluminum, or CPVC panels.

System 5 - Sherwin-Williams. Examination of the test panels for chalking showed the stainless steel and aluminum panels to exhibit a chalking rate of "6". The coupled panels when tested for chalking showed one to rate "6", the second a "4". Chalking CPVC panel resulted in a rating of "4". When compared to the nonexposed control, the exposed panels exhibited a dull, flat finish on exposed faces. The protected edges appeared to retain gloss although less than that present on the control. Examination of the panel surfaces where chalk testing was performed revealed a slightly yellow dot at the test locations. The test areas remained flat in gloss. The color change of panels was to a light yellowish color of flat chalk on panel faces, the protected edges a deeper yellow.

Darker brown staining was noted around the edges of aluminum panels and on one of the coupled panels. Once again, this appeared related to the distribution of condensing humidity. When examined for blistering, none of the panels exhibited blistering at scribes or edges. This included seams of coupled panels. Examination of the panels for evidence of substrate corrosion found neither stainless steel nor aluminum panels to exhibit evidence of substrate corrosion. Examination of the coupled panels found no evidence of corrosion at the scribe, however, one panel (#381) appeared to have a slight reddish discoloration at the base of the scribe. There was no evidence of corrosion formation and may be associated with discoloration due to migration of condensing water along the seam. Examination of the CPVC panels found no lifting or separation of the coating. The impact area of the stainless steel panel contained a slight crater and, although the paint was cracked, the coating was adherent to the panel. The reverse side exhibited one slight crack near the center of the impact area. The aluminum panel contained a slight dimple with a semi-circular cracking, however, the coating remained in place. The reverse side of the panel contained a starburst pattern, less than 1/2" in diameter. The impact area of the coupled panel included a circular area void of coating. The outer coating edge was adherent. The CPVC panel impact area, exhibited a small dark spot, however, there was no indication of fracture or a dent. The reverse side of the impact contained hairline cracks extending approximately 1 1/4" in diameter.

System 6 - UTPlast Extra. When evaluated for chalking, all of the test panels were rated a "9". There was no visible transfer to the test cloth, however, at the test locations there was a slight change in gloss. When visually compared to a non-exposed control the exposed panels had a decrease in gloss, to a flat black color, with minute dark spots scattered on the panel. These were probably associated with the flame application of the plastic powder. The darker spots contrast in gloss to the lighter more reflective black coating surface. Examination of color change showed that the panels remained black in color, however, due to the decrease in gloss, the black appeared a flatter and duller. It was noted that the edges of the panels protected by the support apparatus retained their original gloss and color. Viewed on angle, the chalking test locations exhibited spots of increased gloss. Examination for blistering found that stainless steel, aluminum and coupled panels did not exhibit evidence of blistering. Examination of the CPVC panels also found no blistering along scribes or edges. Examination of the panels for evidence of corrosion found no indication of corrosion on stainless steel panels at the scribes. A small white dot at the end of one of the scribes (panel #421) was judged not significant. Examination of coupled panels found no evidence of corrosion on panel #463, however, it was noted the exposed face of panel #464 contained a slight white, dulling color on the bottom half of the panel. There were indications of slight corrosion and the bottom edge of the aluminum coupled panel. No evidence of corrosion was visible at the scribe. There was no evidence of separation or delamination of the coating on CPVC panels at scribes or edges. Examination of the impact area of the stainless steel panel showed there to be fractured coating approximately 1" in diameter, which has lifted from the surface. The center was loose and easily removed from the substrate with a finger. The coating remained stuck to itself. The reverse side of the impact contained a small starburst pattern approximately 1/4" in circumference. Examination of the impact area on the aluminum panel found a smooth, uniform crater where the impacted struck. The reverse side of impact contained no evidence of damage. The impact on the coupled panel included a crater with fracturing of the coating on the outer perimeter. The interior of the crater contained split and separated coating . Visible substrate did not exhibit corrosion. The reverse face of the panel had no effect. The CPVC panel showed no effect on direct or reverse impact faces.

System 7 - UTPlast Ultra, over Aluminum. Evaluation of the test panels for chalking resulted in a rating of "9", no transfer of chalk to the test cloth. The test locations had a slight increase in gloss. When compared to an unexposed control the panels do not appear to have had a significant decrease in gloss. It should be noted that on the coupled panels and the CPVC panels the spray pattern of application was clearly evident over the thermally applied aluminum powder. This was not the case for stainless steel and aluminum panels. The pattern noted may be associated with heat distribution during the application of the coatings. When examined for blistering the stainless steel, aluminum and coupled panels did not exhibit blistering or separation. Examination of the CPVC panels found indication of blistering on CPVC panel #562 in the vicinity of the scribe. Lifted areas of coating were present on CPVC panels, originating within the scribe and resulting from of corrosion of thermally applied aluminum powder. Examination for corrosion found the stainless steel panels to exhibit no evidence of corrosion at the substrate or the aluminum film beneath the coating. Likewise, the aluminum substrate panels did not exhibit evidence of corrosion. Examination of the coupled panels found indications of aluminum corrosion on edges and one corner where the coating appeared damaged. There was no evidence of corrosion along the seam of the coupled panels. Examination of the CPVC panels revealed the aluminum coating film to be separated from the substrate. This is likely associated with heat application to the CPVC. The plastic coating remained adherent to the thermally applied aluminum film. The CPVC also showed the aluminum coating film to be delaminating from edges of test panels as well as periodic white flecks on the panel surface and lifting at the scribe. When peeled back, the aluminum film folded away revealing unaffected substrate beneath it. Examination of the impact areas on the stainless steel panels revealed a dimple at the point of impact. The coating was pushed away and revealed substrate. No effect was noted on the reverse side of the panel. The aluminum panel direct impact, also exhibited a uniform crater with unfractured coating. The reverse side of the panel showed no effect. No effect of impact was noted on the CPVC coated panel.

System 8 - Elite 8844 over Aluminum. When evaluated for chalking the test panels were all rated "4". The point of test was seen as a more yellowed colored dot. When visually compared to a nonexposed control the exposed panels exhibited a slight yellowing in color. The support protected areas of panels were more yellow than the exposed panel faces which contained a white surface powder over the dull, flat, yellowish coating. Some streakiness, associated with the white powdering surface, was consistent with the pattern of condensation. It was noted that a darker brown staining was present below the scribe on one of the stainless steel panels, on a coupled panel steel face and around the perimeter of the scribe of aluminum panel. Examination for blistering showed there to be no indication of blistering on any of the panels including the areas of scribe, edges, and seams of coupled panels. Examination of the test panels for evidence of corrosion showed there to be no indication of corrosion on the stainless steel panels at the scribes, edges or impact areas. Likewise, the aluminum test panels did not give any indication of corrosion of the substrate nor did the coupled panels. There was no evidence of corrosion, lifting or separation of the coating on CPVC panels. Examination of the areas of impact found there to be a slight dimple on the stainless steel panel. The center contained fractured coating, yet the edges were smooth and uniform. The reverse side had minor, barely discernible, cracking within the perimeter of the support. The aluminum test panel contained a dimple in the face of the panel. The reverse side exhibited a starburst pattern, approximately 1/3" in diameter. Examination of the impact area on the coupled panel found a dimple with some fracturing of the coating in the center, however, all the coating was intact. The reverse side of the impact showed no effect. Examination of the CPVC panel found no effect from direct impact, however, the reverse side contained a 5-pointed starburst pattern originating at the center.

System 9 - Plasite 7122. Examination of the test panels for chalking resulted in a rating of "6" for test panels examined. The test point locations were difficult to see when examined. There was no clear indication of the test point. When compared to an unexposed control the exposed panels demonstrated a dulling and a slight change to a light yellow color. The edges of the panels which were protected from exposure retained their original gloss and color. When examined for blistering there were no indications of blistering at the scribes of the stainless steel, aluminum panels or at the scribes, edges, or seams of the coupled panels. No evidence of blistering was observed at the scribes or edges of the CPVC panels. Examination of the coatings for evidence of corrosion found no indication of corrosion on the stainless steel or aluminum panels. One coupled panel had a slight reddish color at the lower portion of the stainless steel face, adjacent to the aluminum test panel. No evidence of corrosion was noted on the second coupled panel. No separation or lifting of the coating on either CPVC panel was noted. Examination of the steel panel impact areas found a dimple pattern with slight damage and fracturing of the coating. Lifting of coating along the perimeter of the dimple was noted. The reverse side of the impact showed no effect. Examination of the aluminum panel impact showed a dimple with no rupture of the coating. The reverse side of the impact exhibited a starburst pattern, approximately 1/2" in diameter. Examination of the direct impact face on the coupled panels showed there to be a crater formed with lifting along the perimeter. The reverse side of the impact showed no effect. Examination of the CPVC panel for direct impact revealed no effect on the panel face, however, the reverse side contained a 5-pointed starburst pattern, the edges of which had lifted.

System 10 - Aquatapoxy. Examination of the exposed panels for chalking resulted in a rating of "2" for all exposed panels. The panels surfaces were dulled with a white chalky surface material and, at the point test location, the test removed the white powdery material revealing a flat, yellow color coating beneath. When compared to a nonexposed control, the panels had developed a yellow color with white surface chalk. The protected edges of the panels yellowed, however, they retained the gloss of the original coating. A dark brown staining along tops bottoms and in the vicinity of the edges was noted. This was associated with the migration of condensate down the panel faces. Chalk, gathered as a result of the chalk test, could be blown off of some areas. When examined for blistering there was no indication of blistering in the vicinity of the scribes or panel edges, including the edges of the coupled panels. It should be noted that the coating "creeps" away from sharp panel edges, however, the seam between the stainless steel aluminum panels parts of coupled was thoroughly coated. No indication of blistering was evident on the CPVC panels. Examination of the test panels for evidence of corrosion found the stainless steel and aluminum panels to be free of evidence of corrosion. It was noted that the lower scribes of panels appeared to contain a white material. No evidence of substrate corrosion was visually apparent and the white discoloration was associated with surface chalk. Examination of the coupled panels, found that panel #791, showed evidence of red-rust corrosion at the bottom right-hand edge of the scribe on the stainless steel panel. There was no indication of corrosion on the aluminum panel face. It was noted that the bottom portion of panel #791 exhibited brown rust color staining. The bottom right-hand corner of stainless steel coupled panel #792, exhibited brown stain as dots. This may have been the result of exudation of the resin portion of the coating material. Examination of panel surfaces subject to impact found the stainless steel panel, impact area cracked in a ring like pattern approximately 1 1/4" in diameter. Within the ring the coating was lifted and separated from the substrate. Lifted coating points exhibited a dark brown staining. There were minor indications of a light, white discoloration on the panel surface, probably associated with migration of chalk on the panel. The aluminum test panel direct impact face contained a dent. There were four cracks around the dimple formed by the impact. These were not interconnected. The reverse impact face exhibited very fine cracks in a starburst pattern. The coating did not appear to have lifted from the surface. Examination of impact on the coupled panel was similar to that observed on the stainless steel. A circular pattern, approximately 3/4" in diameter, was present with coating from the interior absent. Examination of the reverse impact side showed no effect. Examination of the impact area on the CPVC panel found no effect on the direct face. The reverse face exhibited starburst cracking. The coating was not lifted and cracks appeared as dark lines in the coating surface.

Section IV C

NASA-JSC Facility Exposures

Test panels placed in the WETF Rotunda and the exterior Laydown area near Building 36 were installed May 3, 1994. System #1 test panels were installed late due to the need to reapply the coating system to test panels. The original coating application was rejected due to excessive film build (30+ mils DFT) above the manufacturer's recommendation of 15 mils. System #1 panels were installed approximately May 14, 1994. Test panel installation into the WETF Pool for immersion exposure (WETF, Cathode, Repair) was delayed due to NASA maintenance activities. All systems were installed in the WETF pool May 23, 1994. The "Repair" panels were removed from the WETF Pool August 15, 1994 to conduct hand tool/power tool surface preparation on scribes, impacted surfaces and edges exhibiting evidence of coating failure. "Touch-up" coating application was performed and the coating systems allowed a proper cure period prior to return to immersion exposure on August 24, 1994. All systems under test were removed from their exposure environments on October 4, 1994 for evaluation. It should be noted that the Rotunda samples were inadvertently placed in the WETF Pool for a period of approximately five days. Observations recorded and reported for the panels subject to "Rotunda" exposure reflect total exposure, including the transitory immersion.

LAYDOWN AREA EXPOSURE - 3700 HOURS

System 1 - PF 112. In general the panels exhibited little effect from a total of approximately 3480 hours exposure. Due to late installation, this system experienced about 260 hours less exposure than the other test systems. The gloss was a little more dull than that of an unexposed control. The panels are subject to smears and marks on the surface due to handling. Examination for chalking shows there to be no evident change in gloss at test locations where the chalk test was performed and all were rated as "10". There was no indication of blistering of coating or rusting (corrosion) of the panel substrate subsequent to exposure.

System 2 - NSP 120. The panels, when evaluated for chalking exhibited ratings of "8". Visually compared to a control panel, the gloss of exposed panels appears to have changed significantly and there has been a slight change in color. The exposed panels appeared more yellow than the unexposed control. The exposed panels did not exhibit blistering nor was there any indication of corrosion on the panels at edges, X-scribes or the seams of coupled panels. The direct impact area of aluminum panel #109 does exhibit what appeared to be minute corrosion on the exposed aluminum substrate. It should be noted that at the impacted areas of the stainless steel, aluminum and coupled panels exhibited cracking and fracturing of the paint in a circular pattern. This indicates the coating to be somewhat brittle on these substrates. The point of impact showed no effect on the face of the CPVC panel, however, minor cracking was exhibited on the reverse side of the impact.

System 3 - Devran 230. Test panels were tested for chalking and resulted in a rating of "8". When visually compared to controls, the exposed panels exhibited a decrease in gloss and a slight yellowing in color. The coupled panels appeared to have changed slightly more in hue than the steel, aluminum, or CPVC panels. When tested for chalking the test locations exhibited an increase in gloss. The panels did not exhibit blistering. When examined for the presence of corrosion none was visually evident. This included seams and edges of the coupled panels. The direct impact areas on the stainless steel, aluminum and coupled panels exhibit small dot due to damage at the time of impact. This resulted in slight crumbling of the coating, approximately the diameter of the impact ball with apparent surface corrosion being associated with imbedded coating and difficult to discern. There was no visible impact damage on the CPVC panel face but a star burst pattern was present on the rear of the panel at the impacted point.

System 4 - Carboline 890. The aluminum, stainless steel and CPVC panels exhibited a chalking rating of "6" when tested. The coupled panels when tested were rated "8". Compared to the control panel, gloss was reduced. The color of the coating had become yellowed as compared to an unexposed control panel. None of the panels exhibited blistering on the face, along edges nor in the vicinity of scribes, and all panels were rated "10". When examined for corrosion products, none of the panels exhibited visual evidence of corrosion on the scribes, seams or edges and were rated "10". Examination of the direct impact areas did not reveal evidence of corrosion. The impacted areas are approximately the diameter of the impact ball. The reverse impact side of the panel coating was fractured. The CPVC panel exhibited a slight circular impact dot and crack but no dent. The coating on the reverse side of the CPVC panel was cracked in a pie shaped fashion and "wedges" lifted from the surface.

System 5 - Sherwin-Williams. Chalking for all the single panels (aluminum, stainless and CPVC) was rated "8", however, the coupled panels were rated "6" indicating an increased degree of chalking vs. the single panels. The chalk test locations exhibited an increase in the gloss of the coating. When visually compared with a control panel, the panels under exposure exhibited a decrease in gloss. There was also a color change noted, the exposed panels being "off-white" relative to the white control panel. When examined for blistering, no blistering was present on panel faces nor around scribes. When examined for corrosion products none of the panels exhibited visible corrosion product at the scribes nor was corrosion product noted around the edges. At the areas of direct impact, the stainless steel panel substrate was exposed, approximately the diameter of the impact ball. The aluminum panel showed a smaller diameter substrate exposure. The coupled stainless steel panel exhibited a loss of coating at the impact point, approximately the diameter of the ball. On the CPVC panel, a slight mark was seen. However, there was no dent in the panel or fracturing of the coating on the front side. The reverse side of the CPVC panel exhibited cracking.

System 6 - UTPlast Extra When tested for chalking, all panels were rated "9". The point of testing could be seen when viewed at an acute angle. When visually compared to an unexposed control the exposed panels did not exhibit dulling or change in the color. It should be noted that the thermal spray application pattern could be seen when viewed at an angle, probably due to texture associated with product flow out and manner of application. Examination of the exposed panels for blistering revealed that the panels did not exhibit blistering on the panel faces nor in the vicinity of the scribes. Examination of the coupled panels at the seams, and bolts did not reveal blistering. Examination of the exposed panels for corrosion showed no evidence of corrosion of the stainless steel, aluminum or coupled panels. No evidence of lifting or corrosion product was noted on the coated CPVC panels. Examination of the areas of direct impact show the paint to exhibit a circular fractured pattern on the stainless steel panel with a dimple where the coating was pushed away from the impact area. The coating was cracked and separated in a circular pattern. The aluminum panel exhibited a dent in the coating at the impact point. The impact on the coupled panel exposed substrate and the coating was "pushed" aside resulting in a crater-like formation with cracking. The impact area of the plastic CPVC panel (which was curved as a result of heating during application) did not exhibit damage on the front or reverse side. The reverse impact side of the stainless steel panel #417 exhibited a small, 1/4" area with a star pattern crack.

System 7 - UTPlast Ultra over Aluminum. Evaluation for chalking resulted in a rating of "9" for all panels. A rating of "9" indicates no chalk transfer but a slight mark at the test area. Discoloration of the panel surfaces was not evident. When examined for blistering no blisters were present on the panel faces, in the vicinity of the scribes, edges or seams. CPVC panel #557 revealed a #2 size blister at an edge due to undercutting. This appeared to simply reflect a heat affected area during application of aluminum and plastic coatings. Adhesion testing confirmed poor bonding. Examination of the panels for corrosion products revealed none to be present. CPVC panel #558 exhibited lifting of the thermally applied aluminum from the substrate in the vicinity of the scribe. Impact areas of the coupled, stainless steel and aluminum panels only exhibited a crater at the point of impact. In all cases, the coating material was in place, simply deformed and adherent. The CPVC panel did not show evidence of an impact area on the face of the panel. The back of the panel was not coated to minimize further deformation of CPVC panels during flame application.

Deformation of the CPVC panels of this coating system, as well as coating systems #1 and #6, also thermally applied, indicates an inappropriate use of thermally applied systems over heat sensitive substrates such as plastic materials.

System 8 - Elite 8844, over Aluminum When evaluated for chalking, a rating of "8" on single panels and 6 on coupled panels resulted due to chalk transfer to the test cloth. There was a slight change in panel sheen at the test point areas. When visually compared to an unexposed control, the exposed specimens had yellowed.

When examined for blistering none of the exposed panels were found to exhibit blistering. Examination of the panels for corrosion product revealed none to be present on stainless steel, aluminum or coupled panels. No evidence of corrosion product (due to aluminum undercoat) was apparent on the plastic CPVC panels. Examination of the impact areas on the stainless steel panels shows a dimple, approximately the diameter of the impact ball, and small cracks in the coating. The aluminum panel exhibited a dent from the impact of the ball, however, the coating was smooth, uniform and noncracked. The reverse side of the aluminum panel, exhibited a star-shaped crack. The CPVC panel direct impact showed no effect, however, the reverse side exhibited a 4-pointed star-like crack. It should be noted that during the application of the Elite 8844 over the thermally applied aluminum what appeared to be "bubbles" migrated through the coating film leaving small depressions in the coating. This is believed to be associated with the porosity of thermally applied aluminum powder.

System 9 - Plasite 7122. When evaluated for chalking, the exposed test panels were rated "6" with a slight change in gloss at the point of testing. When visually compared to a nonexposed control, the coating was found to have yellowed slightly to an "off white" color and exhibited a decrease in gloss. When examined for blistering, none of the test panels exhibited blistering on the face and no evidence of blistering or undercutting was apparent at scribes.

Evaluation of the panels for corrosion revealed no evidence of corrosion on stainless steel, aluminum panels or coupled panels. When examining impact areas, coating on stainless steel panel #661 was observed to be deformed with a slight fracture around the diameter of the impact area. A slight amount of surface corrosion appeared to be present underneath. The impact area of the aluminum panel was slightly deformed by the tip of the impact ball but not fractured. The reverse side exhibited a star-type fracture. Examination of the impact area of the coupled panel revealed the circular pattern of impact with a slight lifting of the coating. Examination of the CPVC impact panel exhibited no evidence of direct impact. The reverse side, however, did exhibit cracking.

System 10 - Aquatapoxy A6. When evaluated for chalking, the panels were rated "6". When visually compared to a nonexposed control, the exposed panels showed a marked change in color to yellow. When examined for blistering none of the panels exhibited blisters. Examination for corrosion revealed none to be present on stainless steel, aluminum, or coupled panels. This system, applied by brush, did exhibit creepage and, therefore, reduced coverage at edges and corners. Examination of impact areas on stainless steel and coupled panels, revealed the impacted area to expose the substrate in a circular 3/4" diameter area. This was associated with coating brittleness. Radially cracked due to impact, the coating was separated from the substrate, however, beyond the cracked area, the coating appeared well adhered. A similar pattern was not observed on the aluminum panel, however, the reverse face was cracked. The face of the CPVC impact panel showed no evidence of impact. The reverse side, exhibited a starburst crack which was adhered to the surface.

ROTUNDA EXPOSURE - 3700 HOURS

It should be noted that the test panels were inadvertently placed in immersion (WETF pool) for five (5) days. Thus the observations reflect this exposure as well.

System 1 - PF 112. (Approximately 3460 hours exposure) In general the panels seem to exhibit little effect from exposure. The gloss was equivalent to that of an unexposed control. The panels were shown to be subject to smears and marks on the surface due to handling. Examination for chalking showed there to be a slight change in gloss at the test locations where the chalk test was performed after about 2000 hours exposure, however, final examinations were rated "10". There was no indication of blistering or corrosion of panel substrates.

System 2 - NSP 120. The panels, when evaluated for chalking exhibited none. When compared to a control panel, the gloss of exposed panels does not appear to have changed significantly although there was a slight change in color. The exposed panels appeared more tan than the unexposed control. The exposed panels did not exhibit blistering nor was there any indication of corrosion on the panels on edges, at X-scribes or seams of the coupled panels. The direct impact area of stainless steel panel #85 did exhibit a spot of corrosion on the exposed substrate. It should be noted that the impact areas of the stainless steel, aluminum and coupled panels exhibited cracking and fracturing of the paint in a circular pattern. This indicates the coating to be brittle. The point of impact exhibited no effect on the face of the CPVC panel, but minor cracking on the reverse side of the impact point was present.

System 3 - Devran 230. Test panels were tested for chalking and resulted in all being rated "9". A rating of "9" indicates little or no transfer to the test cloth, however, a change of gloss was visible where tested. When visually compared to controls, the exposed panels exhibited a decrease in gloss and a slight change in color. Where tested for chalking the test locations exhibited an increase in gloss. The panel faces did not exhibit blistering, however, aluminum panels exhibited minute #4 blisters in the vicinity of the scribe. Density was less than "few" and was associated with corrosion. When examined for the presence of corrosion, the scribe of panel #192 (aluminum) a trace amount was visually evident. Minor corrosion was noted at direct impact areas on the stainless steel, aluminum and coupled panels. There was no visible impact damage on the CPVC panel face but the reverse was cracked. The exposure environment is considered mild, however, the immersion of test panels in the WETF pool has probably contributed to the blistering and corrosion noted.

System 4 - Carboline 890. None of the panels exhibited chalking, however, a slight change in gloss was evident where the chalk test was conducted. Compared to the control panel, exposed panel gloss appears similar. The color of the coating is very slightly gray compared to a control panel. None of the panels exhibited blistering on the face, along edges nor in the vicinity of scribes, and all panels were rated "10". When examined for corrosion products, none of the panels exhibited visual evidence of corrosion on the scribes, seams or edges and were rated "10". Examination of the direct impact areas did not reveal evidence of corrosion. The impacted areas are visually evident and approximately the diameter of the impact ball. The reverse side of the panel coating was fractured where impacted, the cracked area of coating within the circumference of the impact support ring was adhered. The CPVC panel exhibited a slight circular impact dot and appeared lifted in a 1" diameter. The coating within the support ring circle on the reverse was lifted from the surface and cracked in a pie shaped fashion.

System 5 - Sherwin-Williams. All panels were rated "9", for chalking. There was no chalk transfer to the test cloth, however, at the test location there was a visible increase in the gloss of the coating. When visually compared with a control panel, the panels under exposure exhibited a decrease in gloss. There was no apparent color change as the exposed panels appeared similar to the control panel. When test panels were examined for blistering, none was noted. Examination for corrosion products found that none of the panels exhibited visible corrosion at the scribes nor was any corrosion product observed around edges or other surfaces. At the areas of direct impact, the stainless steel panel substrate was exposed approximately the diameter of the impact ball and slightly discolored. The aluminum panel contained a dent from the impact but the coating remained in place. A slight mark from impact could be seen on the CPVC panel and no dent or fracture in the CPVC panel coating was present. The reverse side of the CPVC panel contained barely visible cracking of the coating, but no separation of the coating from substrate occurred.

System 6 - UTPlast Extra When tested for chalking, results of chalking were rated "10", no transfer onto the test fabric or visible surface change. When visually compared to an unexposed control the exposed panels did not exhibit dulling or a change in the color. An application pattern texture could be seen when viewed at an angle. Examination of the exposed panels for blistering revealed none on the panel faces nor in the vicinity of the scribes. Examination of the coupled panels at the seams and fastener bolts did not reveal evidence of blistering. Examination of the exposed panels for corrosion showed no evidence of corrosion of the stainless steel, aluminum or coupled panels. No evidence of coating separation or lifting was noted on coated CPVC panels. Examination of the areas of direct impact found the coating to exhibit a circular fracture pattern on the stainless steel panel with a dimple where the coating was forced away from the impact area. The coating was cracked and separated in a circular pattern. The aluminum panel exhibited a dent in the coating at the impact site with no cracking. Impact on the coupled panel exposed the substrate, the coating was pushed aside in a crater-like formation and a trace amount of corrosion product was visible at the center of the coupled panel impact area. The CPVC panel (which was curved) did not exhibit damage on the front or reverse side as a result of impact. The reverse impact side of the stainless steel and aluminum panels exhibited small, 1/4" area, star-like cracks.

System 7 - UTPlast Ultra over Aluminum. Evaluation for chalking resulted in ratings of "6" for stainless steel and aluminum panels. The coupled panels exhibited a chalk rating of "9" and CPVC panels were rated "8". The degree of discoloration of the panel surfaces is consistent with the chalking scale. The aluminum and stainless steel panels exhibited a white surface deposit to a greater extent than the coupled or CPVC panels. When visually compared with an unexposed control panel, all exposed panels exhibited a gray-white surface deposit which had a waxy-like feel as opposed to a powder as customarily observed. The stainless steel panels and aluminum panels appeared as if they were mist coated light gray. The coupled panels exhibited localized discoloration, particularly the seam of panel #540. The CPVC panel surface deposits appeared to be more light blue in color than the other panels. When examined for blistering no blisters were present on the panel faces, in the vicinity of the scribes, edges or seams of coupled panels. Examination of the CPVC panels revealed a #2 blister on panel #555. Edge undercutting indicated an area of corrosion of applied aluminum beneath the plastic coating. Examination of the panels for corrosion products revealed corrosion products along portions of scribes on stainless steel, aluminum and coupled panels. CPVC panels exhibited corrosion in the vicinity of the scribe. It should be noted that CPVC panel edges were not sealed. Corrosion products were found to be the result of corrosion of thermally applied aluminum. No blisters appear to have developed as a result of corrosion of applied aluminum. Impact areas of the coupled, stainless steel and aluminum panels simply exhibit a crater at the point of impact. In all cases, the coating material was in place, simply deformed, and relatively adherent. The CPVC panel, did not show evidence of an impact area on the face of the panel. The back of the panel was not coated.

Temporary immersion in the WETF pool contributed to the effects noted. The extent of surface discoloration of all panels is believed to be associated with the aluminum substrate. Corrosion product observed and described above is also believed to be related to thermally applied aluminum powder. Deformation of the CPVC panels due to thermal application of this coating system has been previously noted.

System 8 - Elite 8844, over Aluminum When evaluated for chalking, none of the panels tests resulted in chalk transfer to the test cloth. There was a slight change in panel sheen at the test point areas thus, panels were rated "9". Overall, the coating system appeared to have retained much of its gloss appearing similar to the gloss of an unexposed control. When visually compared to an unexposed control, the exposed specimens are observed to have yellowed in color.

When examined for blistering, four (4) of the exposed panels exhibited blistering on the panel face. Stainless steel panel #580 exhibited three small, #4 blisters associated with the applied aluminum. Aluminum panel #601 also exhibited three (3) small blisters, perhaps 2 mm diameter (#6). Both coupled panels did exhibit blistering on the stainless steel substrate. Panel #621 contain #2F blistering as did #622, although with fewer blisters. Examination of the panels for corrosion product revealed minor white corrosion product at the holes of stainless steel panels. Aluminum test panels did not exhibit areas of corrosion. The coupled panels did not exhibit areas of corrosion at scribes, however, the stainless steel and aluminum coupled panels did exhibit areas of white corrosion product at edges and bolts. No corrosion was apparent on the plastic CPVC panels. Examination of the impact areas on the stainless steel panels shows a dimple, approximately the diameter of the impact ball, and small cracks in the coating within. The aluminum panel exhibited a dent from the impact of the ball, however, the coating was smooth, uniform and noncracked. The reverse side of the aluminum panel, exhibited a star-shaped crack. The starburst crack was less than 1/2" in diameter. Corrosion product was present at the impact area of the coupled panel. The CPVC panel direct impact showed no effect, however, the reverse side exhibited a 3-point crack approximately the diameter of the support ring. No corrosion product was observed to be present. Application of the Elite 8844 over thermally applied aluminum resulted in "gas" bubbles which migrated through the coating film leaving what appeared to be small fisheyes or pinholes in the coating. This was particularly evident on aluminum panels and believed to be associated with the porosity of the applied aluminum. It is speculated that the Elite 8844, without the coat of aluminum, would have exhibited better performance.

System 9 - Plasite 7122. When evaluated for chalking, the exposed test panels were rated "9" indicating no transfer of chalk to the test cloth, however, a slight change in gloss at the point of testing. When visually compared to a nonexposed control, the coating was found to exhibit a minor decrease in relative gloss. When examined for blistering, none of the test panels exhibited blistering.

Evaluation revealed no evidence of corrosion except for impacted metal surfaces which "grayed". When examining impact areas, coating on the stainless steel panel, was observed to be deformed with a slight fracture around the diameter of the impact. Although intact, the coating could be peeled free with a thumbnail. A slight amount of surface corrosion was visible underneath the loose coating. The impact area of the aluminum panel was found to be similar to the stainless steel panel. The reverse side of the aluminum panel exhibited a single fracture line. Examination of the impact area of the coupled panel revealed a circular pattern of impact with a slight lifting of the coating. Although cracked around the perimeter, the coating could not be gently lifted by thumbnail. Examination of the CPVC impact panel revealed no evidence of direct impact other than a slight discoloration, the reverse side, however, did show cracking.

System 10 - Aquatapoxy A6. When evaluated for chalking, the panels were rated "9" due to a slight change in gloss at the point of chalk test. When visually compared to a nonexposed control, the exposed panels showed a slight change in color resulting in a mother-of-pearl luster to the surfaces. Little change of gloss was apparent. When examined for blistering none of the panels exhibited evidence of blistering along edges, the face of the panels or in the vicinity of scribes. Examination for corrosion revealed no evidence of corrosion in the vicinity of the scribes on stainless steel, aluminum, or at scribes on coupled panels. One coupled panel (#785), did show minute evidence of corrosion at the impact. Applied by brush, creepage away from sharp corners was noted. There was no evidence of coating failure on the CPVC panels, except for separation due to impact. Examination of impact areas on stainless steel panels, revealed the impact area to extend beyond the immediate area of impact and associated with coating brittleness. Although the coating separated from the substrate, beyond the impact damage the coating appeared well adhered. A small dent was observed on the aluminum panel. Impacted coating on the coupled panel was lifted from the substrate. On probing, the fractured coating separated from the substrate. The face of the CPVC impact panel showed no evidence of impact although the reverse side exhibited a starburst crack. The reverse side of the aluminum panel also contained a starburst crack.

WETF POOL EXPOSURE - 3200 HOURS

System 1 - PF 112. Examination for chalking shows there to be no change in gloss at the location where the chalk test is performed and all panels were rated a "10". In general the panels seem to exhibit little change in gloss. In addition, color was essentially the same as the unexposed control. The panels are subject to smears and marks on the surface due to handling. There was significant indication of blistering and corrosion of the aluminum panel substrate at scribes panel #24 more so than panel #23. The stainless steel, CPVC and stainless steel portion of coupled panels exhibited no blistering or corrosion. The corrosion product and associated "blisters" at scribes of aluminum substrate portion of coupled panels were noted to be related to creepage. Due to this observation, these scribes and those of other panels subject to the WETF pool environment were separately rated using Table 1 of ASTM D1654. An ASTM D 1654 "factor" was applied to the D610 corrosion rating to yield a grading value. Significantly no other panel defects were noted for this system.

System 2 - NSP 120. The panels, when evaluated for chalking exhibited no transfer but were rated "9" due to marks left at test points. Visually compared to a control panel, the gloss of exposed panels has dulled and there has been a change in color. The exposed panels appeared more tan than the unexposed control. Only the exposed coupled panels exhibited blistering. Blistering was noted to be present only on the aluminum substrate portion of coupled panels and was more significant on panel #127 than panel #128. Corrosion was noted on the X-scribes of panel #84 (stainless steel) and on the seam of coupled panel #128. The direct impact area of the panels did exhibit apparent corrosion, however, coating particles were also present. It should be noted that the impact areas of the stainless steel, aluminum and coupled panels exhibited cracking and fracturing of the paint in a circular pattern, indicating the coating to be somewhat brittle. The point of impact, shows no effect on the face of the CPVC panel, but exhibited some minor cracking on the reverse side of the impact. This was true of the stainless and aluminum panels as well.

System 3 - Devran 230. Test panels were tested for chalking and for all single panels resulted in ratings of "9". A rating of "9" indicates little or no transfer to the test cloth, however, a change of gloss was visible where tested. The coupled panels exhibited chalk transfer to the test cloth and one was rated "8", the second "6". When visually compared to controls, the exposed panels exhibited a decrease in gloss and a slight change in color. The panel faces did not exhibit blistering, however, the aluminum test panels did exhibit blisters in the vicinity of scribes and seams of coupled panels. Typically the blisters were few, and associated with corrosion products. When single panels were examined for the presence of corrosion, one stainless steel and both aluminum panels exhibited corrosion. The stainless panel (#168) had a corrosion spot near the center, the aluminum panels exhibited corrosion at scribes. Corrosion was noted along the seams and edges of the coupled panels. The direct impact areas on the stainless steel, aluminum and coupled panels exhibit small dot due to damage at the time of impact. This resulted in slight crumbling of the coating, approximately the diameter of the impact ball. There was no visible impact damage on the CPVC panel. The reverse sides of the aluminum and CPVC panels were cracked.

System 4 - Carboline 890. None of the panels exhibited chalk transfer, however, a slight change in gloss was evident where the chalk test was conducted. The panels were rated "9". Compared to the control panel, gloss is dull. The color of the coating did not appear significantly different when compared to a control panel. None of the panels exhibited blistering on the face, along edges nor in the vicinity of scribes. All panels, except aluminum panel #272, were rated 10. Panel #272 had minute blistering on an edge. When examined for corrosion products, aluminum and stainless steel panels exhibited visual evidence of corrosion at holes or impact surfaces. The seams of coupled panels exhibited corrosion associated with the aluminum substrate. Examination of the direct impact areas did not reveal evidence of corrosion except on panel #249, a stainless steel panel. The impact damaged areas were approximately the diameter of the impact ball. The reverse side of the panel impact revealed coating to be fractured. The cracked coating was adherent. The CPVC panel exhibited a slight circular impact dot which was cracked around the circumference. The coating within the circle of reverse impact was cracked in a pie shaped fashion and lifted from the surface.

System 5 - Sherwin-Williams. All the panels were rated "9" for chalking, meaning that no chalk was transferred to the test cloth but the test location exhibited an increase in gloss. When visually compared with a control panel, the panels under exposure exhibited a decrease in gloss. There was little apparent color change. When examined for blistering, the stainless steel and aluminum panels exhibited no blistering on the panel face nor around scribes. One aluminum panel, #354, exhibited blisters, greater than 1/4" in diameter, around the panel hole. Coupled panels exhibited blistering along the seam, predominately on the aluminum substrate. Panel #374 was more severely blistered than coupled panel #373. One blister, approximately 1/2" diameter, was found to have undercut the coating beyond its apparent diameter. Blisters were also noted along holes of the aluminum portion of the panel. The companion coupled panel, #373, exhibited similar blister patterns but less severe. No blisters were noted on the coated CPVC panels. When examined for corrosion products one aluminum panel (#354) exhibited visible corrosion product at the hole. In addition it was noted that coating had chipped from the bottom edge revealing corrosion product. Coupled panels exhibited corrosion product at the seam between the stainless steel and aluminum panels. Coupled panel #374 exhibited more severe corrosion along the seam in the vicinity of the blisters. At the areas of direct impact, the stainless steel panel substrate was exposed approximately the diameter of the impact ball. The aluminum panel shows a dent from the impact but although cracked, the coating remained in place. The coupled stainless steel panel exhibited a loss of coating at the impact side, approximately the diameter of the ball. On the CPVC panel, a slight mark can be seen on the coating, however, there is no dent in the panel or fracturing of the coating on the front side. The reverse side of the impacted panels does not exhibit cracking.

System 6 - UTPlast Extra When tested for chalking, results of chalking were rated "9" with no transfer to the test fabric. The point of testing was seen when viewed at an acute angle. When visually compared to an unexposed control the exposed panels do exhibit some dulling but do not exhibit a change in the color of the panel. The application pattern can be seen when viewed at an angle. Examination of the exposed single panels for blistering revealed that the panels did not exhibit blistering on faces nor in the vicinity of the scribes. Examination of the coupled panels at seams, and bolts did not reveal evidence of blistering. Examination showed minute evidence of corrosion at the scribe of stainless steel panel #413 and aluminum panel #436. The corrosion product was revealed as discoloration and did not extend beyond the scribe. There was no indication of undercutting. Both of the coupled panels exhibited white corrosion product on the edge of each aluminum panel and along the seam of coupled panel #455. No evidence of lifting or corrosion product was noted for the coated CPVC panels. Examination of the areas of direct impact show the coating to exhibit a circular fracture pattern on the stainless steel panel with a dimple where the coating was "pushed" away from the impact area. The coating was separated in a circular pattern. The aluminum panel exhibited a smooth dent in the coating at the impact. Visually, corrosion product was present on the reverse side of the impact area. The impact on the coupled panel revealed substrate and the coating pushed aside in a crater-like formation which included cracking and lifting. Impact of the plastic CPVC panel (which was curved) did not exhibit damage on the front or reverse side. The reverse impact side of the stainless steel panel, (#413), exhibited a small, 1/4" area with a star pattern crack and corrosion spot.

System 7 - UTPlast Ultra over Aluminum. Evaluation for chalking resulted in mixed ratings including "4", "6" and "8". The coupled panels exhibited a chalking rating of "8" while the CPVC panels were rated "4" and "6". The degree of discoloration of the panel surfaces is consistent with the chalking scale. Both the aluminum panels and stainless steel panel #496 (rated 4) exhibited a white surface deposit to a greater extent than the coupled or CPVC panels. When visually compared with an unexposed control panel, all exposed panels exhibited a gray-white surface deposit which had a waxy-like feel as opposed to a dry powder as customarily observed. Stainless steel panel #496 and aluminum panels appeared as if they were coated light gray. The coupled panels exhibited localized discoloration and along with the CPVC panels appeared to be more blue in color than the other panels. When examined for blistering no blisters were present on the panel faces, however, in the vicinity of scribes corrosion products created lifting with a blister-like appearance on stainless and aluminum panels. Examination of the CPVC panels revealed a similar appearance. Examination of the panels for corrosion products revealed corrosion products along portions of scribes on stainless steel, aluminum and CPVC panels. The coupled panel scribes did not exhibit evidence of corrosion. Coupled panels did exhibit white corrosion product around bolt heads (stainless steel side) panel seams and edges of the aluminum substrate. Coupled panels also exhibited corrosion products along the edges. It was unusual that neither coupled panel exhibited corrosion products at scribes. A minor amount of white corrosion was noted at the fastener nuts on the backside. CPVC panels exhibited corrosion, lifting and curling of the thermally applied aluminum from the substrate in the vicinity of the scribe and undercutting along the top edges was significant. It should be noted that CPVC panel edges were not sealed. Corrosion products are the result of thermally applied aluminum powder. The "apparent blisters" developed as a result of corrosion of applied aluminum. Impact areas of the coupled and stainless steel aluminum panels simply exhibit a crater at the point of impact. A minute amount of material, visible as small white color at the bottom of crater, were noted although the base of the crater was predominately black (coating). The white color probably resulted from the "chalk". In all cases, the coating material was simply deformed and adherent. The CPVC panel did not show evidence of an impact area on the face. The back of the panel was not coated due to heat deformation of CPVC during flame application.

As discussed above for System #1, an ASTM D1654 "factor" was applied to the rated value. The surface discoloration of all panels may be associated with the applied aluminum substrate, however, this has not been established.

System 8 - Elite 8844, over Aluminum When evaluated for chalking, none of the panels tests resulted in chalk transfer to the test cloth and resulted in ratings "9". There was a slight change in panel sheen at the test point areas. Overall, the coating system had lost much of its gloss although chalk testing left gloss spots, at the point of test. When visually compared to an unexposed control, the exposed specimens are observed to have changed in color to a tan.

When examined for blistering none of the exposed panels exhibited blistering on the panel face. The stainless steel and aluminum panels did exhibit dense "blistering" along the scribes due to formation of corrosion product associated with the aluminum undercoat. The coupled panels exhibited corrosion induced blistering at scribes of the aluminum substrate. There was no evidence of blistering on CPVC panels. None of the panel faces, away from the areas of scribes, exhibited blistering. The observed blisters, due to corrosion and undercutting were also rated as a corrosion failure. Examination of the panels for corrosion product revealed white corrosion product at the scribes of stainless steel and aluminum panels. The coupled panels did exhibit slight corrosion at scribes of stainless steel, however, the aluminum coupled panels exhibited areas of white corrosion product which, as indicated above, were associated with blisters. Coupled panels had small blister-like corrosion areas near bolt heads and nuts. No evidence of white corrosion product was apparent on the CPVC panels. Examination of the impact areas on the stainless steel panels shows a dimple, approximately the diameter of the impact ball, and corrosion cracks in the coating. The aluminum panel exhibited a dent from the impact of the ball, however, the coating was smooth and noncracked. The reverse side of the aluminum panel, exhibited a star-shaped crack with corrosion product within. The starburst crack was less than 1/2" in diameter. Corrosion product was present at the impact area of the coupled panel. The CPVC panel direct impact showed no effect, however, the reverse side exhibited a 5-pointed star-like crack approximately the diameter of the support ring. No corrosion product was observed to be present. It is speculated that use of the Elite 8844, without the coat of aluminum beneath, would have shown better evidence of corrosion resistance. Generally, defects associated with the surface film were due to the thermally applied aluminum powder. The ASTM D1654 "factor" applied is reflected in the "corrosion" performance rating.

System 9 - Plasite 7122. When evaluated for chalking, the exposed test panels were rated "9", indicating no transfer of chalk to the test cloth, however, a slight change in gloss at the point of testing. When visually compared to a nonexposed control, the coating was found to have yellowed slightly and exhibited slight decrease in relative gloss. When examined for blistering, corrosion associated blisters were noted on aluminum panels in the area of holes. Coupled panel aluminum substrate scribes and seams showed blisters related to undercutting as a result of corrosion.

Evaluation of the panels for corrosion revealed no evidence of corrosion at the scribes of the stainless steel or aluminum panels. As noted above, there was corrosion along the seam on the aluminum side of coupled panels, the fastener nuts and scribes. These were present in blister-like patterns which contained white corrosion product. Additionally, white corrosion products were noted to be present along seams.

The impact area of the aluminum panel was devoid of coating and the reverse side exhibited a star-type fracture with corrosion product. Examination of the impact area of the coupled panel shows the circular pattern of impact with a slight lifting of the coating. Although cracked around the perimeter, the coating could not be gently lifted with a thumbnail. Examination of the CPVC impact panel shows no evidence of direct impact. The reverse side, however, does show cracking with separation of the coating.

System 10 - Aquatapoxy A6. When evaluated for chalking, single panels were rated "9" due to a slight change in gloss at the point of chalk test. The coupled panels were rated "10". When visually compared to a nonexposed control, the exposed panels showed a slight change in color resulting in a light tan surface. Gloss was duller than the control but seemed due to a surface film. When examined for blistering none of the single panels exhibited evidence of blistering along edges, the face of the panels or in the vicinity of scribes. The aluminum portion of coupled panels exhibit small blisters, only one or two being present. Examination for corrosion revealed no evidence of corrosion in the vicinity of the scribes on stainless steel, aluminum, or coupled panels. The coupled panels did, however, show evidence of corrosion along the outer edge of the aluminum panels and panel #783 had a corrosion spot on the aluminum scribe. This system, applied by brush, exhibited creepage away from edges. This contributed to occurrence of corrosion on exposed aluminum edges of coupled panels. There was no evidence of coating failure on the CPVC panels. Examination of impact areas on stainless steel panels, revealed the impact area to be somewhat circular, extending beyond the immediate area of impact, with spot corrosion on the exposed substrate. Where cracked due to impact, the coating separated from the substrate, however, beyond the crack the coating appeared well adhered. An impact dimple was observed on the aluminum panel. The reverse side was cracked but coating remained. The circular pattern, due to impact damage to coating on the coupled panel was lifted from the substrate. On probing, lifted coating separated from the substrate. The face of the CPVC impact panel showed a thin circular crack. The reverse side, exhibited a starburst crack which remained adhered to the surface.

WETF-REPAIR SYSTEMS - 3000 HOURS CUMULATIVE EXPOSURE

Duplicate stainless steel aluminum and CPVC panels for each coating system were placed in the WETF pool for 2000 hours exposure. Each panel contained an "X" scribe on the bottom third of the panel and one member of each pair was impacted, 90 inch-lbs for metal and 60 inch-lbs for CPVC, prior to immersion. Subsequent to 2000 hours, the panels were removed from exposure and the scribed and impacted surfaces subject to hand-tool and power-tool cleaning at the scribed and impact damaged points. The lower half of each panel was then subject to touch-up employing the coating system previously applied. Panels were returned to the WETF pool for an additional 1,000 hours exposure. Upon removal the "repair panels" were evaluated in same manner as described above.

System 1 - PF 112. Chalk testing resulted in ratings of "9" for all panels including "old" and "touch-up" coating. Surface gloss and color was similar to that of an unexposed control and only a slight "dulling" was noted on panels #16 (stainless steel) and #38 (aluminum). Blistering and corrosion noted along the scribes of aluminum panels after 2,000 hours exposure were repaired and did not present after an additional 1,000 hours exposure. CPVC panels did not exhibit good "repair" results. Panel #75 was bubbled from thermal application of the repair coating and Panel #76 exhibited very poor adhesion. No blistering or corrosion was present on any of the panels after termination of exposure in the WETF pool.

System 2 - NSP 120. All test panels were rated "9" when evaluated for chalking and none exhibited evidence of blistering or corrosion subsequent to repair and reimmersion in the WETF pool. Corrosion product noted at the scribes of one stainless steel panel after 2,000 hours exposure appeared to have been eliminated as a result of touch-up coating. It was noted that small pimples were present in the touch-up coating, probably arising from the intercoat surface, however, no blistering or corrosion was observed. The touch-up coating was of a higher gloss and exhibited less color change than the originally applied coating films.

System 3 - Devran 230. All panels were rated "8.5" when evaluated for chalk, this included a rating of "8" on repaired and "9" on existing coatings. The touch-up coating was more yellowed than the original coating but both exhibited similar gloss which was dull when compared to a control. The touch-up coating was found to be soft after removal from the WETF pool. The film, however, after two days of non-exposure was found to be hard and adherent.

System 4 - Carboline 890. Chalk evaluation resulted in a rating of "9" for all panels. The repair coating contained brush marks from application radicating poor flow-out when brush application is employed. The film provided good coverage and was uniform and intact. The color between existing and touch-up were very similar although the touch-up had a somewhat higher gloss. CPVC panel #332 exhibited evidence of substrate damage from power tool cleaning but coating coverage was good and adherent. Aluminum panels (#285, #286) exhibited minor corrosion at the panel holes and were rated accordingly. This observation was on an area not subject to touch-up and was not apparent after 2000 hours exposure when panels were removed to perform system repair.

System 5 - Sherwin-Williams. The panels were evaluated for chalk and all rated "9" including existing and touch-up surfaces. The touch-up coating matched the color of the previously applied film with a slight difference in gloss. Brush applied, the touch-up did not exhibit brush marks or rough texture indicating good flow properties. No evidence of blister or corrosion formation was noted on the panels with the exception of minor points at the panel hole of an aluminum panel. This location did not exhibit corrosion at the time repair was conducted and was not part of the touch-up area.

System 6 - UTPlast Extra. The test for chalk resulted in ratings of "9". Panel color of both existing and repair coatings was similar to that of a control panel with only slight change in gloss. No corrosion or blistering was evident on the test panels. Repair included full replacement on panel #428 (stainless), full overcoating of stainless steel panel #427 and cutting away the coatings on the bottom half of the aluminum panels and full overcoating. Additional work employing thermal spray application on CPVC resulted in severe deformation and a rough "tie-in" area where the repair coating was applied over the existing film. Thermal application on CPVC did not result in an acceptable product due to deformation. The repair coating was found to be adherent.

System 7 - UTPlast Ultra over Aluminum. Test panel #509, a stainless steel panel, was repaired by blast cleaning and application of a full overcoat. Repair did not include reapplication of the aluminum powder coat. Slight coating discoloration was found to be present, similar to the blue/white wax-like film previously described for this system. Aluminum panel #531 was repaired in a like manner, abrasive blast cleaning and application of a full replacement coat. The remaining metal panels exhibited a rough texture at the point of coating tie-in and, visually, "bubbling" of the thermally applied plastic was evident on the stainless steel panel. The lower one half of the CPVC panels had coating removed by cutting and scraping. The applied repair coating exhibited a rough texture due to application of the coating with minimal preheating of the substrate. The lower temperature limited flow of the applied film droplets on the surface. None of the panels exhibited corrosion or blister formation.

System 8 - Elite 8844 over Aluminum. Chalk ratings for the touch-up and existing coatings were rated "8". The panels were a more yellow color than an unexposed control and had lower gloss. The touch-up coating was of a higher gloss than the existing film. The touch-up coatings exhibited voids and bubbles in the coating film, particularly in the areas of repaired scribes. These were more severe on the metal panels than the CPVC panels. Probing and opening did not revel the presence of corrosion product nor was undercutting apparent. The previously applied aluminum powder coating was noted to result in surface defects associated with its porosity. The observed voids and bubbles appear to reflect this characteristic. No blisters were evident and the panels did not exhibit evidence of corrosion.

System 9 - Plasite 7122. Chalk testing resulted in a rating of "9" for both existing and touch-up coating on all panels. Compared to an unexposed control the color appeared very similar although dulling of the coating was apparent. The touch-up surfaces were of higher gloss than the existing film. Visually, areas which had been scribed can be seen, however, the touch-up film is providing full coverage. No evidence of blistering or corrosion was observed.

System 10 - Aquatapoxy A6. Touch-up coatings were applied in two manners. One each of the stainless steel, aluminum and CPVC panels were subject to repair underwater. The companion of each was recoated by brush application. Subsequent to surface preparation the underwater repairs were performed in a vessel containing tap water. The mixed coating was troweled across the lower half of each panel using a wooden "popsicle" stick. The underwater technique was as recommended by American Chemical Company, the manufacturer. Troweling was performed in one direction pressing the coating onto the panel surface to displace water and air bubbles. The resulting film surfaces were found to be dimpled with the dimples up to 4 mm in diameter. The coating was found to fully cover and be adherent to the substrates. One panel, stainless steel #756 exhibited a crack in the film but no indication of associated blistering or corrosion. The three panels repaired by brush application had a smoother, more continuous film. Pinholes were noted on CPVC panel #812 at the tie-in point. The repair films and existing films had chalk ratings of "9".

The repair film was less discolored than the existing film and exhibited a higher level of gloss. No blistering or corrosion was evident on the examined panels.

WETF-CATHODIC PROTECTION - 3200 HOURS

Duplicate stainless steel and aluminum test panels were exposed in WETF immersion while connected to "sacrificial" zinc anodes. Plastic coated single strand copper wire (10 gage) attached the test panels, in series, to the anode. The connection point included a wrap of copper wire around a bolt which, when tightened, provided electrical contact to test panels. Conductivity and low voltage holiday testing was performed to verify contact. The exposed metal surfaces were coated with "Raychem Prep" #51052, an asphaltic mastic manufactured by Raychem, Houston, Texas, prior to immersion. The material was employed as a sealer to isolate the points of electrical contact from the exposure medium (WETF pool water). This included all bolt and wire connections.

It should be noted that panels were scribed with an "X" on the bottom one-third, to the substrate, and one of each pair subject to 90 inch pounds impact. These surfaces were not "insulated" with the asphaltic mastic.

Examination of the test panels after exposure resulted in the following observations.

System 1 - PF 112. Chalking was rated "10". No evidence of corrosion or blistering was noted on panel faces nor in the scribe or impact surfaces with the exception of aluminum panel #42 exhibiting slight corrosion at the impact surface.

System 2 - NSP 120. Chalking was rated "9", no transfer to the test cloth but slight change at the chalk test point. The impact point exhibited cracked, lifted and imbedded coating with exposure of the substrate. When examined for blistering and corrosion stainless steel panel #101 exhibited #2F blisters and slight evidence of corrosion at the point impacted. No other panels exhibited blistering or corrosion.

System 3 - Devran 230. A rating of "8" was obtained from chalk testing of all panels. No blistering was present on the test panels. Minute traces of corrosion product appeared to be present in the scribe of one stainless steel (#182) and one aluminum panel (#205). Light brushing removed the residue and no further evidence of substrate corrosion was visible.

System 4 - Carboline 890. Chalk testing resulted in rating each panel "9". No evidence of blister formation or corrosion was present with the exception of a "dot" at the impact point of panel #287, an aluminum substrate.

System 5 - Sherwin-Williams. Chalk ratings were found to be "9" for all panels. No blistering or corrosion was found to be exhibited by the aluminum test panels. The stainless steel panels did exhibit #4F blisters on the panel face, principally on the upper third of the panels. Panel #345 contained a minute corrosion related blister on the scribe.

System 6 - UTPlast Extra. The system did not exhibit any blistering or corrosion on the exposed panels. Color was not visibly changed and chalk tests resulted in rating of "9".

System 7 - UTPlast Ultra over Aluminum. The chalk testing results were rated "4" for all panels. This was consistent with the occurrence of the white waxy surface deposited noted in other observations above. Aluminum test panels exhibited blister like formations and white corrosion product at the scribes and stainless steel panel #512 contained a larger than #2 blister between scribe lines. Due to creepage and undercutting at the scribe lines an ASTM D1654, Table 1 "factor" was employed as part of the rating index associated with blisters and undercutting. The corrosion was judged to be related to the thermally applied aluminum powder undercoat. Probing did not reveal substrate corrosion.

System 8 - Elite 8844 over Aluminum. Chalk testing resulted in rating of "9" on three (3) of the four (4) panels. Aluminum panel #615 was rated "8". Stainless steel panels exhibited blistering near the panel holes in association with corrosion. A spot of white corrosion product was present on stainless steel panel #553 in the center of the impact area. Minor white corrosion product was present on scribes but examination showed no undercutting of the film. Corrosion resulted from the applied aluminum undercoat rather than visually apparent substrate attach.

The use of the zinc anode in conjunction with thermally applied aluminum powder appears to be associated with the corrosion noted for the applied aluminum powder for both Systems #7 and #8.

System 9 - Plasite 7122. No evidence of corrosion was present on the stainless steel panels although panel #670 exhibited a blister on one edge. The aluminum test panels exhibited no blistering or evidence of corrosion. Chalk ratings for all panels were "9".

System 10 - Aquatapoxy A6. Chalk testing resulted in ratings of "10" on the stainless steel panels and "9" for the aluminum. No blistering was present any of the test panels. Only one panel exhibited any indication of corrosion product. The exposed substrate at the impact point of stainless steel panel #757 contained small white surface deposits on the steel. Due to white color the deposits may have resulted from deposition associated with exposure to the WETF pool water rather than substrate loss.

SIMULATED POOL EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/11/94	Start
6/13/94	800
8/4/94	2000

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	Chalking ASTM D4214 Exposure Hours 2000	Blistering ASTM D714 Exposure Hours 800	Blistering ASTM D714 Exposure Hours 2000	Rusting ASTM D610 Exposure Hours 800	Rusting ASTM D610 Exposure Hours 2000	Evaluation Summary D4214	Evaluation Summary D714	Evaluation Summary D610	Evaluation Summary Score
ss	11	1	9	9	10	10	10	10				
ss	12	1	10	9	10	10	10	10				
al	33	1	9	9	10	10	10	8				
al	34	1	9	9	10	10	10	10				
c	55	1	10	9	10	10	10	7				
c	56	1	10	9	10	10	10	6				
p	71	1	9	9	10	10	10	10				
p	72	1	9	9	10	10	10	10	9.0	10.0	8.9	27.88
ss	93	2	10	10	10	10	10	10				
ss	94	2	10	10	10	10	10	10				
al	115	2	10	10	10	10	10	9				
al	116	2	10	10	10	10	10	10				
c	137	2	10	10	10	10	10	10				
c	138	2	10	10	10	10	10	8				
p	151	2	10-	10	10	10	10	10				
p	152	2	10	10	10	10	10	10	10.0	10.0	9.6	29.63
ss	177	3	9	9	10	10	10	9				
ss	178	3	9	9	10	10	10	10				
al	199	3	9	9	10	10	10	8				
al	200	3	9	9	10	10	10	9				
c	219	3	9	8	10	9	10	8				
c	220	3	9	8	10	9	10	8				
p	233	3	9	9	10	10	10	10				
p	236	3	9	9	10	10	10	10	8.8	9.8	9.0	27.50
ss	259	4	10	9	10	10	10	10				
ss	260	4	10	9	10	10	10	10				
al	281	4	9	9	10	10	10	10				
al	282	4	9	9	10	10	10	10				
c	301	4	10	9	10	10	10	9				
c	302	4	9	9	10	10	10	9				
p	317	4	9	9	10	10	10	10				
p	318	4	9	9	10	10	10	10	9.0	10.0	9.8	28.75
ss	341	5	9	9	10	10	10	10				
ss	342	5	9	9	10	10	10	10				
al	363	5	9	9	10	9	10	9				
al	364	5	9	9	10	10	10	10				
c	383	5	9	9	10	8	10	8				
c	384	5	9	9	10	9	10	8				
p	399	5	9	9	10	10	10	10				
p	400	5	9	9	10	10	10	10	9.0	9.5	9.4	27.88
ss	423	6	10	10	10	10	10	10				
ss	424	6	10	10	10	10	10	10				
al	445	6	10	10	10	10	10	10				
al	446	6	10	10	10	10	10	9				
c	465	6	10	10	10	10	10	9				
c	466	6	10	10	10	10	10	9				
p	481	6	10	10	10	10	10	10				
p	482	6	10	10	10	10	10	10	10.0	10.0	9.6	29.63

KTA ENVIROTEST EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/11/94	Start
6/13/94	800
8/4/94	2000

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	2000	Blistering ASTM D714 Exposure Hours 800	2000	Rusting ASTM D610 Exposure Hours 800	2000	Evaluation Summary D4214	D714	D610	Score
ss	7	1	10	8	10	10	10	10				
ss	8	1	10	8	10	10	10	10				
al	29	1	10	8	10	10	10	10				
al	30	1	10	8	10	10	10	10				
c	51	1	10	8	10	10	10	9				
c	52	1	10	8	10	10	10	9				
p	67	1	10	8	10	10	10	10				
p	68	1	10	8	10	10	10	10	8.0	10.0	9.8	27.75
ss	89	2	9	6	10	10	10	10				
ss	90	2	9	6	10	10	10	10				
al	111	2	9	6	10	10	10	10				
al	112	2	9	6	10	10	10	10				
c	133	2	9	6	10	10	10	9				
c	134	2	9	6	10	10	10	9				
p	147	2	9	6	10	10	10	10				
p	148	2	9	6	10	10	10	10	6.0	10.0	9.8	25.75
ss	173	3	9	8	10	9	10	10				
ss	174	3	9	8	10	9	10	10				
al	195	3	9	8	10	10	10	10				
al	196	3	9	8	10	10	10	10				
c	215	3	9	6	10	10	10	9				
c	216	3	9	6	10	9	10	8				
p	229	3	9	8	10	10	10	10				
p	230	3	9	8	10	10	10	10	7.5	9.6	9.6	26.75
ss	255	4	9	8	10	9	10	10				
ss	256	4	9	6	10	9	10	10				
al	277	4	9	6	10	9	10	10				
al	278	4	9	6	10	9	10	10				
c	297	4	9	6	10	10	10	10				
c	298	4	9	6	10	10	10	8				
p	313	4	9	6	10	10	10	10				
p	314	4	9	6	10	10	10	10	6.3	9.5	9.8	25.50
ss	337	5	9	8	10	10	10	10				
ss	338	5	9	8	10	10	10	10				
al	359	5	9	8	10	10	10	10				
al	360	5	9	8	10	10	10	10				
c	379	5	9	8	10	10	10	9				
c	380	5	4	8	10	10	10	10				
p	395	5	9	8	10	10	10	10				
p	396	5	9	8	10	10	10	10	8.0	10.0	9.9	27.88
ss	419	6	10	9	10	10	10	10				
ss	420	6	9	9	10	10	10	10				
al	441	6	9	9	10	10	10	10				
al	442	6	9	9	10	10	10	10				
c	461	6	10	9	10	10	10	9				
c	462	6	9	9	10	10	10	9				
p	485	6	10	9	10	10	10	10				
p	486	6	10	9	10	10	10	10	9.0	10.0	9.8	28.75

SIMULATED POOL EXPOSURE EVALUATION RESULTS

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	Chalking ASTM D4214 Exposure Hours 2000	Blistering ASTM D714 Exposure Hours 800	Blistering ASTM D714 Exposure Hours 2000	Rusting ASTM D610 Exposure Hours 800	Rusting ASTM D610 Exposure Hours 2000	Evaluation Summary D4214	Evaluation Summary D714	Evaluation Summary D610	Evaluation Summary Score
ss	505	7	4	2	10	10	10	7				
ss	506	7	4	2	10	10	10	7				
al	527	7	4	2	10	10	10	7				
al	528	7	4	2	10	10	10	7				
c	547	7	8	8	10	10	10	7				
c	548	7	8	8	10	10	10	8				
p	563	7	6	6	10	10	10	4				
p	564	7	6	6	10	10	10	4	4.5	10.0	6.4	20.88
ss	587	8	9	9	10	10	10	7				
ss	588	8	9	9	10	10	10	7				
al	609	8	9	9	10	10	10	7				
al	610	8	9	9	10	10	10	7				
c	629	8	10	9	10	10	10	8				
c	630	8	9	9	10	10	10	8				
p	643	8	10	9	10	10	10	10				
p	644	8	10	9	10	10	10	10	9.0	10.0	8.0	27.00
ss	668	9	9	9	10	10	10	10				
ss	669	9	9	9	10	10	10	10				
al	691	9	9	9	10	10	10	9				
al	692	9	9	9	10	10	10	10				
c	711	9	9	9	10	10	10	8				
c	712	9	9	9	10	10	10	8				
p	725	9	9	9	10	10	10	10				
p	726	9	9	9	10	10	10	10	9.0	10.0	9.4	28.38
ss	751	10	10	9	10	10	10	10				
ss	752	10	9	9	10	10	10	10				
al	772	10	10	9	10	10	10	10				
al	773	10	10	9	10	10	10	10				
c	793	10	10	9	10	10	10	10				
c	794	10	10	9	10	10	10	10				
p	807	10	10	9	10	10	10	10				
p	808	10	10	9	10	10	10	10	9.0	10.0	10.0	29.00
	Summary	All	9.1	8.7	10.0	9.9	10.0	9.0	8.7	9.9	9.0	27.65

Aluminum		8.8	8.5	10	9.95	10	8.95	8.5	10.0	9.0	27.40
Coupled		9.4	9	10	9.75	10	8.3	9.0	9.8	8.3	27.05
CPVC		9.1	8.9	10	10	10	9.4	8.9	10.0	9.4	28.30
Stainless		8.9	8.5	10	10	10	9.35	8.5	10.0	9.4	27.85

KTA ENVIROTEST EXPOSURE EVALUATION RESULTS

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	Chalking ASTM D4214 Exposure Hours 2000	Blistering ASTM D714 Exposure Hours 800	Blistering ASTM D714 Exposure Hours 2000	Rusting ASTM D610 Exposure Hours 800	Rusting ASTM D610 Exposure Hours 2000	Evaluation Summary D4214	Evaluation Summary D714	Evaluation Summary D610	Evaluation Summary Score
ss	501	7	6	2	10	9	10	10				
ss	502	7	9	2	10	9	10	10				
al	523	7	6	2	10	9	10	10				
al	524	7	4	2	10	9	10	10				
c	543	7	9	8	10	10	10	8				
c	544	7	9	6	10	10	10	8				
p	551	7	8	4	10	10	10	10				
p	560	7	8	4	10	10	10	10	3.8	9.5	9.5	22.75
ss	583	8	9	8	10	10	10	10				
ss	584	8	9	8	10	10	10	10				
al	605	8	9	8	10	10	10	10				
al	606	8	9	8	10	10	10	10				
c	625	8	9	8	10	8	10	9				
c	626	8	9	8	10	8	10	9				
p	639	8	9	6	10	10	10	10				
p	640	8	9	6	10	10	10	10	7.5	9.5	9.8	26.75
ss	663	9	9	6	10	10	10	10				
ss	664	9	9	6	10	10	10	10				
al	686	9	9	6	10	10	10	10				
al	687	9	9	6	10	10	10	10				
c	707	9	9	6	10	9	10	9				
c	708	9	9	6	10	10	10	9				
p	721	9	9	6	10	10	10	10				
p	722	9	9	6	10	10	10	10	6.0	9.9	9.8	25.63
ss	747	10	9	6	10	10	10	10				
ss	748	10	9	6	10	10	10	10				
al	768	10	9	6	10	10	10	10				
al	769	10	10	8	10	10	10	10				
c	789	10	10	8	10	10	10	9				
c	790	10	8	8	10	10	10	9				
p	803	10	10	6	10	10	10	10				
p	804	10	10	6	10	10	10	10	6.8	10.0	9.8	26.50
	Summary	All	9.0	6.9	10.0	9.8	10.0	9.7	6.9	9.8	9.7	26.40

Aluminum	8.75	6.8	10	9.8	10	10	6.8	9.8	10.0	26.60
Coupled	8.9	7.2	10	9.7	10	8.9	7.2	9.7	8.9	25.80
CPVC	9.2	6.7	10	10	10	10	6.7	10.0	10.0	26.70
Stainless	9	6.8	10	9.7	10	10	6.8	9.7	10.0	26.50

QUV (ASTM G53) EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/12/94	Start
6/14/94	800
8/5/94	2000

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	Chalking ASTM D4214 Exposure Hours 2000	Blistering ASTM D714 Exposure Hours 800	Blistering ASTM D714 Exposure Hours 2000	Rusting ASTM D610 Exposure Hours 800	Rusting ASTM D610 Exposure Hours 2000	Evaluation Summary D4214	Evaluation Summary D714	Evaluation Summary D610	Score
ss	9	1	10	10	10	10	10	10				
ss	10	1	10	10	10	10	10	10				
al	31	1	10	10	10	10	10	10				
al	32	1	10	10	10	10	10	10				
c	53	1	10	10	10	10	10	10				
c	54	1	10	10	10	10	10	10				
p	69	1	10	10	10	10	10	10				
p	70	1	10	10	10	10	10	10	10.0	10.0	10.0	30.00
ss	91	2	8	4	10	10	10	10				
ss	92	2	6	4	10	10	10	10				
al	113	2	4	4	10	10	10	10				
al	114	2	6	4	10	10	10	10				
c	135	2	6	4	10	10	10	10				
c	136	2	6	4	10	10	10	10				
p	149	2	6	4	10	10	10	10				
p	150	2	6	4	10	10	10	10	4.0	10.0	10.0	24.00
ss	175	3	6	6	10	10	10	10				
ss	176	3	6	6	10	10	10	10				
al	197	3	6	6	10	10	10	10				
al	198	3	6	6	10	10	10	9				
c	217	3	8	6	10	10	10	10				
c	218	3	6	6	10	10	10	10				
p	231	3	8	6	10	10	10	10				
p	232	3	8	6	10	10	10	10	6.0	10.0	9.9	25.88
ss	257	4	6	2	10	10	10	10				
ss	258	4	4	2	10	10	10	10				
al	279	4	6	2	10	10	10	10				
al	280	4	4	2	10	10	10	10				
c	299	4	4	2	10	10	10	10				
c	300	4	6	2	10	10	10	10				
p	315	4	6	2	10	10	10	10				
p	316	4	6	2	10	10	10	10	2.0	10.0	10.0	22.00
ss	339	5	8	6	10	10	10	9				
ss	340	5	8	6	10	10	10	10				
al	358	5	8	6	10	10	10	10				
al	361	5	6	6	10	10	10	10				
c	362	5	8	4	10	10	10	10				
c	381	5	6	6	10	10	10	10				
p	382	5	6	4	10	10	10	10				
p	397	5	8	4	10	10	10	10	5.3	10.0	9.9	25.13
ss	421	6	9	9	10	10	10	10				
ss	422	6	9	9	10	10	10	9				
al	443	6	10	9	10	10	10	10				
al	444	6	10	9	10	10	10	9				
c	463	6	10	9	10	10	10	10				
c	464	6	9	9	10	10	10	9				
p	479	6	9	9	10	10	10	10				
p	480	6	10	9	10	10	10	10	9.0	10.0	9.6	28.63

QUV (ASTM G53) EXPOSURE EVALUATION RESULTS

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 800	Chalking ASTM D4214 Exposure Hours 2000	Blistering ASTM D714 Exposure Hours 800	Blistering ASTM D714 Exposure Hours 2000	Rusting ASTM D610 Exposure Hours 800	Rusting ASTM D610 Exposure Hours 2000	Evaluation Summary D4214	Evaluation Summary D714	Evaluation Summary D610	Evaluation Summary Score
ss	503	7	9	9	10	10	10	10				
ss	504	7	9	9	10	10	10	10				
al	525	7	9	9	10	10	10	9				
al	526	7	9	9	10	10	10	10				
c	545	7	10	9	10	10	10	9				
c	546	7	10	9	10	10	10	10				
p	561	7	10	9	10	10	10	6				
p	562	7	10	9	10	10	10	6	9.0	10.0	8.8	27.75
ss	585	8	6	4	10	10	10	10				
ss	586	8	6	4	10	10	10	10				
al	607	8	8	4	10	10	10	10				
al	608	8	6	4	10	10	10	10				
c	627	8	6	4	10	10	10	10				
c	628	8	6	4	10	10	10	8				
p	641	8	8	4	10	10	10	10				
p	642	8	8	4	10	10	10	10	4.0	10.0	9.8	23.75
ss	665	9	8	6	10	10	10	10				
ss	666	9	8	6	10	10	10	10				
al	688	9	8	6	10	10	10	10				
al	690	9	8	6	10	10	10	10				
c	709	9	8	6	10	10	10	10				
c	710	9	8	6	10	10	10	10				
p	723	9	8	6	10	10	10	10				
p	724	9	8	6	10	10	10	10	6.0	10.0	10.0	26.00
ss	749	10	4	2	10	10	10	8				
ss	750	10	4	2	10	10	10	10				
al	770	10	2	2	10	10	10	10				
al	771	10	4	2	10	10	10	10				
c	791	10	6	2	10	10	10	8				
c	792	10	4	2	10	10	10	10				
p	805	10	4	2	10	10	10	9				
p	806	10	4	2	10	10	10	9	2.0	10.0	9.3	21.25
	Summary	All	7.3	5.7	10.0	10.0	10.0	9.7	5.7	10.0	9.7	25.44

Aluminum	7.2	5.8	10.0	10.0	10.0	9.8	5.8	10.0	9.8	25.60
Coupled	7.4	5.7	10.0	10.0	10.0	9.7	5.7	10.0	9.7	25.40
CPVC	7.4	5.7	10.0	10.0	10.0	9.7	5.7	10.0	9.7	25.40
Stainless	7.2	5.8	10.0	10.0	10.0	9.8	5.8	10.0	9.8	25.60

LAYDOWN AREA EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/3/94	Start
6/10/94	912
7/25/94	1992
10/5/94	3720

Type	Panel	System	Chalking ASTM D4214			Blistering ASTM D714			Rusting ASTM D610			Evaluation Summary			
			Exposure Hours			Exposure Hours			Exposure Hours						
Panel	#	#	900	2000	3700	900	2000	3700	900	2000	3700	D4214	D714	D610	Score
ss	5	1	10	9	10	10	10	10	10	10	10				
ss	6	1	10	9	10	10	10	10	10	10	10				
al	27	1	10	9	10	10	10	10	10	10	10				
al	28	1	10	9	10	10	10	10	10	10	10				
c	49	1	10	10	10	10	10	10	10	10	10				
c	50	1	10	10	10	10	10	10	10	10	10				
p	65	1	10	9	10	10	10	10	10	10	10				
p	66	1	10	9	10	10	10	10	10	10	10	10.0	10.0	10.0	30.00
ss	87	2	10	8	8	10	10	10	10	10	9				
ss	88	2	10	8	8	10	10	10	10	10	10				
al	109	2	10	8	8	10	10	10	10	10	9				
al	110	2	10	8	8	10	10	10	10	10	10				
c	131	2	10	8	8	10	10	10	10	10	9				
c	132	2	10	8	8	10	10	10	10	10	10				
p	145	2	10	8	8	10	10	10	10	10	10				
p	146	2	10	8	8	10	10	10	10	10	10	8.0	10.0	9.6	27.63
ss	171	3	10	9	8	10	10	10	10	10	9				
ss	172	3	10	9	8	10	10	10	10	10	10				
al	193	3	10	9	8	10	10	10	10	10	9				
al	194	3	10	9	8	10	10	10	10	10	10				
c	213	3	10	8	8	10	10	10	10	10	9				
c	214	3	10	8	8	10	10	10	10	10	10				
p	227	3	10	9	8	10	10	10	10	10	10				
p	228	3	10	9	8	10	10	10	10	10	10	8.0	10.0	9.6	27.63
ss	253	4	10	8	6	10	10	10	10	10	9				
ss	254	4	10	8	6	10	10	10	10	10	10				
al	275	4	10	8	6	10	10	10	10	10	9				
al	276	4	10	8	6	10	10	10	10	10	10				
c	295	4	10	6	8	10	10	10	10	10	9				
c	296	4	10	8	8	10	10	10	10	10	10				
p	311	4	10	8	6	10	10	10	10	10	10				
p	312	4	10	8	6	10	10	10	10	10	10	6.5	10.0	9.6	26.13
ss	335	5	10	9	8	10	10	10	10	10	9				
ss	336	5	10	9	8	10	10	10	10	10	10				
al	357	5	10	9	8	10	10	10	10	10	9				
al	358	5	10	9	8	10	10	10	10	10	10				
c	377	5	10	9	6	10	10	10	10	10	9				
c	378	5	10	9	6	10	10	10	10	10	10				
p	393	5	10	9	8	10	10	10	10	10	10				
p	394	5	10	9	8	10	10	10	10	10	10	7.5	10.0	9.6	27.13
ss	417	6	10	10	9	10	10	10	10	10	10				
ss	418	6	10	10	9	10	10	10	10	10	10				
al	439	6	10	10	9	10	10	10	10	10	10				
al	440	6	10	10	9	10	10	10	10	10	10				
c	459	6	10	9	9	10	10	10	10	10	10				
c	460	6	10	9	9	10	10	10	10	10	10				
p	475	6	10	10	9	10	10	10	10	10	10				
p	476	6	10	10	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00

LAYDOWN AREA EXPOSURE EVALUATION RESULTS

Type	Panel	System	Chalking ASTM D4214 Exposure Hours			Blistering ASTM D714 Exposure Hours			Rusting ASTM D610 Exposure Hours			Evaluation Summary			
Panel	#	#	900	2000	3700	900	2000	3700	900	2000	3700	D4214	D714	D610	Score
ss	499	7	10	10	9	10	10	10	10	10	10				
ss	500	7	10	10	9	10	10	10	10	10	10				
al	521	7	10	10	9	10	10	10	10	10	10				
al	522	7	10	10	9	10	10	10	10	10	10				
c	541	7	10	10	9	10	10	10	10	10	10				
c	542	7	10	10	9	10	10	10	10	10	10				
p	557	7	10	10	9	10	10	6	10	10	10				
p	558	7	10	10	9	10	10	10	10	10	10	9.0	9.5	10.0	28.50
ss	581	8	10	10	8	10	10	10	10	10	10				
ss	582	8	10	10	8	10	10	10	10	10	10				
al	603	8	10	10	8	10	10	10	10	10	10				
al	604	8	10	10	8	10	10	10	10	10	10				
c	623	8	10	9	6	10	10	10	10	10	10				
c	624	8	10	9	6	10	10	10	10	10	10				
p	637	8	10	9	8	10	10	10	10	10	10				
p	638	8	10	9	8	10	10	10	10	10	10	7.5	10.0	10.0	27.50
ss	661	9	10	8	6	10	10	10	10	10	9				
ss	662	9	10	8	6	10	10	10	10	10	10				
al	684	9	10	9	6	10	10	10	10	10	10				
al	685	9	10	9	6	10	10	10	10	10	9				
c	705	9	10	8	8	10	10	10	10	10	9				
c	706	9	10	8	8	10	10	10	10	10	10				
p	719	9	10	8	6	10	10	10	10	10	10				
p	720	9	10	8	6	10	10	10	10	10	10	6.5	10.0	9.6	26.13
ss	743	10	10	9	6	10	10	10	10	10	9				
ss	744	10	10	9	6	10	10	10	10	10	10				
al	766	10	10	9	6	10	10	10	10	10	10				
al	767	10	10	9	6	10	10	10	10	10	10				
c	787	10	10	10	8	10	10	10	10	10	9				
c	788	10	10	10	6	10	10	10	10	10	10				
p	801	10	10	9	6	10	10	10	10	10	10				
p	802	10	10	9	6	10	10	10	10	10	10	6.3	10.0	9.8	26.00
	Summary	All	10.0	9.0	7.8	10.0	10.0	10.0	10.0	10.0	9.8	7.8	10.0	9.8	27.57
	Aluminum		10.0	9.1	7.8	10.0	10.0	10.0	10.0	10.0	9.8	7.8	10.0	9.8	27.55
	Coupled		10.0	8.8	7.9	10.0	10.0	10.0	10.0	10.0	9.7	7.9	10.0	9.7	27.60
	CPVC		10.0	8.9	7.8	10.0	10.0	9.8	10.0	10.0	10.0	7.8	9.8	10.0	27.60
	Stainless		10.0	9.0	7.8	10.0	10.0	10.0	10.0	10.0	9.7	7.8	10.0	9.7	27.50

Date:	Hrs
5/3/94	Start
6/10/94	900
7/25/94	200
10/5/94	3700

ROTUNDA EXPOSURE EVALUATION RESULTS

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours			Blistering ASTM D714 Exposure Hours			Rusting ASTM D610 Exposure Hours			Evaluation Summary			
			900	2000	3700	900	2000	3700	900	2000	3700	D4214	D714	D610	Score
ss	3	1	10	9	10	10	10	10	10	10	9				
ss	4	1	10	9	10	10	10	10	10	10	10				
al	25	1	10	9	10	10	10	10	10	10	9				
al	26	1	10	9	10	10	10	10	10	10	10				
c	47	1	10	10	10	10	10	10	10	10	10				
c	48	1	10	10	10	10	10	10	10	10	10				
p	63	1	10	9	10	10	10	10	10	10	10				
p	64	1	10	9	10	10	10	10	10	10	10	10.0	10.0	9.8	29.75
ss	85	2	10	8	10	10	10	10	10	10	9				
ss	86	2	10	8	10	10	10	10	10	10	10				
al	107	2	10	8	10	10	10	10	10	10	10				
al	108	2	10	8	10	10	10	10	10	10	10				
c	129	2	10	10	10	10	10	10	10	10	8				
c	130	2	10	10	10	10	10	10	10	10	10				
p	143	2	10	8	10	10	10	10	10	10	10				
p	144	2	10	8	10	10	10	10	10	10	10	10.0	10.0	9.6	29.63
ss	169	3	10	9	9	10	10	10	10	10	9				
ss	170	3	10	9	9	10	10	10	10	10	10				
al	191	3	10	9	9	10	9	9	10	10	9				
al	192	3	10	9	9	10	10	9	10	10	8				
c	211	3	10	9	9	10	10	10	10	10	9				
c	212	3	10	9	9	10	10	10	10	10	10				
p	225	3	10	9	9	10	10	10	10	10	10				
p	226	3	10	9	9	10	10	10	10	10	10	9.0	9.8	9.4	28.13
ss	251	4	10	8	10	10	10	10	10	10	10				
ss	252	4	10	8	10	10	10	10	10	10	10				
al	273	4	10	8	10	10	10	10	10	10	10				
al	274	4	10	8	10	10	10	10	10	10	10				
c	293	4	10	10	9	10	10	10	10	10	10				
c	294	4	10	10	9	10	10	10	10	10	10				
p	309	4	10	8	10	10	10	10	10	10	10				
p	310	4	10	8	10	10	10	10	10	10	10	9.8	10.0	10.0	29.75
ss	333	5	10	9	9	10	10	10	10	10	9				
ss	334	5	10	9	9	10	10	10	10	10	10				
al	355	5	10	9	9	10	10	10	10	10	10				
al	356	5	10	9	9	10	10	10	10	10	10				
c	375	5	10	9	9	10	10	10	10	10	9				
c	376	5	10	9	9	10	10	10	10	10	10				
p	391	5	10	9	9	10	10	10	10	10	10				
p	392	5	10	9	9	10	10	10	10	10	10	9.0	10.0	9.8	28.75
ss	415	6	10	10	10	10	10	10	10	10	10				
ss	416	6	10	10	10	10	10	10	10	10	10				
al	437	6	10	10	10	10	10	10	10	10	10				
al	438	6	10	10	10	10	10	10	10	10	10				
c	457	6	10	10	10	10	10	10	10	10	9				
c	458	6	10	10	10	10	10	10	10	10	10				
p	473	6	10	10	10	10	10	10	10	10	10				
p	474	6	10	10	10	10	10	10	10	10	10	10.0	10.0	9.9	29.88

ROTUNDA EXPOSURE EVALUATION RESULTS

10/5/94	3700		Chalking ASTM D4214			Blistering ASTM D714			Rusting ASTM D610						
Type	Panel	System	Exposure Hours			Exposure Hours			Exposure Hours			Evaluation Summary			
Panel	#	#	912	1992	3700	912	1992	3700	912	1992	3700	D4214	D714	D610	Score
ss	497	7	10	6	6	10	10	10	10	10	9				
ss	498	7	10	6	6	10	10	10	10	10	9				
al	519	7	10	6	6	10	10	10	10	10	9				
al	520	7	10	6	6	10	10	10	10	10	9				
c	539	7	10	9	9	10	10	10	10	10	9				
c	540	7	10	8	9	10	10	10	10	10	10				
p	555	7	10	6	8	10	9	8	10	10	9				
p	556	7	10	6	8	10	10	10	10	10	9	7.3	9.8	9.1	26.13
ss	579	8	10	9	9	10	10	10	10	10	9				
ss	580	8	10	9	9	10	9	8	10	10	9				
al	601	8	10	9	9	10	9	8	10	10	10				
al	602	8	10	9	9	10	10	10	10	10	10				
c	621	8	10	9	9	10	7	5	10	10	8				
c	622	8	10	9	9	10	8	6	10	10	8				
p	635	8	10	9	9	10	10	10	10	10	10				
p	636	8	10	9	9	10	10	10	10	10	10	9.0	8.4	9.3	26.63
ss	659	9	10	9	9	10	10	10	10	10	9				
ss	660	9	10	9	9	10	10	10	10	10	10				
al	681	9	10	9	9	10	10	10	10	10	9				
al	682	9	10	9	9	10	10	10	10	10	10				
c	703	9	10	10	9	10	10	10	10	10	9				
c	704	9	10	10	9	10	10	10	10	10	10				
p	717	9	10	9	9	10	10	10	10	10	10				
p	718	9	10	9	9	10	10	10	10	10	10	9.0	10.0	9.6	28.63
ss	741	10	10	9	9	10	10	10	10	10	9				
ss	742	10	10	9	9	10	10	10	10	10	10				
al	764	10	10	9	9	10	10	10	10	10	10				
al	765	10	10	9	9	10	10	10	10	10	10				
c	785	10	10	10	9	10	10	10	10	10	8				
c	786	10	10	10	9	10	10	10	10	10	10				
p	799	10	10	9	9	10	10	10	10	10	10				
p	800	10	10	9	9	10	10	10	10	10	10	9.0	10.0	9.6	28.63
	Summary	All	10.0	8.8	9.2	10.0	9.9	9.8	10.0	10.0	9.6	9.2	9.8	9.6	28.59

Aluminum	10.0	8.6	9.1	10.0	9.9	9.8	10.0	10.0	9.7	9.1	9.8	9.7	28.55
Coupled	10.0	9.6	9.3	10.0	9.8	9.6	10.0	10.0	9.4	9.3	9.6	9.4	28.20
CPVC	10.0	8.6	9.3	10.0	10.0	9.9	10.0	10.0	9.9	9.3	9.9	9.9	29.10
Stainless	10.0	8.6	9.1	10.0	10.0	9.9	10.0	10.0	9.5	9.1	9.9	9.5	28.50

WETF POOL EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/23/94	Start
6/29/94	1200
10/5/94	3200

Type	Panel	System	Chalking ASTM D4214 Exposure Hours		Blistering ASTM D714 Exposure Hours		Rusting ASTM D610 Exposure Hours			Evaluation Summary				D1654
Panel	#	#	1200	3200	1200	3200	1200	3200	Adj.	D4214	D714	D610	Score	factor
ss	1	1	10	10	10	10	10	10	10					
ss	2	1	10	10	10	10	10	10	10					
al	23	1	10	10	9	9	10	10	8					
al	24	1	10	10	8	9	10	9	6.3					
p	61	1	10	10	10	10	10	10	10					
p	62	1	10	10	10	10	10	10	10	10.0	9.7	9.1	28.72	0.92
ss	83	2	8	9	10	10	10	9	8.1					
ss	84	2	8	9	10	10	5	10	10					
al	105	2	8	9	10	10	10	10	10					
al	106	2	8	9	10	10	10	10	10					
p	141	2	8	9	10	10	10	10	10					
p	142	2	8	9	10	10	10	10	10	9.0	10.0	9.7	28.68	0.98
ss	167	3	9	9	10	10	10	10	10					
ss	168	3	9	9	10	10	10	9	9					
al	189	3	9	9	8	9	10	10	6					
al	190	3	9	9	9	9	10	10	7					
p	223	3	10	9	10	10	10	10	10					
p	224	3	10	9	10	10	10	10	10	9.0	9.7	8.7	27.33	0.88
ss	249	4	9	9	10	10	10	8	8					
ss	250	4	9	9	10	10	10	8	8					
al	271	4	9	9	10	10	10	8	8					
al	272	4	9	9	10	9	10	9	9					
p	307	4	10	9	10	10	10	10	10					
p	308	4	10	9	10	10	10	10	10	9.0	9.8	8.8	27.67	1.00
ss	331	5	9	9	10	10	10	10	10					
ss	332	5	9	9	10	10	10	10	10					
al	353	5	9	9	10	10	10	9	9					
al	354	5	9	9	10	9	10	10	9					
p	389	5	9	9	10	10	10	10	10					
p	390	5	9	9	10	10	10	10	10	9.0	9.8	9.7	28.50	1.00
ss	413	6	10	9	10	10	10	10	9					
ss	414	6	10	9	10	10	10	10	10					
al	435	6	10	9	10	10	8	10	10					
al	436	6	10	9	10	10	8	10	9					
p	471	6	10	9	10	10	10	10	10					
p	472	6	10	9	10	10	10	10	10	9.0	10.0	9.7	28.67	0.97
ss	495	7	6	9	10	10	7	9	7.2					
ss	496	7	6	4	10	10	10	10	9					
al	517	7	4	4	9	10	7	9	7.2					
al	518	7	4	4	9	9	3	10	7					
p	553	7	6	4	9	9	3	3	0.9					
p	554	7	6	6	9	7	5	3	1.2	5.2	9.2	5.4	19.75	0.65
ss	575	8	10	6	9	8	6	6	3					
ss	577	8	10	9	9	9	6	7	4.2					
al	599	8	10	9	9	9	5	7	4.2					
al	600	8	10	9	9	9	10	9	5.4					
p	633	8	10	9	10	10	10	10	10					
p	634	8	10	9	10	10	10	10	10	8.5	9.2	6.1	23.80	0.72
ss	657	9	10	9	10	10	10	9	9					
ss	658	9	10	9	10	10	10	9	9					
al	679	9	9	9	10	10	10	9	9					
al	680	9	9	9	10	9	10	10	10					
p	715	9	9	9	10	10	10	10	10					
p	716	9	9	9	10	10	10	10	10	9.0	9.8	9.5	28.33	1.00

WETF POOL EXPOSURE EVALUATION RESULTS

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 1200	Chalking 3200	Blistering ASTM D714 Exposure Hours 1200	Blistering 3200	Rusting ASTM D610 Exposure Hours 1200	Rusting 3200	Rusting Adj.	Evaluation Summary D4214	D714	D610	Score	D1654 factor
ss	739	10	8	9	10	10	10	9	9					
ss	740	10	8	9	10	10	10	10	10					
al	762	10	8	9	10	10	10	10	10					
al	763	10	9	9	10	10	10	10	10					
p	797	10	9	9	10	10	10	10	10					
p	798	10	8	9	10	10	10	10	10	9.0	10.0	9.8	28.83	1.00
	Summary	All	8.9	8.7	9.8	9.7	9.2	9.3	8.7	8.7	9.7	8.7	27.04	

	Chalking 1200	Chalking 3200	Blistering 1200	Blistering 3200	Rusting 1200	Rusting 3200	Rusting Adj.	D4214	D714	D610	Score
Aluminum	8.7	8.6	6.0	9.5	8.3		8.2	8.6	9.5	8.2	26.31
Coupled	9.2	8.8	9.5	8.7	9.2		7.8	8.8	8.7	7.8	25.35
CPVC	9.1	8.7	9.0	9.8	9.4		9.1	8.7	9.8	9.1	27.61
Stainless	8.9	8.7	9.0	9.9	9.2		8.6	8.7	9.9	8.6	27.18

WETF Coupled Panels

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 1200	Chalking 3200	Blistering ASTM D714 Exposure Hours 1200	Blistering 3200 ss	Blistering 3200 al	Rusting ASTM D610 Exposure Hours 1200	Rusting 3200 ss/adj	Rusting Adj. al/adj	Evaluation Summary D4214	D714	D610	Score	D1654 factor
c	45	1	10	10	10	10	9	10	10	3					
c	46	1	10	10	8	9	9	8	10	3	10.0	9.3	6.5	25.75	0.65
c	127	2	9	9	10	10	5	10	10	7					
c	128	2	10	9	10	10	9	10	10	10	9.0	8.5	9.3	26.75	1.00
c	209	3	9	6	10	9	9	10	10	8					
c	210	3	9	8	8	10	9	10	10	8	7.0	9.3	9.0	25.25	1.00
c	291	4	10	9	10	10	10	10	10	8					
c	292	4	10	9	10	10	10	10	10	8	9.0	10.0	9.0	28.00	1.00
c	373	5	10	9	10	10	8	10	10	8					
c	374	5	10	9	10	9	6	10	9	5	9.0	8.3	8.0	25.25	0.98
c	455	6	10	9	10	10	10	9	10	7					
c	456	6	10	9	10	10	10	10	10	7	9.0	10.0	8.5	27.50	1.00
c	537	7	8	8	10	9	10	9	10	6					
c	538	7	6	8	10	10	7	9	10	6	8.0	9.0	8.0	25.00	1.00
c	619	8	9	8	7	6	6	10	4.9	2.5					
c	620	8	8	8	8	6	6	5	6.3	2.5	8.0	6.0	4.1	18.05	0.65
c	701	9	9	9	10	10	6	10	10	6.3					
c	702	9	9	9	8	10	6	6	10	4.9	9.0	8.0	7.8	24.80	0.90
c	783	10	9	10	10	10	7	10	10	4.5					
c	784	10	8	10	10	10	9	8	10	8	10.0	9.0	8.1	27.13	0.88
	Summary	All	9.15	8.80	9.45	9.40	8.05	9.20	9.51	6.14	8.8	8.7	7.8	25.35	

REPAIR SYSTEM EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/23/94	Start
6/29/94	900
8/15/94	2000
10/4/94	3200

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 900	2000	3200	Blistering ASTM D714 Exposure Hours 900	2000	3200	Rusting ASTM D610 Exposure Hours 900	2000	3200	Evaluation Summary D4214	D714	D610	Score
ss	15	1	10	10	9	10	10	10	10	10	10				
ss	16	1	10	10	9	10	10	10	10	10	10				
al	37	1	10	10	9	9	8	10	9	7	10				
al	38	1	10	10	9	9	8	10	9	8	10				
p	75	1	10	10	9	10	10	10	10	10	10				
p	76	1	10	10	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00
ss	97	2	10	9	9	10	10	10	10	10	10				
ss	98	2	10	9	9	10	10	10	8	8	10				
al	119	2	10	9	9	10	10	10	10	9	10				
al	120	2	10	9	9	10	10	10	10	10	10				
p	155	2	9	9	9	10	10	10	10	10	10				
p	156	2	9	9	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00
ss	182	3	9	9	8.5	10	10	10	10	10	10				
ss	185	3	9	9	8.5	10	10	9	10	9	10				
al	203	3	9	9	8.5	10	10	9	10	9	10				
al	204	3	9	9	8.5	9	9	9	9	9	10				
p	239	3	9	9	8.5	10	10	9	10	10	10				
p	240	3	9	9	8.5	10	10	10	10	10	10	8.5	9.3	10.0	27.83
ss	263	4	10	9	9	10	10	10	10	10	10				
ss	264	4	10	9	9	10	10	10	10	10	10				
al	285	4	10	9	9	10	10	10	10	10	9				
al	286	4	10	9	9	10	10	9	10	10	8				
p	321	4	10	9	9	9	9	10	10	10	10				
p	322	4	10	9	9	10	10	10	10	10	10	9.0	9.8	9.5	28.33
ss	349	5	9	9	9	10	10	10	10	10	10				
ss	350	5	9	9	9	10	10	10	10	10	10				
al	371	5	10	9	9	10	10	9	10	10	9				
al	372	5	10	9	9	10	10	10	10	10	10				
p	403	5	9	9	9	10	10	10	10	10	10				
p	404	5	9	9	9	10	10	10	10	10	10	9.0	9.8	9.8	28.67
ss	427	6	10	9	9	10	10	10	10	10	10				
ss	428	6	10	9	9	10	10	10	10	10	10				
al	449	6	10	9	9	10	10	10	10	10	10				
al	453	6	10	9	9	10	10	10	10	8	10				
p	477	6	10	9	9	10	10	10	10	10	10				
p	478	6	10	9	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00
ss	509	7	4	4	9	9	9	10	9	8	10				
ss	510	7	4	4	9	9	9	10	10	8	10				
al	531	7	4	4	9	10	8	10	10	8	10				
al	536	7	4	4	9	9	8	10	8	8	10				
p	567	7	6	6	9	9	8	5	9	8	5				
p	568	7	6	6	9	9	8	5	9	8	5	9.0	8.3	8.3	25.67
ss	591	8	9	9	9	9	9	8	8	8	9				
ss	592	8	9	9	9	8	8	8	8	8	10				
al	613	8	9	9	9	8	8	8	10	8	9				
al	614	8	9	9	9	8	9	8	8	9	9				
p	647	8	9	9	9	9	9	9	8	9	10				
p	648	8	9	9	9	10	10	10	10	10	10	9.0	8.5	9.5	27.00

REPAIR SYSTEM EXPOSURE EVALUATION RESULTS

8/15/94 2000
10/4/94 3200

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 900	2000	3200	Blistering ASTM D714 Exposure Hours 900	2000	3200	Rusting ASTM D610 Exposure Hours 900	2000	3200	Evaluation Summary D4214	D714	D610	Score
ss	673	9	9	9	9	10	10	10	10	10	10				
ss	674	9	9	9	9	10	10	10	10	10	10				
al	696	9	9	9	9	10	10	10	10	10	10				
al	697	9	9	9	9	10	10	10	10	10	10				
p	729	9	9	9	9	10	10	10	10	10	10				
p	730	9	9	9	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00
ss	756	10	9	9	9	10	10	10	10	10	10				
ss	759	10	9	9	9	10	10	10	10	10	10				
al	777	10	9	9	9	10	10	10	10	10	10				
al	779	10	9	9	9	10	10	10	10	10	10				
p	811	10	9	9	9	10	10	10	10	10	10				
p	812	10	9	9	9	10	10	10	10	10	10	9.0	10.0	10.0	29.00
	Summary	All	9.0	8.7	9.0	9.7	9.6	9.6	9.7	9.5	9.7	9.0	9.6	9.7	28.25

Aluminum	9.0	8.6	9.0	9.6	9.4	9.6	9.7	9.2	9.7	9.0	9.6	9.7	28.25
CPVC	9.0	8.8	9.0	9.8	9.7	9.4	9.8	9.8	9.5	9.0	9.4	9.5	27.65
Stainless	8.9	8.6	9.0	9.8	9.8	9.8	9.7	9.5	10.0	9.0	9.8	10.0	28.65

CATHODE PANEL EXPOSURE EVALUATION RESULTS

Date:	Hrs
5/23/94	Start
6/29/94	900
10/4/94	3200

Type Panel	Panel #	System #	Chalking ASTM D4214 Exposure Hours 900	3200	Blistering ASTM D714 Exposure Hours 900	3200	Rusting ASTM D610 Exposure Hours 900	3200	adj	Evaluation Summary D4214	D714	D610	Score	D1654 factor
ss	19	1	10	10	10	10	10	10	10					
ss	20	1	10	10	10	10	10	10	10					
al	41	1	10	10	10	10	10	10	10					
al	42	1	10	10	10	10	10	9	9	10.0	10.0	9.75	29.75	1.00
ss	101	2	10	9	10	5	9	8	8					
ss	102	2	10	9	10	10	10	10	10					
al	123	2	10	9	10	10	10	10	10					
al	124	2	10	9	10	10	10	10	10	9.0	8.8	9.5	27.25	1.00
ss	181	3	9	8	10	10	10	10	10					
ss	182	3	9	8	10	10	10	9	9					
al	205	3	9	8	10	10	10	9	9					
al	206	3	9	8	10	10	10	10	10	8.0	10.0	9.5	27.50	1.00
ss	265	4	9	9	10	10	10	10	10					
ss	266	4	9	9	10	10	10	10	10					
al	287	4	9	9	10	10	10	9	9					
al	288	4	9	9	10	10	10	10	10	9.0	10.0	9.8	28.75	1.00
ss	344	5	9	9	10	6	10	10	10					
ss	345	5	9	9	10	6	10	9	9					
al	366	5	9	9	10	10	10	10	10					
al	367	5	9	9	10	10	10	10	10	9.0	8.0	9.8	26.75	1.00
ss	429	6	10	9	10	10	10	10	10					
ss	430	6	10	9	10	10	10	10	10					
al	450	6	10	9	10	10	10	10	10					
al	451	6	10	9	10	10	10	10	10	9.0	10.0	10.0	29.00	1.00
ss	511	7	6	4	10	9	10	10	10					
ss	512	7	6	4	10	6	10	10	10					
al	532	7	6	4	10	5	8	10	4					
al	533	7	6	4	10	5	10	10	6	4.0	6.3	7.5	17.75	0.75
ss	593	8	10	9	10	5	9	9	9					
ss	594	8	10	9	10	7	10	9	9					
al	615	8	10	8	10	10	10	9	9					
al	616	8	10	9	10	10	10	9	9	8.8	8.0	9.0	25.75	1.00
ss	667	9	10	9	10	8	10	10	10					
ss	670	9	10	9	10	10	10	10	10					
al	683	9	9	9	10	10	10	10	10					
al	689	9	9	9	10	10	10	10	10	9.0	9.5	10.0	28.50	1.00
ss	754	10	9	10	10	10	10	10	10					
ss	757	10	9	10	10	10	10	9	9					
al	761	10	8	9	10	10	10	10	10					
al	775	10	9	9	10	10	10	10	10	9.5	10.0	9.8	29.25	1.00
	Summary		9.1	8.5	10.0	9.1	9.9	9.7	9.5	8.5	9.1	9.5	27.0	
	Aluminum		9.1	8.5	10.0	9.5	9.9	9.8	9.3	8.5	9.5	9.3	27.20	
	Stainless		9.2	8.6	10.0	8.6	9.9	9.7	9.7	8.6	8.6	9.7	26.85	

TABLE D-9

EXPOSURE EVALUATION SUMMARY

Average System Panel Ratings by Environment and Substrate

System Number	Rotunda Al	Rotunda Cpl	Rotunda CPVC	Rotunda SS	Rotunda Avg.	Laydown Al	Laydown Cpl	Laydown CPVC	Laydown SS	Laydown Avg.	WETF Pool Al	WETF Pool Cpl	WETF Pool CPVC	WETF Pool SS	WETF Pool Avg.	System Score	Relative Score	System Rank
1	9.83	10.00	10.00	9.83	9.92	10.00	10.00	10.00	10.00	10.00	8.72	8.30	10.00	10.00	9.25	29.17	1.000	10
2	10.00	9.67	10.00	9.83	9.88	9.17	9.17	9.33	9.17	9.21	9.67	8.90	9.67	9.35	9.40	28.48	0.976	8
3	8.83	9.50	9.67	9.50	9.38	9.17	9.17	9.33	9.17	9.21	8.17	8.70	9.67	9.50	9.01	27.59	0.946	4
4	10.00	9.67	10.00	10.00	9.92	8.50	9.17	8.67	8.50	8.71	9.00	9.40	9.67	9.00	9.27	27.89	0.956	7
5	9.67	9.50	9.67	9.50	9.58	9.17	8.50	9.33	9.17	9.04	9.17	8.30	9.67	9.67	9.20	27.83	0.954	6
6	10.00	9.83	10.00	10.00	9.96	9.67	9.67	9.67	9.67	9.67	9.50	9.20	9.67	9.50	9.47	29.09	0.997	9
7	8.33	9.50	8.67	8.33	8.71	9.67	9.67	9.00	9.67	9.50	6.87	8.40	4.68	8.20	7.04	25.25	0.865	1
8	9.33	7.50	9.67	9.00	8.88	9.33	8.67	9.33	9.33	9.17	7.60	5.62	9.67	6.53	7.36	25.40	0.871	2
9	9.50	9.50	9.67	9.50	9.54	8.50	9.17	8.67	8.50	8.71	9.33	8.12	9.67	9.33	9.11	27.36	0.938	3
10	9.67	9.33	9.67	9.50	9.54	8.67	8.83	8.67	8.50	8.67	9.67	8.85	9.67	9.50	9.42	27.63	0.947	5
Averages	9.52	9.40	9.70	9.50	**9.53**	9.18	9.20	9.20	9.17	**9.19**	8.77	8.38	9.20	9.06	**8.85**			

System Number	QUV-Weatherometer Al	QUV-Weatherometer Cpl	QUV-Weatherometer CPVC	QUV-Weatherometer SS	QUV-Weatherometer Avg.	KTA-Envirotest Al	KTA-Envirotest Cpl	KTA-Envirotest CPVC	KTA-Envirotest SS	KTA-Envirotest Avg.	Simulated Pool Al	Simulated Pool Cpl	Simulated Pool CPVC	Simulated Pool SS	Simulated Pool Avg.	System Score	Relative Score	System Rank
1	10.00	10.00	10.00	10.00	10.00	9.33	9.00	9.33	9.33	9.25	9.33	8.50	9.67	9.67	9.29	28.54	0.984	9
2	8.00	8.00	8.00	8.00	8.00	8.67	8.33	8.67	8.67	8.58	9.83	9.67	10.00	10.00	9.88	26.46	0.912	5
3	8.50	8.67	8.67	8.67	8.63	9.33	8.00	9.33	9.00	8.92	9.17	8.33	9.67	9.50	9.17	26.71	0.921	7
4	7.33	7.33	7.33	7.33	7.33	8.33	8.33	8.67	8.67	8.50	9.67	9.33	9.67	9.67	9.58	25.42	0.876	2
5	8.67	8.33	8.00	8.50	8.38	9.33	9.17	9.33	9.33	9.29	9.33	8.50	9.67	9.67	9.29	26.96	0.930	8
6	9.50	9.50	9.67	9.50	9.54	9.67	9.33	9.67	9.67	9.58	9.83	9.67	10.00	10.00	9.88	29.00	1.000	10
7	9.50	9.50	8.33	9.67	9.25	7.00	8.33	8.00	7.00	7.58	6.33	8.50	6.67	6.33	6.96	23.79	0.820	1
8	8.00	7.67	8.00	8.00	7.92	9.33	8.33	8.67	9.33	8.92	8.67	9.00	9.67	8.67	9.00	25.83	0.891	4
9	8.67	8.67	8.67	8.67	8.67	8.67	8.17	8.67	8.67	8.54	9.50	9.00	9.67	9.67	9.46	26.67	0.920	6
10	7.33	7.00	7.00	7.00	7.08	9.00	9.00	8.67	8.67	8.83	9.67	9.67	9.67	9.67	9.67	25.58	0.882	3
Averages	8.55	8.47	8.37	8.53	**8.48**	8.87	8.60	8.90	8.83	**8.80**	9.13	9.02	9.43	9.28	**9.22**			

Aggregate Results for Systems

System Number	1	2	3	4	5	6	7	8	9	10
System Score	28.86	27.47	27.15	26.65	27.39	29.05	24.52	25.62	27.02	26.61
Relative Score	0.99	0.95	0.93	0.92	0.94	1.00	0.84	0.88	0.93	0.92
System Rank	9	8	6	4	7	10	1	2	5	3

Section V

Discussion of Results

Overview

Ten (10) coating systems were selected for comparative performance under field and laboratory exposure and testing. The generic systems employed are described in Table V-1 "Generic Description of Candidate Coating Systems".

Assessment of coating performance under project exposure environments included rating individual coating system panels for chalking (ASTM D4214), blister formation (ASTM D714 and ASTM D1654, Procedure B) and occurrence of corrosion (ASTM D610 and ASTM D1654, Procedure A). Individual system panel ratings for each exposure environment and substrate are provided in Tables IV D-1 through IV D-8. Duplicate panels were employed for each exposure environment and substrate.

There were eight (8) exposure environments to which test panels were subjected. QUV-Weatherometer (ASTM G-53), KTA-Envirotest, and Simulated (WETF) Pool exposures were conducted at the KTA-Tator, Inc. Humble, Texas facility for a period of 2,000 hours. Weightless Environment Training Facility (WETF) immersion, WETF Rotunda and Laydown Area (outdoor) exposures took place at the National Aeronautics and Space Administration (NASA), Johnson Space Center (JSC) in Houston, Texas. WETF (immersion) exposure lasted approximately 3,200 hours. Rotunda and Laydown Area exposed panels received a final project evaluation after approximately 3,700 hours exposure.

In addition to the six (6) environments above, "Repair" panels and "Cathode" protected panels were placed in WETF immersion. Repair panels were removed and subject to coating touch-up after 2,000 hours and returned for an additional 1,000 hours exposure. Cathode panels included stainless steel and aluminum panels connected to sacrificial zinc anodes. Cathode panels were in immersion for approximately 3,200 hours. The Repair and Cathode panel exposures have been considered as an additional two (2) exposure environments. Because they are somewhat unique, these are addressed separately from the six (6) environments identified above.

Four (4) substrate types were coated with each system. These included aluminum (6061T6), stainless steel (grade 304), chlorinated poly-vinyl chloride (CPVC) plastic and a coupled aluminum and stainless steel.

Each test panel subject to exposure was assigned a numeric rating for each of the three (3) evaluation criteria: chalking, blistering and corrosion. The maximum rating for a single panel for any one criterion is "10". A rating of "10" indicates no effect. For each coating system an average rating for each rating criteria was calculated for characteristics of interest such as substrate, exposure environment or combinations of these. Mathematically, the sum of individual panel rating scores, divided by the number of panels for a given evaluation criterion will result in a maximum average of "10".

Summing the average scores for each evaluation criteria provided what has been called the "System Score". A maximum system score of 30 would indicate that there were no effects from exposure.

A "Relative Score" was also calculated for various sets of performance data to more easily compare coating system performances relative to each other. The highest system score in the group was divided into all system score values. Thus, while a "perfect" system score may be "30", within categorized data the coating system (or characteristic of interest) performing "best" would have a relative score of 1.00 even it its system score was less than 30. Systems performing less well, within the set examined, will have a relative score less than 1.00.

Examination of data collected as a result of exposure has resulted in the findings summarized below.

In addition to data obtained as a result of test panel exposure, additional test panels for each of the coating systems were prepared and subjected to physical tests. Physical testing of the coating systems included Taber Abrasion (ASTM D4060), Tape Adhesion Testing (ASTM D3359, methods A and B) and Impact Resistance (ASTM D2794). Results obtained are presented in Tables IV A-1, IV A-2 and IV A-3 respectively.

Evaluation of coating system suitability and performance also included experiences and observations encountered during system application, examination of prepared panels and subjective evaluation of color and gloss retention on test. An example of the effect of application was the deformation of CPVC substrate panels during application of thermally applied systems.

Finally, economic considerations were addressed. This related primarily to the cost of materials as a function of surface area to be coated. Equipment costs, in general, are included to provide a frame of reference. Capital costs, depreciation, consumables and related items, as well as application labor costs, have not been addressed. Application of a chromate pretreatment was recommended for System #9 only and was limited to aluminum substrates. The additional application step was not included in costs.

Exposure Performance

Individual panel and system ratings were considered in aggregate to examine average scores by substrate and average scores by exposure environment. This approach permitted comparisons to establish general substrate "susceptibility" and environment "aggressiveness". Comparison of overall system performance was also considered in aggregate for all panels by system.

Based upon the average aggregate score for all panels by substrate, the aluminum/stainless steel "coupled" panels exhibited the lowest average score. This suggests that the coupled panel substrate will be more difficult to protect by use of coatings than aluminum, stainless steel or CPVC substrates. Results of this comparison for all substrates are presented below.

Substrate	Average Score	Relative Score	Rank
Coupled	26.53	0.97	1
Aluminum	27.01	0.98^{6}	2
Stainless Steel	27.19	0.99^{2}	3
CPVC	27.40	1.00	4

As described above, the relative score was calculated by dividing each average score by the highest average score for the set of values presented. A higher relative score indicates better "performance", as does a higher "Rank". The Relative Score tends to normalize scores within the group or category under evaluation. Rank simply indicates order without consideration of the magnitude of differences between categories.

Exposure environments were compared in the same manner. The Average Scores and Relative Scores were determined. Results are tabulated below.

Environment	Average Score	Relative Score	Rank
QUV (G-53)	25.44	0.89	1
KTA Envirotest	26.40	0.92	2
WETF Pool	26.56	0.93	3
Laydown	27.56	0.96	4
Simulated Pool	27.65	0.97	5
Rotunda	28.59	1.00	6

The values indicate that the relative "aggressiveness" of the exposure environments of the QUV and KTA Envirotest are the most aggressive, resulting in lower average and relative scores, while the Rotunda and Simulated Pool exposures were least aggressive. It should be noted that the QUV, KTA Envirotest and Simulated Pool exposures lasted 2,000 hours compared to 3200 hours for the WETF pool and 3700 hours for the Laydown and Rotunda exposures. Data from repair and Cathode panels have not been included in the above assessment.

Aggregate scores for each of the ten (10) coating systems, including all substrates and exposure environments, were summed and their average scores calculated. Average Score, Relative Score and Rank for each of the coating systems, when listed from lowest to highest values, resulted in the following:

System	Average Score	Relative Score	Rank
7	24.17	0.83	1
8	25.81	0.88	2
4	26.97	0.92^{2}	3
10	27.06	0.92^{5}	4
3	27.22	0.93^{0}	5
9	27.34	0.93^{5}	6
5	27.49	0.94^{0}	7
2	27.62	0.94^{4}	8
6	29.04	0.99	9
1	29.25	1.00	10

The results of the system assessment indicate that, overall, Coating System #1 performed better than the other nine (9) systems included in the study. System #6 also performed well, achieving a close Relative Score (0.993) to System #1 (1.000). Both systems are thermally applied plastic powder coatings. System #7 and #8, which included topcoats of a thermally applied plastic powder and an epoxy coating respectively, exhibited the lowest performance rankings of all systems. Both systems were applied over a thermally applied aluminum powder coating. The presence of the aluminum undercoat was judged to lead to significantly decreased panel performance.

The remaining six (6) systems (#2, #3, #4, #5, #9 and #10) are epoxy coatings. The Relative Scores (0.92 to 0.94) are clustered as a group, compared to the plastic systems or overcoated aluminum powder first-coat systems.

Coating System performance was evaluated on a more detailed level by comparison of System Scores and Relative Scores within substrate and exposure environment categories. While the "susceptibility" of a substrate or "aggressiveness" of an environment has been considered above, the coating system(s) which exhibited better relative performance within specific environments and/or applied to specific substrates are of principal interest. Table V-2 presents average panel rating by exposure environment and substrate. Repair and Cathode panels are not included and are discussed separately.

Aggregate data presented previously indicated that the Coupled panel substrate was the most "susceptible" to the effects of exposure. Examination of Relative Scores for each coating system by substrate provides for comparison of each systems performance on each of the substrates employed in the study.

Comparison of performance on substrates with the aggregate scores shows comparable performance for Systems #1 and #6, both performing well on all substrates. Systems #7 and #8, in general, perform less well than the other systems. It is noted, however, that System #7, applied to coupled panels, was the third best "performer" but the lowest rated system for all other substrates. This inconsistant observation is not explained, however, it is noted that average for the coupled panels, environments in which System #7 exhibited high relative scores, principally due to chalking. Among the remaining systems, Systems #2 and #5 followed Systems #1 and #6 in Relative Score. System #5 exhibited a low relative score for coupled panel substrate. Overall, System #10 and System #4 were in the lower half of relative scores, and System #3 and System #9 were mid range. The order of performance, from highest to lowest relative score, for coating systems on each substrate is summarized below starting with the most "susceptible" substrate.

Coating System Relative Scores by Substrate

Coupled	System #	6	1	7	2	4	10	9	3	5	8
	Relative Score	1.00	0.98	0.94	0.94	0.93	0.92	0.92	0.92	0.91	0.82
Aluminum	System #	6	1	5	2	9	10	3	4	8	7
	Relative Score	1.00	0.98	0.95	0.95	0.93	0.93	0.91	0.91	0.90	0.82
Stainless	System #	1	6	5	3	2	9	4	10	8	7
	Relative Score	1.00	0.99	0.95	0.94	0.93	0.92	0.90	0.90	0.86	0.84
CPVC	System #	1	6	3	2	5	8	9	4	10	7
	Relative Score	1.00	0.99	0.95	0.94	0.94	0.93	0.93	0.92	0.90	0.77
All	System #	6	1	2	5	3	9	4	10	8	7
	Relative Score	1.00	0.99	0.95	0.94	0.93	0.93	0.92	0.92	0.88	0.84

Examination of coating system performance based upon relative scores was conducted to arrange the systems by exposure environment. This provided the following summary table.

Coating System Relative Scores by Exposure Environment

QUV-G53	System #	1	6	7	9	3	5	2	8	4	10
	Relative Score	1.00	0.95	0.93	0.87	0.86	0.84	0.80	0.79	0.73	0.71
KTA-Enviro.	System #	6	5	1	3	8	10	2	9	4	7
	Relative Score	1.00	0.97	0.965	0.93	0.93	0.92	0.90	0.89	0.89	0.79
WETF Pool	System #	6	10	2	4	1	5	9	3	8	7
	Relative Score	1.00	0.995	0.993	0.979	0.978	0.972	0.963	0.952	0.777	0.743
Laydown	System #	1	6	7	2	3	8	5	4	9	10
	Relative Score	1.00	0.967	0.95	0.92	0.92	0.917	0.90	0.87	0.87	0.867
Sim. Pool	System #	2	6	10	4	9	1	5	3	8	7
	Relative Score	1.00	1.00	0.98	0.97	0.96	0.94	0.94	0.93	0.91	0.70
Rotunda	System #	6	1	4	2	5	9	10	3	8	7
	Relative Score	1.00	0.996	0.996	0.99	0.96	0.958	0.958	0.94	0.89	0.87
All	System #	6	1	2	5	3	9	4	10	8	7
	Relative Score	1.00	0.99	0.946	0.94	0.935	0.93	0.92	0.916	0.88	0.84

Systems #6 exhibited the first or second highest Relative Score in all exposure environments. System #1 yielded the next higher Relative Scores with six (6) first or second highest Relative Scores in four (4) of the environments. System #1 performed third highest for the KTA-Envirotest, however only mid range for WETF and Simulated Pool environments. System #7 scored lowest in four (4) of the six (6) environments and System #8 next to lowest for three (3) of the six (6) environments. The remaining Systems tended to cluster in overall Relative Score performance, however, some notable observations were made. Systems #4, #9 and #10 exhibited low overall Relative Scores particularly in the Laydown exposure. This is associated with generally low scores when evaluated for chalking relative to the other coating systems. System #10 and #4 exhibited high Relative Scores for the WETF environment (immersion) and simulated pool immersion.

When excluding Systems #1 and #6 (high Relative Score) and Systems #7 and #8 (low Relative Score), the six (6) remaining systems are more easily compared. System #3, for example, exhibits lower scores than the other five (5) coating systems for immersion environments (simulated pool and WETF panels). Systems #5 and #9 also exhibit lower Relative Scores for immersion testing in the simulated pool and WETF. Among these systems, Systems #2, #4 and #10 exhibit the highest Relative Scores in immersion service.

Under relatively mild exposure environments, (i.e. Rotunda and Laydown area), Systems #2, #4 and #5 exhibited the highest relative scores when Systems #1 and #6 are not considered.

A final consideration in the assessment of the exposure data for the six (6) environments discussed above, is the relative influence of the performance criteria employed. The relative importance of scoring values for chalking, blistering and corrosion by coating system and exposure environment has been examined. The comparison was performed by summing the average system score for a rating criteria (maximum of 10) for each exposure environment. A "perfect" score total is 60. Each score was divided by 60 to provide the relative performance for each coating system by evaluation criteria. The results are provided below.

System	Chalk	Blisters	Corrosion
1	0.95	0.99	0.95
2	0.78	0.99	0.97
3	0.80	0.98	0.94
4	0.71	0.99	0.97
5	0.80	0.98	0.96
6	0.93	1.00	0.97
7	0.66	0.97	0.83
8	0.76	0.94	0.88
9	0.76	0.99	0.96
10	0.71	1.00	0.96
Overall	0.78	0.98	0.94

Blister formation did not occur on any of the System #6 panels examined. This has resulted in a calculated score of 1.00. In addition, System #6 exhibited the lowest extent of corrosion product formation and second lowest degree of chalking. Overall, chalking occurrence exhibited the greatest influence on aggregate system scores followed by corrosion and blistering.

When the three evaluation criteria are examined by exposure environment, as should be expected, aggregate score is more influenced by chalking than corrosion or blistering. Comparison between environments shows that QUV Weatherometer, KTA-Envirotest and Laydown area exposures result is the greatest chalking on the coated panels. The WETF Pool exposure (immersion) resulted in more blistering and corrosion than the other exposure environments.

Environment	Chalk	Blisters	Corrosion
Rotunda	0.92	0.98	0.96
Laydown	0.78	1.00	0.98
WETF Pool	0.87	0.95	0.84
QUV-Weatherometer	0.57	1.00	0.97
KTA-Envirotest	0.69	0.98	0.98
Simulated Pool	0.87	0.99	0.90
Overall	0.78	0.98	0.94

Chalking is not considered to be as significant an effect as blister or corrosion formation. When all three evaluation criteria are assessed in aggregate, the coating systems rank differently than when blistering and corrosion are examined without chalking. This is discussed separately.

Table V-3 provides average panel ratings for each system by evaluation criteria and exposure environment.

Repair panel and Cathode panel results are presented in Tables IV D-7 and IV D-8 respectively. Since the panels were handled as separate "environments", the outcomes of their evaluations have not been addressed above.

All test panels were scribed prior to exposure and one of each pair subject to impact. The repair panels, removed after 2,000 hours immersion in the WETF Pool were spot prepared and had touch-up coatings applied. The procedures are described elsewhere. Subsequent to repair, the panels were returned to the WETF Pool for an additional 1,000 hours exposure.

Outcome of evaluation results are based upon a comparison to WETF immersion. Overall system scores, based on evaluation criteria, from Repair panels and WETF panels are presented below. The Repair panel scores were found to be consistently higher than WETF panel scores. The relative scores for repair systems indicate that Systems #7 and #8 exhibited greater effects from exposure than the other eight (8) systems. System #9 showed an increase in relative performance, compared to WETF exposure, increasing in rank from fourth to ninth out of ten systems.

Coating	Relative Score				Repair	WETF
System	Chalking	Blistering	Corrosion	Overall	Total	Total
1	0.90	1.00	1.00	1.00	29.00	28.05
2	0.90	1.00	1.00	1.00	29.00	28.23
3	0.85	0.93	1.00	0.96	27.83	26.88
4	0.90	0.98	0.95	0.98	28.33	27.70
5	0.90	0.98	0.98	0.99	28.67	27.70
6	0.90	1.00	1.00	1.00	29.00	28.40
7	0.90	0.83	0.83	0.89	25.67	21.10
8	0.90	0.85	0.95	0.93	27.00	22.38
9	0.90	1.00	1.00	1.00	29.00	27.43
10	0.90	1.00	1.00	1.00	29.00	28.38
Overall	0.90	0.96	0.97			

Cathode panel performance was compared to WETF performance in the same manner as the Repair panels.

Coating	Relative Score				Cathode	WETF	Outcome
System	Chalking	Blistering	Corrosion	Overall	Total	Total	
1	1.00	1.00	0.98	1.00	29.75	28.08	improved
2	0.90	0.88	0.95	0.91	27.25	28.53	not effective
3	0.80	1.00	0.95	0.92	27.50	26.50	improved
4	0.90	1.00	0.98	0.96	28.75	27.00	improved
5	0.90	0.80	0.98	0.90	26.75	28.25	not effective
6	0.90	1.00	1.00	0.97	29.00	28.50	improved
7	0.40	0.63	0.75	0.60	17.75	22.60	not effective
8	0.88	0.80	0.90	0.86	25.75	21.20	improved
9	0.90	0.95	1.00	0.96	28.50	28.00	improved
10	0.95	1.00	0.98	0.98	29.25	28.75	improved
Overall	0.85	0.91	0.95				

The Cathode panels were exposed for the same number of hours and under the same environmental conditions as the WETF panels. When compared by the evaluation criteria system, scores which are higher than WETF System scores are labeled "improved". When Cathode System scores are less than WETF system scores, "not effective" is indicated. Systems #2, #5 and #7 when attached to a zinc anode, did not exhibit system scores as high as those for panels not connected to an anode. The values for System #7 suggest that the aluminum powder coat was not cathodically protected by the zinc anode. All other systems exhibited higher system scores for Cathode panels when compared to WETF panel system scores.

Only the "companion" aluminum and stainless steel panel scores from WETF immersion were compared. In aggregate, aluminum and stainless steel average rating scores were 8.77 and 9.06 respectively for WETF exposure and 9.07 and 8.95 for Cathode aluminum and stainless panels. Any benefit which may be achieved appears to be associated with the aluminum substrate.

The influence of chalking, as the least meaningful of the evaluation criteria, and low system scores of systems #7 and #8 were examined. Without including the chalking scores, system rankings, overall, were altered. Briefly, from highest to lowest system relative scores the following list resulted.

With Chalking, System:	#6	#1	#2	#5	#3	#9	#4	#10	#8	#7
Relative Score:	1.00	1.00	.95	.94	.93	.93	.92	.92	.88	.85
Without Chalking, System:	#6	#2	#10	#4	#5	#9	#1	#3	#8	#7
Relative Score:	1.00	1.00	.99	.99	.99	.99	.99	.97	.92	.91

Note the clustering of relative scores which resulted. This suggests little overall differences between systems, exclusive of Systems #7 and #8.

Changes in average scores, by environment, when systems #7 and #8 are not included were as follows:

Environment	All Systems	Without Systems #7&#8
QUV-Weatherometer	8.48	8.45
KTA Envirotest	8.80	8.94
WETF Pool	8.85	9.27
Laydown	9.19	9.15
Simulated Pool	9.22	9.53
Rotunda	9.53	9.71

The range of average scores becomes slightly larger. However, the same comparison, without including the chalking ratings resulted in the following:

Environment	All Systems	Without Chalk Systems #7&#8
QUV-Weatherometer	9.87	9.91
KTA Envirotest	9.78	9.83
WETF Pool	8.96	9.33
Laydown	9.87	9.86
Simulated Pool	9.47	9.66
Rotunda	9.71	9.83

The range of average values is reduced and the apparent aggressiveness of exposure environments is changed.

The outcome of the adjustments made above indicate that, in terms of aggressiveness, immersion service (WETF pool, simulated pool) is the most "aggressive" environment. Further, corrosion ratings were generally lower, on average, than blister ratings within each of the six environments. This is shown in Table V-3.

System Relative Scores, when chalking and Systems #7 and #8 are not included, the result in System ranking are as shown in the following table:

System #	Relative Score	Rank
1	0.98^5	2
2	0.99^6	7
3	0.97^3	1
4	0.99^2	5
5	0.98^7	4
6	1.00^0	8
9	0.98^7	3
10	0.99^4	6

Significantly, system #1 falls in rank being next to last (Rank=2) as opposed to first (Rank=10) as orginally evaluated. Systems #6, #2, #4 and #10 are the highest ranked systems. Systems #4 and #10 increased from the lower ranked half, when initially assessed, to the top half of system rankings.

More importantly, the relative scores suggest that in aggregate, without considering chalking performance, the systems do not differ greatly in performance. This does not include Systems #7 and #8. Therefore, since environmental service results find immersion to be the most aggressive, immersion service performance appears to be a reasonable first basis for selection of coating subsequent to immersion service, physical properties and chalking performance provide additional basis for selection.

The observed performance of System #6, being generally better than that of other systems, could be related to the system film thickness. The manufacturer recommendation for the system is for 16 mils thickness, however, the application resulted in nearly 24 mils. It is noted that System #7, also exhibiting about 24 mils film thickness compared to the recommended 16 mils, did not perform well.

Periodic Examination

The project design did not require intermittent evaluation of test panel performance. Thus, it was not intended to include assessment of the predictive value of shorter term evaluation results however, intermentent evaluations were performed. A general comparison of the system score data collected at approximately 800 hours exposure for the Simulated Pool, QUV Weatherometer and KTA Envirotest with that collected after 2000 exposure found a correlation coefficient of 0.93.

Comparison of System Score intermittent observations (for all exposure environments) with observations at the termination of exposure exhibited a correlation coefficient of 0.90. Thus, the relationship appears both strong and directly related. This is not unexpected and indicates that if effects are to be exhibited, they begin to occur after shorter exposure times than those employed in this study. The rate of "deterioration" was not examined nor was a predictive model investigated. The reader is cautioned that comparison of such paired data does not necessarily permit drawing conclusions between exposure environments and the future degree of effect, i.e. chalk, blistering or corrosion formation. For example, paired data of intermediate and final evaluations for all panels evaluated for chalking (all systems, environments and substrates) yielded a correlation coefficient of 0.75 while blister formation and corrosion formation had correlation coefficients of 0.46 and 0.54 respectively. Thus, any predictive model which may be developed from the intermittent data collected will require careful assessment of validity.

Physical Test Performance

Taber abrasion test results, ASTM D4060, showed that Systems #1, #7 and #6 thermally applied plastics exhibited the lowest change in weight loss on test. Next in performance were Systems #10, #2 and #8. The weight loss for these six (6) systems was in the range of 25 to 85 milligrams (mg). The remaining four (4) systems exhibit weight losses in the range of 105 to 207 mg.

Tape Adhesion Testing, ASTM D3359, Methods A (X-cut) and B (cross hatch), showed that all systems exhibit relatively good adhesion. Averaging adhesion scores for both methods A and B, showed that Systems #6, #1 and #9 have the highest scores. Method "B", the more rigorous of the two methods, indicated Systems #3 and #4 exhibit the poorest adhesion. When compared by substrate, coatings applied to the CPVC substrate generally exhibit lower adhesion while the stainless steel and aluminum substrates exhibit essentially the same degree of adhesion. System #7, thermally applied aluminum powder, topcoated with thermally applied plastic, exhibited the lowest adhesion ratings on CPVC, particularly by Method B. Significantly System #7 was rated "5" for both methods A and B on stainless steel and aluminum substrate.

Impact resistance was performed per ASTM D2794. Systems were ranked based upon the lowest direct and reverse impact loads at which coating damage could be observed. Systems #1 and #7 reached apparatus load capacity without damage to the coatings by either direct or reverse impact. Systems #3 and #9 performed slightly better than the remaining systems when subject to direct impact. System performance under reverse impact, with the exception of Systems #1 and #7, was generally similar for Systems #2-#5 and #8-#10. System #6 exhibited the least reverse impact resistance.

When examined by exposure environment, system #7 exhibited 0A and 0B ratings for CPVC panels in the laydown area a 1B on CPVC exposed to QUV-Weatherometer exposure and OB on CPVC exposed in the simulated pool. System #1 exhibited 0A and 0B ratings for repaired CPVC panels. All other adhesive tests for the thermally applied plastic coatings were 5A and 5B.

The influence of heat on the CPVC film may be responsible for the low ratings observed. No consistant pattern was evident.

Overall, systems #3, #4, and #5 exhibited poorer adhesion than the other coating systems examined. This was related to low adhesion ratings when evaluated by Method B subsequent to exposure by QUV-Weatherometer, simulated pool, KTA-Envirotest and

WETF pool immersion. Systems #3 and #4 exhibited 3B and 2B ratings after exposure in the first two of the above environments. Other than the above observations adhesion tests were found to be 5A, 4A and 5B, 4B.

Observations and Experience

During performance of this project observations about color and gloss changes during testing, as well as experience with coating applications were noted. Although subjective, these observations provide additional insight regarding performance and application. It should be recalled that Systems #6 and #7 were black in color thus color/gloss cannot be directly related to the observations made on the remaining (white) coating systems.

Sections IV B and IV C provide observations regarding panel gloss and color change. Neither of these characteristics examined were subject to measurement as part of the study design. Panels subject to exposure were visually examined for changes in color and gloss versus their control panels. General trends were noted, and result in the following observations.

In general, with the exception of System #1 which exhibited little color change, all other systems exhibited some color change. Systems #8 and #2 exhibited greater visual color shift than the other systems.

Visual comparison of the degree of color change for the white coating systems found that Systems #3, #4 and #5 became a duller white color while System #1 did not exhibit a color change due to immersion in the WETF pool. System #8 "yellowed" more than the other systems followed by Systems #2, #9 and System #10. Systems #6 and #7 were black coatings and were not considered.

Exposure in the Rotunda resulted in System #2 "yellowing" the most, followed by Systems #8, #10 and #3. System #4 "grayed" in color. System #1 exhibited no change.

Any decrease in gloss appeared to be associated with chalking. Visual examination found that in general, System #1 retained gloss better than the remaining systems, followed by Systems #6, #5 and #3. Decrease in gloss appears to be sensitive to the exposure environment. For example, the Systems exposed in KTA-Envirotest all exhibited dulling and no ranking was easily established. Simulated pool exposed specimens showed that gloss "retention" was best for System #10, followed by System #2, #8 and #9.

System #1 appears superior in gloss and color retention. The other systems, being epoxies, are subject to color change and dulling due to the exposure environment. While changes are relative, dulling and slight color changes should be expected.

Application properties of the systems are briefly described below for the systems applied by KTA-Tator. Observations made during application of System #1, applied by Plastic Flamecoat, and System #6, applied by Vesca Plastics are also provided.

System #1. For application of this thermally applied plastic powder, preheating of the substrate is required. Several problems were noted. First, control of film thickness was difficult at times despite application by an experienced worker. Initially, coated panels exhibited too high film thicknesses. Removal of the coating system and reapplication was necessary. Film thickness was more consistent during reapplication. Second, heat distribution, particularly for coupled panels, lead to application difficulties. Also CPVC panels were deformed during preheating and application.

System #2. Application was performed by conventional spray. Due to gradual viscosity change with the product, recommended film thickness was not easily achieved. Several different spray tips were used to achieve an even flow of material. Thinner was also added, after discussion with the manufacturer, to control flow. None of the above methods appeared to improve application. The coating appears better suited to airless application.

System #3. Application was performed by conventional spray. The coating system was not easily applied due to high viscosity. Application remained difficult, but improved after adding the manufacturer's recommended amount of thinner. Subsequently, an additional 5% by volume of thinner was added, as suggested by the manufacturer, to achieve a uniform application pattern.

System #4. Both the primer coating and topcoat were easily applied by conventional spray. Film thicknesses were achieved without sagging or running.

System #5. The coating was applied by conventional spray. Application was problem free.

System #6. This thermally applied plastic required preheating of the substrate prior to application. The desired surface temperature, assessed by pyrometer, was found to be difficult to achieve with the coupled aluminum and stainless steel panels. CPVC panels were warped by excessive heating, and therefore lower heating and application rates were required.

System #7. This system consisted of a thermally applied aluminum powder, followed by an overcoat of a thermally applied plastic. Application was performed by Vesca Plastics, Freeport, Texas. Heat-related application problems with CPVC substrates has been discussed previously. Aluminum powder application over aluminum, stainless steel and coupled panels occurred with relative ease. The aluminum film, however was observed to be rough and was comprised of molten aluminum droplets deposited over each other to obtain film thickness. Application of the plastic coating appeared more difficult than that for Systems #1 and #6. The additional aluminum coat increased heat distribution problems during preheating and application. Temperature differentials as great as 50-70°F were noted from the front to back of metal test panels. This excessive heating caused bubbling and burning of the plastic film. Although this was overcome, bubbling in the plastic film occurred due to air within the aluminum undercoat. Upon cooling, the plastic was "drawn" back to a continuous film with a dimple like texture. The droplet-like pattern of the aluminum coat also occurred in the plastic film in cases where heat control was poor.

System #8. The product was applied by conventional spray over a thermally applied aluminum. The aluminum coat was applied by Vesca Plastic as noted above. Problems encountered during and after application included pinholing and "fish eyes" in the coating. These observations may be due to gassing of the aluminum coating.

System #9. Application was performed by conventional spray. Spray application was conducted with ease. Initial film character was patterned but subsequent flow out resulted in a smooth uniform coating.

System #10. The coating system normally requires plural component application. Application was by brush as the required equipment for plural application was not readily available. Application was difficult due to product viscosity and pot life. A smooth uniform coat was not obtained and the coating tended to creep from edges and corners.

Economic Considerations

Application equipment for epoxy coating materials is, in general, widely available and coating contractors will normally have purchased this equipment. Plural component equipment, such as that recommended for System #10, is more limited in distribution, and more expensive. Finally, equipment required for application of thermally sprayed materials is limited in distribution and normally sold by companies specializing in sale of these coatings.

Equipment costs are summarized below, based upon communication with suppliers. A more detailed break down is provided in the appendix.

Conventional Application	$1,500.00
Airless Application	$3,800.00
Thermal Plastic/Aluminum (Systems 6 & 7)	
Flame Spray	$11,800.00
Fluidized Bed	$14,300.00
Thermal Plastic Application (System #1)	
Fluidized Bed/Pistol 60 ft2/hr	$1,600.00
Gravity Feed/Pistol 100 ft2/hr	$5,400.00
Plural Component Application (System #10)	
Complete Unit	$20,000.00

The above is not a market survey of available equipment and the thermal application equipment and plural component equipment costs were obtained from the manufacturers of the coating materials included in the study. Consumable supplies and parts are not included. Air compressor costs are not included.

Beyond equipment costs, which may be purchased or rented, material costs were obtained from the manufacturer of the coatings. Table V-4 provides costs for the coating materials. Costs have been computed, based upon manufacturer prices, for coverage of

1000 square feet at recommended dry film thickness. These are summarized as follows:

System - Generic Type	Cost/1000 ft^2	Material/1000 ft^2
#1 - EMA Plastic*	$1,175.00	100 lbs.
#2 - Phenolic Epoxy	$1,000.00	12.5 gal.
#3 - Amide Epoxy	$400.00	12.4 gal.
#4 - Amine Epoxy	$500.00	3.8, 5.5 gal. (two coating materials)
#5 - Amine Epoxy	$670.00	20.1 gal.
#6 - Polyamide Plastic	$2,400.00	106.7 lbs.
#7 - Al/EAA Plastic*	$2,560.00	28.2/106.7 lbs. (two coating materials)
#8 - Al/Amine Epoxy	$750.00	28.2 lbs, 10.5 gal. (two coating materials)
#9 - Phenolic Epoxy	$1,110.00	23.9 gal.
#10 - Amine Epoxy	$680.00	10.0 gal.

* EMA - ethylene methacrylic acid, Al aluminum powder undercoat
EAA - ethylene acrylic acid. The aluminum powder undercoat cost is estimated to be approximately $500/1000 ft^2.

Product costs are seen to be quite variable. For the thermally applied plastic materials Systems #6 and #7, the cost is more than double that of System #1, which is also a thermally applied plastic. The epoxy systems also exhibit considerable cost variations, with costs from $400.00 - $1,000.00 per 1,000 square feet. Chromatic acid pretreatment of aluminum, recommended by the manufacturer of System #9, would add about $17.00 per 1000 ft^2 material cost when coating aluminum.

In conjunction with equipment costs, System #1 would be the least expensive process of the thermally applied plastic coatings. System #10 the most expensive of the epoxy coatings, assuming plural component application of System #10.

It should be recognized that consideration of coating materials is only one component of overall costs for materials, fabrication and assembly of equipment. Surface preparation and coating application labor costs will probably not vary much from one material to the next. Rather, the number of application steps (coats) could be employed to estimate labor. When aluminum substrates are to be coated, an additional (pretreament) step is associated with System #9.

TABLE V-1
Generic Description of Candidate Coating Systems

System No.	Application Method and Generic Description of Materials	Preparation and Application Data: Surface Prep	Profile mils, avg	Coats #	DFT, mils average	Manufacturer's Product Data: Vol. Solids %	VOC lb/gal	Application Equipment*	Ambient Limits RH	Temp (F)	Coverage ft2/mil-Gal.	Material gal. @dft 1000 ft2	VOC lb/gal solids
1	**Thermally Applied** Plastic Ethylene methacrylic acid	SP-5	1.9	1	15.8	100%	0	Thermal Spray	100%	N/A	*per lb.* 100	*lbs.* 158.0	0.0
2	**Conventional Application** two-component phenolic epoxy	SP-5	2.5	4	15.9	100%	0	B,R,C,A	100%	45+	1605	39.6	0.0
3	**Conventional Application** two-component polyamide epoxy	SP-5	2.5	2	8.7	71%	2.1	B,R,C,A		32+	1139	21.5	3.0
4	**Conventional Application** two-component, primer polyamine alum. epoxy	SP-5	2.3	1	8.7	90%	0.74	B,R,C,A	95%	50-100	1444	6.7	0.8
	two-component, top coat amine epoxy		-	1	14.8 (total)	75%	1.78	B,R,C,A	80%	50-110	1203	16.4	2.4
5	**Conventional Application** two-component polyamide epoxy	SP-5	2.2	2	12.3	61%	2.76	B,R,C,A	85%	55-95	978	41.2	4.5
6	**Thermally Applied** Plastic Polyamide 11	SP-5	3.4	1	23.7	100%	0	Thermal Spray	-	-	150	158.0	0.0
7	**Thermally Applied** Aluminum Powder Primer and Plastic top coat ethylene acrylic acid	SP-5	3.7	2	23.8 (total)	100%	0	Thermal Spray	-	-	*per lb.* 150	*lbs.* 317.3	0.0
8	**Thermally Applied** Aluminum Powder Primer **Conventional Application** amine-epoxy top coat	SP-5	3.6	2	10.4	70%	2.3	B,R,C,A		50+	1091	27.2	3.3
9	**Conventional Application** two-component epoxy phenolic	SP-5 (employed by NASA)	2.3	2	14.0	56%	3.4	B,C,A		50	898	55.7	6.1
10	**Brush Application** Two-component amine epoxy	SP-5	2.5	2	18.7	100%	0	B,R,P	100%	50-90	1600	23.4	0.0

Comments: *Equipment: B=brush, R=roller, C=conventional spray, A=airless, P=plural or Special Thermal Spray.
** Preheated Substrate Temperature
VOC, lbs/gal. solids: Calculated as: (VOC lbs/gal.)/(Volume Solids %)

TABLE V-2

EXPOSURE EVALUATION SUMMARY

Average System Panel Ratings by Environment and Substrate

System	Rotunda					Laydown					WETF Pool					System	Relative	System
Number	Al	Cpl	CPVC	SS	Avg.	Al	Cpl	CPVC	SS	Avg.	Al	Cpl	CPVC	SS	Avg.	Score	Score	Rank
1	9.83	10.00	10.00	9.83	9.92	10.00	10.00	10.00	10.00	10.00	8.72	8.30	10.00	10.00	9.25	29.17	1.000	10
2	10.00	9.67	10.00	9.83	9.88	9.17	9.17	9.33	9.17	9.21	9.67	8.90	9.67	9.35	9.40	28.48	0.976	8
3	8.83	9.50	9.67	9.50	9.38	9.17	9.17	9.33	9.17	9.21	8.17	8.70	9.67	9.50	9.01	27.59	0.946	4
4	10.00	9.67	10.00	10.00	9.92	8.50	9.17	8.67	8.50	8.71	9.00	9.40	9.67	9.00	9.27	27.89	0.956	7
5	9.67	9.50	9.67	9.50	9.58	9.17	8.50	9.33	9.17	9.04	9.17	8.30	9.67	9.67	9.20	27.83	0.954	6
6	10.00	9.83	10.00	10.00	9.96	9.67	9.67	9.67	9.67	9.67	9.50	9.20	9.67	9.50	9.47	29.09	0.997	9
7	8.33	9.50	8.67	8.33	8.71	9.67	9.67	9.00	9.67	9.50	6.87	8.40	4.68	8.20	7.04	25.25	0.865	1
8	9.33	7.50	9.67	9.00	8.88	9.33	8.67	9.33	9.33	9.17	7.60	5.62	9.67	6.53	7.36	25.40	0.871	2
9	9.50	9.50	9.67	9.50	9.54	8.50	9.17	8.67	8.50	8.71	9.33	8.12	9.67	9.33	9.11	27.36	0.938	3
10	9.67	9.33	9.67	9.50	9.54	8.67	8.83	8.67	8.50	8.67	9.67	8.85	9.67	9.50	9.42	27.63	0.947	5
Averages	9.52	9.40	9.70	9.50	**9.53**	9.18	9.20	9.20	9.17	**9.19**	8.77	8.38	9.20	9.06	**8.85**			

System	QUV-Weatherometer					KTA-Envirotest					Simulated Pool					System	Relative	System
Number	Al	Cpl	CPVC	SS	Avg.	Al	Cpl	CPVC	SS	Avg.	Al	Cpl	CPVC	SS	Avg.	Score	Score	Rank
1	10.00	10.00	10.00	10.00	10.00	9.33	9.00	9.33	9.33	9.25	9.33	8.50	9.67	9.67	9.29	28.54	0.984	9
2	8.00	8.00	8.00	8.00	8.00	8.67	8.33	8.67	8.67	8.58	9.83	9.67	10.00	10.00	9.88	26.46	0.912	5
3	8.50	8.67	8.67	8.67	8.63	9.33	8.00	9.33	9.00	8.92	9.17	8.33	9.67	9.50	9.17	26.71	0.921	7
4	7.33	7.33	7.33	7.33	7.33	8.33	8.33	8.67	8.67	8.50	9.67	9.33	9.67	9.67	9.58	25.42	0.876	2
5	8.67	8.33	8.00	8.50	8.38	9.33	9.17	9.33	9.33	9.29	9.33	8.50	9.67	9.67	9.29	26.96	0.930	8
6	9.50	9.50	9.67	9.50	9.54	9.67	9.33	9.67	9.67	9.58	9.83	9.67	10.00	10.00	9.88	29.00	1.000	10
7	9.50	9.50	8.33	9.67	9.25	7.00	8.33	8.00	7.00	7.58	6.33	8.50	6.67	6.33	6.96	23.79	0.820	1
8	8.00	7.67	8.00	8.00	7.92	9.33	8.33	8.67	9.33	8.92	8.67	9.00	9.67	8.67	9.00	25.83	0.891	4
9	8.67	8.67	8.67	8.67	8.67	8.67	8.17	8.67	8.67	8.54	9.50	9.00	9.67	9.67	9.46	26.67	0.920	6
10	7.33	7.00	7.00	7.00	7.08	9.00	9.00	8.67	8.67	8.83	9.67	9.67	9.67	9.67	9.67	25.58	0.882	3
Averages	8.55	8.47	8.37	8.53	**8.48**	8.87	8.60	8.90	8.83	**8.80**	9.13	9.02	9.43	9.28	**9.22**			

Aggregate Results for Systems

System Number	1	2	3	4	5	6	7	8	9	10
System Score	28.86	27.47	27.15	26.65	27.39	29.05	24.52	25.62	27.02	26.61
Relative Score	0.99	0.95	0.93	0.92	0.94	1.00	0.84	0.88	0.93	0.92
System Rank	9	8	6	4	7	10	1	2	5	3

TABLE V-3

AVERAGE PANEL RATING BY EXPOSURE ENVIRONMENT

System	Rotunda			Laydown Area			WETF Pool		
Number	Chalk	Blisters	Corrosion	Chalk	Blisters	Corrosion	Chalk	Blisters	Corrosion
1	10.0	10.0	9.8	10.0	10.0	10.0	10.0	9.6	8.5
2	10.0	10.0	9.6	8.0	10.0	9.6	9.0	9.6	9.6
3	9.0	9.8	9.4	8.0	10.0	9.6	8.5	9.6	8.8
4	9.8	10.0	10.0	6.5	10.0	9.6	9.0	9.9	8.9
5	9.0	10.0	9.8	7.5	10.0	9.6	9.0	9.4	9.3
6	10.0	10.0	9.9	9.0	10.0	10.0	9.0	10.0	9.4
7	7.3	9.8	9.1	9.0	9.5	10.0	5.9	9.2	6.1
8	9.0	8.4	9.3	7.5	10.0	10.0	8.4	8.4	5.6
9	9.0	10.0	9.6	6.5	10.0	9.6	9.0	9.4	9.1
10	9.0	10.0	9.6	6.3	10.0	9.8	9.3	9.8	9.4
Overall	9.2	9.8	9.6	7.8	10.0	9.8	8.7	9.5	8.4

System	QUV-Weatherometer			KTA-Envirotest			Simulated Pool		
Number	Chalk	Blisters	Corrosion	Chalk	Blisters	Corrosion	Chalk	Blisters	Corrosion
1	10.0	10.0	10.0	8.0	10.0	9.8	9.0	10.0	8.9
2	4.0	10.0	10.0	6.0	10.0	9.8	10.0	10.0	9.6
3	6.0	10.0	9.9	7.5	9.6	9.6	8.8	9.8	9.0
4	2.0	10.0	10.0	6.3	9.5	9.8	9.0	10.0	9.8
5	5.3	10.0	9.9	8.0	10.0	9.9	9.0	9.5	9.4
6	9.0	10.0	9.6	9.0	10.0	9.8	10.0	10.0	9.6
7	9.0	10.0	8.8	3.8	9.5	9.5	4.5	10.0	6.4
8	4.0	10.0	9.8	7.5	9.5	9.8	9.0	10.0	8.0
9	6.0	10.0	10.0	6.0	9.9	9.8	9.0	10.0	9.4
10	2.0	10.0	9.3	6.8	10.0	9.8	9.0	10.0	10.0
Overall	5.7	10.0	9.7	6.9	9.8	9.8	8.7	9.9	9.0

TABLE V-4
Material Cost Comparison

Coating System	Manufacturer's Product Data and Recommendations					Material gal. @dft 1000 ft2	VOC lb/gal solids	Material Cost per gal	Material Cost @dft 1000 ft2
	Coats #	DFT, ea. (mid)	Vol. Solids %	VOC lb/gal	Application Equipment*				
System #1 Ethylene methacrylic acid	1	10	100%	0	Thermal	*lbs.* 100.0	0.0	$11.75	$1,175.00
System #2 phenolic epoxy	2	10	100%	0	B,R,C,A	12.5	0.0	$80.00	$996.88
System #3 polyamide epoxy	2	5	71%	2.1	B,R,C,A	12.4	3.0	$31.50	$389.52
System #4 polyamine alum. epoxy	1	5	90%	0.74	B,R,C,A	3.8	0.8	$60.00	$230.84
amine epoxy	1	5	75%	1.78	B,R,C,A	5.5	2.4	$48.70	$269.88
System #5 polyamide epoxy	2	6	61%	2.76	B,R,C,A	20.1	4.5	$33.00	$663.78
System #6 Polyamide 11	2	8	100%	0	Thermal	*lbs.* 106.7	0.0	$22.63	$2,413.87
System #7 Aluminum Powder	1	2	100%	n/a	Thermal	28.2	n/a	$17.98	$506.48
Thermal Plastic ethylene acrylic acid	2	8	100%	0	Thermal	*lbs.* 106.7	0.0	$19.27	$2,055.47
									$2,561.95
System #8 Aluminum Powder	1	2	100%	n/a	Thermal	28.2	n/a	$17.98	$506.48
amine-epoxy	2	4	70%	2.3	B,R,C,A	10.5	3.3	$22.95	$240.41
									$746.89
System #9 epoxy phenolic *Pretreatment of aluminum substrate (only).	2	6	56%	3.4	B,C,A	23.9	6.1	$46.40	$1,107.22
System #10 amine epoxy	2	8	100%	0	B,R,P	10.0	0.0	$67.15	$671.50
*Chromate pretreatment (Alodine 1201), as recommended by manuf. of System #9. Recommended application, by manuf. of Alodine 1201, coverage approx. 800ft2/gallon.						1.3		$13.36	$16.70

Section VI

Conclusions and Recommendations

Thermal application procedures should not be employed on substrates such as CPVC, which are not heat tolerant. Elevated temperatures cause deformation of the substrate, present a risk of charring the substrate and may cause surface contamination due to decomposition products. Although adhesion appears acceptable it was found to be less than that achieved on metal substrates.

Use of thermally applied aluminum metal powder over the substrates included in this program did not result in improved system performance. Both System #7, with a thermally applied plastic topcoat, and System #8, overcoated with an epoxy, were more affected by exposure than systems without an aluminum powder coat. Corrosion products observed on Systems #7 and #8 were predominantly associated with the applied aluminum coating. It appears that the aluminum powder coat was more reactive to the exposure environments than the substrate metals and acted as a sacrificial anode. Additionally, the metal powder coating, as applied, was porous and non-uniform. This contributed to difficulties in over coating.

Thermally applied plastic coatings, System #1 and System #6, generally performed better than the epoxy coatings. Adhesion was comparable over metal substrates, impact resistance was superior and resistance to chalking greater, as compared to epoxy systems. The overall ratings did not show the plastic systems to be more corrosion resistant than epoxy coatings. System #1 exhibited less corrosion resistance than five (5) of the seven (7) epoxy systems.

Cyclic exposures, specifically QUV-Weatherometer and the KTA Envirotest were found to be the most aggressive of the environments included in the study when all three evaluation criteria are considered. This was found to result primarily from chalking of the coatings under ultraviolet (UV) light exposure.

WETF pool and simulated pool exposures, both immersion environments, contributed primarily to the general occurrence of blistering and the formation of corrosion product. Chalking occurred in these environments but was of less significance than noted in the QUV, Laydown and KTA Envirotest environments. The importance of the immersion environments and their relative "aggressiveness" is evident when chalking is removed as an evaluation criteria for all environments. Based upon blistering and corrosion data only, immersion environments are found to be the most "aggressive".

The Rotunda exposure, the least severe of all exposures, resulted in little overall chalk formation. The occurrence of blistering and corrosion on panels subject to Rotunda exposure is attributed to an inadvertent immersion in the WETF pool. Chlorine by products and associated pool water constituents were not rinsed from panel surfaces.

Laydown area exposure, as expected, exhibited outdoor effects from sunlight exposure, such as chalking. Blistering and corrosion were of no significance as discriminating effects.

Dissimilar metals in contact, the aluminum-stainless steel coupled panels employed in this project, were affected to a greater degree than aluminum, stainless steel or CPVC test panels alone. This was related to immersion exposure in the WETF Pool, Simulated Pool and the KTA-Envirotest, which included cyclic immersion. The aluminum side of the panels were more affected than the stainless steel side.

The mild environment of the WETF Rotunda does not contribute to discrimination between coating system. Selection of a coating system appropriate for WETF use should be principally based upon immersion data with respect to blister and corrosion formation and QUV weatherometer exposure for chalk resistance. The inadvertent immersion of Rotunda specimens in the WETF pool is of limited value as adjunct information.

Coating systems #6, #2, #10 and #4 are the leading candidates for consideration as coating systems. This results from exhibiting greater relative scores for blistering and corrosion in immersion service. System #1 performed well in all environments except the simulated pool, however, chalk resistance was the principal reason as it was superior to other coatings. Systems #10 and #4 moved up in rank when chalking was not considered in the assessment. System #5 remained midrange whether or not chalking was included in system ranking.

Physical test results show that, of the above systems, #6, #10 and #2 exhibited 43 mg, 50 mg and 65 mg weight change respectively from Taber abrasion testing. Only system #1 (25 mg) and system #7 (30 mg) exhibited lower weight change. System #5 exhibited an average weight loss of 105 mg.

Adhesion testing results showed that System #6 demonstrated 5A and 5B ratings for all substrates in each of the exposure environments. System #2 was rated no less than 4A and 4B, system #10 was consistently rated 5A , 4A and 5B, 4B with the exception of test panels subject to QUV-Weatherometer exposure. System #10 exhibited 5A and 3B ratings on stainless steel, aluminum and CPVC substrates subsequent to QUV-Weatherometer exposure. System #4 exhibited consistent ratings of 5A or 4A for all exposures, however, ratings of 3B or 2B were exhibited on panels exposed in the QUV-Weatherometer, simulated pool, KTA Envirotest and the WETF pool aluminum panel (3B). System #5 exhibited 5 or 4 ratings by both the A and B test methods of ASTM D 3359.

Impact resistance testing, ASTM D 2794, found that System #6 fractured at 16 inch-pounds and 1 inch-pounds from direct and indirect impact respectively. System #2 exhibited cracking at 8 inch pounds direct and 3 inch-pounds indirect impact. Only system #10 exhibited a lower direct impact resistance (4 inch-pounds). System #4 and system #5 fractured at 16 inch pounds direct impact. These two systems and system #10 exhibited reverse impact resistance up to 3 inch pounds. System #6 differed significantly from the greater than 176 inch pound impacts withstood by system #1 and #7, the other plastic coating materials in the study.

The thermally applied plastic of System #7 and epoxy coating of System #8 would have probably exhibited better performance had they not been applied over the aluminum powder coating. Porosity in the aluminum coating contributed to difficulty in overcoating and uniformity in topcoat films. Corrosion at the panel scribes of System #7, specifically in WETF and simulated pool immersion can be attributed to the aluminum coat. System #8 ratings were also impacted as a result of the aluminum undercoat, however, to a lesser extent than noted for System #7.

The chalking found to be present on System #8 is related to the epoxy coat and unrelated to the aluminum undercoat. Chalking on System #7 was visually dramatic due to the contrast of the white film on the black colored topcoat. Rating was, however, related to transfer and therefore comparable to the assessment made on other coating systems. The nature of the film on the System #7 panels has not been established. The source is likely a leachable plasticizer migrating to the panel surface as a result of water and moisture. Chalk ratings for System #7 were lower in immersion service than non-immersion service. This was not an observation consistent with performance of the other two (2) plastic coatings when examined. Two (2) of the physical properties of System #7 were comparable to that of System #1, exhibiting high impact resistance and little weight loss when abrasive testing was performed.

Without the presence of the aluminum coat beneath System #7 performance would be expected to be similar to that of System #1, with lower chalking ratings. System #8 performance would be comparable to the other epoxy coatings for blister and corrosion formation, but with chalking ratings as observed.

The costs associated with use of coating materials of the systems above (#6, #2, #10, #4) show coating system #6 material to be the most expensive, $2.40/ft^2$ at the manufacturer's recommended film thickness and estimated coverage. Application equipment for flame spray application would require a capital investment of about $11,800.00. Fluidized bed application equipment would cost approximately $14,300.00.

Material costs for systems #2, #10 and #4 are approximately $1.00/ft^2$, $0.70/ft^2$ and $0.50/ft^2$ respectively. These costs are based upon manufacturer recommended film thickness and coverage rates. System #2 ($1.00/ft^2$) and #4 ($0.50/ft^2$) can be applied by conventional or airless spray equipment. Conventional spray application for system #2 was found to be difficult due to viscosity, however, airless spray application, observed in the field, does not appear to present significant difficulty for an experienced applicator. System #4 was easily applied by conventional spray but can also be applied by airless spray. Equipment costs for system #2 and #4 are approximately $1,500.00 for conventional application and $3,800.00 for airless application. System #10 is not an expensive coating material compared to those discussed above. However, for application by plural component airless spray the equipment system, as a package is approximately $20,000.00. Experienced applicators are recommended. Application by brush or roller is not recommended except for small areas or touch-up work are to be performed. Brush application of test panels was found to be difficult due to coating thickness (viscosity) and pot life. Field application by roller, from experience, is also difficult to accomplish on large surfaces.

Identification of a single coating system which performs well in the three NASA-JSC environments, WETF immersion, Rotunda Storage, Laydown (outdoor) Area did not result from this study. Comparisons, made on a relative basis, have indicated System #6 as the one system most closely approaching the "single system" ideal. However, System #6, being thermally applied, is not suited for use on heat sensitive substrates. Additionally, the coating exhibited brittleness on reverse impact. Since the material supplied was colored black, color change could not be compared to the white systems.

Material costs and equipment costs for System #6 make it the most expensive of the thermally applied coatings. The system, as applied by the manufacturer approved applicator, was 33% thicker than system recommended dry film thickness. This may have contributed to performance and, at the thickness applied, would increase material costs an equivalent amount.

System #1, also unsuited to use on heat sensitive substrates, performed well with the exception of immersion service. Effects under immersion service were associated with intentionally scribed (cut) coating. Impact resistance was very high, suggesting that impact damage will be tolerated. Color retention and low chalk formation suggest that, in the absence of cutting damage, System #1 will perform successfully in all NASA-JSC environments. Repair was more easily accomplished than that for System #6. The materials costs are one half that of System #6 and equivalent to the more expensive epoxy coatings. Equipment costs are slightly more than required for airless application of liquid organic coatings.

Epoxy system overall performance found that when chalking is considered, System #2 was the highest ranking epoxy system. System #2 performed well on all substrates and in immersion service. When chalking is not included, Systems #2, #10, and #4 results are nearly equivalent.

Drawbacks to System #2 include material cost, high for an epoxy, and application difficulties encountered by conventional spray application. Further, System #2 "yellowed" to a greater extent than the other epoxy coatings.

System #10 chalks and exhibits brittleness on impact. However gloss retention was good in immersion environments as were blister and corrosion resistance. Application was found to be difficult and non-uniform by brush or roller. The short pot life also presented difficulties. Creepage from sharp corners was noted. Although these difficulties may be overcome by plural component airless spray application, equipment costs are the highest. The ability to perform touch-up under water suggests System #10 may be suitable for use on immersed, fixed equipment.

System #4 performed reasonably well in immersion but is subject to chalking. The coating was found to be slightly less adherent than most systems when subject to crosshatch adhesion testing (ASTM D3359 Method B). System #4 material and equipment costs represent an economic advantage.

Selection of an epoxy system will involve a trade off between immersion performance and chalk resistance. Coating to be applied to frequently used equipment, maintained indoors, should be selected for corrosion resistance due to immersion cycles. When limited immersion but long term storage (out-of-doors) is anticipated, then coating chalk resistance will be more important.

Use of data from coating systems tested to estimate potential performance of coating systems not tested should be dealt with cautiously. All candidate coatings submitted by manufacturers are presented in Appendix F. Generally, epoxy systems which were evaluated clustered in performance for blistering and corrosion and were subject to differentiation by chalking evaluations. Physical testing properties of the epoxies exhibited some variability but in abrasion resistance, not adhesion or impact resistance. The untested candidate epoxy systems would be expected to perform within the same range of observations.

Chalking characteristics for polyamide epoxies under exposure were, in aggregate, ranked higher than the amine or phenolic epoxy systems. However evaluation for blister and corrosion occurrence found that all epoxy systems clustered in overall performance. It should be expected that as a class, epoxies will cluster in performance. Polyamide coatings offer good water resistance, comparable to amine epoxies. Amine epoxies are generally reported to provide better chemical resistance than polyamide epoxies, a characteristic not necessarily critical in WETF application.

The candidate coatings identified for consideration and presented in Appendix F were predominantly epoxy systems but also included urethane systems. No urethane systems were employed in the study and may merit investigation for immersion service. Chalk resistance and color retention of urethanes are common, desirable characteristics. Historically, water immersion service use of urethanes has been limited. Urethanes offer abrasion resistance, impact resistance and are common exterior finish coats.

The thermally applied plastics are a newer class of coating materials. As sheet employed for linings, plastics offer corrosion resistance, film thickness (build) and predictable permeability limits. Use of thermally applied plastic for water immersion service or water tank lining is relatively new. When compared to move conventional epoxy coatings the costs associated with application equipment and materials, does not appear justified based upon performance results of this study.

Future coating system research should include actual and laboratory cyclic testing where test panels or specimens are physically moved from immersion, outdoor and indoor environments on a scheduled basis. The combination of the different environments can be better assessed as they interact rather than as discrete exposures. For example, the inadvertent placement of Rotunda test panels in the WETF pool resulted in observations of blistering and corrosion which were unexpected as the Rotunda is an otherwise mild environment.

Measurement of gloss and color change should be included in future studies. Although eight (8) of ten (10) coating systems evaluated were "white", it was clear than not all whites are the same. Each coating exposed exhibited some degree of color shift from the original "white" toward brown, yellow or gray. Existing system control panels can be employed for color and gloss change evaluations of the exposed panels which have been returned to NASA-JSC.

Selection of coating systems for future studies should be developed through an investigation/solicit protocol rather than solicit/select. Coating manufacturers were asked to provide data from other testing programs, if available. However, no such information was forth coming. Generally, manufacturers tended to have their standard systems submitted for inclusion, or in some cases viewed the study as a mechanism to experiment or test materials in new environments.

Adhesion by substrate for metal panels was essentially equivalent and overall coating performance on aluminum was not very different from that on stainless steel. No evidence was found to indicate that pretreatment of aluminum substrate, if properly prepared and coated, was discriminatory.

This suggests that assessment of coating system performance can be limited to one substrate and, further, that such a substrate might be selected to exacerbate evidence of poor performance. Screening of coatings for performance under aggressive or difficult conditions would then contribute to minimizing efforts for detailed assessment of numerous materials.

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Author(s):

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