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Development of a Unique Polyurethane Primer/Topcoat

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ABSTRACT

USBI Company, a Division of Pratt & Whitney Government Engines and Space Propulsion, is involved in corrosion and environmental research and development activities both at their headquarters in Huntsville, Alabama and their Florida Operations at Kennedy Space Center, Florida. The programs involve the development of environmentally compatible materials that improve the corrosion protection of expensive Solid Rocket Boosters (SRB) that are part of the Space Shuttle systems developed and managed by Marshall Space Flight Center in Huntsville, Alabama. Coatings For Industry, a paint manufacturer in Souderton, PA helped formulate and produce the first lot of BOOSTERCOAT paint. High strength aluminum aerospace flight hardware exposed to harsh seacoast environments and seawater immersion presently uses high volatile organic compound (VOC) chromated and lead bearing primers and epoxy topcoats for corrosion protection. Epoxy paint tends to be brittle and has relatively low Ultraviolet (UV) exposure resistance. A unique, environmentally compatible, non-leaded/non-chromated, low VOC polyurethane single coat (primer/topcoat) trade named BOOSTERCOAT© has been developed for excellent corrosion protection, flexibility, adhesion, chemical and solvent resistance properties. This report will discuss the development of BOOSTERCOAT© and the potential opportunities for commercial use in the energy, transportation, chemical, maritime, structural fields.

INTRODUCTION

USBI Company is responsible for the assembly and refurbishment of the non-motor components of the Solid Rocket Booster (SRB) as part of the Space Shuttle system shown in Figure 1, and which is developed and managed by Marshall Space Flight Center in Huntsville, Alabama. Programs are underway to develop and evaluate environmentally compliant coatings for use on aluminum alloy and high strength steel alloy aerospace flight hardware in order to mitigate corrosion and ultimately extend the useful service life of these unique and expensive structures. The initial study focused on the replacement of high VOC, chromated / lead bearing epoxy primers with that of an environmentally compatible polyurethane single coat primer/topcoat. Coatings For Industry (CFI) located in Souderton, Pennsylvania helped formulate and manufacture the unique polyurethane single coat primer/topcoat. A significant joint effort was required between USBI and CFI in order to establish a production test article in a relatively short time frame. The new coating had to be compatible with the application of special thermal protective system (TPS) materials that coat the majority of SRB non-motor components. Operations such as robotic sanding Figure 2, vapor blast and vacuum cleaning and finally the spraying of TPS materials that contain aggressive solvents were all severe tests that the new paint system would have to endure. Launch vehicles located by the ocean are also subject to harsh seacoast environments before launch (sitting on the launch pad for months at a time, in close proximity to the ocean) and immersion after splashdown at sea and tow back to the refurbishment facility. Thus the coating, trade named BOOSTERCOAT©, was developed for excellent corrosion protection, flexibility, adhesion, abrasion resistance, chemical and solvent resistance and productivity enhancing electrostatic spray and plural component/air assisted airless spray capabilities. These same environmentally compatible and operationally desirable properties are needed for coating structures of fossil and nuclear power plants , also chemical processing plants and transportation equipment such as railcars, tractor trailers and earth moving equipment. The same paint resin system has also been tested as graffiti resistant for architectural structures and will sustain the use of methylene chloride solvent for removing the graffiti without removing the basecoat.

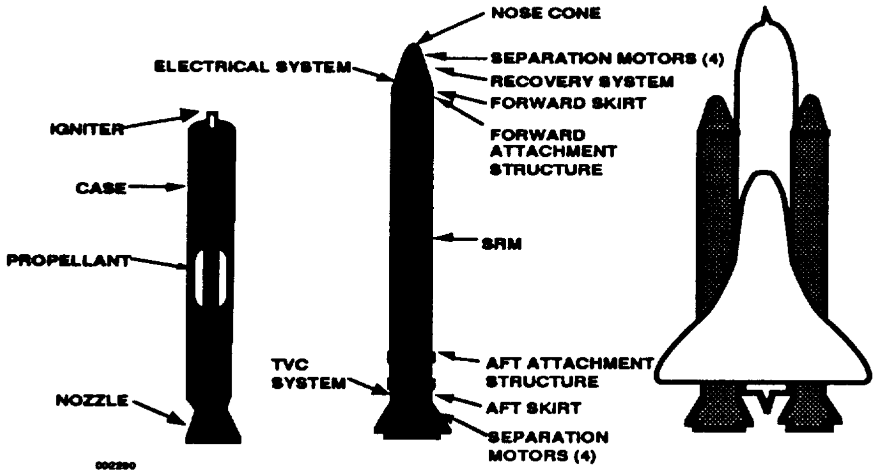

Figure 1 Space Shuttle's SRB

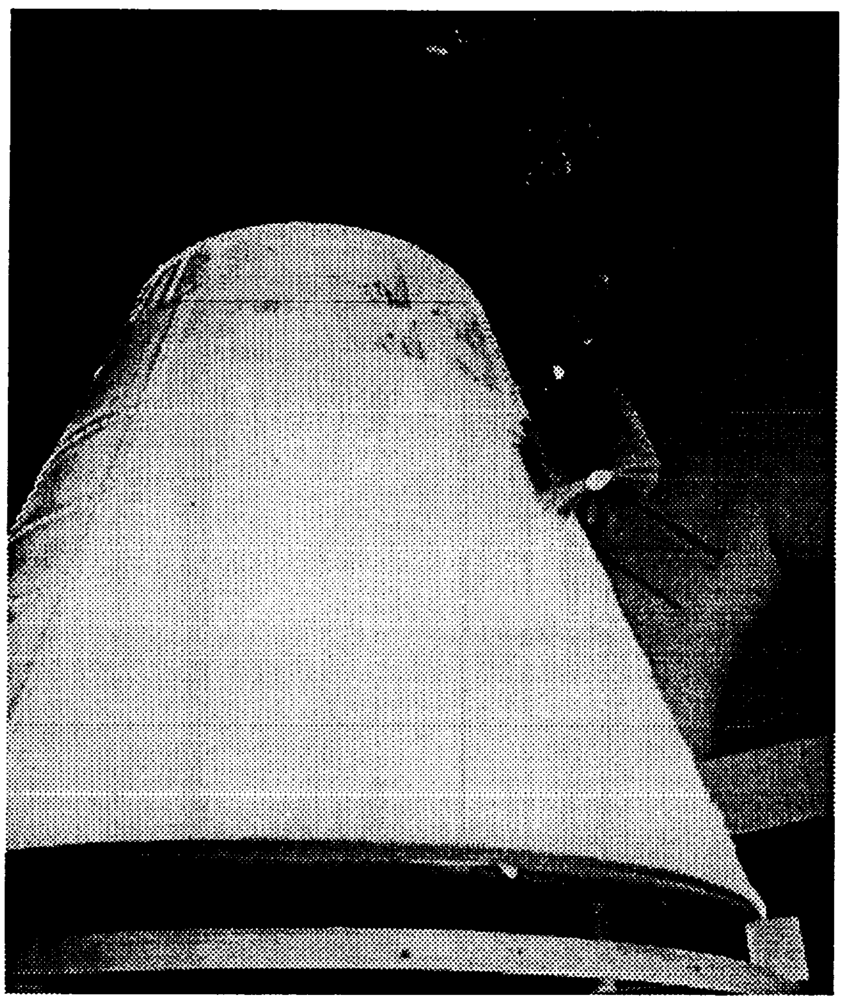

Figure 2 Robotic Sanding

DISCUSSION

Neat Resin Evaluation

The first phase of this program involved the selection and screening of eight resin systems consisting of saturated polyester and polyester polyols that were applied to deoxidized and chromate conversion coated 2219-T87 test panels and also to coated 4130 and 4340 high strength low alloy steel materials.. Specimens were allowed to cure for seven days at room temperature and were then checked for adhesion using ASTM D-3359[1](Adhesion by Tape Test) procedures. Results of adhesion tests were 5B or 4B rating for all resin systems, where 5B corresponds to no removal of the coating and 4B corresponding to small flakes of the coating that are detached at intersections with less than 5% of the area is affected, after the tape is pulled from the coating. The eight resin systems were also applied to 2024-T0 test panels and bent 180 degrees over a mandrel for flexibility testing. Chemical and solvent resistance testing consisted of the following: immersion of the test panels in 15% hydrochloric acid and 31% sodium hydroxide for 96 hours. Methyl ethyl ketone (MEK) and methylene chloride were also rubbed 100 times (200 passes) using a saturated cotton rag with firm finger pressure. From these initial screening tests, two resin systems were then selected for further evaluation.

Pigmented Resin Evaluation

Various environmentally compatible corrosion inhibiting pigments were then mixed with the two candidate resins and applied 0.003"(0.08mm) dry film thickness to deoxidized and chromate conversion coated 2219-T87 test panels and allowed to cure for seven days at room temperature. Initial critical pigment volume concentration (CPVC) was determined by establishing high and low limits through manufacturer's pigment volume concentration (PVC) recommendations and other relevant literature[2], then exposing those panels to salt spray testing. Panels were scribed with an "X" through the coating to substrate, and then placed in a 5% neutral salt spray solution in accordance with ASTM B-117. Additional scribed panels were placed on beach exposure racks located at NASA - Kennedy Space Center facilities as shown in Figure 3. Photos of the salt spray panels were taken weekly and Figure 4 shows coating #1 after 2000 hours of exposure.

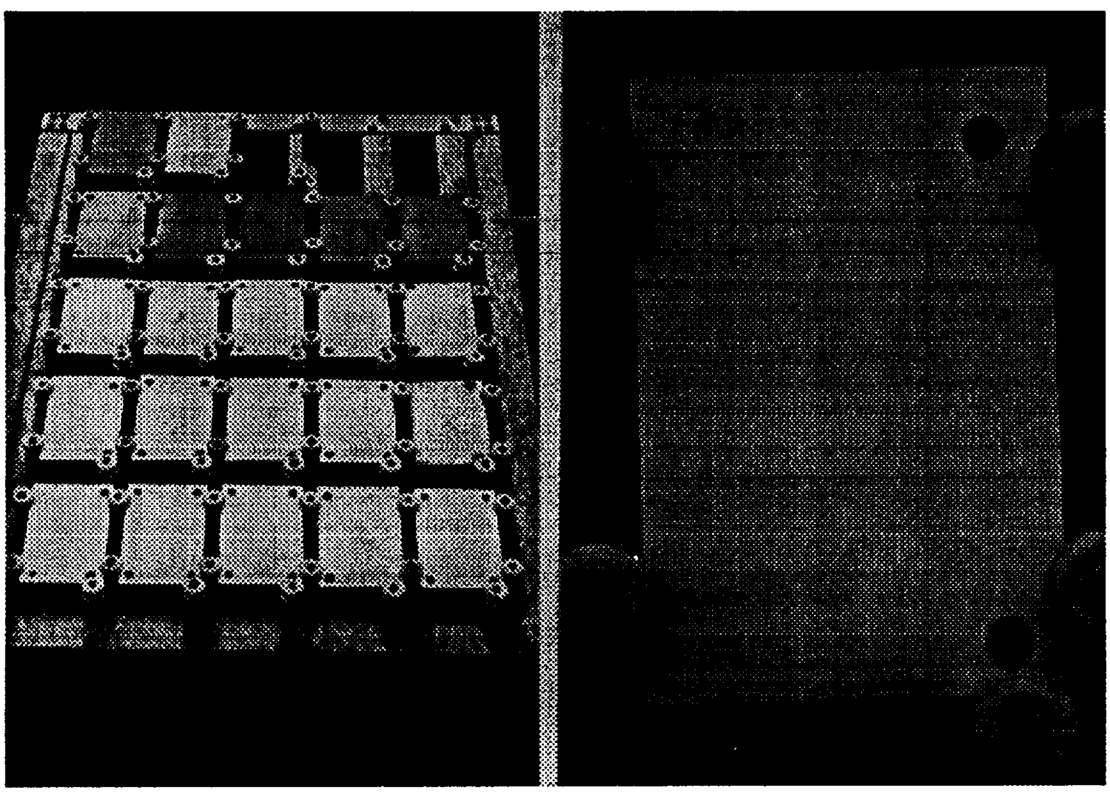

Figure 3 Beach Exposure Racks and Panel

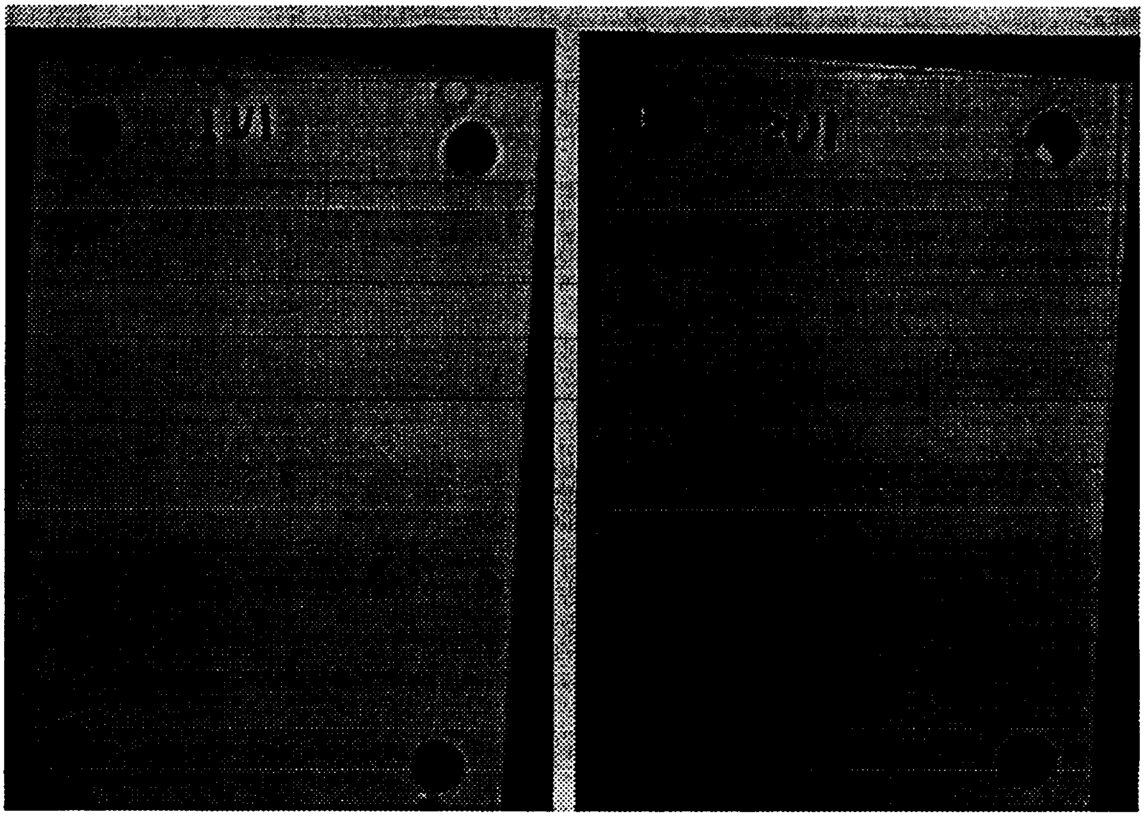

Figure 4 Booster Coat After 2000 Hours Salt Spray

Results of salt spray tests showed that resin #1 outperformed resin #2 using visual standards outlined in ASTM D-714 (Standard Test Method for Evaluating Degree of Blistering of Paints). This test method provides a standard procedure for describing the size assessed on a 0-10 scale, with "No.10"-no blistering, No.8 representing the smallest size blister easily seen by the unaided eye. Blister standards Nos.6, 4, and 2 represent progressively larger sizes. Blister density of an area is described as : few, medium, medium dense and dense, using photographic reference standards as the guide. Beach exposure testing confirmed the results obtained by ASTM B-117, although taking many more months for results. A study was initiated to evaluate the optimized coatings using electrochemical impedance spectroscopy (EIS) as a method for short term testing to predict long term performance.EIS measurements were made using an EG&G PARC 273A potentiostat interfaced to a EG&G Model 5210 lock-in amplifier; the system was computer interfaced for scanning and data manipulation (Figure 5). A three electrode cell configuration developed by EG&G and denoted as the Flat Cell and consisted of a Pyrex glass cylinder body with polypropylene end caps and working electrode clamping system. The reference electrode was silver and the reference electrode solution was silver chloride / saturated potassium chloride. The counter electrode was platinum plated rhodium. The working electrode sealing gasket was knife edged teflon with an exposed area of 1 cm^2. Impedance scans were made between 100 kHz and 10 mHz, with occasional excursions to 1 mHz. An applied voltage amplitudes of 10-20 mV were utilized for the tests. As can be seen in Bode plots (Figures 6 and 7) very little change in impedance as related to ionic pore resistance occurred in a year and further substantiates the results found in salt fog chamber and during beach exposure tests. Panels were manufactured in the production environment using shop personnel and equipment. Paint was flatwise tensile tested for adhesion and all BOOSTERCOAT tests surpassed the present coatings being used. Additional tests were performed on the adhesion of TPS materials to the prepared substrate and the adhesion values were equal to or greater than the present system.

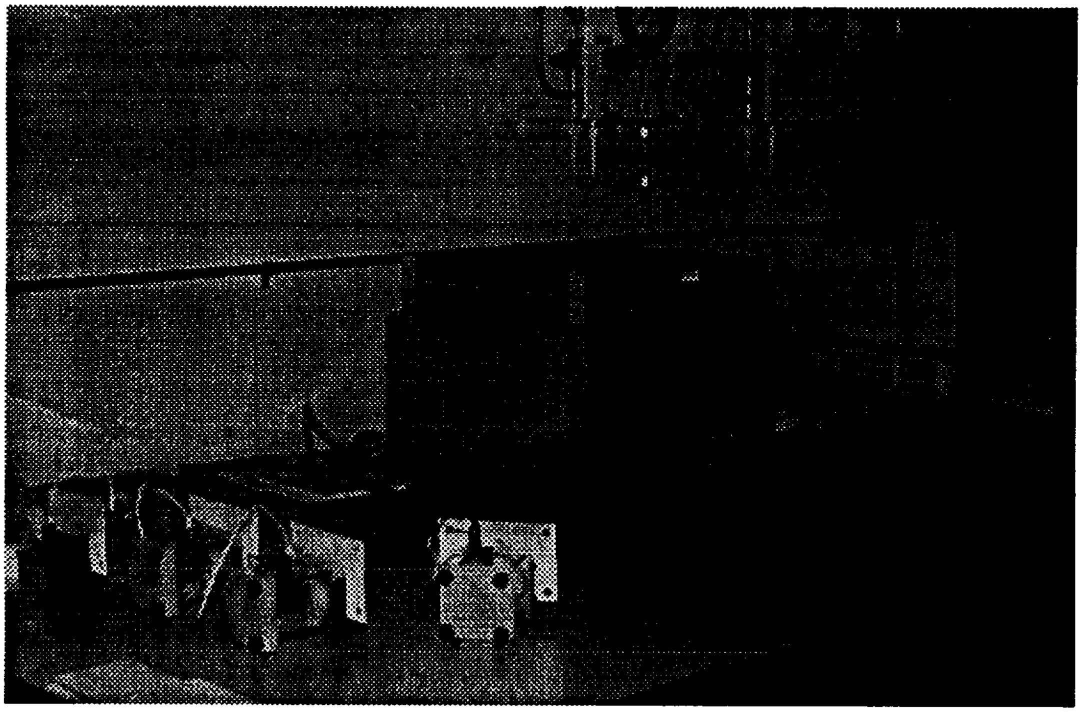

Figure 5 EIS Equipment With Flat Cell

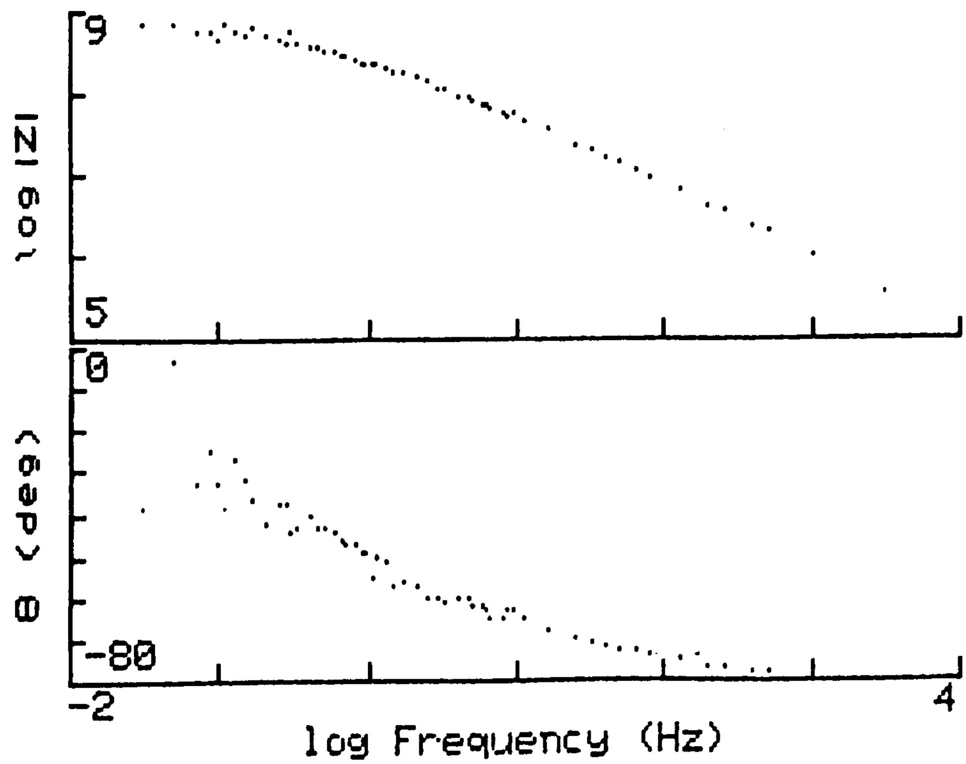

Figure 6 Bode Plots – 4 Mil Coating

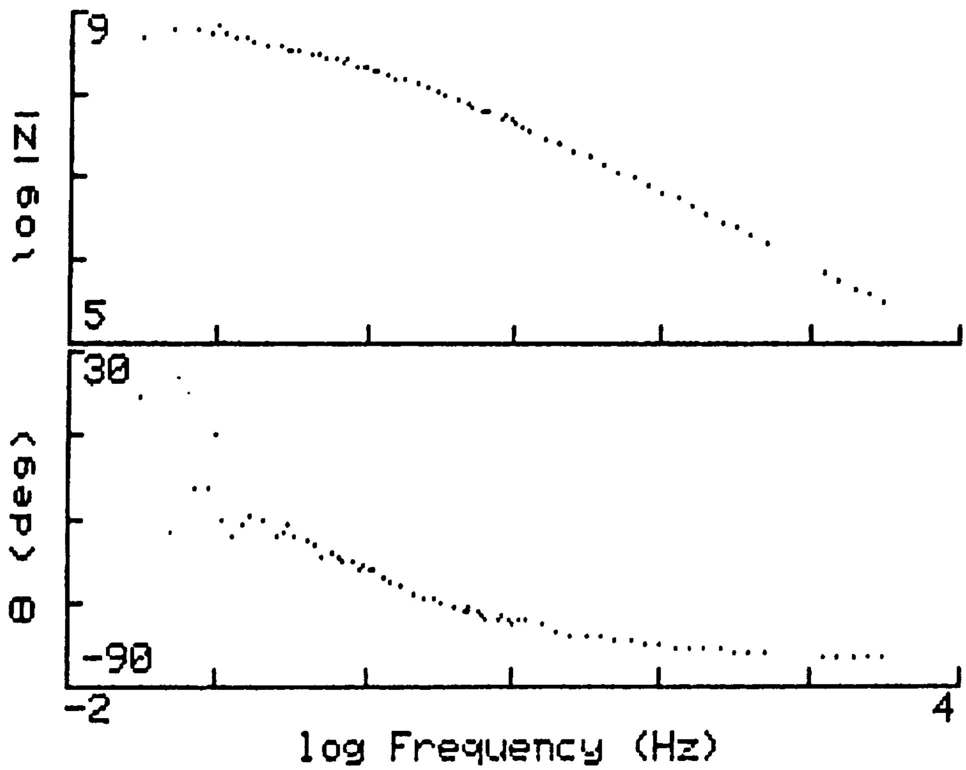

Figure 7 Bode Plots – 3 Mil Coating

CONCLUSION

The environmental testing of a non-chromated, non-leaded polyurethane single coat primer/topcoat allowed for optimization of the resin and corrosion inhibiting pigmentation system. Additional testing under production environments such as robotic sanding, vapor-blast cleaning and application of TPS materials with aggressive solvents helped prove its compatibility with the SRB environments. The new paint was accepted by technicians preparing and applying it to various substrates, and found it easier to work with than the present two coat system. The polyurethane paint does not require induction time prior to use, and with only one type of paint required greatly simplifies the logistics of shelf life and certification requirements. Applications for many other fields than aerospace exist. Energy and power generation, chemicals, transportation, architectural and many others await its application.

ACKNOWLEDGMENTS

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