Advanced Technology in Field Applied Thermoplastics for Corrosion Protection Superior to Thermoset Coating Systems

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ABSTRACT

The control, mitigation and prevention of corrosion in environments ranging from mildly corrosive to severe atmospheric conditions to underground exposures (such as pipelines) to chemical spill and fume exposures has long been focused on the use of thermosetting polymers such as epoxies, polyesters, vinyl esters and urethanes. For the most part these materials have worked reasonably well in applications such as structural steel and equipment coatings, architectural paints, vessel linings, concrete coatings, secondary containment linings, and floor toppings. However, these thermosetting materials also have major limitations such as service temperature, lack of tolerance for a wide range of field conditions including humidity, temperature and substrate preparation, cure time, ease of repair, and related installation issues. Thermoplastics have known advantages over thermosets in water resistance, flexibility, higher temperature capability, and film integrity. Until recently, the use of thermoplastics as corrosion resistant coatings has been limited to shop application in controlled environments where electrostatic application and oven curing allow for proper particle distribution, controlled film thickness and integrity and substrate encapsulation. Heretofore, field application of thermoplastics has been impractical and only marginally successful in a few limited applications. Development of new technology in the areas of thermal bonding agents and more dimensionally stable thermoplastic powder coating materials has resulted in significantly increased potential for use in field applications in a wide variety of uses.

KEYWORDS

Thermoplastics; Thermal Bonding Agents; Permeability; Field Application; Salt Fog; Cathodic Disbondment.

INTRODUCTION

Plastics, in layman s terms, are pliable, moldable materials. Plastics are generally defined by their ability to be shaped and molded easily. Thermoplastics are organic polymer (plastic) compounds that can be melted and reformed in their original state. One way Thermoplastics are distinguished from Thermosets is by this property of melting to liquid and reformation to solid. Thermosets are organic polymers that once cured cannot be returned to the liquid or melted state. Cured Thermosets are cross-linked plastics that once formed cannot be melted and reformed.

Many industries use a wide variety of thermoplastic materials for corrosion resistance and many other uses. Until recently, these molten thermoplastics have been limited primarily to OEM (Original Equipment Manufacturers) shop built and controlled environment shop applications. Typically the use of thermoplastics for corrosion resistance has been limited to powder application to heated or electro-statically charged metallic surfaces followed by melting in an oven. Field application of thermoplastics has been almost exclusively done in the solid state (sheets) to large relatively flat surfaces. Until recently, field application of thermoplastics in liquid (molten) form has been limited by VOC regulations. Field application of powdered thermoplastics in the molten state has been largely ineffective and impractical for several reasons.

Molten thermoplastic materials shrink when cooled rendering them dimensionally unstable when applied in a molten state to most structural shapes. Application to structural members such as I-beams, angle, channel, flat surfaces, and the inside radius of curved surfaces has been impractical and unsuccessful. Mechanical bond of molten thermoplastics has been dependent on utilizing the shrinkage mechanism of the material as an advantage, for example, application to the external surfaces of circular shapes such as spheres and cylinders (pipe). In addition, chemical bond of molten thermoplastics to metal surfaces has not been possible in the past.

DISCUSSION

New technology developments allow molten thermoplastics to be applied almost anywhere, under widely varying environmental conditions. This new field application technology is based on significant technology advances. The invention of unique primer and basecoat materials known as Thermal Bonding Agents allow for exceptionally strong tensile bond strength to substrates such as metals, existing coatings and concrete when snap-cured by the application of the molten topcoat. Thermal Bonding Agents (US Patent Pending for Flame Activated Primers by Shah A. Haque, KCC Corrosion Control Co., Ltd.)[1] provide unique chemistry that results in superior bond strength between thermoplastic powder coatings applied in molten form and metallic or non-metallic (e.g., concrete) substrates. Specially formulated thermoplastic topcoats are more dimensionally stable during cooling, reducing the deleterious effects of shrinkage. These modified topcoat materials remain well bonded to any shape surface and provide an almost infinite variety of product uses.

Thermoplastics surpass thermosets in corrosion resistance performance for several reasons. All organic polymers can be defined by, and their uses and performance limited by, their glass transition temperature, known as T_g. Below their T_g, polymers become harder and more brittle, they are by definition in their glassy state. Polymers like polystyrene and epoxy are generally most effectively used below their T_g. Above their T_g, polymers become pliable and more flexible. Elastomeric (rubbery) polymers such as polyisobutylene and poly-isoprene are used above their T_g.

In corrosion resistant applications where resistance to water and chemical permeation are critical to successful long-term performance, the use of polymers with higher T_g can be an advantage. Certain thermoplastics have higher T_g than thermosets, therefore they possess performance properties beyond the capabilities of thermosets. The resulting performance advantages are longer life coatings, higher temperature resistance (coatings and linings), improved chemical and permeation resistance, improved physical properties, and in some cases better abrasion, erosion and wear resistance.

In addition, many thermoplastics, such as polyethylene and polypropylene contain no receptors or reactive sites for water and its component H^+ and OH^- ions, thus they shed water at the molecular level. In contrast, thermoset polymers such as epoxies, polyesters and urethanes possess sites that will react with water and its component H^+ and OH^- ions. Thus water can and does permeate and ultimately chemically react with thermoset polymers.

EXPERIMENTAL PROCEDURES

Salt Spray (Fog) Test [2,3] (ASTM B-117) — Coated steel panels are placed in an enclosed chamber maintained at 95°F and are continuously exposed to salt (5% sodium chloride in water) spray or fog to simulate conditions in a severely corrosive environment in an accelerated manner. The coating in the center of the panel is scratched or cut in a crisscross method (called a scribe) to expose bare steel and allow corrosion at a steel/coating discontinuity for evaluation of edge lifting and undercutting. Evaluation of the coated panels are visual until termination of the test, at which time the degree and extent of undercutting at the scribes and blistering on the face of the coating is measured.

Chemical Resistance (and Liquid Permeation) of Protective Linings [4] (ASTM C-868 -Modified Corrocell version KCC Test Method PPM-A1.00) — Steel panels are coated and placed on the open ends of a cylindrical glass cell. Reagent liquid is placed in cylinder and temperature is controlled as desired. The modified apparatus includes temperature control chambers on the outside of the test panels to vary external wall temperature of test panels. Liquid permeation through the lining is quantitatively evaluated by measurement of impedance across the test fluid and the steel panel interface.

Cathodic Disbonding of Pipeline Coatings [5] (ASTM G-8) - Test specimens in the form of coated pipe sections are suspended in an alkaline electrolyte solution. The coating is perforated in multiple sites to simulate coating discontinuities. Electrical stress is obtained by either sacrificial anode or impressed current applied to the pipe to simulate cathodic protection in underground pipeline installations. Impressed current provides a more severe electrical stress condition and thus was used in the tests reported herein. This test provides an accelerated condition for coatings to loosen at holidays and measures their resistance to film undercutting under impressed current and alkaline immersion conditions.

TEST RESULTS

Salt Spray (Fog) Test [2,3] (ASTM B-117) — Thermoset coatings such as epoxy, polyester, urethane and siloxane systems when tested in salt fog according to ASTM B-117 are evaluated by the extent of lifting at the edges of the scribe, undercutting and blistering on the face of the coating. In general terms, coating systems that withstand this test for 3,000 to 5,000 hours with moderate damage are considered to have performed well. Thermoplastic systems including thermal bonding agent used as primers have recently been tested for 10,000 hours by independent test lab.[(1)] The test results show only moderate lifting at the scribes, and no significant undercutting or blistering of the coating. This result is unparalleled for any atmospheric coating system previously tested by this internationally known lab. This testing indicates that thermoplastic coating systems will provide significantly extended service life than traditional thermoset system.

Chemical Resistance (and Liquid Permeation) of Protective Linings [4] (ASTM C-868 -Modified Corrocell version KCC Test Method PPM-A1.00) - This modified version of the ASTM C-868 Atlas Test cell allows for controlled variation of the outside cold wall temperature and measurement of the water ion flow through the lining membrane from the test fluid to the coated steel substrate. Independent lab tests indicate thermoplastic-coated panels at 30 mils thick to be more than 100 times less permeable than fiberglass reinforced thermoset polyester at 125 mils thick. (Refer to Graphs 1 and 2 on page 6)

Cathodic Disbonding of Pipeline Coatings [5] (ASTM G-8) — Industry standards for coatings typically used underground include testing for disbondment under cathodic protection. Shop applied fusion bonded epoxies are generally considered the industry performance standard. In a 30-day test comparing fusion-bonded epoxy to thermoplastic with thermal bonding agents, the following results were obtained.

Average Disbonded Area (sq.in.)	
Fusion Bonded Epoxy	1.005
Thermoplastic	0.296

Equiv. Diameter Disbonded (in.)	
Fusion Bonded Epoxy	0.988
Thermoplastic	0.635

(1) Salt Fog Exposure Test Report: ITI Anti-Corrosion , Inc., Houston, TX; Laboratory File #7515

CONCLUSIONS

Thermoplastics have many advantages over thermoset coatings in field application and use. Thermoplastics are powder coatings applied in a molten state, therefore there are zero Volatile Organic Compounds (VOCs) emitted, no overspray droplets and no cure time. Void free applications are assured. The molten thermoplastic is ready for service as soon as it cools and solidifies, often a matter of minutes, not hours or days. Weather and humidity restrictions are significantly reduced. Moisture condensed on the target substrate is vaporized by the mild preheating required in the application process, therefore humidity and dew point considerations which limit most thermoset coatings do not apply to thermoplastics. The number of steps is reduced, thereby significantly reducing labor input as well as elapsed time of installation. Completion schedules are more predictable and of significantly shorter duration. Repair and touch-up are simple and permanent. Service life is extended by a factor of two or three over traditional coating systems.

REFERENCES

1 US Patent Pending: Flame Activated Primers By Shah A. Haque, KCC Corrosion Control Co. Ltd.

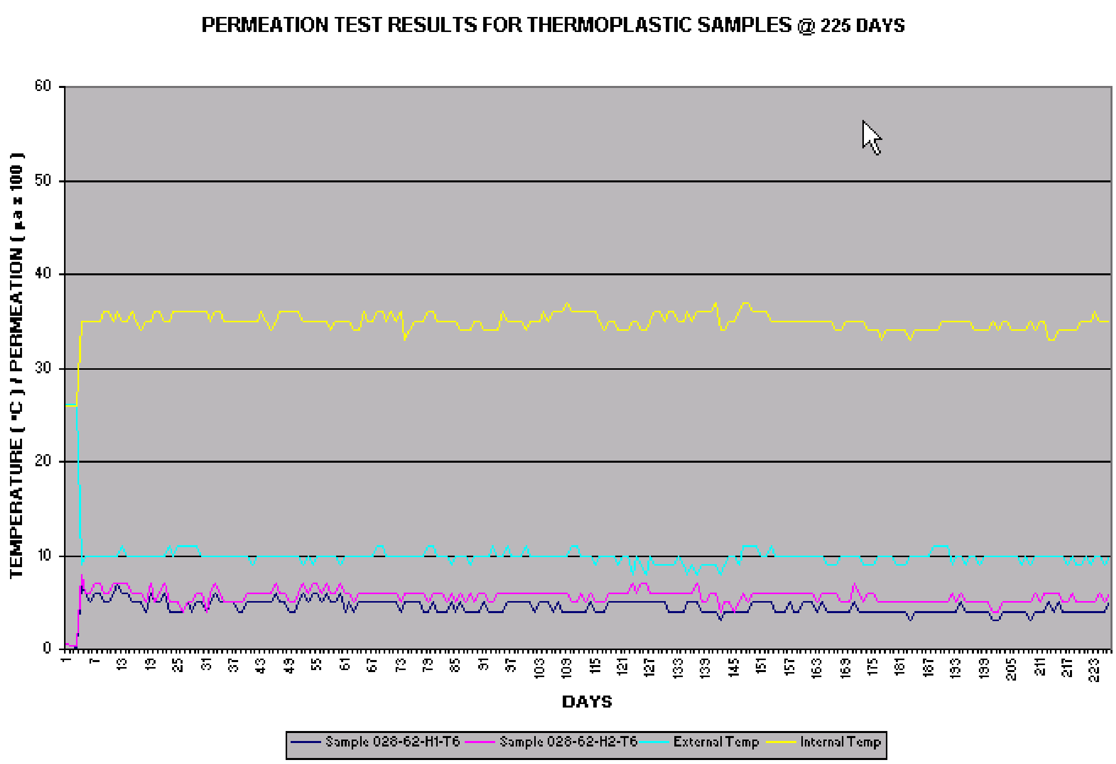
2 ITI Anti-Corrosion Salt Fog Testing Laboratory File #7515

3 ASTM B 117-97 ASTM Book of Standards Volume 03.02

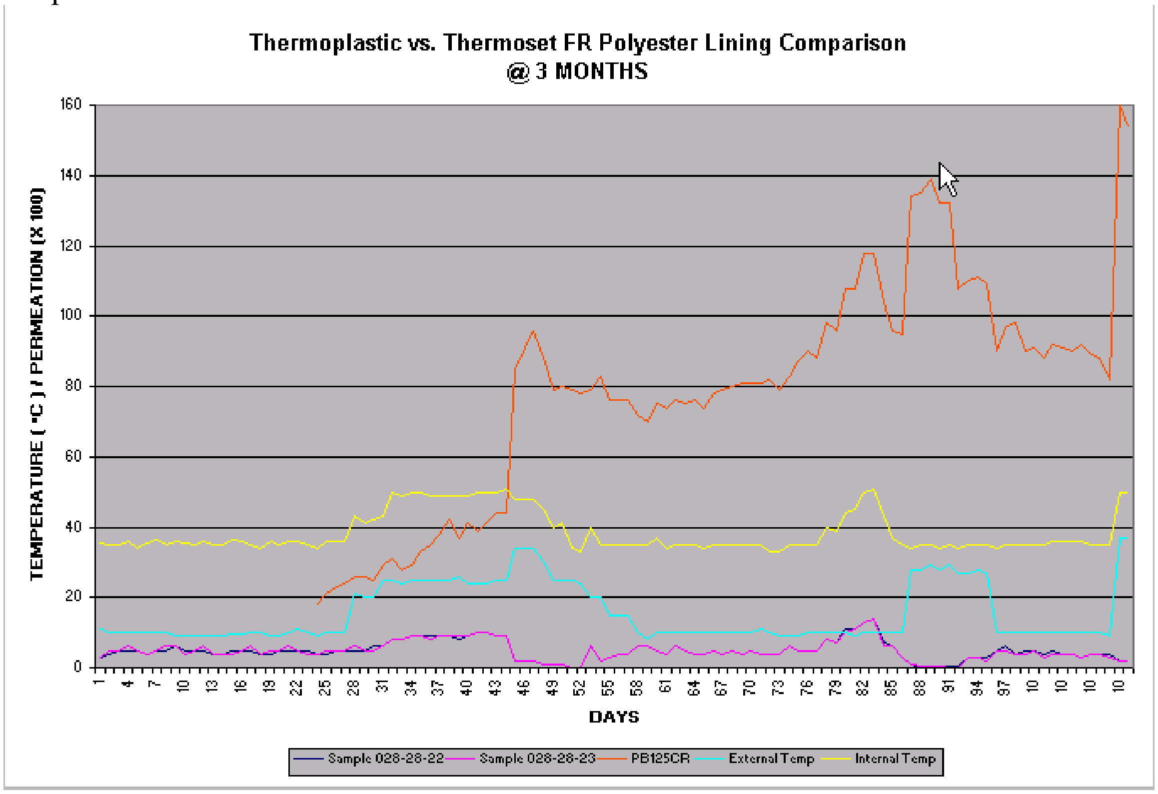
4 ASTM C 868-85 ASTM Book of Standards Volume 04.05

5 ASTM G 8 ASTM Book of Standards Volume 06.02

Graph 1.



Graph 2.



Thermoplastic vs. Thermoset FR Polyester Lining Comparison
@ 3 MONTHS
TEMPERATURE (°C) / PERMEATION (X 100)
DAYS
Sample 028-28-22
Sample 028-28-23
PB125CR
External Temp
Internal Temp