

# Polysiloxane Coatings – A Mature Technology

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**SUMMARY: The features and benefits (environmental, cost, durability) of Polysiloxane chemistry will be compared and contrasted with some conventional coating systems. Selected case histories have been chosen to illustrate the benefits of this technology and potential project cost savings are discussed. New developments will be briefly reviewed.**

**Keywords: Polysiloxane, Case History, VOC**

## 1 INTRODUCTION

The search for clean, green technologies, in all fields of organic coating chemistry has never been more evident than over the last decade. Selected areas of development can easily be identified from various sectors of the coatings industry i.e.

- The areas of development in Coil Coating are hot melt, Powder, High solids and waterborne
- Powder Coatings are moving towards Super Durable technologies which are TGIC free and there is also a move towards coatings which offer low temperature cure e.g. IR/UV
- Wood technologies are being focused on systems which are extremely low in VOC and have better chemical resistance, impact resistance etc cf. existing technologies
- Heavy Duty is moving almost exclusively to higher solids epoxy, Urethane and NISO systems. Waterborne Inorganic Zinc systems are a special area of interest.

It is clear therefore that the focus of most technologies has been to:

1. Reduce volatile organic compounds.
2. Replace hazardous / toxic crosslinkers / componentry.
3. Produce coatings with lower temperature cure / faster cure response.
4. Produce more cost effective coatings with higher performance attributes.
5. Improve transfer efficiencies / reduce waste.

The development and release of Polysiloxane coatings for the heavy duty market was seen as a breakthrough in technology as this system offered super low VOC with outstanding performance attributes.

Polysiloxane coatings can now be considered to be mature by world standards. The technology was introduced into the global market in 1993 and over this time greater than 3 million square metres of substrate has been painted with this product. The applications have been many and diverse i.e. OEM, maintenance, new construction, anti graffiti. Many specifiers and applicators have utilised the cost effectiveness and life to first maintenance of the Siloxane two coat system (i.e. zinc rich epoxy or inorganic zinc rich primer) in preference to the use of three or more coat systems.

This paper will outline some of the practical advantages, durability, cost benefits and performance attributes of Siloxane technology.

## 2 FEATURES OF POLYSILOXANE COATINGS

### 2.1 Coating Durability Profile

The chemistry and patent know-how of Siloxane coatings is well known and the interested reader can follow the patent trail in the literature. Previously reported QUV data has fingerprinted polysiloxane technology as being a coating with extremely good weatherability. Florida exterior weathering data – 45° South – 5 years continuous exposure, has validated that

Polysiloxane coatings are very durable (refer to Figure One). This data, is proof that Siloxane coatings have excellent aesthetic weathering attributes in terms of gloss retention and chalk resistance properties.

Australasia has a unique but severe weathering microclimate (when viewed from a global perspective). This microclimate displays extremes in ambient temperature and incident solar radiation. As a result many conventional resin systems and pigmentation vehicles which are commonly used in the USA and Europe prematurely breakdown due to heat and UV initiated degradation when exposed under Australasian weathering conditions. Pigmentation choice can have a huge bearing on the overall colour retention and aesthetic appearance of weathered paint films.

To illustrate this concept compare the panels in Table One, both panels were initially the same colour but compare the colour shift after 8 years exposure @ 45° North, Auckland exposure (resin system polyester-melamine, similar data has been replicated in other durable resin chemistries). The difference in Colour retention can be attributed directly to the pigmentation routes which were utilized in each formulation. This understanding of pigment technology know-how has been incorporated into the PSX700 formulations as manufactured by Ameron in Australasia.

The practical advantages to the consumer are better colour retention coupled with the well known chalk resistance and gloss retention attributes of Polysiloxane technology.

## **2.2 Dirt Pickup Properties**

A less obvious attribute of this Siloxane chemistry is the resilience of the coating to dirt pickup. Dirt pickup is a difficult attribute to quantify but is a highly valued and desirable feature of any coating. For example, a significant amount of research has been carried out in Asia to identify and correct the variables which accentuate dirt pick up in Architectural Acrylic emulsion technology. Polysiloxane films have good resilience to dirt pick up. This feature is probably associated with the high Tg of the final coating aligned with the low surface tension properties of the resin(s) incorporated into the formulation.

## **2.3 Abrasion / Anti-graffiti / Chemical Resistance**

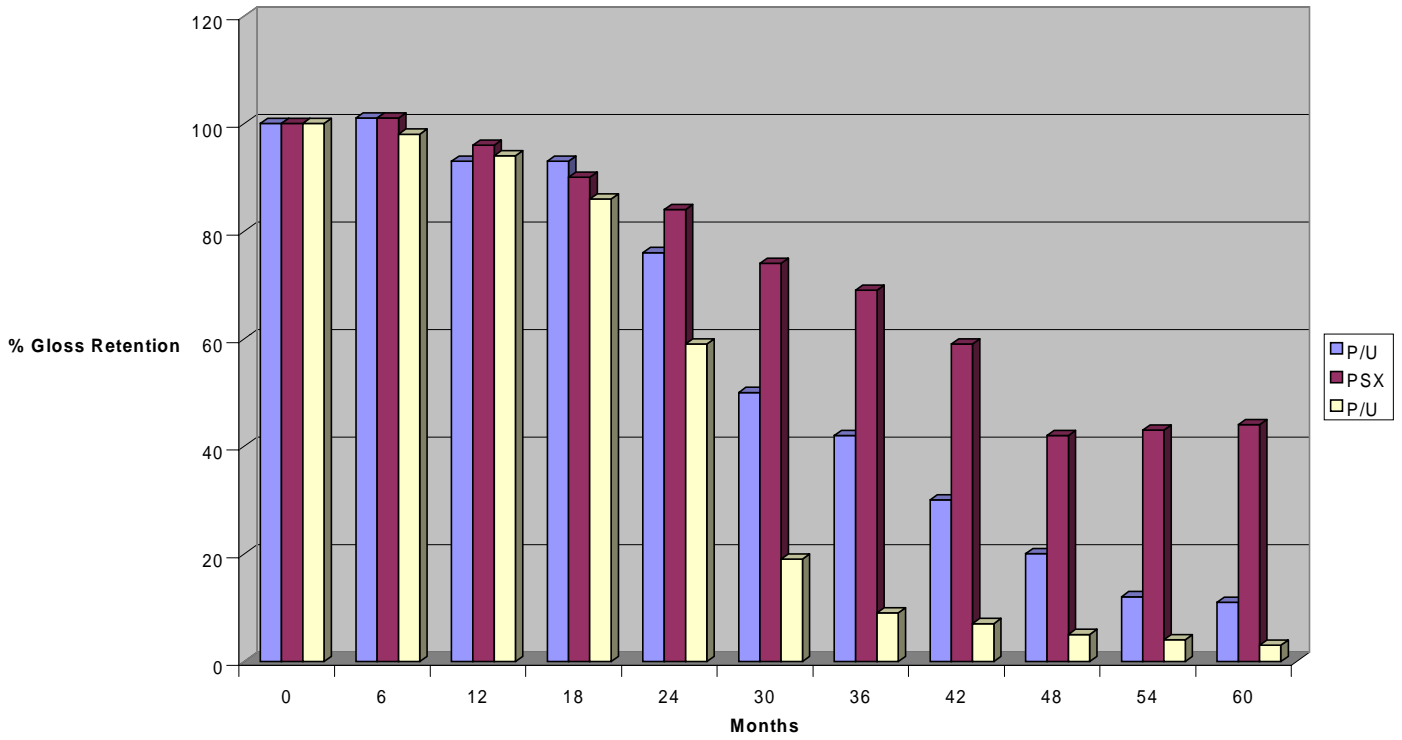
Anti-graffiti resistant coatings have been the subject of much discussion in the Chemical literature. This is understandable as the costs of undoing graffiti lies at \$30 per habitant in some of the worst affected areas of the USA and up to \$10 per person in Australia. Not surprisingly, there is an ever increasing demand for coatings which offer genuine anti-graffiti properties, both permanent and sacrificial. Essentially, three differing types of coating system are available

- Systems with temporary, sacrificial protection, typically based on non crosslinked resins such as Acrylic dispersions or emulsions, waxes, silicon dispersions and the like.
- Permanent systems based on Siloxane chemistry, crosslinked epoxy or polyurethane
- Semi-permanent systems are also available, typically these contain a sacrificial layer on the surface of a permanent coating

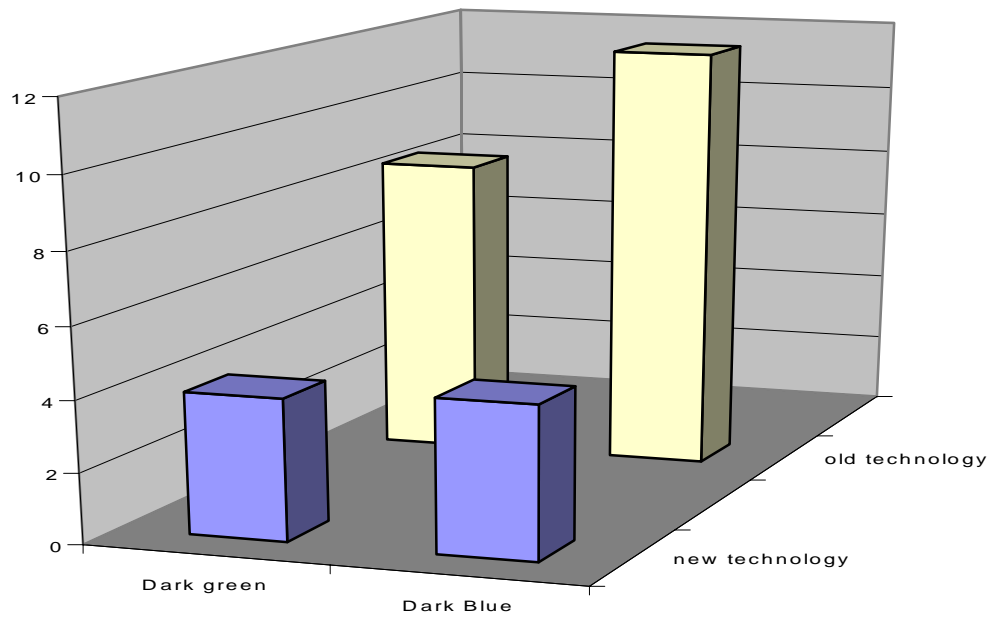
The surface of Polysiloxane coatings, being low in Surface energy, are not easily 'wetted out' by common spraypaints such as Urethane alkyds or Styrenated alkyds. As the paint does not 'wet out' the surface it tends to 'bead' and as such is relatively easy to remove with common solvents or anti-graffiti removal cocktails. In addition to their anti Graffiti potential, Polysiloxane coatings have genuine chemical resistance AND proven abrasion resistance. Such properties are relatively unique in a coating.

A summary of Polysiloxane abrasion and chemical resistance properties are detailed in Tables One and Two. Table Three details the gloss retention (a good gauge of surface marring/visual aesthetics which remain visible after graffiti removal) after 10 cycles of graffiti removal (spray can). The polyurethane system suffered from gloss loss and extreme softening whilst the Siloxane coating was unaffected after graffiti removal had been implemented.

**Polyurethane versus Polysiloxane Florida Exposure Data**



**Colour Retention (DE) of two Colours exposed with differing pigmentation routes (45N) Auckland**



<i>SYSTEM +</i>	<i>Mg LOSS</i>
SBS / EPOXY MASTIC	102
SBS / POLYESTER POLYURETHANE	60
SBS / PSX700	53
ZINC EPOXY / EPOXY GLOSS FLAKE / POLYURETHANE	161
SBS / ZINC EPOXY / PSX700	66

+ All systems treated with a 1 kg load / 1000 cycles, CS17 weight.

**Table 1. Comparative Abrasion Resistance of Several Commercial Coatings**

	<i>PSX700</i>	<i>EPOXY MASTIC</i>	<i>ACRYLIC P/U</i>
Sodium Hydroxide (50% (ac))	10	10	10
Hydrochloric Acid (conc)	10	10% = 10	37% = 8
Sulphuric Acid (conc)	6	25% = 10	0
Phenol	8	0	0
Phosphoric Acid	10	8	8
Acetone	10	10	10
Ammonium Hydroxide (conc)	10	30% = 10	30% = 10
Ethanol	10	10	10
<i>Key: 10 = No change; 0 = Complete failure</i>			

**Table 2. Comparative Chemical Resistance Data of Several Commercial Coatings**

	<i>P/U COATING</i>	<i>PSX700</i>
Marker Pen	Heavy Rub = light stain	Hand Rub – no change
Aerosol Paint	Permanent stain / soft. Gloss retention = 80%	Hand rub / no change Gloss retention = 100%

**Table 3. Anti-Graffiti Resistance Properties of a 2K Polyurethane cf. PSX700 after 10 cycles of Graffiti Removal**

## 2.4 Gloss retention validated to ASTM D-523 (10 cycles of graffiti removal).

In addition to these attributes, the fire propagation rating of Polysiloxane coatings (refer to next section) have meant that it can be specified for jobs like the tunneling surfacer for the London Underground where the use of polyurethane systems is not really an option. Polyurethane systems from a toxicological viewpoint can be problematic as it is known that when urethanes are subject to heat toxic gases such as Isocyanates and Hydrogen Cyanide can be evolved.

## 2.5 Exhaustive Testing of Polysiloxane Chemistry

Polysiloxane coatings have been exhaustively tested and benchmarked against many technical standards in the protective coatings industry. For example, the two coat system i.e. epoxy zinc / PSX700 passes NEPCOAT (North East Protective Coatings Committee) standard for protective coatings and the NORSOK (Norwegian Technology Standards Institution) M501 specifications. An independent assessment of the Polysiloxane two coat system (NACE paper 619) noted it as the top performer in a demanding test regime programme which incorporated the widest range of coating systems. Typical test performance data for Siloxane coatings is detailed in Table Four.

<i>STANDARD TEST METHOD</i>	<i>TYPICAL DATA</i>
ASTM D4541 pull off adhesion on Sa 2.5 blasted Steel surface. One coat on blasted steel surface @ 150 um dft	No less than 2000 psi (Elcometer Adhesion)
Cyclic exposure test, 168 cycles totaling 4200 hrs with each cycle being 72 hrs Salt spray test (Synthetic sea water ISO 7253), 16 hrs drying in air, 80 hrs UV-A ASTM G53	Passes 4200 hr test
ASTM D2247 (Cleveland Humidity) testing water resistance in 100% relative humidity. One coat at 150 um dft on blasted Steel.	5500 hours pass
ASTM E84-84 Standard method for test of Surface Burning Characteristics of Building materials. (One coat 375 – 500 um DFT over 11 gauge steel carbon steel).	Flame Spread 10 Smoke developed 16 NFPA Class A
ASTM B117. D9/PSX700 Salt Spray testing to 5000 hrs. surface preparation Sa 2.5 blasted steel surface. 75 um D9/125 um PSX 700	After 5000 hrs of salt Spray testing excellent blistering/face/scribe corrosion performance
ASTM G53 – UVA	4000 hours pass

**Table 4. Typical Siloxane Test Data for Corrosion Performance of POLYSILOXANE Siloxane Topcoat**

## 2.6 Projected Service Life of Polysiloxane Technology

NACE have published data on the projected service life of various coatings in a variety of corrosive environments i.e. this data provides the service life in years before first maintenance and repainting in terms of a practical as well as an ideal timeframe. A practical timeframe refers to maintenance at 5-10 % of coating breakdown with active rusting present. The ideal timeframe refers to time to first maintenance at 3-5 % coating breakdown with no active rust present.

Extensive test data obtained from natural and long term accelerated testing has shown that an epoxy zinc/Polysiloxane system will conservatively provide a 30 % increase in the service life to first maintenance as compared with a three coat conventional system (based upon NACE data).

Table Five details the predicted service life of conventional systems (two coat and three coat – NACE data) as compared with the predicted service life data for two coat Polysiloxane systems.

In addition to improved life to first maintenance, other factors such as productivity, cost, and environmental issues can influence the coating which is specified by the engineer/.architect. table Six illustrates a worked example of predicted cost saving data for an onshore project based on the coating of 10,000 m<sup>2</sup> of Sa 2.5 blasted Steel (conventional 3 coat system vs. 2 coat PSX700 system).

<i>NACE system 72</i>		<i>NACE system 78</i>	
Service life 12 years (Practical)		Service life 15.1 years (Practical)	
Service life 8 years (Ideal)		Service life 10.1 years (Ideal)	
	Dft (μm)		Dft (μm)
Zinc rich epoxy	75	Zinc Rich epoxy	75
Polyurethane T/C	25	HB Epoxy	125
	200 um	P/U topcoat	<u>40</u>
			240

**TABLE 5. Service life calculations of Conventional systems (2 Coat and 3 Coat) cf. Polysiloxane Systems**

<i>PSX System</i>		<i>PSX SYSTEM</i>	
Service life 18.5 years (Practical)		Service life 18.9 years (Practical)	
Service life 12.3 years (Ideal)		Service life 12.6 years (Ideal)	
	Dft (μm)		Dft (μm)
Zinc epoxy primer	75	Ameron D9	75
Polysiloxane	<u>125</u>	PSX700	<u>125</u>
	200		200

**Polysiloxane alternatives**

Other data (calculations as above) are available on various other multicoat systems.

<i>NACE system 63</i>		<i>PSX SYSTEM</i>	
Service life 18. years (Practical)		Service life 18.5 years (Practical)	
Service life 12. years (Ideal)		Service life 12.3 years (Ideal)	
	Dft (μm)		Dft (μm)
I.O.Z	75	Zinc Rich epoxy	75
Epoxy HB	125	PSX700	<u>125</u>
Polyurethane topcoat	<u>50</u>		200
	250		

**Table 6. Service life, Cost, Environmental and Productivity illustrations of a Conventional 3 Coat System cf. 2 Coat System on Sa. 2.5 blasted steel (Spray application only)**

### APPLIED COST SAVINGS

Total Applied Cost Savings –2.8 %

Total Man hour Savings 13.5 %

### VOC EMISSION REDUCTIONS

A total of 1.72 tonnes of emissions (56.2%)

### COATING WEIGHT REDUCTIONS

Total weight Savings 1.15 tonnes

### WASTE DISPOSAL REDUCTIONS

Total waste disposal reduction of some 35.8 %

It is interesting to refer to the situation in Europe where compliant paint coatings are now required to be used by legislation and disposal and recycling of waste are huge issues.

## 2.7 Proven Experience – Case History – Peace Bridge

The Peace Bridge crosses the Niagara river between Buffalo, N.Y. and Fort Erie, Ontario. The bridge is a riveted lattice girder design and is composed of five steel arches of varying widths with an additional truss span across the adjacent Black Rock Canal. Originally, the bridge was painted with red lead primer and overcoated with alkyd topcoat.

The refurbishment of the Peace Bridge project started in early 1994 with the specification calling for abrasive blasting with 100% lead abatement followed by painting with a zinc rich epoxy (75µm) / PSX700 (125µm) system. Three or more coat systems were discarded as they offered no commercial or technical advantage over the two coat system. I.e. extra labour costs and material costs whilst providing no extra benefit in lifetime to first maintenance calculations.

After a five year period the coating system was inspected by Mr Ko Keijman (Technical Director – Ameron BV). After 5 years of weathering the Siloxane system was in pristine condition. The PSX700 system had lost little gloss and showed no signs of chalking; excellent corrosion performance was afforded to the steel edges and rivet heads. These areas were traditionally difficult to protect with conventional 3 coat system.

Other notable two coat case histories which could be used for case history analysis are:

- The painting of the British Gas Armada Fixed Platform (epoxy zinc / PSX700).
- Exxon Singapore Aromatics Plant (Inorganic zinc / PSX700).
- Shell Martinez Refinery (Inorganic zinc / PSX700).

Many other case histories are available for offshore new build and maintenance – only illustrative examples have been cited here.

## 2.8 New Developments in Polysiloxane Chemistry

Some new and exciting Siloxane chemistries have recently been patented or patent applications are underway.

Some of the chemistries which are being patented are:

1. Isocyanate – Siloxane (moisture cured) with no free isocyanate.
2. Acrylic Siloxane with extremely fast cure response, potentially suitable for a multitude of applications.
3. Single pack Siloxane – variant of Polysiloxane
4. Plural component Siloxane – variant of Polysiloxane

The area of Siloxane chemistry is of extreme interest to Ameron and many other new research initiatives are ongoing.

### 3 CONCLUSIONS

This brief paper has summarised some of the benefits of Siloxane chemistry.

- Extremely good durability / colour retention / gloss retention.
- Extremely low VOC.
- Good anti-graffiti properties.
- Resistance to dirt pickup.
- Good overall chemical resistance.
- Cost benefits in labour utilisation, coating film builds whilst maintaining excellent corrosion resistance.
- Excellent abrasion resistance.
- Low temperature cure / drying attributes.

Some of these properties are unique amongst a coating with extreme solids with a VOC comparable to most waterborne systems.

New chemical variants in Polysiloxane coating chemistry are continuing to be developed at a rapid rate.

This area of research will continue to develop as more stringent environmental laws take hold in the global coatings market place.

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