"Hypothetical - Can we design a coating system for 100 Year Durability?"

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Contents

This presentation does not necessarily represent the views of AkzoNobel International Paint

Design Remit:
Durability of the asset for a 100 year income life

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Design for a 100 Year Durability

It is not unusual for design houses to be asked to design public assets with a durability of 100 years or more

Materials durability investigations examine the properties of materials, their reactions with each when exposed to a particular operating environment and how to avoid adverse reactions that will shorten a material’s life.

Of the available choices, Protective Coatings are still one of the cheapest and most commonly used materials selected for the corrosion protection of carbon steel and concrete – the most commonly used building materials in use today

Design for a 100 Year Durability

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There is coting industry recognition that

"No individual protective coating will last 100 years without maintenance at regular intervals"

The challenge is, how do we use coatings with a stated life expectancy of less than the design requirements to "get us over the line".

Protective Coatings for Long Term Exposure

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This presentation will discuss some of the currently available Protective Coatings Technology to investigate if it is possible to design a Protective Coatings System that will have a life expectancy of 100 years.

A “Hypothetical”

This presentation will focus on liquid protective coatings for fabricated Carbon Steel and does not include PFP materials.

Coatings Types

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Liquid coatings can be sub divided into two general categories: -

Decorative:

- Coatings that provide: -
  - Protection of the substrate
  - Colour
  - Texture
  - Hiding power
  - Highlights (wood stains etc.)
  - Accents (metallic, flocks, reflectance)

Coatings Types

Protective Coatings :

Protection by:

- Barrier Isolation Methods (envelope)
- Chemical Inhibition (zinc phosphate)
- Galvanic (zinc based)

Coating Types

To understand how we can design a Coating System for long term exposure we need to know something about how these coatings work and what causes them to fail: -

By themselves

Or as part of a multiple coat system

Coatings Failure

ORGANIC COATINGS will degrade and eventually break down when exposed to: -

Abrasion & Impact

Ultra Violet Light (sunlight)

Wet / Dry cycle times

Solvents (including water)

Temperature (usually above 120-150 °C)

Acids and Alkalis (chemical attack)

Coatings Failure

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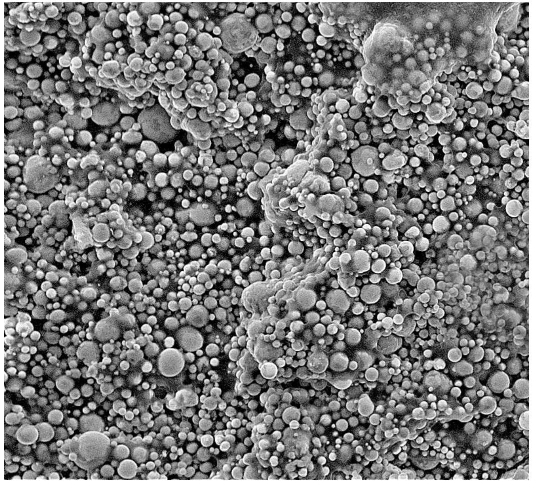
INORGANIC ZINC COATINGS will degrade / fail when exposed to:

Acids and Alkalis (chemical attack)

Constant running water

Temperature (usually above 400 °C)

Inorganic coatings for corrosion protection are usually produced as zinc containing primers and suit exposure in pH 6-9 conditions if not top coated



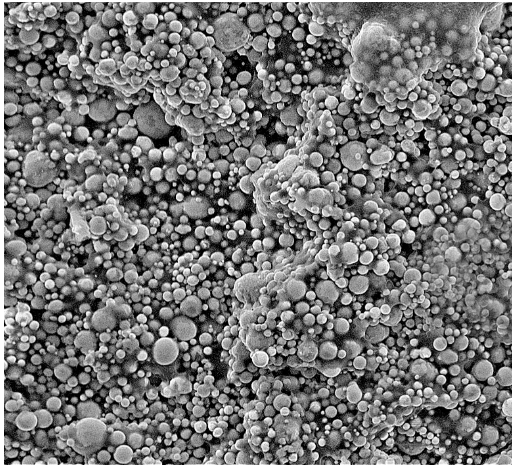
SEM of Inorganic Zinc Silicate

Galvanic Protection of Carbon Steel

Coatings that provide Galvanic Protection have been classified by Australian Standards in AS/NZS 3750 which designates two sub categories: -

AS/NZS 3750.9 “Organic Zinc Rich Primers

AS/NSS 3750.15 “Inorganic Zinc Silicate Primers”



Galvanic Protection of Carbon Steel

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INORGANIC ZINC COATINGS:

- “Equivalent” to Hot Dip Galvanizing-”Galvanic Protection”
- Unaffected by UV (sunlight) and Most Solvents & non flowing water
- Very high Abrasion Resistance – Faying Surface – Friction Grip
- Easier to overcoat with organic coatings than Galvanizing
- Temperature resistance to 400-540ºC
- Resists undercutting of the film even if rust develops at wear or damaged sites (3)

Only come in grey or grey/green colour

Coatings with Barrier Properties

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Organic Resin Coatings such as: -

Epoxy Zinc rich coating as a primer under organic coatings.
Easier to overcoat than Inorganic Zinc Silicates

Adhesion promoting Epoxy Primers with or without Zinc Phosphate pigments for corrosion protection

High Solids / Ultra High Solids Epoxy, Polyester or Vinyl Ester with pigments such as MIO, Ceramics and Micronised Glass Flake for enhanced Barrier Properties and Abrasion Resistance

High Gloss Polyurethane, Polysiloxane, Fluoropolymer, Polyaspartic for colour retention, abrasion resistance and chemical resistance

The Traditional Approach to Long Term Coating Performance

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Understanding the individual properties of these coatings has given specifiers and manufacturers the opportunity to combine compatible resin systems together into a Coating System to extend the durability of the total system by utilising the individual properties of each layer in the system.

Primer:	**Inorganic Zinc Silicate / Epoxy Zinc Rich**
Intermediate 1:	**High Solids Epoxy MIO or Glass Flake**
Intermediate 2:	**High Solids Epoxy MIO or Glass Flake**
Finish:	**High Gloss Polyurethane / Polysiloxane etc.**

The Traditional Approach to Long Term Coating Performance

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This specification approach was based on the knowledge that by combining several generic resin systems together the "Coating System" would achieve: -

Resistance to loss of colour – Polyurethane, Polysiloxane etc.

Resistance to Abrasion, Moisture Vapour Permeation – Epoxy MIO

And if all that failed the zinc primer would activate and give galvanic protection

The Traditional Approach to Long Term Coating Performance

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Offshore Oil Production Platform coated in a traditional 4 coat system

1. IZS
2. HS Epoxy MIO
3. HS Epoxy
4. Polyurethane

The Traditional Approach to Long Term Coating Performance

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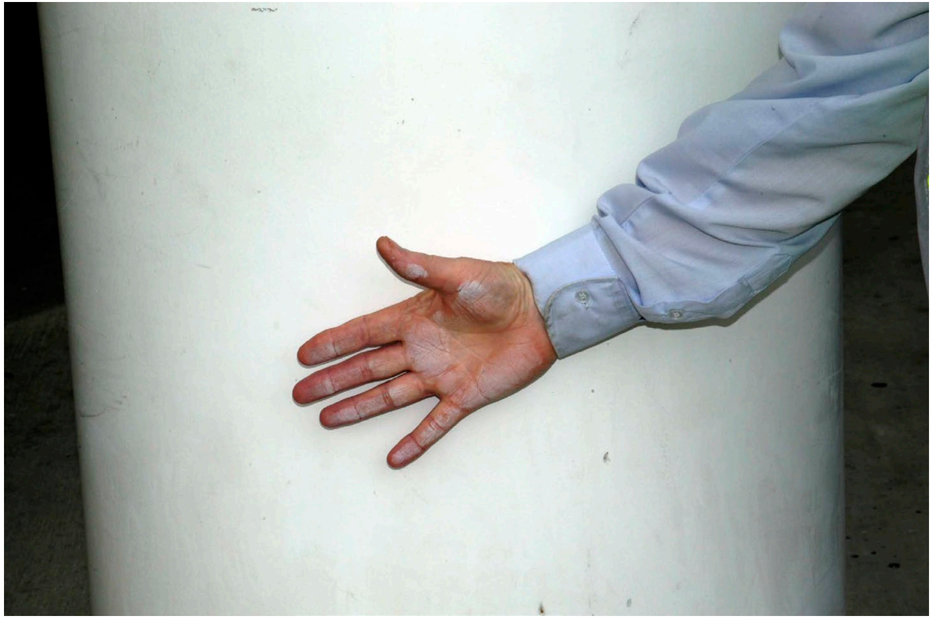

Paint has “chalked” and lost Gloss

The problem was, the “life” of the coatings system was often judged on the Aesthetics of the coating and in many cases the owner decided (or was talked into) re-painting when only the finish coat was showing signs of distress

The Traditional Approach

In many cases, the "Coating System" that was used did not lend itself to easy re-coating methods and in many cases the "maintenance" of these systems required severe abrasion or total removal of the whole coating system.

The colour of the Flare Boom is "supposed" to be the same as the Platform – Safety Yellow. There was less than 1% corrosion but it was re-painted by full removal and replacement to restore the colour.

The Traditional Approach

The coating system was replaced before the Owner received any value from the intermediate coats or the primer coat!

The Owner only received the benefit of a 12-15 year service life. How long would it have lasted if Aesthetics (colour) was ignored?

An Alternative Approach

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Rather than coating the new asset with a multi-coat system, why not apply the coating system to accessible areas in timed stages over the required asset life so that the performance life of each individual coating could be used to achieve the desired durability outcome?

An Alternative Approach

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Primer Coat:

Inorganic Zinc is unaffected by:-

Sunlight & Ultraviolet Radiation

Rain & Dew

Bacteria & Fungi

Temperatures up to ~400 ºC

Based on this, our alternative approach would use this coating as the initial treatment for the prepared steel.

An Alternative Approach

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How long can the IZS last?

AS 2312.1. 2017 " Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings" has Table 6.3 that suggest the durability for various coating types and coating systems when exposed to various categories of Corrosivity, being C1; C2; C3; C4; C5-I; C5-M and T

Table 6.3 of the standard lists both Solvent Borne and Water Borne Zincs (IZS) and shows the following differences: -

An Alternative Approach

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Extract from AS 2312.1 2014 Table 6.3 – Inorganic Zinc

Designation As per AS 2312.1 2014 Table 6.3	Dry Film Thickness	Category C 1	Category C 2	Category C 3	Category C4	Category C5-M
Inorganic Zinc Silicate Solvent Borne (IZS 1 & 4)	75 Microns	25 +	25+	15-25	10-15	5-10
	125 Microns	25+	25+	25+	15-25	10-15
Inorganic Zinc Silicate Water Borne (IZS 2 & 3)	75 Microns	25+	25+	25+	15-25	5-10
	125 Microns	25+	25+	25+	15-25	10-15

An Alternative Approach

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In this table, Inorganic Zinc Silicate is rated to last longer than organic zinc / systems in atmospheric categories C3, C4, & C5 (the most common atmospheric classifications for Protective Coatings) In some cases the inorganic zinc can last 25 years +.

25 Years in C 3 is ¼ of our design life requirement!

There are no single coat Organic Coating systems in AS 2312.1. 2017 Table 6.3 that have a durability rating of 25 years or more. Several multiple coat systems using thick films and multiple coats do suggest a 25 + year durability.

An Alternative Approach

AS 2312.1 2017 only shows the suggested durability of inorganic zinc silicate coatings is 25+ years.

We know of a range of applications where the time to first maintenance requirements of a single coat of Inorganic Zinc Silicate was over 60 years! ([1]) in C 3 exposure.

An Alternative Approach

Then again, there is the original IZS case history of the Morgan-Whyalla Pipeline of 70+ years. (3)

If, in the right exposure environment (C 3) we managed 40 years, then that's 40% of our design requirement.

Maintenance Choices

At this time, the recommended method of maintenance would be to clean up the weathered / degraded zinc by HP waterjetting, spot blasting rusted areas and roughening the remaining surface by Abrasive Brush Blast Cleaning to remove the weathered outer layer and then applying a combination of organic coatings such as surface tolerant epoxy / polyurethane top coat.

How long would that get us toward our 100 year goal?

Maintenance Choices

If we go back to Table 6.3 of AS 2312.1. 2017 we can see that the longest durability (for new systems) of 25+ years in C 3 is System PUR 5 or PSL 2 consisting of Zinc rich Primer; High Build Epoxy and Polyurethane or Polysiloxane top coat.

Considering we would be overcoating a weathered zinc primer, the logical choice after spot repair of the zinc would be Epoxy Mastic with Polyurethane (225 microns total) which is rated with a durability of 25 years in C3 as equivalent to PUR 6.

That would only progress us to near 65% of our goal.

Maintenance Choices

But, If we initially only applied the inorganic zinc silicate primer and we got 40 years from that, what would we get if we could add some more IZS without taking off the residual, well adhered zinc?

Can we do that?

Maintenance Choices

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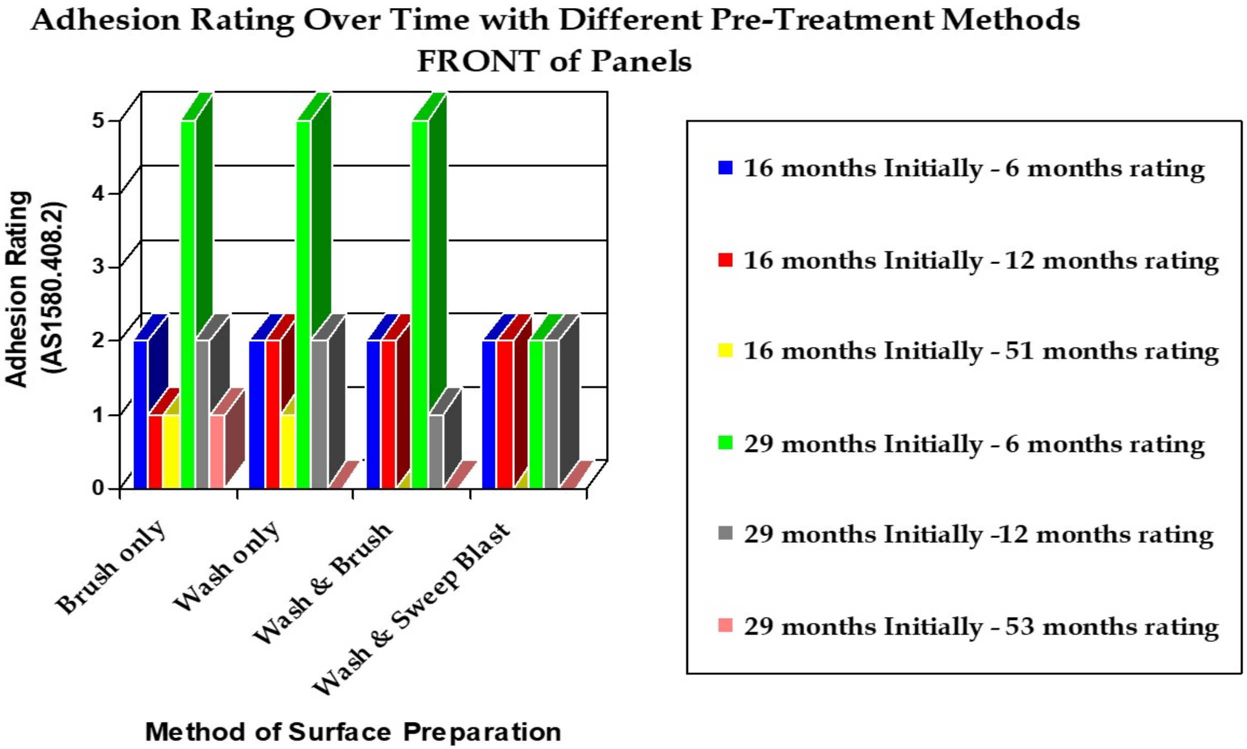
According to Francis, Ellis & Walker (1) Yes, we can

The work conducted by these gentlemen and Riding (2) showed that by preparing the degraded zinc surface by a range of established methods, it was indeed possible to recoat aged and degraded Inorganic Zinc Silicate and achieve good adhesion. .

The surface preparation method used in trials did not appear to affect the adhesion of the new IZS to the old IZS, just cleaning and opening of the surface was adequate.

Interestingly, the adhesion of the new IZS to the old IZS improved over time.

Maintenance Choices



AS 1580.408.2 Adhesion –Knife test. Method B Intersecting Cut.

3. Jagged removal up to 3.0 mm at intersection or along the incisions
2. Jagged removal up to 1.5 mm at intersection or along the incision
1. Slight Trace of peeling or removal at intersection or along the incisions
0. No removal

Ref (2)

Maintenance Choices

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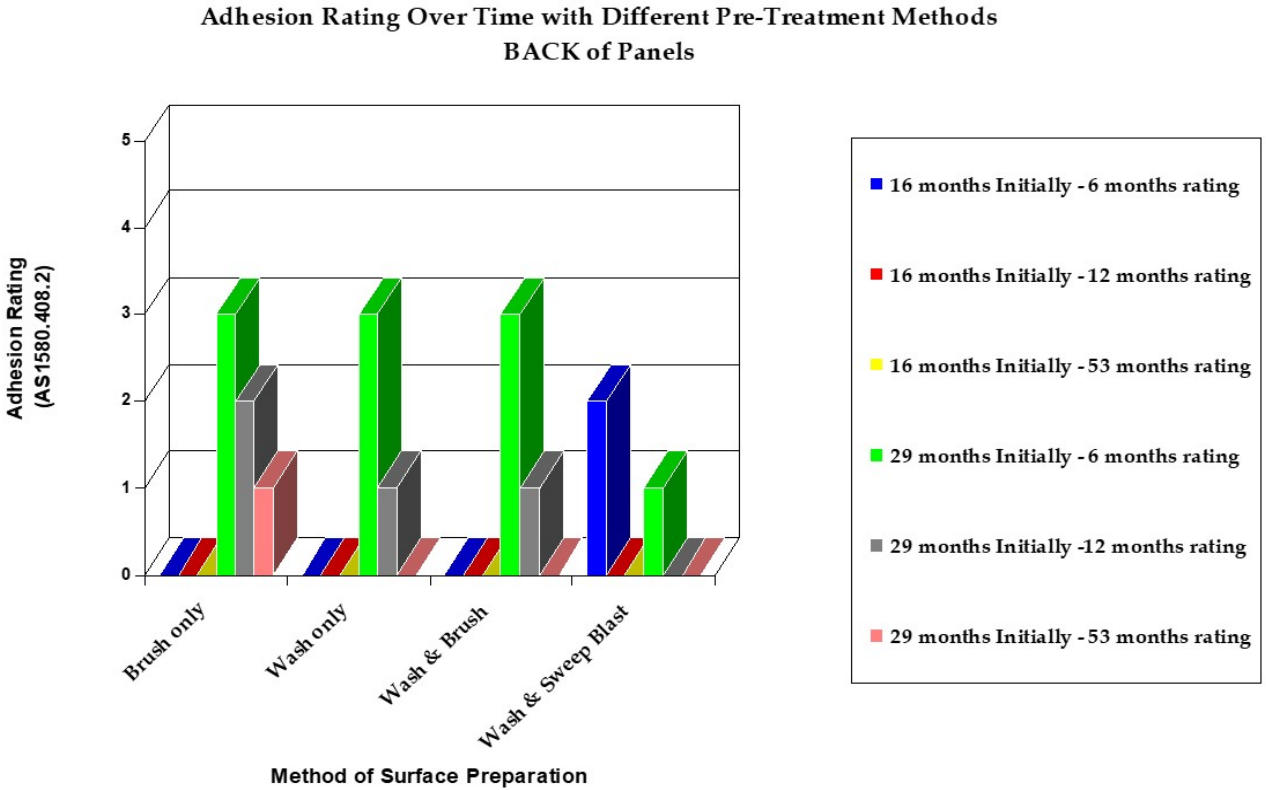

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Maintenance Choices

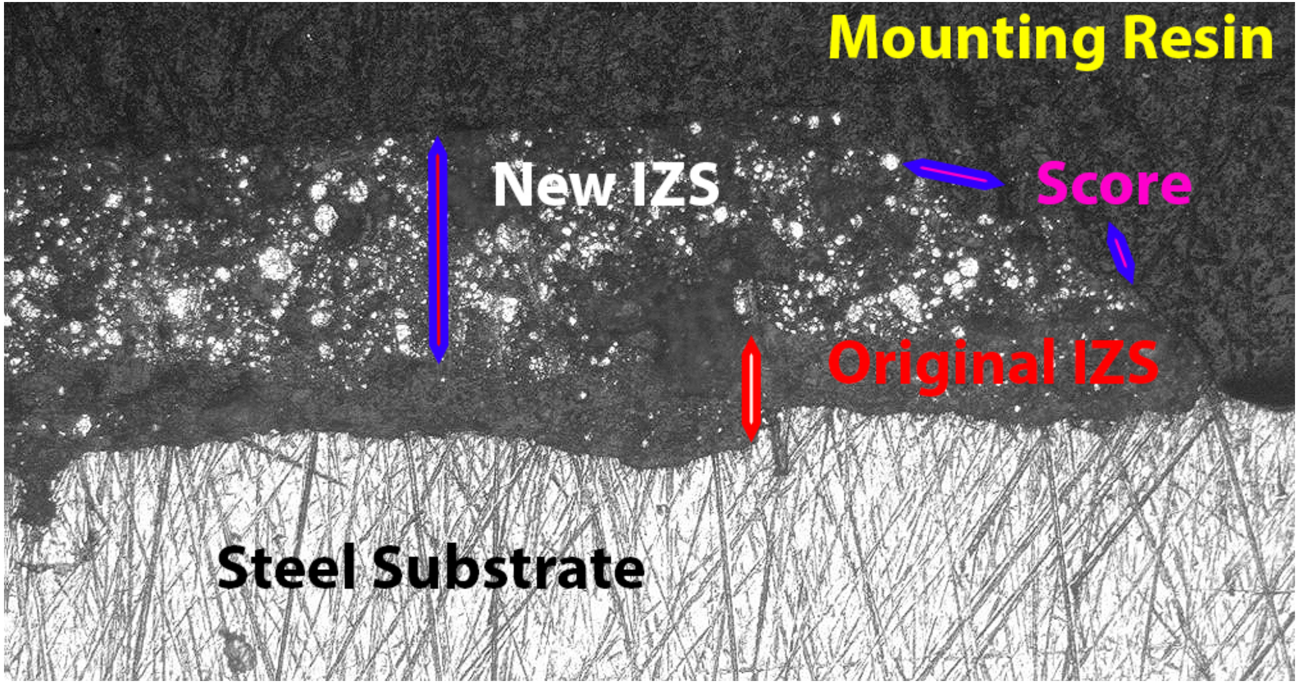

Photo E. Riding

Maintenance Choices

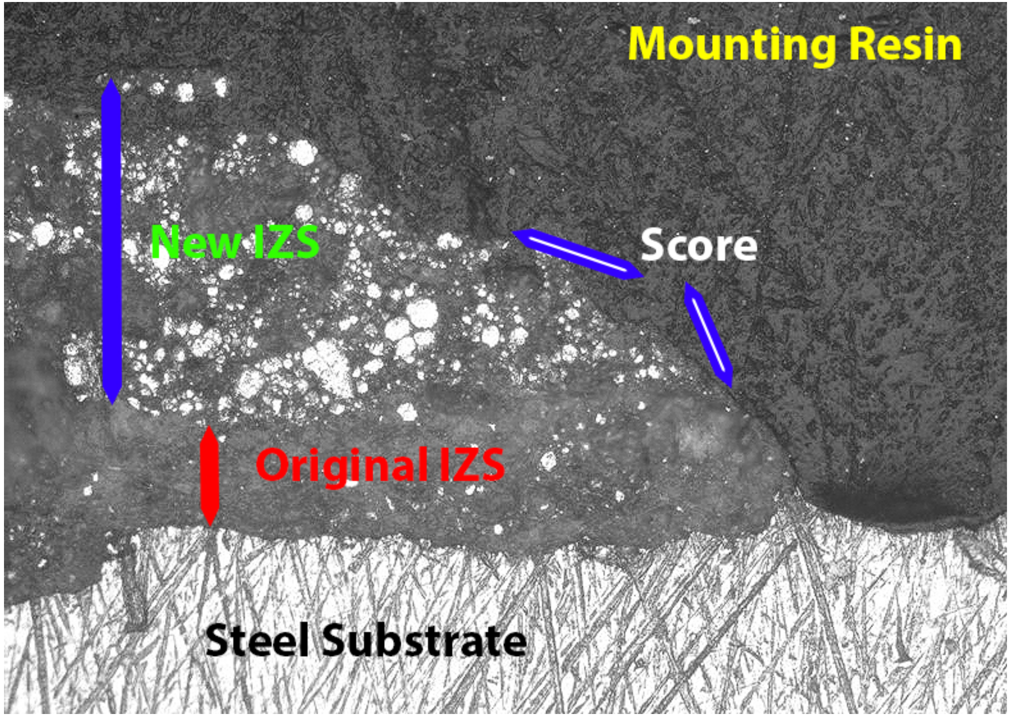

Photo E. Riding

Maintenance Choices

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Re-application of the old IZS with a new coat may not give us the same thickness as the original coating but by adding to the available zinc thickness and being conservative in our expectation, we can confidently expect corrosion resistance and coating performance to 70% of the original coating.

The score so far:

Original IZS Coating 25-45 years

Second application 18- 30 years

43 (conservative) to 75 (confident) years to go

Maintenance Choices

A third application of IZS may not be such a good idea

At the third application, the use of surface tolerant coatings may be a good idea.

What performance can we expect from these coatings?

Maintenance Choices

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Again, we look to AS 2312 Table 6.2

Designation	Dry Film Thickness	C1 Very Low	C2 Low	C3 Medium	C4 High	C5 M Very High Marine
Epoxy Mastic Over St 3 EPM2	**150** microns	25 +	10-25	5-10	2-5	-
Epoxy Mastic over ST3 EPM3	**400** Microns 2 x coats	-	15-25	10-15	5-10	2-5

Maintenance Choices

When we apply 1 coat of Epoxy Mastic (200 microns) and one coat of polyurethane (50-75 microns) over the now degraded but still intact IZS, the new coating system in combination with the zinc equates to Paint System PUR 5 (Zinc Rich Primer + Epoxy Mastic + Polyurethane)

We now have a combined coating service life of 25+ years in C 3.

Maintenance Choices

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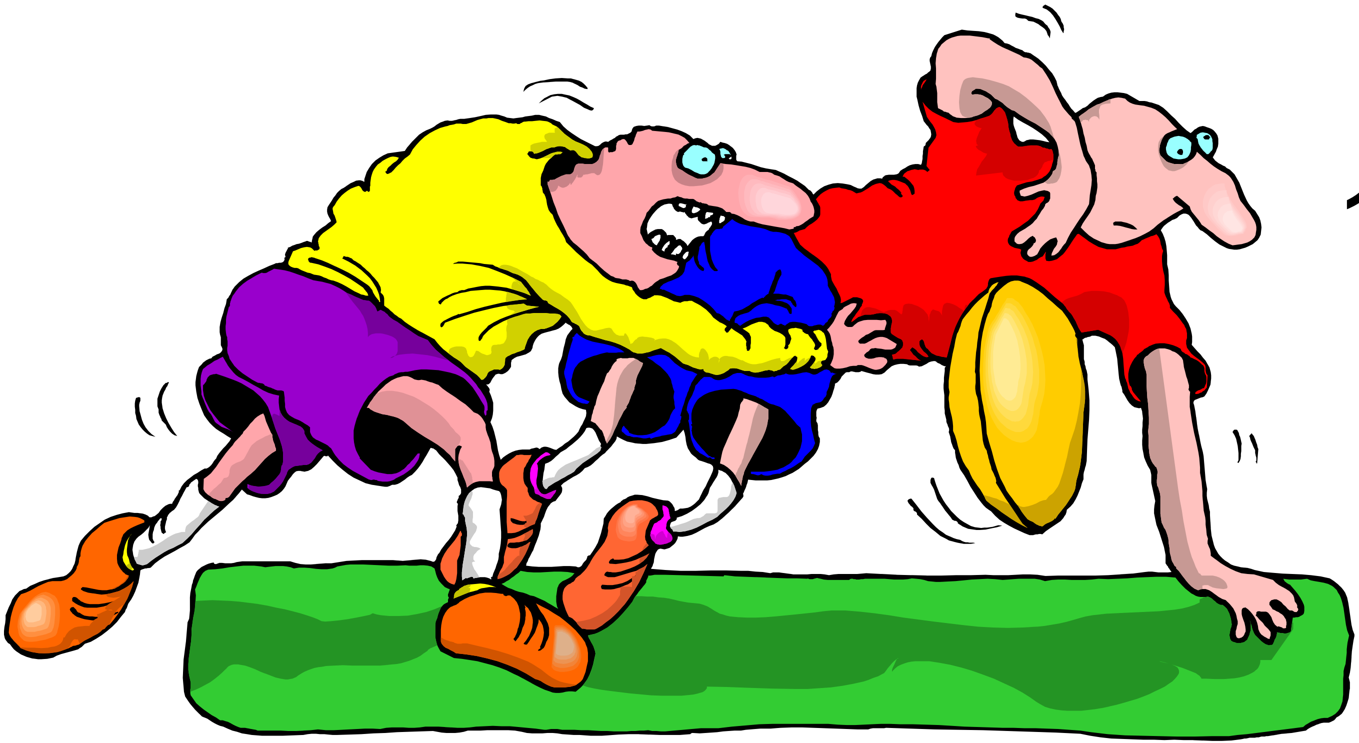
Initial Coating	Life expectancy years In AS 2312-2107 Category C 3 Exposure	Total Years Exposure	
		AS 2312-2107	Confident
Inorganic Zinc Silicate (125 microns)	25+	25+	40*
1st Maintenance: Clean up the zinc and re-apply IZS to itself (75 microns)	15-25	15-25	20
2nd Maintenance: Epoxy Surface tolerant system of 1 coats Epoxy mastic + 1 coat Polyurethane with surface abrasion	25+	25+	15
3rd Maintenance Epoxy Surface tolerant system of 1 coats Epoxy mastic + 1 coat Polyurethane with surface abrasion	25+	25+	15

* Based on known case histories

Did we get "over the line"?



100?

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Maintenance Choices

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The idea of using a coating system "progressively" is theoretically possible but it depends on many factors that are not usually in the control by the specifier or design house.

1. Access to the facility after it opens for business.

2. Practicality of carrying out maintenance painting while the asset is in full operation

3. Access to the substrate: How many services are mounted onto the structure and is it safe to work around them (Microwave Towers, Reactors, Distillation Vessels etc.)

4. The initial quality of the painting work and the quality of the subsequent treatments always impacts on the service life of each and every coat of paint. Owners need to get serious about field inspection.

Summary: -

Combining coatings that maximise the individual film protective properties before maintenance is a suggested method of maximising the protective properties of each individual coating instead of applying multiple coat system and judging the maintenance requirements on the aesthetics or erosion of the top coat.

Knowledge of the operating environment, temperatures and exposure conditions (and expected changes) are necessary when designing long term protective coating systems.

Summary: -

Today's Protective Coatings materials will not last 100 years by themselves.

Protective Coatings Systems need to be designed so that they can be maintained for the lowest cost using current materials technology at the time of design.

The asset owner should be advised that he will need to carry out regular inspections and planned maintenance painting of the asset over the 100 year life of the asset.

Commercial Relationships

The asset owner needs to establish a working relationship with the coating manufacturer that extends past the supply of the initial coating and into the future maintenance programs if the scheme is to succeed.

The current demand for "Guarantees" are a part of the relationship and may involve commitments to use the same manufacturer for the scheme so guarantees / warranties are maintained.

The advantages to the manufacturer include:-

- Ability to forecast stock requirements for planned maintenance periods
- Ability to plan support staff for maintenance periods
- Foreword sales forecasts past the current fiscal year.

Thank you

References

(1) Francis, Ellis & Walker . Repair of Single Coat Inorganic Zinc Silicate Coatings Paper 044 Corrosion Control 007

(2) Riding E. (Ted) Graphs of cure – slides

Macro Photos – Recoated IZS slides

(3) Francis. R A rock-Like Coating That can Protect for Decades – Materials Performance January 2019