

Corrosion

Exclusively



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- Using thermoplastics for infrastructure protection – Part 2
- Comprehending coating adhesion – Part 1
- NACE – The future of corrosion control
- Construction bolting ten years on
- From the KETTLE





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President's Comment

About two months have passed since the beginning of 2020 (the year of perfect vision?) and it seems to be a slow start for many businesses with seemingly conflict occurring amongst our political leaders. This has had the effect of many questioning whether the future of the country is in good hands and wondering whether we as Southern Africa Incorporated will be able to ride out the political turmoil sooner rather than later. Hopefully we emerge from this

turmoil although a bit worse for wear and tired, but smiling as we as a region have made it and are now wiser and more resilient.

Possibly we may have a more focused resolve to survive and grow under the newly emerging future dispensation. Perhaps for many of the players in the industry that have not already done so, the time is right to spread our business risk and cast our nets further afield than just locally and aim to generate a larger portion of our income from foreign sources.

However, despite some localised elements currently facing economic gloom and doom we need to realize that our industry will always need solutions to deal with corrosion. Even if the economy is slow and in a downward cycle, in the words of Neil Young songwriter from the 70's "Rust Never Sleeps". Thermodynamically, corrosion will always occur, however it is the rate at which it happens where our fight lies.

At the Core it is business as usual with work already afoot to improve our value to our members. We also intend to focus on improving our database as the key foundation from which to operate all future systems on.

Watch this space as the saying goes.

In addition, 2020 is a year of our biannual AfriCorr conference. AfriCorr2020 will be held on 2 – 4 September. Planning is currently advanced to hold this prestigious conference. This is the 3rd AfriCorr in the series and once again like in 2018 we are partnering with NACE and have secured a wonderful venue at which the event will take place. Misty Hills Country Hotel, Conference Centre & Spa. The call has gone out for submission of papers and for sponsorships for this event. Please visit <http://africorr.nace.org> for further information. I look forward to your participation in AfriCorr2020

Greg Combrink, President – Corrosion Institute of Southern Africa

OBJECTIVE OF THE MAGAZINE

"The objective of 'Corrosion Exclusively' is to highlight CORRISA activities, raise and debate corrosion related issues, including circumstances where inappropriate material and/or coatings have been incorrectly specified, or have degraded due to excessive service life. Furthermore, it shall ensure that appropriate materials or coatings, be they metallic or otherwise, get equal exposure opportunity to the selected readers, provided these are appropriate for the specified exposure conditions on hand."



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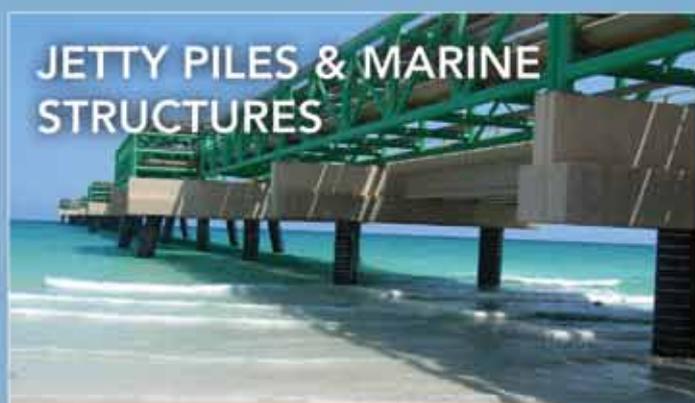
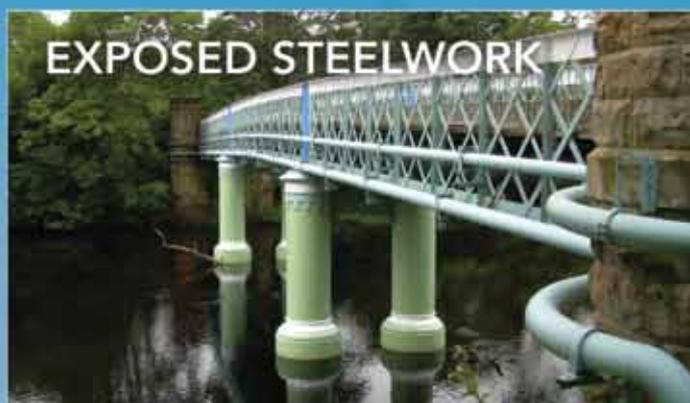
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Cover: Our coastal cities and towns have endless examples of failed coatings and corrosion. When are we going to learn?



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Editorial Comment

Following 20 odd years of promoting hot dip galvanizing to specifiers located around South Africa, where travelling up to 18 weeks of the year to the areas where galvanizing plants were situated, allowed me the privilege of engaging with specifiers, one on one or one on group. This had a profound effect on the understanding of hot dip galvanizing and the throughput of steelwork through the respective galvanizing plants.



This active promotion over the last five years seems to have ceased and I am now astounded at the misinformed level of understanding that some specifiers have when it comes to the word “galvanizing”.

Recently having been requested to inspect and assess some hot dip galvanized components, I found while talking to a senior engineer of a reputable company that he had very little understanding of what constituted general hot dip galvanizing. Promotion of this coating amongst specifiers is clearly lacking.

The word “galvanizing” incorporates several different forms of coatings, including: general or batch, continuous sheet, tube hot dip galvanizing as well as zinc electroplating (or electro-galvanizing) & a zinc rich paint or “cold galv”. Each of these coatings has its place when considering their use in corrosion categories C1 to C5X.

CorrISA continue to invite interested consulting engineers, architects and specifiers to attend their regular technical evenings at the CORE in Midrand, Kelvin Grove in Cape Town and recently in Durban, where interesting corrosion related topics are presented. Following questions from the audience, the evening continues where free refreshments are served and some serious networking with corrosion control specialists takes place.

In this edition we include several articles addressing practical methods of corrosion control, including:

- Using thermoplastics for structures – Part 2 (of 3).
- Comprehending coating adhesion part 1. To stick or not to stick.
- NACE expert roundtable discussion – The future of corrosion control.
- Construction bolting ten years on.

From the KETTLE, a regular contribution on hot dip galvanizing we discuss surface conditions F20A (Preventing distortion by hot dip galvanizing by way of design or fabrication techniques) and F29 (Ungalvanized surfaces caused by entrapped air).

Acting Manager of CorrISA, Linda Hinrichen provides an insight into CorrISA affairs.

Graham Duk the Western Cape chairmen gives an account of the Cape Region and the recently appointed KZN chairperson Karyn Albrecht, introduces her committee and the KZN activities.

We report on CorrISA technical activities in Gauteng, KZN and Cape Region.

Under Education we include a NACE educational course CIP 1 that took place in late January this year.

“SPOTLIGHT” focuses on Alan Davies of Bergstan South Africa and the “RUST Spot” features Dave Harworth of Structural Applications.

We wish to thank all our advertisers who continually support the publication in spite of the tough economic situation we find ourselves in. It is through the support of people and companies like yourselves that this publication will eventually be considered a “must read” magazine amongst all Southern African specifiers when requiring an effective corrosion control method.

We also wish to thank our contributors, who painstakingly offer us technical articles of value.

Terry Smith

Using thermoplastics for infrastructure protection in marine and other challenging environments

Prepared by A&E Communications & Technical Department for Australasian Corrosion Association (ACA)

Presented by Sean Ong (General Manager, Asia) at Corrosion & Preventions 2017 Conference, Sydney, Australia

PART 2 (OF 3)

Testing

Accelerated weathering

A common weathering test is ASTM G154, in which samples are exposed to 42 cycles of 8 hours of UVA-340 ultra-violet light at a temperature of 60°C followed by 4 hours of condensation at 50°C for a total of 21 days of exposure. Like many other standard tests, this may provide a benchmark for comparison but does it has very little to say about what will happen in the real world.

Other tests such as ASTM D4587 and G 155 provide for a similar combination of UV irradiation, heat and water while ASTM B117 focuses on a combination of water salt and heat. All these tests are widely accepted in assessing suitability of materials for outdoor use but, for example, a 1 000 hours of UVA exposure is only the equivalent of 1 year in South Florida and a bolt that has passed a 1 000 hours hot salt fog test may be completely unserviceable within 18 months in some environments, as we have seen.

So, in order to provide some real-world equivalency, the scale of the testing for CIST was revised to be significantly longer and under more extreme conditions.

HOUR COUNTER	MONTH	WEEK 1	WEEK 2	WEEK 3	WEEK 4
672	1	UV	UV	HSF	UV
1344	2	UV	HSF	UV	UV
2016	3	HSF	UV	UV	HSF
2688	4	UV	UV	HSF	UV
3360	5	UV	HSF	UV	UV
4032	6	HSF	UV	UV	HSF
4704	7	UV	UV	HSF	UV

Indicates the samples in UV Cabinet
 Indicates the samples in HSF Cabinet

Figure 9: Exposure schedule.

For the weathering test, it was decided that the rapid half-daily cycles of wet and dry specified under ASTM G154 were not representative of natural weather cycles and a regime was implemented that allowed much longer periods of exposure to each element of the test. The cycles were between UV exposure and hot salt fog (HSF) exposure and the test was to run for 6 months.

The UV exposure was via 4 x 15w 450nm UVA tubes arranged to give continuous 360°

exposure while the HSF element employed standard ASTM B117 parameters with 5% salinity, fog temperature 47°C and chamber temperature 35°C.

The samples were prepared using carbon steel test pieces, blasted and coated with a single coat of epoxy and fastened using standard nickel-plated B7 bolts. They were then coated with CIST using 2 coats at 2mm per coat, with edges sealed using standard cable ties and the pipe ends left unprotected.

HSF PARAMETER			
Salinity, IN	5%	Salinity, OUT	5%
pH		Fog Collectors Data	
pH in	7.2	Fog Collector 1	2.0 ml/hr/80cm ²
pH out	6.5	Fog Collector 2	1.8 ml/hr/80cm ²
Temperature		Pressure	
Saturated Air Temp	47°C	Chamber Pressure	1 bar
Chamber Temp	35°C	Air Intake Pressure	0.9 MPa
Hygrometer		Downtime	
Web Bulb	35°C	From	-
Dry Bulb	35°C	To	-
UV PARAMETER			
UV LAMP NO	4	PLACEMENT	360 DEGREE
WAVE LENGTH		15W / 450nm	
HEATER NO	2	AVERAGE TEMPERATURE	45 DEGREE C

Figure 10: Exposure parameters.

The test pieces were then entered into the UV cabinet to initiate their exposure (Figure 11). Samples were exposed to the weathering process in different orientations to expose all areas, testing for ingress as well as weathering. A number of small buff-coloured CIST coated bolts were included to allow interim removals as required.

As the number of weeks increased, it became increasingly obvious that a longer period was needed as there was no discernible effect on the CIST. It was decided to leave the samples



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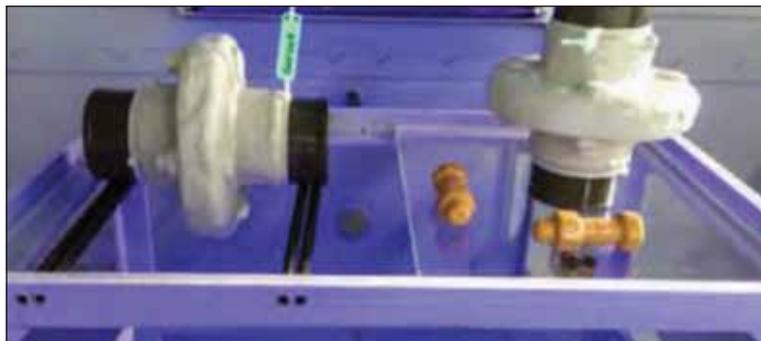


Figure 11: Samples at start of test.



Figure 12: Slight fading after 4 500 hours.

in for another six months and remove one of the small bolts to assess the changes so far. The material was cut from the bolt to see if there had been any changes either to the bolt or the CIST coating.

The bolt itself displayed no signs of deterioration, and although the exterior

of the CIST coating was found to be relatively free of inhibiting oil, inside the encapsulation inhibitors were evident on all surfaces. Visual examination of the surface showed slight fading, about 5% compared with a reference sample (Figure 12) and microscopic analysis of the surface of the coating showed no deterioration of the

surface structure (Figure 13). Analysis of a section through the coating confirmed a slight oil loss at the surface but showed that oil was uniformly present throughout the coating (Figure 14).

It was concluded that the accelerated weathering cycle over 6 months had no detrimental effect on the CIST encapsulation and that all performance criteria remained at 100%.



Figure 13: No crazing or cracking.



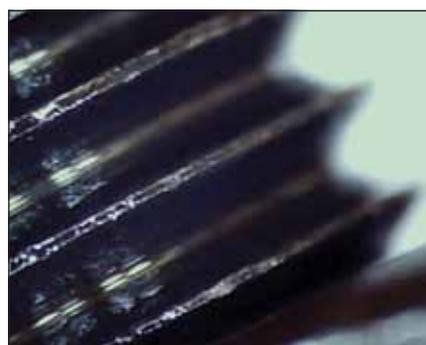
Figure 14: Slight drying on outer edge.

ASTM B117 Hot salt fog testing

Most authorities agree that there can be no extrapolation of an HSF test to correlate with a defined number of years – but they will agree that the longer the test, the more likely it is that a successful outcome will be achieved in the real world. So it was decided that an unprecedented 10 000 hours (nearly 14 months) of continuous HFS testing would go a long way to showing what CIST could achieve.



Figure 15: Bolt thread and removed coating show optimum oil deposition.



After 10 000 hours the uncoated control piece displayed significant levels of deterioration but the CIST samples were in excellent condition. No corrosion or deterioration of any kind could be detected within the CIST encapsulation, bolts, nuts and flange were in perfect condition.

Cyclic inhibitor loss test

CIST is an active coating, the deposition of the inhibiting oil on to the substrate and the ability of this inhibition process to prevent corrosion are key elements in the overall corrosion protection package so, if this deposition is a continuous process, how long can the coating maintain its performance?



Figure 16: Control plus one sample removed at 4 500 hours and final sample at 10 000 hours.

In fact, the process by which inhibiting oil is maintained on the encapsulated substrate



Figure 17: Cyclic test piece before and after coating plus thread and coating interior after test.

is more akin to the water cycle that governs the world's rainfall than it is to a constantly pouring tap. On application, the hot material deposits a thin film of oil between the coating of CIST and the substrate. On cooling, some of this is reabsorbed into the CIST and, as the substrate surface and ambient temperatures go through their natural cycle, a continuous cycle of deposition and absorption is maintained. Loss through the surface of the CIST encapsulation is negligible, it soon becomes almost dry to touch but a 'dew point' effect is maintained between the substrate and the CIST producing sufficient inhibitors to fill the pits and crevices within the bolted structure, coating all internal surfaces without escaping into the environment.

For this test, an encapsulated substrate was subjected to a continuous cycle of temperature variations from 45°C to 4°C on a 24-hour cycle for six months. The weight of the substrate and the applied CIST material was recorded before and after encapsulation. The sample was suspended over a tray to collect any potentially escaping liquids.

A laboratory oven was used to raise the substrate to 45°C during the day, overnight the substrate was transferred to a refrigerator monitored at 4°C. The substrate was removed from cooling at 9am and kept at ambient temperature until 11.00 when it was replaced in the oven. The oven was set to 45°C and switched on for 3 hours. After 3 hours the oven was switched off and the substrate allowed to cool in ambient temperatures for 2 hours before repeating the cycle, five days on, two days off. At weekends the substrate was left alternately at 45°C or ambient temperatures.

Over the six-month period there was no significant change in weight nor any escape of oil on to the tray. Initially weekly measurements were taken but, with no changes found, the interval was increased to monthly. At the end of six months, the material was removed and examined. Good oil deposits were found within the encapsulation, on bolt threads, metal and CIST interior surfaces. Other than some soiling from handling, no surface effects were found on the CIST exterior.

Date	Weight Uncoated	Weight Coated
17-8-12	1427.5g	1565.0g
21-9-12	N/A	1565.0
18-10-12	N/A	1565.1
23-11-12	N/A	1565.0
2-1-13	N/A	1565.0
31-1-13	N/A	1564.9
28-2-13	1427.6	1565.0

Figure 18: Cyclic test results.

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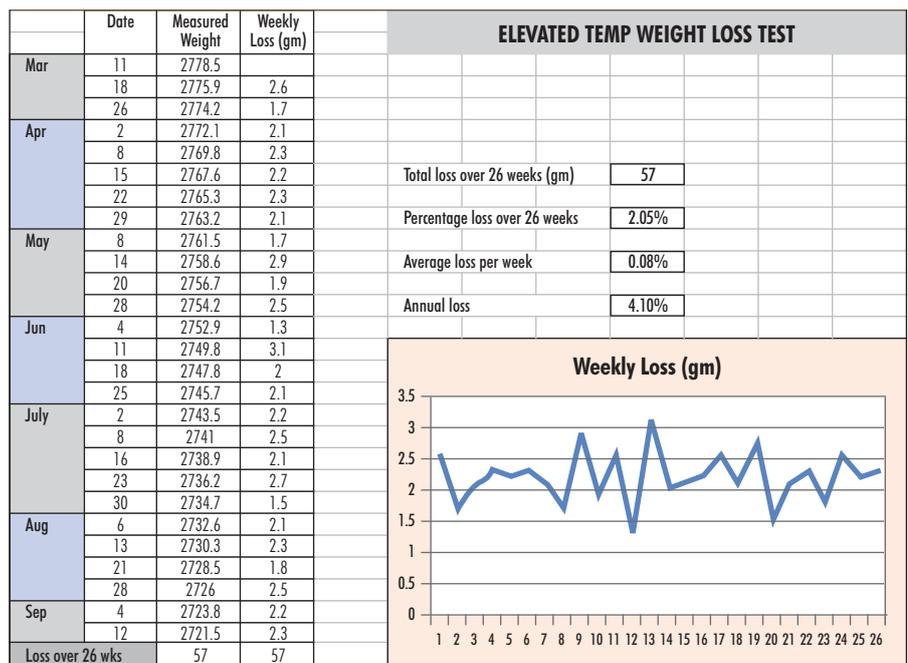


Figure 19: Test results.

Sustained high temperature test

A measured and weighed sample of CIST material was placed in a laboratory oven for 3 months at 80°C in order to establish the rate of inhibitor loss at elevated temperatures. At the end of each week the material was removed from the oven, measured, weighed and immediately returned to the oven to maintain its temperature. Weight loss was consistent with an average loss of 0.08% per week. Weekly measurements showed no measurable shrinkage over the period.

Impermeability – sustained deluge test

Not satisfied that standard tests were sufficiently demanding, a deluge test was devised to run on a CIST-coated flange and pipe. A 20% saline solution was cycled at approximately 400 litres an hour for 11 hours a day, 5 days out of 7 for 6 weeks. Ambient temperatures were between 24°C and 38°C. The steel pipe substrate and flange were new and uncoated low-carbon steel, a section along the length of the pipe was abraded prior to coating with CIST to provide the best potential conditions for corrosion. The CIST encapsulation was sealed using a standard tie-wrap technique.

At the end of the test the CIST was cut away to reveal the substrate. No corrosion of any kind was found within the CIST

encapsulation, whereas significant corrosion occurred along the length of the exposed, unprotected pipe.

So, if testing provides such encouraging results, how has the material performed in the real world?

The Editor would like to thank ACA for Part 2 of this contribution.



Figure 20: Test substrate at 7 days (top), 28 days (centre) and 38 days (bottom).

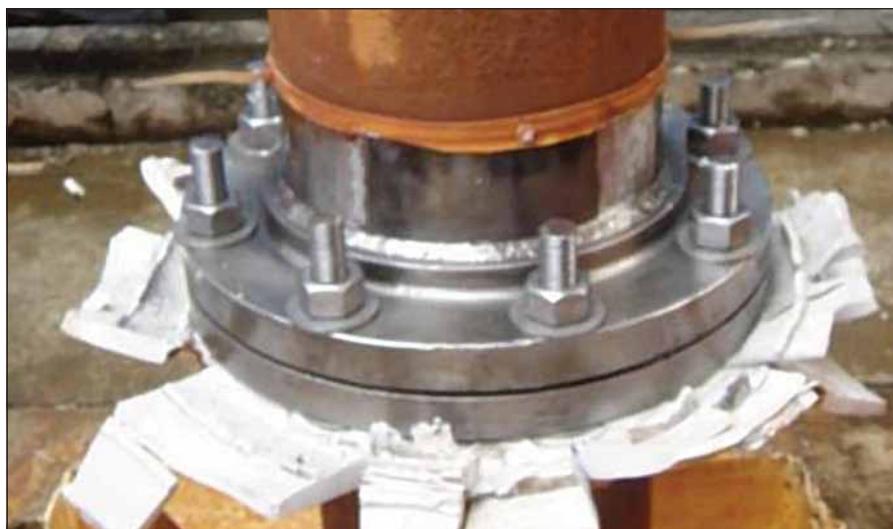


Figure 21: Completely unblemished interior after 6 weeks.



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Comprehending coating adhesion: To stick or not to stick?

By Rob Francis, R A Francis Consulting Services, Ashburton, Victoria, Australia.

PART 1

Introduction

Liquid epoxies are the workhorse for the protective coating industry, providing economic protection to steel and other substrates in a wide range of atmospheric, submerged and buried environments. One of their major advantages over other generic types is their excellent adhesion to steel substrates and previous coatings. However, if applied to polyethylene, as for example, field joint coatings on three-layer polyethylene pipeline coatings as shown schematically in Figure 1, they do not adhere. Yet there is no problem applying epoxies to steel or fusion bonded epoxy pipeline coatings. Such behaviour is puzzling to specifiers and applicators used to dealing with epoxies on steel.

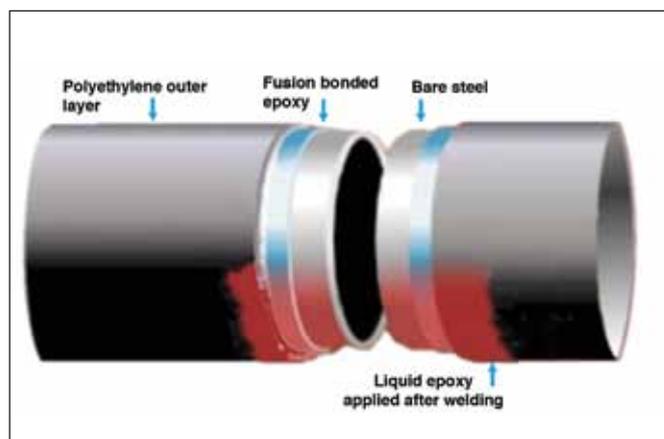


Figure 1: Liquid epoxy field joint coatings can have problems adhering to polyethylene mainline pipeline coatings.

This paper looks at the factors that determine whether or not a given coating will adhere to a substrate. It discusses why epoxy usually shows good adhesion to most substrates and why there are problems with polyethylene and related polymers. It discusses the reasons abrasive blasting the surface does not assist adhesion in this case and in fact can make it worse, and looks at treatments for such surfaces to try to improve adhesion. There are coatings that can successfully adhere to polyethylene and similar surfaces and their mechanism of bonding is reviewed. Finally, there is brief review of methods that are used for measuring coating adhesion and why results of these tests bear little relationship to actual interfacial bonding forces. First some background on adhesion fundamentals.

Basics of coating adhesion

Consider a situation where a paint is applied to a surface. To adhere to a substrate it must first wet, or stick to, the substrate. Wetting can be defined as adhesion of a liquid to a solid. The coating will wet the substrate only when the relative surface energies of the coating and the substrate are appropriate. All surfaces have surface energy

(also known as surface free energy or surface tension for liquids) as a result of the atoms or molecules tending to orient themselves to minimise the surface area. In a liquid, droplets will tend to form a spherical shape which has the smallest surface area for a given volume. Solids also have a surface energy and try to minimise their surface area by causing an applied liquid to spread across this surface. However, the surface tension of the liquid will oppose this property by attempting to minimise its own surface area. As a result, there is a competition between these two tendencies. To determine if a given liquid will wet a given surface, we need to look at the relative surface energies of each. The two components cannot be looked at separately.

Surface energy is defined as the amount of work or energy required to create a unit area of surface and has units such as Joules per square metre (J/m^2). Surface tension is the force per unit length acting upon an imaginary line drawn on the surface. The SI units for surface tension are Newton per metre (N/m), which is numerically equivalent and used interchangeably with Joules per square metre. Because N/m is a rather large unit, surface tension is commonly expressed as milli Newtons per metre (mN/m) which is equivalent to the old unit of dyne/cm used in past literature and still widely quoted. Similarly, surface energy is usually quoted in milli Joules/ m^2 (mJ/m^2). For liquids, the term surface tension rather than surface energy is more commonly used, so to enhance ease of comprehension this term will be used.

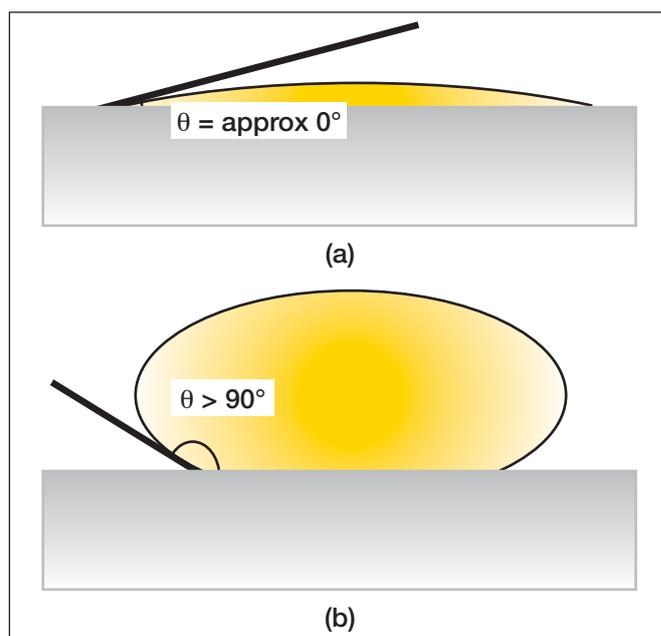


Figure 2: Contact angle (θ) for a liquid on a solid with (a) good wettability and (b) poor wettability.

High surface energy		Medium surface energy		Low surface energy	
Surface	mJ m ⁻²	Surface	mJ m ⁻²	Surface	mJ m ⁻²
Metals (ideal)	500 - 5,000	Epoxy paints	~50	Polyethylene	31
Metal oxides	200 - 500	Alkyd enamel	45	Polypropylene	30
Metals (realistic in air)	50 - 500	Polyurethane paint	43	Mineral spirits	24
Water	73	Polyester	43	Methyl isobutyl ketone (MIBK)	24
		Polyvinyl chloride (PVC)	40	Ethanol	22
		Acrylic emulsion	32	Hydrocarbons	~20
				PTFE	18

Table 1: Surface energy of substrates, coatings and related materials.

A polar molecule such as water has a relatively high surface tension because of the hydrogen bonding forces exerted on the surface molecules by the internal molecules beneath it. A non-polar liquid, such as hexane, will not have these forces and has a lower surface tension. The surface tension of liquids can be measured relatively easily using, for example, the capillary rise method. One end of an open bore capillary tube is immersed into the solution and the height to which the solution rises is related to the surface tension. Surface energy of solids is more complex and usually measured indirectly using the contact angle method discussed below.

A drop of liquid placed on a surface may spread out or ball up, depending on how it wets the surface. Raindrops bead up on a freshly waxed car because the surface energy of the water is higher than that of the wax. In contrast, if the surface energy of the liquid is less than that of the substrate, such as soapy water on an oil-free surface, it will spread out and wet the substrate thus making the intimate contact necessary for good bonding. If it wets the surface, the contact angle (θ) between the liquid and the surface is very small, as shown in *Figure 2(a)*. A liquid which completely wets the surface will have a contact angle of 0° . A liquid which shows poor wetting properties will have an angle greater than 90° , as shown in *Figure 2(b)*.

For a drop of liquid on a surface shown in *Figure 2*, the substrate and the liquid in air will each have a different surface free energy value. For wetting, the surface energy (tension) of the liquid being applied must be lower than the surface energy of the solid. Practically, the surface tension of the liquid would need to be at least 10 mJ/m^2 lower than the surface energy of the substrate. The surface energy of a substrate depends on the type of material as well as its cleanliness and roughness. *Table 1* gives surface energy figures for some surfaces, coatings and related materials. On typical well-prepared metals, the surface energy is of the order of several hundred millijoules per square metre. So, even if not perfectly clean, they have much greater surface energy than typical paints (20 to 70 mJ/m^2) and wetting of such surfaces is not normally a problem. However, plastics such as polyethylene and PTFE are low energy surfaces and the same coating would not wet the surface. Adding solvent to a coating will lower surface tension and viscosity, enabling better flow over a surface, but

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still not allow wetting of a low energy surface. Modern coatings with low or no solvent have higher surface energy and viscosity and are more likely to have difficulty wetting out a surface. It is worth noting that actual surface energy figures of metal surfaces are an order of magnitude less than ideal values.

From a practical point-of-view, relative surface energy studies can be carried out placing drops of coating on a substrate and watching the spreading. If the droplet remains as a small ball (high contact angle) wetting is poor and adhesion problems must be expected. If the drop spreads across the surface (low contact angle) the coating will wet the surface and should have good adhesion. However, sometimes solvents or additives can create an atmosphere above the drop that may cause a drop that initially wets the surface to ball up and de-wet the surface.

Roughening of low energy surfaces

Table 1 shows that surfaces such as polyethylene, polypropylene and PTFE are inherently low energy (18 to 31 mJ/m²) and cannot be wetted by typical coatings such as epoxies. Is there anything that can

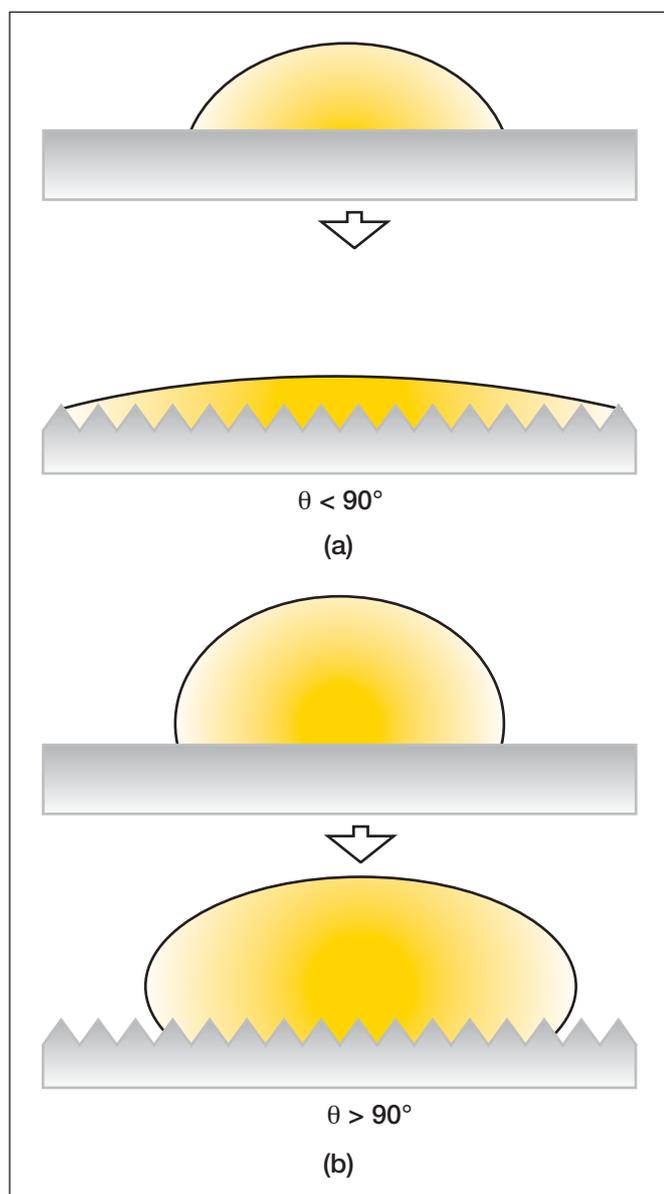


Figure 3: Effect of surface roughness on contact angle.

overcome this inherent incompatibility between epoxies and low energy surfaces? Abrasive blasting is a quick and economical means of cleaning and preparing metals and other surfaces to improve coating adhesion, so it would be the obvious first method to look at to see if this can allow wetting of a low energy surface.

Surface roughness will have an effect on wetting, contact angles and adhesion. This effect can be through a number of different mechanisms. Roughness is generally agreed to improve wettability and increase dry adhesion of paints on metals by increasing surface area and providing resistance to shear stresses in coating curing and during service, but it can have a negative effect on wetting of low energy surfaces. This unusual behaviour can again be explained in terms of wetting and contact angles.

For most organic liquids with a contact angle less than 90°, such as epoxy on steel as shown in Figure 3(a), the effect of roughening is to make the contact angle lower so the effect of roughening is to improve wettability. However, if the surface is contacted by a liquid with a contact angle greater than 90°, such as epoxy on polyethylene, then roughening has the opposite effect of increasing contact angle and reducing wettability, as shown in Figure 3(b). Therefore, the wet adhesion of an epoxy on a roughened surface of polyethylene is less than that on a smooth surface. Trapping of air pockets and difficulty filling surface features, especially with viscous materials, with a poorly wetting liquid can also reduce adhesion on low energy surfaces. In addition, gap filling may be competing with curing of the coating. One reason fast curing epoxies, for example, may not have the same adhesion as their slow curing equivalents is that the fast curing epoxy does not have time to fill the crevices on the substrate. Overall, roughening a low energy surface by blast cleaning will not improve wetting of the surface by paint coatings and have a detrimental effect on adhesion.

Abrasive blasting cannot be used to prepare low energy surfaces. The next possibility is to look at changing the chemical rather than physical properties at the surface.

Treatment of polyethylene surfaces

The introduction of more polar groups, such as hydroxyl or carbonyl groups, on the polyethylene or polypropylene surface will raise the surface energy of a substrate. This requires surface treatments usually involving surface oxidation, such as by propane torches, corona discharge techniques or acid etching. Figure 4, from the work of Rauhut⁽¹⁾, shows that flame treatment and chromic acid etching can raise the surface energy of polyethylene to about 40 mJ/m². At the same time, a significant improvement in adhesion is achieved. In addition, such process will remove contaminants and weak boundary layers. However, it should be noted that such surface modification may be complex, will typically add to time spent and cost and may have environmental or health and safety issues. Furthermore, excessive treatment can reduce adhesion if a weakly adherent surface layer is formed.

The main surface treatments are:

- Corona discharge or plasma treatment is achieved by applying a high voltage of 5 to 50 kV which oxidises the surface. An 'active' gas such as oxygen or inert gas such as nitrogen may flood the gap between the electrode and plastic surface. UV radiation along

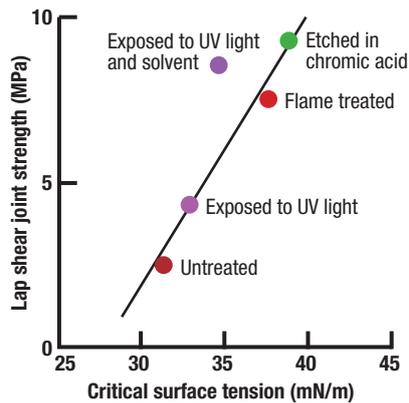


Figure 4: Lap shear joint strength versus critical surface tension for LDPE pre-treated by various methods⁽¹⁾.

with ions, radicals and electrons generated in the corona attack the surface oxidizing it to a depth of approximately 5 nanometres within a few seconds increasing to ten times this depth with further treatment. After treatment, the surface contains numerous reactive polar species which raises the surface energy, but ablation, oxidation and cross-linking of the surface layer will also take place. UV radiation alone, as used in the work described in Figure 4, will cause similar surface modification.

- Flame treatment produces similar polar species to those created during corona discharge treatment, modifying the surface to a slightly greater depth. The process can overheat surfaces so is not used on thin film.
- Chromic acid preferentially etches regions of low and zero crystallinity of the plastic simultaneously oxidizing and etching the surface. It is much slower than corona discharge or flame treatments but creates much better mechanical keying as root-like cavities may form in the surface.

Is the significant improvement in adhesion due to the approximately 10 mJ/m² increase in surface energy? A quick back-of-the-envelope calculation shows that this is nonsense. Surface energy of 10 mJ/m² is equivalent to 0.01 N/m surface tension, or a gravity load of about 1 gram (~0.01 Newton) removing a one metre wide strip of the material. This is far less than the force required to remove a sticky *Post-It* note! Yet the actual joint strength has increased many times with the flame or chemical treatment. So this improvement in joint strength is not due to the small increase in surface energy from surface modification from the chemical or other treatments; but rather from some other factor. In fact, what is happening is that the treatment opens up the crystalline surface of the polyethylene making it more amenable to intermingling and entanglement of the polymer chains of the adhesive. The more the chains are intermingled, the harder it is to pull them apart. However, if opened up too much, the rough surface can reduce adhesion. Also, time can cause crystallinity to heal itself and the adhesion of a treated surface can drop away over time. The

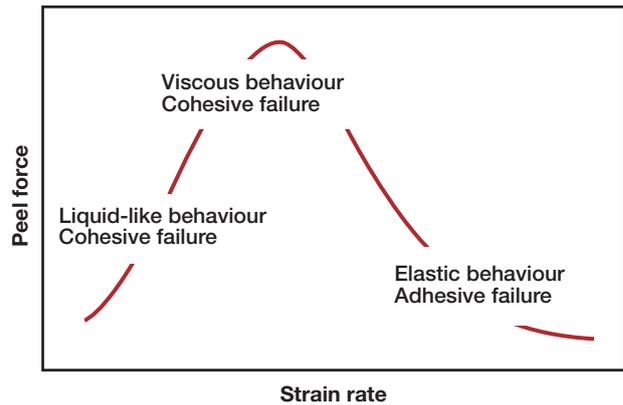


Figure 5: Relationship between peel force and viscoelastic properties.

increase in surface energy does assist initial wettability, but it does not cause the increase in adhesion. Improvements in wettability and bonding arise from complex topography rather than polar groups introduced by surface oxidation⁽²⁾.

Coatings for low energy surfaces

Because of the difficulty in wetting, alternative coatings are required if good adhesion to polyethylene or other low energy surfaces is required, such as a field joint coating for a polyolefin mainline coating. AS 4822⁽³⁾ Appendix K recommends cold applied polymeric tapes and heat shrink sleeves field joint coatings for polyethylene mainline coatings. Polymeric tapes and heat shrink sleeves are examples of pressure sensitive adhesives, and the adhesion mechanism is more complex than simple wetting of the surface.

Pressure sensitive adhesives (PSAs) have a backing film with a special adhesive that can bond to a variety of surfaces. The adhesive strength can range from easily removable *Post-It* notes to high-strength, high adhesion, corrosion protection tapes and sleeves. They can adhere with relatively light pressure, the adhesives remain permanently tacky at room temperature and the materials are elastic enough to be handled by hand. There is a fine balance between the adhesive flow, which is just sufficient to flow into surface crevices, and cohesion of the adhesive which resists flow. Another advantage of pressure sensitive tapes is that the bond is immediate so there are no clamps required or cure time. PSAs will usually have operating temperature limitations and, by remaining soft, may have limited resistance to shear forces. Unlike many PSAs, corrosion protection tapes and sleeves are required to be permanent.

PSAs usually bond to surfaces through dispersion (van der Waal's bonds). Pressure-sensitive adhesives are unique among adhesives in that they do not cure or undergo a chemical or physical change during the bonding process. The adhesive material when the tape is applied is identical in properties to that there when the tape is doing



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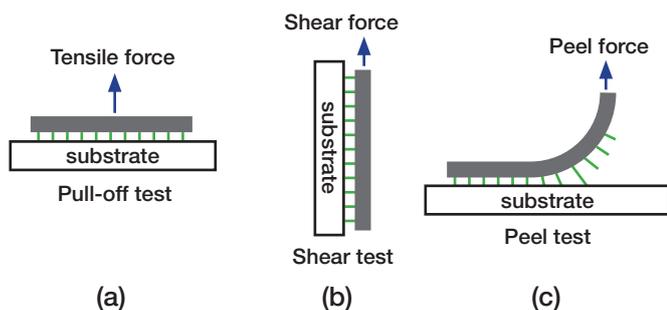


Figure 6: Three common test types for measuring adhesion: pull-off, shear and peel.

its job or when it is being peeled off. An epoxy, on the other hand, is liquid when applied but solidifies to resist deformation in service. PSAs are examples of viscoelastic materials that show liquid-like behaviour for bond formation along with solid-like behaviour to resist debonding. When the adhesive is applied to the substrate and pressure is applied, it makes immediate contact for initial adhesion as it acts as a viscous liquid but because of the elasticity, resists separation when stressed like a solid.

In theory, PSAs must meet the same requirements regarding contact angle and surface energy so they can wet the substrate and they will stick better to higher energy substrates such as metals or PVC than low energy surfaces. But there is a lot more than just getting the surface energy right. Pressure sensitive adhesives make use of their unique viscoelastic nature of the adhesive to wet the surface so it is their low modulus rather than viscosity which promotes wetting. Figure 5 shows how adhesion and cohesion properties change with peel speed (strain rate). At very low peel speeds, the adhesive acts like a liquid and very low peel strength is measured. However, as the peel rate increases, the adhesive becomes more viscous and the forces are now used up in pulling the adhesive apart. The adhesive fails in a cohesive manner and the required peel force increases. At very high strain rates, the adhesive acts largely as a glassy solid and easily fractures, resulting in much easier removal.

The mechanism of PSA adhesion is different from other adhesion combinations. In many PSAs, it is interaction between the molecule

chains some small distance from the surface that provides the strength, not the adhesion of the chains to the surface. The important fact is that they remain liquid at the interface. Even if the surface energy of the adhesive is much greater than the substrate, the backing tape will cause the adhesive to wet out the substrate by eliminating the air at the air/adhesive interface⁽⁴⁾.

Roughening the substrate can reduce adhesion with PSAs. The high viscosity of the adhesive does not get a chance to fill the surface features on the substrate of a roughened surface. As a result, there can be built-in defects which can initiate failure. The surface must be clean and free from dust, oil and moisture, but roughness can have a negative effect.

Measuring adhesion of coatings

There are many methods for measuring the “adhesion” of a coating with for example, a recent draft standard ISO/TR 19402⁽⁵⁾ listing 44 different methods. These are often adapted from test methods for adhesives, and can be divided into three main techniques, as shown schematically in Figure 6, with tensile, shear or peel loading operating. The different approaches will give widely varying results for many reasons. Firstly, each method applies a load on the coating in different directions and the loading direction will usually vary over the area of the testing sample. It is difficult if not impossible to generate stresses only in the desired direction, and actual forces are usually some combination of tensile, compression and shear. Further, the rapid loading rates inherent in the equipment and methods used will amplify the measured failure strength compared to that achieved under normal viscoelastic processes in polymers. Also, equipment or methods that apply an uneven manual load will produce lower readings than consistent, automatic equipment.

The basic features of the three test types are described below:

- Pull-off or tensile stress is created when a load is applied perpendicular to the surface. Although this is the major component of most test methods used for measuring adhesion of coatings, such forces are rare on a coating in service. A major problem is that if the load is applied slightly off-axis, then stress direction changes to peel, and failure mechanism and force changes. This seemingly simple test can yield widely diverse results depending on the apparatus and methodology used.
- Shear stresses operate when a force is applied parallel to the coating surface. Such stresses would be applied to a coating when, for example, the substrate expands and contracts at a different rate to the coating such as from temperature changes. This property is difficult to test on most coatings, although methods are available to assess such stresses in tapes and sleeves (for example AS 4822 Appendix H) as shear is an important stress imposed by movement of pipelines underground.
- Peel loads concentrate all the stress at the interface where the coating pulls from the surface. But stress distribution is very complex and there is in fact a compression zone just ahead of the peel front causing local changes to the adhesive. Excessive extension of the backing can contribute to failure at the adhesive/substrate interface. So factors such as the modulus and strength of the backing and thickness and strength of adhesive are more important than interfacial adhesion. Furthermore, values are in terms of force per unit length, which cannot be compared with

About the author

Rob Francis has over 40 years’ academic, industrial and consulting experience in corrosion and protective coatings. Dr Francis has a B.Sc. in metallurgy and a Ph.D. in corrosion science. He has authored or co-authored over forty technical papers or presentations on corrosion and coatings. He edited the publication “Inorganic Zinc Coatings”, for the ACA in 2013. He has been awarded the JPCL editor’s award twice and was made a JPCL Top Thinker in 2012. He was awarded the Victor Nightingall award for outstanding contributions to the protective coating industry by the ACA in 2014 and made an ACA Life Member in 2016.



results from tensile or shear values which are determined in terms of force per unit area. Although it does not represent conditions that a coating may experience in-service, the peel test has been found to provide a reasonable indication of how well a coating has been applied by determining how well it is bonded to the substrate.

These basic principles underlie numerous test methods ranging from simple qualitative picking at coating with a sharp knife, through to measuring the pull-off strength using sophisticated tensile testing equipment. Part 2 of this paper looks closely at pull-off testing along with an examination of the method, results obtained and how they may be interpreted.

Practical adhesion values measured for coatings are almost always orders of magnitude greater than thermodynamic work of adhesion as determined by wetting experiments. The measured adhesion strength will be influenced by many factors independent of forces at the coating/ substrate interface including elastic, viscoelastic and plastic deformation which occurs during testing and energy involved in molecular bond breaking. There will be relaxation of the internal stress which will always decrease the inherent adhesion strength. These stresses are usually many times the adhesion from molecular interactions between the film and the substrate. So measured adhesion strength depends on the chemical and physical properties of the coating and substrate, the loading rate, temperature, joint geometry and many other factors. The measuring technique can also introduce factors which results in values obtained by various methods being not directly comparable.

Adhesion testing methods do not, in fact, measure the actual adhesion of a coating to a substrate or another coating, and the results from the various methods cannot be compared with one another. There are other problems relating such testing to coating performance:

- The coating is subject to very high stress and strain levels during testing which it would rarely see in practice. In service, coatings have been observed to delaminate under much lower stress levels than measured values.
- As discussed, rapid loading during testing results in a different failure mechanism and value from that which would be observed with slow testing. In service, loading rates on coatings are likely to be very slow.
- The coating under test will be a very small sample compared to coating applied in practice and variations in properties such as thickness, defects and contamination will cause local stress concentrations which have a significant effect on results.
- The small sample, uneven loading, strain rate variations, viscoelastic behaviour and many other factors cause wide scatter in the data produced.
- The substrate thickness and flexibility can affect results, especially with field testing.
- The peel test only applicable to tough, flexible coatings and initiating a strip for peel testing can be difficult in coatings with strong adhesion
- In pull-off testing, if load is even slightly off centre, results will be completely different from results with normal loading. In addition, the type of glue can influence results.

Results from adhesion tests should not be used to explain any fundamental property of a coating system, but methods can be

used to monitor changes in adhesion due to weathering, surface treatments, application variables, etc.

Conclusions

- a) Adhesion of coatings to substrates can generally be explained in terms of surface energy differences. Epoxies for example have lower surface energy than metallic substrates so easily wet and adhere to these surfaces. However, polyethylene has a low surface energy and epoxies will not wet such surfaces.
- b) Roughening the surface improves wetting of high energy surfaces but has a detrimental effect on low energy surfaces.
- c) Low energy surfaces can be treated to improve adhesion of coatings, but the improvement in adhesion is due to opening up the surface allowing molecular intermingling rather than the small improvement in surface energy.
- d) Tapes and shrink sleeves adhere to low energy surfaces due to their high viscosity, by remaining liquid and their viscoelastic properties.
- e) There are many methods for measuring coating “adhesion”, but they do not in fact measure interfacial adhesion. Such tests apply complex stresses and cannot be used to explain fundamental adhesion properties of coatings.

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The Editor wishes to thank Rob Francis for this article.



NACE International Expert Roundtable

Predicting corrosion control developments of the future

By Gretchen Jacobson, MP Managing Editor

Back in 1943, NACE International was established in Houston, Texas by 11 engineers focused on cathodic protection (CP) to address metal pipeline degradation. Now 36 000+ members strong, NACE has evolved into a worldwide organization that is involved in every industry and area of corrosion prevention and control. In 2018, NACE celebrated its 75th anniversary, a milestone made possible by the knowledge, expertise, and continued support of its members from around the globe. In this article, six panelists share their predictions on where the corrosion industry is going in the next 25 years and beyond. They are Nick Birbilis, College of Engineering and Computer Science, Australian National University; Rick Eckert, DNV GL; Fred Goodwin, BASF; John R. Scully, Materials Science and Engineering, University of Virginia, and *CORROSION* technical editor-in-chief; Neil G. Thompson, DNV GL, and Jack Tinnea, *MP* technical editor.

Nick Birbilis

When considering the important future developments in the industry of corrosion control, the prospects are as complex as they are plentiful. Identifying such prospects requires one to zoom out a little from the technological question (i.e., what will the future of corrosion control resemble?), and consider the key factors or indicators that can be rationally identified as significant in influencing what the future of corrosion control. Such factors include, but are not limited to the following.

Legislation

Undoubtedly the unpredictability of politics is something we are constantly reminded of. In many cases, the most (financially and socially) significant decisions when it comes to corrosion control are often placed in the hands of lawmakers. Two significant examples include the phasing out and imminent replacement of chromate containing corrosion preventative compounds,¹ and the long-term disposal plans for nuclear waste. In the case of chromate replacement, some nations and industries are somewhat more advanced than others; however, it is fair to say that no equivalent (and broadly applicable) alternatives have been found to date – such

that the corrosion protection regimes we will see for everything from galvanized garden sheds to the next commercial jetliner are yet to be determined (let alone their long-term durability). The issue of nuclear waste storage varies from nation to nation for countries with nuclear power generation; however, the world is watching for a long-term strategy in the United States, which is yet to be determined following the shelving of the Obama-era Yucca Mountain Repository project.

New alloys / materials

The development of new materials is now occurring at a pace greater than ever before. In part, computation has allowed materials design to evolve from what was historically plant trials to documented demonstrations of desktop alloy design with industrial utility.² Alloy development has come so far since the second world war that a catchphrase of the automotive industry is “nearly all the alloys used in an automobile are different each 10 years” – meaning that materials we seek to protect are also always evolving. In fact, even in what is considered a very conservative industry – the aircraft industry – the change in the dominant structural alloy of commercial aircraft has also seen an active evolution from the aluminium alloys

AA7022, to AA7079, to AA7075, to AA7050, to AA7150, to AA2050 – all in the past five decades alone. This latter example relating to the evolution of aircraft alloys is an example of changing the alloy used in order to improve durability (i.e., a decision based on corrosion protection, albeit corrosion resistance inherent to the alloy). In such a vein, the design of corrosion-resistant alloys is an area of active research.

A “hot-topic” at the moment, is so-called compositionally complex alloys (a subset of which are often termed high-entropy alloys) that have demonstrated exceptional corrosion resistance in aqueous and atmospheric conditions.³ Such alloys are not yet optimized in terms of a complete property portfolio for engineering applications, but there is no doubt that future corrosion protection will be dealing with (i) new materials that are presently under development, and (ii) materials with inherent corrosion resistance being designed to be more durable – and not necessitating “traditional” corrosion control. I could add many more examples, but we can look no further from the present rapid uptake of additive manufacturing to produce net-shape components, from a range of new (and old) alloys, with



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Figure 1. Mixed materials “body in white” for Chevrolet Malibu and Cadillac CT6. Image courtesy of General Motors and from reference 4. Reproduced under a Creative Commons Attribution 4.0 International License.

disabilities that are only presently under study.

Complex systems

The great unknown is the evolution of complex systems. If we went back 15 years (or less), most of us were not carrying around a laptop, let alone a smartphone. Yet now, the pervasive nature of new technology sees us all carrying items that are being used in a manner (and environments) for which such materials have not previously been used. In other words, as technologies evolve (in general), its very likely we will see more drones, more driverless cars, and then a transition to perhaps flying cars... I paint this picture to emphasize that a flying car would obviously need to be light, and have a unique (cost effective) propulsion system, as we can't all afford a superalloy gas turbine. As such, we don't know precisely what we will be dealing with, but one certainty is that there will be many new materials and technology interruptions, and all will have ramifications in terms of corrosion control.

In regards to complex systems, there are numerous ones that are also presenting the extremes of our capabilities in corrosion protection. For example, the sequestration and transportation of supercritical carbon dioxide (CO₂) (in the carbon capture and storage cycle) remains a significant challenge in the case of contaminated CO₂; whilst the renewable energy sector (which is not only coming but will be dominant in the next 25 years by all projections) presents durability unknowns in everything from solar thermal generation, to proposed grid storage solutions.

Finally, I will also provide one example that combines both issues of legislation and complex systems, highlighting the complexity of future corrosion control. In

most nations, the United States being no exception, automotive emission policy (of which the state of California has amongst the world's strictest targets), means that lightweight material systems are now being integrated into automobiles. A recent study (2018) by Liu and co-workers⁴ of General Motors reveals the extreme complexity of a contemporary mass-market automotive “body in white” (Figure 1), indicating that the durability of an automobile relies on the durability of a multi-material system

– with widely varying material types (and electrochemical personalities!).

In summary, one thing that we should always remember, especially all of us corrosion engineers (aka, “rust busters”) is that engineering materials are all “anthropogenic” – in other words, man-made. As a result, their properties, good or bad, are our doing. Consequently, we have the ability to create materials with durability in mind, and an increasing responsibility to do so on the basis



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of the planet's finite resources. In the future, for corrosion control, we need to be smarter! We also need to learn more from the past, and also be more proactive in education. One alarming point that was raised from the most recent of the rotating national surveys on the cost of corrosion (the latest being recently published from a meticulous national survey in China,⁵ is that the percent GDP cost of corrosion is not dropping...this can only mean that society is not learning, or society is willing to make errors in judgment. Assuming it is not the latter, there is an increasing and even more significant role for NACE International in the future of corrosion control.

Rick Eckert

Microbiologically influenced corrosion (MIC) impacts many different assets and industries, and yet it is a corrosion process that is still not completely understood – despite the current advances being made in the field of genomics. MIC is typically found to be associated with diverse functional types and genera of microorganisms that develop into biofilms, forming syntrophic or complementary metabolic relationships that enhance microbial growth and activity. The spatial and metabolic relationships between the different members of the biofilm community and the electrochemical process of corrosion are still being investigated. Application of molecular microbiological methods (MMM) in the oil and gas industry has led to a greater understanding of the diversity of bacteria and archaea (and fungi) that exist in production and storage wells, piping, process plants, and tanks; however, characterizing a multitude of different microorganisms has not always been helpful to asset operators who simply want to know how to mitigate MIC. Industry wants a straightforward diagnostic test for MIC that provides actionable results.

Genomic methods fall into different “omics” scientific disciplines, including:

- Metagenomics – the study of genetic material (DNA) from entire microbiological communities in a given environment to understand diversity and function
- Proteomics – the study of proteins as a measure of gene expression and cellular activities and functions
- Metabolomics – the comprehensive study of chemical metabolites produced by microbiological communities to help characterize their activities

Each of these “omics” produces information that needs to be translated and integrated with other information about the chemical environment and physical conditions in which the collective of microorganisms live, to understand who is there and what they are doing, particularly in relation to corrosion. Since to date there has been no singular data element found that is diagnostic for MIC, a successful future test method would likely need to integrate numerous chemical and microbiological factors using a model and some form of machine learning, based on a large and reliable data set. From such a future model and data set, relationships between the microbiology, chemistry, materials science, and physical conditions of a given environment could be determined and the propensity for MIC positively identified.

Probabilistic modelling tools may be one way to start predicting MIC based on the information available today; in the future, these predictions would then be improved upon as machine learning approaches are developed and incorporated into the model. Thus, future technology for MIC diagnosis would have most of the necessary data built into the tool (model) so that the parameters that needed to be obtained through sampling and analysis would be few, and the technology used to perform any analysis would be contained within one device. With accurate and reliable MIC diagnosis, prevention and mitigation measures could be more effectively applied, resulting in

improved asset integrity, longevity, and sustainability.

Fred Goodwin

I work with concrete so most of my comments apply to the corrosion of reinforcing steel in concrete. Concrete is claimed to be the second most common man-made material (after potable water), with about 1 cubic yard produced for every person on the planet per year resulting in more than twice as much concrete being used than the entire quantity of steel, aluminum, glass, plastic, and wood. Much of this concrete is reinforced with steel to improve its tensile properties. Thermodynamically, steel is going to corrode at some point, but the high alkalinity of the concrete embedment passivates the steel from corrosion until either the pH falls below about 9, deleterious ions ingress into concrete (such as chlorides), or the electrical potential of the steel is influenced such as from stray current leakage. Corrosion of reinforcing steel in concrete is considered to be the primary cause of concrete deterioration. Two universal rules of concrete construction are that concrete cracks and steel rusts.

Increased use of monitoring technology

As technology improves and infrastructure deteriorates, monitoring of factors related to corrosion will increase. The objective of monitoring should change from monitoring of the initiation time of corrosion or the rate of corrosion propagation to indications of when preventative maintenance should occur. In other words, monitoring will be used to indicate when protective actions should occur for the greatest effect on the life cycle cost of the structure. Monitoring systems will evolve to be durable for the long life of concrete and be wirelessly connected without requiring external power (such as through radio frequency identification [RFID] technology) and to also be less consuming of power as battery technology improves.



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Increased usage of robotic inspection

Investigation of corrosion is time consuming and often involves difficult location access which is costly and potentially hazardous. Drones are already in common use for improved visual inspection as they can locate a camera in areas that would otherwise only be accessible with scaffolding or rope work. Experimentation with drones using contact sensors is beginning where the positioning of the drone will allow contact of a probe to the concrete surface such as for crack identification, resistivity testing, or reinforcing steel location (pachometer or ground penetrating radar). Positioning and control will continue to improve an allow better and longer access, with eventual development of additional monitoring technologies such as over current protection, or even linear polarization resistance. Further development of drone technology will allow improved underwater inspection through miniaturization, perhaps small robots that can crawl to provide up-close inspections.

Preventative and proactive maintenance

It has been stated that the most successful concrete repair is the one that is never done. Studies of concrete repairs indicate that the durability of the repairs is usually less than the durability of the remaining structure. This is caused by dissimilarities of the repair material to the host concrete (such as restrained shrinkage occurring in the fresh repair material bonded to concrete that has long ago stopped shrinking, resulting in cracking and disbondment), failure to address the repair holistically (repairing only locally visible damage rather than addressing the causes of deterioration in the entire structure), and deferring repairs until corrosion damage becomes visible. When one purchases an automobile, it comes with a manual that includes scheduled maintenance to extend the vehicle service life. If one ignores changing the oil, then in a few years one will replace the engine.

On the other hand, if one were to change the oil every 1 000 miles (1 609km), the service life will be greatly extended but the maintenance cost will also be quite high. For a concrete structure a maintenance plan needs to be developed and implemented to determine the “sweet spot” for concrete maintenance to maximize the service life and minimize the maintenance cost, just like the car service manual does for the vehicle owner. Since each structure is different, the maintenance plan will need to be customized and the inherent value of the plan communicated to the owner.

Service life analysis, life cycle costing, and asset management

ACI 365.1R⁶ describes three types of service life: Technical, Functional, and Economic. Technical service life is the time in service until a defined unacceptable state is reached, such as spalling of concrete, unacceptable safety level, or failure of elements. Examples of the technical end of service life include (a) structural safety is unacceptable due to material degradation or exceeding the design load-carrying capacity, (b) severe material degradation, such as extensive corrosion of steel reinforcement, and (c) excessive deflection under service load due to decreased stiffness.

Functional service life is the time in service until the structure no longer fulfills the functional requirements or becomes obsolete due to change in functional requirements. Examples include (a) the need for increased clearance, higher axle and wheel loads, or road widening, (b) aesthetics become unacceptable – for example, excessive corrosion staining, and (c) functional capacity of the structure is no longer sufficient – for example, a football stadium with insufficient seating capacity.

Economic service life is the time in service until replacement of the structure or part of it is more economical than keeping it in

service. Examples include (a) maintenance requirements exceed available resource limits, and (b) replacement to improve economic opportunities – for example, replacing an existing parking garage with a larger one due to increased demand.

If one is considering the service life of a concrete sidewalk, it is replaced when it becomes aesthetically unpleasing, uneven, or sufficiently rough to become a tripping hazard. If one is considering the service life of a concrete nuclear reactor containment vessel, the considerations for service life optimization become much more critical. Designing the concrete structures for optimum service life involve many factors such as the concrete quality, the service environment, the attention to detailing, and the protective systems employed. Consideration of the tradeoffs between initial cost, inspection, monitoring, maintenance, downtime, and decommissioning over the service life of the structure is one description of life cycle costing where having a higher initial cost with lower maintenance costs is compared to other alternatives. Asset management is consideration of the life cycle costs of the components of a system such as treatment and distribution of a municipal water system including the intake of raw water, treatment to make it potable, delivery to points of usage, and treatment of the waste water, all of which include many individual components of machinery, pipelines, etc. Service life analysis, life cycle costing, and asset management will continue to expand in complexity and usage to address corrosion-related issues.

Maintenance incorporated into BIM

Building Information Modelling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of construction and is rapidly being accepted as a tool for construction design, scheduling, procurement, and management. In BIM a



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three-dimensional model is developed of the structure and construction sequence overlaid to avoid time conflicts (a fourth dimension) and optimize costs (a fifth dimension). BIM also covers spatial relationships, light analysis, geographic information, and the quantities and properties of building components (for example, manufacturers' details). A logical extension of BIM is to also include the asset management and deconstruction of the structure throughout the building's service life. Combining all these properties into a model reduction of corrosion issues is a natural consequence such as through improved detailing, better water management, and service life modeling.

Increased use of alternatives to steel concrete reinforcement

The simple answer to addressing reinforcement corrosion issues in concrete is to replace steel with a less or noncorroding material. While alternative reinforcement is already available in the forms of stainless steel, galvanized steel, fiber reinforced polymer (FRP), or epoxy coated reinforcement, the cost is often much greater, the development of the reinforcement (load transfer) is different, or defects in the epoxy coating can accelerate corrosion propagation. Many technical advancements are ongoing with the use of synthetic fibers to create ductility in concrete by balancing the fiber elongation, bond, and tensile strength to that of the concrete binder commonly referred to as ECC (Engineered Cementitious Composite). With the proper balance of material properties, many very fine cracks occur that are held tightly together by the embedded fibers, resulting in an isotropic composite material. Many treatments are available for fine cracks such as elastomeric coatings, membranes, and hydrophobic sealers that can minimize the ingress of deleterious materials into the cracks. In addition, polymeric fibers can improve the fire resistance of concrete by

melting to form escape channels for trapped water as it turns into steam. Conventional concrete is pretty good compared to other building materials at surviving floods, fires, hurricanes, tornados, tsunamis, and other natural disasters, except for earthquakes. ECC can greatly improve the survivability of concrete in seismic events due to the ductility and crack stitching effects of the specialized fibers. Concrete develops its physical properties over long time periods as cement hydration occurs, so another evolution of ECC will be balancing of the fiber properties to the concrete properties as the concrete matures (such as control of plastic and drying shrinkage). The advent of 3D printing with concrete will also likely require fibers, but if conventional reinforcing steel is used the consistency and quality of placement can be greatly enhanced through robotic placement thereby reducing the corrosion risk.

New corrosion inhibitors

Corrosion inhibiting admixtures are added to concrete to increase the stability of the passivating layer on the reinforcing steel formed by the alkalinity of concrete. Current technologies include nitrites, amino alcohols, amine esters, and amine carboxylates and have been commercially available for several years. The development of concrete admixtures is a mixture of both art and science as many factors must be balanced to produce the required performance of the concrete. Research continues to develop new technologies and materials to reduce corrosion of reinforcing steel.

Geopolymer embedment of ICCP anodes in concrete to address acidification

Cathodic protection (CP) is the only rehabilitation technique that has been proven to stop corrosion in salt-contaminated bridge decks regardless of the chloride content of the concrete according to the U.S. FHWA (Federal Highway Administration). Impressed current CP (ICCP)

has been successfully used for many years to address corrosion issues in reinforced concrete but suffers from the deterioration of anode embedment materials due to the acid formed during operation of the system. Geopolymer materials are alternative inorganic binders that are resistant to acids and can have the appropriate physical characteristics for durability in concrete and tailored to the proper resistivity for satisfactory current distribution in ICCP. Research continues to develop appropriate formulations for this application.

New and existing infrastructure

The American Society of Civil Engineers Report Card estimates a U.S.\$4.6 trillion investment is required over the next 10 years just to return our infrastructure to the quality it was in 1988, with a predicted U.S.\$2.1 trillion funding gap compared to the estimated funding. In 1990, it was estimated that between U.S.\$1 and U.S.\$3 trillion is required to rehabilitate all the reinforced concrete structures suffering from distress. It is unlikely that this situation is improving. More than two miles (3.2km) out of every five miles (8km) of America's urban interstates are congested. Traffic delays cost the country U.S.\$160 billion in wasted time and fuel in 2014. One out of every five miles of highway pavement is in poor condition and our roads have a significant and increasing backlog of rehabilitation needs. Almost 40% of our bridges are 50 years or older, with 56 007 rated as structurally deficient in 2016, averaging 188 million trips across a structurally deficient bridge each day. The average age of the 90 580 dams in the country is 56 years with the number of high-hazard potential dams climbing to nearly 15 500 in 2016, with deficient high-hazard potential dams estimated at 2 170. Nearly 240 million Americans rely on the nation's 14 748 treatment plants for wastewater sanitation, yet the Environmental Protection Agency (EPA) estimates that at least 23 000 to 75 000 sanitary sewer overflow events occur



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in the United States each year from the 800 000 miles (1.3 million km) of public sewers and 500 000 miles (0.8 million km) of private lateral sewers. There are an estimated 240 000 water main breaks per year in the United States, wasting over two trillion gallons (7.6 trillion liters) of treated drinking water according to the ASCE Report Card 2017.

Not only is our existing infrastructure in deteriorating condition, but the need for new infrastructure continues to grow both for developed and developing countries. In developed nations, reduction of traffic congestion, faster transportation networks, and the achievement of larger aspirations drive demand. In developing countries, as the standard of living improves so does the need for infrastructure. Since such a large quantity of infrastructure is constructed from concrete that is reinforced with conventional steel, corrosion will continue to be an issue. The existing infrastructure components such as bridges, buildings, airports, dams, piers, canals, etc. continue to deteriorate, requiring either replacement or more frequent and expensive repairs. Concrete construction and maintenance are growth areas with corrosion of reinforcement the primary driver of much of this growth.

John R. Scully

When thinking about the future of corrosion control technologies deployed by industry over the next 25 years and beyond, we should think about both new innovative developments on the horizon and also the state of maturity of existing corrosion control technologies that continue to evolve and become more sophisticated.

The stages of maturity mark the progress of existing corrosion control strategies. In my opinion, every strategy has a conceptual or notional phase, a proof-of-concept stage, and a qualitative implementation stage where the evolution of knowledge leads to the identification of certain metrics and target parameters that define the threshold for adequate control of a certain form of corrosion. At this point there is often a data-rich, computational implementation stage that becomes very quantified. The first stage is a point in development where the idea of the technology becomes widely accepted but it is still somewhat conceptual. For instance, in the evolution of CP as a corrosion control method, the concept became widely accepted that an

actively corroding metal could be polarized to potentials equal to or more negative than its reversible electrode potential for metal dissolution and thereby achieve thermodynamic immunity. Or alternatively, cathodic polarization could be achieved to a potential between the freely corroding potential and the reversible electrode (Nernst) potential for metal dissolution and that condition could substantially lower the corrosion rate by slowing corrosion kinetics.

In the first stage there was the “concept.” The next stage was adaption of several highly useful quantitative criteria or specific “metrics” that concisely define successful control. Examples include the 100 mV instant off potential, and the protection potential criterion of -850 mV vs. copper/copper sulfate (Cu/CuSO₄) electrode as well as other semi-quantitative “rules of thumb.” These metrics have become standardized and widely accepted. However, this stage was just one level of sophistication on the rung of progress. That is because such a criterion could not be achieved spatially across an entire cathodically protected structure at all locations – verification of the CP threshold level was only achieved at first at a few spots on the structure. In stage three, enough was known about the theory of CP and the metrics for success that this knowledge could be combined with growing computational capabilities to map the potential distribution across the entire structure. Computer generated finite element potential and current distributions are now fairly routine and can examine the spatial dependency of CP. Distributed remote sensors (i.e., reference electrodes) can monitor the potential at many locations. The potential distribution on a pipeline can now be explored in detail to assess CP levels.

A similar “set of stages” can be used to describe other corrosion control strategies such as coatings, safe limits for high-strength materials given the threat of hydrogen embrittlement in harsh environments, and choice of a corrosion-resistant alloy. Concepts lead to simple metrics. Simple metrics are now being replaced with more sophisticated models and tools. Stages of maturity define the current progress in most if not all corrosion control strategies.

What is next? There are many promising new corrosion control strategies yet to emerge. One benefits from the coming age of cyber physical systems. Here corrosion

control will likely follow along the lines of the “smart cities internet of things” concept where many varieties of distributed sensors will in real time interrogate the corrosion “state of health” of a structure or system and algorithms or digital tools will make decisions either automatically or with owner inputs. In the future, many of the sensors needed will be powered by the nearby environment, harvesting energy from their surroundings without connection to the grid. The cyber physical world is here to stay and will likely expand into corrosion. These strategies will create enormous amounts of data. It is said that 90% of the world’s data has been generated in the last two years. This data collected is rich in information but too large to manage. Materials informatics, data sciences, and machine learning are but a few strategies that rely on such increasingly large amounts of data such as those generated from all those sensors. Data sciences approaches will be necessary to understand how to handle and interpret all that information but could establish relationships and trends impossible to see otherwise that could aid corrosion control. Such relationships might not be detected using conventional approaches. Data sciences approaches may also reveal relationships between environmental or material factors and corrosion that might not be discovered by conventional means.

All these possibilities and more point toward a bright and exciting future in the corrosion control industry.

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Neil G. Thompson

In the 2017 Frank Newman Speller Award lecture, Narasi Sridhar described knowledge-based predictive analytics. I believe that knowledge-based analytics will make the largest difference in how we approach corrosion management. I am not referring to simple data trending, or data-centric correlative analysis (as Dr. Sridhar describes it), but combining correlative analysis with predictive modeling. These models can be empirical/semi-empirical models based on available data, expert-knowledge base models, or they can be mechanistic models based on scientific principles. Today, we are most successful using models to predict within a given variable space represented by the data. Predicting outside this variable space is very difficult.

As knowledge-based analytics continues to grow along with the analytical capabilities of data processing, the ability to combine data, empirical models, expert models, mechanistic models, and machine learning principles will allow for improved corrosion prediction in both variable space and time. Understanding the uncertainty associated with corrosion predictions will allow the engineer/operator to better understand how to utilize the information and when additional data may be required to decrease the uncertainty, if necessary. Moving toward the ability to provide near real time predictions will be critical to meeting expectations of operators and, in many cases, the public. For example, there is now almost zero tolerance for failures of any kind on energy pipelines. Environmentalists and the general public use these failures as justification to oppose new pipelines or shut down existing pipelines. I think our business as usual approach to corrosion control as well as integrity assessments will require significant changes and updating. The predictive capability of knowledge-based analytics, modeling, and machine learning tied to integrity assessment and near real

time risk management will form the basis for these changes and the ability to predict pipeline critical conditions before a failure happens.

Jack Tinnea

Almost 50 years ago, I was working in my first job after graduation, doing research on cement chemistry for the civil engineering department of my alma mater. At that time, the University of Illinois had a Materials Engineering Group that included folks from ceramic, chemical, civil, and metallurgical engineering with occasional visits by someone from the physics or chemistry departments. Today, Illinois has a Materials Science and Engineering Department that rose from the merging of previous metallurgy and ceramic engineering departments.

Materials science can offer the practicing corrosion engineer many choices in controlling corrosion. I see the materials science field much like electrochemistry was in the time of Sir Humphry Davy when the father of CP made his greatest discovery: Michael Faraday. Yes, in the 1820s when Davy and Faraday were developing CP for the British Navy, our understanding of electrochemistry had advanced from Coulomb, Galvani, Priestly, and Volta, but in terms of where we are today our use of electricity was just getting started.

Nanotechnology

Early in my career, impressed current CP (ICCP) anodes were primarily cast iron or graphite. These were soon joined by platinum-clad anodes that evolved from finding a second market place for niobium-copper cored wires that were being manufactured for use in magnetic resonance image (MRI) scanners for hospital use. These MRI wires were soon found to be excellent platforms for ICCP if the wires were coated with a thin layer of platinum. In what seemed like just a few more years, mixed metal oxide (MMO) arrived. MMO anodes typically

involved using ruthenium oxide (RuO_2) or iridium oxide (IrO_2) either singly or in various combinations to coat a titanium substrate. Titanium oxide (TiO_2) has a similar rutile-type structure as RuO_2 and IrO_2 and similar ionic radii of Ti^{+4} (0.075nm), Ru^{+4} (0.076nm), and Ir^{+4} (0.077nm) that allow the development of a tertiary solid solution that arguably could be considered an early form of nanotechnology.⁷

Today, science and engineering periodicals are filled with discussions of nanotechnology.⁸⁻⁹ Our understanding of nano-scale includes not just the manufacture of new products but our understanding of corrosion itself on the nanoscale.¹⁰ On the proactive side, as we better learn how to assemble materials atom-by-atom, we will produce amazingly corrosion-resistant materials with a wide range of structural and thermal properties. Likewise, on the reactive side, it allows us to better understand why corrosion occurred in one location and not the other when on the macro-scale the two locations appear so very similar.

Corrosion engineers are familiar with anodes and cathodes, but recent advances in development in battery anodes and cathodes may lead to batteries that will easily power CP systems in remote locations with unimaginable service lives. Perhaps our grandchildren may develop a means to re-direct or capture destabilizing ions present in the environment and in the process assist with in situ repair of protective oxide layers, like those present on stainless steels.

Cross-pollinating

Cross-pollinating is another area that likely will produce advances. For example, corrosion can be a problem with guitars, particularly electric guitars. Although this is not a topic frequently addressed by NACE, perspiration from the guitar player can cause corrosion of screws securing the pick guards and even can cause corrosion of the pickups (pups). Microphones are transducers that



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convert mechanical sound waves travelling through the air into variations in an electrical signal that get sent to the amplifier and then the speakers. The pups on an electric guitar are not microphones but are magnet-based transducers known as a variable reluctance sensor. Pups detect changes in the proximity of ferrous material, namely the steel strings of the guitar, so stringing your electric guitar with nylon strings will not work well – pups are not microphones.

Pups have a permanent magnetic core that is wrapped with thousands of turns of fine enameled copper wire. The fine enamel can age and start to flake. Add to that the close proximity of alnico or ferrite magnets, and it should be obvious to a corrosion engineer that perspiration could cause corrosion issues or result in partial short-circuiting of the pickup with a loss of performance. To protect the pups, some manufacturers employ just a wrap or two of electrical tape others add an additional coat of enamel, lacquer, or epoxy to the outer face of the enameled copper wires. Still others use a mix of about 20% beeswax and 80% paraffin, melt the wax and then submerge the pup into the melted wax for 15 to 30 minutes or until the pup stops bubbling from the wax displacing air voids between with layers of the copper wire and the magnetic core. Over time, potting the pups with wax provides longer protection than the others, and problems can be easily corrected by melting the wax, whereas pups that are potted in epoxy and develop problems are typically just thrown away because removing the epoxy is likely to damage the windings.

In another area of potting and/or coating electrical components, epoxies, silicones, polyurethanes, polysulfides, and cyanoacrylates are used to protect printed circuit boards as are plasma and vapor applied coatings. Vapor phase corrosion inhibitors are also used.

Remote monitoring of major infrastructure elements often requires sensors to be embedded in concrete for as much as 80 years or more. To date, the published literature includes more than a few discussions of such embedded sensors failing in much less than that time interval.¹¹⁻¹³ Achieving highly reliable embeddable sensors to fit the demands placed by 100-year infrastructure service lives might be facilitated through cross-pollinating. Perhaps by treating first with a vapor phase inhibitor, followed by potting with a material that provides good wetting characteristics to give excellent penetration, and that followed by a hydrophobic and/or alkaline-resistant coating would do the trick.

Conclusion

I believe that we are just at the start of an era of tremendous advances in our understanding of materials science. The next quarter century will bring not only amazing advances in materials themselves but in miniaturization that will greatly extend our ability to monitor and understand. Not all the real “wow” moments in technical advancement are in the past. There are infinite possibilities for similar breakthroughs for generations to come.

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From the KETTLE

The role specifiers and end-users have in selecting a corrosion control coating, suggests that all aspects of a hot dip galvanized coating be highlighted and if necessarily de-mystified. The intension of this series of surface conditions is to ensure that the customer or specifier has a greater understanding of the coating so that it is not necessarily rejected or accepted for the wrong reasons, resulting in wasted time for all personnel. See F20A and F29.

Legend	
A	Accept R Reject REP Repair
F20A	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%;"> <p>DESCRIPTION: Preventing distortion by hot dip galvanizing by way of design or fabrication techniques.</p> <p>CAUSE: When steel components are heated to the hot dip galvanizing temperature of approximately 450°C, some internal stresses can be released resulting in distortion.</p> <p>When very high internal stresses are generated in a steel structure, it is possible that the highest levels of stresses that are above the elasticity of the steel (Young's Modulus is partially reduced at the hot dip galvanizing temperature) then the steel may no longer accommodate the higher level internal stresses. Such stresses are released as plastic deformation and distortion may result.</p> <p>Double end dipping of slender components can exacerbate the problem. #1</p> <p>Refer also to the "Steel Protection Guide", Chapter 9 and "Facts about Hot Dip Galvanizing - Practical Guidelines" - "Design for hot dip galvanizing" available from HDGASA.</p> <p>EFFECT / REMEDY: By altering the shape towards a more symmetrical fabrication, including the addition of stiffeners, shortening the width or length, selecting similar material thickness in a component or allowing the thinner sections to artificially cool more slowly, etc. distortion can be reasonably controlled.</p> <p>For further information, contact the HDGASA.</p> <p>ACCEPTABLE TO SANS 121: A / R</p> <p>ACCEPTABLE FOR DUPLEX AND ARCHITECTURAL FINISH: A / R</p> </div> <div style="width: 50%;">       </div> </div>
F29	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%;"> <p>DESCRIPTION: Ungalvanized surfaces caused by entrapped air.</p> <p>CAUSE: Badly positioned or non-existent vent holes can result in air entrapment resulting in uncoated areas. Besides the uncoated area, which must now be repaired, the pre-condition can also lead to explosions in the zinc bath. See F32.</p> </div> <div style="width: 50%;">   </div> </div>

F29 continued

EFFECT / REMEDY:

Steel is hot dip galvanized at a temperature of about 450°C, the coating will take place if the steel is perfectly clean and the component is fabricated knowing that molten zinc must be able to access all surfaces. Should this not be possible, air traps will occur, leading to uncoated areas.

ACCEPTABLE TO SANS 121:

R / REP

ACCEPTABLE FOR DUPLEX AND ARCHITECTURAL FINISH:

R / REP



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NACE Corrosion & Protection of Concrete Structures and Buildings	
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Construction bolting ten years on

By R J Pietersma, CBC Fasteners (Pty) Ltd, October 2018

The use of construction bolt assemblies in terms of the new standard EN14399 has been underway for the best part of nearly ten years now. It has been a steep learning curve to say the least. This article is to share some insights to technical jargon and risks.

Are South African manufacturers geared up?

Up until the new power station builds very few construction bolts were being installed, hence there was a general lack of awareness and capability. This was on many fronts and not just bolting. Medupi and Kusile changed this and it has clearly been established that design engineers, manufacturers and construction companies had a long way to go to catch up with developments internationally and best practice standards. This includes bolting amongst a whole range of other requirements.

Experience tells, when choosing the construction bolt route, the first call is a manufacturer capability study with audit of the production processes and quality system and compliance with ISO 898-1&2 as well as with all the requirements of EN 14399 and most importantly, EN14399-2. Unfortunately in practice bolts and nut assemblies still continue to be a last minute panic purchase.

SANS 10094

SANS 10094, the standard dealing with Construction Bolting has recently been updated and approved. This standard does not recommend grade 10.9 Hot Dip Galvanized (HDG) bolts because of the risks of HE or HisCC. Nevertheless, in practise, there is still a call for this product. The risk can be controlled by the manufacturer avoiding acid contact and further controlling excessive hardness levels at the upper limit of grade 10.9. Further risks associated with undue stressing of grade 10.9 HDG bolts will be avoided if good installation practice is adopted.

EN14399-3 (grade 8.8 and 10.9) vs. EN14399-4 (grade 10.9 only)

Why a universal standard is not adopted is a puzzle. Clearly there were principles that were not negotiable which has led to two possibilities. The historical position has largely been maintained in that the EN14399-4 nut (previously DIN 6915), has a lower height. The intended reason is that the nut threads should fail first (not guaranteed) in the event of over tightening, purposefully avoiding a sudden bolt fracture, with installer safety being compromised. Usual construction practice is that one would like to see the bolt fail in the event of over tightening because one would know it had occurred, whereas with thread failure, this may not present itself immediately and a future calamity may be lurking when the right conditions prevail. In South Africa, SAISC and SANS 10094 recommends the use of EN14399-3 in grade 8.8 and 10.9. Shear through threads is allowed whereas in EN14399-4 there is a shorter thread and the shear plane is through the shank of the bolt.

Whatever the bolt and nut assembly used, once pre-loaded and subsequently removed, they cannot be re-used. The reason is that the threads may have been subject to plastic strains during tightening.

Myth of torque vs. tension

The talk is always about torque, whereas the objective is clamp, a spring condition holding surfaces together. Torque (or the torsional rotation effort) is merely the means to getting to the correct clamping force. This whole process would be simple were it not for the introduction of friction. When tightening a bolt and nut assembly, 50% of the effort is as a result of friction between the nut and washer face, 40% is in the thread contact and a mere 10% of the effort is creating the clamping force. This friction can vary. In a rusted bolt and nut (B&N), coefficient of friction it is as much as 0.35, in a un-lubricated hot dipped galvanised B&N is starts at 0.19 and increases up to 0.27 as additional torquing takes place. With molybdenum disulphide lubrication (MoS₂), coefficient of friction is between 0.10 from 0.16. So, by way of example, in the case of torquing a M20 bolt at 464 Nm with a coefficient of friction of 0.14, clamping force of 127kN is achieved; when the coefficient is 0.10, less torque of 363Nm will achieve an increased clamp load of 134kN.

This leads us to the next important point, the lubrication of nuts.

Pre lubricated nuts with molybdenum disulphide (MOS₂)

There may be a misconception since there has been so much talk and use of pre-lubricated nuts that this is a new standard requirement. Whilst we recommend pre lubricated nuts for the reason there is a tested coefficient of friction that can be relied upon, this is by no means a general requirement. EN14399 specifically makes reference to surface finish as processed, meaning lightly oiled, or as agreed between purchasers and manufacturer. Nevertheless, appropriate lubrication is required during installation, particularly with HDG bolts. In the case of no lubrication, galling will take place and in laboratory testing we have established the potential of failure due to torsional tension.

In the case of the turn of nut method of fastening in the B&N assembly with lubrication, up to 25% to 35% additional clamp can be obtained than required by the standard. Without lubrication, the likelihood of thread failure is almost 100%. All the torque value will be absorbed by the galling effect of the soft galvanised layer on the bolt and if the bolt has not started to fail due to torsional tension, the correct tension will not have been achieved and a loose bolt left in place with future potential failure consequences.

We really do recommend pre lubricated nuts that have been baked to a dry condition. The advantages; it avoids the wrong lubricant choice, the risk of attracting grit on nuts during installation due to sticky lubricant is reduced, the under or over application of lubricant



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is avoided and; of most importance, certification of the coefficient of friction is supplied, together with recommended torque values. This testing in terms of EN14399-2 also provides confirmation that the B&N assembly complies with the rigorous requirements of the standard.

Another question that has been raised, is it possible to paint over a lubricated nut? MoS2 is oiloscopic, which means it cannot tolerate detergents. So cleaning with an industrial degreaser would be the appropriate first step, then priming followed with a final overcoat. Under no circumstances should acid be used to clean.

Installation equipment

Many bolters rely on torque wrenches having been recently calibrated. One of the over looked checks that needs to be undertaken is the wrench verification. This should take place on the day the wrench will be used by testing at least 3 bolts of the diameter to be installed with that wrench on that day. The verification takes place using a static torque meter. The reason for this verification is that calibration can change if, for example, the wrench was dropped. We have observed that many installers do not verify their equipment, nor have the required equipment to undertake the verification. However if one is using the turn of nut method (TON), recommended by SAISC, verification of equipment can be avoided. Provided the markings are correctly made and the tightening process is properly supervised, TON will result in a reliably tensioned assembly.

Conclusion

Experience in the field is that there is a huge amount of poor communication between original design through the manufacturers of Bolt and Nut manufacturers and the installer tightening the final bolt. Some of examples include, a request for Nylock nuts for EN 14399 construction bolts, failing this, Clevelock nuts or a rejection of pre-lubricated nuts because the black colour gives the impression the nuts have not been HDG. Fortunately, many mistakes are covered by the tendency to “over design/deliver”; not only in bolt manufacture but also in structural design. As a result problems get caught in a normal distribution curve of an applied margin of safety and no adverse outcome takes place. Where outcomes are likely to be negative as in some of the above examples, responsible Bolt and Nut manufacturers make recommendations and institute appropriate training.

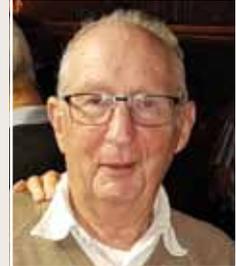
The greatest adversity has been where design engineers have not been involved in the pre-qualification of manufacturers and audit of their quality systems and have not ensured complete certification is in place based on comprehensive testing. Thereafter they have not been on site verifying compliance to their original specification (which is prescribed in regulations of the Occupation Health and Safety Act). Where all this has occurred timeously, we have seen trouble free installation. Where this was deficient, particularly in the early stage of manufacturer prequalification, adverse outcomes have often prevailed. It is emphasised, the problems have not been the fastener manufacturer but the end users poor understanding of their requirements of a design engineer. Unfortunately the B&N manufacturers have often been unfairly fingered in the process.

OBITUARIES

David Livesey-Goldblatt

26 March 1945 to 3 January 2020

David Livesey-Goldblatt during the 70’s, worked for one of the larger paint manufacturer’s in South Africa, he always assisted youngsters with paint technology and guided them through the laboratories with kind guidance and assurance.



After leaving Plascon which was situated in Luipaardsvlei, Krugersdorp, he ventured into the corrosion industry on his own to assist with quality control and processes.

David immediately established himself as a reputable, knowledgeable paint consultant giving clear and accurate technical corrosion advice to those that required it. The industry appreciated his technical ability and above all honesty which resulted in him working not only locally but also well into Africa.

While David had an extensive knowledge in decorative as well as industrial paint systems from various suppliers in South Africa, he mainly focused on the industrial side of corrosion involving painting, hot dip galvanizing, duplex coating systems and general corrosion.

David’s strength was to appease both the client and coating supplier into an equally solvable solution for both parties, using his friendly manner and confident smile.

David was an enthusiastic committee member of CorriSA in Cape Town for a number of years and always willing to share his work experiences via presentations at the technical evenings.

A quote from his son Daryl about his father David “The most undeniable thing that can be said about my dad is both deceptively simple yet overwhelmingly true... he just made the world a better place.”

David leaves his wife Dawn, son Daryl, daughter Ruth as well as grandchildren Jonah, Ryan and Emlyn.

The corrosion industry will miss him.

Juan-Carlo Bronkhorst

It is with deepest regret that we inform you of the passing of *Mr Juan-Carlo Bronkhorst*.

Juan-Carlo attended the CIP 2 course in November 2019. He leaves behind his wife, two children and a third due soon.



Sincere condolences to the family.



Acting Manager's Message

Welcome to Volume 6, Issue 1.

It gives me great pleasure to write this first report back for 2020 in our *Corrosion Exclusively* magazine.

May it continue to grow from strength to strength as a tool of communication, information sharing and news updates.

The new year, colloquially referred to as **Twenty Twenty – Twenty Plenty**, has already successfully held the first CIP1 course which commenced on 27th January and had an enrolment of 14 students. This strong start augers well for the months ahead.

Being the first quarter of the year, there are limited news items to report, suffice to say that there are

some fabulous events lined up. These include the Corrosion Awareness day, the golf day, fishing day, various other events and the monthly technical evenings.

Look out for the emails which will be sent regularly, keeping one and all in the loop so that diaries can be kept up to date.

Here's wishing that the courses and activities continue to ride a wave of prosperity.

Till issue 2, be safe and take care.

Sincerely

Linda Hinrichsen, Acting Manager



Comment – Chairman of the Cape Region

Last year was another busy year for the Corrosion Institute Cape Region. In summary we had our usual:

- Fireside chat at Emplast
- AGM combined with a new ten pin bowling evening
- Mini Expo
- Annual Gala Dinner

Other presentations and site visits included the following:

- Site visit to Gabriel Shocks hosted by Lindsay Adams – Process Engineer
- Pipeline Survey Techniques by Steve Holt, IBL Systems
- A View on The Development of the Galvanizing Industry in China (A 20 Year Journey) by Rob White
- Stainless in Low PH S Bearing Environment by Janet Cotton, One Eighty Degrees
- Asbestos in the Workplace by Rudelle van der Merwe, SafeNet (Africa), organised by Southey
- Understanding the Basics and Therefore the Appearance of Hot Dip Galvanizing. This is More than Meets the Eye by Terry Smith – winner of best speaker
- Simonstown docks site visit hosted Mr Fulufhelo Sithole

This year started with some sad news with the passing of David Goldblatt, a stalwart and legend of the industry. David was a recent member of our committee and a winner of an Honorary Life

Membership award. Our condolences to his family.

On the committee front, I would like to extend our best wishes to Thinus Grobbelaar who has stepped down due to his move to Dubai. He was an integral member of the committee and we really appreciated his contribution. All the best in Dubai Thinus!

We kicked off the year with a very interesting and informative talk entitled High Pressure Blasting – Optimising Abrasive Blasting to Achieve Greater Process Efficiency by Craig Woolhouse from Elcometer. Our plans for the rest of the year will be advised via email and included in the next edition.

If you are new in the industry or one of the stalwarts there is something for everyone at our monthly get together and we encourage you to join us. Feel free to bring a friend.

I would also like to take this opportunity of congratulating Terry Smith, the editor, in maintaining the exceptional quality of the *Corrosion Exclusively* magazine. It is really a world class voice of the Corrosion Institute of South Africa. Even in these difficult economic times, Terry has succeeded in publishing a magazine that we can all be proud of. Well done Terry!

Yours in Corrosion,

Graham Duk on behalf of Bryan Bauermeister, Dan Durler, Daryl Livesey, Flippie van Dyk, Gilbert Theron, Hilton Olivier, Indrin Naidoo, John Houston, Lucinda Blanchard, Pieter van Riet and Terry Smith



Comment – Chairman of KwaZulu Natal

KZN branch held its first technical meeting for the year (see below). The Elcometer evening was a great success with an excellent turnout of 27 people.

We elected the new committee for the year:
Karyn Albrecht: AVAX Projects (Chairperson)
Marco Ashburner: ASP Rope Access (Vice Chairman)
Wayne Sloan: Isinyithi (Events)
Cyril Captain: AVAX Projects (Additional member)
Vusi Zondi: Small Civils/VZ Coatings (Additional member).

We wish them success for the coming year.

We are planning interesting technical presentations for the year – watch this space.

Our goal for 2020 is to grow the Durban branch, but to do that we need all your assistance.

Regards, Karyn Albrecht



The new KZN committee (from left to right): Marco Ashburner (Vice Chairman), Vusi Zondi, Cyril Captain, Karyn Albrecht (Chairperson) and Wayne Sloan.

TECHNICAL EVENTS: Blasting Improvements – Craig Woolhouse

Cape Region



Gauteng Region



KwaZulu Region



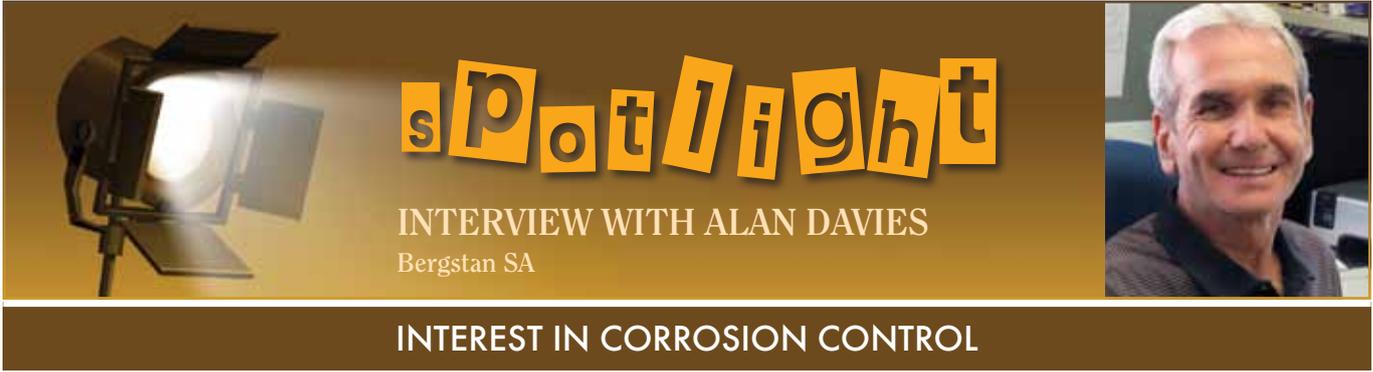
CIP1 TRAINING COURSE: January 2020, Gauteng

The year started off with 14 students that attended the CIP 1 course held in Midrand.

Thank you to our company members, Jotun Paints for supplying the paint requirements and Blastrite for hosting the practical day that was held on Thursday, 30 January 2020.

Unfortunately due to insufficient numbers, the Corrosion Engineering (JHB) course and the CIP 1 scheduled for KZN has been postponed. New dates will be available on our website, once confirmed.





INTERVIEW WITH ALAN DAVIES
Bergstan SA

INTEREST IN CORROSION CONTROL

When I finished school at Durbanville High, I had no idea of which profession I wanted to pursue.

Having always enjoyed drawing, I responded to an advertisement for an apprentice structural steel draughtsman at Dorman Long Swan Hunter in Bellville South. I was duly appointed and started working for them. I attended night classes and obtained a technical diploma whilst doing my apprenticeship. During the latter part of my apprenticeship, I decided to further my studies and applied to do an engineering degree at U.C.T.

Professor Granger was the Dean of Engineering at the time and I shall never forget his "introductory talk". He quoted the pass rate statistics and I was ready to leave right there and then when he told us that only 40% of students did the course in 4 years. The remainder do it in 5, 6, 7 and 8 years.

After obtaining my degree, I joined Clifford Harris and worked on the road construction in Namibia from Mariental to Maltahohe. After a year I left and travelled overseas for a year going through nineteen countries. It was a truly wonderful and enlightening experience. Upon returning, I joined Liebenberg & Stander (now Bergstan) in 1979 and am still there. At some stage I became an associate and subsequently a director. Presently I work in a part time capacity on a "as required" basis.

Having always been involved in steelwork, my preference "leaned" towards steel design. I seldom design concrete structures. With regards to the choice of a corrosion protection system, it depends on the environment the steel is exposed to and the



duration it's required for. I have returned to a few projects quite a while after completion but not very often. This is due to being aware of the "duration" of the system that has been specified.

One of my favourite projects was the conceptual and structural design of a hanger for a "blimp". It turned out to be an economical design and the client was pleased with the outcome both aesthetically and cost wise.

I seldom read technical magazines unless I am sourcing information on a particular issue.

I was not aware of the technical evenings hosted by CorrlSA at Kelvin Grove. Being in a "semi-retired" state at present, life has "slowed" substantially. I believe it will be good to encourage younger members of staff who have an interest in corrosion protection to attend the technical meetings.

Personally, I believe networking is beneficial to promoting better working relationships.

For me, its preferable communicating with someone you know as opposed to someone you don't know.

"Friday after work" does not apply to me being in a semi-retired state. I am a keen cyclist and still ride regularly with a group of locals. I have to date completed 28 Argus Cycle Tours.

THE INSTITUTE AND EDITOR WOULD LIKE TO ACKNOWLEDGE THE ADVERTISERS AND THANK THEM FOR THEIR SUPPORT

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The RUST Spot...



in conversation with Dave Howarth

I was educated at Parktown Boys High School, Princeton College (Johannesburg) and Witwatersrand Technical College (Design & Electrotechs.) We did not have enough funds nor did my marks warrant an education at Wits so I was destined to live on my "wits".

I had several jobs in the next few years but it was at Expandite a Castrol Company with their products for the building and Civil Industries that my career was decided. It was an early promotion to Contracts Manager that set my path as I took to the job with enthusiasm and energy and find myself still contracting with the same mind set after 55 years.

In 1975 together with Chris Ooshuizen we started Structural Applications (Pty) Limited at the time to apply and fit Denso Tapes to structures in the mining, petroleum and general corrosive environments later adding painting, sheeting and waterproofing . It was at this time with the continuous insistence from Barry Claxton that I joined the Corrosion Institute. I served as Secretary for a few years between 1977 and 1982 and gained not only contacts to promote my business but also to share the experiences and expertise of South Africa's best minds. The attitude of the industries and organisations affected by corrosive elements have much too thank those early Corrosion Institute pioneers for the strides made in protection of assets by these erudite individuals.

Changes have come about over the years, as to how I see the Institute now I must confess I am in some ways disappointed and can't be considered as a loyal follower anymore. The aspects of education in corrosion protection is important but we have a population

that requires work and the insistence on laboratory conditions on a working plant is unobtainable and development of cleaning, application and product to meet the in-situ application is where we should be headed. NACE (Not Another Corrosion Engineer) educational system are excellent , but come on guys, come and give us your knowledge as we try to protect the steelwork of the safety system for the Personnel Hoist at the bottom of a mine shaft covered in dust, grime and corrosive products in an always wet shaft. Not everyone can afford to work with high end specs to protect their assets and it is here that experienced individual Contracting companies offer practical solutions.

The Annual Meeting of the Institute used to be a get together of members of the institute and their guests from the industry. A good dinner was supplied and a Guest Speaker chosen. After the official announcements, dinner and the main speech, a large gathering of entirely corrosion involved individuals came together in pairs, small or large groups and discussed one common interest, Corrosion. Now we have invited wives and husbands who complain if we discuss business and the greatest opportunity to grow the institute fails.

Taking current factors into consideration of this near bankrupt country we live in, I still believe that there is a future for corrosion and corrosion control. More even than a lot more common sense the ruling Government needs to create new jobs particularly in the Mining and Industrial Companies and in Municipal environments country wide. Hand in hand with growth, the DMR (Destruction of Mining Resources) has to have their powers restricted, Unions must be controlled to assist in the creation jobs not harass employers with resulting retrenchments and finally replace Municipal Managers who cannot perform and replace with a competent person irrespective of colour or creed. Only when the current government

realises there is a Tunnel will they begin to see the light at the end of it.

As to me the person although almost 77, I am at the office every day as I have been for 42 years and presently excited to be involved with a new venture on which Structural Applications Projects (Pty) Limited embarked on in February 2019. This is a new Flooring Division based in Randburg but available throughout Southern Africa laying Specialised High End Floor Coatings in Polyurethane and or Epoxy to end users in the mining, Industrial, Warehousing , Food Processing, Medical and Farming complexes marketed together with Stonhard of Kempton Park.

It would be remiss of me to discuss the success of the Institute not to mention those associated with that body who helped us build and understand the field we have chosen:- Bob Andrew, Barry Claxton, Prof Paul Robinson, Walter Barnett, Eric Duligal, Eric van Marke and anyone else whom my ancient mind has forgotten.

I am married to Pamela and April this year marks our 55th anniversary, we have two children Gregory (also in structural) and Robyn and are proud grandparents to four grandchildren. We live in a retirement complex in Paulshof, Sandton which we share with a Siamese cat Coco. Pam suffered a "complication" during a gall bladder removal in July 2018 at which time she was affected by one of the "bugs" and spent the 13 weeks in hospital, 6 weeks of which were in ICU in an induced coma to give the access to team surgeons to find and remove the infection. Needless to say Pam is still weak from the experience so our travel is limited to the Kruger Park, Pilansberg and Natal North Coast.

As to my passion it is, life itself and a wish to reach the age of 95 to celebrate my youngest grandchild's 21st birthday.

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