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CORROSION
& MATERIALS

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CONCRETE FEATURE

Inside this Issue:

AUSTRALASIAN CORROSION ASSOCIATION INC.
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Corrosion & Materials

Corrosion & Materials is the official publication of The Australasian Corrosion Association Inc (ACA). Published quarterly, *Corrosion & Materials* has a distribution of 2,500 to ACA members and other interested parties. Each issue features a range of news, information, articles, profiles and peer reviewed technical papers. *Corrosion & Materials* publishes original, previously unpublished papers under the categories 'Research' and 'Professional Practice'. All papers are peer reviewed by at least two anonymous referees prior to publication and qualify for inclusion in the list which an author and his or her institution can submit for the ARC 'Excellence in Research Australia' list of recognised research publications. Please refer to the Author Guidelines at www.corrosion.com.au before you submit a paper to Tracey Winn at twinn@corrosion.com.au

ACA also welcomes short articles (technical notes, practical pieces, project profiles, etc.) between 500 – 1,500 words with high resolution photos for editorial review. Please refer to the Article Guidelines at www.corrosion.com.au before you submit a short article to Tracey Winn at twinn@corrosion.com.au

The Australasian Corrosion Association Inc

The ACA is a not-for-profit, membership Association which disseminates information on corrosion and its prevention or control by providing training, seminars, conferences, publications and other activities.

Front Cover Photo: Stock pile plinth concrete repairs at Kanowna Belle Gold Mine, 19 km north-east of Kalgoorlie.
Photo courtesy Duratec Australia Pty Ltd.

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Vol 42 No 2, May 2017

CHAIRMAN'S MESSAGE

Dean Wall
Chairman

Greetings everyone. Well, Easter Holidays have gone by with this year already a quarter down and as Chairman of the ACA Board team, we have seen some challenging times for our Association.

The Industry we all work in continues to be somewhat affected by market segment down turns in Mining and Oil & Gas and we all continue to be challenged to deliver and achieve targets. I believe that there is however some distant light at the end of the tunnel.

We at the ACA are no different, and are now investing in our future to ensure we deliver further membership benefits and training diversity as a priority. We have decided as part of delivering our Strategic Plan to employ a Sales & Business Development Manager and are pleased to welcome Ross Boucher to the ACA staff, who will support our future efforts in working with Industry and members. Ross comes to us with a wealth of experience and is keen to help roll out our business growth strategy of opportunities for the ACA and the membership to ensure we are in a good position to move forward into the future.

The ACA Board met in February and I can report that the Board team is functioning well as a group and is focused on delivering our Strategic Plan, enhancing our governance, servicing the membership and supporting our ACA staff. The Board sub-committees of Audit, Finance & Risk chaired by Chris Badger and the Governance Committee chaired by Graham Carlisle have also met regularly in overseeing the finances and governance of the Association.

As Chairman I recently had the pleasure of representing the ACA at the NACE Corrosion Conference in New Orleans in March. The ACA was an Industry Association exhibitor and I was joined by our Executive Officer Wesley Fawaz and fellow board member Brad Dockrill. We formally met with fellow Associations in NACE, SSPC and EFC along with others from around the globe. After successful meetings, we are pleased to announce that the ACA will be providing concrete training courses overseas in Pittsburgh, Prague and Kuala Lumpur this year.

It was very pleasing to see 30 plus ACA members presenting, networking and attending the NACE Conference and the subtle help promoting our upcoming ACA Conference in Sydney later this year.

During the NACE conference, we also met with outgoing NACE President Sandy Williams and incoming President Samir Edgar (from India) and discussed our Associations commitment to raising the impact and cost of corrosion to our respective governments and communities. Samir will be coming to Sydney and presenting NACE IMPACT updates to our conference delegates and how they are utilising this tool to make their Governments understand the cost of corrosion on the community.

Samir is also keen for the first ACA/NACE Cricket Challenge next year, so stay tuned for a call for recruits.

The ACA Board will meet again in late May in Sydney following our AGM on the 25 May and I look forward to updating you after these important meetings. I encourage you all to read through our Annual Report on the newly refreshed website.

In closing and on behalf the Board team, thank you for your ongoing support of our Association and I wish you every success for the remainder of 2017.

Dean Wall
Chairman

ACA 2017 Events

Part of the role of the ACA is to organise events that bring together industry experts to present on new technologies, updates to standards, and share knowledge and experiences via case studies on a variety of projects. Here are the events planned for the rest of 2017.

May

Corrosion in the Oil & Gas Industries
Tuesday 23 May | Brisbane | The Gabba

June

Pipeline Corrosion Management
Thursday 29 June | Melbourne | Rydges Melbourne

Introduction to Corrosion
Thursday 29 June | Adelaide | Crowne Plaza

July

Brian Cherry Symposium - Concrete
26-27 July | Melbourne | Marriot Melbourne

August

Introduction to Corrosion
Thursday 24 August | Perth | Seasons of Perth

Corrosion & Asset Management
Thursday 31 August | Sydney | Engineers Australia, Sydney Division

September

Protective Coatings
14 September | Tasmania | Salamanca Inn

October

Corrosion in the Oil & Gas Industries
Tuesday 10 October | New Plymouth | Quality Hotel Plymouth International

November

Corrosion & Prevention
Sunday 12 – Wednesday 15 November | Sydney | International Conference Centre

Branch Events

Each of the 8 ACA Branches will conduct regular technical events throughout 2017. To enquire, you may contact your local Branch at the following email addresses:

New South Wales: nsw@corrosion.com.au
New Zealand: nz@corrosion.com.au
Newcastle: ncl@corrosion.com.au
Queensland: qld@corrosion.com.au
South Australia: sa@corrosion.com.au
Tasmania: tas@corrosion.com.au
Victoria: vic@corrosion.com.au
Western Australia: wa@corrosion.com.au

YCG Events

Targeting individuals under 35, new to the corrosion industry and/or interested in the corrosion industry, the ACA Young Corrosion Professionals conduct regular events. For further details email ycg@corrosion.com.au or go to www.corrosion.com.au

THE AUSTRALASIAN CORROSION ASSOCIATION INC
YOUNG CORROSION GROUP

Wesley Fawaz
Executive Officer

The ACA recently launched a new mobile friendly website integrating membership data and accounts, custom event/training registrations, social media and more. The new website enables members to more efficiently access 'member only' technical content, renew membership (automatic renewals are now also available), register for events and engage with other members on a user-friendly platform.

Also as part of our new digital strategy to deliver more member benefits online, we recently purchased a video camera and live streaming hardware and software which we have started to trial as a tool to offer live streaming of events and to record presentations. The recordings are available for members only on the ACA YouTube account via the new website with a library of video recordings (some already available) set to grow this year and the live streaming option should be offered to members very soon.

This digital strategy is part of the current strategic plan along with creating asset owners and applicator groups to engage and offer new member benefits to these groups.

The Applicators Group was recently established and has met several times already, chaired by Justin Rigby. The group aims to develop action plans to introduce branding for our applicator trades to inspire existing talent and to attract new talent, to engage with Applicator companies and have them active in the ACA membership and to reward initiatives by Applicators that improve the quality of project delivery.

The Asset Owners Group is chaired by Nick Riley aiming to enhance the membership value proposition for Asset Owners, increase engagement and create strong membership growth from Asset Owners. The group was also recently established and is currently working to implement its strategy of developing an online presence, enhancing access to technical information and resources and improving face to face engagement from Asset Owners.

Another action item of the strategic plan is to commission an independent study into the cost of corrosion in Australasia. The ACA has commissioned GHD to facilitate the scoping of this study and two workshops have been conducted so far with several ACA members adding valuable input into the scope. We have unfortunately been unsuccessful to date accessing government funding for the study, but we still hope to proceed as such a study will be invaluable for the ACA membership to highlight the importance of corrosion mitigation.

I welcome new staff member Ross Boucher in the newly developed role of Sales & Business Development Manager. Ross is well known in the industry having worked for ACA members such as Dulux and Cape and I am very confident he will make an immediate impact on the ACA. I'm sure Ross will be calling, visiting and/or introducing himself to you at ACA events throughout this year.

May is the start of the ACA events season, so I do hope that you can make it to one of the one day events in your local city this year as well as the annual conference in Sydney.

Wesley Fawaz
Executive Officer
wesley.fawaz@corrosion.com.au

THE AUSTRALASIAN CORROSION ASSOCIATION INC.

TRAINING

ACA Training Calendar 2017

ACA/ACRA Corrosion & Protection of Concrete Structures

Member $1115 Non-member $1395

Sydney June 5-6

Brisbane September 11-12

ACA Coating Selection & Specification

Member $1560 Non-member $1900

Brisbane June 14-16

New Zealand August 28-30

Melbourne October 16-18

Corrosion Technology Certificate

(Also offered as Home Study)

Member $2330 Non-member $2730

New Zealand October 2-6

Melbourne November 27 - December 1

Hot Dip Galvanizing Inspector Program

Member $1560 Non-member $1900

Adelaide June 1-2

Perth June 26-27

Melbourne July 25-26

Sydney September 14-15

New Zealand November 28-29

NACE Cathodic Protection Program CP 1 –

Australia Member $3335 Non-member $3670

Thailand Member $2600 Non-member $2850

Perth October 9-13

Thailand October 30 - November 3

NACE Cathodic Protection Program CP 2 –

Australia Member $3335 Non-member $3670

Thailand Member $2600 Non-member $2850

Perth October 16-20

Thailand November 6-10

NACE Coating Inspection Program CIP 1

Australia Member $3740 Non-member $4275

Thailand Member $2950 Non-member $3180

Sydney June 19-24

Melbourne July 3-8

Thailand July 10-15

Brisbane July 31 - August 5

Perth September 11-16

New Zealand October 9-14

Sydney November 6-11

Thailand November 27-December 2

All Australian course fees listed are GST inclusive. All NZ and Thailand course fees are exempt from GST.

To calculate the fee pre-GST, divide the fee by 1.1

NACE Coating Inspection Program CIP 2

Australia Member $3740 Non-member $4275

Thailand Member $2950 Non-member $3180

Thailand July 17-22

Brisbane August 7-12

Perth September 18-23

Thailand December 4-9

Prerequisites now apply to this course.

NACE Pipeline Corrosion Integrity Management

Member $2950 Non-member $3250

Perth June 19-23

Melbourne June 26-30

SSPC Concrete Coating Inspection Program

Level 1 $3000 Level 1 and 2 $3500

Melbourne September 25-30

IN-HOUSE TRAINING

Did you know that you can have ACA's suite of courses come to you?

The ACA can present any of its courses exclusively for an organisation; we can also tailor any course to your organisation's specific needs. Please contact the ACA's training department on +61 03 9890 483 or aca@corrosion.com.au

Ross Boucher joins the ACA

Ross Boucher started as the newly created Sales & Business Development Manager on 18 April.

Ross is a current member of the ACA, has undertaken several ACA/NACE/SSPC training courses and has over 33 years' experience in the construction and engineering industry predominantly in the areas of concrete rehabilitation, concrete and steel protection and waterproofing systems in both sales and development roles and in operational management.

Ross's roles over the years before joining the ACA have been many and varied and have included National Major Projects and Marketing Manager at DuluxGroup and later the position of Commercial and Contracts Manager – Heavy Industry.

With the focus of Ross's role to grow membership and attendance at our training and events, the ACA is confident that with this experience, extensive industry contacts and technical knowledge, Ross will make an immediate impact on the ACA's activities.

ACA Exhibits at AOG

The ACA in conjunction with the Maritime Industry Association Limited (MIAL) co-exhibited at the Annual Australasian Oil & Gas Exhibition & Conference in Perth, during 22-24 February this year. The stands situated side by side were in the Maritime Zone section of the Exhibition. The stands were 'womanned' by the ACA's Tracey Winn and MIAL's Alison Saunders. Both booths were well attended.

As part of AOG the ACA hosted a seminar titled 'Corrosion in the O&G Industry' on Friday 24 February, chaired by Graham Carlisle and this too was well attended. A Business Card Draw was conducted at the stand, with the first prize being a bottle of Penfolds Bin 389 Shiraz.

The Business Card draw prize went to Chris Harrey from A & E Systems.

Corrosion in Non-Conventional Oil & Gas

PROUDLY PRESENTED BY: AUSTRALASIAN CORROSION ASSOCIATION INC.

Tuesday, 23 May 2017
8.30am – 6pm

SPONSORED BY: ANTICORROSION TECHNOLOGY · STOPAQ – A SEALFORLIFE COMPANY · International

The Gabba – Gate 6, Vulture Street, Woolloongabba QLD


Overview of Event

The ACA Oil & Gas Technical Group provides a platform for the Oil & Gas Industries. It is a forum to discuss the latest developments and best practices in materials engineering and corrosion control in onshore and offshore environments. This one day technical event will give speakers and participants the opportunity to share their work and experiences from the Oil & Gas Industries to develop best practices, share solutions and look at new technologies.


Time	Name	Presentation Title
8.30	Registration	
9.00	Dr Fikry Barouky	Welcome
	Fikry Barouky, Phil Fleming	Update - Oil & Gas Technical Group
9.30	Wayne Thomson, Anode Engineering	Corrosion Considerations for Onshore Riser Pipes
10.00	Morning Tea	
10.30	Geoffrey Will, QUT	Produced Water Corrosion in Coal Seam Gas Production
11.00	Stephen Challis, Viva Energy Geelong	Benefits of EMAT Technology for Onstream Process Piping Inspection
11.30	Fikry Barouky, Anti Corrosion Technology	Corrosion Management in Oil & Gas is it 'Strategic' or 'Tactical'
12.00	Lunch	
13.00	Jason Vella, QER	High Temperature Corrosion of Stainless Steel Alloys in Shale Gas Retort Systems
13.30	Ivi Cicak, Deakin University	Corrosion Engineering & Coating Testing at Deakin University
14.00	Matthew O'Keeffe, International Paint	Advances in Lining Technologies for Land Based Steel Storage Tanks
14.30	Silvia Chaparro, Curtin University	Assessing the Risk of Microbially Induced Corrosion (MIC) and Treatment
15.00	Afternoon Tea	
15.30	TBC	TBC
16.00	Forum	
17.00	Networking Drinks	
18.00	Close	

Registration: ACA Members – $285 (Incl. GST). Non-Members – $325 (Incl. GST).
Please register online via the ACA website Events tab at www.corrosion.com.au
Registration includes, arrival tea & coffee, morning/afternoon tea and lunch.
Handouts from the Seminar will be available in a hard copy booklet.

For further information about this seminar please contact Bianca Reardon on +61 3 9890 4833 or via email at reardon@corrosion.com.au

To register online go to www.corrosion.com.au/events

The ACA attends NACE '17

ACA's Executive Officer Wesley Fawaz and Chairman Dean Wall, along with a strong contingent of ACA members recently attended the NACE Corrosion 2017 conference in New Orleans, USA.

New Shell-Imperial Centre explores causes of corrosion

The Shell-Imperial Advanced Interfacial Materials Science (AIMS) Centre at Imperial College London was launched in March 2016 with the aim of delivering new insights into materials behaviour and enabling optimal materials selection, design and enhanced predicative capabilities.

The Centre, based in the Department of Materials, focuses on the development of innovative solutions using state-of-the-art and in operando characterisation approaches to materials challenges in the engineering and energy industry.

The Centre focuses on five technical themes exploring research that links nanoscale processes to large-scale materials behaviour. The interdisciplinary research team, which includes six PhD students and three Post-Docs, has been exploiting developments in new ambient pressure systems for spectroscopy and microscopy, as well as central synchrotron facilities to develop new in-situ approaches to study complex systems over length and timescales relevant to industrial processes. The long-term goal of the Centre is to make industrial processes safer, more predictable and more efficient, ultimately resulting in better asset management and operational performance.

The Centre is led by Professor Mary Ryan and was established as a result of a synergistic, ongoing partnership between Shell's Materials and Corrosion R&D team, led by Dr. Lene Hviid, and Imperial's Department of Materials. Professor Ryan also currently holds the Shell/RAEng Chair in Interfacial Nanoscience for Engineering Systems.

"We are providing enhanced materials capabilities across the range of business units within Shell; both in their core and developing areas," Professor Ryan commented. "The Centre is founded on the strong relationship between Imperial and Shell and a great advantage of our programme is the ability to work closely with our technical colleagues within Shell, exchanging knowledge and gaining real insights into operational materials challenges."

The Centre represents a major step forward in corrosion minimisation for Shell, with the 2016 NACE International IMPACT report estimating the global cost of corrosion to be US$2.5 trillion. Corrosion has become a substantial obstacle in many industries, including energy, chemicals, nuclear and automotive with the cost equivalent to 3.4% of global GDP in 2013.

Dr Lene Hviid, General Manager Materials & Corrosion, Shell Global Solutions said, "Increasing our understanding of materials through the nanoscience approach will create a huge opportunity for developing materials with corrosion minimisation and a good performance predictability.

"The design of sophisticated next-generation, anti-corrosion protocols and accurate lifetime predictions is exceptionally challenging and requires a dedicated multi-disciplinary approach to provide the holistic understanding which will ultimately lead to greatly enhanced engineering performance and real world impact. We have been delighted to welcome Professor Ryan and the research team into our technology centres around the globe to further the understanding of the technical challenges, to drive technical innovation and to support the development of transferable methodology in this critical area of research."

The Centre forms one more facet to the longstanding Shell-Imperial relationship with ongoing work at the Sustainable Gas Institute, the fuels and lubricants University Technology Centre and the Qatar Carbonate and Carbon Storage Research Centre.

Courtesy: www3.imperial.ac.uk

The Centre is led by Mary Ryan, Professor of Materials Science & Nanotechnology.

Brian Kinsella celebrates seventy great years

A wonderful event took place at Ascot Waters overlooking the majestic Swan River towards the end of February as people gathered from all corners of the country to celebrate the 70th birthday of young Brian Kinsella. We can happily say that he is still young for his energy, commitment to his team, family and friends is second to none. Brian has retained his integrity despite operating in the lofty environments of academia for three contiguous careers. Speeches were given by colleagues including Warren Green, one of a few who had travelled from the East to help the local admirers in case they got stuck for words with which to describe the multifaceted nature of this humble and unassuming man.

Various friends who know Brian better than most entertained us with stories of cricket prowess, of commitment to local football clubs and his shared interest with his wife Judy of following quadrupeds around a race track. It is part of the Kinsella charm offensive that he allowed many punters to achieve their sense of happiness by beating his chosen mounts. Brian's commitment to the ACA and to promoting better understanding of corrosion processes to the oil and gas industries was partly recognised last year by him being awarded The Corrosion Medal at the Corrosion & Prevention conference in Auckland. Shortly after his party he flew to the NACE Conference in New Orleans to be awarded NACE Fellowship in recognition of his distinguished contributions in the field of corrosion and its prevention.

Brian currently leads community, research and industry engagement programs at the Curtin Corrosion Engineering Industry Centre at Curtin University and has a totally dedicated and committed band of post-doctoral research workers whose bounds knows no limits. Watch this space for future reports on the record breaking status of Brian and his brilliant team.

Ian MacLeod


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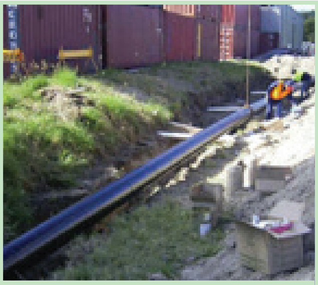
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Move over, Superman! NIST method sees through concrete to detect early-stage corrosion

When you suffer a fall, an on-the-field collision or some other traumatic blow, the first thing the doctor will do is take an X-ray, CT scan or MRI to determine if anything has been damaged internally. Researchers at the National Institute of Standards and Technology (NIST) are using the same principle, but in a more powerful form, to detect corrosion, the primary danger threatening the health of the steel framework within the nation's bridges, roads and other aging physical infrastructure.

What they have developed is a noninvasive "spectral fingerprint" technique that reveals the corrosion of concrete-encased steel before it can cause any significant degradation of the structure it supports. The detection method is described in a new paper in the journal *Applied Magnetic Resonance*.

When water and oxygen corrode iron, different iron oxide products are produced, with the two most common being goethite and hematite. "The brown rust that forms when you leave a hammer out in the rain is mostly goethite, and when a steel reinforcing bar [rebar] corrodes inside a concrete bridge deck, that is mostly hematite," said NIST physical chemist Dave Plusquellic. "We have shown in our new study with goethite, and our previous work with hematite, that terahertz radiation—electromagnetic waves with frequencies 10 to 100 times higher than the microwaves used to cook food—can detect both corrosion products in the early stages of formation."

Current imaging methods for uncovering corrosion use microwaves to record changes in the physical state of the affected steel, such as changes in the thickness of a rebar within the concrete of a bridge or other structure.

"Unfortunately, by the time such changes are detectable, the corrosive process is already well on its way toward causing cracks in the concrete," said physicist and NIST Fellow Ed Garboczi. Additionally, Garboczi said most of the microwave imaging methods rely on comparisons with baseline measurements of the steel taken at the time of construction, a practice that only goes back about 25 years.

"That's a real problem since the average age of the 400,000 steel-reinforced concrete bridges in the United States is 50 years and there is no baseline data available for many of them," he explained.

The NIST terahertz wave detection method works because goethite and hematite are antiferromagnetic. In other words, the pairs of electrons sitting side-by-side within the iron atoms in these materials spin in opposite directions, leaving them unaffected by external magnetic fields. In contrast, the electrons in the iron atoms of a household magnet, which is ferromagnetic, spin in the same direction and are either attracted or repelled by external magnetic fields.

"Terahertz waves will flip the spin alignment of one of the electrons in a pair and get absorbed by hematite or goethite," Plusquellic said. "Using a millimeter wave detector, we discovered that this antiferromagnetic absorption only occurs within narrow frequency ranges in the terahertz region of the electromagnetic spectrum—yielding 'spectral fingerprints' unique to goethite and hematite, and in turn, iron corrosion."

With current advances in terahertz sources and detectors, the new NIST nondestructive evaluation technique has the potential to rapidly detect tiny amounts of iron-bearing oxides from early-stage corrosion of steel surrounded by concrete, polymer composites (such as pipe insulation in a factory), paints and other protective materials.

"In the laboratory, we have demonstrated that a 2-milliwatt terahertz source can produce waves that detect hematite through 25 millimeters of concrete," Plusquellic said. "Using terahertz sources with powers in the hundreds of milliwatts and state-of-the-art receivers with unprecedented signal-to-noise ratios, we should be able to penetrate 50 millimeters, the thickness of the concrete covering the first layer of rebar used in most steel-reinforced concrete structures."

Next up for the NIST team will be an attempt to find a spectral fingerprint for akageneite, an iron corrosion product formed in the presence of chloride ions, which come from sources such as seawater and road deicing salt.

"Akageneite can cause problems in steel-reinforced concrete similar to those seen with goethite and hematite," Garboczi said.

The antiferromagnetic corrosion detection method was first conceived in 2009 by the late William Egelhoff, a NIST fellow and pioneer in the field of magnetic materials.

Courtesy: www.phys.org

An abandoned building on Northern California's McAbee Beach shows the destructive power of corrosion on a steel-reinforced concrete structure. A new NIST evaluation method using terahertz waves can detect the early stages of corrosion on steel rebars directly through their concrete covering. Credit: With Permission by Per Loll, Denmark.

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Improved corrosion protection with flake-type particles of zinc-phosphate

Large quantities of steel are used in architecture, bridge construction and ship-building. Structures of this type are intended to be long-lasting. Furthermore, even during the course of many years, they should not lose any of their qualities regarding strength and safety. For this reason, the steel plates and girders used must have extensive and durable protection against corrosion. In particular, the steel is attacked by oxygen in the air, water vapor and salts. To prevent the corrosive substances from penetrating into the material, a common method is to create an anti-corrosion coating by applying paint layers of zinc-phosphate particles. Recently, research scientists at INM – Leibniz Institute for New Materials developed a special type of zinc-phosphate particle: They are flake-like in shape because they are 10 times as long as they are thick.

The developers will be demonstrating their results and the possibilities they offer at stand B46 in hall 2 at this year's Hannover Messe which took place from 24th to 28th April.

First experiments with those new, flake-type shaped particles indicate, because of their anisotropy, a better solubility compared to spherical particles. "Now, more phosphate-ions are soluted and repassivation of bare metal surface, for example as a consequence of a mechanical damage, is better and faster," the head of the program division Nanomers, Carsten Becker-Willinger says.

"In first test coatings, we were also able to demonstrate that the flake-type particles are deposited in layers on top of each other thus creating a wall-like structure. This means that the penetration of gas molecules through the protective coating takes longer because they have to find their way through the ´cracks in the wall´," the chemist Becker-Willinger explains. The result was, that the corrosion process was much slower than with coatings with spheroidal particles where the gas molecules can find their way through the protective coating to the metal much more quickly.

In further series of tests, the scientists were able to validate the effectiveness of the new particles. To do so, they immersed steel plates both in electrolyte solutions with spheroidal zinc-phosphate particles and with flake-type zinc-phosphate particles. After just a few hours, the steel plates in the electrolytes with spheroidal particles were showing signs of corrosion whereas the steel plates in the electrolytes with flake-type particles were still in perfect condition, even after three days.

The flake-type shaped zinc-phosphate particles are synthesized in a controlled precipitation process developed at INM.

INM conducts research and development to create new materials – for today, tomorrow and beyond. Research at INM is performed in three fields: Nanocomposite Technology, Interface Materials, and Bio Interfaces. INM is an institute of the Leibniz Association and has about 240 employees.

Courtesy: www.phys.org

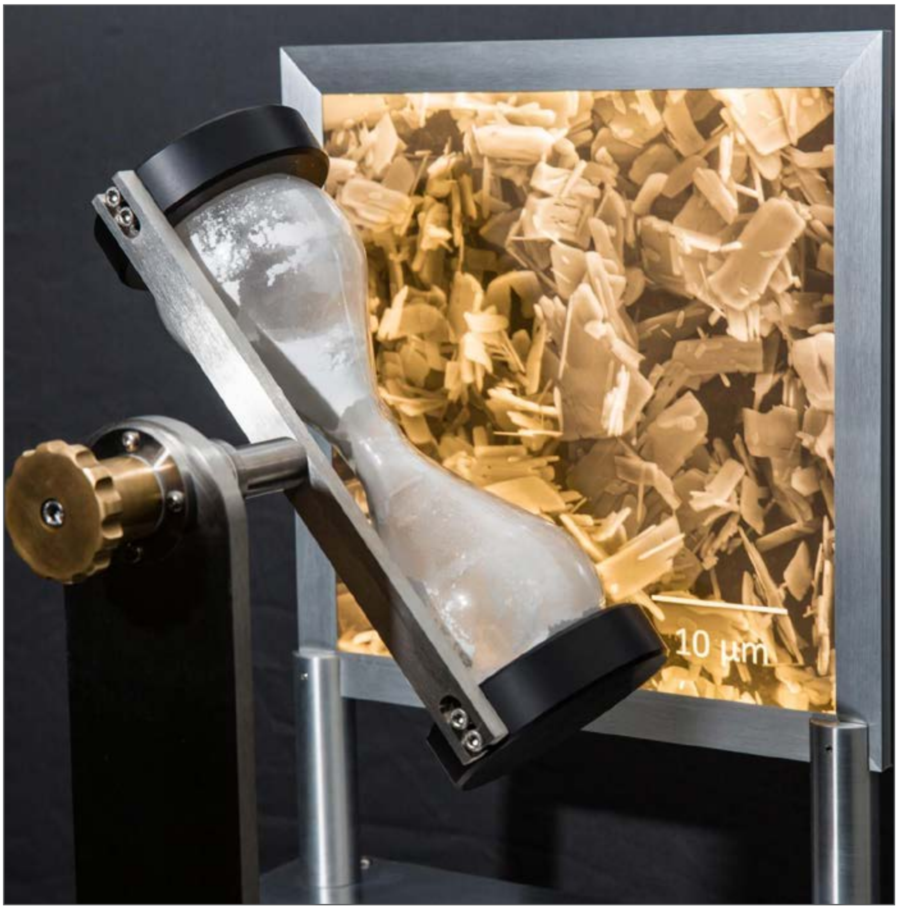


Exhibit for flake like zinc-phosphate particles for better corrosion protection: Because of the disordered arrangement of the flakes, they can not run through the sandglass like spheric particles do. Credit: Ollmann.

Cold spray technology to repair surfaces of corroded aircraft parts

Faster, market competitive and safer aeroplane repairs. That's the goal of a project by The University of Akron and Airborne Maintenance and Engineering Services in obtaining Federal Aviation Administration (FAA) approval for "cold spray" repair of corroded and worn parts on commercial aircraft.

Promising demonstrations and test results of this application were showcased at Airborne Maintenance and Engineering Services at the Wilmington Air Park on March 27. Members of the Ohio General Assembly – including Speaker of the Ohio House of Representatives Cliff Rosenberger and Ohio Senate President Pro Tempore Bob Peterson – viewed progress of Supersonic Particle Deposition (SPD), a groundbreaking aircraft repair method for applying metal particles to rebuild the surfaces of corroded and worn parts.

By extending the useful life of an aircraft's parts, this public-private partnership initiative is anticipated to lead to the first FAA certification for full-scale commercial aircraft repair operations. For a region that is actively expanding the job market by developing emerging technology to grow the aviation sector, this approval is another step forward in additional job and economic development opportunities.

The technique involves a high pressure spraying process in which metal particles contained in a supersonic jet of an expanded gas impact a solid surface with sufficient energy to cause bonding with the surface. This additive manufacturing process builds up and repairs the surface of the metal part without creating a heat-affected zone that would occur during welding or high temperature thermal spray.

Development and testing has been underway for two years, funded by the Ohio Legislature in the last Operating Budget, and supported by The University of Akron's National Center for Education and Research on Corrosion and Materials Performance (NCERCAMP) in collaboration with Airborne Maintenance and Engineering Services (AMES), SAFEngineering, Inc., and U.S. Technology Corporation. The data gathered has provided the foundation with the information required for FAA approval of SPD dimensional restoration of aircraft structure.

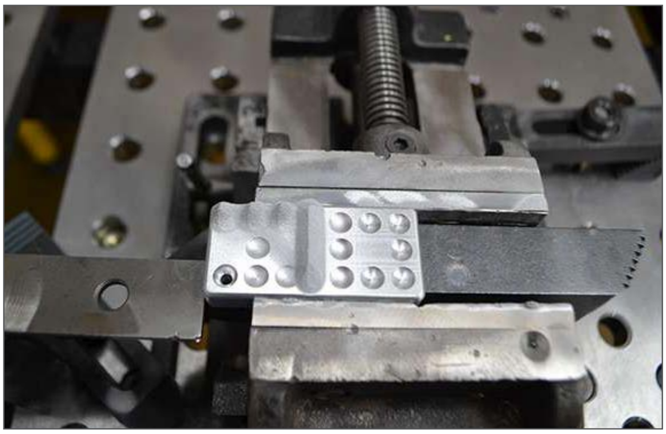
This collective effort has produced numerous achievements with the SPD technology highlighting the effectiveness of public-private partnerships for economic growth. Once the goal of this program is attained, the application of the process is limitless across the commercial aviation sector.

"This technology in commercial applications creates significant ongoing opportunities for economic advancement in Ohio through advanced manufacturing and job growth," said Greg Smith, director of engineering for Airborne Maintenance and Engineering Services.

UA's Corrosion Engineering program is the first of its kind in the United States. Housed at The University of Akron, NCERCAMP provides a multidisciplinary approach to help government and industry develop solutions for corrosion and materials performance challenges. In response to requests from private industry and the Department of Defense in 2006, The University of Akron launched an effort to help address the cost of corrosion on the nation's economy, estimated at more than $400 billion annually. In 2010, NCERCAMP was established by Congress and the U.S. Department of Defense.

Courtesy: www.phys.org

This robotic arm is programmed to apply cold spray technology to repair surfaces of corroded aircraft parts. Credit: University of Akron.

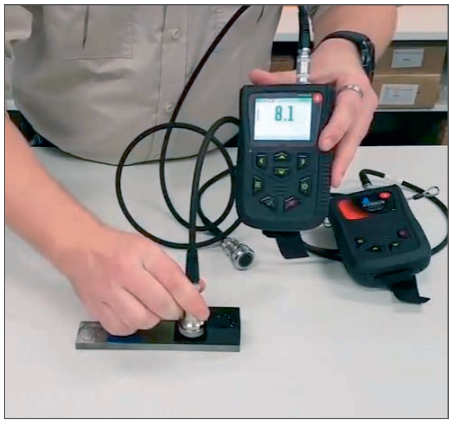


This aluminum domino is a before/after demonstration of how the Supersonic Particle Deposition (SPD), also known as Cold Spray, applies metal particles to a worn part, building up and repairing surface damage. Credit: University of Akron.

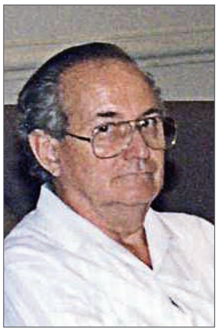
Russell Fraser Sales Unboxing NDT on Youtube

Russell Fraser Sales (RFS) has once again established that they are the leaders in inspection and testing equipment in Australia with their fresh approach to NDT product reviews, launching their "unboxing" video series on YouTube. Russell Fraser and his team of twelve staff are always looking for ways to add value to the customer's interaction and product reviews offer a hands-on look at exactly what's in the box with a walk-through of the different features and pro tips on NDT gear. This follows the recent addition of LiveChat on the RFS website www.rfsales.com.au offering even greater flexibility in accessing the solutions to inspection and testing problems right away.

The first unboxing video in the series features the RFG-4000 ultrasonic thickness gauge and as a response to the high demand for ultrasonic inspection RFS has continued the trend with their latest video "Full unboxing of the Cygnus 2 & Cygnus 4 Mk5 Ultrasonic Thickness Gauges". RFS unboxing videos can be found on the "Russell Fraser Sales Pty Ltd" YouTube channel. Be sure to subscribe to their channel or contact Russell Fraser Sales for more information:



VALE – Brian M Byrne



One of ACA's notable pioneers, Brian Byrne, passed away in Brisbane on 31st January 2017 at the age of 86 following a short illness. Brian graduated in electrical engineering from the University of Queensland in 1952, and commenced work in the Postmaster General's Department (PMG, later Telecom) in Brisbane in their cable protection division. He was specifically involved in early developments of cathodic protection applied to the lead-sheathing of underground cables. He rose to become Manager of Telecom's Line and Customer Support Branch, with around 200 staff including a highly specialised technical group. Work activities extended to identifying circumstances causing failure in equipment, problem solving on interactions between power and telecommunication systems, electrical surge mitigation by lightning and associated earthing design and electric shock hazards.

His knowledge and expertise was sought after throughout Australia, and he represented Telecom on numerous Australian Standards committees and chairing some. A number of these have been called up in both Australian and Queensland legislation. He was the longest serving member of the Queensland State Electrolysis Committee, and was instrumental in preparing CP and interference regulations that became part of the Queensland Electricity Act in 1976. He was convenor of several Queensland joint engineering committees dealing with electrical and telecommunications interactions including electric tram and rail systems, and participated in the International Electrotechnical Commission (IEC) on earthing / lightning matters. On his retirement from Telecom in 1993, Brian provided consulting services for almost 20 years to a number of organisations and business entities concerned with corrosion and electrical safety issues.

During the late 1950's, Brian joined the Queensland Branch of the Australian Association for Corrosion Prevention. At their annual convention in 1960, it amalgamated with a similar body in New Zealand to form what is now the current Australasian Corrosion Association, thus making Brian a founding member of ACA. Several years later, he became Queensland Branch President, then Australasian President at the Queensland conference in 1967. He gave untiring service to the Queensland branch of ACA until 2003, this giving him the distinction of being one of its longest serving committee members. At the Australasian level, Brian presented many conference papers, he was awarded Life Membership in 1973, and he gave the Plenary Lecture at the Auckland conference in 1976. In 1981, he received the Association's Corrosion Medal, and delivered the PF Thompson lecture at the 1989 conference. Brian also gave exemplary service to the Association through his involvement in the Australian Electrolysis Committee from its inception, as Standards Officer for some 15 years, and as Queensland Councillor for many years during the time when States met annually to determine ACA policy and direction. In no small way did he contribute to the growth of ACA membership and its general standing in the technical arena.

Brian persevered and pursued his passion to control corrosion for his entire working life, and was highly regarded for this by many a peer and colleague as well as countless people he mentored. He was quite a private man however, preferring to observe and reflect rather than taking centre stage despite his considerable intellectual capacity. He was very much a 'fount of all knowledge', often taking people beyond their technical comfort zone, but valued never-the-less, humble in approach and generous in spirit. He will be remembered for his unusual humour and dry wit summed up best as from the school of Spike Milligan and the Goons. He was a real gentleman, courteous, thoughtful, never judgemental, a solid friend. He is survived by his wife, Joyce, and four children.

Ian Macleod

Newcastle AGM & Branch Event Pipe Lining & Coating Site Visit

Wednesday 22 February 2017

Simon Krismer continues at the NCL President (2 year term)

ACA Auckland Division April Meeting Report

At the ACA Auckland meeting held on 20th April at The Landing hotel, an enjoyable evening was had by members listening to Prochem General Manager Gary Falloon talking about ‘Keeping your pipes clean’. Prochem is a specialised water treatment company based in Auckland. Gary shared his experiences on the use of specialised corrosion inhibitors in maintaining the water industries and industrial air conditioning system (HVAC) pipelines carrying water.

Gary commenced his talk by regaling the methods used in the early 1980’s for maintaining pipelines when he first started in the water treatment industry. At that time, the use of sodium dichromate provided an effective method of keeping steel water pipes clean and free from corrosion. Even though this chemical provided an effective method of maintaining pipelines, chromium compounds used were environmentally hazardous and they were phased out during the late 1980’s. Ever since, water treatment chemical suppliers have been developing eco-friendly chemical alternatives, using the performance of sodium dichromate as a benchmark.

A number of case studies were then presented and discussed, which ranged from poor design, e.g. galvanized steel boiler connected to stainless steel and copper pipes, incorrect use of corrosion inhibitors, and switching off a boiler unit at night that caused internal condensation, corrosion and an expensive repair. The common theme in all of the cases was the lack of understanding and appreciation of how to design, maintain and operate water pipelines. It is always recommended to seek professional advice to minimise the risk of preventable failures and costly shutdowns.

The evening concluded with discussions of other topics, such as vintage cars, over a meal and a pint at The Landing.

Gary Falloon, Prochem (left), with attendees at the April meeting.

NSW Branch AGM & Trade Show

NSW hosted their Trade Show and AGM on Tuesday 14 March at Ryde Eastwood Leagues Club.

48 people attended. The outgoing President was Peter Hosford and the new President is Alan Bird.

Exhibitors included – Olympus Australia, International Paint, Parchem Construction Supplies, Russell Fraser Sales, Blygold, BlastOne International Group, Omniflex and Denso.

QLD Branch GF Site Visit

Proof – there is dough to be made in materials engineering! This proof was observed by a select group of corrosionistas who attended the Goodman Fielder site visit on Friday 24 March

Goodman Fielder (GF) is a household name, producing many food items across Australia, New Zealand and Asia Pacific. The Carina bakery was established in the early 1960s and currently has two production lines: one bread line and one rolls line. The industrial bakery has the capacity to manufacture approximately – 130,000 loaves of bread per day and approximately 180,000 rolls per day.

Some brands manufactured at the GF Carina site are Wonder, Mighty Soft, Molenberg, Buttercup as well as unbranded which go to various supermarket chains.

The GF Carina plant distributes to Northern NSW as well as all of Queensland. GF in Queensland also has baking sites in Townsville and Burleigh Heads which also produce product brands such as Helgas & Lawsons. Anthony Beckley, the Queensland Maintenance Manager took the attendees through a presentation on the process of making bread products. Throughout the presentation and the plant tour, it was not lost on the group the various performance requirements of the materials used in the machinery at high temperature and dynamic cycles. This site visit was a little different than most, but feedback from the attendees was overwhelmingly positive.

QLD Branch AGM & Tech Event

On Tuesday 28 March the Queensland ACA Branch hosted Andrew Mackintosh from Thomson Greer Law Firm. Usually talks are of a technical corrosion nature, this talk was of a legal nature. As many ACA members are commercial practitioners, they are often faced with signing contracts, sometimes many pages long and full of legal complexity. Andrew's talk entitled 'Contractual Risk' was a welcome introduction on how to minimise risk when presented with a service or product supply contract.

Andrew explained to the audience the difference between consequential loss and direct loss, the former having far greater implications when there is a breach of contract. Andrew cited a couple of examples where a defendant successfully defended a claim and one where the claimant won. Merely stating that consequential loss is excluded is not enough to limit the contractor's risk. Through clear wording, specifying applicable categories and by considering the issue at the outset is a far more effective mechanism to mitigate contractual risk.

Andrew covered the concept of proportionate liability. This concept arose in response to an insurance crisis in the early 2000s. Proportionate liability refers to how damage to property and economic loss is apportioned to the extent of the responsibility for the damage suffered. It was pointed out that some states contracting out of proportionate liability legislation (NSW, TAS and WA). Queensland prohibits contracting out.

The matter of retentions and bank guarantees was covered and Andrew was quick to point out that the trend is now towards bank guarantees. Andrew offered some tips to manage risk, some of which include Australian Consumer Law, standard forms, supply of goods and services vs sale of land.

A relevant part of the talk was directed at the matter of small business contracting. Small business contracts apply to a firm with less than 20 employees, where a contract value of upfront price is less than $300,000 in one year or $1,000,000 in two years.

The talk was very informative an gave the attendees, no doubt either issuing or receiving contracts, a greater appreciation of the complexities and risk mitigation opportunities for firms in the corrosion prevention industry.

VIC Branch AGM & Tech Event

The Victorian Branch AGM and Event 'Managing Your Assets: Approaches to Corrosion and Asset Management' was held on Wednesday 22 March at The Royal Society.

Anthony Bonacci, New Estates & GSC Delivery Manager, AusNet Services presented 'Pipe Corrosion & Asset Management: Managing a CP network to meet regulatory requirements and business objectives' and Scott Wade, Associate Professor, Swinburne University of Technology presented 'Managing ALWC in Marine Assets: An inspection based approach to asset management'.

SA Branch AGM & Quiz Night

The SA AGM and Quiz Night was held on Friday 24 February at the Bombay Bicycle Club

The outgoing President was Alex Shepherd and the new President is Sam O'Neill.

SA Branch YCG Billards Night

This SA YCG event was held on Friday 10 March at the Norwood Ballroom and was sponsored by Jotun and Dulux.

NEWS FROM THE ACA FOUNDATION

Applications Now Open for Three Corrosion Training Scholarships

For both new and long-standing members of the ACA, and for the Foundation's valued Centurion contributors, it is timely to remind ourselves of the Foundation's charter. *The ACA Foundation exists for the purposes of advancing corrosion mitigation through education, by providing scholarships, bursaries and awards for academic excellence. The Foundation also invests in future leader development as well as special projects targeting corrosion education in secondary education and the broader community.*

The Foundation is inviting applications for three Corrosion Training Scholarships which support the recipients with the normal cost of participating in training courses offered by the ACA. Applications close on 9 June 2017. More information is available on the ACA Foundation website www.foundation.corrosion.com.au

Centurion Support

An ACA Foundation Centurion is a person who makes an annual donation of AUD$100 or more, to the ACA Foundation Ltd Scholarship Fund, for as long as they are able. Centurions have done a magnificent job of funding a comprehensive range of Scholarships and now the Foundation is asking for support once more.

Centurions understand the value of developing the technical and professional expertise of those in the corrosion science and engineering industries. The Centurion program is a reflection of the deep commitment of ACA members to study and endeavour in this field. Please visit the Foundation website to see how you can join the ranks of Centurion supporters https://foundation.corrosion.com.au/membership-account/membership-levels/

Is your company interested in learning more about the Foundation's work with a view to sponsoring current or future corrosion science projects in Australian and New Zealand schools? Please contact the ACA Foundation Executive Officer, Linda Lawrie, on+61 3 9890 4833 or email foundation@corrosion.com.au This is an exciting and opportune time to join with the Foundation as it commences the operational stage of its work with students and teachers.

The Foundation's Commitment to STEM Education in Australia

Similar to the NACE International Foundation, the ACA Foundation promotes the study of Science, Technology, Engineering and Maths [STEM] with a view to encouraging the future generation of corrosion engineers, scientists and technicians. In 2017, the Foundation is targeting students in Years 9 & 10 before they make subject choices for their final years of secondary schooling. With seed funding from the ACA Victorian Branch, and an emerging partnership with the national program 'Advancing Science and Engineering through Laboratory Learning' [ASELL], the Foundation is building its presence in this field. The Foundation intends to 'test-drive' various corrosion experiments and activities through the ASELL program and then make these resources available through the Foundation website. The experiments will encourage hands-on, inquiry-based learning, and be designed for today's classrooms. In Victoria, the Foundation's School Project is being led by the Deputy Chair of the Foundation, Ms Sarah Furman. Profiles of Board members can be found on the Foundation website.

The Foundation is also in discussions with ACA Branches in Newcastle and Queensland about innovative ways of working with students to promote corrosion science and engineering.

The Foundation's work contributes to the national agenda to improve student performance in STEM. The latest international research [TIMMS 2015] demonstrates that the mathematics and science achievement of Years 4 & 8 Australian students over the past 20 years has flat-lined while many other countries have improved.

The ACER Director of Educational Monitoring & Research, Dr Sue Thomson, commented, "…the continuing slide in students' mathematical and scientific achievement is occurring at a time when the economy and an increasing number of occupations are requiring graduates with advanced skills in STEM" **The Foundation hopes to play its niche role in arresting this slide in student achievement by focussing on corrosion science.**

The Foundation is also developing a series of profiles of young corrosion scientists and engineers to serve as role models for students in the early years of secondary schooling. If you would like to be part of this resource and appear on the Foundation website please email foundation@corrosion.com.au

The Foundation was recently invited to contribute to the 'Australian Academy of Technological Sciences and Engineering' website with information on careers in corrosion accompanied by profiles of young women corrosion engineers and scientists. Another example of working with other organisations to achieve common goals.

In order to further its work in promoting both STEM and careers in the corrosion industry, the Foundation is seeking sponsorship from companies interested in funding corrosion resources for Australian and New Zealand teachers and students

ACA Standards Update Summary*

Welcome to the corrosion related standards report for May 2017.
The standards reporting for 2017 is scheduled against specific interests and as indicated below:

Issue	2017 Standards search for Specific Interests
February	Oil & Gas
May	Asset Management
August	Protective Coatings
November	Concrete & CP

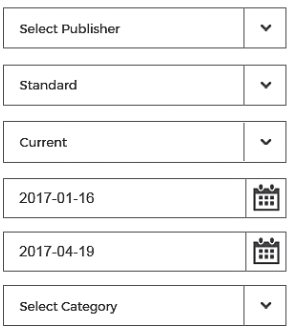
This Standards report focuses on Asset Management in relation to corrosion.

As previously this is in two stages, namely:

1. A global standards and publication focus at **19 April 2017**, searching through SAI Global Publications at https://infostore.saiglobal.com/en-au/Search/Standard/?sortKey=productName-asc&productFamily=STANDARD , for all current publications and standards relating to corrosion and its prevention for the topic of 'Asset Management' with a focus on corrosion.

These results are shown in Table 1.

2. A SAI Global search at https://infostore.saiglobal.com/en-au/Search/Standard/?sortKey=productName-asc&productFamily=STANDARD , with filters set as below,



for **new** standards, amendments or drafts for AS, AS/NZS, EN, ANSI, ASTM, BSI, DIN, ETSI, JSA, NSAI and standards and amendments for ISO & IEC published from **16 January - April 19 2017**, using the key words and key word groups:

- 'durability'.
- 'corrosion' or 'corrosivity' or 'corrosive'; but not 'anodizing' or 'anodize(d)'.
- 'paint' or 'coating'; but not 'anodizing' or 'anodize(d)'.
- 'galvanize' or 'galvanized' or galvanizing'.
- 'electrochemical' or 'electrolysis' or 'electroplated'.
- 'cathode' or 'cathodic'.
- 'anode' or 'anodic'.
- 'corrosion' and 'concrete' or 'concrete' and 'coatings'.

These results are shown in Table 2.

Summary

1. Through SAIGLOBAL Publications for a search on 'Asset Management', with a focus on corrosion, there were 18 AS and NZS citations, with 14 standards and 4 drafts; see Table 1.

There were no citations for "Asset Management and corrosion", but all aspects of corrosion and its prevention are an important part for the optimal life cycle performance of your buildings, structures and equipment assets and need to be included in your asset management strategy; for an overview of asset management refer to Setting a good standard for asset management .

2. Across SAI Global online Standards Publications there was a total of 44 listings of new standards, Drafts and Amendments found that were issued from **16 January - April 19 2017**; 4 from AS AS/NZS as shown below;

   a. DR AS/NZS 2312.1:2014 Amdt 1:2017 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings Paint coatings

   b. AS/NZS 2311:2017 Guide to the painting of buildings

   c. AS 2331.1.2-2001 (R2017) Methods of test for metallic and related coatings Local thickness tests - Coulometric method

   d. AS 1231-2000 (R2017) Aluminium and aluminium alloys - Anodic oxidation coatings

All results are shown in Table 2 (via the ACA website, publications tab at www.corrosion.com.au).

Regards,

Arthur Austin
(Arthur.Austin@alsglobal.com)

***For the full Standards Report, please visit www.corrosion.com.au**

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AUSTRALASIAN CORROSION ASSOCIATION INC.

PIPELINE CORROSION MANAGEMENT

Thursday 29 June 2017 | 8.30am – 6.30pm | Melbourne Rydges – 186 Exhibition Street, Melbourne

Overview

The Australian Pipelines & Gas Association (APGA) and The Australasian Corrosion Association (ACA) have joined together to host a technical seminar to discuss the challenges and solutions for preventing corrosion in pipelines, some of our most vital infrastructure.

Discussion on technologies such as materials selection, coatings and cathodic protection used to attain the desired design life of our assets will be discussed. Speakers will share their experiences by reviewing case studies.

Who should attend?

Presentations will appeal to all industry sectors involved with Pipeline Asset Management – including asset owners, project and integrity engineers, operators, inspection and maintenance personnel, contractors and suppliers.

Cost **$300** (Inc. GST) Price is in Australian dollars.

RSVP Registrations close **Tuesday 27 June 2017**.

Contact

For further information on this event please contact:
APGA – Steve Dobbie on + 61 2 6273 0577 or sdobbie@apga.org.au
ACA – Bianca Reardon on +61 3 9890 4833 or reardon@corrosion.com.au

Program

8.30am	Registration	
9.00am	Welcome & Seminar Opening	
9.10am	Keynote Overview Presentation - The Importance of Corrosion Prevention in the Pipeline Industry	Craig Bonar, Manager, East Coast Grid Engineering, APA Group
9.40am	An Asset Management System for Corrosion Protection	Andy Jones, Planning & Assessment Manager - Pipelines, Jemena
10.15am	The NFPCA – Establishing Capabilities to Meet the Needs of the Pipeline Industry in Coating Assessment	Ivi Cicak, NFPCA Facility Manager, Deakin University
10.50am	Morning tea	
11.20am	Demonstrating Pipeline Integrity Compliance in Accordance with the Remaining Life Review Requirements of AS 2885.3	Alan Bryson, Integrity Manager, East Coast Grid, APA Group
11.55am	Stray Current Mitigation & Cathodic Protection Regulation	Peter Wade, Manager, Electrolysis Mitigation, Energy Safe Victoria
12.30pm	Corrosion Mitigation of a Pipeline in a Metropolitan Area	Jim Galanos, Engineering Manager, Corrosion Control Engineering
1.05pm	Lunch	
2.00pm	Important Decisions When Selecting Long-Term Protective Coatings	David Towns, Business Development Manager, SA/NT, Denso Australia
2.35pm	An Overview of Research Conducted for the EPCRC on Assessing the Performance of Coating & Cathodic Protection Under Complex Pipeline Conditions	Mike Tan, Professor of Applied Electrochemistry and Corrosion Technologies, Deakin University
3.10pm	Afternoon tea	
3.40pm	Electro-magnetic Transducer Technology (EMAT) as a Diagnostic Tool for Detection of Hidden Corrosion - Case Studies	Steve Challis, Engineer, Viva Energy
4.15pm	Speakers Forum	
4.50pm	Close	
5–6.30pm	Cocktail Function & Networking Drinks	

To register online visit the Events tab at www.apga.org.au

Duratec Australia

Q: In what year was your company established?

A: Duratec Australia was established in 2010.

Q: How many employees did you employ when you first started the business?

A: We first started out with ten employees.

Q: How many do you currently employ?

A: We currently employ 353 staff members across Australia.

Q: Do you operate from a number of locations in Australia?

A: We have an Australia-wide footprint with offices in Perth, Kalgoorlie, Karratha, Darwin, Melbourne, Sydney, Brisbane and Adelaide. We also operate special project offices in Tasmania, Wheatstone and Barrow Island and at selected mine sites across Australia.

Q: What is your core business? (e.g. blasting and painting, rubber lining, waterjetting, laminating, insulation, flooring etc.)

A: Duratec Australia is a solutions-based contractor specialising in the protection and remediation of steel and concrete structures. This encompasses a wide range of services including technical surveys, specialist access systems, concrete repair, blasting and painting, high performance coating systems, structural strengthening and waterproofing.

Q: What markets do you cover with your products or services? eg: oil & gas, marine, chemical process, general fabrication, tank lining, offshore etc.

A: We service a wide range of market sectors including: mining, oil and gas, industrial, marine, water and waste water, along with government assets and commercial infrastructure, including heritage buildings.

Q: Is the business yard based, site based or both?

A: Duratec complements our site works capabilities with three blast and paint facilities in Kalgoorlie, Karratha and Darwin. These facilities have dedicated abrasive blasting and painting enclosures able to accommodate any size project from small equipment pieces to large dump trucks.

Q: What is your monthly capacity or tonnage that you can blast and prime?

A: 50 to 100 tonne per week for each of our three regional blast and paint yards and on site to project requirements.

Q: Do you offer any specialty services outside your core business? (eg. primary yard based but will do site touch up etc.)

A: Duratec has diverse civil engineering experience and can provide a wide range of specialist civil services to complement our core capabilities. Our sister company Fortec Australia offers a diverse range of specialist construction, engineering and geotechnical services including the supply of construction products.

Q: What is the most satisfying project that you have completed in the past two years and why?

A: We recently completed corrosion repairs to a reclaimer at Rio Tinto's Yandicoogina Iron Ore Mine in the Pilbara during a scheduled shutdown. Our scope of works included corrosion removal, parent metal repairs and the application of protective coatings in fully encapsulated work zones.

Despite the inclement weather (during which work came to a halt) we were still able to successfully complete the project on time and under budget ensuring no unscheduled downtime for our client.

Q: What positive advice can you pass on to the Coatings Group from that satisfying project or job?

A: Maintaining a mine site's fixed assets is essential in maximising the operational life of equipment, maintaining optimal productivity and avoiding unscheduled shutdowns, so we would emphasise the importance of effective project planning and scheduling, resourcing the best project team and maintaining excellent lines of communication with the client at all times.

Q: Do you have an internal training scheme or do you outsource training for your employees?

A: We conduct both internal and external training and are committed to conducting business in a way that sees the safety of staff and others maintained by ensuring our employees are highly skilled, correctly trained and provided with career development opportunities.

Central to our training strategy is our in-house Training Database where employee training records are entered and tracked to ensure training is current. The database allows individual training plans to be developed, aimed at growing the company's skill base and providing professional development.

Contact
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info@duratecaustralia.com.au
www.duratecaustralia.com.au

DURATEC AUSTRALIA


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REINFORCED CONCRETE CORROSION, PROTECTION, REPAIR & DURABILITY

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TECHNICAL PROGRAM & REGISTRATION INFORMATION

OVERVIEW OF EVENT

The Australasian Corrosion Association (ACA) is holding an International Symposium to highlight the achievements of Brian Cherry in the areas of:

- reinforcement corrosion in concrete
- condition assessment
- modelling & deterioration prediction
- concrete repair & protection
- cathodic protection
- concrete durability options

If Percival Faraday (P F) Thompson is considered 'the Grandfather' of corrosion science and engineering in Australia, then Professor Brian Cherry of Monash University can be considered 'the Father'.

Brian has not just educated in the tertiary space many of the leading corrosion science and engineering practitioners, but he has also educated others in the profession at conferences, seminars and symposia. It is not just his educating abilities that we should be thankful for, but also his research and investigative works in various fields of corrosion science and engineering.

One of the fields that Brian has educated, researched and investigated over many decades is 'Reinforced Concrete Corrosion, Protection, Repair & Durability'.

High calibre International and Australian speakers will each present a keynote of 45 minutes duration. A panel discussion and open forum will be held at the end of each day. Technical papers of high quality and of substantive length will form a hard-copy book for delegates.

PROGRAM DAY 1

Time	Session	Speaker
8:20 – 8:50	Registration Day 1	
8:50 – 9:00	Welcome & Seminar Opening	Organising Committee
	Overview Presentations	
9.00 – 9:50	'Up-to-Date Overview of Aspects of Reinforced Concrete Corrosion'	Warren Green/Frank Collins/Maria Forsyth (Aust)
9:50 – 10:40	'Up-to-Date Overview of Repair & Protection Aspects'	John Broomfield (UK)
10:40 – 11:10	Morning Tea & Exhibition	
	Condition Assessment of Structures	
11:10 – 12:00	'Specialist Examination & Diagnosis'	Jack Tinnea (USA)
12:00 – 12:50	'Corrosion Rate Measurement & Modelling'	Carmen Andrade (Spain)
12:50 – 13:40	Lunch & Exhibition	
	Modelling & Deterioration Prediction	
13:40 – 14:30	'Modelling Durability of Reinforced Concrete Structures'	Rob Melchers (Aust)
14:30 – 15:20	'Modelling of Reinforcement Corrosion Risks in NZ Structures – Experiences of Theory into Practice'	Neil Lee (NZ)
15:20 – 15:50	Afternoon Tea & Exhibition	
	Concrete Repair & Protection	
15:50 – 16:40	'Concrete Repair & Protection – 30 Years of Onsite Performance Experiences in the UK'	John Drewett (UK)
16:40 – 17:25	Panel Discussion & Open Forum	
17:25 – 17:35	Day 1 Closing Remarks	Organising Committee
17:45 – 18:45	Networking Cocktail Function & Exhibition	
18:45 – 22:00	Dinner	

SPONSORED BY:

PROGRAM DAY 2

Time	Session	Speaker
8:20 – 8:50	Registration Day 2	
8:50 – 9:00	Welcome Remarks	Organising Committee
	Concrete Repair & Protection (continued)	
9.00 – 9:50	'NZTA Experiences with the Protection & Repair of Concrete Road Bridges'	Barry Wright (NZ)
	Cathodic Protection	
9:50 – 10:40	'Cathodic Protection of Reinforced Concrete: Is There Anything Still to Learn?'	Jim Preston (UK)
10:40 – 11:10	Morning Tea & Exhibition	
	Cathodic Protection (continued)	
11:10 – 12:00	'ICCP for Reinforced Concrete Structures – State of the Art'	Paul Chess (UK)
12:00 – 12:50	'Cathodic Protection, Cathodic Prevention & Electrochemical Chloride Extraction Experiences'	Zita Lourenco (Portugal)
12:50 – 13:40	Lunch & Exhibition	
	Organic Corrosion Inhibitors	
13:40 – 14:30	'Organic Corrosion Inhibitors – New Build & Existing Structures Performance'	Jessi Jackson-Meyer (USA)
14:30 – 15:20	'Organosilane Corrosion Inhibitors – New Build & Existing Structures Performance'	Neale Berke (USA)
15:20 – 15:50	Afternoon Tea & Exhibition	
	Alternate Metallic Reinforcement	
15:50 – 16:40	'Stainless Steel Reinforcement Performance in Concrete'	Graham Sussex (Aust)
16:40 – 17:25	Panel Discussion & Open Forum	
17:25 – 17:35	Day 2 Closing Remarks	Organising Committee
17:45 – 18:45	Networking Farewell Cocktail Function	

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BE PREPARED - Is Surface Preparation for Concrete Repairs a Fad?

Hamid Khan – Product Segment Manager – Parchem

Prior to the commencement of concrete repairs, the fundamental thing to consider is surface preparation. The amelioration of damaged concrete structures involves many elements, from engineers, applicators and even legal counsel. This paper details the primary value of surface preparation, for without good bonding no repair system can be expected to perform.

Repair Material to Concrete Substrate – An Alien or a Monolithic Bond:

In European standard (EN1504-10:2003), the term bond refers to the adhesion of the applied material or system to the concrete substrate. Hence, adhesion has an underlying importance in the repair of concrete structures. Surface preparation of the concrete substrate is considered to be the most crucial step in a concrete repair project. A poorly prepared surface will result in the weak association to the repair zone, no matter how proficient the applicator or expensive the repair material might be. The repair material when applied, should not act as 'an alien body' to the host concrete substrate, rather, it should become an integral part of the existing concrete restoring the structure to its original monolithic strength. Lukovic et al., (2012), in their paper "Reliable Concrete Repair – A Critical Review", highlighted that the composite system, by the integration of the repair material with the existing concrete forming a monolithic bond, would allow uniform transfer of stresses in the system.

It is pointless to exert efforts to achieve good adhesion to a weak friable substrate as failure of the concrete surface is imminent in such cases. Similarly, a sound surface might result in poor adhesion if the surface is not properly prepared. The good bonding of repair material to the existing substrate predominantly relies firstly upon, the mechanical bond of a well prepared substrate and secondly, upon the chemical bond amid the repair materials. Several other factors determining the bond strength of the repair system, include exposure conditions, properties of the repair materials and concrete substrate to name a few.

Sawn Edges – Doing It Right the First Time:

Saw cutting is used to delineate the perimeter of the repair zone. A disc type mechanical grinder is used for saw cutting the edges along the perimeter of the repair area. The right angled saw cut to a depth of 10-15mm is recommended to avoid any feather edging and it should not be deeper than the reinforced concrete cover. Saw cut squared edges help contain the repair material. The saw cut edges should be roughened slightly by a needle gun or hacking, as a polished vertical sawed face may result in poor bonding.

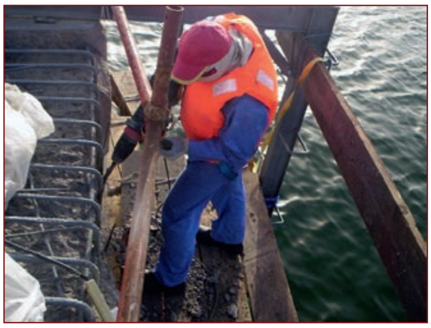
The geometry of the repair area should be in simple square or rectangular shapes. Sharp acute angles and re-entrant corners should be avoided (Figure 1). Some concrete repair field installers usually form excessive or tortuous edge conditions as they try to closely follow the geometry of the distressed concrete. Such complex and zigzag edge conditions often result in shrinkage stresses leading to cracking. Where saw cutting is not possible due to smaller areas, chipping tools should be used to remove concrete, ensuring that the edges of the repair area are cut perpendicular to the substrate.

Figure 1: Concrete Repair Geometry. Source: ACI Webinar, 2013

Removal of Spalled Concrete:

Most of the repairs require surface preparation comprising of roughening, exposure of the aggregates and removal of the damaged, delaminated and loose concrete. Regardless of the type of deterioration, all weak, flaky, unsound and disintegrated concrete must be removed. Defective concrete should be broken back to a sound and dense concrete surface. Prior to the removal of any spalled concrete from a load bearing structure, certified shoring must be provided to the structure. The removal of concrete usually starts with saw cutting the repair boundaries. The deteriorated unsound concrete in the centre of the repair area is then removed. Breaking out and the removal of concrete progresses from the centre outwards towards the edges. The next step is to remove the concrete near the edges without damaging the sound concrete at the interface.

The extent of concrete removal depends on the extent of damage. Concrete may be removed by impacting methods using power tools (Figure 2 and 3), or by hydro-demolition such as water blasting and water jetting. The most commonly used concrete removal techniques are impacting methods such as hand held percussive equipment, pneumatic breakers, chipping hammers and scabblers where repeated striking of a concrete surface with a high powered tool to break the concrete is employed. Whenever unsound concrete is removed using impacting methods such as percussive power tools, the surface of the concrete might exhibit micro-cracking or bruising that will form a weak plane acting as a 'bond breaker'. It is recommended that the remaining concrete should therefore receive additional cleaning and preparation using wet sandblasting or water jetting. To avoid any micro-cracking of the concrete substrate, hydro-demolition or abrasive sand, shot or water blasting sometimes become the preferred choice for contractors.



Figures 2 & 3: Impacting Method - Removal of deteriorated concrete by jack hammer.

Figure 4: Concrete substrate is ready to receive repair materials after final surface cleaning.

Figure 5: Steel cleaning and splicing by lapping after removal of concrete.

Concrete Surface Cleaning – Avoid Bond Breakers:

After removal of the deteriorated concrete the exposed concrete substrate must be cleaned with high pressure water washing, oil free compressed air or other appropriate methods. Normal low pressure water washing at 15 MPa or high pressure water washing at 35 MPa can usually be adopted to clean concrete surfaces that have already been prepared by impacting concrete removal methods. Though, some might consider it a redundant step, surface cleaning is crucial to attain the robust bond between the repair material and the substrate. Surface cleanliness is a critical step in surface preparation after the concrete removal process, and prior to the commencement of repair material application, as any dirt, debris or loose particles can act as 'bond breakers'. Surface cleaning facilitates repair materials having direct contact with the host concrete substrate, increasing the surface contact area and roughness of the surface, resulting in enhanced bonding of the applied repair material (Figure 4).

Steel Reinforcement Surface Preparation – Reaching Behind and Between Corroded Rebars:

On steel reinforcement there may be the problem of corrosion. This normally takes the form of rust. Initiation of corrosion and de-passivation of reinforcement is only possible in the presence of water, oxygen and corrosive agents such as chlorides and carbon dioxide. The rust layer is mechanically weak, poorly bonded to the surface and must be removed prior to any application. According to the American Concrete Institute (ACI 546), all weak, spalled, severely cracked, damaged, and easily removable concrete should be chipped away from corroded reinforcement steel. All corroded steel in the repair area should be fully exposed to full circumference and thoroughly cleaned of all loose scale, corrosion deposits and other contaminants. An old rule of thumb is that at least 20- 25mm of clearance around and behind rebar is required to ensure proper cleaning, encasement and bond of repair materials, also complies with the requirements of ACI, AS, EN and other standards.

If the deterioration of concrete has been caused by corrosion of reinforcement, the products of corrosion must be removed prior to the application of the repair material, or else the repair will be short lived. If the structural capacity of the reinforcement is compromised due to chloride contamination, it is essential to remove all rust from the steel before proceeding. Steel reinforcement should be cleaned to achieve a surface preparation equivalent to AS1627 Part 4, Class 2.5 or Part 2, Class 2. The preferred method is abrasive blasting (SSPC-SP 10/NACE No. 2) or water jetting (Vaughn O'Dea, 2011).

Exposed reinforcement in smaller repair sections can be cleaned manually by using hand or mechanical wire brush and emery paper to reach and clean behind and between the rebars. Exposure of steel reinforcement must also continue along its length until non-corroded steel is reached and continued at least 50mm beyond to show sound rust-free steel. If the steel has lost more than 25 percent of its cross-sectional area due to rusting, splicing of reinforcement bars should be carried out by butt welding the bars with backing plates, lapping the affected bars with supplemental reinforcement (Figure 5) or by introducing coupler mechanical joints. The reinforcement bars used in repairs should conform to the requirements of AS4671 and be of the same Grade as the existing steel. An unbroken coat of anti-corrosion zinc rich epoxy primer is normally recommended to protect the steel reinforcement within repair mortars.

Bonding Agents – Bond Aiders or Bond Breakers:

There are number of repair failures recorded when concrete surface preparation prior to repair is neglected due to a false assumption that poor surface preparation can be compensated by using a bonding agent (Bissonnette et al., 2012). Engineers specify bonding agents as a 'belt and braces' measure to enhance the bond at the repair interface, but it should not be considered by any means a replacement of correct surface preparation. Bonding agents provide an additional step and a layer that can create a weak plane if the manufacturer's instructions are not followed. If the bonding agent is allowed to cure prior to the application of the repair mortar, it would rather act as a 'bond breaker' than a 'bond aider', causing failure of the repair. Sprayed repair mortars, in particular, do not require bonding agents as the shotcrete process exhibit excellent bonding characteristics by itself (Figure 6).

Figure 6: Sprayed repair mortar application .

Drunken Concrete – A Safe Compromise:

When repairs are to be carried out using cementitious mortars, the surfaces must be pre-wetted to achieve a Saturated Surface Dry (SSD) condition after cleaning in order to avoid host concrete absorbing the moisture from the repair mortar that is in fact required for its hydration. Although, the term SSD is somewhat subjective, yet many experts consider it a 'safe compromise' for pre-soaking the concrete. If the concrete is dry and 'thirsty', pre-soaking is of utmost importance. The concrete should be thoroughly pre-soaked so that the concrete is 'drunk' with water. If the substrate is not pre-soaked thoroughly, the rate of movement of water from the repair mortar to the host concrete will be high due to the moisture imbalance between the adherent 'substrate' and the adhesive 'repair mortar'. In the SSD condition, the substrate is damp and saturated but does not contain any free water on the surface. Free water at the surface must be avoided as it can impair the bond at the interface due to increased shrinkage leading to lower material strength and reduced bond strength.

Surface Preparation Safety – Be in Control of Potential Hazards:

The effect of the concrete removal on the structural integrity prior to the commencement of removal of existing deteriorated concrete, must be thoroughly assessed. In case of removal of spalled concrete or damaged reinforcement of structural elements, precautionary measures must be employed by providing temporary support. During the concrete breakout and removal process, dust and debris should be contained so as not to pose any hazard to the stakeholders. The areas of repair should be examined to ensure there are no embedded electric conduits, sockets or utility connection lines that might get damaged during concrete removal. All effective measures should be adopted to ensure the safety of the structure and workers are not compromised by repair activities.

Surface Preparation Testing

The tensile pull-off adhesion test of the existing concrete should be conducted as part of the condition evaluation report. To ensure that the surface preparation procedures were followed as per the specifications, the pull-off strength of the prepared surface prior to repair application is measured. ICRI Guideline No. 210.3-2004, "Guide to Using In-Situ Tensile Pull-off Tests to Evaluate Bond of Concrete Surface Materials" is followed by most engineers. In case of a significant deviation of the pull-off strength of the prepared surface from the tensile strength of the existing concrete, the result should be examined by the engineer for additional surface preparation. Such benchmark criteria would allow the engineer to establish and specify the realistic adhesion strength requirements for the on-site repair condition.

To prequalify the quality of a repair, it is vital to evaluate the quality of surface preparation and eventually the durability of bond. This is done by conducting the direct pull off test on a representative sample area for the cured in-situ repair material. This step of surface preparation testing would verify the tensile bond strength of the repair material and the existing host concrete. During the course of the project, surface preparation needs to be periodically validated using tensile pull-off test method, benchmarking the engineer's specifications and the values obtained during prequalification of the reference sample. VicRoads, Standard Specifications, Section 689 suggests that the mean adhesion or pull off strength to concrete substrate at 7 days should not be less than 0.75 MPa, with no individual result less than 0.65 MPa for substrate mode of tensile failure within existing concrete substrate. Bond values for shotcrete and form-and-pour repairs typically exceed 0.75 MPa and, in most cases exceed 1.0 MPa. The ACI 503R and VicRoads Test Method RC 252.02 are commonly used standards for pull-off testing.

Conclusion:

The best of repair materials, despite the best of mixing and application practices, are destined to fail unless the concrete substrate is properly prepared. The intent of this article is to promote precise specifications for surface preparation rather than taking a broad generic approach. The conventional approach of surface preparation for concrete repairs such as to 'clean and sound' should be avoided. This commonly used phrase is too ambivalent to specify the correct level of surface preparation. There is a need to go beyond the boundaries of a 'clean and sound' approach. Field technicians and installers are the cornerstone in any concrete repair project. They must be provided with thorough technical training to enhance their skills. Surface preparation will often be pivotal in determining the overall performance and durability of a repair. A successful repair means that the resulting multi-layer system acts monolithically, ensuring long service life. Proper attention to surface preparation is essential to achieve a robust bond between repair materials and the existing concrete substrate. Only a strong bond will lead to a strong and durable repair. If you want to get the most out of the repair materials, then be prepared to prepare!

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Charles Darwin University – Corrosion Engineering

Corrosion Research at the School of Engineering and Information Technology is well established and a few projects are on-going. The corrosion research being carried out is relevant to the Northern Territory. As the temperatures in the NT are are higher than most of Australia and more humid than in other places, research into microbially influenced corrosion (MIC) is being undertaken. Mining is another area that is important to the Northern Territory and research into corrosion of hardfacing alloys is being carried out. Another area of focus is the understanding of corrosion of buried infrastructure and, thus, asset management and maintenance engineering are a key part of this research.

Corrosion research at the Charles Darwin University (CDU) is led by Assoc Prof Krishnan Kannoorpatti. Corrosion research at the CDU is multidisciplinary and comprises of Prof Suresh Thennadil, Assoc Prof Suresh Kumar, Damien Hill and Dr Vinuthaa Murthy.

Assoc Prof Krishnan Kannoorpatti is a materials engineer with research experience in corrosion engineering, welding engineering and corrosion modelling. He has helped the local industry to address problems related to corrosion and materials engineering. Prof Suresh Thennadil is a chemical engineer with special interest in developing sensors. Assoc Prof Suresh Kumar is a mechanical engineer with specialisation in asset management and maintenance engineering. Damien Hill is an electronics and control system specialist and is responsible for helping us understand and develop electronic control systems in advanced corrosion instrumentation. Vinuthaa Murthy is a chemist whose interest focuses on chemical and structural stability of surfaces using density function theory.

The corrosion research laboratories are located within the North Australian Centre for Oil and Gas (NACOG). This has been funded by the oil and gas companies and the Northern Territory Government. As a result, the NACOG is able to input the feedback and ideas from the industry for the research carried out at the Centre. Recently, Clough Engineering funded the position of Assoc Prof Suresh Kumar to research in asset management and maintenance engineering.

The corrosion research laboratories provide excellent facilities to carry out corrosion research. The School has subscribed to some key research journals, through the library, including the Corrosion Analysis Network from the American Society for Materials.

Mr. Varmaa Marimuthu recently completed his Master's by research thesis on the corrosion behaviour of hardfacing alloys. The research found that although the hardfacing alloys are selected mainly on their hardness, their corrosion behaviour is not normally a consideration though they are used in areas where corrosion may be an issue. Varmaa was able to show through thermodynamic stability diagrams that carbides could be prone to corrosion. In fact, carbides were to found to dissolve rendering the hardfacing alloys prone to rapid wear. As there is an interest in using the alloys for fuel cells as coatings, this research is key in developing newer alloy carbides.

Research is also being carried out to develop a new corrosion cell to understand corrosion in buried structures. This is closely related to the corrosion influenced by microbes. Preliminary research has shown that the MIC in Darwin waters can be 5 times that of waters in other parts of Australia. It is not clear if it is the temperature effect or the presence of unusual microbes that create more aggressive conditions.

Corrosion researchers at CDU have established close relationships with Monash University, James Cook University and Curtin University. CDU also has a good relationship with the Indian Institute of Technology (IIT), Bombay through the signing of an MOU in corrosion engineering.

Charles Darwin University offers PhD and Masters by research programs in corrosion engineering. There are exciting research opportunities for new postgraduate students interested in corrosion engineering research. Topics include:

- Thermodynamic stability diagrams for hardfacing alloys
- Developing erosion-corrosion models for the mining and the minerals industry
- Microbially Influenced Corrosion in alloys used in the oil and gas industry
- Corrosion modelling for structures exposed to the differential aeration corrosion
- Numerical analysis of corrosion in complex structures

For further information contact krishnan.kannoorpatti@cdu.edu.au.

CHARLES DARWIN UNIVERSITY

NEW PRODUCT SHOWCASE

The ACA does not officially endorse any of the products advertised in *Corrosion & Materials*.

Onsite portable XRD corrosion analysis from Olympus

The economic impact of all types of corrosion and its degradation of infrastructure represents an annual cost of many billions of dollars to industry. Effective corrosion management strategies can help reduce the cost.

One analysis technique that can be used in corrosion management is X-ray diffraction (XRD). According to Dane Burkett, Product Specialist with Olympus, "Traditional analysis of corrosion products only indicates their presence, or their chemical composition, such as iron (Fe)-bearing. XRD can identify and quantify corrosion and scaling products by characterising their crystallographic structure."

Comprehensive compositional materials analysis can now be carried out onsite using the field portable Terra XRD and XRF analyser from Olympus. "Using a Terra unit, our customers can analyse their samples directly on an oil platform, remote plant or refinery," Burkett said. "The results can then be transmitted back to a corrosion expert—either on or offsite—to help devise a solution."

The crystallographic structure of corrosion and scaling products is unique, much like a fingerprint. XRD works by subjecting a sample to a monochromatic X-ray beam and measuring the angles at which the X-rays diffract. A combination of diffraction angles is characteristic of a given phase of a particular corrosion or scaling product.

XRD can also distinguish between different corrosion and scaling products that have the same, or similar chemistry. For example, the ferrous corrosion products goethite, lepidocrocite, feroxyhyte and akaganeite can be distinguished from each other, even though they all have the chemical formula FeO(OH).

The identification of compounds (as opposed to elemental compositions) is crucial for the understanding of corrosion processes. "Different corrosion and scaling products form under different conditions and in different environments," said Burkett. "Information about the presence and quantity of these phases is not only helpful in explaining the corrosion process, but can help to determine the root cause, locate the origin of corrosion in a facility and, at the same time, indicate possible solutions to the problem."

Knowing how corrosion products form allows an engineer to optimise a process to stop or slow their occurrence. For example, the temperature or pressure parameters can be adjusted or leaks can be located and repaired.

The Terra portable XRD analyser is a high performance, self-contained, battery operated, closed-beam XRD system that provides full phase identification of major, minor and trace components. The ruggedised and functional unit combines X-ray Diffraction and qualitative X-ray Fluorescence (XRF) analysis using a specifically developed direct excitation charge coupled device (CCD) 'camera'.

The Terra simplifies sample preparation and to ensure a sufficiently random orientation of crystals, the patented sample vibration chamber built into the unit presents the instrument's optics with multiple orientations of the crystalline structure.

The Terra can be used in a wide range of applications including oil/gas, geothermal and mineral exploration; mineral processing; mineral identification; mid-stream processing for pharmaceuticals and industrial materials; counterfeit drug screening; fire and explosives forensics; and corrosion monitoring.

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Proven in the most severe conditions a product that creates a non-drying barrier of protection is now available in Australia through Russell Fraser Sales (RFS). Fluid Film has become the worldwide standard for corrosion control and equipment maintenance. The unique formula contains no solvents, remains active, will not become tacky and will therefore provide long term protection to all metals as well as superior lubrication on moving parts.

In the critical aerospace & aviation industries, corrosion preventives and lubricants can face a vast and extensive battery of tests to reach chemical approval. Fluid Film has faced intense scrutiny by government research laboratories as advanced as Boeing's Space Systems Division for use on the Space Shuttle and Boeing's Engineering Materials and Process Laboratory for use on aluminum alloys, exceeding process requirements and expectations, ultimately resulting in reduced maintenance costs.

Fluid Film has proven so effective in these industries that specifications were written by the U.S. Navy/Army/Marine Corps, Sundstrand Aerospace, Boeing North America, U.S. Coast Guard, U.S. National Guard, Sikorsky Helicopter and Delta airlines for the use of Fluid Film in a variety of applications. The U.S. Air Force, in accordance with Mil-C-16173-E Grade 2, conducted testing on Fluid Film and it exceeded all performance requirements.

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The economic impact of corrosion is often exacerbated in harsh climatic environments and in workplaces with heavy traffic wear from operation of large vehicles and equipment. Excessive moisture, heat and abrasion can accelerate the deterioration of machinery, vehicles and assets. Applying a protective surface coating is one way of minimising or reducing the effect.

One coating material for harsh conditions—including those in a combat zone—supplied by Rhino Linings Australia (RLA) is Rhino Extreme 11-50 FR. While the material has been available for several years, it was only late in 2016 that the fire resistant nature of the product received certification. RLA's Technical Manager, Robert Idzes, said “The formal certification of Rhino Extreme 11-50 FR has opened up a range of new opportunities for industrial and commercial applications of the product.”

The spray-applied pure polyurea is suitable for any application, such as a fuel bund—secondary containment area—that requires a fire resistant surface. The flame resistant properties of Rhino Extreme 11-50 FR significantly reduces the burn rate allowing safety officers and staff time to extinguish the flames before major damage is caused to the liner or catastrophic failure occurs.

“The Rhino Extreme 11-50 FR is the latest Flame Retardant product to meet US Federal Aviation Regulation 25 (FAR 25) Flammability testing for aircraft,” said Denis Baker, Special Projects Engineer at RLA. “In addition, it also meets UL 94, which is another high standard at the moment for coatings.” The FAR 25.853 tests the self-extinguishing performance of materials under fire conditions.

Due to its excellent blast mitigation properties, Rhino Extreme polyurea is able to contain and minimise shrapnel damage, enabling it to be used on barracks, tactical vehicles, temporary structures and buildings. It can also be used on vehicles and equipment requiring abrasion, corrosion and impact protection and when applied with a textured finish (R10 dry slip resistant rating) it is ideal for foot traffic areas requiring a non-slip surface.

Mixed in a 1:1 ratio, the material is a two-part, flame retardant, elastomeric, polyurea. The product's flame resistance makes it an ideal coating for numerous applications that require a flammability rating, all the more important as fire regulations become more stringent.

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Tools & Tips: Holiday Detection on Coated Steel & Concrete Substrates

By Tom Swan, November 19, 2015 (republished from *Corrosionpedia.com)*

I'm often asked questions about holiday testing or, as the Europeans call it, porosity testing. Of course, pinholes in a newly applied coating can leave the substrate exposed to the environment and vulnerable to corrosion. It is the coating inspector's job to detect and document these defects.

There are two main categories of holiday detectors: low voltage (sponge) testers and high voltage (Jeep) testers. According to almost all of the coating standards, you may use a low voltage tester for coating thicknesses of up to 500 microns (500 µm). If thicker than that, go to a high voltage tester. High voltage testers can be used down to about 250 microns, but I generally do not recommend it if you can use the low voltage tester.

Using Low Voltage (Sponge) Testers

Sponge testers are relatively simple to use. Ground them to the surface and run the damp (wet but not dripping) sponge over the surface. While the coating standards limit the use of sponge testers to 500 micron coatings, I have run a sponge tester side by side with a high voltage tester on coatings up to 1250 microns and have found the same holidays.

On thicker coatings (250 to 500 microns), use a surfactant or wetting agent to make sure that the water doesn't "bridge over" the holidays due to surface tension. Here's another trick not found in any of the standards that I use when holiday testing small areas such as the inside of a valve: Grab the sponge tester in one hand and use your other hand with a damp finger to find any pinholes. On some models you might get a small shock, but you are an inspector so you can take it. Note: This tip is only for a low voltage tester.

A sponge tester generally costs $500 to $600 for a battery-powered detector. ASTM standards require 67.5 volts. ISO standards use 9 V for steel and 90 V for concrete. Several low voltage testers on the market have user-selectable voltages that will do all three voltages.

Choosing a High Voltage Tester

High voltage testers are generally in the $3,700 to $6,500 range and the features can vary widely. It is best to work with someone knowledgeable when purchasing one to make sure that you get the model and features you want. Most high-voltage testers will top out at 35,000 to 40,000 volts, but 90% of users will rarely need over 10,000 volts.

There are two types of high voltage holiday testers: direct DC and pulse types.

Direct DC is generally less expensive and works well on dry coatings. Because the DC tester puts out a constant current as it goes over the surface of the coating, it can impart a current into the coating that will back-feed to the wand causing detection of a "false" holiday. There is a sensitivity knob on these meters to adjust the milliamp setting that will trigger a "beep" from the meter. For most coatings, the default setting will generally work; however, if you are getting "beeps" (or Jeeps) from the meter without a spark, you may need to change the setting.

Pulse-type meters are more versatile in that they can be used in damp environments even with moisture condensation on the coatings. The electrical pulses are generated between 20 and 60 Hz. Each electrical pulse is "on" for a time period of 20 to 200 microseconds. They do not require the sensitivity knob. While the pulse-type meter has the advantage of being able to work in damp conditions, both types of meters will work under most circumstances with proper training.

Tips on Testing Coated Concrete

Using a high voltage detector on steel or conductive substrates is generally straightforward. When it comes to testing for holidays on coatings on concrete, it can get a little tricky.

I do not have any experience in very dry, desert environments, but generally there will be enough moisture and salts present in concrete to make it conductive. When testing pipelines, inspectors sometimes just drag the ground cable along on the ground since both soil and concrete conduct electricity. But a proper earth ground is always best.

To create a proper ground for holiday testing concrete, I generally recommend the following steps:

If available, ground the detector to rebar in the concrete.

If rebar is not available, steel is often bolted directly to the concrete. You can ground the detector to the bare steel.

If testing a slab with no steel rebar, drive a piece of rebar into the ground to at least the depth of the slab and immediately next to the slab. It helps if you make sure that the soil is wet. Use this as your ground.

An alternative grounding method is to place a 50mm x 50mm piece of ordinary metallic window screen wire flat upon the concrete surface. Place wet sandbags over the entire metallic surface and connect the ground wire to the screen wire. The wet bags placed upon

The relevant local Standards for holiday detection/continuity testing are AS 3894.1 (High voltage) and AS 3894.2 (Wet sponge).

the screen wire ensure intimate contact of the screen wire against the concrete surface. This grounding method is usually sufficient for either low voltage "wet sponge" testers, or high voltage "spark-type" holiday detectors.

Check the electrical ground of the detector by touching the brush to the bare concrete substrate and observe the audible signal. No audible signal means inadequate grounding and a better ground must be obtained or the signal sensitivity increased.

As with metal, first follow the specs; next, go to product data and application bulletins; and then go to the coating manufacturer.

If you still do not have a voltage setting, do not use the settings recommended for steel. The best way is to find several areas representative of the coating to be tested at varying distances from the ground. Create a holiday and determine the voltage necessary to create a spark, twice the distance across the coating if the coating is thick.

For example, if the coating thickness measures 2500 microns, the spark should "jump" 5000 microns across the surface then down to the substrate. If the resistance increases as you move away from the ground, you will need to increase the test voltage or, preferably, move the ground point.

Several concrete coating manufacturers are now making conductive primers. By using one of these primers, you can follow the procedures for holiday testing metallic substrates. However, since they cost more than standard primers, they are seldom used unless a holiday-free surface is critical.

Inspector tests for holidays on a section of pipe using a full spring electrode. Source: Tinker and Rasor

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Acidification Induced Deterioration of Concrete Cathodic Protection Systems and its Management

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1. Introduction

Sir Humphrey Davy was the founder of cathodic protection (CP). Davy postulated in January 1824 [1], that it would be possible to prevent corrosion of copper sheathing on ships by connecting it to zinc, tin or iron [2]. This was based on his observations and conclusions from over two decades of working with galvanic couples, and he certainly considered the beneficial effects for the more positive metal in the couple at least as early as 1812 [2]. The copper sheathing on the ships was needed to reduce fouling and prevent attack on the timber by worms. Davy then reported on full-scale trials in June 1824 [3] and showed the complete effectiveness of zinc and iron in protecting the copper [2]. He also published in June 1825 [4] the influence of ship movements on the efficiency of the protection action and the effects on fouling [2].

Davy's work defined the two ways in which we apply CP to this very day, by using galvanic anodes or by imposing impressed current where current is forced from an anode through the electrolyte onto a structure (cathode) using a DC power supply [2]. Both methods of CP act to shift the potential of the structure to be protected in the negative direction. The anode is consumed while the cathode is protected if there is sufficient current to provide the requisite polarisation [2].

2. Impressed Current CP of Concrete

In terms of CP of reinforced and prestressed concrete structures and buildings, it is known that a properly designed, installed, operated and maintained impressed current system will halt reinforcement and prestressing steel corrosion in concrete. This is regardless of the chloride content or depth of carbonation in the concrete as well as the extent and rate of reinforcement or prestressing steel corrosion [5].

CP has been applied to reinforced concrete structures and buried pre-stressed concrete pipelines since the 1950's [6] [7]. Richard Stratfull first applied impressed current CP to atmospherically exposed steel in concrete in a successful trial in 1959 [8]. Stratfull continued to investigate and experiment with impressed current CP, and in 1973 undertook the first full scale installation on a concrete bridge deck in California [9]. Direct experience with impressed current CP of concrete structures in Australia dates back to the 1980s [10].

An impressed current CP system works by converting the reinforcing steel (or prestressing steel) surface into a cathode, hence the name, and moving the anodic reaction onto an alternative material [10].

There are many types of impressed current anodes, and selection of the correct anode is important in determining the systems overall cost and durability. The variability in impressed current anode types presents the CP designer with great flexibility in providing the optimum protection current at the correct locations for the desired structure life. Combinations of impressed current anodes can also be utilised to provide the most whole-of-life (life cycle) cost effective solution. Table 1 provides an outline of the various impressed current anode types by category [11].

3. 'Galvanic CP' of Concrete

There are various galvanic anode types for the provision of cathodic current to reinforcing steel (or prestressing steel) in concrete. The extent of cathodic current provision by such anodes may or may not lead to CP per se in accordance with concrete CP standards (e.g. AS 2832.5, [12]; BS EN ISO 12696, [13]).

Galvanic anodes based on metallised coatings (electric arc sprayed) of pure zinc (>99% purity) have been applied to a limited extent to structures in Australia since the mid-1990s and those based on aluminium-zinc indium to a limited extent since 2000 [14]. Galvanic systems for concrete that are based on embedded zinc (Zn) anodes or Zn sheet anodes are a more recent development in Australia [5]. The embedded Zn anodes are typically encased in a medium that is formulated to maintain the electrochemical activity of the Zn (since Zn is prone to passivation from oxides from its own corrosion products) [5]. Table 2 provides an outline of the various galvanic anode types by category [11].

Surface Applied	Encapsulated	Immersed/Buried
■ Organic conductive coating ■ Arc sprayed zinc ■ Thermally sprayed titanium ■ Conductive cementitious overlay	■ Electrocatalytically coated titanium mesh or grid, surface installed and embedded into cementitious overlay ■ Electrocatalytically coated titanium ribbon, ribbon mesh or grid, embedded into cementitious grout in recesses (chases, slots or grooves) cut into the cover concrete ■ Electrocatalytically coated titanium strip, mesh, grid or tubes, embedded into cementitious grout in holes drilled into the concrete ■ Platinum-coated titanium rods in conductive graphite-based backfill in holes drilled into the concrete ■ Conductive titanium oxide ceramic tubes embedded in cementitious grout in holes drilled into the concrete	■ High-silicon iron (with chrome for chloride environments) ■ Mixed metal-oxide-coated titanium ■ Platinised titanium ■ Platinised niobium

Table 1. Concrete Impressed Current Anode Types by Category [11].

Surface Applied	Encapsulated	Immersed/Buried
■ Arc sprayed zinc	■ Zinc mesh within jackets	■ Cast zinc alloys
■ Arc sprayed Al-Zn	■ Zinc mesh in cementitious overlay	■ Cast aluminium alloys
■ Arc sprayed Al-Zn-In	■ Discrete zinc anode in patch repairs	■ Cast magnesium alloys
■ Adhesive zinc-sheet	■ Discrete zinc cylinders	
	■ Discrete rolled zinc sheet	
	■ Discrete zinc strips	

Table 2. Concrete Galvanic Anode Types by Category [11]

4. "Hybrid CP" of Concrete

In the last 5 or so years, systems referred to as "hybrid CP or hybrid anode systems", have emerged in Australia [15]. These systems were primarily developed in the UK and involve an array of embedded Zn anodes that are operated in impressed current mode initially (for a number of weeks) and then in galvanic mode [5]. [16] proposed that "hybrid CP" systems for concrete are more correctly termed "hybrid treatment" and not "hybrid CP" as CP in accordance with standards or codes (e.g. AS 2832.5, 2008; BS EN ISO 12696, 2012) may not necessarily be achieved with such systems but rather a corrosion rate reduction can be gained.

5. Acid Generation at Anode Surfaces

Oxidation of water can occur at concrete CP system anode surfaces resulting in the production of hydrogen ions and consequent generation of acid, i.e.:

$$2H_2O \rightarrow O_2\uparrow + 4H^+ + 4e^- \qquad (1)$$

Oxidation of hydroxyl ions can also occur at concrete CP system anode surfaces, resulting in consumption of alkalinity and consequent reduction in pH, i.e.:

$$4OH^- \rightarrow 2H_2O + O_2 + 4e^- \qquad (2)$$

However the voltages at which reactions 1 and 2 occur are significantly different and clearly are pH dependent. If chloride ions are present then oxidation of chloride ions to chlorine gas can also occur, i.e.:

$$2Cl^- \rightarrow Cl_2\uparrow + 2e^- \qquad (3)$$

The chlorine gas consequently dissolves in water to form hypochlorous acid and hydrochloric acid, ie.:

$$Cl_2 + H_2O \rightarrow HOCl + HCl \qquad (4)$$

Such acid generation at anode surfaces has been known for nearly 200 years for metallic cathodic protection [3] as well as since Faraday in 1834 whereby "*the positive pole that attracts oxygen, acids &c., or more cautiously, that it determines their evolution upon the surface*" [17]. This is confirmed by the reaction scheme shown in Equation 1 with the liberation of oxygen resulting in an increase in the acid concentration.

As it was known for metallic CP since its inception in 1824, it is a concomitant change that acid generation at anode surfaces will occur during concrete CP.

6. Acidification Induced Deterioration of Concrete ICCP Systems

Acidification induced deterioration of reinforced concrete structures to which impressed current CP has been installed has occurred in Australia, perhaps in situations where it could have been avoided through appropriate design. Oxidation reactions at anode surfaces generating acid has led to the neutralisation and deterioration of the cementitious grout and concrete around anodes in various reinforced concrete bridge and wharf structures.

Examples of acidification induced deterioration on reinforced concrete bridge sub-structure elements in which impressed current CP has been installed are shown at Figures 1 to 4. The impressed current anode system design in this instance was electrocatalytically coated titanium ribbon anode embedded into cementitious grout in recesses (slots) cut into the cover concrete.

The design of management options for acidification induced deterioration has not been possible for the structure owners of some bridge concrete CP systems, including above, as the opportunity for maintenance and rectification had passed i.e. the grout had become so deteriorated it was beyond redemption. The deterioration in these instances is attributed to the original system design, installation and operation errors, but most particularly improper design.

Examples of local acidification induced deterioration on reinforced concrete wharf sub-structure elements in which impressed current CP has been installed are shown at Figures 5 and 6. The impressed current anode system design in this example was electrocatalytically coated titanium ribbon mesh anodes embedded into cementitious grout in recesses (slots) cut into the cover concrete.

Figure 1. Example of deterioration/acidification of proprietary cementitious based backfill mortar within ribbon anode slots (typical).

Figure 2. Example close-up of acidification and neutralisation of backfill mortar in ribbon anode slot (typical).

Figure 3. Example of acidification of backfill mortar to expose anode ribbon and anode electrical (positive) connection (typical).

Figure 4. Example, another, of acidification and loss of backfill mortar to expose anode ribbon and anode connections (typical).

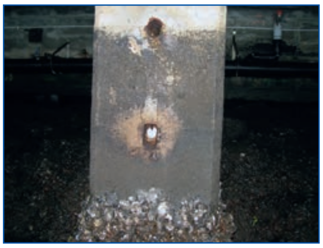

Figure 9. Example of acidification induced deterioration at pile anode locations (typical).

Figure 10. Example close-up of acidification induced deterioration to pile anode grout and concrete (typical).

Figure 5. Example of local deterioration/acidification of proprietary cementitious based backfill mortar within ribbon anode slot (typical).

Figure 6. Example of local acidification and neutralisation of backfill mortar in ribbon anode slot (typical).

Figure 11. Example of acidification induced deterioration to pile anode cable insulation (typical).

Figure 12. Example of loss of grout due to acidification and exposure of end of titanium current distributor (conductor bar) and end of anode (typical).

In these instances a maintenance process could be designed involving removal of deteriorated mortar, reinstatement with a more acid resistant mortar and application of a high-build (epoxy) coating system as shown at Figures 7 and 8. This process has led to the ongoing successful protective performance of the systems with minimal ongoing maintenance costs to the structure owners and implementation of the maintenance process by structure owner resources and not CP suppliers or CP contractors.

Figure 7. Example of localised "acidification" repairs undertaken by structure owner resources to wharf soffit element (see grey epoxy coating in photo) (typical).

Figure 8. Example of localised "acidification" repairs to anode ribbon slots undertaken by structure owner resources (see grey epoxy coating in photo) (typical).

Acidification induced deterioration is also possible of the grout and concrete surrounding discrete impressed current anodes. Examples of this type of deterioration to reinforced concrete wharf piles are shown at Figures 9 to 12. The impressed current anode system design in this instance was electrocatalytically coated titanium discrete ribbon mesh anode embedded into cementitious grout in holes drilled into the concrete.

The maintenance recommendations for this system then included:

1. Investigate systematically the extent of acidification induced deterioration to the piles and pile anodes.

2. Investigate the deterioration extent (i.e. depth, grout, concrete, anode, conductor bar, cable, etc.) within representative piles.

3. Investigate if acidification induced deterioration is occurring at splash and atmospheric zone pile anode locations.

4. Design anode, grout, cabling, etc. repair system including consideration of sub-zoning (more accurate current control, distribution, etc.) and utilisation of the spare channels within the transformer-rectifier unit (TRU).

7. Effects of Acidification

The field examples depicting acidification induced deterioration shown in Section 6 were due to uneven anode current distribution associated with variable anode to electrolyte (environment) resistance, specifically an anode current output that is sufficiently high which leads to too much acid generation via one or all of Reactions (1) to (4). A reduced anode (to electrolyte) resistance will lead to increased anode current output. Consequent excessive acid generation due to the increased anode current output will then lead to acid attack of the alkaline cementitious based grout/mortar and then concrete surrounding the anode.

The reduced anode (to electrolyte) resistance in the field examples shown in Section 6 was due to differences in exposure of the reinforced concrete elements to the marine environment, specifically some sections being more frequently wetted leading to a lower electrolyte (grout/mortar/concrete) resistance. The more frequent wetting, e.g. within the lower tidal zone versus the upper tidal zone, or the tidal and splash zones, or splash versus atmospheric zones, leading to a lower anode (to electrolyte) resistance will then cause 'current dumping' within the anode circuit. More frequent wetting can also occur locally, e.g. reflective wave splash onto a sea wall due to variability in the rock batter (scour protection). 'Current dumping' then results in a too high anode current output. Too high anode current will then lead to excessive acid generation at the anode/electrolyte (grout/mortar/concrete) interface.

The hydraulic binder of concrete, grout or mortar commonly consists of Portland cement or mixtures of Portland cement and one or more of fly ash, ground granulated iron blast-furnace slag or silica fume [18]. The reaction of the cement compounds of Portland cement or Blended cement with water results in the setting and hardening of the cement paste so that it binds the aggregate (coarse and fine) of the concrete, grout or mortar together. A product of the hydration of Portland and Blended cements is $Ca(OH)_2$ together with NaOH and KOH. As a result, concrete, grout or mortar is highly alkaline, pH~13. Acid generated at the anode/electrolyte interface will then react with the $Ca(OH)_2$, NaOH and KOH of the grout/mortar/concrete and ultimately the cement compounds.

Eventually the interface becomes sufficiently deteriorated that contact between the anode and grout/mortar/concrete is reduced leading to increased localised resistance. This in turn can result in increased current flow to other parts of the anode circuit thus raising the current density in these areas. This "knock on" effect can result in whole parts of the anode circuit becoming inoperative and, in extreme cases can cause significant damage to the concrete [19].

In the case of the bridge substructure elements CP system at Figures 1 to 4, management of the acidification induced deterioration was not possible as the damage had become too severe. The above-water and above-ground CP system anode zones were disconnected as no protection was being afforded and it would have been prohibitively expensive to fix the system. Conventional concrete repair, if and when damage becomes structurally significant, is the method of maintenance being adopted for the above-water and above-ground substructure elements of this coastal bridge.

Chess and Broomfield [20] also advise that the acid and chlorine gas generating chemical reactions from anode surfaces can also have implications for appearance (the cement paste normally contains bound iron that can give red staining) and adhesion (if the anode is 'glued' to the concrete surface, the bond strength can be reduced).

The bond of organic conductive coating based concrete CP systems may also be compromised by acid generation.

8. Lessons Learnt from Field Examples

Although the CP systems in the previous field examples were not designed by the authors, the lessons that can be learned from such field examples include:

- Poor design most particularly in the zoning and sub-zoning of the CP anode system within different exposure environments of the concrete elements. For example, lower tidal, upper tidal, splash and atmospheric exposure environments of bridge and wharf substructure elements.
- Improved design to enable more accurate current control and distribution within each anode zone and sub-zone.
- There is a concern that an excessive amount of anode material of too high a surface area is being designed for some systems (e.g. discrete "star configuration" ribbon mesh anodes) and the consequential performance expectations of the grouts is then unreasonable.
- Tighter specification of anode material. Some manufactured anodes are of varying composition, uniformity and quality. Stringent independent inspection, testing and analysis of anode systems prior to and during installation may also be necessary, and rejection of anode designs of too high a surface area.
- Tighter specification of the mortar or grout encapsulating the anode system. Stringent independent inspection, testing and analysis of mortar or grout prior to and during installation may also be necessary.
- Pre-evaluation of specialist contractors to tender a project.
- Pre-qualification and approval of contractor personnel to install anode, grout, mortar, etc. Pre-qualification, approval and maintenance of approval to be via workshops, trials, toolbox talks, test areas during installation, etc. Works by non-approved contractor personnel should then be condemned during any works.
- Consistent and frequent independent inspection and testing by the superintendent or superintendent's representative.
- More stringent and frequent inspection and testing requirements placed upon the contractor.
- Commissioning of the CP system by the structure owner or an independent consultant (that has no interrelationships with product supply, equipment supply or contracting).
- Monitoring and performance assessment of the system in accordance with concrete CP standards (e.g. AS 2832.5, [12]; BS EN ISO 12696, [13]). Within the field examples discussed above, remote monitoring and control systems performed poorly leading to too high a current output for too long a period.
- Current adjustment (typically a reduction) of the system so as to enable optimisation of the system life whilst conserving power.
- Routine maintenance of system components.

9. Acidification Induced Deterioration of Galvanic Anode Systems

The authors have not yet had any direct field experience with acidification induced deterioration of galvanic anode systems for concrete. However, such is considered unlikely since the reaction occurring on the surface of a galvanic anode is oxidation of the metal and not oxidation of water, oxidation of OH^- and/or oxidation of Cl^-. It is noted though that galvanic systems have not been installed for as long as impressed current systems and that investigation of the durability of galvanic anode systems is beyond the scope of this paper and could be the subject of future papers.

10. Acidification Induced Deterioration of Hybrid Systems

Similarly, the authors have not yet had any direct field experience with acidification induced deterioration of hybrid treatment of reinforced concrete. Hybrid systems have only been applied in the last 5 years or so compared with >40 years for impressed current systems. However, investigation of deterioration of the hybrid system is also beyond the scope of this paper and could be the subject of future studies.

11. Acidification Risk Management

As mentioned previously, it is a given that acid generation occurs at anode surfaces for concrete CP. Management of the risk of acidification induced deterioration of concrete CP systems is possible through improved systems design, installation, monitoring and maintenance. Different anode systems, not just in terms of their type but also their chemical composition, can contribute to better management of acidification risk. Mortar and grout formulation changes by suppliers has also contributed to improved acidification risk management. New technologies, technological changes, research into methods of performance evaluation and improvement, will also lead to improved management of the risk of acidification during the service life of concrete CP systems.

11.1 System Design, Installation and Monitoring

The lessons learnt from field examples cited earlier provides a listing of some design, installation, monitoring and maintenance suggestions that could be considered to improve acidification risk management of concrete CP systems.

Early identification of acidification induced deterioration by visual means during the regular monitoring and performance assessment of concrete CP systems is important so that suitable maintenance options can be developed. An example of a maintenance approach is the removal of deteriorated mortar, reinstatement with a more acid resistant mortar and application of a high-build (epoxy) coating system as indicated previously at Figures 7 and 8.

11.2 Anodes

Some anode/encapsulant systems are less susceptible to 'current dumping' and consequent acidification induced deterioration than others, e.g. electrocatalytically coated titanium mesh or grid, surface installed and embedded into cementitious overlay, refer Figures 13 and 14. In this instance a gap of ~300mm is provided within sections of the mesh to account for zoning associated with lower tidal, upper tidal and splash exposure micro-environments.

Figure 13. Example of electrocatalytically coated titanium mesh anode pinned to a bridge pier column concrete surface with plastic plugs and showing gap (~300mm) between anode zones as additional design means of managing current dumping (typical).

Figure 14. Example of cementitious overlay covering the titanium mesh anode to a bridge pier column in a marine environment (typical).

There are different coated titanium anodes available for impressed current CP of concrete, refer Table 1. The Mixed Metal Oxide (MMO) anode coatings consist of one or more oxides of the platinum group metals such as iridium, ruthenium and palladium [20]. The type of MMO coating can affect which of reactions (1) to (3) occur more favourably at the anode surface. For example, it is understood that RuO_2 favours oxygen production, reaction (1), while IrO_2 favours chlorine production, reaction (3) (Chess, 2016). Chess [21] then claims that "the chlorine producing reaction gives much less acidification than the water oxidation reaction".

Callon [19] reports that some anode manufacturers claim that certain physical and geometric properties reduce acid build up by allowing special escape mechanisms for the acid.

It is understood that some commercially available surface mounted anode systems have the ribbon anode surrounded by "glass fibre pads" and in other cases MMO titanium mesh surrounded by a "silicate based mortar".

Callon [19] notes that the ability of an anode to operate at high current densities is not related to the performance of the anode in concrete where the potential damage to the concrete (mortar, grout) is usually the governing factor rather than the consumption of the anode itself. For example Callon [19] advises, it is not uncommon for MMO coated titanium anodes to be rated at 600A/m^2 for 20 years in seawater, whereas concrete current densities much lower than this would result in severe deterioration of the concrete (mortar, grout).

11.3 Acid Resisting Mortars and Grouts

Manufacturers of mortar, grout and shotcrete for use in concrete CP have modified formulations to improve acid resistance. For example, Green et al [22] notes that the grouts and the shotcretes used for some marine wharf substructure projects were proprietary cementitious and CP compatible with known electrical resistivity characteristics and increased alkalinity (buffering capacity). These resist acidification by the electrochemical oxidising reactions at the anode to grout interface.

It is understood that some speciality concrete repair material suppliers have developed "geopolymer hybrid" mortars of claimed increased acid resistance. Other specialist suppliers have developed "silicate based" mortars and grouts of claimed increased acid resistance.

12. Research Opportunities

Investigation, research and development are necessary ongoing activities, and a possible list follows.

- Increased understanding of the reactions that occur at the surface/electrolyte interface of various anode systems.
- Ongoing development of anode materials and types.
- Development of laboratory based protocols for the evaluation of the performance properties (various) of mortars and grouts, including acid resistance assessment under concrete CP conditions.
- Research into modification methods (various) for the improvement of the performance properties (various) of mortars, grouts and shotcretes for use with concrete CP.
- Ongoing investigations into methods of assessing deterioration, including type(s), of anodes, mortars, grouts and shotcretes for concrete CP.

- Ongoing understandings of the performance of galvanic anode systems. Many of the papers available in the literature have been authored or co-authored by representatives from the anode manufacturing companies. Independent, academic and industry based studies are likely to provide more objective views.

- There is a need to improve the understanding of the mechanisms controlling the performance of hybrid treatment systems. As above, independent, academic and industry based studies we suggest will provide more objective views.

13. Conclusions

Acid generation at anode surfaces has been known for nearly 200 years for metallic CP so it is inevitable that acid generation occurs at anode surfaces for concrete CP. This acidification induced deterioration of reinforced concrete structures has occurred on structures for which CP has been installed in Australia.

Oxidation reactions at anode surfaces generating acid has led to the deterioration of the cementitious grout and concrete around anodes in various bridge and wharf reinforced concrete structures. The accelerated deterioration is attributed to poor design, installation and operation errors, but most particularly improper design. Management of the acidification induced deterioration has not been possible with some of the bridge concrete CP systems because maintenance and rectification opportunities have been missed and the damage has become too severe. However, with other systems a management plan has been engineered that has led to the ongoing successful protective performance of the systems with affordable ongoing maintenance costs to the structure owners, and implementation by structure owners rather than specialist CP suppliers or CP contractors.

Management of the risk of acidification induced deterioration of concrete CP systems is possible through improved system design, installation, monitoring and maintenance. Different anode systems, not just in terms of their type but also their chemical composition, mortar and grout formulation changes by suppliers, new technologies, technological changes, research into methods of performance evaluation and improvement will lead to improved management of the risk of acidification during the service life of concrete CP systems.

Designs that have excessive anode material of too high a surface area lead to unreasonable consequential performance expectations of the grouts.

Concrete CP system performance and lifetime extensions need not to be compromised. In the case of impressed current CP, the rate of corrosion of reinforcement and prestressing steel can be stopped regardless of the chloride content or depth of carbonation of the concrete.

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Registration of ICCP Systems – Learnings and Recommendations

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1. Introduction

Within Australia, the formal registration of an Impressed Current Cathodic Protection (ICCP) system differs from state to state. Most States have their own Authority (Electrolysis Committee), the function and roles of which are defined by the relevant State Electrical Safety Act. Some Authorities act as a central point of contact only for testing and mitigation of stray electrical currents, while others are a legislated body for management of new and existing permits and act as asset representatives and mediators.

It is generally considered that the 'Corrosion Industry' is specialised, a fact that is magnified with CP. While the design, installation and maintenance of such CP systems is well established, the nuances in registration of a new ICCP system is not typically well understood by the specialized corrosion industry. This can be compounded by:

1. The language, length and complexities of the Regulations and Codes of Practice;
2. That each of the five current CP Standards are in different stages of reference to the Registration Authority;
3. How each of the CP Standards are reflected in the various Regulations of each Authority; and
4. A disconnection between the expectations of the Asset Owner, Consultant, Contractor and the Registration Authority with respect to the registration process as it relates to CP system operation within a specific timeframe.

The emerging use of complex arrangements of "distributed Transformer Rectifier Unit (TRU)" power supply systems and new technologies used in controlling ICCP systems has changed the industry opinion of what is considered a "separate" ICCP system, and therefore the number of 'registrations' required for a particular system. Currently, the Regulations do not align with this general opinion.

In addition, the timeliness for Registration and stray current mitigation is not always appreciated by stakeholders when setting project program milestones, or undertaking staged installation/commissioning of CP systems for large project installations.

2. Standards and Legislation

There are five Australian Standards that are in the AS 2832 Series – Guide to Cathodic Protection of Metals (see Table 1). The objective of these Standards is to specify the minimum requirements of cathodic protection to specific structure types, dependent on the Standard that is referred to.

At the time of writing, the Standards are published according to the following revisions:

Table 1: List of Australian Standards relevant to registration of CP systems

AS 2832.1	2015	Cathodic protection of metals - Pipes and cables
AS 2832.2	2003 (R2016)	Cathodic protection of metals - Compact buried structures
AS 2832.3	2005 (R2016)	Cathodic protection of metals - Fixed immersed structures
AS 2832.4	2006 (R2016)	Cathodic protection of metals - Internal surfaces
AS 2832.5	2008 (R2016)	Cathodic protection of metals - Steel in concrete structures

Each Standard (with the exception of AS 2832.4) defines the requirement to register a Cathodic Protection (CP) system with the relevant Authority. The purpose of registration is to prove that the CP system can operate without imposing a negative effect on neighbouring structures – referred to as stray current corrosion, amongst other descriptions referenced by the industry.

Ignoring specific exemptions, registration of a CP system is a requirement of legislation written by each State. The registration falls within the role of the relevant Authority to manage. Typically, an Electrolysis Committee operates within the Authority and its role is to advise the Authority of its electrolysis mitigation activities, as well as processing CP system registration applications, and dealing with the general operation of such applications.

3. Registration Complexities

Applications for the registration of a CP system are received and processed by the relevant Authority. For convenience, this will be described as the Electrolysis Committee (EC). The process for registration in Victoria will be used as the typical process for this discussion, as the documentation available from the Victorian Electrolysis Committee (VEC) is the most detailed and readily available. However, where other EC's exist, the registration process is assumed to be of a similar nature for comparison purposes.

Through the revisions of the AS 2832 Series, it is possible to track the evolution of the EC's around Australia. Table 2 following shows a portion of these changes.

From Figure 1, it is clear that the application process is more complicated than would be expected. Considering there are multiple EC's across Australia that are changing regularly (see Table 2), and different categories for registration, the permutations that a person in the industry interested in registering a CP system must be familiar with is beyond reasonable.

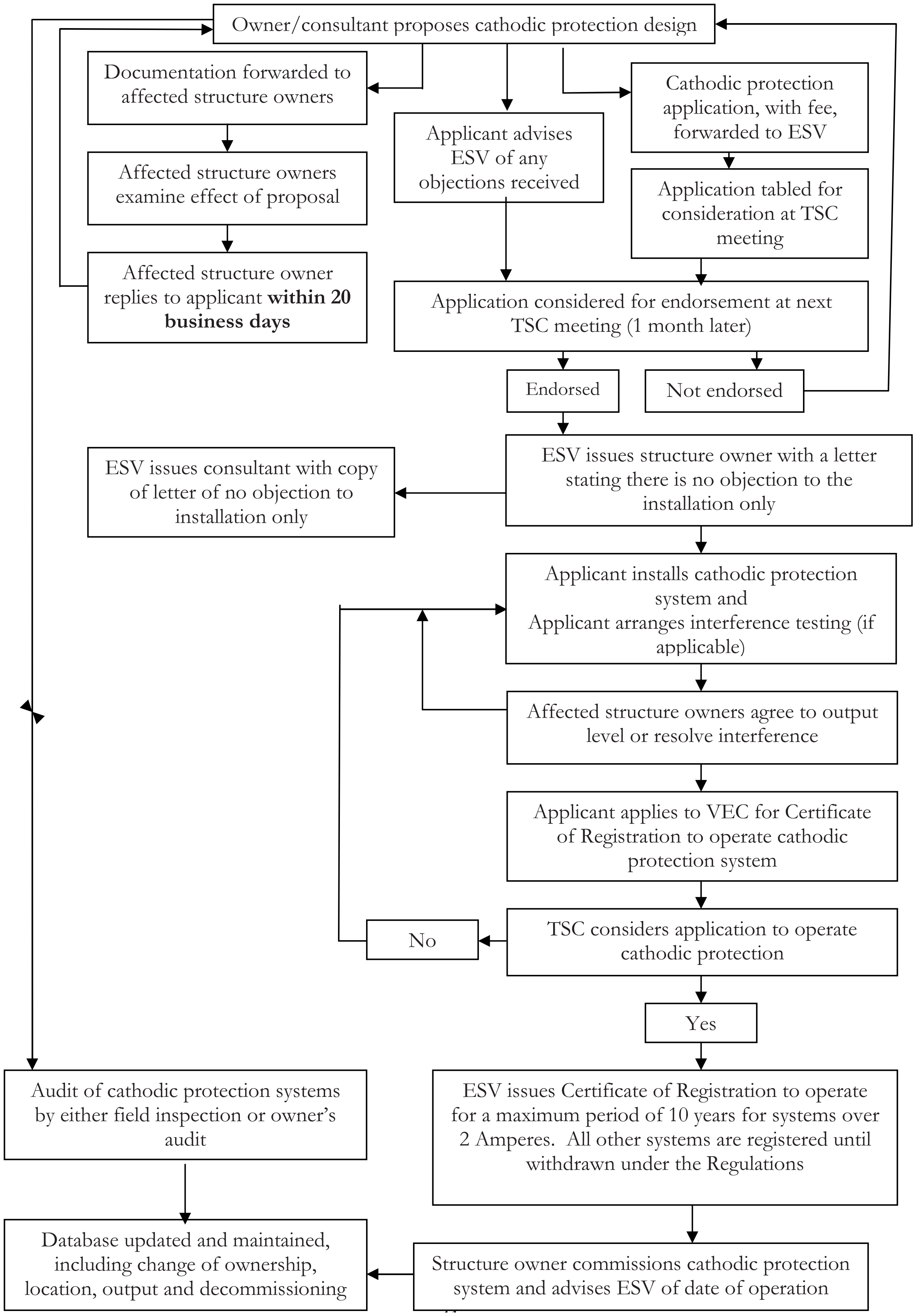
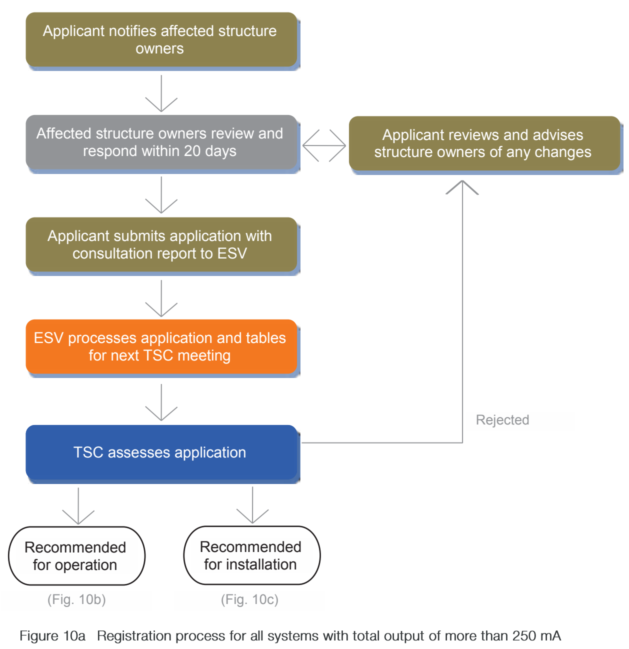


Figure 1: Application Process for ICCP systems with total output of greater than 250 mA [1].

Table 2: Authorities listed within AS 2832 responsible for registration of CP systems

According to AS 2832 Series (Ordered By Date of Standard)								
	AS 2832.2 2003		AS 2832.3 2005		AS 2832.5 2008		AS 2832.1 2015	
State/ Territory	**Electrolysis Committee**	**Authority**	**Electrolysis Committee**	**Authority**	**Electrolysis Committee**	**Authority**	**Electrolysis Committee**	**Authority**
ACT	*ACT Electrolysis Committee*	*ACTEW*	*ACT Electrolysis Committee*	*ACTEW AGL*	*ACT Electrolysis Committee*	*ACTEW AGL*	*Not listed*	-
NSW	*NSW Electrolysis Committee*	*Ministry of Energy and Utilities*	*NSW Electrolysis Committee*	*Department of Energy, Utilities and Sustainability*	*NSW Electrolysis Committee*	*Department of Water and Energy*	*NSW Electrolysis Committee*	*Trade and Investment, Resources and Energy*
NT	-	*The Power and Water Authority*	-	-			*Not listed*	-
QLD	*Electrical Safety Office*	*Department of Industrial Relations*	*Electrical Safety Office*	*Department of Natural Resources*	*Electrical Safety Office*	*Department of Natural Resources*	*Electrical Safety Office*	*Department of Natural Resources*
SA	*South Australian Electrolysis Committee*	-	*South Australian Electrolysis Committee*	*SA Water*	*South Australian Electrolysis Committee*	*SA Water*	*South Australian Electrolysis Committee*	-
TAS	*The Chief Electrical Inspector*	*Workplace Standards Tasmania*	*Tasmanian Electrolysis Committee*	*Workplace Standards Tasmania*	*Tasmanian Electrolysis Committee*	*Workplace Standards Tasmania*	*Tasmanian Electrolysis Committee*	*Workplace Standards Tasmania*
VIC	*Victorian Electrolysis Committee*	*Office of the Chief Electrical Inspector*	*Victorian Electrolysis Committee*	*Energy Safe Victoria*	*Victorian Electrolysis Committee*	*Energy Safe Victoria*	*Victorian Electrolysis Committee*	*Energy Safe Victoria*
WA	*Electrolysis Subcommittee*	*Water Corporation WA*	*Electrolysis Subcommittee*	*Water Corporation WA*	*Electrolysis Subcommittee*	*Water Corporation WA*	*No active committee*	-

This is obviously known and acknowledged by the EC's. In 2015, the VEC updated their "Code of Practice" document to be issued by Energy Safe Victoria. The updated process is shown below:



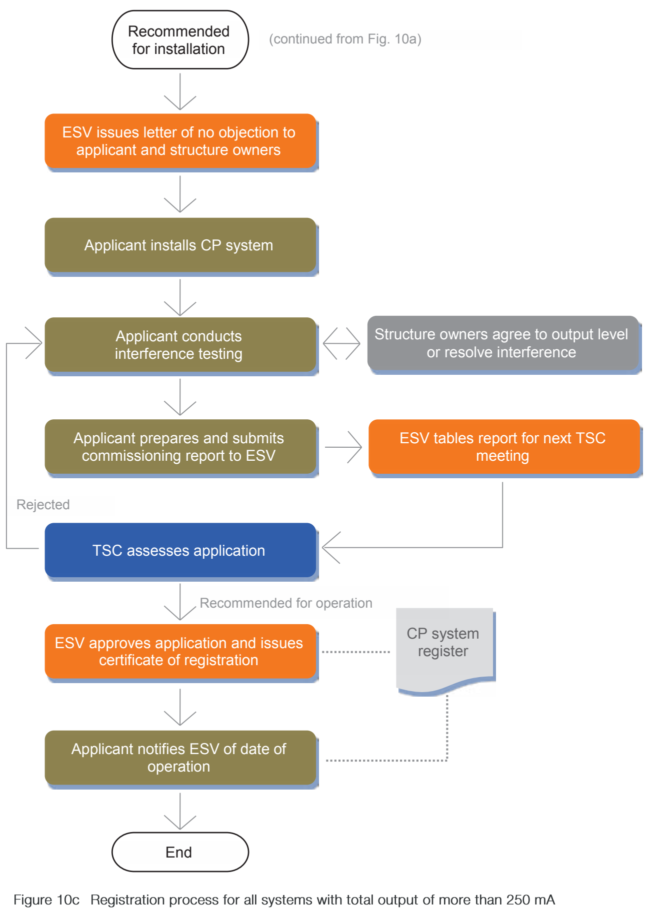


Figure 2: Application process for CP system over 250 mA [2].

In addition, NSW Better Regulation Office conducted a review of the framework of CP system registrations [3]. The paper concluded the present approach is increasingly bureaucratic and based on systems that were 35 years old. The outcome of this paper was to alter the registration process to an online system, which now eliminates the ability to openly converse with the EC on the application, a function which is integral to problem solving the roadblocks and bureaucratic process of granting a permit to operate a CP system.

A common point of confusion is the sequence of registering a CP system and specifically how the timing of testing relates to granting of a permit to operate the CP system. In the case with large CP systems, or CP systems where a stakeholder has voiced concern over the impact such a system may have on their assets, testing of the system is granted prior to operation. To test a system, it must be installed and operated. It seems the only way to test a CP system to see if it is safe is to install and operate the system. A permit to test a system requires operation, but does not grant approval for operation other than for testing. Figure 2 shows that for CP systems where the Technical Subcommittee (TSC) grants operation in the first case, a registration certificate is granted prior to installation, which is opposite to the sequence when testing is required. Such events led to confusion for the contractor installing the CP system – what do they allow for in a program; and with the client who wants a CP system in operation – different approaches can add months to a permit to operate being approved.

Another common point for debate when registering a CP system is determining the number of "Certificates of Registration" required for the CP system. The wording of regulations that defines a single CP system varies across the board, but is in contrast to the general consensus of the industry with respect to concrete CP. In addition, the Regulations catered for CP systems that lend themselves to higher risk of stray current, such as pipelines and ground beds.

For example, a Certificate may be required for "each electrically independent connection between the power source and the structure". It is not uncommon for a large concrete CP system to have over 20 electrically independent connections based on the Transformer Rectifier Unit (TRU) layout. This would require the applicant to pay 20 fees and submit 20 applications. However, the principle of CP, as per the AS 2832 Standards, requires the structure to be electrically continuous. As such, an argument can be made that no connection is independent from another. These two points of view seem to be at odds, and it is not surprising to learn that the Regulator, who collects the registration fees, takes the former view, while the CP System Installation Contractor, on behalf of the owner, who pays the fees, takes the latter. Finally, complications with registration can arise when installation occurs to a large structure and the client requires staged commissioning to take place as the CP system is installed. This is becoming less common with the "awakening" in the industry of the effects of accelerated low water corrosion (ALWC). Should a client require staged commissioning of a CP system, how best would such a process occur? The questions posed by such a situation are many and varied:

- Should a contractor allow to apply for the Registration multiple times over during the duration of the installation project, or allow for testing of the system at such intervals?
- Is the client prepared to manage multiple Certificates of Registration, and the annual maintenance of such a system?
- Was the design created to allow for phased commissioning, or was the designer aware of the intention to commission the system in stages, and is the design capable of being constructed in such a manner?

All these factors can influence the ability to; a) register and/operate part of a complete CP system and b) maintain the CP system within the parameters of the design and the Standards whilst appeasing the Client's expectations.

4. Learnings From a Real World Project Requiring Registration

In the past 24 months, the authors have been involved with the construction, and associated installation, of both water and concrete based ICCP systems. One particular project involves the use of concrete and water ICCP system operated using a single Central Control Unit (CCU). All zones are independently adjustable from the CCU, of which there are more than 150. This design, and hence the technology used in the CP systems, is a reflection of a TRU arrangement that has become more prevalent in the industry, and has advanced to a state where there is now a trend toward using a large quantity of "zones" that allow finer control. The large structure and project dictated that the works contract was split into separable portions.

From a design perspective, there are two CP systems in operation – the water system and the concrete system. The design documentation reflected this. However, the CP systems were designed and built to be controlled by a single CCU. In addition the CCU and cabling was designed to be installed at the far end of the structure which was not due to be constructed/installed until one of the later separable portions of the contract. Therefore, when the first separable portion of the works came to be completed there was no CCU available to power the system and perform mitigation testing. This was due to the designer not being informed of the separable portion nature of construction contract and not taking such requirements into account, and a client who was unfamiliar with the nuances of registering a CP system. Originally the contract was written such that receipt of the Certificate of Registration was required as a prerequisite to granting of the administrative completion milestone of the contract. This contractual requirement was removed from the contract after the client was informed that energisation of the water CP system is expected to take many months hence delaying the issue of Certificate of Registration of the CP System and in turn delaying the achievement of administrative completion of the contract.

As part of the contract, the Client required the application for registration be approved, and interference testing of the CP systems to be completed and approved. Achieving this without a design that allows partial commissioning was complex, and solved with assistance from the EC. The EC requested four (4) separate Certificates of Registration be applied for; – one for each of the concrete CP systems in the two separable portions, and replicated for the water CP system. This was despite the fact the CP system comprises more than 500 number of what the EC defined as "electrically independent connection between the power source and the structure". Through discussion about the intent of the design, practical terms of operation and the separable portions of practical and administrative completion of the contract, the EC acted in their capacity to grant special dispensation for registration. The four Certificates of Registration reflected the initial installation, testing and commissioning of the system and is a reasonable interpretation of the Regulations.

The client now has to maintain four CP systems, which is in contrast to the single CP system or dual CP systems that the client reasonably had an expectation that it was constructing and would own. This may cause confusion in the future when re-registration is required, particularly when taking into account that none of the construction or design documentation makes reference to the four CP systems and the Operations and Maintenance Manual for the CP System is written as a single document covering both the water and concrete CP systems.

5. Possible Improvements

The paper from NSW Industry and Investment "Review of NSW corrosion protection regulation: Final report" proposes recommendations that will not be repeated in this paper. However, they complement the opinions presented in this paper on this topic, and are considered in parallel.

In summary, below is a group of initiatives tabled for discussion, that are proposed as a method of reducing the difficulties of CP system registration, and improving the registration process to increase conformance and adherence within the industry.

1. Address the disconnection that exists when interpreting the Regulations with regards to the number of CP systems that are required for registration, and the total output that applies to said system/s.

2. Make accommodation within the Regulations for new technologies and methods of operation of CP systems that utilise such systems so that the system design, construction, operation and maintenance reflect the system registration.

3. Introduce criteria in the Regulations that reflect the Standards that they apply to. For instance, is it suitable to have different processes for application when considering a CP system that is built to AS 2832.5 compared to AS 2832.3 or AS 2832.1? Currently there is no discrimination in the Regulations, yet there are multiple Standards. In addition, individuals within the industry are generally focused on one or two of these Standards, and yet the Regulations may be tailored more to another. This reduces the adoption of the registration system, as is common with bureaucratic systems, or makes them accessible to individuals with expertise in one system only.

4. A general lack of centralised information on the Agencies that are responsible for registrations. Typically, the relevant standard within the AS 2832 suite is referenced to gain this information, yet as shown above, this data is made obsolete once a government change occurs. The applicable Standard is not generally updated for such a matter, and so can be out of date relatively quickly, as seen in AS 2832.1:2015 showing incorrect information at the time of writing this paper.

5. The registration process is differs substantially from one State or Territory to another. Some States do not even have a body to oversee registration, which undermines the industry as a whole. Standardising the process to be consistent, or moving toward consistency from the current state can only improve the industry practices, and will create opportunity for efficiency, cost savings and adoption across the board.

6. Conclusion

All parties involved in the cathodic protection industry have an interest in ensuring the industry operates in a manner that is functional and professional and complies with relevant legislation and regulations. Where roadblocks to implementation are encountered, opportunities for improvements exist. While the overarching regulations that govern CP system registration are complicated and varied across geographic locations, the stakeholders who inform the Electrolysis Committees responsible for administering and/or approving CP systems all exist within a common group, and have the opportunity to influence how registrations are handled, even within the current framework of regulations. They are constantly striving to ensure the industry follows best practice, and this paper's function is intended to bring into a professional forum, the current issues that exist with registration, and encourage further action to be taken within and by the CP industry where applicable.

7. Acknowledgments

The Authors wish to acknowledge the input of staff members from Freyssinet Australia and Freyssinet New Zealand in providing input on the vast number of projects that have involved CP, and their experiences with registration.

8. References

[1.] Victorian Government, Energy Safe Victoria see: http://www.esv.vic.gov.au/Portals/0/about%20esv/files/VEC%20Code%20Revision%206.pdf accessed 5 March 2016

[2.] Victorian Government, Energy Safe Victoria see: http://www.esv.vic.gov.au/Portals/0/electricity%20professionals/files/Electrolysis_%26_Cathode_Protection/Code_of_ practice_Electrolysis_mitigation_and_cathodic_protection_2015.pdf accessed 5 March 2016.

[3.] NSW Government, Department of Resources and Energy see: http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0008/375704/final -report-review-nsw-corrosion-protection-regulation.pdf accessed 5 March 2016.

INTERESTING CORROSION PHOTOS

This photo shows an Impressed Current Cathodic Protection (ICCP) Transformer Rectifier Unit (TRU) designed and supplied by CCE to provide corrosion protection to a steel reinforced concrete structure at Fisherman's Wharf, Coffs Harbour, NSW.

The painting of the cabinet was done by local artist Jeffrey Baker who has an art shop in Coffs Harbour.

CCE CORROSION CONTROL ENGINEERING

Image taken by Ian MacLeod on his morning jaunt via Treacy Walk where he saw a path that had been repaired and he noticed an emerging pattern where the concrete kerbing had been cut, to allow for expansion etc. and the cracks subsequently appeared in the paving. He suggested that they could have avoided the repairs etc. if they had used a heat gun on the fresh pavement to relieve the stress!

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