A journal of the Institute of Corrosion

Corrosion Management

Issue 182 November/December 2024

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The President Writes

Dear Members,

Welcome to our Final Corrosion Management Journal of 2024. This has been an emotional and landmark month for myself and on 13th November 2024, I formally handed over my duties to **Dr Yunnan Gao**.

Yunnan has been the Institutes' Vice President and one of its Trustees since November 2022, providing excellent support to myself on various ICorr matters over the past two years. He has had extensive working experience in the energy sector both in the UK and overseas and has been an active ICorr Aberdeen branch committee member for the last 10 years, twice holding the Chair position, helping to reinvigorate our Aberdeen branch.

Currently, Yunnan works for bp based in Sunbury, UK. After his PhD studies at Loughborough University, UK, he has worked for operators and technical service companies including Atkins, DNV GL, LR, Repsol Sinopec, Saipem and Stork, in the areas of asset integrity and corrosion management. Yunnan is a UK Chartered Engineer (CEng), a UK Chartered Scientist (CSci), a fellow of ICorr (FICorr), a fellow of IOM3 (FIMMM) and an AMPP Certified Corrosion Specialist.

I have worked very closely with Yunnan and have every confidence that he will continue to implement our planned enhanced service offerings for our members with even further international integration so that all are served to a greater degree than ever before in the history of our Institute.

We are also very pleased to welcome Dr Anthony Setiadi to our new management team. Anthony was one of the organisers for the first ever Young Engineers Programme (YEP) and has supported this initiative through its successful iterations over the past 15 years. He has also been involved in the London branch committee as well as developing and supporting Chartership registrations to Engineering Council for ICorr.

Anthony received his PhD on materials from Sheffield University, UK, and is a Chartered Engineer (CEng) and Fellow of ICorr (FICorr), with experience in academia and industry covering various industries from nuclear, oil and gas and offshore wind. Currently, Anthony works as Chief Consultant for Wood Thilsted, a leading renewable energy consultancy based in London, UK. His background and expertise are in materials and corrosion engineering for offshore and subsea environments.

We wish them both every success in their new roles for the Institute and believe that together they will make a great partnership to lead the Institute from now on. Our new MoU with the Beijing based Chinese Society of Corrosion Protection (CSCP) has now been completed which will bring a most interesting program of International Webinars, Student Awards and more joint events during 2025 and 2026. We completed an extremely successful Webinar series in November with around 400 attendees altogether. Work continues developing other ICorr collaboration opportunities in India and the Middle East.

The months of November and December are particularly busy times for both our Technical and Social Institute Activities, culminating with our London Branch Dinner at the Royal Overseas League (ROSL), always a popular ICorr event. Our regional branch committees also celebrate in many different ways the hard work of their Volunteers over the previous 12 months.

I was very pleased to attend on 21st September the Young Engineer Program Final, kindly hosted by our London Branch. This was a tremendous occasion enjoyed by all, one that truly demonstrated ICorr at its best, improving and progressing the careers of our younger members, who are the future of our Institute. I offer my sincere thanks to all involved in its organisation, with a special mention to all our 2024 sponsors – bp (for the Winner's travel to USA), AMPP (for the Conference and Leadership program), Wood Thilsted (for hosting us throughout 2024) and to LBBC and Intertek CAPCIS out of the other supporting companies of our YEP leaders Danny and Iza. Without all this generosity, it simply would not have been possible.

Please do get involved in our upcoming activities and keep an eye on the ICorr events calendar at: **www.icorr.org/events/**

With my best wishes for your good health and for your future careers and thank you very much for all your support over the last 10 years.

Stephen Tate, President: Institute of Corrosion
president@icorr.org

From the Editor

Dear Members,

Welcome to the November/December issue of Corrosion Management. The overall theme of this issue is "corrosion resistance alloys."

The first technical article is contributed by Dr Roger Francis. This article underscores the importance of understanding material behaviour to optimise heat exchanger design. Practical guidelines for selecting materials are provided to ensure cost-effective and reliable performance. The second technical article, Understanding the Mechanics of Brittleness: Liquid Metal Embrittlement (LME) in Aluminium Alloys, authored by Dr. Mustafa Hashim and Binoy Padmanabhan, provides an in-depth exploration of LME in aluminium alloys, particularly within the oil and gas industry. The third technical article, "Offshore wind farm maintenance: a new coating toolbox," is written by Claus Ackfeld, Joao Azevedo, and Neil Wilds. This article introduces two innovative maintenance coating solutions that cater to offshore wind structures and other demanding environments, ensuring long-term protection and performance.

In Ask the Expert Column, Sarah Bangall has contributed "Significance of PREN for the corrosion resistance of stainless steel". This article explores the significance of PREN, its calculation, and its limitations in predicting performance in diverse environments.

We sincerely welcome all your contributions and encourage you to share your content for consideration. This includes industry news, technical articles, and photos for our "Corrosion Around Us" feature. We would also be delighted to receive submissions for our "Corrosion Morphologies" column and "Fellow's Corner." We look forward to your valuable contributions.

Wishing you a festive December and a holiday season filled with warmth, joy, and cherished moments!

With kindest regards,

Dr Shagufta Khan, FICorr
Consulting Editor, editor@icorr.org

Updates from CORREX

1. 10 Years as Senior Trainer

It with pride and pleasure that I have now been a CORREX senior trainer for 10 years, June 2014. The opportunity came about by chance in the absence of a trainer at the time a course was due to be delivered. I was asked by the then MD of CORREX Bob Crundwell, could I do the training at the Elcometer facility in Manchester for 10 new ICATS trainers? At the time, my wife Jo and I sat on the Highways 19A committee on behalf of contractors, as was known by Bob. I quickly learned the subject material and delivered the course, which was enjoyed by all. 10 years later, still here and looking forward to the future with CORREX.

2. ICATS 20 Years Old

ICATS has just turned 20 years of age, how amazing. Before the ICATS courses were written there was no formal industrial painter training in the UK. A structured learning course was required by the large asset owners. One that would help improve Health and Safety practices on site and in house, one that would improve preparation and painting of surfaces, and reduce injury. Delivering quality work, safely. Where ICATS was primarily designed for Highways, it is now embraced by every part of our industry. I look forward to the next 20 years.

3. Going from Strength to Strength

As the 20th birthday of ICATS comes and then goes into its 21th year, it has become the request and mandated terms for painting of many structures and assets across the UK and now globally. Including, roads and rail, bridges and buildings, floors and equipment.

Many thanks to the continuing support of our clients and welcome to those about to join us. We have all had a serious impact on our most impressive trade, great stuff everyone.

Regards
Kevin Harold
CORREX Managing Director

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ICorr President Handover on 13-11-2024, Stephen Tate to Yunnan Gao

By Yunnan Gao, Stephen Tate and Anthony Setiadi

Dear Members,

The Institute of Corrosion (ICorr) is very pleased to announce the successful election of Dr Yunnan Gao as its New President and Dr Anthony Setiadi as its New Vice President at its AGM held in Neville Hall, Newcastle on 13th November 2024.

Dr Yunnan Gao has been the Institutes' Vice President and one of its Trustees since November 2022, in support of the immediate past president Stephen Tate on various ICorr matters over the past two years. Additionally, Yunnan has been an active ICorr Aberdeen branch committee member for the last 10 years when he has twice held the Chair position, helping to build up the Aberdeen branch from strength to strength. Yunnan has extensive working experience in energy sector both in the UK and overseas for 17 years.

Currently, Yunnan works for bp based in Sunbury, UK. After his PhD studies at Loughborough University, UK, he has worked for a number of energy and technical service companies, including Atkins, DNV GL, LR, Repsol Sinopec, Saipem and Stork, in the areas of asset integrity and corrosion management. Yunnan is a UK Chartered Engineer (CEng), a UK Chartered Scientist (CSci), a fellow of ICorr (FICorr), a fellow of IOM3 (FIMMM) and an AMPP Certified Corrosion Specialist.

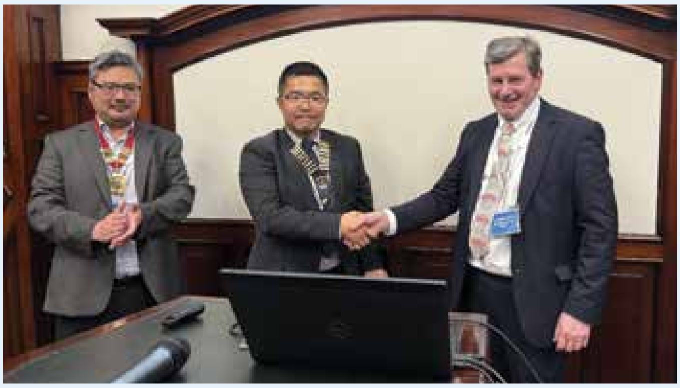


Photo: President Handover on 13/11/2024, Stephen Tate to Yunnan Gao at the ICorr AGM Held at North-East Branch Newcastle, UK.

Photo: Our New ICorr Team, from Left to Right, ICorr New Vice President - Dr Anthony Setiadi, ICorr New President - Dr Yunnan Gao and ICorr New Immediate Past President - Stephen Tate.

Dr Anthony Setiadi has been involved in ICorr for the past 13 years, whereby he was one of the organisers for the first ever Young Engineers Programme (YEP) and has supported this initiative through its successful iterations over the past 15 years. He has also been involved in the London branch committee as well as developing and supporting Chartership registrations to Engineering Council for ICorr.

Anthony received his PhD on materials from Sheffield University, UK, and is a Chartered Engineer (CEng) and Fellow of ICorr (FICorr), with experience in academia and industry covering various industries from nuclear, oil and gas and offshore wind. Currently, Anthony works as Chief Consultant for Wood Thilsted, a leading renewable energy consultancy, based in London, UK. His background and expertise are in materials and corrosion engineering for offshore and subsea environments.

We wish them both success in their new roles for the Institute and believe that together they will make a great partnership to lead the Institute from now on.

At this time, we would like to express our greatest gratitude towards our Immediate Past President - Stephen Tate, who recently retired from Oceaneering after 44 years in the Energy Sector. Stephen has led ICorr for the past two years, where he has demonstrated excellent governance and leadership throughout and made a number of successes, including recent involvement in setting up the new ICorr UK branches in Southwest England and Wales and Central Scotland, as well as a renewal of the MoU with AMPP in the USA and sign-off of the new MoU with CSCP (Chinese Society for Corrosion Protection) in China.

Stephen has set a very high bar for his successors to follow and with Stephen's continued support as immediate past president and working together with the New ICorr President - Dr Yunnan Gao and New ICorr Vice President - Anthony Setiadi, the new team will endeavour to work wholeheartedly to continue the successes of ICorr and bring the utmost value and benefits to the ICorr corrosion community in the UK and overseas for the next two years and beyond.

ICorr Leadership Team's contact details are as follows:

- ICorr New President - Dr Yunnan Gao: **president@icorr.org**
- ICorr New Immediate Past President - Stephen Tate: **past.president@icorr.org**
- ICorr New Vice President - Dr Anthony Setiadi: **vice.president@icorr.org**

Please feel free to contact us directly if you have any issues that you would like to discuss.

On behalf of the new ICorr Leadership Team, we thank you for your past support of the Institute and look forward to working with you over the next two years.

With our very best regards,
Yunnan, Stephen and Anthony

Announcement

ICorr and CSCP Forge Partnership with MoU Signing in Xi'an China

In a significant step toward advancing global collaboration in corrosion science and engineering, the Institute of Corrosion (ICorr) and the Chinese Society for Corrosion Protection (CSCP) signed a Memorandum of Understanding (MoU) during the 22nd International Corrosion Congress held in Xi'an, China.

The agreement was formalised by then ICorr President **Stephen Tate** and Vice President **Dr. Yunnan Gao**, alongside CSCP counterparts President Professor Xiaogang Li and General Secretary Professor Xuequn Cheng, in a ceremonial signing event attended by industry and academic leaders and corrosion experts on **23rd October 2024**.

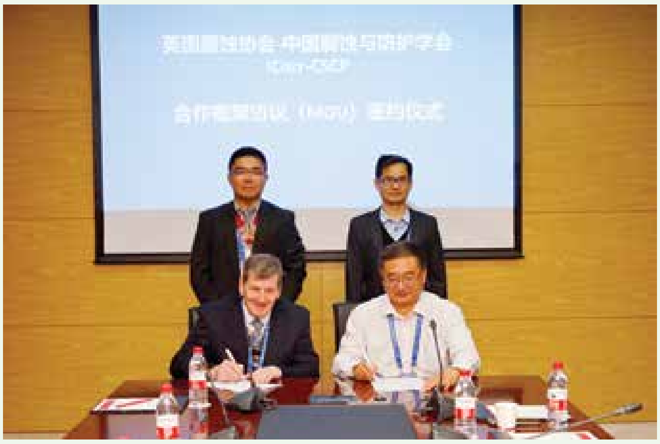


Photo: ICorr-CSCP MoU Signing Ceremony in Xi'an China on 23rd October 2024. *Left front:* ICorr President Stephen Tate; *Left back:* ICorr Vice President Dr. Yunnan Gao, *Right front:* CSCP President Professor Xiaogang Li *Right back:* CSCP General Secretary Professor Xuequn Cheng.

Photo: ICorr Past and Future Presidents and CSCP Leadership Team at the ICorr-CSCP MoU Signing Ceremony at the ICC Congress.

This agreement marked the culmination of 12 months of dialogue and numerous rounds of collaborative discussions between ICorr and CSCP. Both organisations demonstrated unwavering commitment to fostering a global partnership that supports the advancement of corrosion science and engineering.

The MoU reflects the mutual efforts of ICorr and CSCP to create a framework for collaboration, facilitating knowledge exchange, joint activities, and professional development initiatives. The agreement was achieved through great determination and shared aspirations, emphasising the importance of addressing corrosion challenges on a global scale.

By leveraging their combined expertise, the two societies aim to enhance their contributions to the international corrosion community.

This milestone agreement sets the stage for a robust and dynamic partnership between ICorr and CSCP. It paves the way for collaborative activities, workshops, and technological advancements that address pressing industry needs. The signing of the MoU represents not just a formal agreement but also a shared vision for the future of sustainable corrosion solutions and innovation across borders.

Our successful interaction has indeed already commenced with our Joint CSCP/ICorr Webinar series held between 11th and 25th November 2024, attracting over 500 registrants and this will be reported in our Jan-Feb issue of Corrosion Management Journal.

INSTITUTE OF CORROSION

Please look out for further ICorr Events by regularly checking www.icorr.org/events/ where you will see activities from all our branches and divisions.

Visit the ICorr website for all the latest news www.icorr.org

Corrodere Academy Signs 10-Year Partnership Agreement with The Institute of Corrosion to Continue Providing Accredited Courses

Corrodere Academy, a global provider of coatings and corrosion control training and certification, recently signed a 10-year partnership agreement with the Institute of Corrosion (ICorr). This long-term collaboration will ensure Corrodere continues to provide industry professionals with essential skills for combating global corrosion issues.

The agreement was formalised with a visit to Corrodere's office from ICorr President **Dr Yunnan Gao**, where he signed the agreement with Corrodere's Managing Director, **Andrew Deere**. The extended collaboration underpins both organisations' dedication to excellence in corrosion prevention through education and training, ensuring that industry standards remain high and that professionals across the field have access to accredited and respected qualifications.

Dr Yunnan Gao Commented:

"As the President of the Institute of Corrosion, I am thrilled to announce this further extension of our long-term partnership with Corrodere Academy, with whom we have been closely associated since 2010. This agreement not only strengthens our commitment to advancing professional competence in corrosion control but also ensures that industry professionals continue to have access to world-class training and accredited qualifications. Corrodere's rigorous, ICorr-accredited programs in areas such as coating inspection and thermal metal spray provide vital skills needed to combat corrosion on a global scale. By renewing our partnership, we reaffirm our dedication to equipping professionals with the expertise necessary to meet today's industry challenges and maintain high standards across the field."

Corrodere Academy's suite of ICorr-accredited courses includes:

- ICorr Coating Inspection Levels 1, 2, and 3
- Pipeline Coating Inspection
- Insulation Coating Inspection
- Thermal Metal Spray Inspection
- Hot Dip Galvanising Inspection
- Coating Surveys

These courses are designed to meet the stringent demands of the protective coatings industry, equipping participants with the knowledge and skills necessary to inspect, evaluate, and ensure the effective application of coatings.

Photo: Signing of the New Agreement, Andrew Deere - Managing Director at Corrodere Academy with ICorr President Dr Yunnan Gao.

"This new agreement extends our working relationship with ICorr and allows us to continue our mission of delivering top-quality training that meets the rigorous standards of the corrosion industry. Our shared vision with ICorr drives us to continuously improve and innovate, ensuring our courses provide real-world benefits to professionals and the industry alike. We look forward to building on the success of our strategic partnership"

Andrew Deere – Managing Director at Corrodere Academy

This 10-year agreement not only reinforces ICorr's endorsement of Corrodere's courses but also highlights the essential role of accredited training in the coatings industry. With this continued collaboration, ICorr and Corrodere Academy are committed to upholding and enhancing the professional standards that safeguard the integrity and longevity of critical infrastructure and assets.

For more information about ICorr-accredited courses at Corrodere Academy, please visit corrodere.com

Announcement

Stephen Shapcott FICorr, ICorr London Branch Member, Honoured with Prestigious Smeaton Medal

Stephen Shapcott CEng FIMMM FICorr AWeldI, London Branch member, Past Young Engineers Programme recipient and now mentor, and Vice Chair or AMPP UK Chapter, has been awarded this year's Smeaton Medal in recognition of his work in the scale up and deployment of material solutions for next generation low carbon energy sustainable chemical process technologies.

The Institute of Corrosion is also very pleased to announce that Stephen has additionally been recognised as a newly elected fellow of the institute.

When asked about these two notable events in his career occurring in such close succession, Stephen said, "To be a fellow of the Institute of Corrosion has been a careerlong goal and so to be awarded the Smeaton medal just the week before has been a fabulous experience. I hope any success I have had will inspire the next generation of Corrosion Engineers such as those on the Institute's Young Engineers Programme."

All in ICorr offer their congratulations to Stephen on this magnificent double win.

Stephen, who is Head of Materials Engineering - Licencing for Johnson Matthey's (JM) Catalyst Technologies Licensing Business, was nominated by Dr Elizabeth Rowsell OBE CChem FRSC, JM's CTO, for his ability in leading the selection of materials of construction for a wide variety of extreme chemical environments, facilitating the safe deployment of world scale chemical and energy process technologies. The development of these processes has resulted in multiple patent applications.

The origins of the Smeaton medal date from the 1970s. The current, third series of medals has been commissioned by the Smeatonian Society of Civil Engineers to commemorate the 250th anniversary of the formation of the society in 1771. The third series is intended to recognise engineers in the early or mid-stage of their careers who have demonstrated outstanding engineering achievement in the management of hostile environments, such as windstorms, earthquakes, the human body, space, cyberspace, the deep oceans, or under extreme chemical, biological, or nuclear conditions.

The award of the medal to Stephen was announced at the society's luncheon held at the University of Leeds on the 30th of October 2024 to mark 300 years since Smeaton's birth and was presented by HRH The Princess Royal, who is an Honorary Member and past President of the Smeatonian Society.

Further information regarding the current series of Smeatonian Society awards and past winners can be found at the following website:
https://www.smeatonians.org/smeaton-medal

Photo: Stephen Shapcott with Her Royal Highness Princess Anne for the Smeaton Medal Presentation at the University of Leeds, on the 30th of October 2024.

Photo: Guests at the Annual Luncheon of the The Smeatonian Society of Civil Engineers.

Photo: Stephen Shapcott with Johnson Matthey's CTO Elizabeth Rowsell Who Nominated Him for the Medal.

Announcement

Obituary - J D Griffiths

It is with sadness that we must report the death in August 2024 of J D Griffiths, aka 'Dave Griff'. Dave was a coating inspection and quality management expert who contributed hugely to the Institute of Corrosion coating inspector training and certification scheme.

He worked with R J P (Ran) Nicklin, who led one of the larger coating inspection specialists in the 1970's.

Photo: J D Griffiths, Aka 'Dave Griff'.

In the early 1980s, Dave formed J D Griffiths and Associates Ltd, an independent firm of specialist engineers providing quality control, advisory and inspection services within the corrosion control and structural and piping steelwork protective treatment industries. Dave and his colleagues provided specialist expertise in respect of coatings and linings within the marine, oil, gas, petrochemical, product storage, transportation, pipeline and power generation sectors. They provided these services internationally, throughout the United Kingdom, Norway, Italy, Holland, France, Spain, Germany, Saudi Arabia, Libya, Jordan, the United Arab Emirates and Mexico.

Dave also provided independent expert witness and opinion services in cases of technical and commercial disputes, typically between asset owners and contractors.

In later years, much of Dave's time was working with Argyll Ruane Ltd (ARL) who were the delegated body operating the Institute of Corrosion coating inspector training and certification scheme and later also the cathodic protection technician and engineer training and certification scheme. Dave was the Scheme Manager, reporting to the ICorr Governing Board (later formed into the Professional Development and Training Committee, recently deleted) and was often treading a very difficult line of 'working for 2 masters', both ICorr and ARL. He dealt with these challenges with professionalism and honesty.

ARL's key competences related to non-destructive testing (ultrasonic, radiographic etc) and for many years Dave was the prime source of coating expertise as required within the ICorr Scheme. He also worked closely alongside John Thirkettle and Chris Lynch who wrote the early CP courses, along with the other CP tutors, to assist in the delivery of the ICorr CP Scheme.

The Institute owes a considerable debt to the professionalism and dedication that Dave brought to his role as Scheme Manager. He was a significant contributor to the foundation of our scheme.

He will be missed by his wife Jacqui.

A personal note from Brian Wyatt:

Dave was a long-term friend and respected colleague. He was also a man of integrity and of considerable fun. He was the first person I knew with a 'radio phone' in his car (yes, a radio phone, pre mobile phones); great for calling the operator to book a decent restaurant......

We travelled together to Libya to work on one of his projects; I blame him for choosing the route via Malta on what I termed a 'cattle ship'; it was most definitely a dual service vessel. It took me 6 months to recover from the chest infection; I took advice from both our excellent Vet and GP...

The negotiation, that took the time of single escalator ride, of the long-term arrangement whereby ICorr and ARL (who at that time were managing the delivery of the CP courses for us) agreed a commercial arrangement with the CPA for them to promote our courses into their industry. The CPA are the steel in concrete Corrosion Prevention Association, who remain to this day an important partner for our ICorr CP Training and Certification work in concrete. I remember his kindness and courtesy to all, even when vexed.

He will be missed by me and many others in ICorr and beyond.

2024 ICorr Young Engineers Programme - Final Case Study Presentation Evening

On **21st November 2024**, the ICorr Young Engineers Programme (YEP) reached its grand finale with a vibrant presentation evening hosted at the Institute of Corrosion London Branch. The event, led by Danny Burkle and Izabela Gajewska, marked the culmination of months of effort by participants, mentors, and organisers. It was a night to celebrate technical brilliance, teamwork, and innovative thinking in the field of corrosion science. The YEP has been a foundation of ICorr's commitment to developing future leaders in the corrosion industry, providing early-career professionals with opportunities to develop their skills, engage with industry experts, and tackle real-world engineering challenges.

The event was not just a competition but a celebration of innovation, teamwork, and professional growth. The evening also provided an excellent networking platform, connecting young professionals with industry experts.

Photo: Winning Team Presenting.

The Event – 2024 YEP Final Case Study Presentation

A total of **24 early-career professionals** from leading organisations participated in this year's programme. This year's case study challenge centred around a real-world failure of **dump condenser heads at a power station**, requiring teams to identify root causes, propose solutions, and develop long-term mitigation strategies.

The six teams presented their findings to a panel of experienced judges, each bringing a unique perspective to the evaluation. The judging panel included **Stephen Tate, Gareth Hinds, Madeleine Davidson,** and **Chris Williams.** Their collective expertise ensured that the participants received insightful feedback, enhancing the educational value of the programme.

A highlight of the evening was the keynote speeches delivered by **Izabela Gajewska** and **Stephen Tate.** Izabela talked about **the Importance of Corrosion Management**, drawing attention to the staggering global cost of corrosion—estimated at $2.5 trillion annually (£90B within UK)—and the critical need for effective collaboration, education, and risk management strategies to mitigate these impacts.

Stephen Tate followed with an inspiring message, reflecting on the YEP's vital role in advancing the field of corrosion. He highlighted how the programme fosters innovation, builds professional confidence, and develops the leaders of tomorrow.

Programme Achievements: This year's programme was a testament to YEP's growing impact. With over **60 applications**, the highest ever, and extensive engagement on social media generating **10,000+ interactions**, the programme continues to draw attention from the global corrosion community. Since its inception in 2009, YEP has trained over **100 early-career professionals**, equipping them with the tools and knowledge to excel in their careers, many of these YEP graduates are now actively participating within ICorr.

Photo: All YEP Participants and Organisers.

Recognising Excellence: The Winners

The culmination of the evening was the announcement of the winners. **Team 1**, mentored by **Ali Morshed**, took the top honours for their comprehensive and innovative approach to the case study challenge. The team consisted of **Álvaro González Fuentes, Amy Johnstone, Ben Hudson** and **Kishan Nittur Ramesh**, whose outstanding teamwork and technical analysis set them apart.

Photo: YEP Winning Team: Team 1. Left to Right: Yunnan Gao, Kishan Nittur Ramesh, Amy Johnstone, Ali Moshed, Álvaro González Fuentes, Ben Hudson.

In addition to the team award, **Rochelle Holness** was recognised as the **Winning Individual** for her exceptional technical contributions and presentation skills. Rochelle's dedication and leadership earned her a coveted place in the **AMPP Leadership Programme**, where she will represent ICorr at the upcoming AMPP conference in Nashville. Mentors provided invaluable guidance to participants, helping them navigate the technical and practical challenges of the case study. The mentors included: **Ali Morshed, Rob Doggett, Chris Googan, Stephen Shapcott, Andrew Sturgeon** and **Shengqi Zhou.**

Photo: Standout Individual - Rochelle Holness.

Acknowledgements

Special thanks were extended to the mentors, judges, and ICorr experts who contributed to the programme's success, including individuals such as **Stephen Tate, Yunnan Gao**, and others and, our event sponsors **BP, AMPP, Wood Thilsted, Intertek CAPCIS** and **LBBC Baskerville.**

Looking Ahead

The 2024 ICorr YEP Final Presentation Evening was a resounding success, highlighting the importance of nurturing the next generation of corrosion professionals. Congratulations to all participants, particularly the winners, **Team 1** and **Rochelle Holness**, for their remarkable achievements. **A comprehensive report** on the evening, featuring detailed insights from the presentations and feedback from the judges, will be published in the upcoming issue of **Corrosion Management.** Stay tuned for more on the outstanding work showcased during this unforgettable evening.

Join the Young ICorr Committee

Young ICorr is currently looking for new committee members. This is a fantastic opportunity for early career engineers, scientists, and researchers in the field of corrosion to get involved, gain experience, and make valuable connections. If you are interested, please contact Young ICorr for more information at **icorryep@gmail.com**

Parliamentary and Scientific Committee (P and SC) APPG - Special Joint ICorr/UK Government Event: Reuse, Renew or Replace?

Report by Sue Wharton, Science in Parliament (SIP) - The Journal of the Parliamentary and Scientific Committee (All-Party Parliamentary Group).

Photo: P and SC Portcullis House, London. *Image Courtesy of Parliamentary and Scientific Committee APPG.*

On **15th October 2024**, visitors including eleven delegates from ICorr, were welcomed to the discussion meeting by George Freeman MP, new Chair of the P and SC.

The Parliamentary and Scientific Committee is an All-Party Parliamentary Group funded by Membership – for further details go to **www.scienceinparliament.org.uk**

Stephen Tate, President of ICorr, introduced Institute activities; training and informing corrosion engineers at all levels is a key objective. Courses are run, qualifications awarded, specialised meetings held, and financial support given, including for their Young Engineer Programme (YEP), currently running in London.

The APPG then heard four specialist presentations: Gareth Hinds, Senior Fellow and Science Area Leader, Electrochemistry Group at the National Physical Laboratory, gave us his thoughts on 'Raising Awareness of Corrosion'; David Parker, Environmental Consultant, spoke on 'The Potential of Value Retention Processes (VRPs)'; Izabela Gajewska, Intertek CAPCIS Consultancy Services, gave us her ideas on 'Mentoring the Next Generation towards Corrosion Prevention'; and finally Christian Stone of Loughborough University and Concrete Preservation Technologies Ltd, described 'Advanced Corrosion Management Techniques to Reduce Cost and Risk in Our Built Environment'.

Corrosion costs the UK £80 billion per year. Professor Hinds stressed we must raise awareness of this; we have expert knowledge of corrosion control practices, which could save up to 35% of this total. All countries pay the price of corrosion, and the World Corrosion Organisation (WCO), of which he is currently President, promotes global education and best practices in corrosion control; tackling corrosion also fits well with UN Sustainable Development Goals. Ideally, corrosion control should be incorporated in designs for new projects; unfortunately, undergraduate courses tend not to specialise in the subject, with knowledge generally learnt on the job.

David Parker focused on re-use, explaining the concept of Value Retention Processes (VRPs), Refurbishment and repair, re-use, and remanufacturing were reviewed. Benefits from re-use include reduced emissions, saving raw materials, and more skill orientated jobs. Industry and services are aware of benefits but hampered by regulatory and trade barriers and cost pressures.

Izabela Gajewska, Intertek CAPCIS Consultancy Services, and an ICorr Young Engineer, gave us her views on developing the new generation of corrosion engineers.

Optimised corrosion prevention practices can improve safety, protect the environment, and save money. She listed the varied work of corrosion professionals, reiterated the shortage of new engineers, and suggested suitable courses; experienced specialists retiring impacts the transfer of knowledge. Better communication on education, training, and mentoring would enable and encourage more homegrown students. Christian Stone described advanced corrosion management techniques. Much of our built environment uses reinforced concrete, but mid-20th century public infrastructure can now require intervention; current repair strategies are often lacking and work delayed due to budget constraints. Refurbishment of existing structures is better than rebuilding. Britain is a world leader in corrosion surveying and management; electrochemical surveys pinpoint issues and tailor them to specific locations. Hybrid Galvanic techniques are UK inventions, used worldwide. Recent Reinforced Aerated Autoclave Concrete (RAAC) concerns have been tackled using specific survey methods and anodes, now protecting many public buildings.

Photo: L-R Yunnan Gao (ICorr Vice President), George Freeman MP (Past Minister of State in the Department for Science, Innovation and Technology), Gareth Hinds (Past ICorr President/Speaker), Christian Stone (ICorr Speaker), Stephen Tate (ICorr President/Speaker), Stephen Benn (3rd Viscount Stansgate), Izabela Gajewska (ICorr Speaker), David Parker (ICorr Speaker), David Mobbs (Coatings Specialist) and Douglas Mills (Past ICorr Technical Secretary). Image Courtesy of Parliamentary and Scientific Committee APPG.

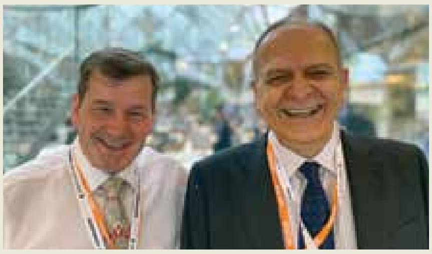


Photo: ICorr President Stephen Tate with ICorr MIC Tutor Tony Rizk. Image Courtesy of Parliamentary and Scientific Committee APPG.

A varied Q and A session discussed RAAC safety, reluctance to use new technology, and shortage of specialist engineers. Reactive attitudes persist; only when a collapse occurs do organisations have to rethink. Better communication and design are needed; short-termism is a false economy.

A national register of structures at risk in all areas is considered desirable. Corrosion engineers can play an important role in sustainability and climate change; there should be more awareness of the value of their skills.

The Institute of Corrosion expresses its special thanks for assistance provided to ICorr by Karen Smith, Leigh Jeffes, Roger Brown and Sue Wharton of the Science in Parliament (SIP) Group.

Reinvigorating the Corrosion Engineering Division: A Vision for the Future

By Danny Burkle

The ICorr Corrosion Engineering Division (CED) has long provided a collaborative space for professionals in corrosion engineering to exchange ideas, share experiences, and develop practical tools for industry applications. Through its working groups, the CED addresses various areas, from cathodic protection to corrosion in concrete, each driven by the needs of its members from industry, academia, and research organisations.

As the division steps into the future, it's poised for a period of transformation aimed at enhancing its impact, broadening its membership, and strengthening its influence in the field.

Strengthening the CED's Leadership and Community

The first step in this renewed focus is the recruitment of a vice-chair, who will work alongside the current CED Chair, **Dr Danny Burkle**, to steer the division's initiatives forward. This new role will bring additional leadership support, helping to balance the demands of CED activities and ensure continuity. Alongside this, the CED is looking to bring in fresh voices by recruiting new committee members, creating a more energised and dynamic team equipped to meet the challenges of modern corrosion engineering.

One of the key goals of this reinvigoration is to enhance collaboration with Young ICorr, fostering stronger connections between early-career professionals and seasoned experts. This partnership will not only provide mentorship opportunities but also infuse the CED with innovative ideas and enthusiasm from the next generation of corrosion engineers.

If you are interested in the vice chair position, or joining the committee, contact Danny.

The Paul McIntyre Award for 2024 and 2025

The Paul McIntyre (PM) Award, a highlight of the CED's annual events, recognises outstanding contributions to corrosion science and engineering. The 2024 award will be presented during the next CED Working Day in April 2025, aligning with Corrosion Awareness Day. The CED is committed to celebrating excellence in the field, and this award remains a prestigious mark of achievement within the corrosion community.

Nominations for the 2025 award can be submitted to Danny.

Looking Ahead to the 2025 CED Working Day

April 2025 will mark an important milestone for the CED with the hosting of the next Working Day and symposium on Corrosion Awareness Day. This full-day event will bring together corrosion professionals from diverse sectors, featuring technical talks by leading experts, active discussions within working groups, and valuable networking opportunities. With the renewed focus on engagement and learning, attendees can look forward to an event that not only provides industry insights but also fosters professional connections.

In the lead-up to this event, the CED is focused on restructuring its committees and processes to better serve its members. Danny will lead efforts to establish a 'revitalised' committee structure, with active involvement from Young ICorr. This refreshed approach aims to enhance the division's offerings and ensure that each working group is well-resourced and able to make meaningful contributions to the broader corrosion community.

Building a Stronger Future for Corrosion Engineering

As the CED embarks on this path of renewal, the commitment to serving its members and advancing corrosion engineering remains unwavering. By recruiting new leadership, engaging younger members, and celebrating achievements through the Paul McIntyre Award, the CED is positioning itself as a pivotal player in shaping the future of corrosion management.

The journey ahead holds exciting possibilities for the CED and its members. With a strategic focus on growth and engagement, the division aims to create a thriving community that supports innovation, fosters collaboration, and strengthens the field of corrosion engineering for years to come.

Contact Danny for more information, for intertest in joining or to provide nominations for the PM award for 2025.

Connect with Danny on LinkedIn:

Telephone: +44(0)7734830749

email: danny.burkle@lbbcbaskerville.co.uk

ICorr Awards – Call for Nominations

Each year the Institute of Corrosion bestows a range of internationally renowned awards in recognition of excellence in corrosion science and engineering and to reward outstanding service to the Institute and the wider corrosion community. Many of these awards are open to nomination by both members and non-members of the Institute. Below is a brief description of each award, together with details of how to nominate potential candidates.

U.R. Evans Award

The U.R. Evans Award is the premier scientific award of the Institute of Corrosion and is presented annually for outstanding international achievements in pure or applied corrosion science. The recipient is selected by a Corrosion Science Division panel and presented with an engraved sword at the annual Corrosion Science Symposium (CSS). The symposium is one which seeks to encourage the participation of the junior members of the corrosion community who would appreciate the visit of, and address by, a corrosion scientist of international repute. The form of the award symbolizes the fight in which we are all engaged. The recipient is also granted Honorary Life Fellowship of the Institute. **Nominations may be submitted at any time via email to the CSD Chair, Julian Wharton (j.a.wharton@soton.ac.uk).**

Prof David Shoesmith (University of Western Ontario, Canada) was presented with the U.R. Evans Award 2024 by Stephen Tate (ICorr President) at the 65th Corrosion Science Symposium, which this year joined Electrochem2024 at Manchester Metropolitan University, held between 11th and 13th September. In his plenary talk entitled 'Corrosion of the Spent Fuel Waste-form and Engineered Barriers in a High-Level Nuclear Waste Repository', David addressed how various intricate electrochemical investigations into the possible long-term corrosion processes within Canadian/Swedish/Finnish deep geological repositories. This was a very fitting commemoration for the centenary of the first publication of Corrosion of Metals by Ulick Richardson Evans in 1924.

Paul McIntyre Award

The Paul McIntyre Award recognises a distinguished senior corrosion engineer who has demonstrated excellence not only as a leading practitioner in the field but also in fostering European collaboration and advancing international standards. This prestigious award includes an engraved trophy, presented at the annual CED Working Day meeting. The recipient will be invited to deliver a short presentation of their professional contributions and is encouraged to submit an article for publication in Corrosion Management. We're also excited to announce that the 2024 award winner will be revealed at the upcoming **CED Working Day on Corrosion Awareness Day on 24th April 2025. Nominations for the 2025 award are now open and should be submitted to the CED Chair, Danny Burkle, at Danny.Burkle@lbbcbaskerville.co.uk by the end of July 2025.**

T.P. Hoar Award

The T.P. Hoar Award is presented to the authors of the best paper published in the scientific journal Corrosion Science during the previous calendar year. The winning paper is selected by a sub-committee of the Corrosion Science Division and the authors receive a certificate and a cash sum of £400.

Galloway Award

The Galloway Award is presented to a student author for the best publication describing original research in corrosion science and engineering as judged by a sub-committee of the Corrosion Science Division. The student should be the primary author of the work and preferably first author. A summary of the winning paper is published in Corrosion Management and the prize consists of a certificate and a cash sum of £300. The Institute does not retain copyright of the material, so this does not prevent separate publication of the work in a scientific journal. **Submissions (in the form of a paper published within the past 12 months or a draft publication) may be sent via email at any time to the CSD Chair, Julian Wharton (j.a.wharton@soton.ac.uk). Supervisors may nominate students.**

Lionel Shreir Award

The Lionel Shreir Award is given to the best student presenter at the annual Corrosion Science Symposium. Selection of the recipient is carried out by a sub-committee of the Corrosion Science Division. The award consists of a certificate and a cash prize of £125.

The Shreir award in 2024 was presented to Amber Sykes (University of Leeds). Amber gave an excellent presentation linked to her PhD research into the evolution of porous $FeCO_3$ layers, and their influence on the CO_2 corrosion rate of carbon steel.

For further details on the Institute awards, including lists of past recipients, please visit https://www.icorr.org/icorr-awards/

ICorr Leadership Strengthens Global Ties at 22nd International Corrosion Congress in Xi'an, China in October 2024

The 22nd International Corrosion Congress, is a prestigious global event dedicated to advancements in corrosion science and engineering and was held on 22nd to 26th October 2024 in Xi'an, China.

Photo: All Attendees of the Opening Ceremony of the 22nd ICC Corrosion Congress in Xi'an. ICorr Presidents: Right 3 and Right 5, 2nd Row, Central Block.

Organised by the International Corrosion Council (ICC) and supported by the Chinese Society for Corrosion Protection (CSCP), the congress brought together corrosion experts, scientists, engineers, and industry leaders from around the world. The event aimed to share the latest research, technological innovations, and sustainable practices in corrosion management across many different industries.

The Institute of Corrosion (ICorr), represented by President Stephen Tate and Vice President Dr. Yunnan Gao, attended the congress upon the invitation from the CSCP and the congress organisers, as providing international support to this congress and following ongoing ICorr/CSCP discussions during the previous 12months. The congress featured a diverse program of keynote presentations, technical sessions, workshops, and networking opportunities. Topics ranged from enhancing corrosion controls and corrosion management procedures to new digital tools and artificial intelligence for corrosion monitoring and mitigation. Xi'an, known for its rich history and role as a cultural hub, served as an inspiring venue for this landmark event and attracted a large audience.

Photo: ICorr Past and Future Presidents and ICC President Elect (2027-2030), Prof. Dr. Zehbour PANOSSIAN from Brazil, during the Congress.

During the Congress, ICorr Presidents actively engaged in discussions with the leadership team of the International Corrosion Council (ICC), including ICC past president Prof. Dr. Günter SCHMITT President (2018-2021) from Germany, ICC President (2021-2024) Prof. Emma ANGELINI from Italy, ICC President Newly Elected President in Xi'an (2024-2027) Prof. Vngaranahalli Srinivasan RAJA from India and ICC President Elect (2027-2030), Prof. Dr. Zehbour PANOSSIAN from Brazil.

Photo: ICorr Past and Future Presidents and ICC Presidents and Congress VIPs at the Congress Dinner.

The ICC Congress provided an excellent platform for ICorr to showcase its initiatives and contributions to corrosion science. ICorr leaders shared insights on professional development programs, such as training and certifications, and emphasised the organisation's dedication to advancing corrosion engineering standards globally.

ICorr's participation at this congress greatly enhanced its mission to contribute to global advancements in corrosion control and its aspiration to promote knowledge exchange and innovation within the international community. The interaction between with the ICC leadership emphasised ICorr's growing influence outside of the UK and reinforced its commitment to strengthening ties with international counterparts.

The ICorr presidents' successful joint participation in the Xi'an conference highlighted the growing interconnectivity and shared purpose of the global corrosion community. It also set the stage for a future defined by mutual support between CSCP/ICC/ICorr and welcome advancement in knowledge sharing.

ICorr North-East Updates: Institute of Corrosion 2024 AGM at Neville Hall

On **Wednesday, 13th November 2024**, the North-East Branch of the Institute of Corrosion hosted the **Institute of Corrosion 2024 AGM** at Neville Hall in Newcastle upon Tyne.

The Historic Lecture Theatre at Neville Hall.

The day commenced with a Technical Offshore Wind Programme, followed by the AGM and concluding with an evening dinner. Almost 70 people from all over the UK attended the Technical Programme and 60 attended the evening dinner, attendees included the ICorr Council, Sustaining Members, Professional members, general members and potential future members. The day was a great success with the variety of engaging content keeping the attendees entertained for almost 9 hours from start to finish.

Photo: The Lord Mayor of Newcastle Upon Tyne Opening the Technical Programme.

Matt Fletcher, Chair of the North-East Branch of ICorr, opened proceedings, which was followed by the formal opening of the Technical Program by the Lord Mayor of Newcastle, who welcomed everyone to Newcastle and described how offshore wind and the project to re-paint the Tyne Bridge brought valuable jobs to the region. Lord Mayor also explained that as he did not have his "driver" available, he was unable to wear his full collection of Mayoral Medals as they were too valuable to be worn in public without the extra security of his "driver!".

The Offshore Wind Technical Programme then opened, consisting of 4 presentations:

Environmental Considerations for Offshore Wind Foundations Corrosion Protection

Dr. Anthony Setiadi Chief Consultant / Associate Director Wood Thilsted

Anthony described how offshore wind industry growth is accelerating as the world is pushing towards renewable energy sources. These wind turbines need to be installed on foundations located in aggressive environments and are prone to corrosion if not protected and/or designed with corrosion in mind. There are various offshore wind foundation types, such as monopiles, jacket tetrabases, gravity bases, and floating structures. The presentation discussed what level of protection is required, what the options are, and how all of this would impact the structural integrity throughout the design life, as well as how fabrication, transport, and installation limitations would affect the corrosion protection design.

Anthony explained how equally important the environmental considerations need to be taken into account with respect to carbon equivalents in producing and protecting these foundations, as well as the potential byproducts expected. In discussing the creation of habitats for nature, Anthony made an interesting point: if habitats are created on the foundations, what happens to these environments when the foundation is decommissioned in the future?

Photo: Dr Anthony Setiadi of Wood Thilsted Presenting.

Assessment of Thermal Spray Aluminium Coating in Synthetic Seawater by Using Complementary Techniques

Dr. (candidate) Adriana Castro Vargas Research Associated – Materials Innovation Centre University of Leicester and NSIRC

Photo. Dr Adriana Vargas of the Materials Innovation Centre University of Leicester Presenting.

Adriana presented the results of her PhD that used complementary techniques, such as in-situ imaging and an analytical rotator, to understand the performance of thermally sprayed aluminium (TSA) coating in simulated marine immersion service. The experimental work involved evaluating TSA in quiescent and flowing synthetic seawater at room temperature. The coating (300 µm thick) was obtained by twin-wire arc spraying of 1050 aluminium alloy on an S355 carbon steel substrate. In quiescent condition, TSA-coated steel samples were evaluated by the optical analysis of sequential images captured in situ: (i) with defects machined before immersion (5% of exposed steel surface); and (ii) with a defect machined after 35 days of immersion (10% of exposed steel surface).

When the defect is machined before the immersion, initial dissolution of iron occurs until the air-formed oxide layer degrades, the electrolyte penetrates the coating, and the aluminium surface is activated. Conversely, when the defect is created after immersion, the aluminium activates rapidly, and the system reaches the range of protective potentials (according to DNV-P-B401), providing immediate protection to the exposed steel. In flowing synthetic seawater, cylindrical coupons were tested in an analytical rotator at 50 rpm and 600 rpm for 10 days. Open Circuit Potential (OCP) and Linear Polarisation Resistance (LPR) measurements were carried out to assess the flow velocity effect and calculate the corrosion rate.

An Introduction to the Offshore Renewable Energy (ORE) Catapult and Its Key Role in Advancing and Derisking Technology in Offshore Wind.

Mr. Tom Chaplin Marketing Manager Offshore Renewable Energy Catapult

Tom Chaplin provided an introduction to the Offshore Renewable Energy Catapult and described the key role it plays in advancing and derisking technology in offshore wind. ORE Catapult is one of the world's leading offshore renewables technology centres, with an unrivalled set of test assets that aim to accelerate the creation and growth of UK companies in the offshore renewable energy sector. Established in 2013, ORE exists to accelerate the development of offshore wind, wave and tidal energy technologies in the UK. Through its world-class testing and research programmes and its unique centres of excellence, ORE works with industry, academia and government to improve technology reliability and enhance knowledge, directly impacting the cost of offshore renewable energy. ORE delivers products and services in four main areas: research, engineering, testing and validation, and supply chain growth.

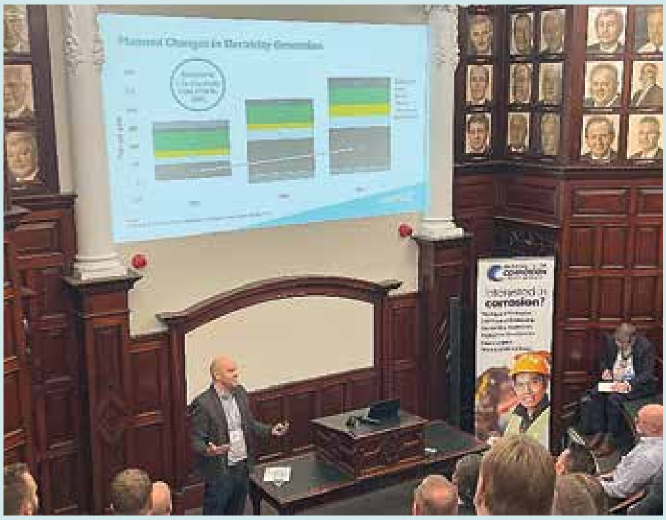


Photo. Tom Chaplin of ORE Catapult Presenting.

Tom showed the scale of the ORE Catapult testing facilities, showing a video of testing a 107 m blade (which needed to be cut down to 100 m to fit in the test facility) and the 14 GW powertrain, which, as a result of the testing, had its capacity increased. Tom also revealed plans to increase the capacity at ORE Catapult to be able to handle wind turbines well into the future with capability to test blades up to 150 m long (and expansion potential to 180 m) and a significant increase in drive train capacity to 23 MW (with potential expansion to 28 MW).

After the presentation Tom was asked about catastrophic failure during testing; although unable to share images, Tom said it had happened and was quite dramatic. All was not lost, as the fractured blade provided insightful data on blade failure to the owners.

Development of ISO 25249 – Corrosion Protection of Offshore Wind Structures

Mr. Simon Daly Consultant – Energy and Infrastructure Safinah Limited

Photo: Questions Following Simon Daly's, Safinah Presentation.

Simon described how a series of parts of a new international standard, ISO 25249, are currently being worked upon. The standard will address the issues of developing a corrosion protection approach for the protection of offshore wind farms. With the growth in offshore wind will come the need for large-scale construction of assets, which will be placed in a corrosive offshore environment.

While the corrosion of steel structures offshore is well documented through experiences in the oil and gas industry, offshore wind energy has encountered its own challenges when it comes to providing corrosion protection. The ISO 25249 standard will address key issues and develop a framework for a more standardised approach to the selection, execution, and operation of a variety of different corrosion protection methods.

continues on page 18

Simon presented on behalf of the program managers for the first 5 parts of this new standard, the development of which will shortly commence within the International Standards Organisation (ISO) framework. During the questions after the presentation, the sharing of experiences gained in the oil and gas industry was discussed. It was generally agreed that to prevent mistakes from 30 years ago being repeated, experiences should be reviewed and shared. It was hoped that with more of the traditional oil and gas companies entering the offshore wind market, this would be more likely to take place.

Following the Technical Program the ICorr AGM took place, details of the AGM can be found in the AGM minutes. At the AGM Stephen Tate passed on the Presidency of ICorr to Yunnan Gao and Yunnan passed on the Vice-Presidency to Anthony Setiadi.

Photo: New Vice President – Dr Anthony Setiadi, New President – Dr Yunnan Gao, Past President – Stephen Tate.

The evening saw a three-course dinner, enjoyed in the library at Neville Hall. As can be seen in the photographs, the library is a beautiful wooden clad room, with many original features, such as elevated bookshelves, bookshelves hidden behind wooden doors, and stained-glass windows. A jazz band played throughout the evening, and the dinner was opened by the new president of ICorr – Dr Yunnan Gao.

Feedback following the event was overwhelmingly positive:

- "NE Hospitality is famous and you certainly lived up to that." - Stephen Tate: outgoing ICorr President.
- "Please accept my thanks for the superb organisation and excellent day yesterday." - Brian Wyatt of CPGB and Council.

The Chair of the NE Branch of ICorr is grateful to the NE Branch Committee for all their hard work in creating a most successful day; all are volunteers and worked tirelessly to make the event a success. Simon Daly, Patrick Johnson, David Mobbs, Bruno Ravel, Barry Turner, and Josie Watson.

Future Meetings

Due to a date clash with London Branch Dinner, NE Branch will now hold its Xmas (Branch) event at the end of January 2025.

There will be a tour of the Newcastle Castle Keep, the cost of which will be £20 a head.

Please contact **nechair@icorr.org** for further details.

ICorr Branch Updates

ICorr Aberdeen Updates

On **Thursday 7th November 2024** the Aberdeen Branch in a joint meeting with TWI welcomed **Dr. Cheng Huan Zhong** of Inductosense Limited, with a talk entitled 'A Pathway to Thickness Measurement Locations (TMLs) Digitalisation.'

Complimentary to the recent presentation to South-West Branch by Erik Fabre this event focussed specifically on Case Studies of Inductosense Applications globally.

Presenter: Dr. Cheng Huan Zhong.

Cheng Huan received a B.Eng. degree in mechanical engineering and a PhD. degree from University of Bristol, England, in 2015. From 2015 to 2016, he was a Research Associate in the non-destructive testing research group at the University of Bristol. Both his PhD and Research Associate work was focused on the development of passive wireless transducers for structural health monitoring. He is a co-founder of Inductosense Ltd, an industrial spin-off from Bristol University in 2015 and the Chief Technology Officer. He has managed multiple product development projects such as sensors, handheld data collector and remote data collector.

A Pathway to Thickness Measurement Locations (TMLs) Digitalisation

Synopsis: Permanently installed sensors provide more accurate results compared to conventional inspection due to their consistent positioning and coupling. However, due to their cost, they are normally used for monitoring critical areas for corrosion rate estimation. There are hundreds of thousands of thickness measurement locations (TMLs) on a process site for piping and vessels, making it challenging to monitor all of them. Inductosense has proposed an alternative approach that combines passive sensors and a different data collection method to enable a cost-effective, consistent, and deployable solution with wide sensor coverage possible at low cost.

Dr. Zhong presented their handheld data collector, robotics, and online solutions and demonstrated how they work together to address different applications with accessibility and inspection frequency. The presentation concluded with a large number of case studies aiming to demonstrate the benefits of this approach.

Amongst applications included were:

- Buried Pipeline Monitoring
- Drones
- Erosion Monitoring
- Integrated Corrosion Management
- Manual Wands
- Overhead Pipework Monitoring
- Production Optimisation
- Remote Data Collectors
- Riser and Flowline Monitoring
- Robots and Crawlers
- Ship Tank Usage
- Specialised Vessel Monitoring
- Subsea ROV Data Collectors

The Event provided interesting opportunities for questions.

Please contact the Aberdeen Chair for details of future ICorr Aberdeen Events.

ICorr Aberdeen Joint Online Meeting with TWI

On **Tuesday 24th September 2024** the Aberdeen Branch held a joint online meeting with TWI and welcomed **Neil Gallon**, Principal Engineer of Rosen, with a talk on **Welding and Metallurgy Requirements for Hydrogen Service.**

Neil Gallon, Principal Engineer of Rosen.

Having previously worked for various consulting and manufacturing companies, including British Steel Tata Steel and GE Wellstream. Neil's, current work with ROSEN UK concentrates on understanding the effects of gaseous hydrogen on steel properties.

Neil outlined the requirements for material selection, welding, and metallurgy of carbon steels for gaseous hydrogen service. He also described the mechanisms and effects of gaseous hydrogen embrittlement, presented current code requirements in terms of material properties (including welding), and gave an overview of recent research and code developments.

Key Points

Hydrogen embrittlement is the detrimental effect of hydrogen on the mechanical properties of metals and alloys.

- The fundamental feature that drives much of the integrity concerns and challenges in gaseous hydrogen pipelines is the absorption of atomic hydrogen within the steel microstructure. The interactions of hydrogen can lead to major degradation of mechanical properties such as strength, durability, fracture toughness, and fatigue crack growth rate. These have been studied by various researchers of material types used in repurposed pipelines, such as API Series 5L X42, X52, X65, X80 and X100.
- The data available to date, is not comprehensive but all show that all performing properties are reduced by increasing levels of Hydrogen.
- While hydrogen pipelines could be purpose-built, it is very likely that a major proportion of the future transmission network will revolve around the integration of existing natural gas or other hydrocarbon infrastructure. Hydrogen pipeline design codes tend to be more constraining or restrictive than that for hydrocarbons. For example, typical hydrogen standards will limit the use of steels up to API 5L X52 (L360) to tackle hydrogen embrittlement issues, while over 45% of the European NG system is designed with higher steel grades.

- The Code for Hydrogen pipeline integrity ASME B31.12 lists pipeline materials suitable for hydrogen transportation. Material compositions and properties are more restrictive than "standard" API 5L requirements on items such as the Charpy shear area requirement, the Maximum YS and UTS (including AWT) and a more restrictive chemical composition. The implications are that additional manufacturing and purchasing restrictions will be necessary and existing natural gas pipelines for repurposing may not meet material requirements. From a design perspective and materials performance factor, hydrogen pipelines will operate at lower pressure than that of natural gas unless specific hydrogen test data (KIH) is available.
- A Material Hardness maximum of 248HV is required for production testing, which is even more severe than sour service requirements.
- The magnitude of the interaction of hydrogen and steel is determined by the specific nature of the steel microstructures and chemistries, not just the grade. This important facet puts a great emphasis on the understanding of materials 'DNA' and on testing. Microstructure performs an important role in achieving higher fracture toughness in the presence of gaseous hydrogen up to 20.7 M Pa and alloy processing design influences final steel microstructure formation.

Mechanism of Hydrogen Embrittlement in Steels

Hydrogen embrittlement is basically the loss of ductility of a metal resulting from the adsorption of Hydrogen.

1. **Adsorption of H_2 to the steel surface.**
2. **Dissociation of H_2 molecule.**
3. **Absorption of H atoms into metal matrix.**
4. **Diffusion to thermodynamically favoured sites e.g. crack tips, dislocation cores, grain boundaries.**
5. **Actual embrittlement takes place *(mechanism unknown).***

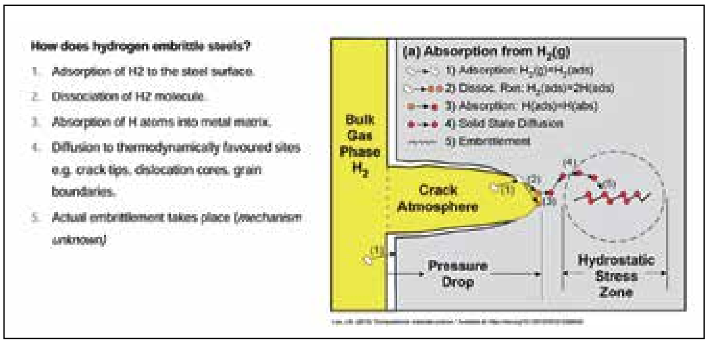


Photo: Explanation of Hydrogen Embrittlement Process.

Hydrogen pipeline integrity depends on material susceptibility, stress, and environment. The possibility of cracking is largely dependent on the environment, and susceptibility to HE is dependent on the amount of hydrogen available. The equilibrium concentration of hydrogen in the metal depends on the partial pressure of hydrogen (Sieverts' law) and its diffusivity (Fick's law). At room temperature, H concentration from gaseous hydrogen is very low.

Neil outlined the effect that hydrogen has on pipeline integrity in terms of the principal properties of strength, durability, fracture toughness, and fatigue crack growth rate.

Hydrogen has a relatively small effect on strength at transmission pipeline pressures, while its effect on ductility is more dramatic; this has implications for fracture toughness. Laboratory studies of the effects of internal hydrogen and surface absorbed hydrogen on tensile strength and ductility demonstrate this slight fall in UTS in charged environments, but dramatic loss of ductility from 18 down to ~3% strain levels.

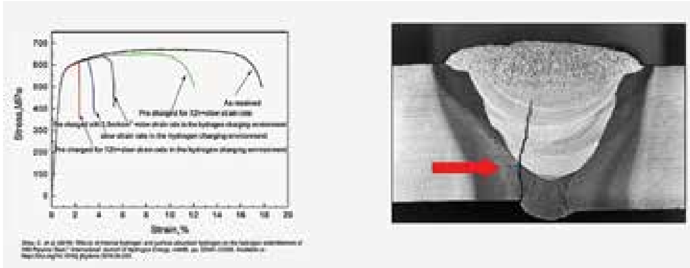


Figure 1: Effects of Internal Hydrogen and Surface-Absorbed Hydrogen on Hydrogen Embrittlement.

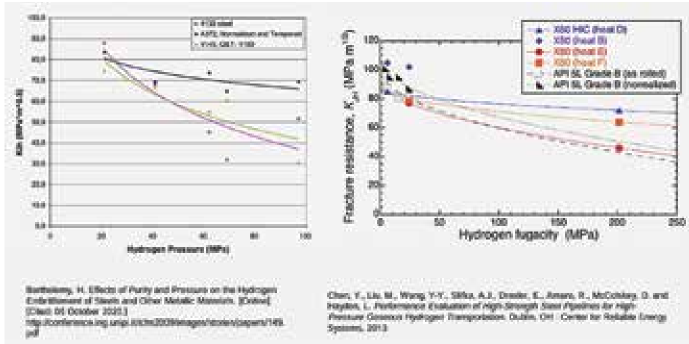


Figure 2: Effects of Purity and Pressure on Hydrogen Embrittlement.

It is also clear that hydrogen reduces toughness from lab studies, but there is large variability in results, possibly due to microstructural differences in pipe grades.

Testing Approaches

There are two main approaches for testing H effects on fracture toughness:

1. Rising load fracture toughness as recommended by ISO 11114-4. This produces a measurable toughness value J, K, CTOD; however, the fracture toughness depends on H kinetics, and the results depend on loading rate.
2. Threshold stress intensity factor KIH – recommended by ASME B31.12 and ISO 11114-4. The results do not depend on H kinetics. However, on the downside, this is a pass-fail outcome, has long testing time with several tests required, and the result is not quantitative.

Photo: NIST High Pressure H_2 Test Chamber.

Source: https://www.nist.gov/image/materialstestinghighpressurehydrogentestchamberjpg

Studies have also been made of fatigue crack growth rates in hydrogen environments:

- As yet, there are currently no agreed standard test protocols, but full-scale tests are currently ongoing, and there is currently a lot of research activity in this area.
- Crack growth da/dt is realised in the laboratory conditions, although there is no evidence that it has happened in pipelines in service, so the implications for pipelines are unknown.

- Crack propagation does not happen all the time; it appears to be due to the pre-conditioning and stress state around the crack tip, with unpublished evidence that sometimes cracks arrest.

In summary, the requirements for material selection, welding, and metallurgy of carbon steels for gaseous hydrogen service are developed, but there remain areas for further study and development:

- Codes are not mature enough to follow prescriptively.
- No clear relationship between in-air and in-hydrogen material properties.
- Likely that extensive programmes of material qualification in gaseous hydrogen will be required.
- Significant amounts of current code developments and research are necessary.

An extensive Q&A followed this well-attended online event, and the Aberdeen ICorr committee offered its thanks to Neil on following his most informative presentation.

The Aberdeen Branch provides a very full technical programme of both in-person and online events. Abstracts of potential papers for the Aberdeen Technical Programme are always welcome for consideration, and anyone wishing to present should correspond soonest with the 2024/2025 Chair and Technical Programme Co-ordinator: **meilingcheah@gmail.com**

Further information about the Aberdeen Branch and past presentations may be found on their website page: Aberdeen Branch - Institute of Corrosion. **https://www.icorr.org/aberdeen/** under Local Technical Programme and to join the Aberdeen Branch mailing list, please contact: **icorrabz@gmail.com**

ICorr London Updates

On **10th October 2024** the branch held a joint meeting with the London Materials Society (LMS), when Ali Morshed presented, "Why Effective MIC Control is Still a Major Challenge in the Industry."

Ali has a PhD in corrosion engineering from University College London and is the author of five corrosion management books, and one book on MIC, with NACE/AMPP. He is a corrosion engineer with more than 21 years of experience, starting his career in the Oil and Gas industry in 2002, and gradually expanded his work to many other industries.

Photo. The chair for the Evening Introducing the Speaker and the LMS Vice Chair, Melissa Tiskaya.

Microbiologically influenced corrosion (MIC) remains as a major integrity threat and cause of failure for many upstream, mid-stream, and downstream, oil and gas assets, despite the continuous technological advances in the areas of oilfield microbiology, metallurgy, and chemicals.

MIC can be defined as corrosion influenced by the presence, or activity, of microorganisms. Such microorganisms can cause corrosion problems for various oil and gas assets either directly or indirectly. The corrosion damage inflicted by them is considered direct when they create, or further increase, the environment's corrosivity (e.g., by acid production through their metabolism). The damage is considered indirect when they attack, deteriorate, or weaken, a corrosion control measure already in place, thus further promoting corrosion. Such affected corrosion control measures include surface coatings and some corrosion control chemicals such as certain types of oxygen scavengers.

Ali explained that the locations or systems most susceptible to bacterial contamination and MIC include, but are not limited to, sea water injection, fire water, cooling water, sand-wash water (where treated sea water is used to wash the sand accumulated in various pressure vessels), water displacement systems (where treated sea water is used to empty a product storage tank), and wet product transfer pipelines and product storage tanks.

He highlighted an important caveat regarding MIC - prevention is always better than cure, because microbial control once lost, may take years to restore, if at all! Extensive field experience from both the UK's North Sea sector and the Persian Gulf r egion indicated that the main root cause of the encountered MIC leaks, failures, and issues, has been either the total lack, of or inadequate, knowledge and expertise in relation to bacterial and MIC basics and fundamentals, among the relevant personnel.

Photo. Ali Morshed Presenting on MIC.

More precisely, MIC incompetency has been the main culprit behind the failures. In general, the observed MIC incompetency can be divided into the following subject areas:

- Bacterial nourishment and growth conditions
- Bacterial and MIC monitoring
- Bacterial and MIC assessment and control

The last two items, when combined comprise the overall bacterial and MIC mitigation process, as was mentioned earlier.Simultaneously, it has also been observed that Oil and Gas assets which successfully managed and controlled the MIC integrity threat were those where the relevant personnel possessed adequate MIC competency, mainly due to the MIC training they had received.

continues on page 22

Ali finished by saying that while MIC incompetency remains the main root cause of bacterial and MIC problems, timely, practical, and adequate MIC training is regarded as the main solution, and way forward for tackling the existing MIC issues for the Oil and Gas assets concerned.

Photo (Right): After an Interesting Q&A Session, Ali was Presented with an ICorr Pen in Appreciation of His Talk, by the Chair for the Evening, ICorr Committee Member, Brian Goldie.

The London Branch also kindly hosted the 2024 Young Engineers (Case Study) Programme reported separately above ***on page 10.***

ICorr Midlands Updates

By Dr Prafull Sharma (Interim Chair, Midland's Branch)

Our Year to Date

Photo: Dr Prafull Sharma, Interim Chair, Midland's Branch.

2024 has been a year of reforming and progress for the ICORR Midlands Branch. The branch, under new leadership of Dr Prafull Sharma, has embarked on initiatives to enhance its activities and strengthen member engagement. One key area of focus has been regional outreach, particularly to universities, aiming to encourage young professionals to join ICORR and contribute to its growing community. Plans are also underway to further develop physical and digital engagement, combining events with an intensified presence on online platforms.

The branch's digital initiatives have shown remarkable success. The ICorr LinkedIn channel, launched just a few months ago, has quickly surpassed 1,000 followers and continues to grow. This platform has become a vital resource for updates, educational content, and community interaction, and we encourage all members to follow it for the latest news. Expanding on this, the branch also launched a YouTube channel this year.

This will serve as a repository for all future webinars and educational resources, making them accessible to a broader audience. Members and followers can now revisit valuable sessions or catch up on missed events at their convenience.

In addition to these digital advancements, on **19th June 2024** the branch has previously hosted a well-received webinar on Generative AI for Corrosion Professionals. This session, attended by over 200 members, explored the applications of artificial intelligence in addressing corrosion challenges, providing attendees with insights into the potential of AI to transform the field. The success of this event has reaffirmed the importance of delivering high-quality, innovative content to members and has inspired plans for several webinars in 2025. Refer to: **www.icorr.org/midlands/Local Technical Programme - 2024 Presentations.**

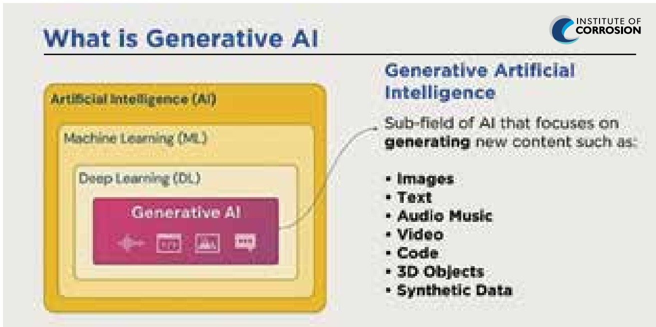


Photo: Midlands Webinar - Generative AI for Corrosion Professionals.

A mini-conference is proposed for 2025, with dates to be announced soon. The conference will bring together industry professionals, researchers, and academics to discuss current trends, challenges, and innovations in corrosion science. Meanwhile, the branch is also collaborating with the Marine Corrosion Forum (MCF) to organise a joint event in April 2025, reflecting a strengthened partnership and a commitment to fostering broader industry collaboration.

Engagement with MCF has been another highlight of the year, exchanging ideas and building connections to enhance ICorr's impact. This collaboration underlines the branch's mission to foster partnerships that amplify the reach and value of its activities.

As we move forward, ICorr Midlands remains dedicated to creating a dynamic, inclusive platform for knowledge sharing and professional development. With plans for innovative digital content, impactful events, and strategic collaborations, the branch is well-prepared to deliver value to its members while advancing the corrosion profession. We thank all ICorr members for their continued support and look forward to your continued engagement in the coming year.

Upcoming Branch Events

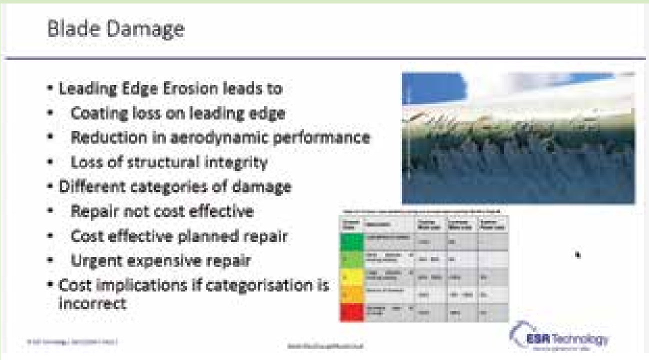
For future events please visit: **www.icorr.org/events/**
If you wish to present, please contact: **midlandschair@icorr.org**

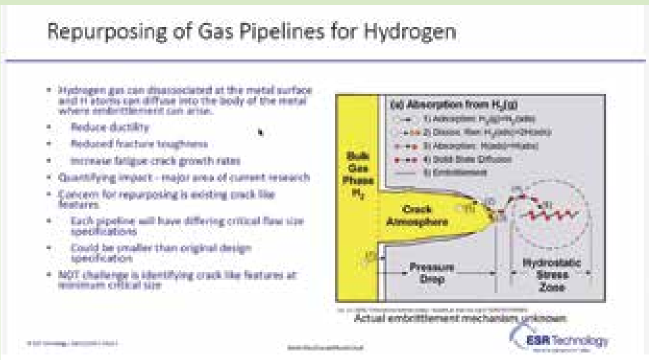
ICorr North – West Updates: Branch AGM and New Committee Members

NW Branch held their AGM on **1st October 2024** at the Luther King House Conference Centre. Representatives from industry and academic research heard from two excellent speakers, **Dr Patricia Conder** from ESR Technology and **Dr Paul Lambert** of Mott MacDonald.

Photo. Dr Patricia Conder Delivering Her Presentation.

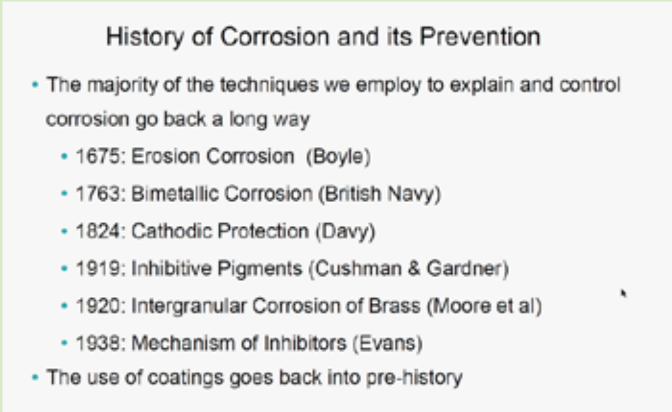
Patricia presented on the topic of "Non-Destructive Testing Challenges in the Net Zero World," covering the challenges of inspecting and testing assets in relation to carbon capture and offshore wind. Conversion of existing assets to process hydrogen and carbon dioxide and testing for the associated changes in degradation mechanisms were some of the many highlights.





Photos: Slides from Patricia Conder's Presentation.

Paul Lambert covered the 200-year anniversary of cathodic protection since its conceptualisation at the Royal Society by Humphry Davy in 1824. The patenting of Portland Cement by Joseph Aspdin, also 200 years ago (!) was also touched upon in an excellent and enlightening presentation.



Photos: Slides from Dr Paul Lambert's Presentation.

Both presentations can be found on the NW Branch Website - **www.icorr.org/northwest/** at Local Technical Programme, along with previous presentations for what has been an excellent year for ICorr NW.

Our New Honorary Secretary

Brenda has been a long-standing member of the Institute and North-West Branch for over 30 years and has served in several important positions and is now the Honorary Secretary of ICorr and a new Trustee. She has been a consultant scientist for 40 years and has acted as an expert for the defence in criminal trials. Brenda is also an RAC-appointed independent inspecting engineer for vehicle paintwork and consultant to the Road Haulage Association. We wish her the very best as she takes over the role of secretary for ICorr nationally.

Photo. Brenda Peters our New Honorary Secretary

continues on page 24

Our New Committee Members

New members with a wealth of academic experience have now joined the committee in the form of **Vincenzo Bongiorno** and **Alyshia Keogh**. We look forward to the continued growth of the branch and more successful events next year.

Photo: Vincenzo Bongiorno, University of Manchester.

Photo: Alyshia Keogh, University of Manchester.

Vincenzo is a research associate at the University of Manchester, where he has been recently awarded his PhD in Materials Science. His research focuses on organic coatings for corrosion protection, electrochemistry, and the interpretation of the electrochemistry of corroding systems with artificial intelligence.

Before starting his PhD, Vincenzo got his bachelor's and master's degrees in chemical engineering at the University of Palermo and worked as a materials engineer at Solvay Speciality Polymers.

When he is not too busy in the lab, Vincenzo loves walking/hiking (when it's not too rainy), reading and writing, and playing guitar.

Alyshia Keogh is soon due to complete a PhD at the University of Manchester in metallurgy and corrosion. Her research has focused on the effect of microstructure on the localised corrosion behaviour of stainless steel for aerospace applications. Alyshia holds a Masters' degree in Materials Engineering from the University of Sheffield and has previously worked in the heat treatment and manufacturing industries. She has participated actively in ICorr this year through her enrolment on the Young Engineer's Programme. Aside from her interest in corrosion, Alyshia enjoys running, cooking, live music, and spending time with her cat.

Upcoming Events:
For future events please visit: **www.icorr.org/events/**
If you wish to present, please contact: **nwchair@icorr.org**

ICorr Wales and South West Hosts Inaugural Event in Southampton

The new Wales and South West of England regional branch held its first event in Southampton on **24th October 2024**. The event was held at Lloyd's Register/Lloyd's Register Global Technology Centre with presentations from **Dr Maryam Bonyadi** and **Dr James Kwame,** both from Lloyd's Register (LR).

Dr Maryam Bonyadi is a Technical and Failure Investigation Senior Specialist at LR. The presentation provided an introduction to LR and the specialist services LR provides. The presentation also included an overview of the LR's Technical and Failure Investigation Department, its team, locations and some of the capabilities. Further, examples of corrosion mechanisms commonly found in the maritime industry were presented.

The second presentation was by **Dr James Kwame**, who is the Senior Manufacturing Technologist at Lloyd's Register, working to develop LR's internal and external technical publications. The presentation provided an insight into liquified CO_2 and the impact of impurities such as H_2O, O_2, SO_2, H_2S, NO_2 and organics which may be present in the CO_2 stream on corrosion and phase change. The talk explored current industry limitations and the general lack of standardisation governing product specifications, such as the quality of CO_2 grades, which present significant challenges in understanding their effect on corrosion and phase change during ship transportation and storage.

The talks gained lots of engagement and interaction from the audience, with many questions and plenty of further discussion. With 20 delegates in attendance, the first Southampton event was deemed a successful one!

Upcoming Event:

The next branch event will take place online on **December 11th 2024**. For more information, contact **swchair@icorr.org**

You can also keep up to date on events by visiting our LinkedIn page; **https://www.linkedin.com/groups/12992293/**

Photo: Delegates Observing the Presentation by Dr Maryam Bonyadi.

Photo: Delegates Observing the Presentation by Dr James Kwame.

Corrosion Around Us: Structural Corrosion of Pedestrian Barriers

By Stephen Tate, ICorr Past President

Pedestrian barriers are essential for maintaining order, safety, and aesthetics in public spaces, whether in parks, around construction sites, during events, or along busy streets. Designed to direct pedestrian traffic and prevent accidents, these barriers often face harsh environmental conditions, constant use, and wear over time. Ensuring their longevity and effectiveness requires consistent and thorough maintenance. One of the biggest threats to pedestrian barriers is structural corrosion, especially for those made of metal, commonly carbon steel, which can compromise their functionality and create safety hazards.

By implementing a proactive maintenance approach consisting of regular inspections, effective cleaning of surface contaminants, rust prevention, fastener checks, and alignment adjustments, corrosion of pedestrian barriers can be reduced. Properly maintained barriers will not only serve their functional purpose but also retain their aesthetic appeal, contributing to safer and more organised public spaces.

Photo: Structural Corrosion of Pedestrian Barriers, Observed in Xi'an China - October 2024.

ICorr Training: The Important Role of our ICorr Tutors

This month, as part of our new Corrosion Management Journal Tutor feature, Profiling Alessandro Bonetti Cathodic Protection Specialist.

Alessandro Bonetti
MSc Materials Engineering

ISO 15257 Level 4 Cathodic Protection Specialist

Tel: 07475055341
Email: alessandro.bonetti@cathodic.co.uk

A practicing cathodic protection engineer with a background in materials engineering and specialised in nanotechnology, Alessandro has had more than 14 years' experience in the cathodic protection industry within the UK as well as Europe, Africa, and the Middle East. His expertise extends from complex land-based cathodic protection systems for tank bottoms, pipelines, in-plant piping, and buried vessels to tank internals, jetty and harbour installations, and offshore structures, including wind farms. He has been involved with offshore CP inspections with remotely operated vehicles, and he is still involved with product design and development for cathodic protection systems and CP monitoring.

Alessandro was ICorr's document controller in 2022 and has been teaching ICorr's BS EN ISO 15257 cathodic protection buried sector courses since 2022. He finds this very rewarding, especially when candidates realise the importance of the measurements they have been performing for years.

ICorr President and Vice President's Visit in TÜV Rheinland Shanghai

TÜV Rheinland Shanghai office welcomed ICorr President Stephen Tate and Vice President, Dr. Yunnan Gao on 29th October 2024. The visit began with a cordial reception by TUV Vice President Dr. Chen Weikang, who warmly greeted the delegation and emphasised the significance of partnership of TUV and ICorr.

During the visit, Stephen Tate and Dr. Yunnan Gao provided meaningful introductions about ICorr, sharing valuable insights. They were kindly given a tour of TUV facilities and engaged in fruitful conversations about future collaborations.

This visit was an invaluable opportunity to discuss TUV ongoing collaboration and to explore new avenues for mutual growth. ICorr President and Vice President had a successful conference call with TUV-qualified tutor (Jianjun Hu) in China, who was working on site, marking TUV's first opportunity to get acquainted.

The President's encouraging words greatly motivated the tutor, setting a positive tone for future collaborations. This call also provided an excellent platform for the tutor to offer valuable feedback, fostering an atmosphere of open communication and mutual respect.

Welcome lunch with ICorr President and Vice President was a fantastic opportunity for the TUV working team to come together and connect. The President took a moment to inspire each team member with motivating words, which set an encouraging tone for the event.

It was a great time to have genuine, uplifting conversations and strengthen TUV team spirit. Everyone left feeling energised and more unified.

Highlights in 2024

- **Translated PCI L2 and L3 into bilingual**
- **PCI L2 Successfully launched in China (5 sessions / 47candidates)**
- **PCI L3 Training and ICorr Transition Exam is going to launch**

Industry News

bp and Iberdrola Announce Final Investment Decision for Largest Green Hydrogen Plant in Spain

bp an ICorr Corporate member, and Iberdrola have given the green light for the construction of a 25 MW green hydrogen project at bp's Castellón refinery, which is expected to be operational in the second half of 2026. This is the first hydrogen project jointly undertaken by bp and Iberdrola through Castellón Green Hydrogen S.L., a joint venture equally owned by both companies.

This initiative, which includes the participation of the Technology Institute of Energy (ITE), has been awarded funding of 15 million euros from the Innovative Value Chain and Renewable Hydrogen Knowledge call of the Spanish Recovery, Transformation, and Resilience Plan, with funding allocated by NextGenerationEU of the European Union. This plant could create up to 500 new direct jobs during its construction.

The 25 MW electrolyser will be powered by renewable electricity through a power purchase agreement (PPA) signed with Iberdrola that will supply 200 GWh/year coming from Iberdrola's photovoltaic and wind projects. The electrolyser will include 5 modules of 5 MW containerised proton exchange membrane (PEM) technology, which will be supplied by Plug Power, a leading manufacturer of green hydrogen solutions. The green hydrogen produced by the electrolysis of water powered by renewable electricity will comply with European requirements to produce green hydrogen (Renewable Fuels of Non-Biological Origin, RFNBO) and will support the transition of bp's Castellón refinery into an integrated energy hub. It's expected around 2,800 annual tonnes of green hydrogen could substitute part of the grey hydrogen currently used by the refinery—currently produced from natural gas—and as such is expected to result in avoiding the emission of 23,000 tonnes of CO_2 per year, equivalent to the emissions of 5,000 cars over the same period. This plant could create up to 500 new direct jobs during its construction.

Source: BP News Release https://www.bp.com

AUTOMA, New ICorr Sustaining Member Achieves ESG Certification

On **7th October 2024**, **AUTOMA** reached a significant milestone in its journey towards sustainability, receiving the prestigious **ESG certification** with an **'A-Excellent'** score from the **Synesgy** platform. This recognition demonstrates the company's ongoing commitment to environmental, social, and governance sustainability.

Synesgy is a global reference platform for companies wishing to assess and improve their ESG performance. Through a self-assessment system, companies can measure their performance and obtain certifications attesting their compliance with international environmental, social, and governance sustainability requirements. Moreover, the platform promotes transparency within supply chains, allowing companies to monitor and audit their suppliers against ESG criteria.

Source: AUTOMA News Release https://www.byautoma.com/en/esg-certification-synesgy/

Oceaneering, ICorr Corporate Member Wins Contract to Build Freedom™ AUV and Remote Operations Centre for U.S. Navy

Houston, Texas – Oceaneering International, Inc. announces today that its Subsea Robotics and Aerospace and Defense Technologies segments were awarded a multi-million-dollar contract by the Defense Innovation Unit (DIU) of the U.S. Department of Defense to build a Freedom™ Autonomous Underwater Vehicle (AUV) and establish an Onshore Remote Operations Center (OROC) for the U.S. Navy.

The award highlights Oceaneering's ability to leverage technology originally developed to support the offshore energy industry into other markets.The vehicle will be manufactured at Oceaneering's Morgan City, Louisiana facility.

Oceaneering has conducted remote operations of commercial subsea robotic systems from OROCs since 2015 and has performed over 120,000 hours of remote operations to date.

Source: Oceaneering News Release

New ISO Standards on Corrosion Protection of Offshore Wind to be Developed

By Birit Buhr, FICorr, Chief Corrosion Engineer, Europeanenergy

A new Joint working group (JWG6) have been created between two technical committees (TC) of ISO.

The two technical committees are:

ISO TC 107: Metallisation and inorganic coatings (project lead)

ISO TC 35—organic coating, but also

ISO TC 156 WG10 (cathodic protection) as a liaison partner to the JWG6

Five projects have been approved, and five draft documents circulated:

25249-1 Corrosion protection of offshore wind structures, design considerations

25249-2 Corrosion protection of offshore wind structures, primary steel components—general requirements for thermal spraying and painting

25249-3 Corrosion protection of offshore wind structures, primary steel components—supplementary requirements for foundations

25249-4 Corrosion protection of offshore wind structures, primary steel components—supplementary requirements for towers

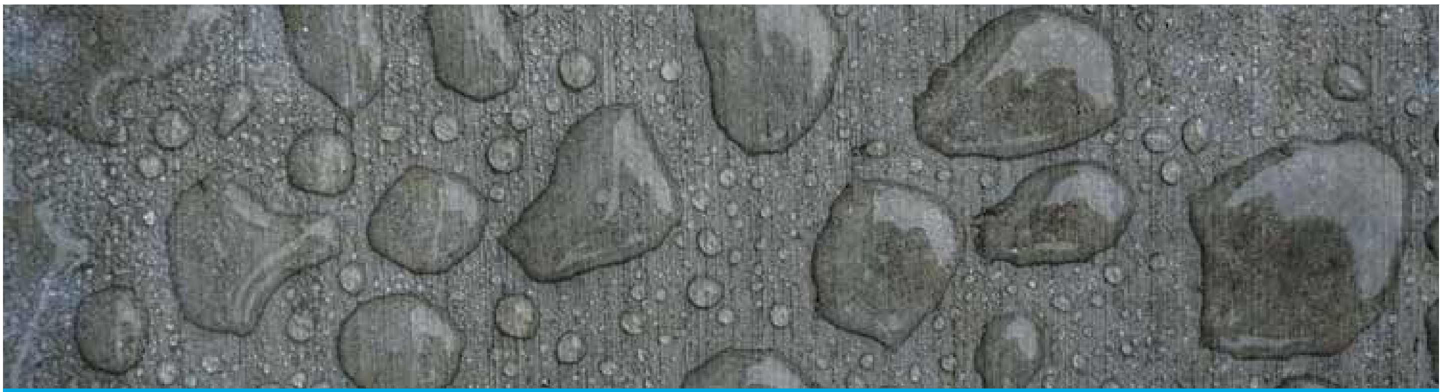
25249-5 Corrosion protection of offshore wind structures, Supplementary requirements for primary structural steel components—structural steel and cast components for nacelles

They are planning for 5 more for secondary steel components, qualification of metallisation and paint systems, repair of surface protection systems, composite structures, and last but not least, environmental impact considerations, including life cycle assessment (LCA).

Offshore wind was born in Denmark in 1992 with the project Vindeby, and therefore it has only been natural that the project initiative comes from Danish Standards and the offshore wind industry here.

ISO support industrial needs and offshore wind is a global industry. The standardisation works will be truly international, with already the following countries supporting the work and the joint working group: Australia, China, Czech Republic, Denmark, Ethiopia, Finland, France, Germany, Ghana, Iran, Italy, Japan, Jordan, Korea, Netherlands, Norway, Poland, Portugal, Russian federation, Spain, Sweden, Switzerland, United Kingdom.

The purpose of the NWIPs is to have overall industry-based ISO standard for the corrosion protection of offshore wind turbine structures to enable these structures to reach their intended service life.



New MCI®-2019 X Adds Greater Flexibility to MCI® Portfolio

Cortec® Corporation is pleased to announce a new addition to its line of concrete surface treatments. MCI®-2019 X is a 40% silane penetrating water repellent minus the typical Migrating Corrosion Inhibitors of MCI®-2019. The reason for not including MCI® is the same reason that Cortec® released MCI®-2018 X without MCI® in early 2024: some contractors need more options to adapt to specific project budgets and parameters. Here is a closer look at how MCI®-2019 X might fit into the picture.

Redundant or Complementary Protection

MCI®-2019 X provides water repellency by chemically reacting with the alkaline environment of concrete and creating a hydrophobic layer to reduce the ingress of water and other corrosives. This water repellency offers standalone benefit and is even better paired with a penetrating surface applied corrosion inhibitor (SACI). Historically, this combination has been available with MCI®-2018 and MCI®-2019, two silane water repellents that contain Migrating Corrosion Inhibitors. However, to get the highest concentration of SACIs on the market, users must opt for MCI®-2020, which contains a higher dose of MCI® without water repellent. While applying MCI®-2020 with either MCI®-2018 or MCI®-2019 on top would provide enhanced protection due to the presence of MCI® in both products, some contractors may prefer to apply just a water repellent on top of MCI®-2020 due to budget limitations or other project parameters. For cases like these, MCI®-2018 X and MCI®-2019 X are excellent alternatives to adapt to project needs.

Is 100% or 40% Silane Better?

But why would someone choose MCI®-2019 X over MCI®-2018 X? The answer, again, goes back to project and budget needs. Using a 40% silane water repellent is naturally more budget friendly than a 100% silane water repellent because of the lower concentration of a commodity in high demand. Yet that is not the only advantage. Contractors applying water repellent to previously treated concrete surfaces must think about ensuring good penetration and compatibility. This usually requires the thorough removal of water repellent residue before another product can be applied. However, MCI®-2019 X is one water repellent that may be applied over residue from previously worn-off treatments, thus replenishing the water repellency that the concrete has lost. This low-labor benefit is especially helpful in maintenance applications where a water repellent is reapplied every 5 to 10 years.

Slippage and Appearance

As a silane water repellent, MCI®-2019 X is a good choice for concrete structures where slippage is a concern. Since silane molecules are so small, they tend to penetrate deeper than other types of water repellents, making them less likely to cause water puddling or slippage. They also do not darken or change the appearance of concrete, an ideal characteristic for protecting historical structures.

More Flexibility for Contractors

With this new addition to Cortec's MCI® portfolio, contractors have greater flexibility to tailor a surface protection system to their concrete repair or maintenance project. Whether they want a two-in-one MCI® water repellent (MCI®-2019), a doubled-up protection system of SACI + SACI water repellent (MCI®-2020 plus MCI®-2019), a simple water repellent (MCI®-2019 X) on top of high concentration SACI (MCI®-2020), or a 40% silane water repellent (MCI®-2019 X) alone, contractors can make their pick on what seems to be the best choice for their jobs.

Julie Holmquist

email: jholmquist@cortecvci.com

U.R. Evans and The Corrosion of Metals: A Century of Influence

This year marks a momentous milestone for the corrosion science community—the centenary of the publication of The Corrosion of Metals by Ulick Richardson Evans in 1924. This pioneering work laid the foundation for modern corrosion science, transforming it from a fragmented collection of empirical observations into a rigorous, quantitative discipline. As we celebrate this historic achievement, it is fitting to reflect on Evans' profound contributions and the enduring impact of his groundbreaking research.

U.R. Evans: A Visionary in Corrosion Science

Ulick Richardson Evans was described in the Biographical Memoirs of Fellows of the Royal Society as the "Father of the modern science of corrosion and protection of metals". Evans was born in Wimbledon and received his education at Marlborough College (1902–1907) and King's College, Cambridge (1907–1911), where he pursued the Natural Sciences Tripos, specializing in chemistry in Part II. Following his studies, he began research on electrochemistry in Wiesbaden and London, but his work was interrupted by the outbreak of the First World War.

He served in the army from August 1914 until 1919. After the war, he returned to Cambridge, where he dedicated the remainder of his life to research and prolific writing on the corrosion and oxidation of metals.

His keen intellect, innovative experiments, and commitment to advancing the field quickly earned him international recognition.

Published at a time when the scientific understanding of corrosion was in its infancy, The Corrosion of Metals was revolutionary. It was the first textbook to comprehensively explain the mechanisms of corrosion, with a particular focus on the electrochemical nature of metal deterioration. Evans' insights provided engineers and scientists with the tools to address real-world corrosion challenges systematically, heralding a new era of research and practical applications.

The Impact of The Corrosion of Metals

Evans' book was not only an academic milestone but also a practical guide that addressed the pressing needs of industries reliant on metals. Its immediate translation into German, French, and Russian underscored its global importance. The book introduced concepts such as passivity, electrochemical corrosion mechanisms, and methods of protection that remain central to the field today.

Over the next five decades, Evans continued to expand and refine his work, publishing additional seminal texts, including Metallic Corrosion, Passivity, and Protection (1937) and An Introduction to Metallic Corrosion (1948). His ability to elucidate complex scientific principles with clarity and rigor inspired generations of corrosion scientists and engineers.

A Legacy that Lives On

Evans' contributions extended beyond his publications. He was an influential mentor, guiding researchers from around the world in their pursuit of corrosion science. His work provided the foundation for many of the engineering advancements that now enable us to protect critical infrastructure, transportation systems, and industrial equipment from the damaging effects of corrosion.

His legacy is perpetuated through the U.R. Evans Award, established by the Institute of Corrosion in 1976. This prestigious award, symbolized by an engraved sword, honors outstanding achievements in corrosion science, continuing Evans' mission to foster collaboration and innovation in the field.

Photo: Professor Nick Birbilis UR Evans Award Presentation on 11th September 2023.

Photo: Engraved Sword.

Ask the Expert

The Significance of PREN for the Corrosion Resistance of Stainless Steel by Sarah Bagnall

Sarah Bagnall, Director Consultancy Services at R-TECH Materials, CEng. MSc, BSc

INSTITUTE OF CORROSION

Meet the Author

Sarah Bagnall

Sarah is a materials engineer specialising in failure analysis, for the petrochemical, process, and power generation industries. Currently, she is Director of Consultancy Services at R-TECH Materials. With over 600 failure investigations conducted to date, Sarah has broad experience with a wide range of engineering components, metallic and non-metallic materials, and industries. Sarah has extensive expertise in the corrosion of a wide range of materials, particularly for the chemical processing and petrochemical industries.

Q. What is the Significance of PREN for the Corrosion Resistance of Stainless Steel?

Calculating PREN and How to Apply it

Stainless steels are well known for their superior corrosion resistance, which is primarily a consequence of the significant chromium addition. When exposed to oxygen, stainless steel forms a passive film due to its 10.5% (or more) chromium content. This film protects the material from rusting and even has self-healing properties. Other elements can be added to further improve the corrosion performance, such as Nickel, Molybdenum, and Nitrogen.

Not all stainless steels are created equal. Different grades exist, and their corrosion resistance can vary significantly. The corrosion resistance between grades can be compared by using the Pitting Resistance Equivalent Number (PREN). The calculation used for PREN is as follows:

$$PREN = Cr\% + 3.3 \times (Mo\% + 0.5 \times W\%) + 16 \times N\%$$

Examples of stainless steel grades and the calculated PREN numbers are given in Table 1 and Figure 1 below.

Grade	Minimum PREN
3CR12 (1.4003)	10.5
430 (1.4016)	16
304 (1.4301)	17.5
316 (1.4401)	23
2205 (1.4462)	31
904L (1.4539)	32
Nitronic 50 (1.3964)	33
Superduplex (1.4410, 1.4501, 1.4507)	40
6% Mo (1.4529, 1.4547)	42

Table 1: Comparison of Stainless-Steel Grades Based on the PREN.

Performance in Service

While the PREN is useful for ranking and comparing the different grades for relative resistance to corrosion, it cannot be used to predict whether a particular grade will be suitable for a specific application, where pitting corrosion may be a hazard. All environmental and operating conditions must be taken into consideration.In some industries, notably the oil and gas sector, specifications may place tighter restrictions on the PREN for specific grades than that implied by the minimum composition of the grade defined in EN or ASTM Standards.

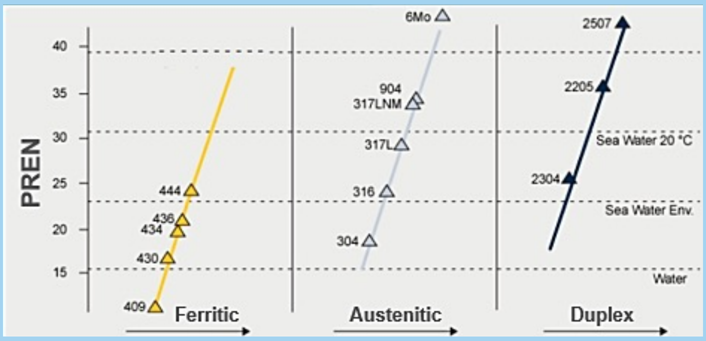


Figure 1. Comparison of Stainless-Steel Grades Based on the PREN

In practice, the vast majority of stainless steels deployed across industry are of the 300 series type with lower PREN values, where external pitting is actually quite common in service at ambient temperatures.

Corrosion resistance is not only affected by the chemical composition of the material but also by the heat treatment condition. If the material is heat treated incorrectly during manufacture or welding, microstructural changes can occur which effectively means that the material is no longer a stainless steel in a localised area. Exposure to temperatures in the range 370-815°C allows the precipitation of chromium rich carbides/nitrides along the grain boundaries. These precipitates are rich in chromium and deplete the area directly adjacent to the boundary of chromium, thereby increasing the likelihood of localised corrosion in the form of intergranular attack, pitting or stress corrosion cracking in a corrosive environment.

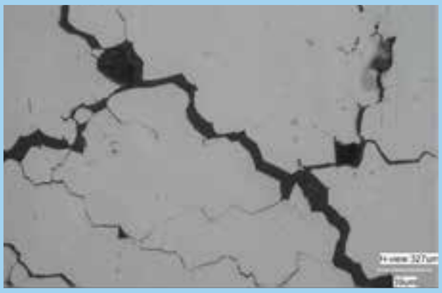


Figure 2. Cracking of a Sensitised Stainless Steel Bolt Which Had Been Heat Treated Incorrectly During Manufacture.

Further Guidance

The British Stainless Steel Association (BSSA) exists to promote and develop the manufacture and use of stainless steel across the UK and Ireland. Based in Sheffield, the Association provides technical advice, information, training, and education in all aspects of stainless-steel usage. They may be contacted at: **www.bssa.org.uk**

The Limits of Use of Copper Alloy and Stainless-Steel Heat Exchanger Tubes

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INSTITUTE OF CORROSION

Meet the Author

Dr. Roger Francis

Dr Francis has been a corrosion engineer for over 45 years. He has wide experience in the fields of marine corrosion, desalination, sour oil and gas corrosion, mineral processing, and the chemical and process industries. He has published over 100 technical papers in all these areas, particularly on copper alloys and duplex stainless steels. Roger has written seven books on various aspects of corrosion and has jointly edited three other books. The most recent was on corrosion in desalination plants. Dr. Francis has served on several standards committees working on corrosion testing of both copper alloys and stainless steels. In particular he was involved with the committee turning NACE MR0175 into ISO 15156. The author has served as chair of NACE Europe, two terms as the NACE (now AMPP) European Area Director and also as Chair of NACE STG 32 (Oil and Gas; metals). He was made a NACE Fellow in 2005 for his work in marine corrosion. In 2014 he received the T J Hull Award for his work in publications. In 2012 he set up his own corrosion consultancy business, RF Materials. In 2023, he received the Institure of Corrosion Paul McIntyre award presented to a senior corrosion engineer who, as well as being a leading practitioner in his field, has advanced European collaboration and international standards development.

Alloys

The compositions of the common copper alloys used for tubing are shown in Table 1, and those of some common stainless steels are shown in Table 2. Nickel aluminium bronze (NAB) is also shown, because although it is not used for tubes, it is widely used for tube sheets with copper alloys. Tube sheets with stainless steel tubes tend to be in the same alloy, or one with a similar corrosion resistance to the tubes.

Name	UNS No.	Nominal Composition (wt.%)					
		Cu	Zn	Ni	Fe	Mn	Al
Al-Brass	C68700	77	Bal	-	-	-	2
90/10 Cu-Ni	C70600	Bal	-	10	1.5	1	-
70/30 Cu-Ni	C71500	Bal	-	30	0.7	0.7	-
66/30/2/2 Cu-Ni-Fe-Mn	C71640	Bal	-	30	2	2	-
NAB	C63200	Bal	-	4.5	4	-	9

Table 1: Compositions of The Copper Alloys.

Name	UNS No.	Nominal Composition(wt.%)						
		Fe	Cr	Ni	Mo	N	Cu	Other
304L	S30403	Bal	18	8	-	-	-	-
316L	S31603	Bal	17	10	2	-	-	-
6%Mo	S31254	Bal	20	18	6	0.2	0.7	-
2304	S32304	Bal	23	4	0.3	0.15	0.3	-
2205	S32205	Bal	22	5	3	0.17	-	-
Z100	S32760	Bal	25	7	3.6	0.25	0.7	0.7W
2507	S32750	Bal	25	7	3.6	0.25	-	-

Table 2: Compositions of the Stainless Steels.

Corrosion

The two principal types of corrosion commonly seen in heat exchangers are erosion corrosion and pitting/crevice corrosion.

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Erosion Corrosion

Erosion corrosion of copper alloys (also known as impingement attack) has the appearance of smooth water-swept pits, often like horseshoes, with the "horses" going upstream, as shown in Figure 1. It is well known that copper alloys suffer erosion corrosion if the water velocity is too high, and limits of use have been established for seawater, as shown in Table 3. These velocities increase as the iron content of the Cu-Ni alloys increases. It is important to avoid turbulence raisers, which can greatly increase local water velocities.

Figure 1: Erosion-Corrosion of A Copper-Nickel Heat Exchanger Tube.

Alloy	Maximum Velocity (m/s)
Al-Brass	1.5 – 2.0
90/10 Cu-Ni	2.0 – 3.0
70/30 Cu-Ni	2.5 – 3.5
66/30/2/2 Cu-Ni-Fe-Mn	3.0 - 4.0

Table 3: Suggested Safe Water Velocities for Copper Alloy Heat Exchanger Tubes.

Where the seawater contains chlorine or hypochlorite additions to control fouling, it is important to keep the chlorine concentration as low as possible, as higher concentrations can cause erosion corrosion[2]. Figure 2 shows the effect of chlorine concentration on the general corrosion rate of copper alloys in seawater[3].

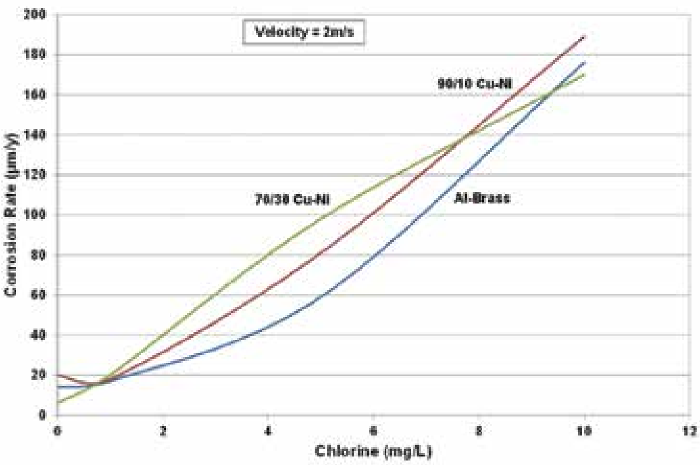

Figure 2: Effect of Chlorine on the Corrosion Rate of Copper Alloys.

When silt is present, such as in the Severn estuary, the corrosion rate rises rapidly, as shown in Figure 3[4]. Silt is usually particles up to 50 μm diameter and larger particles are referred to as sand, which is more aggressive. The data in figure 3 was collected from a number of power stations along the Severn estuary where the silt burden varies significantly. Figure 3 shows that even the 66/30/2/2 Cu-Ni-Fe-Mn alloy suffered significant attack at high suspended solids levels and a special alloy with 3% iron and 3% manganese was significantly better. Only titanium suffered little metal loss at the higher silt concentrations.

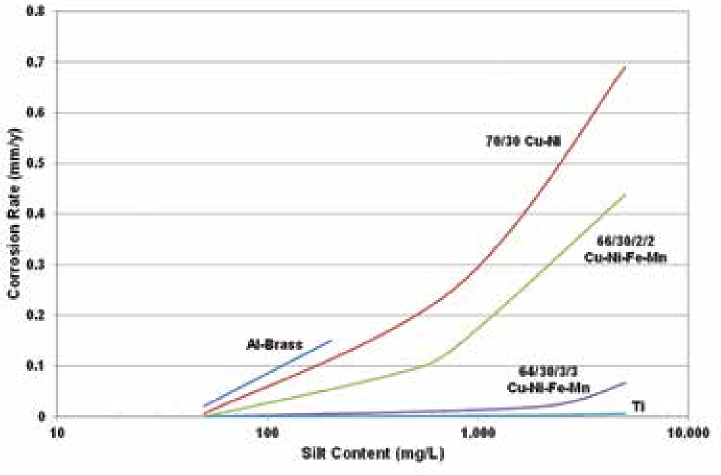

Figure 3: Erosion-Corrosion of Some Copper Alloys Versus Silt Content.

Stainless steels can be very resistant to erosion corrosion in seawater (according to grade) and the results of jet impingement tests at 30 m/s and 30°C for 30 days are shown in Table 4[5]. M-bronze is a gunmetal widely used by the US navy and all the stainless steels showed only slight (316L) or zero attack (super-duplex and 6% Mo austenitic).

Alloy	Maximum Depth of Attack (mm)
M-Bronze	0.81
316 L	0.06
6% Mo	0.00
Super- Duplex	0.00

Table 4: Impingement Attack After 30 days at 30°C and 30 m/s Jet Velocity.

In the presence of sand, super-duplex stainless steel shows a high resistance and the limits of use were described by Francis and Byrne[6], as shown in Figure 4. They also describe several case histories where this data was used to justify the use of super-duplex, which subsequently performed well in service. One example involved heat exchangers with a water velocity of 2 m/s and up to 50,000 mg/L of suspended solids. The heater exchangers have performed well in service.

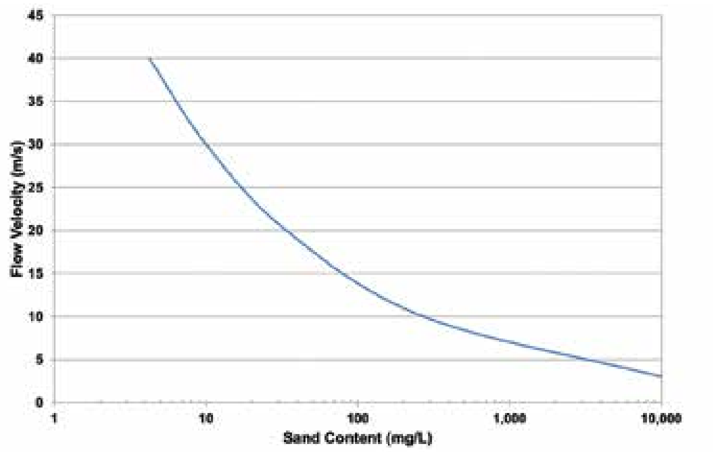

Figure 4: Conservative Safe Velocity Limit for Super-Duplex Stainless Steel Erosion Corrosion.

Erosion corrosion is not a significant problem for copper alloys, so corrosion at roller expanded joints with copper alloy tube sheets is not a problem. Erosion corrosion is also not a problem for copper alloys irrespective of chloride concentration and temperature[1]. However, some contaminants in the seawater may cause pitting under normal heat exchanger operating conditions. The two main pollutants that cause problems are sulphide and ammonia. Sulphide is produced when water is stagnant and sulphate reducing bacteria (SRB) become active. When this sulphide polluted water mixes with aerated seawater, the mixture can be very corrosive to copper alloys and as little as 0.01 mg/l sulphide can cause pitting of heat exchanger tubes[7]. Ammonia is a pollutant that can come from a number of sources, both natural and industrial.

Figure 5 shows pitting of a 66/30/2/2 Cu-Ni-Fe-Mn tube exposed to aerated water containing sulphide. The pitting becomes more severe as the velocity increases, as shown in Figure 6[7]. If the pollution is intermittent then copper alloys can be satisfactory if they form protective films in clean seawater. This can be encouraged by dosing with ferrous sulphate[8]. In more polluted waters stainless steel or titanium is a better choice.

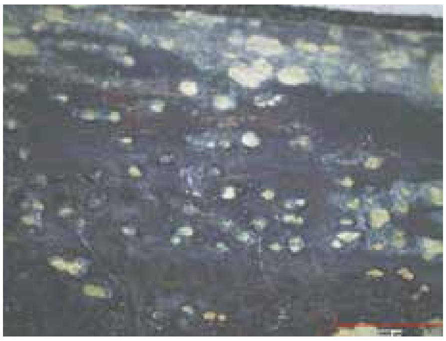

Figure 5: Sulphide pitting of a 66/30/2/2 Cu-Ni-Fe-Mn heat exchanger tube.

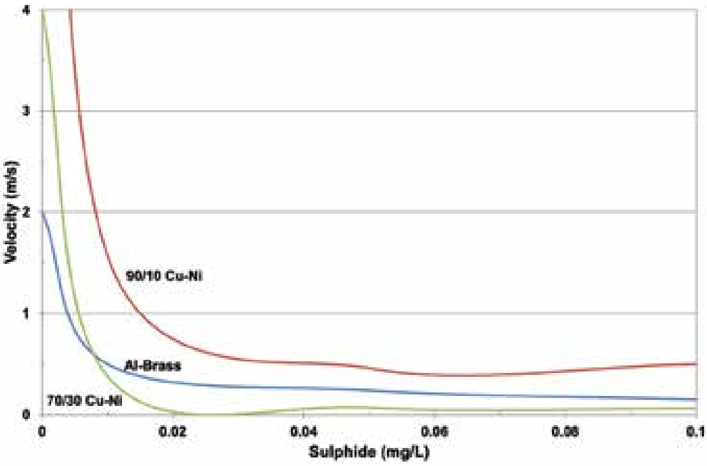

Figure 6: Iso-Corrosion Curves (0.1 mm/Y) for Some Copper Alloys as a Function of Velocity and Sulphide Content of the Seawater.

Figure 7A shows crevice corrosion of a 90/10 Cu-Ni tube which had a nozzle inserted into the end. It was dosed with seawater containing 2 mg/L ammonia, as ammonium sulphate for 60 days. There was a small amount of heat transfer across this tube while a similar tubes with no heat transfer suffered no corrosion. Figure 7B shows the tube after acid cleaning and a deep trough can be seen all around the tube, just outside the crevice. The corrosion is characterised by re-deposited copper in the corrosion products.

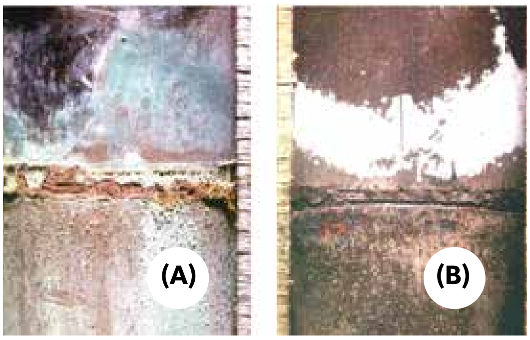

Figure 7: Crevice Corrosion of 90/10 Cu-Ni Caused by Ammonia Pollution. (A) As-received; (B) Acid Pickled.

If the tubes are dosed with ferrous sulphate solution for an hour a day on start up for 60 days, protective films will form and no further dosing is required. If attack due to ammonia has already started, then the tubes must be acid cleaned before starting the ferrous sulphate treatment[8].

Stainless steels are susceptible to crevice corrosion and pitting in the presence of chloride, which increases as the temperature and chloride concentration increase. Crevice corrosion starts at about 25 to 30°C less than pitting corrosion. Figure 8 shows the threshold for crevice corrosion for the lower alloy stainless steels[9]. Super-duplex and 6% Mo austenitic are not shown on the graph because they are routinely used at much higher chloride concentrations (10,000 to 100,000 mg/L). Crevice corrosion can be avoided in stainless steel heat exchangers by seal welding the tubes to the tube sheets.

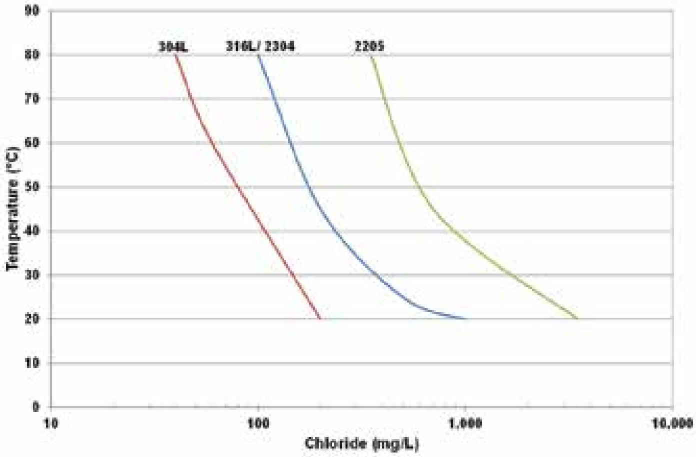

Figure 8: Limits of Use to Resist Crevice Corrosion for Some Stainless Steels.

If there are contaminants or additions to the cooling water that are oxidizing, the risk of pitting and crevice corrosion increases. A common addition is chlorine or hypochlorite to control fouling. With a typical addition of ~0.5 mg/L chlorine at the inlet water box, the maximum temperature of use for superduplex heat exchanger tubes seal welded to the tube sheet in seawater is 60 to 70°C, depending on the scaling tendency of the water. At higher temperatures it is necessary to fit resistor controlled cathodic protection (RCP) into both water boxes[10], or change to a higher alloy material. This could be a hyper duplex stainless steel, such as UNS S32707, a high Ni-Cr-Mo alloy, or titanium. The presence of sulphides and ammonia generally has no significant effect on the corrosion resistance of stainless steels, sulphide inclusions from manufacture can initiate pitting (nucleation sites) though.

Case Histories

History 1

The copper-nickel heat exchangers in the heat rejection section of a multi-stage flash (MSF) desalination plant were suffering repeated failures due to pitting corrosion, as shown in Figure 9. The pits were filled with a pale yellow-green product and sulphide was detected in the pits. The seawater feed was free of sulphide, but the plant had experienced numerous shutdowns for non-heat exchanger reasons. During the shutdowns the heat exchangers and the 400 m long FRP feed pipes were left full of stagnant seawater. After 15 days 15 mg/L sulphide was measured in the feed pipe seawater. On start up this would mostly flush through the system, but blind take-offs would retain heavily polluted seawater that would slowly leach into the main cooling water flow, causing the observed corrosion. The solution was to acid clean the tubes to remove the sulphide films. It was demonstrated that water could be bled from the discharge end of the feed pipe if the pumps were kept going during shutdown. This slow flow would prevent the formation of sulphide by SRB in the seawater.

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History 2

A Spanish mineral processing plant was using nickel alloy C-276 (UNS N10276) seam welded heat exchanger tubes to handle a raffinate (spent acid) that was being heated to 87°C, and had the following composition.

Chloride - 0.2 g/L	Sulphuric Acid - 66.6 g/L
Copper – 13 g/L	Zinc – 4.9 g/L
Iron – 50 g/L	Arsenic – 00.4 g/L

The tubes failed by pitting after 8 months in service. There was severe general corrosion and deep pitting, particularly on the weld, as shown in Figure 10.

Figure 11 shows a typical polarisation curve for stainless steels and nickel alloys in aggressive environments. If the alloy is in the passive region the corrosion rate can be low, but the presence of oxidizers can move the potential into the transpassive zone.

This causes a large increase in the corrosion rate and can also cause pitting if chlorides are present. The corrosion of the C-276 occurred because copper and iron are strong oxidizers and the alloy went transpassive. The corrosion on the weld was more severe because the tubes had not had post weld heat treatment after welding, and the as-welded microstructure was more susceptible to corrosion. The pitting of the parent metal showed C-276 to be unsuitable. Z100 superduplex works well in such solutions because the high chromium content gives it an extended passive range. Z100 tubes have now been in service for over 10 years.

Figure 9: Pitting of CU-Ni Tubes from an MSF Desalination Plant.

Figure 10: Pitting and Weld Corrosion of a C-276 Heat Exchanger Tube.

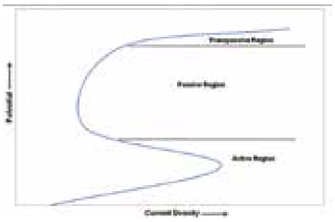

Figure 11: Schematic Polarisation Curve for a Stainless Steel in an Aggressive Solution.

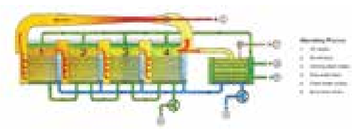

Figure 12: Schematic Diagram of a MED Desalination Plant.

History 3

Figure 12 shows a schematic diagram of a multiple effect desalination plant (MED). The heat exchangers in the evaporators are the reverse of the conventional design, with treated seawater sprayed on the outside of the tubes and water vapour condenses inside the tubes. In Figure 12 four stages or effects are shown, but commercial plants may have a dozen or more stages. The traditional materials of construction for the evaporators were aluminium brass or 90/10 Cu-Ni tubes with 316L tube sheets and support plates. The evaporator shell was solid 316L or steel clad internally with 316L. The 316L resists corrosion in seawater because much of the oxygen content is drawn off with the water vapour. With the reduced cost of titanium and the introduction of low cost lean duplex stainless steels, the cost of the evaporators can be reduced. In modern plants the tubes are titanium with 2304 duplex stainless steel tube sheets, support plates and evaporator shells. Because the 2304 resists corrosion in most marine atmospheres (but not as resistant as 2205 grade), the outside of the evaporator does not usually need painting, or other maintenance.

History 4

Sulphuric acid is the most commonly used commercial chemical. It is produced by reacting sulphur dioxide and sulphur trioxide with pure water and air, which generates a lot of heat (up to ~180°C). This heat must be removed before the acid can go to storage. Traditionally this was done with a 316L heat exchanger with anodic protection on the shell side to prevent corrosion by the hot strong acid. The cooling water was a closed loop with low chloride, treated water, which was further cooled by seawater through a titanium plate heat exchanger, as shown in Figure 13.

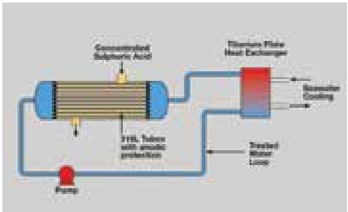

Figure 13: Schematic Diagram of a Traditional Sulphuric Acid Cooler.

Superduplex stainless steel has excellent resistance to seawater and has been used in heat exchangers since the early 1990's. Some superduplex stainless steels also have excellent resistance to hot, strong (≥96%) sulphuric acid. Figure 14 shows the iso-corrosion curves (0.1 mm/y) for two superduplex alloys in sulphuric acid. It can be seen that the addition of copper to the alloy gives it a much increased resistance to corrosion in strong acid. By using Z100 tubes in the acid cooler it is possible to remove the treated water loop, the titanium plate heat exchanger and the anodic protection with substantial savings. This advantage has been utilised at several sulphuric acid plants in China and North America.

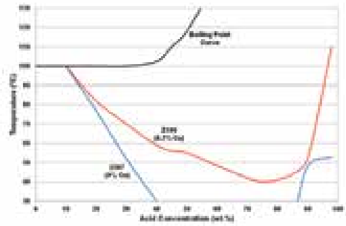

Figure 14: Iso-Corrosion Curves (0.1 mm/y) for Two Super-Duplex Stainless Steels in Sulphuric Acid.

Conclusions

Copper alloys and stainless steels have been widely used in heat exchangers for over 100 years, generally with excellent performance.

The limits of use of these alloys are well known and can be applied during heat exchanger design to select an appropriate alloy. With detailed knowledge of alloy properties and corrosion resistance it is possible to reduce the cost of heat exchangers.

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Understanding the Mechanics of Brittleness: Liquid Metal Embrittlement (LME) in Aluminium Alloys

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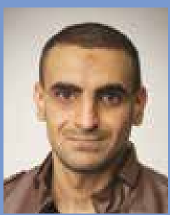
Meet the Authors



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Introduction

The oil and gas industry relies heavily on metallic components operating under harsh conditions that can be susceptible to Liquid Metal Embrittlement (LME). This phenomenon results in a dramatic reduction in a metal's ductility and a heightened susceptibility to brittle fracture under stress [1]. A common example includes the embrittling effect of mercury impurities on aluminium components in cold box units. This article explores the factors influencing the susceptibility of aluminium alloys to LME, examining the effects at both the atomic and metallurgical levels. Through a detailed analysis of embrittlement mechanisms, including the interactions between liquid metals and grain boundaries, we aim to shed light on the critical variables that govern LME behaviour. Furthermore, the article addresses the challenges faced in real-world oil and gas operations, offering insights drawn from both experimental studies and practical field applications.

Mechanisms of Liquid Metal Embrittlement (LME)

The exact mechanism of Liquid Metal Embrittlement (LME) remains a topic of ongoing research due to the intricate interplay between metallurgical and chemical factors. While established mechanisms like interfacial adsorption and bulk diffusion explain a significant portion of LME, the specific processes can vary depending on the material combination, environmental factors (temperature, pressure, additional elements), and the stress state. This complexity makes it challenging to develop a universally applicable model for predicting LME susceptibility [2]. However, ongoing research continues to refine our understanding at the atomic and metallurgical levels, paving the way for more accurate prediction and mitigation strategies in the oil and gas industry. This section explores these mechanisms in detail, focusing on their metallurgical and chemical effects.

Interfacial Adsorption

This mechanism proposes that liquid metal atoms readily adhere (adsorb) onto the surface of the solid metal. This process, driven by a combination of chemical and metallurgical factors, minimises energy and promotes adhesion [3]. Chemically, electron transfer or covalent bond formation between the liquid and solid metal creates an attractive force, essentially pulling the atoms closer. Metallurgically, the inherent surface energy of the solid metal seeks a lower energy state. By spreading out and covering the solid's surface, the liquid metal atoms can help achieve this, further strengthening the bond. Additionally, wettability, or how well the liquid metal adheres to the solid, plays a part. Good wettability, where the liquid metal spreads readily, leads to more extensive and stable adsorption. Ultimately, the interplay between these chemical and metallurgical factors dictates the strength and extent of interfacial adsorption, setting the stage for the potential consequences of LME [4].

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These consequences include the formation of brittle intermetallic compounds at the interface due to the reaction between adsorbed liquid metal atoms and the solid metal. These compounds further reduce the overall ductility of the material and create preferential crack initiation sites. Additionally, the weakened atomic bonds at the interface make the solid metal more susceptible to crack initiation under stress. The liquid metal film at the interface can also act as a lubricant, promoting the propagation of existing cracks [3,5].

Bulk Diffusion

In this process, liquid metal atoms slowly penetrate the solid metal through a thermally activated process. While generally slower than interfacial adsorption, bulk diffusion becomes increasingly significant at elevated temperatures, where the thermal energy provides the necessary activation for atomic movement. The diffused liquid metal atoms preferentially segregate to grain boundaries, which are the regions between individual crystals within the solid metal's microstructure. These grain boundaries are inherently weaker than the crystal interiors due to their disordered atomic structure. The presence of liquid metal atoms at these boundaries further weakens the interatomic forces that bind the grains together, reducing the material's overall cohesion and its ability to resist crack propagation, particularly along the grain boundaries. This specific type of LME is often referred to as intergranular embrittlement [6,7].

Stress-Assisted Diffusion

Building upon the mechanism of bulk diffusion, stress-assisted diffusion proposes that the applied stress can significantly accelerate the penetration of liquid metal atoms into the solid metal [8]. This acceleration occurs because the applied stress creates a chemical potential gradient. Chemical potential, encompassing both the concentration and energy of a species in a specific location, dictates its tendency to move [9]. In the context of LME, the applied stress alters the Gibbs free energy within the solid metal, creating a non-uniform chemical potential landscape. This essentially creates a more favourable condition for liquid metal atoms to move towards regions of lower chemical potential, typically grain boundaries [10]. This can be understood as a "downhill" diffusion path driven by the stress, supplementing the thermal energy available for diffusion. Consequently, stress-assisted diffusion allows liquid metal atoms to penetrate deeper and faster into the solid's microstructure compared to bulk diffusion alone. This deeper penetration and the resulting higher concentration of liquid metal atoms at grain boundaries further intensify the weakening effect observed in bulk diffusion. The compromised interatomic forces at these boundaries, combined with the deeper penetration of liquid metal atoms, significantly increase the material's susceptibility to LME [11]. It's important to note that these mechanisms, interfacial adsorption, bulk diffusion, and stress-assisted diffusion, can often occur simultaneously. This interaction creates a synergistic effect that intensifies the overall embrittling effect.

Liquid Metal Embrittlement (LME) of Aluminium by Mercury in Cold Natural Gas Processing Units

Liquid Metal Embrittlement (LME) can occur in aluminium components used within cold boxes of natural gas processing units. Cold boxes are critical components that separate natural gas liquids (NGLs) from the raw gas stream. The final temperature of the cooled gas exiting a cold box can vary depending on the specific design and operation of the unit. Standard Cold Boxes (NGL Separation) typically operate in a temperature range of below -43°C to -162 °C. This range is effective for separating a significant portion of NGLs from the raw gas stream for various applications. However, in Liquefied Natural Gas (LNG) production, specialised cold boxes operate at much lower temperatures than -162°C. This extreme cooling allows for the extraction of a wider range of NGLs and the creation of LNG, a liquid form of natural gas for transportation [12].

Figure 1: Cold Box Heat Exchanger Unit in A Natural Gas Liquefaction Process Plant.

The primary source of mercury (Hg) contamination in these cold boxes can be traced back to the raw natural gas itself. Trace amounts of mercury can be naturally present in some gas reservoirs and can be carried along with the gas stream. Additionally, some anti-foaming agents used in upstream processes can also contribute to mercury contamination.

However, the susceptibility of aluminium to LME by mercury is highly temperature dependent. The critical temperature range for LME in this context falls within the typical operating range of cold boxes [13, 14].

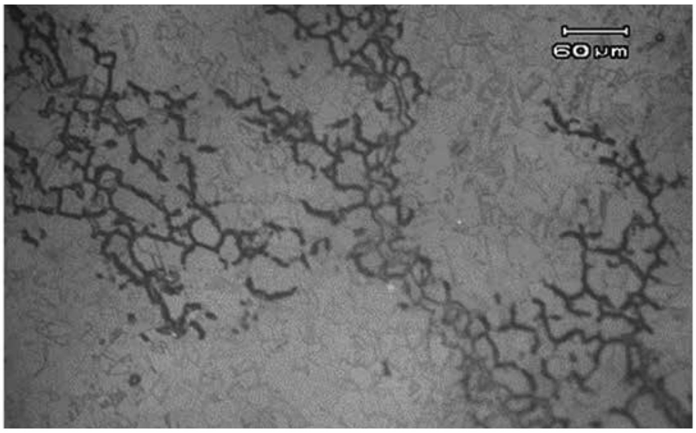

Figure 2: Cracks in Aluminium Caused by Mercury Liquid Metal Embrittlement (LME).

Temperature Effect on LME of Aluminium and Mercury

The effect of temperature on the Liquid Metal Embrittlement (LME) of aluminium (Al) by mercury (Hg) is significant and can be observed across different temperature ranges. At temperatures significantly below the operating ranges of cold boxes (e.g., below -162°C), both Al and Hg undergo notable changes. Mercury may remain liquid due to solidification lag or the presence of trace elements, but its interaction with aluminium becomes less relevant. Unlike mercury, aluminium does not become excessively brittle at these low temperatures. Instead, it retains desirable mechanical properties like high strength and stiffness due to its face-centred cubic (FCC) crystal structure [15].

The critical window for LME of aluminium by mercury lies within the typical operating range of cold boxes. Even though the freezing point of mercury is -38.8°C, residual liquid mercury may still be present during operation due to a slight delay in complete solidification during cool-down processes and the presence of trapped pockets or alloys with lower freezing points. This residual liquid mercury can interact with aluminium grain boundaries and potentially induce LME [13].

During a planned or unplanned shutdown of a cold natural gas processing unit, the temperature within the cold box will begin to rise from the typical operating range. The high boiling point of mercury (around 357°C) ensures it remains liquid even at temperatures exceeding the operating range. At higher temperatures, liquid mercury might exhibit slightly greater mobility within the system, potentially reducing its ability to form concentrated pockets at aluminium grain boundaries, a crucial step for LME to occur. As the temperature rises, the aluminium's ductility is likely to improve compared to the operating range. The concern within the operating range is that extremely low temperatures can reduce the aluminium's ability to absorb stress without cracking. At higher shutdown temperatures, this becomes less of a concern.

Atomic-Level Analysis of Liquid Metal Embrittlement (LME) in Aluminium by Mercury

Liquid mercury (Hg) exhibits a high affinity for aluminium (Al) at the atomic level, leading to Liquid Metal Embrittlement (LME) in cold natural gas processing units. The mechanisms behind this weakening interaction and its acceleration of cracking in aluminium are complex and multifaceted. While the exact details remain under investigation, the presence of mercury disrupts the strong metallic bonds within aluminium's grain boundaries, ultimately making it more susceptible to cracking under stress [13]. This disruption weakens the overall cohesion of the aluminium structure, reducing its ability to resist deformation (ductility) and leading to a loss of strength and increased susceptibility to cracking. In some cases, depending on the specific temperature and concentration, mercury and aluminium can form intermetallic compounds at the atomic level. These compounds can be even more brittle than the surrounding aluminium matrix, creating weak points within the structure [16].

The liquid nature of mercury at the operating temperature of cold boxes allows it to easily migrate along grain boundaries within the aluminium microstructure, which are regions of inherent weakness. As the liquid mercury accumulates at these grain boundaries, it further weakens the already lower cohesive strength due to the electron transfer and disruption of the aluminium lattice. This creates preferential pathways for crack initiation and propagation under stress, leading to faster and more catastrophic failure of the aluminium component [13]. Mercury atoms can also become adsorbed onto the surface of existing micro voids or microcracks within the aluminium structure. This adsorption process can reduce the surface energy of the crack, making it easier for the crack to propagate even under lower applied stress. In some instances, the presence of mercury at the crack tip can promote further void or microcrack growth through mechanisms like stress concentration and diffusion-assisted processes.

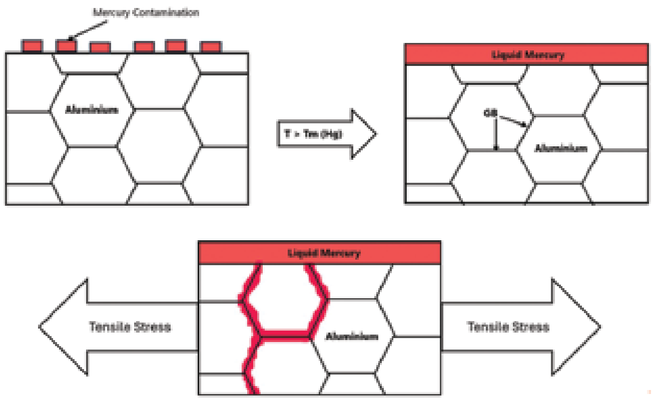

Figure 3: Illustration Of Liquid Metal Embrittlement (LME) Of Aluminium in A Mercury Environment.

Metallurgical-Level Analysis of Liquid Metal Embrittlement (LME) in Aluminium by Mercury

Aluminium's susceptibility to Liquid Metal Embrittlement (LME) by mercury is influenced by its microstructure and alloying elements. This analysis explores how the presence of magnesium (Mg), silicon (Si), and copper (Cu), along with grain size, surface condition, and pre-existing defects, can impact the aluminium susceptibility to LME by mercury [13, 16].

- Alloying Element effect

As the solidification process occurs, silicon (Si), which has a higher electronegativity, and magnesium (Mg), which has a lower electronegativity than aluminium (Al), interact with Al to create intermetallic compounds such as Al_3Mg_2 and Al_5Si_2. These intermetallic compounds are generally less detrimental than those that form directly between aluminium and mercury (Hg). Furthermore, the scattered presence of these compounds throughout the microstructure helps prevent the formation of extensive, weak zones at the grain boundaries, improving overall strength [13, 17, 18]. While the presence of Al_3Mg_2 and Al_5Si_2 intermetallic can be beneficial by improving strength, a potential complication arises in Al-Mg alloys. During welding, the Al_3Mg_2 compound tends to concentrate at grain boundaries [23]. This concentration can create a microstructure that is particularly vulnerable to mercury-induced Liquid Metal Embrittlement (LME) [26].

However, copper (Cu) plays a detrimental role. Its atomic structure and properties allow Cu atoms to substitute for Al atoms, creating vacancies within the lattice. This, combined with Cu's different electronic structure that weakens surrounding bonds and its inherent high mobility, significantly increases the diffusion rate of Hg within the aluminium matrix. This faster diffusion allows Hg to reach grain boundaries and voids more readily, promoting crack initiation and propagation, ultimately leading to LME [16, 18, 19, 20].

Liquid Hg can exploit defects in the protective aluminium oxide layer to access underlying Al and the Al_3Mg_2 and Al_5Si_2 intermetallic. Due to its affinity for both Mg and Si, Hg can extract these elements, forming brittle Hg-Mg and Hg-Si intermetallic. This weakens the overall structure and increases LME susceptibility [16].

The concept of sacrificial behaviour for Magnesium (Mg) and Silicon (Si) suggests some protection against Liquid Metal Embrittlement (LME). Due to their higher reactivity compared to Aluminium (Al), under certain conditions, they preferentially react with Mercury (Hg), forming less detrimental Mg-Hg and Si-Hg intermetallic compounds at grain boundaries compared to a direct Al-Hg interaction. This 'sacrificial' behaviour, where Mg and Si essentially 'sacrifice' themselves to react with Hg, is thought to offer some protection against LME by reducing the susceptibility of the aluminium matrix. However, the influence of Mg-Hg and Si-Hg intermetallic on LME susceptibility is not straightforward. While the presence of Mg-Hg and Si-Hg intermetallic can be beneficial by reducing the formation of more detrimental Al-Hg phases, their overall impact on LME susceptibility is complex. Factors such as their concentration at grain boundaries and the total amount present within the aluminium matrix play a crucial role. When these intermetallic compounds are present in high concentrations, they can have an adverse effect, potentially leading to increased brittleness and thus, increasing the risk of LME [21, 22, 26].

Illustrating this complexity, the interaction between liquid Hg and Al_3Mg_2 is not a straightforward process. Therefore, when liquid Hg comes into contact with Al_3Mg_2, it preferentially reacts with Mg due to the higher electronegativity difference between Hg and Mg compared to Hg and Al. This reaction consumes Mg from the Al_3Mg_2 intermetallic compound, potentially leading to the formation of Hg-Mg intermetallic at the grain boundaries [28]. The consequence of this reaction on the remaining Al element in Al_3Mg_2 depends on the extent of the Mg-Hg reaction. A limited reaction might cause some weakening, but a more extensive reaction could lead to the formation of detrimental Al-Hg phases and a substantial increase in LME risk [24,25,26].

- Grain Size and Microstructure

The grain size and overall microstructure of the aluminium alloy can also play a role. Finer grain boundaries create a larger total area of grain boundaries within the material. These grain boundaries can act as barriers, hindering the propagation of cracks initiated by mercury interaction, with coarser grains, fewer and larger grain boundaries exist, offering less resistance to crack growth. Moreover, finer grains present a more complex diffusion path for mercury atoms attempting to travel through the material. This increased path length can slow down the process of mercury reaching critical locations like grain boundaries and voids, potentially reducing the risk of LME initiation. In coarser grains, these diffusion paths are straighter and more readily available for mercury atoms to travel. This allows mercury to reach critical locations like grain boundaries and voids more quickly, potentially accelerating the initiation and propagation of cracks [3, 23].

- Surface Condition and Pre-Existing Defects

The surface condition of the aluminium component can be a factor. Surface imperfections like scratches or machining marks can act as stress concentrators and initiation points for cracks, especially in the presence of liquid mercury. Additionally, pre-existing defects like microcracks or porosity can also be exploited by mercury to accelerate crack growth.

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Summary

This analysis sheds light on the multifaceted mechanisms of Liquid Metal Embrittlement (LME) in oil and gas operations. Understanding the interplay between material properties, processing conditions, and specific liquid metal interactions is crucial for selecting appropriate materials and implementing mitigation strategies. By carefully considering factors like alloying elements, grain size, and surface condition, the industry can minimise LME risks and ensure the safe and reliable performance of critical equipment.

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Offshore Wind Farm Maintenance – A New Coating Toolbox

Claus Ackfeld, Joao Azevedo, and Neil Wilds, Sherwin-Williams, Protective and Marine

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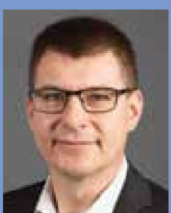
Meet the Authors



Claus Ackfeld

Joao Azevedo **Neil Wilds**

Claus Ackfeld is a Corrosion Protection Engineer from Germany and has over 30 years of experience in corrosion protection of steel structures by paint systems. Currently he is in the Product Management Department with Sherwin-Williams Protective and Marine Coatings division. In this role, he is responsible for a wide range of coating systems for onshore and offshore steel structures, for hydraulic steel structures, and for infrastructure. He has been with Sherwin Williams for 2 years after spending 28 years with another global coatings company.

Joao Azevedo currently holds the position of Energy Segment Director at Sherwin-Williams Protective and Marine Coatings Division, EMEAI region. He joined the protective coatings business in 1999 as Sales Director of Euronavy, in Portugal, acquired by Sherwin-Williams in 2008. After early Business Development roles in Sherwin-Williams, became Marketing Director in 2017, Strategy Director in 2021 and assumed the current role in 2023. Joao holds a Chemical Engineering (MSc) degree from Technical University of Lisbon IST-UTL and a MBA from the Catholic University of Portugal (UCP). He is also a NACE 3 certified coating inspector.

Neil Wilds is from the United Kingdom and has over 38 years of technical coatings experience with low temperature curing epoxies and high heat CUI and insulation coatings and is currently a Global Product Director CUI / Testing with Sherwin-Williams Protective and Marine Coatings division. Neil is also a member of multiple coating societies and is actively involved in the development of coating corrosion and CUI test standards with AMPP and ISO. He has been with Sherwin-Williams for 8 years, after spending 29 years with another global coatings company.

The offshore wind power sector is growing fast, but protecting these structures against corrosion in this aggressive environment can be problematic. Originally their protection relied on the standards, Norsok M-501 [1] and ISO 12944-9 [2], which give guidelines specific to the oil and gas industry, but which were not necessarily suitable for the renewable sector – as a result, a lot of these early offshore wind towers suffered premature corrosion. Such assets are subject to early coating breakdown and corrosion, particularly in the inter-tidal and splash zones, due to a combination of factors; exposure to the most aggressive CX offshore atmospheric corrosiveness [2], unmanned – meaning no crew present for regular inspection or maintenance, structural movements much more pronounced than oil and gas offshore assets, and last but not the least, doubts about the usual offshore Oil and Gas coating specifications to provide extended durability when facing such aggressive conditions. Over the years many coating systems have been used including, ceramic, solvent-free, glass-flake, polyester, but premature corrosion breakdown has been detected in all systems used in the field.

The systems applied at new build to protect offshore wind foundations have not reached the 30+ year protection lifetime yet, and probably never will – despite misleading predictions based on compositional requirements (as per the existing standards). As no one system currently meets the expectations of the offshore operators, there is a need for a novel cost-effective maintenance coating system.

There is no "silver bullet" system which meets all the requirements at new build, and major offshore energy companies are now setting-up pre-qualification programmes for new build coating systems.

Hence, the offshore wind operators are facing two important needs to ensure a prolonged life in an aggressive environment, 1) redefine the new construction coating specifications to assure the required durability, without the comfort of misleading Oil and Gas-based compositional coating standards, or track records; 2) find maintenance solutions addressing both the lack of environmental conditions control, and difficult access. This article covers this second need.

The New Maintenance Coating Tool Box

Maintenance and repair coating application differs from a new build/shop application situation in two key aspects: 1) reduced control over surface preparation quality and environmental conditions, and 2) difficult access to the areas to coat, which is far more time-consuming and costly than in a shop.

Two technologies developed by Sherwin-Williams can enable asset owners and contractors alike to mitigate the negative impact of the above challenges in terms of cost, time of execution, and quality of the protection. Both technologies address the need for surface preparation tolerance and are solvent-free. One is more tolerant to moisture, low surface profile, and flash rust and suitable for larger repair projects (Dura-Plate(R) 301W). The other is designed to facilitate the early repair of small areas of damage in difficult to access areas, or during day-to-day operations by less skilled staff (RepacorTM SW-1000). The latter is also a proven effective solution to repair damages during handling, transportation, and installation of the offshore structures.

The uniqueness of both of these technologies can expand owners' and contractors' options when designing these asset's maintenance cycle. This is true for a vast array of energy and infrastructural assets, which one or another of these technologies can help, depending on access and scale of the repairs needed – or both used in combination, if being considered early in the maintenance cycle. One specific activity provides the best example, though: offshore wind structures.

Maintenance Solutions

Before maintenance painting, surface condition is important, and preparation needs to be minimal due to access/skilled labour availability, also when do you carry out spot repair, or more major repainting to extend life? With regular inspections, maintenance intervals can be dependent on percentage breakdown of the protective coating. As access is difficult offshore, the cost effectiveness of any maintenance system is important, plus there is also a need to reduce the amount of downtime.

Dura-Plate® 301W

For repair of larger surface areas, Dura-Plate 301W, a surface tolerant 2K epoxy is an ideal solution. 301W is the latest evolution of the Dura-Plate 301-series of products, with a track record in offshore and onshore applications spanning over 25 years and with over 15 million m^2 protected in offshore projects alone. It is a low-temperature application and curing version of the Dura-Plate 301K ultra-surface and moisture-tolerant high-solids epoxy coating platform. Dura-Plate 301W may be applied at ambient and substrate temperatures as low as 2°C. It is engineered to provide outstanding adhesion and anti-corrosion performance over a wide range of surface preparation techniques, including water jetting, abrasive blasting, and hand or power tool cleaning.

The unique formulation of Dura-Plate 301W allows it to be applied over damp and medium flash rusted metal substrates (tolerant to Wa2 M - ISO 8501-4) and without dew point restrictions. It is tolerant to low surface profile roughness and is easy to apply by single-leg airless spray, brush, or roller. A typical coating system would be 2x125-150 microns. These characteristics significantly broaden the acceptable application windows to drive efficiencies in coating schedules for both new construction and maintenance projects and are thus ideal for off-shore wind tower structures.

301W has been assessed by operators in both the offshore and onshore energy sectors for its adhesion to damp, low-profile, and abrasive blasted surfaces and its suitability as a surface and humidity-tolerant coating to reduce traditional downtime in maintenance painting due to weather conditions.

The performance of a single coat of 301W on rusty steel (prepared to St3) was assessed after 5,000 hours exposure to artificial weathering (ISO 11507) [3] and humidity (BS 3900 F2) [4]. No coating defects were observed in either test.

3rd party testing confirmed the excellent adhesion of a single coat of Dura-Plate 301W at an average dft of approx. 250 microns to various substrates (damp, low surface profile) all cured under 100% relative humidity, with average pull-off adhesion above 15 MPa, and where the failure mode was either cohesive or partially glue failure (Figure 1).

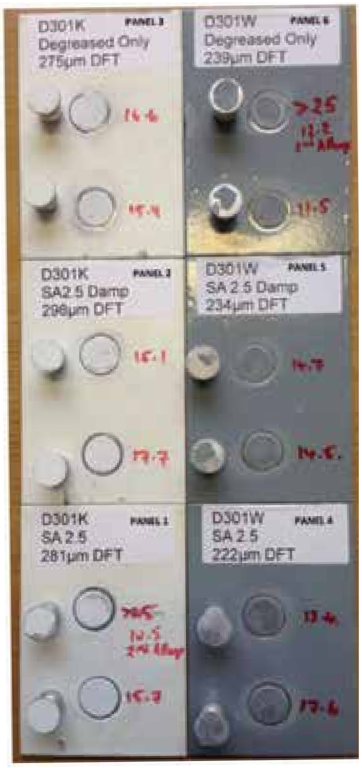


Figure 1: 301W Panels After Pull-Off Testing, Showing Failure Mode and Measured Values. Figure Also Shows Results from Adhesion Testing of A Previous Version of The 301 Series.

Note: The top dollies on Panels 1 and 6 show the result after the second attempt to pull. First attempt showed no failure, with dollies in place after interrupting pull-off when dial reached 25 MPa (maximum). No detachment was observed between the coating film and the substrate in any of the 12 pull-off readings performed over 6 panels. In addition, no meaningful difference or trend was detected between the adhesion over dry abrasive blasted steel and the

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adhesion over damp or smooth non-blasted steel. Curing at the 100% humidity and temperatures tested was normal and did not impact the results.

A third-party laboratory was commissioned to carry out flexibility testing of Dura-Plate 301W-coated samples using a four-point bend method. Ten sample plates (250 x 25 x 6 mm) were coated with a single coat Dura-Plate 301W at an average dft of 220 microns and evaluated at 3% and 5% strain testing (Figure 2).

Figure 2: 301W Flexibility Samples After 4-Point Bend Testing.

No cracking or failure was observed after testing at both 3% strain and 5% strain. In a further evaluation by an offshore maintenance services company, the report stated that during application, it was clear that the 301W was easy to apply with brush and roller, and that the coating spreads smoothly, and once dried, the surface becomes smooth and glossy. When applied with a brush in the usual manner, it's easy to achieve a dry film thickness ranging from 150 to 200 µm. With the necessary attention, a dry film thicknesses of 250 to 300 µm with just one coat on flat and easily accessible surfaces, was easily achieved. The adhesion of the 301W on a Sa 2.5 blasted substrate was good. Even under extreme conditions (exaggerated) with a too-wet surface, the adhesion remained good, and the adhesion on the substrate exhibiting heavy flash rusting (Grade H) even achieves an adhesion value of 8 MPa.

When evaluated as a maintenance coating system at an onshore asset, it was found to be effective in reducing downtime during scheduled maintenance by around 70%, which computed to cost savings of approx. £135K

Repacor™ SW-1000

For small area (spot) repair, Repacor SW-1000 is very suitable and has a good record in this application.

The advantage of this product is that it is a two-component solvent-free ultra-fast drying coating supplied in a cartridge, which can easily be applied by less-skilled staff, e.g., rope access technicians (Figure 3).

Figure 3: Rope Access Technician Conducting Spot Repair.

Repacor SW-1000 is the result of a three-year research project by Sherwin-Williams to develop a coating solution that could simplify maintenance repair work on offshore wind structures. The safety of rope-access applicators using this product was also a prime consideration in the development. Compared to the 2-3 layers needed with traditional technologies, it requires only a single layer of coating, easily dispensed using a standard sealant gun without the need for mixing, to obtain the necessary performance. Repacor is compliant with NORSOK M-501 [1] and meets the highest standards in anti-corrosion protection.

Repacor SW-1000 has all the properties of traditional multi-coat protection systems built into a single coat of 500-micron dry film thickness. Despite the single coat, it is expected to mimic the original performance of offshore wind structure coating systems. It is UV-resistant and no additional topcoat is needed, which is a major advantage in offshore environments. It also has a cure time that is around four hours faster than alternative aerosol systems, and the unique cartridge application process means the applicator can effectively work from a backpack, so only needs to make one journey to carry out the task, and waste packaging is also minimised.

Both a battery-operated bristle blaster for surface preparation and the cartridge of Repacor can be carried in the backpack of a rope access technician, enabling an easy to apply 1-coat fix, saving money and time.In addition, one of the main properties needed from a repair system is good adhesion to the existing substrate after suitable preparation, together with continued good corrosion protection. 3rd party testing was carried out to determine both the adhesion of Repacor SW-1000, and its suitability to provide corrosion protection in this environment.

Coated steel panels, which had been exposed to a corrosive environment, were repaired using Repacor SW-1000 and then subjected to 4,200 hours of cyclic corrosion protection tests in accordance with ISO 20340 Annex A, after removal of the damaged coating by spot grit basting to SA 21/2, and manual application of one coat of Repacor SW-1000 at 500um dft.

After testing, the panels were visually assessed, followed by adhesion testing and measurement of corrosion at the scribe. The results are given in Table 1 and Figure 4. Note, testing carried out by Fraunhofer IFAM, Bremen, Germany, and results are reproduced with approval.

Evaluation Before Exposure: System Repacor SW-1000				
		Specimen 1	Specimen 2	Specimen 3
DIN EN ISO 2808	Film thickness [µm]	506 – 607	539 – 692	497 – 544
DIN EN ISO 4624	Adhesion strength [MPa]	8,7 MPa	8,2 MPa	8,3 MPa
	Failure type	10 % AB 90 % B	10 % AB 90 % B	10 % AB 90 % B
Evaluation After Exposure: System Repacor SW - 1000. Duration: 4200 hours (500 um)				
DIN EN ISO 4624	adhesion strength [MPa]	10,5 MPa	9,3 MPa	9,8 MPa
	Failure type	100 % B	100 % B	100 % B
Corrosion at the scribe	[mm]	2,6	1,6	1,8
DIN EN ISO 4628-2	Degree of blistering	0 (SO)	0 (SO)	0 (SO)
DIN EN ISO 4628-3	Degree of rusting	Ri 0	Ri 0	Ri 0
DIN EN ISO 4628-4	Degree of cracking	0 (SO)	0 (SO)	0 (SO)
DIN EN ISO 4628-5	Degree of flaking	0 (SO)	0 (SO)	0 (SO)
DIN EN ISO 4628-6	Chalking	0	0	0

Table 1: Test Results for System, 1x Repacor SW-1000.

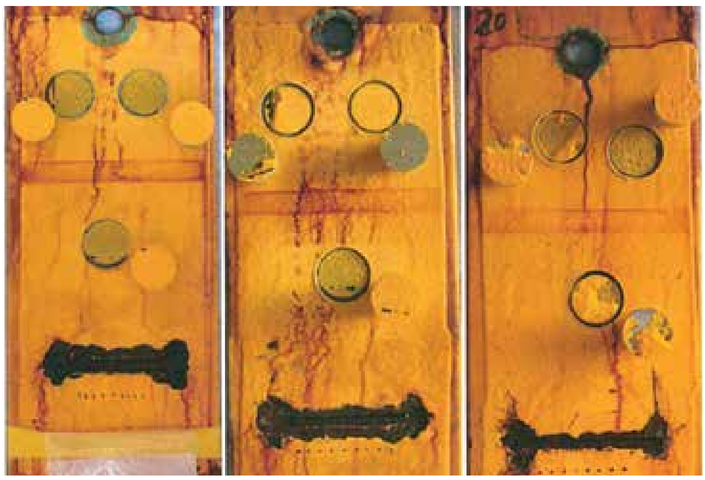

Figure 4: Pull-Off Adhesion Test, And Scribe Corrosion Test Results.
Note: The Central Section of the Scribe Shows the Repair Area.

Adhesion after qualification testing was > 9 MPa (100% cohesive break), there was zero degree of blistering, rusting, cracking, flaking, and chalking, and corrosion at the scribe of the repair area averaged 2mm.

Examples of spot repairs using Repacor SW-1000 carried out in the field are shown in Figures 5 and 6.

(a) **(b)** **(c)**

(d) **(e)**

Figure 5: The Application Stages of Repacor SW-1000 Maintenance Coating. (a) Area Prepared (b and c) Applying the Repacor (d) Smoothing the Applied Material (e) Finished Repair.

(a)

(b)

(c)

(d)

Figure 6: Preparation and Application of Repacor SW-100. (a) Rusted area to be Repaired (b) Preparing the Surface (c) The Prepared Surface Ready for Coating (d) Applying the Repacor SW-100.

Repacor SW-1000 is thus transforming the maintenance and repair of offshore wind turbine towers. It is therefore also an excellent solution for onshore industrial environments if a simple-to-apply, high-performance, durable, and cost-effective coating is required.

New Maintenance Strategy

In addition to having a new maintenance coating toolbox for offshore wind structures, a new strategy is proposed to ensure a long-term successful operation of wind farms.

If we look at the experience gained by operators in the offshore oil and gas (O&G) sector, then regular inspection and maintenance is the key to protection of these platforms over the life of the field, and thus maximum revenue generated.

However, there is a big difference between offshore O&G assets and wind tower structures. The platforms are manned, and thus can have continuous inspection for any corrosion problems and the ability to carry out spot repairs to the coating before the breakdown gets serious, requiring major repainting. Offshore wind structures are unmanned, so currently any inspection of the tower and maintenance painting is not straightforward.

Figure 7: Wind Blade Inspection.

As mentioned above, the major areas of coating breakdown and corrosion, due to alternating wet and dry periods are at the intertidal and splash zones (as with O&G platforms), in addition to impact/abrasion damage in these areas caused by boat access. These are the areas on offshore structures which are difficult to access. However, there is a strategy which could be put in place to help. The wind turbines/blades themselves need maintenance over the lifetime of the wind farm, again to ensure long term successful operation. Currently, to determine any maintenance (or replacement) of the turbine blades, they are inspected at regular intervals, for example in the first 5 years of operation, then roughly at 10-year intervals. This is carried out by technicians sent out by vessel to the tower. These (rope access) technicians could also be used to inspect the base of the tower, and could apply Repacor to any damaged areas with minimum training, and thus help to ensure long term corrosion protection.

Conclusions

Solutions serving the most demanding scenario (offshore wind structures) will perform well in any other maintenance and repair situation. The relative usefulness and cost-benefit balance of Dura-Plate® 301W and RepacorTM SW-1000 approaches will be different on a case-to-case basis, which is the reason why it is important to count on both solutions in the maintenance and repair tool box. Each one alone or in combination can be used in offshore oil and gas, onshore energy assets, bridges and highways, and other situations wherever difficult application conditions are in the way of achieving durability of repairs using conventional solutions.

References

1) Norsok M-501 rev 6.

2) ISO 12944-9 paints and varnishes — corrosion protection of steel structures by protective paint systems— part 9: protective paint systems and laboratory performance test methods for offshore and related structures.

3) ISO 11507 paints and varnishes – exposure of coatings to artificial weathering – exposure to fluorescent UV lamps and water.

4) BS 3900 F2 M methods of test for paint. Durability tests on paint films. Determination of resistance to humidity (cyclic condensation).

The Institute values the support of the companies and organisations who are Corporate or Sustaining Members. A detailed listing of these members is published annually as a stand-alone supplement to the January/February issue of Corrosion Management, and a regularly updated searchable listing is published on the Institute's website.

CORPORATE MEMBER COMPANIES

BILFINGER
4 Greenhole Place,
Aberdeen AB23 8EU
Email: johnny.morton@bilfinger.com
Web: www.uk.bilfinger.com

BP
Chertsey Road, Sunbury on Thames,
Middlesex TW16 7LN Tel: 0203 401 9908
Email: chris.williams3@uk.bp.
W: www.bp.com

CARBOLINE
Unit 2, Dorsey Way, Leicester LE19 4DB
Email: Rob Allan rallan@carboline.com
Web: www.carboline.co.uk

CORRODERE (NEW CORPORATE MEMBER)
T: +44 (0) 1252 732 236
Email: Lucy Pavia lucy@corrodere.com
Web: www.corrodere.com

INTERNATIONAL PAINT LTD
International Paint Ltd,
Stoneygate Lane, Gateshead,
Tyne and Wear England, NE10 0JY
Email: suman.bhat1@akzonobel.com
Web: www.akzonobel.com

JOTUN PAINTS (EUROPE) LTD
Stather Road, Flixborough,
Scunthorpe, North Lincolnshire DN15 8RR
Tel: 01724 400 125 Fax: 01724 400 100
Email: enquiries@jotun.co.uk
Web: www.jotun.co.uk

OCEANEERING INTERNATIONAL
Building 3, Levels 2&3,
Aberdeen International Business Park,
Dyce Drive, Aberdeen, UK, AB21 0BR
Tel: 01224 758500
Email: adodds@oceaneering.com
Web: www. oceaneering.com

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AUTOMA (NEW SUSTAINING MEMBER)
Ancona (An) - Italy
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Email: sales@byautoma.com
www.byautoma.com

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Technoparkstr 1, Zurich 8005, Switzerland
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www.bacgroup.com

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United Kingdom
Tel: +44 (0) 1476590666
Email:sales@cathodic.co.uk

3C CORROSION CONTROL COMPANY AB
Box 324, 23 Landskrona, Sweden
Tel: +46 418 411 900 Fax: +46 418 411 935
Email: info@3ccc.se Website: www.3ccc.se

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Tel: +706 557 9624
Email: brianwyatt@controlcorrosion.co.uk

CORROSION TECHNOLOGY SERVICES EUROPE LTD
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Email: enquirieseu@ctsonline.com www.ctsonline.com

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Tel: 905-634-7751 Email: contact@rustrol.com
www.rustrol.com

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www.mapei.co.uk

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www.akakusoil.com

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Email: mail@denso.net www.denso.net

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JOTUN PAINTS (EUROPE) LTD
Stather Road, Flixborough, Scunthorpe,
North Lincolnshire DN15 8RR
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Email: enquiries@jotun.co.uk Web: www.jotun.co.uk

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WF17 9XA Tel: 01924 354700
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www.ryscocorrosion.com

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SUSTAINING MEMBER COMPANIES

D&P COATINGS LIMITED
Ellesmere Port, England
linkedin.com/in/d-and-p-coatings-ltd-862036259

R-TECH MATERIALS (NEW SUSTAINING MEMBER)
Email: info@r-techmaterials.com
Phone: +44 (0) 1656 748 000
Web: www.r-techmaterials.com

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Tel: 01793 380 389 / 0747 654 3218
Email:info@specialistcoatings.net; www.specialistcoatings.net

TPS360
Cardiff, Wales https://www.tps360.co.uk/

CATHODIC PROTECTION CONSULTANCY SERVICES

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CESCOR UK LTD
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Email: dimitrios.mamalopoulos@cescor.co.uk

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Tel: 01442 767 899 www.corrosionengineering.co.uk

CORROSION CONTROL LTD
Tel: 01785 711560 Fax: 01785 711560
Email: brianwyatt@controlcorrosion.co.uk

SEGCORR LTD
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Tel: +44 (0) 1246 457900 www.cathelco.com

CCSL
Tel: 01952 230900 www.corrosioncontrolservices.co.uk

CORROCONSULT UK LIMITED
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Tel: 01252 732236 www.corrodere.com

FUTURE PIPE LIMITED
Tel: 0207 8388660 www.futurepipe.com

GMA GARNET (EUROPE) GMBH
Tel: 01606 836223

INFRASTRUCTURE ANALYTICS LTD
Tel: 028 9532 0131 Email: info@ infrastructureanalytics.co.uk

LAKE CHEMICALS & MATERIALS LTD
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ELSEVIER SCIENCE LTD
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INSTITUTE OF METAL FINISHING
Tel: 0121 6227387 www.uk-finishing.org.uk

QUALITY CONTROL

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TRAINING AFFILIATES

CORRODERE ACADEMY
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Visit the ICorr website for all the latest news www.icorr.org

Institute Events

INSTITUTE OF CORROSION

DIARY DATES 2024/2025

BRANCH DATES

11th December 2024, Wales and South West England Branch Technical programme, Corrosion and Ethics Navigating Heritage Preservation Challenges:
Speakers: Dr Nicola Emmerson, Cardiff University and Dr Paul Lambert, Mott MacDonald.
Contact: swchair@icorr.org

12th December 2024, ICORR Midlands Branch
Online Webinar Event "Corrosion Under Insulation (CUI) and its Predictive Management"
Contact: midlandschair@icorr.org

26th - 28th May 2025
CEOCOR 2025 CONGRESS
La Mole in ANCONA, ITALY.
Abstracts by **1st Feb** to: Secretariat: info@ceocor.lu

COURSES AND EXAMS

CP Exams
December 5th at 8:00 am - 5:00 pm
CP Level 4 Exams Northampton HQ

Schedule for CP Courses at Northampton HQ
For more information about CP courses and certifications please visit: www.icorr.org, Training then 'Cathodic Protection, Training, Assessment and Certification Scheme.

4th-8th November 2024
- ICORR Training and Examination Centre
Cathodic Protection Buried ISO Level 3

Schedule of Corrodere Courses for 2024

3rd-4th December 2024
ICorr Coating Inspection Level 1 course

10th-11th December 2024
Coating Supervisor course

3rd-7th March 2025
Fundamentals of Corrosion for Engineers. Course to be held at Corrosion House, Northampton.

19th-23rd May, 2025 March 2025
MIC - Microbiological Training Course to be held at Corrosion House, Northampton (1,4 and 5 Day Options available).

13th-17th October, 2025
MIC - Microbiological Training Course to be held at Corrosion House, Northampton (1,4 and 5 Day Options available).

Schedule of Argyll Ruane Courses

Coatings Training Courses Available in 2025

Industrial Coatings Applicator Training Scheme (ICATS) Level 1 at Dunfermline
Available on Request.

Hot Dip Galvanising Inspector Level 2
Available on Request at Sheffield and Dunfermline
Sign Up Anytime for Online Course Recertification Exam.

Insulation Inspector Level 2 at Dunfermline
19th-21st April 2025
22nd-24th September 2025
Sign Up Anytime for Online Course Recertification Exam.

Passive Fire Protection (PFP) Coatings Inspector (Epoxy) Level 2 at Sheffield and Dunfermline
Flexible course dates.

Passive Fire Protection (PFP) Coatings Inspector (Epoxy) Level 3 at Sheffield
Available on request.
Sign Up Anytime for Online Course Recertification Exam.

Pipeline Coatings Inspector Level 2 at Sheffield and Dunfermline
Available on request.
Sign Up Anytime for Online Course Recertification Exam.

ICorr Transition Programme Levels 1 and 2, Online
Sign Up Anytime.

Protective Coatings Inspector Level 1 at Sheffield
20th-27th January 2025
17th-24th February 2025
17th-24th March 2025
07th-14th April 2025

Protective Coatings Inspector Level 2 at Sheffield
03rd-10th March 2025

Protective Coatings Inspector Level 3 at Sheffield
12th-16th May 2025
Sign Up Anytime for Online Recertification Exam.

BRANCH CONTACT DIRECTORY

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