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First of all, I hope you are all keeping safe and well. We are living through very challenging times and the future remains uncertain, which can be unsettling. My thoughts are particularly with those who have lost loved ones or whose livelihoods have been affected by the COVID-19 pandemic.

Now more than ever the importance of community comes to the fore. The Institute of Corrosion is in many ways like a family, and we are determined to support our members in any way we can.

I will be highlighting below the ways in which we are continuing to provide services to our members through online platforms during the lockdown period, but we also have a duty to look after our more vulnerable members. If you require assistance with delivery of food or medical supplies or if you are living alone and would appreciate the opportunity to have a chat with another member (not necessarily just about corrosion!) please let me know by emailing gareth.hinds@npl.co.uk, and we will endeavour to help where possible.

We have been very pleased at the success of our online activities in recent weeks. The Corrosion Engineering Division (CED) Working Day on April 29 was attended by more than 50 people from as far afield as India and New Zealand, while the series of five webinars organised at the end of April by the Aberdeen Branch, in conjunction with the Marine Corrosion Forum, attracted over 100 participants to each event. I also gave a presentation at a World Corrosion Organisation (WCO) webinar to mark World Corrosion Awareness Day on April 24, which was attended by over 250 people.

In order to facilitate these and other events, the Institute has signed up to a Zoom Pro account, which is available for use by all branches, divisions and committees. This online meeting software has a number of useful features, including parallel breakout rooms, which were trialled very successfully for the five Working Group meetings during the CED Working Day. Please contact Head Office (admin@icorr.org) for details on how to access the Institute of Corrosion Zoom facility for online meetings and events.

Our Young Engineer Programme has also gone online. This year’s programme was heavily oversubscribed, with more than 60 applicants of which 32 were selected to participate, highlighting the success and growing popularity of the programme. The delegates will receive online training and mentoring in a range of corrosion-related disciplines and will work together in groups on an industry case study. Each group will present its solution to a panel of Institute of Corrosion judges in November – hopefully in person by that time! The winning team will be rewar ded with a free trip to the NACE conference in Salt Lake City in 2021.

Training courses are an important component of the Institute’s commitment to upskilling and professional development of our members. We offer a range of online training courses (check the website for details) so if you are finding that you have time to spare during the lockdown it may be worth looking into attending one of these. It could be a valuable use of your time that will boost your career when life returns to normal.

Our social media activities continue to expand and I hope you are finding it easier to keep track of what is going on across the wide range of Institute activities. I encourage you all to share and comment on our posts and blogs to take maximum advantage of the functionality these digital tools provide.

Finally, I wish you and those close to you continued health and strength and hope that we will all have the opportunity to enjoy meeting in person again when we have made it through this difficult period.

Gareth Hinds, Institute of Corrosion President
**Institute News**

**Membership Subscription Rates 2020/2021**

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**Sustaining Membership Annual rate from 1st July 2020 is £396.00 (plus VAT)**

“GOLD” Sustaining Membership Annual rate from 1st July 2020 is £766.00 (plus VAT)

**New Applicants**
All new applications for Individual membership must be accompanied by a payment of £95.00. The applicant will immediately be admitted into the Institute as an Individual Member.

**Students**
*Applications should be accompanied by proof that you are a student to qualify for free membership.

**January - March Applications**
Applications submitted between 1st January and 31st March (i.e. in the second half of the subscription year) need submit only half the annual rate plus the full Registration fee of £15 (i.e. £55.00 for Individual Members).

**April – June Applications**
Applications during April, May and June will be treated as being made on 1st July.

**Payments**
Payment may be made by cheque or credit/debit card. Overseas members who wish to receive the Institute’s journal Corrosion Management by air mail should add £30.00 to their subscription payment.

**Grade Transfer**
Applications for transfer to a higher grade should be made on the Professional Membership Application Transfer Form and be accompanied by a payment of £58.00, being £25.00 administration fee plus the £33.00 difference between Individual and Professional Membership or £36.00 being £25.00 administration fee plus the £11.00 difference between Individual and Technician Membership.

Candidates should realise that an application for Professional membership can take up to six months. While the Professional Assessment Committee makes every effort to process applications more quickly than this, they can be helped by candidates ensuring full and complete fulfilment of the requirements, especially the provision of an adequate training and experience report.

Subscription rates for Life Membership, Members in retirement and unemployed Members are available on request.

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**ICATS News**

It has been tough time for everyone for a while now but hopefully by the time you read this, we will see the light at the end of the tunnel. Once guidance on easing the lockdown is clearer, Corrosion House will re-open, as will many other businesses. When this happens, an announcement regarding courses at Northampton will be placed on the CORREX website and emails sent to trainers and clients.

It is acknowledged that there is a backlog of replacement cards, and other information people are waiting for, but please be patient with Denise and her team at Head Office, as it may take some time to catch up.

We will be continuing to develop ICATS in the UK and overseas in the ensuing months and Kevin will be visiting clients when he can.

A reminder that there is a supply of ICATS, ICA black books, and Trainers should email Kevin (kevin@paintel.co.uk) if they require copies of the book.

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Social Media

During the COVID-19 induced lockdown, the use of social media has exploded. Numbers from The Institute of Corrosion’s social media accounts show that members are staying in touch and connected to their professional life as well as their personal.

Coronavirus has shown the world many things. One of these is that our human need to connect with others remains strong - and when we can’t interact in person, we’ll find other ways of doing so. From cave drawings to smoke signals to telegrams to telephones, we humans have always innovated new ways to interact remotely.

Of course, the world has moved on from smoke signals to social media as a preferred channel of communication, interaction, and information sharing. The unprecedented times in which we currently find ourselves has shown just how much we now rely on social media – and the Institute of Corrosion has not been left behind.

According to recent data from GobalWebindex, social media is a core activity of people in lockdown. Almost half of internet users say they are spending more time on their social media and on messaging services. More than a third are spending more time on mobile apps. Interestingly, now the social media bug has hit, one in five people expect to continue to spend more time on their social media after the COVID-19 outbreak has passed.

The Institute has been developing its social media this year. It can now be found on LinkedIn, Facebook, Instagram, and Twitter (links to these sites can be found in the March/April Corrosion Management). Content includes blogs, news, and market information which is shared with the world. The Institute’s members are encouraged to become involved in the conversation about corrosion by posting on the Institute’s social media and sharing its content, and this is beginning to happen.

Our social media numbers are growing tremendously. For example, the number of members on the LinkedIn group page are up by around 15% this year, and moving toward 2,500. That’s a faster rate of growth than the LinkedIn platform itself has experienced. Its number of members has only increased by around 2.25% this year.

The Institute’s ambition of increasing global reach is being helped by its social media presence, too. When breaking down its audience, the number of visitors to the website – in large part driven by its social media and organic search – increased by around 9.5% in the last three months compared with the previous three months.

While the UK accounts for around a third of site visitors, the Institute’s new focus on digital communication channels is paying dividends around the globe. Visitor numbers from the Europe rose strongly, led by the Netherlands with a colossal increase of more than 25%. Visitors from the United States increased by a very impressive 15%. India was next on the list, with almost 13% more visitors than in the previous period, followed by Nigeria and UAE among others.

When the Institute rebranded, it rebranded its website simultaneously. The greater depth of content on the site now includes regular blogs, news, details of all training and certifications, and a members-only area with exclusive content. The efforts by all involved are being recognised by a growing audience.

Together with its improving social media presence and this magazine, the Institute of Corrosion is keeping a worldwide community in touch with all the latest news, views, and developments in corrosion. Additionally, it is providing new ways for you to develop your professional network through your membership of the Institute of Corrosion.

Points that were noted at the recent Council meeting, in which a good deal of appreciation was expressed for the work of both the magazine and recent social media activity.

European Corrosion Medal for ICorr Past-President

Stuart Lyon, ICorr President between 2005 and 2007, and who continued afterwards as CEO of CORREX Ltd until 2012, has been awarded the European Corrosion Medal for 2020. This is the most prestigious honour of the European Federation of Corrosion (EFC) and recognises: “achievements by a scientist, or group of scientists, in the application of corrosion science in the widest sense”.

In a 35-year career at Manchester, Stuart has published over 200 papers, supervised over 60 PhD/ MPhil research students and over 80 MSc and Undergraduate project students. He is a regular attendee of, and presenter at, EuroCorr, an organiser of EFC events (especially EuroCorr 2008 in Edinburgh) and active participant in EFC Working Parties - notably: WP4 (Nuclear Corrosion); WP6 (Surface Science & Mechanisms of Corrosion Protection); WP7 (Corrosion Education); WP8 (Physico-chemical Methods of Corrosion Testing); WP14 (Coatings). Since 2006 he has been Editor-in-Chief of “Corrosion Science Engineering and Technology” an IoM3/EFC journal.

Over his career, he has worked with the energy sector (nuclear core materials, radwaste containers, and hydrocarbon applications in upstream and downstream) and helped to set up research partnerships at Manchester with the UK nuclear industry (the Materials Performance Centre - MPC), BP (the International Centre for Advanced Materials - ICAM), EdF Energy, and Airbus. Since 2012, he has led a strategic research partnership for AkzoNobel’s global corrosion protective coatings business applying innovative analytical and microscopy techniques to the study of paints and paint performance.

Stuart, who is AkzoNobel Professor of Corrosion Control at the University of Manchester, was recognised by the EFC Award Jury for his: “wide contribution and significant research particularly in the fields of atmospheric corrosion, corrosion protection by organic coatings as well as corrosion inhibition using emerging and novel analytical techniques for advancing the fundamental understanding of corrosion mechanisms. He is widely recognised as a corrosion scientist with an international scientific reputation at an academic level who, at the same time, has made a strong impact on industrial applications in corrosion and corrosion protection”.

Previous winners from the UK include Graham Wood (who established Manchester as a world-wide centre of excellence in corrosion research) in 1999 and Redvers Parkins in 1996. Graham and Redvers were also Past-Presidents of the Institution of Corrosion Science and Technology, the predecessor body of ICorr.

The presentation of the EFC Corrosion Medal Award Ceremony will be held in conjunction with the EUROCORR 2020 meeting, and will be followed by an acceptance address by Stuart.
Corrosion Engineering Division (CED)

Working Day, Wednesday 29 April 2020

This one-day meeting was the latest in a series of working days held by the Corrosion Engineering Division. This year’s meeting had the theme of ‘Corrosion Control in Transport and Infrastructure’. Originally, it was planned that the meeting would be held at the fascinating conference venue at the National Railway Museum, York. However, due to the coronavirus lockdown, it was no longer possible to go ahead with a physical meeting and so the division held the meeting on-line using the Zoom platform (set up by the Institute), for the first ever on-line Institute of Corrosion Symposium. The meeting was joined by 60 corrosion engineers from around the world who had pre-registered for the meeting, including from India and New Zealand, despite the time zone differences. Nick Smart (Jacobs) chaired the meeting, which followed the published agenda and timetable. After the technical talks, the meeting divided into individual CED working groups, using the Zoom breakout room facility.

The first talk was given by Phillip Watkinson (Corrocoat) who presented ‘Fascinating Uses of Heavy Duty Glassflake Coatings in Transport Applications’. Phillip described the technical background to glass flake coatings and how they have developed over the years, initially from crude trowel- or brush-applied coatings, using predominantly polyester resins, through to spray-applied coatings using epoxy formulations, that can now be easily sprayed internally on pipes with diameters ranging from 50 mm to over 1 metre. Modern coatings can also be applied using an aerosol method. The methods for producing glass flake have evolved so that now it is possible to have close control over the thickness of the flake used (±1 µm) and to minimise the curvature in the glass flakes. Phillip highlighted the many desirable properties of glass flake coatings and illustrated their application in various industries, including their use on train axles, train air brakes, dip tanks for applying coatings to car bodies and a propeller shaft.

Chris Atkins (Mott MacDonald), presented the second talk entitled ‘Innovations in Preserving Transport Infrastructure’. This presentation focused on the ‘embodied energy’ concept of building materials, which can be applied when considering the amount of energy that is consumed in producing a range of building materials. It is important to take account of this factor in relation to achieving Net Zero carbon emissions by mid-century. By applying the ISO definitions of environmental conditions (ISO 9223) and the decrease in corrosion rate with time (ISO 9224), the approach taken is to evaluate the energy lost in allowing corrosion to take place for steel or galvanised steel, with coatings reapplied every 15 years over the life of a structure. By analysing the predicted energy consumption involved, it is possible to determine the relative energy efficiencies of various coating strategies, such as galvanising, depending on the corrosivity of the environment, the energy consumed in producing the initial material, and the availability of recycling facilities.

Steve Paterson (Arbeadie Consultants), 2019 Paul McIntyre award winner presented the third talk on ‘Managing Corrosion in Ageing Offshore Infrastructures’. This talk summarised the background to the operation of existing North Sea offshore facilities beyond their original design life, with some structures predicted to be operating for 45 years or more. This can be compared with the operation of the Forth Rail bridge which was originally opened in 1890 and it still going strong because of ongoing maintenance regimes. The various considerations for extending the lifetimes of offshore installations were reviewed and the current guidance available from the Energy Institute was highlighted. Steve summarised the various ageing mechanisms that need to be considered in assessing future lifetimes and the following mechanisms were recognised as key current primary threats to facilities/pipelines: fabric degradation – external corrosion, corrosion under insulation, microbial corrosion, sand erosion and preferential weld corrosion. These corrosion issues were illustrated with a number of examples taken from field operations, followed by a discussion of future challenges, not least of which is the possible closure of facilities due to the current Covid-19 pandemic and the retention of the necessary technical skills within the workforce.

Turning from the oil and gas industry to the nuclear industry, Cliff Harris and Clive Harrison (both Jacobs) presented a talk entitled ‘Corrosion Monitoring of Dry Fuel Storage Containers in Nuclear Facilities’, which focused on the corrosion aspects of dry storage of spent nuclear fuel removed from the Pressurised Water Reactor (PWR) at Sizewell. Spent nuclear fuel is moved from initial wet storage in ponds at the power station and placed into purpose-built dry storage facilities, because there is currently no geological disposal facility (GDF) available within the UK. The fuel is placed into a stainless steel multi-purpose canister (MPC), which is filled with inert gas, welded shut and then placed into a steel and concrete overpack. This system provides passive cooling through the use of convective air flow induced by the high operating temperature of the MPC, and has a planned storage life of up to 100 years. Corrosion studies have focussed on the possibility of atmospherically induced stress corrosion cracking due to the deposition of deliquescent sea salt particles. A corrosion evaluation test programme has involved the use of environmental monitoring combined with the construction of a full-size, fully monitored, MPC corrosion simulator, backed up by laboratory test programmes of SCC susceptibility under a range of test conditions and a study of the deliquescent properties of various deposited salt analogues.

Before the lunch break, Gareth Hinds (ICorr president) gave a ‘virtual’ presentation of the 2020 Paul McIntyre Award to Professor Carmen Andrade, who was located in Madrid, Spain (see report below), highlighting her many achievements in the field of applied corrosion science and corrosion engineering. Following the presentation, Professor Andrade gave a brief illustrated summary of her activities during her career and expressed how honoured she felt to receive the award.

The final talk of the day was given by Pablo Merino (CLH Pipeline Systems) entitled ‘A New CP Approach on Non-Isolated and Aged Pipelines: A Case Study’. The talk was concerned with the corrosion protection of the very large pipeline systems, extending for 10s of km, that support the UK infrastructure, for example for distributing aviation fuel. The presentation covered a review of the various options for managing an oversaturated CP system, which used an impressed current cathodic protection system. Inspections had shown that the pipeline was not achieving the require BS EN 12954 criteria, and that the coating was deficient in a number of areas. The remediation options considered included electrical isolation, coating rehabilitation, upgrading the CP system, and changing the CP criteria to a less restrictive one. The last of these was the only feasible one, backed up by the use of an external corrosion monitoring system, based on an electrical resistance corrosion rate measurement technique.

The final talk was followed by a set of parallel working group meetings for all the CED working groups, namely nuclear, coatings, oil and gas, cathodic protection and corrosion in concrete. At the end of the afternoon, Nick Smart thanked all the participants and contributors, and so ended the first on-line CED meeting. He looked forward to holding the next CED working day meeting at the National Railway Museum next Spring, pandemic permitting! Copies of the presentations will be put in the members area of the ICorr web site, together, where possible, with recordings of the presentations that were given.

Paul McIntyre Award

The winner of this year’s Paul McIntyre Award is Carmen Andrade. The announcement was made during the on-line CED meeting on 29 April, at which she also gave a short presentation.

Until her retirement, Dr Carmen Andrade was a Research Professor at the Institute of Construction Sciences “Eduardo Torroja” of the Spanish National Research Council (CSIC), working in the field of concrete durability and reinforcement corrosion. At present she is visiting Research Professor at the International Centre for Numerical Methods in Engineering (ICMNE). She is the author of numerous papers, has been editor of several books, and has supervised around 30 PhD theses. She has received several awards, including the R. N.
Whitney Prize 2013 by NACE, Robert L’Hermite Medal 1987 from RILEM, "Manuel Rocha” of the Presidency of Portugal, and the “ALCONPAT Prize” in recognition her distinguished career. She is an honorary doctor of the University of Trondheim (Norway) and of the University Alicante General Director of Technology Policy of the Ministry of Education and Science, and advisor to the Secretary of State for Universities in the Ministry of Science and Innovation, Spain.

Branch News

Aberdeen Branch

The branch held its 7th event of the 2019/2020 session, on 27 April. This was the first of 5 technical presentations of the annual joint Institute of Corrosion/MCF (Marine Corrosion Forum) programme, held Online this year over 5 days, due to the COVID crisis. The heavily over-subscribed webinar was jointly chaired by Dr Yunnan Gao (ICorr-ABZ) and Institute of Corrosion HQ jointly promoting.

The branch was very pleased to host Adam Lea-Bischinger, a Sr. Consultant with Fokus – Reliability, who currently holds several roles in Aberdeen including, Branch Chair of IAM – Institute of Asset Management, online course tutor in Asset Management for the University of Aberdeen, and Sr. Advisor to the Board of Pavan Asset Value Managers.

Adam has 15 year’s experience working in maintenance, reliability, asset management and inspection covering major oil and gas, power, mining and infrastructure projects worldwide, and holds a masters degree in Engineering, Materials and Corrosion with post graduate training in Inspection and NDT.

Adam spoke enthusiastically on asset management and how it can deliver value to an organisation. He carefully described the six core elements of asset management, the work of IAM, and the development and roll-out of ISO 55000:2014 which defines terminology, requirements and guidance for implementing, maintaining and improving an effective asset management system, and gave examples of UK and overseas companies operating the ISO 55000 system, including many utilities, major transport operators and drilling companies, who all having significant investments to protect and maintain for their full life-cycle.

The now established standard has three key parts:
ISO 55000 – Asset Management – Overview, Principles and Terminology
ISO 55001 – Asset Management – Management systems – Requirements
ISO 55002 – Asset Management – Management systems – Guidelines for the application of ISO 55001

According to the IAM, “These three international standards are important not only for their content, but because they represent a global consensus on what asset management is and what it can do to increase value generated by all organizations.”

The conceptual model, developed by IAM to show the core elements of the ISO 55000 series standard containing six main groups and thirty nine subjects is detailed below:

---

**Strategy & Planning**
- Asset Management Policy
- Demand Analysis
- Strategic Planning
- Asset Management Planning

**Organisation & People**
- Procurement & Supply Chain Management
- Asset Management Leadership
- Organisational Structure
- Organisational Culture
- Competence Management

**Decision Making**
- Capital Investment Decision Making
- Operations & Maintenance Decision Making
- Lifecycle Value Realisation
- Resourcing Strategy
- Shutdown/Outage Strategy

**Lifecycle Delivery**
- Technical Standards
- Asset Creation/Acquisition
- Systems Engineering
- Configuration Management
- Maintenance Delivery
- Reliability Engineering
- Asset Operations
- Resource Management
- Shutdown/Outage Management
- Fault & Incident Response
- Asset Disposal

**Risk & Review**
- Risk Management
- Contingency Planning
- Sustainable Development
- Management of Change
- Asset Health Monitoring
- AM System Monitoring
- Management Review
- Asset Costing & Valuation
- Stakeholder Engagement

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The importance of team-working and good communication was heavily stressed, so as to achieve good LOF – Life of Field Design, and to avoid the too often prevailing SILO (compartmentalised) type mentality within organisations.

An extensive Q&A followed with questions on topics such as the use of ‘Hands-Free’ asset management software, conditioning monitoring, cyber security threats from wireless devices, and the management of ‘Late Life’ assets. Various aspects of implementation of ISO 55000 guidance were also discussed and highlighted global differences in asset management methods and regulation.

Following from the success of the April webinar with MCF which had an attendance exceeding 70 on all 5 days, it is now planned that the Institute of Corrosion will work together with MCF to continue the close co-operation now established, for its July meeting, in Birmingham, with webinars running between 6-10 July 2020, as the resumption of ‘Face to Face’ meetings is not being expected before that date.

On the 29th April, members of the Aberdeen Branch also participated in the online CED Working Day and Symposium on ‘Corrosion Control in Transport and Infrastructure’, with Alistair Seton of the Aberdeen Committee chairing the Oil and Gas Working Group.

There has been much debate of late concerning the impacts of the coronavirus outbreak, but both the Institute of Corrosion/MCF Webinars and the CED Online event, has proven beyond doubt that such obstacles can be overcome and that the demand for corrosion learning by whatever method, is as strong as ever.

As usual, full details of future branch events can be found on the ICorr Website, or by contacting: ICorrABZ@gmail.com. Copies of the majority of past branch presentations can be found at: https://sites.google.com/site/icorrabz/resource-center, and a photo gallery for all Aberdeen events may be found at: https://sites.google.com/site/icorrabz/event-gallery.

It should be noted that the planned Aberdeen event of Tuesday 23 June – ‘Industrial visit (Oceaneering), an Alternative / Interactive Industrial Event’, is currently postponed (awaiting Scottish Government instructions), with a new date to be advised, as soon as is possible.

London Branch

As with other Institute of Corrosion meetings, the branch’s March and April technical presentations had to be cancelled due to the pandemic. The committee held an online meeting under its new chairman, Ben Moorhouse of BP, to discuss how to move forward under the current situation. The committee would like to thank Paul Brooks the outgoing chair for the hard work he put into the branch during his tenure.

Contingency plans were discussed to hold a replacement Annual General Meeting and next season’s regular talks (October onwards) via online video conferencing, if they cannot be held in person. Further information will be available in later issues of this magazine, and on the Institute website.

Young Engineer Programme (YEP)

ICorr’s Young Engineer Programme once again broke new ground as it held its first ever meeting online in May, for the reveal of its 2020 case study.

The grand surroundings of the Royal Over-Seas League might have been replaced with the homespun comforts of participants’ living rooms, but the content of the meeting remained as topical as ever with Steve Paterson from Arbeadie Consultants Ltd presenting the 2020 case study for the seven participating groups.

Focusing on an onshore titanium pipe corrosion failure, Steve described a scenario where several leaks were experienced in the piped onshore glycol desalination plant that required further investigation, giving the participants plenty to think about ahead of presenting their findings in November.

As an experienced technical expert with a deep knowledge of subsea engineering and corrosion management systems, Steve’s puzzling scenario ensured that the 32 participating young engineers - representing 19 companies, each with a wide and interesting variety of specialist backgrounds – had plenty to discuss on the evening.

The young engineer’s broad set of specialities include mechanical and materials engineering, welding, materials and more. These were all put to the test when discussing the desalination plant, which is used to periodically remove the salts from mono-ethylene glycol, used for hydration and corrosion control in gas pipelines from three offshore fields.

With the help of a mentor assigned to assist each group, the young engineers were posed with problems at the end of the presentation. These included proposing root causes for the defect, how to perform a corrosion risk assessment to determine if the plant is safe to operate, suggesting alternative materials, and identifying what mitigation options could be applied to prolong the service life of this section of the desalination plant, among others.

The YEP has been running for a number of years and delivers a technical competency framework that’s consistent with the Institute of Corrosion’s professional standards, to help prepare graduates for entry into the industry with a broad range of knowledge. As well as providing an opportunity to network with likeminded professionals, the programme also offers participants a stepping stone into the industry, and is the first stage in achieving MiCorr and CEng status.

In what might be the first of many online meetings, the evening ran according to schedule, although participants and guests had to make their own tea and coffee during the scheduled break. Prior to that though they were entertained by Tim Evans, Caroline Allanach and Danny Burkle who offered a reflection on their 2018 winning case study.

Caroline and Danny discussed how they approached the case study and the fantastic resulting prize of a trip to the 2019 NACE Conference in Nashville, while Tim provided a critical assessment of their reaction and solution to the failure that occurred.

The case study was concluded by a series of questions and answers, before Trevor Osborne from Deepwater Corrosion Services brought the first ever online YEP meeting to a close with a message of thanks. The participants will attend four more lectures before reconvening in November to present their case study.
Corrosion Monitoring and Inspection

Corrosion monitoring and inspection are essential components of a corrosion management programme and numerous books, papers and conferences are dedicated to these subjects. This article focuses on some key points of these activities and the reader is encouraged to review the literature for more detailed information.

To minimise safety, environmental and business risks whilst maximising reliability, it is essential that equipment is maintained in a condition appropriate for the service required. Equipment in this condition is described as Fit-for-Service (FFS), i.e. the equipment can operate safely under defined operating conditions for a defined operating period. It should be noted that equipment that is FFS does not have to look nice or be corrosion free – although that is often desirable for other reasons! Corrosion is one of many possible degradation mechanisms that can negatively impact the condition of equipment and ultimately render it not FFS. Corrosion monitoring and inspection are used to determine if equipment is FFS and to predict how long it will remain so.

The definitions of corrosion and inspection can become blurred but broadly inspection involves quantifying the safe, usable wall thickness of metallic equipment and identifying defects such as thinning, cracking or pitting, caused by corrosion. Inspection is usually the most accurate way to determine current equipment condition but has the obvious disadvantage that any damage that is detected has already occurred. Inspection is therefore a lagging indicator.

To complement inspection methods, a leading indicator is needed; something that will identify that degradation is occurring and provide enough warning so that an intervention can be implemented well in advance of the problem impacting FFS. In practice a true leading indicator is difficult to obtain but this is what corrosion monitoring strives to do.

For both corrosion monitoring and inspection it is critical that the correct locations are selected. This requires a full understanding of the corrosion threats, the probable corrosion rates and the consequence of failure, i.e. a risk-based approach.

Corrosion Monitoring

Historically corrosion monitoring was exclusively associated with the measurement of corrosion rates. However, this definition has been extended to include the measurement of the performance of corrosion control barriers, e.g. the availability of corrosion inhibitors, the condition of coatings, or the electrical potential of equipment under cathodic protection control.

Corrosion Rate Monitoring

In broad terms corrosion rate monitoring is the measurement of a representative corrosion rate for a given piece of equipment exposed to a corrosive service. There are several techniques that can be used either as standalone or in concert with each other. Ideally corrosion monitoring is designed to provide real time feedback on the corrosion control process. It is important to remember that any given monitoring technique will have limited accuracy and sensitivity, and should be chosen to provide appropriate information. Monitoring is used for corrosion on both internal and external surfaces, but for this article only internal monitoring is discussed. Traditional methods for internal corrosion monitoring include:

i. Mass (weight) Loss Coupons.
ii. Electrical Resistance (ER) Probes.
iii. Electrochemical Monitoring (e.g. linear polarization resistance (LPR), AC Impedance).

Clearly there is a cost to installing and running corrosion monitoring programmes and this needs to be balanced against the value that they will provide. For probes, the ideal situation is to have them hard wired or wirelessly connected into the equipment control system which is best done during design and construction.

There can be a significant operating cost to manage coupons and probes which obviously depends on the size of the programme. Insertion and retrieval of coupons and probes into pressure containing equipment may present safety risks and must be done by specially trained personnel. Analysis of coupons requires laboratory facilities and the analysis of data requires appropriate training. These contribute to the cost of the programme and so the value of the data must be carefully considered. Monitoring data should never be considered as simply nice to have. If the data are not actively used and acted upon it begs the question of why invest in the expense and effort of installing corrosion monitoring facilities.

Corrosion Barrier Monitoring

To reduce corrosion rates to an acceptable level, corrosion engineers use a variety of mitigation methods known as barriers. These fall into two broad categories as follows:

i. Passive Barriers: these are barriers which require little or no active management during the lifetime of the equipment, e.g. the use of a material that is resistant to corrosion in the specified fluid.
ii. Active Barriers: These are barriers that require active management by corrosion engineers. This can range from periodic visual inspection to monitor the condition of paint coatings to daily adjustment of corrosion inhibitor injection pumps.

It should never be assumed that because a barrier has been installed it will always work as designed. Where active barriers are employed it is essential that their performance is monitored to ensure they continue to perform as designed over the lifetime of the equipment. This is known as corrosion barrier monitoring, i.e. a corrosion monitoring programme is not just about measuring corrosion rates.

A good corrosion management programme will have at least one barrier in place for each credible corrosion threat and each of these barriers should be monitored to ensure they are working as designed.

Inspection

The majority of inspections are carried out using well-established techniques that have been available for many years, i.e. Visual Testing (VT), Ultrasonic Testing (UT), Radiography Testing (RT), Magnetic Particle Testing (MT) and Dye Penetrant Testing (PT).

Many of these techniques have been built into both internal and external tools, e.g. intelligent (smart) pigs, drones and subsea remote operating vehicles (ROVs).

Many inspection instruments are now small enough such that they are truly portable and can be handheld by a single person. Inspection equipment can also be permanently installed on facilities to provide point measurements at known defects or more extensive, circumferential or longitudinal coverage. Another important development is the increased use of remotely controlled crawlers and drones which can carry cameras to locations that are difficult or costly to access, such as subsea pipelines, flare stacks and offshore platform jackets.

An important development in radiography is the widespread use of digital radiography which uses electronic detectors instead of traditional film
plates. The resolution of the digital “plates” provides very high-quality images with each pixel offering 250µm resolution. The high sensitivity also allows either lower strength radiation sources to be used or shorter exposure times. In addition, modern data processing provides very fast data acquisition and analysis of images which allows the images to be seen in almost real-time.

Collection and Analysis Data

Following data acquisition by corrosion monitoring and inspection, it is paramount that the data are stored, analysed and interpreted. Real-time transmission of corrosion data from electrically based monitoring (e.g. ER, LPR, oxygen probes) has been available for many years although it required the installation of hard wiring from the probe to a control centre. In recent years there have been significant advances in the availability and reliability of wireless communications. This has enabled data to be transmitted relatively inexpensively from corrosion monitoring locations in real-time.

Many companies provide software that can take multiple data inputs and correlate them with the corrosion monitoring data. As an example, taking temperature, pressure and flow rate data from a pipeline to estimate an unmitigated corrosion rate. These data are then presented in a corrosion dashboard which can be seen at any location around the world. The above figure shows a typical dashboard that displays real time fluid flow rates, velocities, sand rates and estimated corrosion rates.

Future Considerations

Inspection techniques can measure equipment wall thicknesses very accurately but historically they have required skilled technicians to make the measurements using portable equipment. The cost of this has meant that repeat inspections were undertaken at a frequency of 1-5 years. However, with improvements in technology, the use of permanently installed inspection equipment has blurred the boundary between what was traditionally referred to as Inspection and Monitoring, and the use of inspection techniques as ‘real-time’ corrosion monitoring tools has become more common. These non-intrusive, highly sensitive technologies are able to work through solid external coatings (e.g. FBE, PE, 3LPP). They are increasingly becoming the preferred methods for corrosion monitoring going forward and offer the option to eliminate intrusive monitoring and the risks associated with it.

Guided wave UT is increasingly being used to monitor long lengths of piping and pipelines. It is probable that these techniques will be used to provide close to 100% coverage of equipment to provide real time measurements at all locations. This would be a key step towards intelligent equipment which self identifies problems.

Corrosion monitoring and inspection programmes can generate large volumes of data which are often reviewed in isolation. There have been significant advances in data analytics (so called “Big Data”), artificial intelligence and machine learning. These technologies can rapidly analyse vast quantities of structured (e.g. data) and unstructured (e.g. reports) information to provide insights that may have been missed.

Finally, engineers and technologists continue to find new and improved methods for monitoring and inspection. Perhaps one day corrosion may be eliminated but until then it is certain that better methodologies for monitoring and inspection will continue to appear.
Fellow’s Corner

Permeable membrane try to reach a state of equilibrium regarding their concentration. If you have a strong solution on one side and a weak solution on the other, water will pass through the membrane attempting to dilute the strong solution until it is isotonic with the other side of the membrane. From this we can therefore deduce that salts become a major issue in either immersion or very damp conditions, blistering is not going to be very likely in a dry, air-conditioned environment. The next thing to consider is the permeability of the applied coating, this will be affected by a multitude of factors but mainly the density of the coating matrix and its resistance to the flow of water through it, and the applied thickness. Also, the concentration gradient across the membrane must be considered.

When it comes to coatings, there are several considerations, particularly when using certain words; glass flake is a particular one when it comes to permeability! Glass flake coatings come in a whole range of varieties of binder, flake size,flake shape and flake density. A cheaply made ground glass powder in a cheap epoxy binder applied at low DFT will never perform as well as a proper, high density glass flake with a flake size of 1/16” or larger, trowel-applied, solvent free polyester based coating, with a DFT of over 1mm!

There is then the issue that stainless steels, duplex and super duplex materials suffer from chloride induced stress corrosion cracking and with these, when in a high-risk application, there is a need to see chloride ion contamination as close to zero as is practicable. This is not helped by the fact that many epoxyes have chlorides in their formulations, so regardless of how low you get the contamination on the surface, the wrong selection of coating immediately undoes all the hard work!

As can be seen, there is no one answer fits all, unless you take a totally risk aversed viewpoint, where there is a zero tolerance. There are two ‘normally acceptable’ values that tend to be bandied around and these came originally from the NORSOK M-501 guidelines:

- The maximum content of soluble impurities on the blasted surface as sampled using ISO 8502-6 and distilled water, shall not exceed a conductivity measured in accordance with ISO 8502-9 corresponding to a NaCl content of 20 mg/m² •

20mg/m² was adopted for immersion and 50mg/m² for atmospheric maintenance. These numbers are not based on any particular science but are pretty arbitrary and were there as a guideline. The next problem is the interpretation - is it total salts? a specific salt such as sodium chloride? or is it just the chloride part? Having defined what you deem necessary to test for, the next problem is how do you test for it? This opens another major can of worms!

In all honesty, there is not a single answer, you need to look at the individual requirement. The coating manufacturers should have done the necessary testing in a variety of scenarios with their products, and should be able to confirm what level of contamination is acceptable and what DFT of the material is required to give the required performance in the situation envisaged. Independent verification of the testing by a third-party test lab is a very useful indicator of the potential performance to confirm manufacturers’ claims.

Therefore the simple answer is to use the 20 and 50 mg/m² for carbon steels etc. and as close to zero for S/S, duplex and super duplex as a safe bet base guideline to work from, but it is essential to make sure that the materials, specification and environment are assessed together with making sure that the most suitable choices are made to meet the performance needs.

Simon Hope, Consultant Technical Authority, Auquharney Associates Ltd.

Readers are invited to submit generic (not project specific) questions for possible inclusion in this column. Please email the editor at, brianpce@aol.com
COVID-19: back to the workplace in safe and healthy conditions

The COVID-19 crisis is putting pressure on employers and workers. Once the physical distancing measures achieve a sufficient reduction in COVID-19 transmission rates, national administrations are authorising a gradual resumption of work activities.

Appropriate preventive measures help to achieve a safe and healthy return to work and contribute to suppressing transmission of COVID-19. EU-OSHA (Occupational Safety and Health Administration) has produced occupational safety and health guidance to help in this process.

You can read the guidance, “Back to the workplace: Adapting workplaces and protecting workers” at:
https://oshwiki.eu/wiki/COVID19:_Back_to_the_workplace_Adapting_workplaces_and_protecting_workers

Members of NACE International and SSPC overwhelmingly vote in favour of merging the two Organisations

During the two-week voting period, thousands of members of the two associations cast votes, with an overwhelming 89% of NACE members and 88.3% of SSPC members in favour of the merger.

Several steps are required before completion of the combination and most changes will not be immediate. Initial efforts will be focused on determining the new governance and membership structure by January 1, 2021. Member volunteers will drive discussions and decision-making to ensure the final combined organisation represents the best interests of the membership. McKinley Advisors will continue to serve as a third party, independent advisor to assist both organisations with combining resources, knowledge, and cultures.

NACE International CEO, Bob Chalker and SSPC Executive Director, Bill Worms issued the following joint statement, “From the time each of us began working for our organisations we have believed our members can be stronger together. We are devoted to providing our members with the best services, education, and products possible and we know this combined organisation will accomplish that and more. We are pleased to see this come together and look forward to a bright future ahead for the members of NACE and SSPC.”

Corrosion to Covid-19: one start-up company’s effort to support UK front line workers

Hexigone Inhibitors, a Sustaining Member Company, who usually manufacture chromate-free corrosion inhibitors, are now using their large mixing vessels to produce hand sanitiser to help protect staff on the front line. The sanitiser, which meets the standard set by the World Health Organisation, is already in use in local organisations.

The UK Government’s innovation agency, Innovate UK, linked-up Hexigone with pharmaceutical giant, Glaxosmithkline, who subsequently donated 8,000 litres of isopropanol to ramp-up production.

For the sanitiser to be effective, it must contain at least 60% alcohol. The batches made by Hexigone are 75% - precisely made to the WHO recommended formulation - ensuring that the coronavirus and other microbial pathogens are killed. Other ingredients include water to dilute, glycerol to moisturise, hydrogen peroxide to kill any fungal spores, and finally, lemongrass essential oil to scent the sanitiser.

Survey Drones can now go beyond line of sight

The use of drones for aerial inspection and survey is increasing, and their usefulness is set to increase with a demonstration by AmeyVTOL of a drone inspection carried out beyond the visual line of sight.

AmeyVTOL is a joint venture between Amey and aerial robotics specialist VTOL Technologies. AmeyVTOL’s drone, known as The Flying Wing, has a flight range of up to 100 km, and sensors that enable it to capture and send data in real time.
During the demonstration, The Flying Wing autonomously surveyed an area out of the sight of the pilot up to 2km away.

According to Amey, the success of the trial opens up the use of drones for inspections of long linear infrastructure such as roads, railways and overhead power lines, saving time and cost, and improving the safety of staff. The demonstration project was part of a government-sponsored Rail First of a Kind (FOAK) programme promoted by Innovate UK through the Small Business Research Initiative.

It is reported that AmeyVTOL will now be offering this survey capability to other infrastructure owners and operators.

Guidelines for Non-destructive Inspection by Phased Array Ultrasonic Testing

The shipping Classification Society, ClassNK, has released its “Guidelines for Non-destructive Inspection by Phased Array Ultrasonic Testing”.

Phased array ultrasonic testing is an advanced non-destructive inspection technology that enables the visualising of flaw detection results and the digitising of the record-keeping process. It has higher detection performance for defects in materials and welded joints compared to conventional ultrasonic testing.

In recent years, the application of phased array ultrasonic testing in various industrial fields has been increasing, and it has also been gradually spreading in the shipbuilding field, taking advantage of the above features.

Based on the knowledge acquired from its R&D, ClassNK has comprehensively summarised the requirements for non-destructive inspection by phased array ultrasonic testing and specific flaw detection procedures for butt welded joints of carbon steels in the shipbuilding field into its guidelines.

These guidelines are available to download free of charge via ClassNK’s website www.classnk.com for those who have registered for the ClassNK “My Page” service. To register for the “My Page” service free of charge, go to the ClassNK website www.classnk.com and click on the “My Page Login” button.

Elcometer Technical Manager Appointed as NACE Standards Board Vice Chair

Following the recent formation of their new Standards Board, NACE International, has appointed David Barnes, has been Technical Manager at Elcometer, as their Vice Chair.

David has been Technical Manager at Elcometer for over nine years, and has worked closely closely with NACE, SSPC, ASTM, BSI and ISO on standardisation, writing and presenting technical papers at industry conferences around the world.

David will serve a three-year term as the NACE Standards Board Vice Chair, followed by a further three years as its Chair. His term as Vice Chair is scheduled to begin on 20th June, 2020.

Playing a vital role in providing oversight and management of the NACE Standards Programme, David’s role as Vice Chair will include developing strategies, objectives and tactics to enable the programme to better respond to the standardisation needs of the corrosion industry. He will also overlook the performance of the NACE Standard’s activities - including global growth in the standards portfolio and being responsive to the industry’s standardisation needs.

Site safety training video

The latest video in the Napo safety cartoon series, covers working on a construction site and shows some of the common hazards and risks to be found there. The video can be found at, https://www.napofilm.net/en/napos-films/napo-safe-site

Napo is the hero of the cartoon series. He is symbolic of an employee working in any industry or sector. Napo is not limited to one specific job or work environment but his personality and physical appearance remain the same in all the films. Napo is a normal person - neither good nor bad, neither young nor old. In this respect, he is neutral.

Napo is an original idea conceived by a small group of OSH communications professionals and their video resources are to enable organisations to use Napo films to raise awareness about health and safety topics within groups of their own staff and supply chains. The resources enable organisations to deliver advice on health and safety topics, and will help generate discussion around the topics. They are also suitable for use on vocational training courses. More information about Napo, and list of all the video resources can be found at, https://www.napofilm.net/en

2020 PDA CONFERENCE AND EXHIBITION

PDA Europe is organising its Annual Conference and Exhibition on 17-18 November 2020 at the Crowne Plaza Hotel, Porto, Portugal

The applications of polyurea are widespread and the technology keeps on innovating and improving, and this event is a unique forum in Europe for all the stakeholders of Polyurea and has been designed to discuss and present all its facets.

This year, the event will take place over two days with the General Assembly taking place on the 17th. The two days are packed with presentations, interactive sessions, education courses, spray gun workshop, table top exhibition and networking moments. There are sponsorship and table top exhibition opportunities, and more details about the event can be found at, www.pda-europe.org
Latest Literature

Abrasion resistance of coatings for hydraulic structures

A report has been published recently comparing the abrasion resistance of conventional vinyl-based coating systems, polymer with polymer matrix composite coatings, fibrous polymer coatings, and ultrahigh molecular weight polyethylene (UHMWPE).

There is an increased demand for abrasive wear-resistant coatings that add durability to steel hydraulic structures, particularly for those subjected to flowing water with debris and alternate wet/dry cycles. These coating systems provide not only corrosion and chemical resistance, but also good erosion and abrasion resistance to the metallic surfaces, which are constantly exposed to flowing water containing sand particles and debris. Generally, vinyl-based coatings are used on hydraulic steel structures to protect them from corrosion and abrasion.

This new study, by U.S. Army Corps of Engineers, evaluated the abrasion of six coating systems using a reciprocating abrader under dry and wet conditions. The wettability of the coating systems and its effect on the wear rate under the presence of water was also studied. In addition, scanning electron microscopy of the wear tracks on different coatings was conducted to study and identify their failure mechanisms.

Based on the results, UHMWPE and polymer-ceramic composite coatings were found to perform significantly better than the conventional vinyl-based coatings.

The study was published in the Journal of Coatings Technology and Research, Volume 17 (2020).

Enhanced corrosion resistance and weathering resistance of waterborne epoxy coatings

This new study focused on the enhanced corrosion resistance and weathering resistance of waterborne epoxy coatings with polyetheramine-functionalised graphene oxide. Polyetheramine (D230), an epoxy curing agent, was grafted on graphene oxide (GO) surfaces, which can be stably dispersed in a waterborne curing agent for more than 8 months. Waterborne epoxy coatings reinforced by D230-functionalised GO (DGO) were applied on carbon steel surfaces.

According to the electrochemical impedance spectra, the impedance modulus at 0.1 Hz remained at 2.2 × 10⁸ Ω after 150 days of immersion in 3.5% NaCl with a 0.2 wt% DGO-reinforced waterborne epoxy coatings, whilst that of the neat epoxy coating dropped below 1 × 10⁷ Ω after 10 days. In addition, the addition of DGO was found to enhance the weathering resistance of waterborne epoxy coatings. After 60 days of the UV aging test, the yellow colour index of a neat epoxy coating was 1.6 times that of a 0.5 wt% DGO/epoxy coating. The residual pencil hardness of the 0.5 wt% DGO/epoxy coating was three levels higher than that of neat epoxy coating.

The study was published in the Journal of Coatings Technology and Research, Volume 17 (2020).

STANDARDS UP-DATE

ISO

The following documents have obtained substantial support within the appropriate ISO technical committees during the past two months, and have been submitted to the ISO member bodies for voting, or formal approval.

ISO/DIS 1460    Metallic coatings — Hot dip galvanized coatings on ferrous materials — Gravimetric determination of the mass per unit area. (Revision of 1992 standard)
ISO/DIS 8180    Ductile iron pipelines — Polyethylene slewing for site application. (Revision of the 2006 standard)

ISO/FDIS 22462  Metallic and other inorganic coatings — Test method for the friction coefficient measurement of chemical conversion coatings
ISO/FDIS 22410  Corrosion of metals and alloys — Electrochemical measurement of ion transfer resistance to characterize the protective rust layer on weathering steel

New international standards published during the last two months
ISO 11845:2020  Corrosion of metals and alloys — General principles for corrosion testing
Belzona have launched a two-component, polymeric, solvent free system, Belzona 5871, providing a thermal insulation barrier with corrosion protection, and sub-zero “cool-to-touch” properties. According to the company, the new product is designed to be applied to metal pipework, ducting and other industrial equipment. It is thermally insulating, providing protection against contact-burn injuries, eliminates corrosion/CUI, condensation and anti-icing, improving safety and durability, and can be applied by brush, cartridge or plural spray, expanding upon application to produce a lightweight, closed-cell foam, which reduces the surface temperature of metallic substrates to below 60 °C. It has excellent corrosion resistance prevents corrosion and eliminates corrosion under insulation (CUI), concluded the company.
Corrosion Failure Investigations and the Role of an Expert Witness

Dr. Phillip Munn CEng, Midland Corrosion Services Ltd.

For 20 years, the author’s company has been involved in carrying out failure investigations in a variety of industries. The majority of which have been in buildings and building services, involving failures in closed heating and cooling systems or once-through drinking water type systems. The failures and consequential damages due to leaks can result in many millions of pounds of costs to hospitals, hotels, commercial office buildings, schools and colleges, every year in the UK.

Corrosion damages due to primary or secondary corrosion effects include leaks, poor flow and blockages in pipework, pumps, valves and heat exchangers. Both general and various forms of localised corrosion can occur on a whole range of materials, including stainless steels, carbon steel, galvanised steel, copper, brass and aluminium. Each of these materials have their own range of influencing factors for different failure modes. Information on the corrosion likelihood in closed recirculating systems can be found in BS EN 14868:2005 (1) and in open water distribution and storage systems in BS EN 12502:2004 (2). An overview of corrosion of copper and copper alloys in plumbing systems by the author is given in reference 3.

In addition, often poor flow or poor heat transfer across heat exchangers due to corrosion and scale deposits goes unnoticed, resulting in poor efficiency and increased energy costs. It has been estimated that CO₂ emissions from houses and buildings are at least 20% of the UK total, and therefore, if efficiencies in heating and cooling systems can be maintained, this would make a sizable contribution to reducing the overall carbon emissions.

When a consultant or corrosion expert is called in to investigate a failure, often the manufacturer of the failed component (OEM) is blamed. However, this is true in perhaps only 5% of cases with 95% being due to system factors (design, installation, commissioning and operation). Initially, one would review any records on installation, commissioning and operation, e.g. type 1 pitting or erosion corrosion in copper pipes, or OIC (Oxygen Induced Corrosion) and/or MIC in steel radiators. However, inspection of failed components by itself will not get to the root cause of why the failure occurred and what may be done to prevent further damages occurring. A complete failure investigation then includes most, if not all of the following:

- Collation of all background information
- Inspection & analysis of failed components
- Analysis of water/debris samples, etc.
- A site visit to inspect the system and take in-situ measurements
- Reviewing any records on installation, commissioning and operation

For any failure analyses, a multi-disciplinary approach is needed to determine the cause and the correct solutions. For example in building services, this involves having a good understanding of corrosion, materials of construction, system design and engineering, and in the author’s case, water treatment. Many reports have been written by specialists in one of the areas, especially at universities, who focus on their own expertise and miss out other key areas. Therefore, inevitably they do not get to the root cause of the problem. One also needs to keep abreast of relevant standards (BS, ISO, NACE etc.); guidance documents (e.g. CIBSE, BSRIA), and industry practice. These cannot be applied retrospectively, i.e. if work carried out was in 2015, then the standard from 2018 cannot be applied. Even if some standard or guidance has not been properly followed, this does not mean that this has contributed to the cause of the failure. However, the party involved may be liable for not properly fulfilling the contract.

Also, having a proper Quality Management System in place (ISO 9001/ISO 17025/UKAS) is essential in keeping track of everything. All samples received, or sent out, need to be properly logged, labelled and securely stored. Notebook procedures and proper training for all staff carrying out the work needs to be in place. This is essential if the evidence is to be used in a court case, and if sub-contractors are used (e.g. for analysis), these should also have a QMS or be audited for quality of service.

In cases of litigation, the consultant/expert may be appointed straight away by a solicitor but from the author’s experience, they are more often appointed initially by an interested party, e.g. system installer, to carry out a failure investigation. However, one should always assume that when an expert is sent a failed component for investigation that it could lead to litigation. I had a case several years ago from a hospital where I was asked initially by the installer of the heating and chilled water systems to ‘have a quick look’ at a failed section of pipework. This led to a further 4 years of work involving looking at dozens of samples, many meetings with other experts and lawyers, and ultimately to an out of court settlement of around £10 million.

In litigation, there are often several interested parties involved, especially when there are substantial damage claims. For example, in building services, this may include the owner of the building, main contractor/sub-contractors, designer, installer, commissioning company and water treatment company. All these parties can appoint a legal team and experts in different fields. Thus, in larger cases there may be separate experts appointed in M&E (mechanical and electrical) engineering, corrosion, microbiology and water treatment, but in small cases, you may be the only expert representing your client.

The legal process involves many stages which include:

- Claimant’s/defendant’s case
- Counter claims – part 11 claims (when a party being sued takes out a counter claim against the subcontractor who did the work)
- Other pleadings submitted to court
- Expert reports
- Witness statements
- Joint expert meetings and statements (without solicitors and without prejudice)
- Mediation – to try to reach agreement before going to court
- Court proceedings

Nearly all failure investigations I have been involved with have been dealt with as a civil case. However, I once gave evidence in a Crown Court criminal case, instigated by the Office of the Rail Regulator against a boiler inspector who had approved a defective steam boiler, which had the potential to result in injury or death. The difference between civil and criminal cases is that in criminal cases, there is a judge and jury while in civil cases the outcome is decided solely by a judge. In criminal cases the defendant is guilty only if the case is proven beyond all reasonable doubt. In civil cases, the verdict is based on balance of probabilities (i.e. whether there was more than a 50% chance that the defendant’s actions were responsible for the damages incurred).

Civil cases in England and Wales are governed by the Civil Procedure Rules (England & Wales). In Scotland, there is a different court system, but the following rules would still apply:

- The expert must be independent
- His/her duty is to the court not to their client
- The expert’s fees must not be dependent on the outcome of the case
- The expert must state which areas are outside their area of expertise or knowledge
- There must be a signed statement to this effect in the expert’s report

It should be remembered that as an expert, you do not do your client a favour by agreeing to everything they want, or believe. If you do, there is a risk that they believe they have a much stronger case than they have in reality and then they could take things all the way to court and lose at great
expense. It is sometimes better to say that they have a reasonable case in certain areas but that they should try to reach an agreement on damages with the other side before involving expensive litigation.

You must also always be aware that you are an independent expert and not their advocate. That is the job of the lawyers and it’s for them to present the best possible case on behalf of their client. Lawyers and barristers will always try to get you to put the best possible spin on any evidence in support of their clients. However, you need to stand firm behind your true beliefs and, if you do, they will respect you for this and never force you to change your mind. At the end of the day, what they want is an expert who is firm in his/her opinion. A weak or uncertain expert will not be able to stand up to cross-examination by the opposing side’s barrister in court. I always approach this from the view of: ‘Would I be saying the same thing if I were representing the other side?’ If you can honestly say ‘Yes’, then you are acting as a true independent expert.

References
A brief Insight into Microbiologically-Influenced Corrosion (MIC)

Tony Rizk.

Microbiologically-Influenced Corrosion (MIC) is a major problem in industrial systems and has been responsible for a number of high-profile failures, including the Prudhoe Bay Oil Spill, Alaska in 2006 and the methane leak from a South California storage facility in 2015 [1].

MIC signifies the influence of sessile micro-organisms on the kinetics of the corrosion process. It is estimated that around 20% of all corrosion failures [2] are due to MIC. Despite that, MIC is not considered a major topic in corrosion training curricula. This article gives a brief introduction to the identification, monitoring and mitigating of MIC.

Industrial Microbiology

Microbes have been detected in the harshest environments from subsea volcanic vents to glaciers. Sulphate Reducing Bacteria (SRB) are the best-known corrosion-influencing group of microbes. They use short chain fatty acids for growth and sulphate for respiration. The oxidation of acetate and the reduction of sulphate by SRB are presented in Equation 1:

\[ \text{CH}_3\text{COO}^- + \text{SO}_4^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{HCO}_3^- + \text{S}_2 \] (1)

Short chain fatty acids are readily available in formation water while sulphate rich seawater is widely used for secondary recovery injection in the oil industry. Wet elemental sulphur is acidic and is known to result in metal perforation.

SRB are capable of forming colonies [3] over a wide range of pH (from 5 to 9.5), temperature (4°C to 90°C), pressure (up to 1,000 bar), salinity (up to 18%) and a shear stress up to 84 N/m².

Biofilms (colonies attached to metal surfaces) are responsible for corrosion. Their formation depends on a number of parameters, including condition of metal surface, fluid properties and microbial adhesion mechanisms. They are initiated by planktonic (floating) cells and vary in thickness from 0.5 µm up to several centimetres.

Corrosion Causing Microbes

Areas under microbial attachment are anodic caused by micro-condition changes on the metal surface. Microbes are symbiotic and a range of different microbial groups should be investigated including:

- **Total Bacteria (TB) and Total Archaea (TA)** (Archaea-high temperature microbes, active at over 80°C)
- **Acid Producing Bacteria (APB)**
- **Sulphate Reducing Bacteria (SRB) and Sulphate Reducing Archaea (SRA)**
- **Iron Oxidising Bacteria (IOB) and Iron Reducing Bacteria (IRB)**
- **Denitrifying Bacteria (DNB)**
- **Methanogens**
- **Sulphur Oxidizing Bacteria (SOB)**

Monitoring Techniques

Different techniques are available for microbial monitoring, these include:

**Serial Dilution**

Media based technique which represents viable population density. It requires up to 28 days incubation and usually conducted in triplicate to improve the reliability of numbers (most probable number-MPN). Growth is measured by changes to the growth media (e.g. colour, turbidity, etc.).
Dip Stick
A simple test for anaerobic microbes using a proprietary coated stick. It requires 24 hours incubation.

RapidCheck®
A ½ hour proprietary technique specific to SRB. It uses purified antibodies to bind to a key enzyme in the metabolic pathway of dissimilative sulphate reduction.

ATP
Adenosine triphosphate is the primary energy carrier in living organisms. It reacts with luciferase producing a light. The technique measures living microbial activity and is suitable for optically clear media.

<table>
<thead>
<tr>
<th>Test/feature</th>
<th>qPCR</th>
<th>MPN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanism</strong></td>
<td>Quantifies specific microbial genes based on sequencing amplification of the rRNA gene</td>
<td>Selective and based on growth indication (color, turbidity, etc.)</td>
</tr>
<tr>
<td><strong>Sampling</strong></td>
<td>Unaffected by oxygen</td>
<td>Strictly anaerobic for SRB</td>
</tr>
<tr>
<td><strong>Testing preparation</strong></td>
<td>Particular procedures/specific primers</td>
<td>Simple and selective</td>
</tr>
<tr>
<td><strong>Special requirements</strong></td>
<td>Specialist operator</td>
<td>Practical/less training</td>
</tr>
<tr>
<td><strong>Field/lab applicability</strong></td>
<td>Laboratory based</td>
<td>Field and laboratory</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Expensive</td>
<td>Inexpensive</td>
</tr>
<tr>
<td><strong>Quantitative</strong></td>
<td>Quantitative</td>
<td>Semi-quantitative</td>
</tr>
<tr>
<td><strong>Test duration</strong></td>
<td>Two hours</td>
<td>28 days</td>
</tr>
</tbody>
</table>

| Sample | Liquid | Yes | Liquid | Yes |
| Solid | Yes | | Solid | Yes |
| Biofilm | Yes | | Biofilm | Yes |
| Dry | Yes | | Dry | No |
| Old | Yes | | Old | No |
| Colored | Yes | | Colored | No |

| Microbial Group | Total bacteria | Yes | Total bacteria | Yes |
| Sulphate reducing bacteria (SRB) | Yes | Sulphate reducing bacteria (SRB) | Yes |
| Sulphate reducing archaea (SRA) | Yes | Sulphate reducing archaea (SRA) | Difficult |
| Acid producing bacteria (APB) | Yes | Acid producing bacteria (APB) | Yes |
| Iron-oxidizing bacteria (IOB) | Yes | Iron-oxidizing bacteria (IOB) | Difficult |
| Iron reducing bacteria (IRB) | Yes | Iron reducing bacteria (IRB) | Difficult |
| Denitrifying bacteria (DNB) | Yes | Denitrifying bacteria (DNB) | Yes |
| Sulphur oxidizing bacteria (SOB) | Yes | Sulphur oxidizing bacteria (SOB) | Difficult |
| Methanogens | Yes | Methanogens | Difficult |

FISH/DAPI
The combination of FISH (Fluorescence in situ hybridisation) and DAPI (4’,6-diamidino-2-phenylindole) provides active and total cell and results can be obtained within 48 hours.

qPCR
Quantitative Polymerase Chain Reaction technique is based on the amplification of sequencing of the 16S rRNA gene.

DGGE
Denaturing gradient gel electrophoresis has similar initial steps to qPCR, then the DNA is loaded onto polyacrylamide gels to which an electric field is applied.

Table 1: qPCR vs. MPN techniques.
Sampling Procedures

Different systems require different sampling procedures and planktonic sampling can be used to estimate the density and diversity of colonising microbes. In all cases, samples should be collected as close as possible to their source. The best representative samples are collected using on-line coupons, pigging sludge, surface scrapings and sediment. Samples should be collected during normal operation and free of contamination. Collected samples should be preserved, transported and stored at 4°C.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid samples</td>
<td>Repeat samples should be collected over a period of time. Sampling points are best be at the 6 o’clock position or close to it, as precipitation provides a good environment for microbial growth.</td>
</tr>
<tr>
<td>On-line coupons (sidestream)</td>
<td>On-line coupon is considered most representative technique for sessile sampling under real operating conditions.</td>
</tr>
<tr>
<td>Pigging sludge</td>
<td>Pigging sludge samples provide information on both colonising microbial communities and the by-products affecting corrosion.</td>
</tr>
<tr>
<td>Sediment</td>
<td>Sediment provides an adequate environment for microbes to grow and to be shielded from chemical antimicrobial treatments.</td>
</tr>
<tr>
<td>Surface scrape</td>
<td>A good representation of microbial colonies. Scraping samples collected from the failure zone are highly representative of microbial activities.</td>
</tr>
<tr>
<td>Failed section</td>
<td>Provides best evidence of failure and of microbe-induced reactions (should be properly handled to avoid contamination and oxidation of sample).</td>
</tr>
</tbody>
</table>

Table 2: MIC sampling.

Materials Affected by MIC

MIC is manifested predominantly in the form of localised corrosion. Zones of stagnation and precipitation are particularly susceptible to MIC as they provide a good environment for attachment.

Carbon steel

SRB reduce sulphate to sulphide to complement the oxidation of carbon. Biogenic sulphide reacts with the metal to form the electrically conductive iron-sulphide (FeS). FeS is a strong cathode and its effect on corrosion is unpredictable[5].

Stainless Steel

MIC mechanisms in stainless steel include biogenic sulphide adhesion, ennoblement of corrosion potential, cathodic depolarisation, acidic conditions and differential aeration that breaks the passive layer and initiates localised corrosion at zones of lower chloride concentration. Subsurface tunnelling can occur with Mn-rich alloys (more likely to occur under chlorinated water, and preferentially at Mn sulphide inclusions) and sulphide rich biofilms.

Figure 5: Cavernous or ink-well type MIC pitting of 316L SS.

Aluminum Alloys

Aluminum oxide protective film is susceptible to attack by halide ions and is vulnerable to biogenic acids and the release of CO₂.

Copper Alloys

Areas under the biological deposits on copper become deprived of oxygen (anode) surrounded by the large oxygenated areas (cathode). This can lead to the formation of nantokite (CuCl), and a form of corrosion termed as “bronze disease”.

Stress corrosion cracking has been observed in Admiralty Brass due to ammonia generation by denitrifying bacteria (DNB).

Figure 6: Microbially induced stress corrosion cracking of brass.

Nickel Alloys

A passive film is formed on Ni-Cu alloys with more than 30% nickel and protects against uniform corrosion [6]. Alloys containing less than 30% of nickel behave like copper. Sulphide can modify/break the oxide layer. Seawater-developed deposits of SRB can lead to pitting and the de-alloying of nickel.
Microbiological Attack of Welds

The combination of physical and compositional changes induced by welding facilitate microbial colonization, making welds more vulnerable to MIC [7]. The likely increase in MIC at weldment zones is caused by changes in surface chemistry and the formation of an electrochemical/galvanic cell.

Minimising weldment susceptibility to MIC involves better finishing of weldment area, the use of inert gas shielding and the avoidance of high heat-input welding processes.

Microbiologically-Influenced Deterioration of Concrete

Microbes are inhibited by the high alkalinity of newly-prepared cement due to the formation of calcium hydroxide (Ca(OH)₂). The drop of pH to 9.5 or less allows microbes to penetrate the micro-cracks or capillaries.

Biogenic H₂S, organic acids and CO₂ further attack concrete components and compromise its integrity. Biogenic acids degrade the cementitious material and may generate compounds with swelling properties, including gypsum (CaSO₄), which increase the internal stresses leading to the formation of cracks.

Microbial Degradation of Polymeric Materials

Synthetic polymers have a slow biodegradation process. The degree of biological attack depends on the length of the macromolecule chains. There are a number of different possible mechanisms for the biodeterioration of composite polymers by microbially generated enzymes [8] including direct attack of the resin, blistering/cracking due to gas evolution and polymer destabilization by concentrated sulphide.

Mitigation Methodologies

Selecting the most suitable mitigation technique depends on the application and on operational, environmental, health and safety and financial considerations.

Chemical Treatment

Biocides/disinfectants differ considerably in their mode of action, effects on corrosion, application, microbial immunity, environment, and health and safety aspects. The aim of biocide treatment is merely to reduce the impact of microbial activities to a tolerable limit. Batch dosing of biocide kills most microbes and reduces H₂S concentration (in the case of SRB). After biocide effect is diminished, SRB re-grow and so does biogenic H₂S. A second dose is applied and so forth. The aim is to maintain H₂S at a tolerable limit (Figure 8).

Nutritional Treatment

The selective removal of required compounds (e.g. sulphate in the case of SRB) is an effective approach in restraining microbial activities, particularly when coupled to other control techniques such as biocide dosing or biocidal competitive exclusion.

Mechanical Treatment

Pigging is highly effective against sessile colonies particularly when accompanied by squeezing concentrated biocide between pigs.

Biological Control

Nitrate stimulates denitrifying bacteria (DNB) to control the activities of SRB. The stimulation of DNB leads to a significant change in the redox potential [9] and denies SRB the needed carbon source for their activities.

Electrical Treatment

Cathodic protection is effective at controlling MIC at potentials -900 mV or higher. Microbes are prevented from attaching to the metal surface due to the generation of hydroxyl radicals caused by the applied potential.

Physical Treatments and other technologies

Other treatments to control microbes in various systems are widely used. Ultra-violet irradiation (UV) and filtration (ultrafiltration and reverse osmosis) are used in water purification and food processing. Researchers are also experimenting with modern technologies, including quorum quenching, phage, and less environmentally damaging chemicals to control detrimental microbes.

Root Cause Investigation Analyses

MIC can only be confirmed if a clear concurrence between the results of different analyses is established. The investigation should include; biological, geochemical and nutritional analyses, visual, microscopic, and elemental and compositional structure examinations.

Conclusions

The best approach to avoid microbial problems is to ensure inclusive consideration at the design stage followed by good in-service monitoring and an effective response scheme:

Prevention

- Inclusive at the design stage to ensure fit-for-purpose materials, specific antimicrobial treatment and free, so far as is possible, from process system anomalies such as stagnation zones
- Hydrostatic testing (hydrotests) should be performed competently and...
should include the addition of anti-microbial treatment and be properly
drained and dried after testing

- Better finishing of field construction processes, including weldment areas,
  with inert gas shielding, coating, piping alignment and elevation changes
  (bathymetric survey), etc.

**Mitigation**

- Good water quality, monitor changes in water chemistry over time and
  prevent deposition settlement
- Start anti-microbial measures from onset to minimise sessile buildup
- Maintain flow rates above the critical minimum to reduce sessile colonies
- Minimise the buildup of large deposit settlements in tanks
- Regular squeezing of high biocide concentrations with pigging wherever possible
- Apply a programme of frequent flushing and anti-microbial treatment of
  stagnant zones

**Acknowledgement**

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Predictive Corrosion Under Insulation Monitoring using Electro-Magnetic Guided Radar

Prafull Sharma, CorrosionRADAR Ltd, Cambridge, UK.

Corrosion has been an inherent problem for structures, machines, and equipment since the industrial revolution. The problem is more challenging in the hidden and difficult to access areas, for example in the case of thermally insulated and buried pipes, where corrosion on the outer surface of the pipes remains undetected due to the surrounding insulation - commonly known as Corrosion Under Insulation (CUI), as shown in figure 1.

CUI is caused by the presence of moisture in the insulation. Regardless of how secure and sealed the insulation is, in practice there are areas prone to water ingress, thereby creating the conditions that subsequently cause CUI [1]. One industry sector which suffers severely with CUI is Oil & Gas in all its segments (upstream, midstream, and downstream). The O&G sector alone spends several billion dollars annually in identifying CUI, mitigating against the risks it poses, and repairing the damage it causes to their assets [2].

The industry often relies on manual practices of visual inspection, narrowed down with Risk Based Inspection methods, to identify the broad zones that are prone to CUI and then use manual spot measurement techniques to check for its existence [3]. Such an approach may involve periodically removing the insulation in selected areas for the visual inspection, however, this technique has many limitations and risks, such as:

- It is a labour intensive and time-consuming procedure
- CUI tends to be localised, and unless the inspected section is accurately positioned, sites of corrosion can be easily missed
- Removing insulation is costly, particularly if scaffolding is required, which increases the cost of inspection significantly
- It is heavily dependent on operator knowledge and relies on their experience to identify the areas to inspect, which adds a degree of risk, as moisture can travel within the insulation, and therefore, CUI could occur at unexpected locations leading to potentially catastrophic failures

Given that the current industry approach which is based on manual periodic inspection and insulation removal, implementation of a predictive maintenance, enabled by continuous automated monitoring, can offer significant advantages. Using continuous monitoring can reduce the need for insulation removal, and provide remote data over a long period of time, which in turn leads to reduced costs and increased safety for the industry (figure 2).

![Figure 2: Predictive maintenance using continuous monitoring has several advantages over reactive maintenance practices.](image-url)
Figure 1: Corrosion Under Insulation is a big asset integrity issue.
Predictive CUI Monitoring System

There is an opportunity to bring in predictive corrosion management with automated monitoring techniques enabled by advances in Industrial Internet of Things (IIoT). Such advancement provides remote data and analytics over a long period of time leading to significant cost savings and reducing the risks to the industry. This is a unique monitoring technology to detect, locate and monitor key indicators which may lead to CUI, such as corrosion on a sensor and moisture (wetness) in the insulation.

The novel predictive CUI monitoring system is based on a sensor mounted on the external surface of pipes and vessels. The key technical technology behind the new high-resolution monitoring system from CorrosionRADAR is the Electro-Magnetic Guided Radar (EMGR). This new system is suitable for wide range of structures and applications, including on large surfaces (such as process vessels and tanks) and complex geometries (e.g. valves and flanges), and for long-range requirements (e.g. pipelines).

The system provides an embedded and permanently installed sensing network for monitoring, locating and predicting industrial asset corrosion, and can be retro-fitted to existing and ageing assets, as well as being installed at the construction phase of new assets. The primary outputs of the sensor system are the identifications of corrosion-prone locations, corrosion rate, and future projections (using historical moisture profiling) all along a pipe’s axis.

The sensor can be applied in different configurations such as helical, line, ring or even mesh depending on the asset, and the coverage needed, after consultation with the asset owner. The data is either transmitted to a remote server located on the cloud from where the user can access the data through a cloud dashboard (figure 3), or resides in local server at client’s premises.

The applications of this predictive CUI monitoring system also include cold pressure vessels and pipes insulated with insulation materials such as cellular glass, as shown in figure 4. The system contains a CR Node (an ATEX certified electronics with wireless transmitter), a bridge cable which connects the Node to the sensor and thirdly the sensor itself. The sensors are analogous to a heat tracing system and are installed in a very similar way on the asset. There can be multiple sensors installed on an asset to give more coverage, alternatively, due to the flexibility of the sensors, they can be installed in a helical arrangement to provide more surface coverage.

The existing asset condition does not affect the sensor reading, but once installed, the sensor becomes a representative sample of the pipe corrosion at a much earlier stage, before catastrophic corrosion levels occur.

The sensor is not affected by the pipe coating, or cathodic protection. It locates corrosion-prone sites, and then the inspectors can interpret this data and evaluate any risk to the pipe based on field conditions, such as pipe protection reliability, age etc. This helps in more data-driven Risk Based Inspections.

Principle of Sensing – Electro-Magnetic Guided Radar (EMGR)

The working principle of the predictive CUI sensor (both corrosion and moisture sensor) is based on Electro-Magnetic Guided Radar (EMGR), which was invented at Cranfield University in the United Kingdom. This patented sensing system is in the form of a long thin flexible waveguide placed in close proximity to the external surface of the asset and permanently embedded in the insulation. A long-range distributed corrosion sensor acts as a thin flexible waveguide line with the external layer of the waveguide being made up of carbon steel material.

This external layer of the sensor corrodes itself in the presence of a corrosive environment (under the insulation and around pipe external surface). When an electromagnetic wave is sent along the sensor, the time of flight of the reflected signals are interpreted using proprietary algorithms to locate corrosion on the sensor very precisely. This technology can pinpoint the location of corrosion (and insulation wetness) along the sensor length up to several hundred metres, making it the longest-range distributed sensor for corrosion detection available. Figure 5 shows a representative pipe and the radar signals from the sensor are shown above it, and which indicate two spots developing a risk of CUI over time.
indicating onset of corrosion.

Figure 5(a): Sensor signals with microwave reflections of time of flight indicating onset of corrosion.

The corrosion sensor is complemented by a moisture sensor, which is also based on EMGR technology but with a different waveguide structure suitable for the detection of moisture, as it does not contain a sacrificial outermost layer. The data logged is transmitted wirelessly into a remote database and is also used to assess the CUI risks, and predict the likely development of corrosion with time along a pipe length.

This system uses the latest advancements in industrial “Industrial Internet of Things “ (IoT- the Internet of things is a system of interrelated computing devices, provided with unique identifiers and the ability to transfer data over a network without requiring human interaction) providing wireless connectivity and battery powered technology along with cloud-based analytics platforms.

The corrosion and moisture sensors are installed under the insulation, adjacent to the external wall of pipes or process vessels. A single line sensor can provide spatially continuous coverage of a complex pipe network (hundreds of metres in length) from a single location and can locate corrosion with an accuracy of a few centimetres. Their range and sensitivity are not affected by the condition or geometry of the pipe, and large surfaces such as vessels and tanks can be covered by installing the line sensors in different configurations (e.g. mesh).

Figure 5(b): Representative sensor signal showing reflections from two spots where sensor is corroded.

The Benefits of Predictive CUI monitoring

The corrosion and moisture sensors are installed under the insulation, adjacent to the external wall of pipes or process vessels. A single line sensor can provide spatially continuous coverage of a complex pipe network (hundreds of metres in length) from a single location and can locate corrosion with an accuracy of a few centimetres. Their range and sensitivity are not affected by the condition or geometry of the pipe, and large surfaces such as vessels and tanks can be covered by installing the line sensors in different configurations (e.g. mesh).

This new sensor system allows remote monitoring, data collection and storage. The collected data is fed into analytical models to determine the location of suspicious insulation spots, and the severity of the threat to the structure, essentially creating a highly reliable and accurate corrosion map of the asset. The system allows asset managers to make informed decisions in RBI methodology, carry out “what-if” analysis, and plan and deploy their resources to maximum effect. As a result, the risk and the inspection costs can be reduced by narrowing down the suspicious zones.

For a new build pipeline, the sensor is easily mounted during the construction phase. For an existing structure, installation requires opening the insulation manually and placing the sensor underneath, which is best done during an inspection programme.

The novel system enables operators to switch from relying solely on RBI to inspect damaged metal surface, to CUI monitoring using real time and manually placing the sensor underneath, which is best done during an inspection programme.

The case study below shows a real-life case of a predictive CUI monitoring system installed with both corrosion and the moisture sensors, deployed in a flammable environment of a petrochemical plant. Figure 6 shows a two channel CR Node electronics connecting two 20m lengths of bridge cable (one for corrosion sensor and one for moisture sensor) which in turn connect to the corrosion and moisture sensors installed on a pipe. The data collected autonomously over a period of time was transmitted wirelessly over a cellular network to the cloud-based server to which the end user can access the dashboard.

The response of the moisture sensor is shown in figure 7, and that of the corrosion sensor in figure 8. The moisture sensor length is 5m and is active from about the 20m to 25m locations. The start and end of the sensor indicates a peak due to reflections of the electromagnetic wave. Water was manually poured at about the 24m location which showed a new peak indicating the presence of water in the insulation at that location.

The corrosion sensor length is 11.5m and starts from about the 20m to 31.5m locations. As is the case with the moisture sensor signal, the start and end of the sensor indicates a peak due to reflections of the electromagnetic wave. An accelerated corrosive environment was created by the end user at the location of 29.5m by injecting a corrosive solution of PH below 3. The pipe temperature was maintained at 70 C during the trials. After about 5 months a corrosion signal was detected as shown by the peak at 29.5m location due to accelerated corrosion of the sensor.

Figure 9 shows another use case where the monitoring system was applied to a 25m high production column. There were two areas selected by the end user to monitor the asset mainly around the rings of the column. A two channel CR Node was used to log the data from two corrosion sensors. The installation of the sensors was carried out during a turnaround of the plant during which a scaffolding was already being put in place for a routine inspection of CUI. The end user decided to install this monitoring system to move from periodic maintenance to condition based maintenance, so that so that future turnarounds could be optimised based on the condition of the asset indicated by the monitoring system.

The installation of the sensors was carried out during a turnaround of the plant during which a scaffolding was already being put in place for a routine inspection of CUI. The end user decided to install this monitoring system to move from periodic maintenance to condition based maintenance, so that so that future turnarounds could be optimised based on the condition of the asset indicated by the monitoring system.

A cost benefit analysis conducted with a facility resulted in estimated cost savings of at least 40% over an inspection cycle spanning over 12 years. It was assumed that the inspection cycle for a critical asset is 4 years with partial insulation removal of between 10% to 20%, and a full 100% strip at the end of 12 years. It was also assumed that with CUI monitoring, the inspections are reduced by narrowing down the suspicious zones.

The improved system unlock have a direct and significant impact of the demand for scaffolding, and the volume of insulation removal and replacement.
Figure 6: The layout of the field deployed use case on a pipeline.

Figure 7: Response of the moisture sensor: black line indicates baseline and red line indicates signal in presence of water at 24m location.

Figure 8: Response of the corrosion sensor: blue line indicates baseline and red line indicates signal in presence of corrosion at 29.5m location.

Figure 9: Pictures of the field deployed units on a production column in a helical sensor layout.
Summary
Predictive CUI monitoring using Electro-Magnetic Guided Radar (EMGR) is a promising new technique for managing CUI in assets specially in the Oil & Gas sector. This system gives operators continuous information about the risks associated with a corrosive environment that is hidden under the insulation. Availability of such information gives operators an early indication of potential CUI and insulation wetness, which can be rectified quickly and with a relatively low cost if done early. If not tackled early on, over time the impact of CUI increases significantly, and in the extreme case of an unplanned shutdown, huge financial and reputational losses can occur. But with the use of this monitoring system the potential losses can be avoided as well as cost savings realised due to reduced inspection scope. The systems described are already being used by several plant facilities around the globe, and can reduce the inspection costs by over 40%, and be a long-term solution for the safety of the critical assets.

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

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Tel: +44 (0) 1952 290321 Email: sales@bacgroup.com
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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

CORROSION CONTROL INCORPORATED
494 Fairplay Street, Rutledge, Georgia 30663, USA
Tel: +1 706 557 9624 Email: engineering@3ccc.se

CORROSION TECHNOLOGY SERVICES

DENERO (WINN & COALES DENO LTD)
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Tel: 0208 670 7511 Fax: 0208 761 2456
Email: mail@denero.net www.denero.net

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EQUIPMENT TECHNOLOGY SERVICES

DEEPWATER EU LTD
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EQUIPMENT TECHNOLOGY SERVICES
Due to the current restrictions, ICorr meetings are being held online. At the time of going to press, the following branch meetings are expected to be held.

**BRANCH DATES**

**6-10th July 2020**  
**Aberdeen Branch**  
Daily Corrosion Webinars, Lunchtime 12-1 pm, (MCF in collaboration with ICorr Aberdeen Branch).

**25th August 2020**  
**Aberdeen Branch**  
Interactive Industrial Visit / Inspection Methods Technical Q&A.

**24th September 2020**  
**Aberdeen Branch**  
Joint webinar with TWI  
High Tensile Steel Bolts and Nuts – Hydrogen Embrittlement and Failure in Corrosive Environments.  
Alan Denny, AKD Materials Consulting Ltd.

IMechE are now starting to run courses (for up to 8 people) at their Sheffield training centre, and accommodation can be arranged.

The range of online ICorr training courses is continuing. For further information, see [www.argyllruane.imeche.org](http://www.argyllruane.imeche.org)

Online training courses provided by Corrodere are continuing. For all enquires, contact Meena Tipson on 01252 732234.

**ADDITIONAL DIARY DATES**

**30th September – 2nd October 2020**  
**CEPE Annual Conference and General Assembly**  
Madrid, Spain

**17th – 18th November 2020**  
**PDA Europe, Conference & Exhibition**  
Porto, Portugal

**BRANCH CONTACT DIRECTORY**

**ABERDEEN:**  
Stephen Tate (Chairman)  
Email: icorrabz@gmail.com

**LONDON:**  
Benjamin Moorhouse (Chairman)  
Steve Barke (Secretary)  
Email: icorr london@gmail.com

**MIDLANDS BRANCH:**  
Paul Segers

**NORTH EAST:**  
Email: icorrne@hotmail.com

**NORTH WEST:**  
Michael Leahy (Chairman)  
Email: michael.stash.leahy@gmail.com

**YORKSHIRE:**  
Nigel Peterson-White  
Tel: 07793 710559  
Email: nigel@pretreat.co.uk

**CSD DIVISION:**  
Julian Wharton  
Email: J.A. Wharton@soton.ac.uk

**CED DIVISION:**  
Nick Smart  
Tel: 0118 913 7752

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