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Editorial copy date for May/June 2020
Issue is:
15th May 2020

Subscriptions
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Outside Europe £130.00 airmail, £80.00 surface mail

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ISSN: 13 55 52 43

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It’s impossible for me to open this column without mentioning the ongoing coronavirus outbreak. The situation is unprecedented in the history of the Institute and is clearly going to dominate the activities and priorities of our members for many months. We have put in place policies, working arrangements and contingency plans where possible but of course there is still a lot of uncertainty. Our main priority is the wellbeing and safety of our members, officers and staff and our thoughts go out to all those who have been affected in any way. I trust that you are all are all following the official government guidelines and looking after each other where possible. It has been a very difficult time for everyone and the Institute is no exception. Cancellations have hit local branch and division events, committee meetings and training courses. However, it has been great to see our tight knit community rally round and show a positive spirit in the face of adversity.

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Paintel recently held an ICATS, Industrial Coating Applicator course. One of the attendees was unemployed and being funded by the Welsh government to assist in gaining employment. Another of attendees, mentioned him to his boss and asked him to attend a meeting after the fourth day of the course, and this resulted in a job offer on successfully completing and passing the ICA course. Both attendees now work for the same company. This shows how ICATS training plays such an important part in providing the future work force for our contracting industry.

It was announced recently that IMechE, in association with Hodge Clemco, were to become an ICATS Approved Training Centre. That process is moving forward even as you read this article. IMechE are currently working on their new LMS (Learning Management System) to enable teaching ICATS as well the Painting Inspector and other courses. Once the ICATS courses have been added to their LMS, the next part of the process is to get them translated into multiple languages by specialist technical translators.

On the 10th March, Kevin Harold, was the guest speaker at the “Energy Coast” evening in Cumbria, organised by Sellafield Nuclear Facility. Kevin’s presentation was called “Coating Contractor Tales, a journey of enlightenment”, which was the story of how when Kevin joined the industry in 1976 there was little or no PPE or guidance, up to today and the impact ICATS has had on him and the rest of the industrial painting industry. The presentation was followed by a Q&A session on ICATS, and David Mobbs was also on hand to answer questions on behalf of ICorr.

ICATS ‘little black books’ for the ICA course are now available. The book includes course information and other additional useful pages, and replaces downloads that many people never look at again. The book fits nicely into a top pocket of a pair of overalls and gives quick reminders including standards, procedures and useful stats and facts.

Email kevin@paintel.co.uk for a black book including details of where and when your ICATS training took place. Copies of the books will also be supplied to ICATS approved training centres over the next few weeks. ICATS trainers will also be contacted to ensure they get access to the books too.

Coronavirus is affecting all of us at the moment one way or another. During this period all ICATS courses have been postponed until further notice, and Kevin is working on other ideas for remote ICATS training. If anyone has any ideas or would like assistance on any ICATS matters, please email Kevin, on kevin@paintel.co.uk.

Once significant bans have been lifted new course dates with promotional discounts, will be announced.
Welcome to the latest issue of the magazine. This month there are two comprehensive technical articles, Markus Büchler of the Swiss Society for Corrosion Protection on the effectiveness of corrosion mitigation by CP, and the second part of the ship painting article from Safinah.

For the two new columns introduced in the previous issue, Don Harrop describes the use of Corrosion Inhibitors in oil and gas production in the ”Fellows Corner”, and the questions in ”Ask the Expert” are on linings for acid storage tanks and how to choose the most suitable for equipment non-intrusive corrosion/erosion monitoring. Remember to send your technical questions for answer by our industry experts.

Finally, I would just like to add my good wishes to that of Gareth, to you all in this troublesome time and remember to keep yourselves and family safe.

Brian Goldie, Consulting Editor
Social Media

ICorr is now using social media to promote the activities of the Institute to both members and non-members. ICorr has a website that is the primary online source of information. In addition, several social media platforms which provide a fast way of disseminating information and which direct users to the website for further information have been set up. Links to the website and the social media platforms are:

ICorr Website: www.icorr.org

LinkedIn Group page: this is a discussion group where anyone, including Institute members, can interact and join in discussions. Since anyone can post opinions on this page they may not represent official ICorr views. ICorr will remove any items deemed to be inaccurate or offensive. www.linkedin.com/groups/4308333/

LinkedIn Company page: this is where the Institute posts official news that is specific to ICorr, articles and upcoming events. Editorial access to this site is limited to a small number of approved individuals. www.linkedin.com/company/6321450/admin/

Young ICorr LinkedIn page: this is kept updated with content published on our website and other social medial platforms. In addition to this the Young ICorr group post events and information about seminars www.linkedin.com/groups/8599206/

Twitter page: this includes regular updates, tweets linking to our blog posts and ICorr News and Events www.twitter.com/institutecorrosion

Facebook page: this is used to generate traffic, with links to our social media, website, ICorr News and blogs. www.facebook.com/icorradmin/

Instagram page: this is used to generate traffic, with links to our social media, website, ICorr News and blogs. www.instagram.com/institute_of_corrosion/

For assistance or queries about any of these sites and platforms, please contact:

- David Horrocks (ICorr) david.horrocks@bamnuttall.co.uk
- Jonathan Phillips (Square One) jonathan@squareone.co.uk
- Gareth Hinds (ICorr) gareth.hinds@npl.co.uk
- Bill Hedges (ICorr) bill.hedges@bp.com

ICorr has engaged a professional blog writer to produce weekly blogs for this is used to generate traffic, with links to our blog posts and ICorr News and Events www.twitter.com/institutecorrosion

For blog or technical content ideas, in the first instance please contact:

- Jonathan Phillips (Square One) jonathan@squareone.co.uk
- David Horrocks (ICorr) david.horrocks@bamnuttall.co.uk
- Bill Hedges (ICorr) bill.hedges@bp.com
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- Bill Hedges (ICorr) bill.hedges@bp.com

ICorr has engaged a professional blog writer to produce weekly blogs for posting on social media using material provided by ICorr and its members.

All ICorr members are encouraged to interact and stimulate conversation on our social media platforms, which helps ICorr achieve its aims, including supporting its members and raising awareness of the work of the Institute and its members.

Key areas to focus on when engaging with our social media are:

- Benefits of membership of ICorr
- Training opportunities
- Our vision and core values
- Our professional support mechanisms
- Our expertise in science, engineering & technology

Remember that when you engage on social media (through ICorr platforms) you are representing the Institute of Corrosion. It is important that posts are polite, respectful and in keeping with the Institute’s status as a trusted and respectable professional society. Members are encouraged to read our Social Media Code of Conduct, which can be found in the Members Area of the website.

Corrosion Science Division

U.R. Evans Award

After careful deliberation the CSD committee nominated Prof R.A. (Bob) Cottis (University of Manchester) as the recipient of the 2020 U.R. Evans Award. This decision has been ratified by the ICorr Council and it is planned that this will be awarded at the 61st Corrosion Science Symposium being held as a standalone meeting at the University of Southampton in September 2020.

Prof Cottis has been a champion of corrosion education throughout his entire career with seminal contributions within UMIST/Manchester, and activities linked to EFC WP7 Corrosion Education and NACE International. He joined the Corrosion and Protection Centre, UMIST in 1979, initially as a lecturer, then senior lecturer, reader and professor. He was appointed Professor Emeritus in Corrosion Science and Engineering on his retirement in 2011. Nonetheless, he has continued his research into hydrogen embrittlement and electrochemical noise measurements.

He has been active in the development of teaching in the field of corrosion, being responsible for the development of a distance learning approach to the MSc in Corrosion Control Engineering, and Director of the Teaching and Learning Technology Programme (TLTP, funded by the UK higher education funding bodies HEFCE, IIEFCW, SHEFC and DENI) Consortium that developed the Engineering Corrosion (Ecorr) courseware to support corrosion teaching. In 2005 he was awarded the T.J. Hull Award of NACE International, given in recognition of outstanding contribution to NACE in the field of publications.

Prof Cottis has also contributed to the international development of the subject in several areas. The main focus of his early research was the mechanistic aspects of corrosion fatigue. Both in respect of crack initiation, which is significant primarily for smaller components and where he demonstrated the role of corrosion in assisting the initiation process, and crack growth, where his work showed that
larger cracks, such as those found in offshore structures, are relatively unaffected by corrosion and hydrogen entering the steel is a more important factor. In collaborative work he was responsible for the clarification of the interpretation of the results of existing electrochemical techniques and contributed to improvements in the statistical interpretation of pitting corrosion, both of which are of considerable industrial significance. On a more fundamental note, he also developed very efficient algorithms for the modelling of alloy corrosion. Most recently, he has been one of the leaders in the development of a fundamental understanding of the theoretical basis of electrochemical noise measurements, and in the better understanding of the capabilities and limitations of the use of artificial neural network methods for modelling corrosion processes.

As a reminder, the award criteria are: an international reputation and service to the corrosion science community, a contribution to dissemination – publications, professional bodies, patents and IPR, conferences and events. Plus a contribution to industry – especially of an inter-disciplinary nature, publications, professional bodies, patents and IPR, conferences and events.

As part of the Institute social media campaign, Young ICorr also has a paper published in the last 12 months to the CSD Chair by 4 Sept 2020.

New Sustaining Member

Forward Protective Coatings Ltd

Forward Protective Coatings Ltd is one of East Midlands foremost industrial coatings applicators, specialising in painting steelwork for most industries. They can apply most paint systems on structural steel and fabrications and also on stainless steel and aluminium items. Operating from a 30,000 square foot facility based in Mansfield, Nottinghamshire, they have a lifting capacity of up to 20 tonnes. As well as applying protective paint systems, they can also apply thermal spray coatings, passive fire protection and powder coatings, and have crews to provide on-site touch up or full paint systems.

FPC pride themselves on providing the highest quality products with a service that is one of the best in the industry, and have experience in providing coatings for the most demanding of industries and are able to tailor inspections and certifications to meet any client requirements.

New Sustaining Member

Hexigone

Hexigone manufacture corrosion inhibitors that are safe, smart and up to ten times more effective than other alternatives. Their vision is to create a more sustainable world through ‘chemically intelligent’ coatings developed in collaboration with industrial partners.

Their technology, Intellii-on, protects in a completely unique, ‘smart’ way via three modes of electrochemical protection. The active ingredient sits dormant in a micro-reservoir and is triggered ‘on demand’ when corrosion ions are sensed at the coating surface. These are then sequenced into the coating, preventing cathodic disbondment and filiform corrosion. Due to the micro-reservoir system, Intellii-on is able to offer corrosion protection using chemicals that were previously incompatible with coatings – significantly increasing the lifetime of the end product.

As a new company to the coatings industry, they have already made global connections with over 50 partners formulating with their product, which has three variations (AX1, AX2, AS1) that are suitable for drop-in replacement within primers and solvent borne systems for ferrous and non-ferrous substrates. High performance has been seen across the O&G, ACE, marine, aerospace, automotive refinishing and architectural industries.

Young ICorr

From left to right, James McGladdery, Danny Burkle, and Caroline Allanch, from Young ICorr, at the CHAIN event.

With the current energy and medical problems in society “Engineering the new decade” is going to be challenging. Young ICorr joined forces with early career engineers from the IMechE, ICE, IStruE, IChemE and IET, for a one day event held at 1 Birdcage Walk in London, to take a closer look at how innovation and collaboration across the engineering industry will help solve some of the key challenges. CHAIN 2020 included a series of engaging talks delivered by a range of experts from industry, government and engineering Institutes, each was followed by inquisitive panel discussions. A standout of the day was the interactive workshop focussing on inter-discipline collaboration and its newfound importance in winning contracts for prospective projects. Notably, all of the presentation’s subject matter could all be linked to corrosion, such as fire safety, urban building, cyber security, future energy and engineering in healthcare. The final talk of the day was set to a vote and titled “What will it take to decarburise London?” - a hot topic of the day sparking debate between all disciplines.

It was great to meet engineers working in corrosion across such a wide range of industries at the networking event at the end of the day. Young professionals were also able to find out about the industry specific training courses and local branch talks that ICorr offers, as well and the Young ICorr group.

The next Young ICorr meeting is planned for Thursday the 23rd of April at the University of Leeds, where we are honoured to have a talk from Professor Anne Neville to celebrate corrosion awareness day. Further details will be available through the LinkedIn group, https://www.linkedin.com/groups/8599206/, and we look forward to seeing you then.

As part of the Institute social media campaign, Young ICorr also has a twitter page, https://twitter.com/Ylcorr
Institute News

New Sustaining Member
Solent Protective Coatings

Solent Protective Coatings are a forward looking company combining the latest innovations, technologies, techniques, equipment and products with excellent experience, and can offer solutions to all aspects of surface preparation, corrosion protection and application of protective coatings both for preservation and presentation.

Their staff have considerable experience in operations undertaken by the company and have established a very good reputation for service and quality. The overall intent of the company philosophy is to create a strong relationship with their customers, professional teams and the supply chain, which is based on trust and co-operation and represents a genuine partnership.

Their key services include abrasive grit blast surface preparation, passive fire protection, thermal spraying, protective coatings application, and UHP water blasting. Their expert staff and partners are available to ensure that your project is full specified and planned with the right people, equipment and materials to deliver the results you require.

Branch News

Aberdeen Branch

The branch held its 5th event of the 19/20 season at RGU Aberdeen, with a paper entitled “Structural Integrity Issues: under-deck, air-gap, splash zone assessment / deterioration / repair mechanisms, (for corroded / fatigued conductors, caissons and risers)” by Chris Tierney, SETS. This was a highly successful 1st joint presentation with EI – The Energy Institute, with 75 attendees.

The first part of the presentation considered, conductor integrity, hidden risks and corrosion mitigation, and in the second part Chris discussed new platform-launched technologies for repair of caissons and conductors subsea on ageing assets. After a decade in the subsea engineering sector with Technip, Chevron Upstream Europe, and Pro Dynamic Lifting (PDL), Chris founded SETS in 2011 as a subsea engineering and consultancy specialist. A platform splash zone is an area of multiple risks to production due to the high likelihood of mechanical damage to elements running through this area, cracking and in some geographical locations, very high corrosion rates. SETS provide innovative, engineering and tooling services to deliver efficient conductor management and repair solutions. The company have continued to innovate, learn and produce solutions for this difficult work zone and have been at the forefront of the design and development of technically advanced subsea tooling for conductor cleaning and inspection, clamp repair and shim installation. Unusually, their technology is remotely operated from topside, eliminating the requirement for diver support, and dramatically reducing time and cost. Their success in this area has resulted in the recent acquisition of the company by AquaTerra (Kintore, Aberdeenshire).

The SETS presentation concentrated on conductors but the technology is equally applicable to caissons and risers. Conductors run from seabed to wellhead, providing environmental protection to the most vulnerable well components. A conductor should be considered a complex system, and its integrity managed accordingly, spanning wells, structural and operational functions. The condition of conductor and guide frames at the spider deck reflect the condition of these at the first elevation subsea. These are the most highly utilised areas in a conductor system, subjected to the greatest environmental loads and generally where majority of defects present themselves. The presentation discussed in detail, marine corrosion, fretting, fatigue, damage mechanisms and progression rates affecting conductors on ageing assets. Chris explained how different marine environments worldwide impact on conductor, caisson and riser integrity and following this, there were many thoughtful questions from the audience.

The February 2020 evening meeting with 55 attendees opened with a discussion of the new ICorr logo and re-branding of the Institute to provide a much needed re-start and more professional focus, with the key being firmly on corrosion prevention by all available means. Following this introduction, there were very informative twin presentations by DNV-GL on risk based inspection activities, covering both PSVs (Pressure Safety Valves) and FPSO’s (Floating Production, Storage and Offloading) units.

The first presentation, by Dr Chris Bell discussed how data analysis of servicing has helped reduce cost and improve safe interval servicing of PSVs. PSVs are installed in process and utility systems to prevent build-up of internal pressure, or external effects such as fire. Over pressurisation of any vessel, or other equipment item, with energy released from the pressurised fluid, or the hazardous or flammable nature of the contents, can have significant consequences on a platform. Valves can block through build-up of wax, gunk or corrosion products within the system and the PSV will fail to lift. For this reason, PSVs are classified as safety critical when protecting hydrocarbon containing equipment and must be safety tested on a regular basis. The testing cannot generally be done in-situ, and valves most usually have to be taken onshore, tested, refurbished and refitted. Typically there are over 100 PSVs on a platform so it is worth optimising the maintenance interval. This can be done by data analysis to find the appropriate time to service the valve based on previous history and ensure a safe practice whilst minimising costs, and the inspection interval can be set so that the residual risk of failure is acceptable.

0.5 billion hours of service data for PSVs have been analysed from 10,311 tests and 544 failures by DNV-GL to allow optimisation of maintenance intervals and manage the inspection of PSVs. A methodology was developed that combined qualitative and quantitative RBI analysis. This multi-layered assessment gained the most information possible from the data, and as an outcome, the average maintenance interval was changed from 37 to 44 months and the test failure rate dropped. So, for an average PSV maintenance cost of £1,000, total cost has now reduced by £ 1.1m from £6.5m to £5.4m per year.

The second presentation was by Dr Madhu Parlapalli, who presented a paper on risk based inspection (RBI) of FPSO Cargo Tanks. Risk based inspection in the oil and gas industry of piping, pressure vessels and other critical equipment has been used more recently for planning structural inspections. For floating structures like FPSOs where there are additional requirements to satisfy in the form of Classification Society rules, although risk based approaches are allowed under these rules there are relatively
few examples of where this has been applied to plan structural inspections on FPSOs, for items such as cargo or ballast tanks.

It is operationally quite inconvenient to carry out inspections of these tanks on a fixed 5-year interval in line with a standard Class schedule. A risk-based inspection schedule has to take account of all relevant degradation mechanisms and the corresponding means of inspection. For FPSO cargo tanks, the main degradation threat is fatigue cracking and corrosion/corrosion degradation and of course general accessibility for inspection. The RBI process involves developing a structural hierarchy of ‘accessible’ elements, identifying the relevant ‘failure modes’ and damage mechanisms then evaluating the ‘probability’ ranking for the relevant mechanism. The ‘consequence’ ranking for safety, environment or business impact is then added, and the risk level is evaluated using an agreed risk matrix with the client/owner. An inspection plan can then be developed for different inspection activities to form an optimised inspection schedule. Case studies were presented for ‘hotspots’ identified on an FPSO and RBI analysis used to look at the fatigue degradation mechanism and a coating degradation mechanism. An extensive Q&A followed these 2 excellent papers.

Full details of future branch events can be found on the diary page of this magazine and on the 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 can be found at: https://sites.google.com/site/icorrabz/event-gallery

A special reminder is drawn to the August 2020 Annual Corrosion Forum (ACF), which unfortunately has now been cancelled owing to the Covid-19 outbreak and knock-on financial effects.

London Branch

The February talk was given by George Winning, Technical Service Manager for Clariant Oil Services in Africa, a Fellow member of ICorr and London branch committee member. George explained in his presentation why the corrosion inhibitor injection systems are required, and reviewed typical systems and corrosion control options, both mechanical and chemical. This was an excellent talk which produced significant discussion amongst those attending.

Within oil and gas operations there is a need to maintain and optimise production through life. One of the most common options to achieve this is the use of water injection to maintain reservoir pressure. With the use of these systems comes issues regarding corrosion as the presence of oxygenated water, scale and microbial growth can lead to premature failure unless efficiently mitigated.

The above corrosion threats were outlined in the presentation, followed by discussion on how the various systems used, amongst seawater, aquifer water, river water and other systems such as PWRI and water and gas (WAG), determine the most suitable mitigation methods.

This led onto the need for the fit-for-purpose design of the system, the maintenance of any mitigation measure and the required monitoring to ensure safe and efficient operation.

This brought up a discussion on many subjects covered. These included microbial monitoring of the system and identification of the most reliable methods, which opened up a philosophical debate on whether any method is truly reliable and led to a conclusion that a number of methods, Serial dilutions, ATP, qPCR or even H2S monitoring should be used in conjunction with trend mapping to ensure the system is running at its optimum level. Other questions revolved around reliability of systems, particularly the deoxygenation system, with the conclusions that effective maintenance and monitoring of the system to identify problems at an early stage are imperative to allow changes to the operation to be made and the system optimised. It was also highlighted that water injection systems are regularly overlooked, as they are not seen as the sales point in oil and gas production, and leaks are not of high environmental concern. This is a mistake as these systems are the most important measure taken to maintain oil production in the secondary oil recovery phase of a project and overlooking these in the short term will affect the economics of the asset in the long term.

The talk was well received being described as ‘Master Class’ and well delivered with clear and relevant arguments made. It was closed with a vote of thanks and a presentation to the speaker.
Midland Branch

The February meeting was held at Impalloy’s new manufacturing facility in the West Midlands, with Impalloy also sponsoring the food for the event, and Prafull Sharma of CorrosionRADAR, gave a very interesting talk on the monitoring of Corrosion Under Insulation (CUI), Latest Developments and Trends.

Prafull provided with an enlightening presentation into the trends of monitoring CUI and oil and gas inspections in general. Hidden corrosion such as CUI continues to be a big challenge for the asset integrity management of industrial facilities. Industry still spends a huge amount of their maintenance budget on routinely opening up the insulation to inspect the pipes and equipment. There is a growing trend to remotely monitor corrosion in accessible locations using the wireless connectivity and battery powered devices. A new innovative sensor system for monitoring CUI has been developed by CorrosionRADAR. The sensing principle uses Electromagnetic Guided Radar (EMGR), which uses a permanently embedded sensor into the insulation. The data is transmitted wirelessly onto a cloud or on-premises platform and visualization is performed using a remotely accessible dashboard.

The presentation also detailed the latest developments in remote monitoring technology for Corrosion and CUI. The company have produced a very comprehensive monitoring database utilising 3D models of the plant requiring monitoring. Discussions followed about modification of the system to cover many other aspects of the corrosion dictionary, which Prafull said would be possible! Watch this space!

Following the presentation, a branch meeting was held, with Paul Segers taking on the chair. Detailed discussions followed about future events, membership etc. The branch is looking for new committee members from outside of the CP discipline, in coatings, research, monitoring, etc. If you would like to be involved please contact Paul via via the ICorr office.

Industry News

Up-coming Conferences/Exhibitions

Due to the outbreak of the Coronavirus (COVID-19) around the world, many of the major up-coming events have been cancelled or postponed. These include, CORROSION 2020 (NACE) conference and expo in the USA which is now scheduled for June 14-18, 2020. In Europe, Eurocoat in France, PaintExpo in Germany, and Surface World and Surfex in the UK, have all been postponed until later this year.

Akzo Releases Update on Spray-Painting Drone

AkzoNobel recently released an update on its partnership with Apellix, Jacksonville, Florida, which won the 2019 Paint the Future challenge, for their collaboration on a computer-controlled spray-painting drone.

According to the company, Apellix’s custom-built drone is tethered to the ground for its power and coating supply, however, its flies autonomously. The drone uses “unique software flight control,” which the companies say can more accurately apply coatings and capture painting data.

While drones fly really well, robots perform repetitive tasks easily. Apellix has been able to combine the best of both worlds.

“Building upon our software-controlled robots that make contact with a structure to take steel and paint thickness measurements, we’ve attached a specially designed spray-painting system to a custom drone controlled by computers, commented Robert Dahlstrom, Apellix Founder and CEO.

The application aims for benefits such as reduced application time and less waste, as well as increases safety.

“Developing a drone is easy,” said Michael Hindmarsh, AkzoNobel Venture Lead. “Spraying paint is relatively easy too. But developing a computer-controlled drone that can spray paint is actually quite challenging. A lot of skill and expertise has to go into getting the drone to apply a good quality coating in a consistent and reproducible manner. That’s where our collaboration comes in.

Pilot project begins for floating wind turbines

RWE Renewables and Saitec Offshore Technologies have teamed up to develop a floating platform for offshore wind turbines.
The two companies plan to test new approaches to the affordable installation and operation of wind farms in deep waters. They have launched a joint pilot project called ‘DemoSATH’ that will lead to testing of a floating platform next year off Spain’s Basque Coast.

The SATH technology is based on a twin hull made of modular prefabricated concrete elements that are subsequently braced. The objective of the project is to collect data and gain real-life knowledge from the construction, operation and maintenance of the unit. The pilot project will last 3.5 years: 18 months for the planning and construction, followed by a two-year operating phase.

The structure and the 2MW wind turbine will be assembled in the port of Bilbao. The base of the structure will be approximately 30m wide and 64m long. The platform including the turbine will be towed to its anchorage point in a test field two miles off the coast, where the sea is about 85m deep. Hybrid mooring lines, composed by chains and fibre, anchored to the seabed will hold the floating body in position. The plant is expected to go into operation in the third quarter of 2021. The electricity generated during the project will be fed into the Spanish power grid.

DemoSATH will be Saitec Offshore’s second project in open waters, as the deployment of a scaled 1:6 model off the coast of Santander is scheduled for April this year.

The repainting of Øresund Bridge gets under way

Nearly 20 years after its opening, a multi-year project to repaint the Øresund Bridge, the combined rail and motorway bridge, which links Denmark and Sweden, has begun.

The repainting of this 300,000m² steel structure has been described as the largest investment in the bridge since its inauguration.

According to the press release, the top layer of the five-layer painting system will wear out within the next 10 years, thus new top coats have to be applied to be able to maintain the lower coats, which protect the steel from corrosion. To achieve the application of two new layers of paint, the bridge consortium ordered special custom-built platforms, allowing painters to be safe from passing trains and traffic. The initial phase of the painting operation will be carried out by Muehlhan Denmark.

Promising floating wind technologies get funding

Eight technologies that are being developed to help commercialise the floating wind sector have been selected as winners of a technology acceleration competition, funded by the Scottish government and run by the Carbon Trust’s Floating Wind Joint Industry Project (JIP), and share £1m of Scottish government funding.

The competition was designed to address four key industry challenge area that need to be overcome to commercialise floating wind. The four areas were identified in Phase 1 of the Floating Wind JIP: monitoring and inspection, mooring systems, heavy lift maintenance and ‘tow to port’ maintenance.

The successful applicants are from a variety of sectors including oil & gas, IT & telecommunications, and engineering. The innovations range in maturity, therefore the funding will be used to support different activities from desktop studies to offshore demonstration.

The winning companies and technologies were: Fugro, AS Mosley and University of Strathclyde (monitoring and inspection), Technology from Ideas and WFS Technologies (monitoring and inspection), Dublin Offshore (mooring systems), Intelligent Mooring Systems and University of Exeter (mooring systems), RCAM Technologies and the Floating Wind Technology Company (mooring systems), Vryhof (mooring systems), Conbit (heavy lift maintenance), and Aker Solutions (‘tow to port’ maintenance).

According to the Carbon Trust, floating offshore wind is an emerging renewables sector, with significance for places like Scotland where water depths often do not allow for the use of fixed bottom turbines, and that floating wind is forecast to scale up to 12GW of capacity globally by 2030, becoming a market estimated to be worth £32bn.

New Product Manager appointed for Elcometer Limited

Tracy Salt has been appointed as the new product manager for Elcometer. According to the company, Tracy has worked alongside Elcometer’s senior management team for more than 20 years, and not only has an invaluable knowledge of their extensive product range, but also a comprehensive understanding on the product development process within the company. In her new position, Tracy becomes responsible for the management and introduction of its comprehensive range of products specifically designed for the Protective Coatings Industry.
European Paint Market

This is the fourth time Ceresana has analysed the entire European market for paints and coatings, which totalled 9.1 million tonnes in 2019.

Architectural coatings are the most important application area for paints and coatings, and the report predicts that by 2027, around 58% of all paints and coatings will be used in the construction industry. This usage, the second largest sales market, is heavily influenced by the economic situation of the respective country, and an average growth of approx. 1.2% per year is expected in the European demand for paints and coatings in this area.

In addition to the division between the individual application areas, this market study also examined the demand per product type. The increased focus on sustainability and the protection of the environment is, however, raising interest in water-based paints and coatings as well as other environmentally friendly alternatives. Water-based paints and coatings currently account for about 58% of the entire European market.

Chapter 1 provides a comprehensive account and analysis of the European market for paints and coatings – including forecasts until 2027. It features the development of demand, revenues, as well as production. The different application areas of paints and coatings are examined separately: construction, industry products, transportation, wood processing, and other applications. Demand is additionally split by product types: vinyl, acrylics, alkyd, epoxy, PUR, polyester, other polymers, and other paints and coatings.

Chapter 2 analyses 21 individual European sales markets, such as most EU member states as well as, for example, the United Kingdom, Russia, and Switzerland.

Chapter 3 provides useful company profiles of the most important manufacturers of paints and coatings, arranged according to contact information, revenues, profits, product range, production sites, and profile summary.

Hempel coatings protect ISG containers

Hempel has announced that in just eight years it has painted 20,000 mining containers for Intermodal Solutions Group (ISG). The milestone 20,000th coating was completed in January 2020, and during this eight-year partnership more than 1.5 million litres of paint has been used to protect the containers against the highly abrasive and corrosive materials they carry, as well as the external environment.

ISG’s patented maritime and mining containers are unique, with a patented tippler operating system that rotates and tips the container to empty out the material being carried. This means they generally only need to be loaded and unloaded once to transport copper/nickel concentrate, iron ore, minerals, and other commodities from source to ship. Previously, material was loaded and unloaded several times during transit to the final destination.

The Interior paint solutions used included, Hempadur Multi-Strength 45751 and Hempadur Conterior 47751, both self-priming, high-solid, epoxy coatings, which cure to a highly abrasion and corrosion resistant coating. Externally, the traditional three-coat system consisting of Hempatex Hi-Build 46410, a high-build acrylic topcoat was used to provide resistance to saltwater, splashes of aliphatic hydrocarbons, animal and vegetable oils, together with Hempadur Primer 1530C, an epoxy mid-coat containing zinc phosphate as corrosion inhibiting pigment, and Hempadur Zinc 1536C, a zinc-rich epoxy primer that cures to a hard wearing and highly weather-resistant coating, concluded the company.

Latest Literature

A new study, focused on highly dispersed graphene oxide–zinc oxide nano-hybrids in epoxy coating to give improved water barrier properties and corrosion resistance, has been published recently.

The study introduces a novel approach of using the stable surface property of zinc oxide (ZnO) to facilitate the dispersion of graphene oxide sheets in an epoxy coating. Graphene oxide-ZnO nano-hybrids were successfully formed and demonstrated by Fourier transform infrared spectroscopy and X-ray photoelectron spectroscopy analyses. They were found to be well dispersed in an epoxy matrix with no significant agglomeration, verified by field emission scanning electron microscopy with energy-dispersive X-ray spectroscopy. Based on these investigations and testing, the well-dispersed nano-hybrids in the epoxy coatings had effectively improved water barrier properties, as well as adhesion and corrosion protection, in comparison with neat epoxy (EP) and simple graphene oxide–epoxy coatings.

The study was published in Journal of Coatings Technology and Research, January 2020, Volume 17, Issue 1.
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 8407 Corrosion of metals and alloys — Removal of corrosion products from corrosion test specimens (Revision of 2009 standard)


ISO/DIS 11127-8 Preparation of steel substrates before application of paints and related products — Test methods for on-metallic blast-cleaning abrasives — Part 8: Field determination of water-soluble chlorides

ISO/DIS 14571 Metallic coatings on nonmetallic basis materials — Measurement of coating thickness — Microresistivity method

ISO/FDIS 11844-1 Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 1: Determination and estimation of indoor corrosivity (Revision of 2006 standard)

ISO/FDIS 11844-2 Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 2: Determination of corrosion attack in indoor atmospheres (Revision of 2005 standard)

ISO/PRF 11845 Corrosion of metals and alloys — General principles for corrosion testing (Revision of 1995 standard)

ISO/FDIS 21062.2 Corrosion of metals and alloys — Determination of the corrosion rates of embedded steel reinforcement in concrete exposed to simulated marine environments

ISO 218093:2016/FDAm Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 3: Field joint coatings — Amendment 1: Introduction of mesh-backed coating systems

ISO/DIS 22848 Test method for measuring stress corrosion crack growth rate of steels and alloys under static-load condition in high temperature water

ISO/DIS 23123 Corrosion control engineering life cycle—General requirements

ISO/DIS 23221 General requirements for pipeline corrosion control engineering life cycle

ISO/DIS 23222 Corrosion control engineering life cycle — Risk assessment

ISO/DIS 23449 Corrosion of metals and alloys — Multielectrode arrays for corrosion measurement

New International standards published during the last two months.

ISO 8044:2020 Corrosion of metals and alloys — Vocabulary


ISO 15184:2020 Paints and varnishes — Determination of film hardness by pencil test

ISO 18086:2019 Corrosion of metals and alloys — Determination of AC corrosion — Protection criteria

ISO 22426:2020 Assessment of the effectiveness of cathodic protection based on coupon measurements

CEN

Standards published within the last two months.


This is a method for evaluating the carbonation resistance of concrete using test conditions that accelerate the rate of carbonation. After a period of preconditioning, the test is carried out under controlled exposure conditions using an increased level of carbon dioxide. This procedure is not a method for the determination of carbonation depths in existing concrete structures.

The following standard has been up-dated.

BS EN 17243:2020 Cathodic protection of internal surfaces of metallic tanks, structures, equipment, and piping containing seawater

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Corrosion Inhibitors in Upstream Oil and Gas Production

The use of corrosion inhibitors to mitigate the threat of internal corrosion affecting the design and operation of upstream oil and gas production infrastructure and facilities has proved to be a successful, resilient, flexible and cost-effective means of managing that threat over the past 60+ years. A corrosion inhibition system generally requires relatively low capital outlay but carries a continuous whole life operating cost associated with ongoing cost of chemical, deployment and injection system management and associated maintenance, and supporting corrosion monitoring and inspection. Viewed on an NPV (net present value) basis, usually makes the use of Carbon and Low Alloy Steels (CLASs) together the most economically attractive option at the design stage of project - the base case consideration, a position unlikely to change in the future.

The history of the use of corrosion inhibitors has not been without its troubles, certainly in the early years when going through a learning curve of sound fundamental understanding of how they function versus meeting user demand. However, issues should they arise are now generally associated with insufficient or poor attention to managing inhibitor application and not per se inhibitor performance. Application is not just about the technology and method but how it is then consistently managed: it is a “cradle to grave” commitment and certainly not a “fit and forget” option.

The benefits of chemical corrosion inhibition can be summarized as:

- Cost effective - can be sensitive to how the economics are calculated but generally it is the most capex efficient option.
- Extend use of materials with established and favourable engineering properties - primarily talking about use of CLASs.
- Flexible response - can be adjusted to meet changing operating conditions.
- Retrofit treatment - response to unexpected increase in system corrosion, a change in service conditions and/or life extension.
- Assurance - where there is limited access/opportunity for inspection and/or corrosion monitoring
- Can be applied to sweet (H₂S free) and sour (H₂S containing) systems, but the presence of even very low levels of oxygen (ppb level) can adversely affect performance of most inhibitor species, as can high temperatures (>150°C).

What are they?

Commercially supplied corrosion inhibitors are formulated products. Typically, they contain 10% to 25% active inhibitor species – N, S O or P functional long chain organic compounds. A product’s primary constituent is the carrier solvent which is key to effective inhibitor deployment in a system. The formulation is a critical element affecting efficacy of performance versus specific application, and why there is not, at least so far, a “silver bullet” corrosion inhibitor suitable for all applications. Consequently, undertaking appropriate testing/screening of products required to work must be understood and defined, not least because:

- They will determine the methodology and scope of the test programme required for sound inhibitor selection;
- They will determine the criticality and order of importance of factors affecting performance – e.g. if compatibility with another production chemical(s) is likely to be an issue, then it needs to be decided which one can a compromise on performance be accepted if unable to find a fully compatible optimum solution.
- If the operating system to be treated has already experienced a level of corrosion damage this can be more challenging to manage to an acceptable level of inhibition.
- Flow regime will influence the effectiveness of deployment in the field and influence the location of potential corrosion hot spots – e.g. sharp bends; dead legs.
- Poor system cleanliness can be detrimental to inhibitor performance – e.g. build-up of solids, presence of wax or scale.

In recent years much effort has been directed at the development of test methods for studying and evaluating corrosion inhibitor performance. This has resulted in increased sophistication, especially when combined with use of ex situ and in situ surface analysis techniques, while being manageable and not excessively expensive to establish and run in a conventional laboratory environment. Good background reading and reference can be found in: EFC Publication #39 - The Use of Corrosion Inhibitors for Oil and Gas Production; ASTM G-170-06, 2012 – Standard Guide for Evaluating and Qualifying Oilfield & Refinery Corrosion Inhibitors in the Laboratory; NACE International Publication 1D196, Item No. 24192, 1996 - Laboratory Test Methods for Evaluating Corrosion Inhibitors: Technical Committee Report, Task Group T-1D-34; UK Health & Safety Executive, Research Report RR1023, 2014 – Reliable Corrosion Inhibition in the Oil and Gas Industry.

Whether one or several test methods will be needed to generate data suitable for making a final selection for field deployment will depend on the complexity of the field conditions. For field conditions that are particularly complex, and the infrastructure/facilities are of high criticality, then it may be deemed necessary to conduct final inhibitor testing/selection using a large diameter flow loop able to simulate multiphase flow. There are only a limited number of such facilities available; for example, in the USA at Ohio University and the University of Tulsa, and in Norway at the Institutt for Energiteknikk (IFE).

Inhibitor performance is commonly expressed and measured in terms of efficiency - the percentage amount an inhibitor can reduce the uninhibited corrosion rate when presented at a given concentration, usually the optimum concentration to achieve maximum efficiency. (NB. The uninhibited corrosion rate is often that measured in the lab or predicted...
Inhibitor film persistency/coverage that may result in localised corrosion or complete loss of protection.

**In conclusion**

It is perhaps not unreasonable to claim that the advent of oilfield corrosion inhibitors back in the 1950’s and their subsequent development has resulted in a significant enabling technology for the cost-effective development and successful growth of oil and gas production. Looking back, some may even claim inhibitors to be ‘a game changer’ technology! Going forward, with new projects exploiting reservoirs with fluids of increasing complexity and more aggressive environments, consistently achieving high inhibitor efficiency of performance and application will be paramount to economic project delivery and integrity risk management.

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What is the best lining for a hydrochloric acid storage tank? DD

Equipment fabricators looking to offer corrosion protection for the storage of hydrochloric acid have a number of materials at their disposal. Whatever method is selected this should be able to create a safe environment, without compromising the tank integrity as well as maintain continuous operation and avoid adverse effects on the cargo itself.

At a very basic level solutions can be divided into inorganic and organic. The inorganic solutions may include; metallic solutions, such as alloys which are capable of resisting a wide range of acids including hydrochloric, and ceramic solutions, such as bricks /tiles, often used in conjunction with an organic solution such as vinyl esters or furans in the joints and behind the brick system. The organic solutions may include; thermoplastics which are bonded or physically adhering to the metal substrate, and reactive thermoset types which cross-link to form an acid resistant coating barrier.

Whilst resin coating types are widely used in acid secondary containment areas, their use in tanks and vessels is considered a higher risk, however they remain attractive due to the relatively low cost of installation when compared to metallic or ceramic options. Phenolic or Novolac epoxies can provide suitable resistance to hydrochloric acid (though they are less resistant to more oxidising acid species) provided that they are formulated with a suitable hardener, with amine hardeners generally being more resistant than amidies, though still susceptible to acid hydrolysis and subsequent degradation.

Vinyl esters have high resistance towards both oxidising and non-oxidising acids and offer a suitable solution for hydrochloric acid providing both good chemical resistance and ease of application. Their good overall resistance arises from the extensive presence of aromatic groups within the resin and the presence of methyl groups which have the effect of stabilising the ester linkage.

However, colour change of the coating material is a commonly found phenomenon with acid materials, and can result in adverse effects on the acid cargo itself (colour tainting) which may not be acceptable where stringent quality checks or high purity requirements are to be found. SD

What is the best intrusive corrosion monitoring devises for pipelines and process pipework? AB

The answer to this, is to some extent in the question itself, as firstly, it is important to determine what level of monitoring is actually required (it’s criticality) and where that equipment is best located in service (in hazardous or non-hazardous zones) and accessibility for future maintenance, as many regulatory requirements and operator site specific standards must be met both at initial installation and for future maintenance of such equipment.

A key factor is operating temperature, and design modifications are usually required for sensors in constant contact with very hot surfaces. It may also be necessary to temporary remove thermal insulation from pipework and protective safety cages, for installation and to repair this afterwards to prevent water ingress.

If significant erosion of material is expected, sensors must also be correctly positioned to monitor key ‘impact points’ on bends, tees and other geometric configurations, and to be able to do this effectively. It is necessary to have a clear understanding of the internal flow rate and regime e.g. laminar or turbulent, as may be indicated by the Reynolds number (Re), which can be calculated by multiplying the fluid velocity by the internal pipe diameter and then dividing the result by the kinematic viscosity. The flow regime is influenced by the fluid properties, the flow conduit size and rates of each of the phases.

For internal corrosion degradation, the likely orientation of this damage must first be determined and the appropriate spacing of sensors specified in sufficient numbers to detect the expected deterioration mode, such as shallow or deep pitting, distributed or localised decay, bottom of line, top of line, etc.

Most sensors (magnetic or clamped) rely of having an associated power pack with the batteries typically lasting between 3-9 years according to the selected interval between measurements. It is very important that the measurement interval suits the type of data being collected, e.g. high frequency data gathering is required for well-commissioning activities where solids production is an expected risk.

Note that this equipment may be either of the relocatable/re-use type, when only temporary/short-term measurement is required, or of the more permanent types, perhaps installed more comprehensively with multiple sensors, e.g. for CUI, or other more intensive applications, even under water such as on subsea pipelines.

Non-intrusive devices provide additional monitoring possibilities where intrusive devices are not available. They are also extremely useful where intensive/regular measurement is required and avoid labour intensive (and often less accurate) manual data gathering methods. Compared to intrusive devices, they are more frequently of the automated type with data transmission to control rooms or using vendor installed software, or alternatively linked to the client’s systems. As with all such equipment however, the devices must be regularly checked/calibrated at site, so as to provide reliable data.

Consideration of all the above factors will greatly influence successful applications/outcomes in this growing area of the CM equipment market. ST

Readers can submit generic (not project specific) questions for possible inclusion in this column. Please email the editor at, brianpce@aol.com
Assessing the effectiveness of mitigation of corrosion based on today’s understanding of cathodic protection

M. Büchler, SGK, Swiss Society for Corrosion Protection, Zürich, Switzerland.

Since the first use of cathodic protection (CP) in 1928 [1], this technology has been successfully used worldwide for corrosion protection of pipelines. The effectiveness of CP is well recognised and has significantly contributed to the increased lifetime of buried infrastructure, and thus the risks associated with the transport and distribution of oil and gas have been significantly decreased, since corrosion related leaks can essentially be prevented by the use of an effective CP. As a consequence, the demonstration of effectiveness of CP is of the highest importance, especially in those areas where the installation and operation of the CP is associated with a legal requirement. The requirements for the demonstration of effectiveness of CP are given in EN ISO 15589-1 [2] and are based on the so called IR-free (voltage drop across a resistance-free) potential (EIR-free) at individual coating defects. The effectiveness can be demonstrated, when EIR-free is more negative than the protection potential (Ep), which corresponds to the minimum required electrochemical polarisation of individual coating defects on the pipeline. For normal soils that value is -0.85 VCSE. Consequently, the requirements of EN ISO 15589-1 are related to the EIR-free of individual coating defects. Unfortunately, the EIR-free of individual coating defects cannot be assessed directly in many cases. The methods for measuring the EIR-free are given in EN 13509 [3], and based on this standard the demonstration of effectiveness of CP is solely possible based on the so-called Intensive Measurement Technique, which is a concurrent DCVG and CIPS survey, with a synchronous interruption of all cathodic current sources. By means of an extrapolation of the voltage gradients and the potential data, the EIR-free can be determined mathematically. While this procedure is technically correct, it has some important limitations. The intensive measurement technique was developed on poorly coated pipelines exhibiting major coating defects, and as such, the associated voltage gradients were significantly larger than 100 mV and exhibited usually more than 30%IR. At these coating defects a reliable calculation of the EIR-free on the basis of the intensive measurement technique was usually possible, since the contribution of influencing factors affecting the reliability of the extrapolation was normally negligible. Consequently, the protection criteria given in EN ISO 15589-1, and the intensive measurement technique, were and still are associated with the assessment of effectiveness of CP on bituminous coated pipelines.

The introduction of new coating systems based on Polyethylene (PE) and Fusion Bonded Epoxy (FBE) has significantly changed the situation. The size of coating defects and the associated voltage gradients have significantly decreased, which was accompanied by a decrease of the total current demand. On these modern pipelines it is no longer possible to determine reliable data based on the intensive measurement technique. The small voltage gradients and relevant contribution of disturbing influencing voltage gradients prevented the reliable calculation of the EIR-free on individual coating defects.

Instead it was often attempted to approximate the EIR-free by means of the so-called instant-off potentials (Eoff), which were determined by synchronous interruption of all cathodic current sources including rectifiers, decoupling devices, galvanic anodes and drainage bonds. According to EN 13509 these Eoff-values may only be used for the determination of the EIR-free when equalising currents, cell currents due to foreign anodes or foreign cathodes, and stray currents are not present. This condition is never satisfied in the case of heterogeneous bedding conditions and various coating defect sizes on the pipeline. On the basis of EN 13509 it is correspondingly not possible to perform a demonstration of effectiveness by means of Eoff values. According to EN 13509 an assessment of the EIR-free and hence the demonstration of effectiveness of CP on such pipelines is only possible on the basis of coupon measurements, since they usually allow for excluding the IR-error by interrupting all exchange and cell currents. Coupons, however, only allow for the demonstration of the effectiveness of CP of the pipeline, when these coupons are representative of coating defects on the pipeline under investigation.

These issues were addressed in a panel discussion within CEOCOR and the conclusions were published [5]. Based on these discussions the following technically correct conclusions are possible:

- Eoff more negative than -0.95VCSE, many of the coating defects are protected.
- EIR-free on a coupon more negative than -0.95VCSE, the coupon and all coating defects identical (size, bedding conditions and mass transport) to the coupon are protected.
- EIR-free on a coating defect more negative than -0.95VCSE, the measured coating defect is protected.

These conclusions confirm that neither the assessment of the Eoff nor the EIR-free potential on individual coating defects, or coupons, allow for the demonstration of the effectiveness of CP on all coating defects on a pipeline. If follows that it is technically not possible to demonstrate compliance with EN ISO 15589-1. While it is possible to increase the level of polarisation, and hence corrosion protection, by shifting the on-potential (Eon) to more negative values, this also increases the risk of over-polarisation and associated disbonding of the coating. These problems, associated with the correct adjustment of the level of CP, are further complicated by the increasing presence of AC and DC interference conditions. In order to satisfy the requirements of ISO 18086 [6] with respect to minimising the risk of AC corrosion, the Eon must be shifted in the positive direction. In contrast the mitigation of DC interference according to EN 50162 [7] the Eon must be shifted in the negative direction in order to meet the requirements with respect to the EIR-free. Taking into account the discussed difficulties associated with the measurement of EIR-free according to EN 13509 in presence of stray currents, it follows that it is technically not possible to demonstrate the effectiveness of CP on modern interfered pipelines on the basis of the normative requirements. Considering the legislative implications
and the associated security risks, this is unacceptable. Therefore, in the past years an alternative procedure for demonstrating the effectiveness of CP was developed, which will be presented below.

**Alternative procedure for demonstrating effectiveness of CP**

The new approach to demonstrate the effectiveness of CP is based on today’s understanding of the processes involved in CP, as it is described in [8]. The application of a cathodic current correspondingly results in an increase of the steel surface pH along the equilibrium line for hydrogen evolution as shown in Figure 1. At an EIR-free more negative than -0.85 VCSE a steel surface pH of 9 is reached and conditions for passivation are present. A higher level of polarisation is achieved when the EIR-free reaches -0.95 VCSE which correspond to a pH of 10.5 according to Figure 1. This increased surface pH is sufficient to ensure passivating conditions even in aggressive conditions. This consideration first emphasised by Leeds [9] explains the processes taking place under CP and the relevance of the associated threshold values in EN ISO 15589-1.

Furthermore, today’s understanding of the processes taking place under DC interference can be expanded to combined DC and AC interference conditions as discussed in [10]. This approach is based on DVGW GW 28 B1 [11] and DVGW GW 21 [12], and both these documents have the status as recognised ‘state of the art’ in Germany. It is common to both documents that the assessment of the effectiveness of CP is based on 24-hour average values of Eoff and the AC-voltage (Uac). Contrary to the EIR-free, these parameters can readily be assessed on pipelines and today’s monitoring technology can automatically record them remotely. The concept of 24-hour average interference values is furthermore included in ISO 18086 as well as ISO/DIS 21857 [13]. This procedure allows for the first time for identical procedures for interference conditions is associated with a Jref of 2 mA/m².

Consequently, there must be a reference potential (Eref), which is required to ensure Jref and establishing effective CP by meeting Eq. According to equation (2) Eref can be determined. This difference between Ep and Eref will (depending on Rand A) ensure Jref and hence effective CP on a given coating defect.

\[
J_{\text{ref}} = \frac{E_{\text{ref}} - E_{\text{p}}}{R \cdot A} \quad (2)
\]

It immediately follows from equation (2) that R and A have a relevant effect on Eref. R can be described for a circular coating defect with diameter d and soil resistivity \( \rho \) by means of equation (3) [14].

\[
R = \frac{\rho}{2 \cdot d} \quad (3)
\]

Combining equations (2) and (3) result in equation (4) for describing Eref.

\[
E_{\text{ref}} = E_{\text{p}} - J_{\text{ref}} \cdot \pi d \cdot \rho \quad (4)
\]

This approach allows for the calculation of the required Eref for any given coating defect diameter and a required Jref. The associated soil resistivity \( \rho \) is possibly unknown. Anyway, the correct identification of the required Ep according EN ISO 15589-1 and the use of DVGW GW 28 B1 require a knowledge of the soil resistivity. Correspondingly is needed for the demonstration of effectiveness of CP and the mitigation of the AC corrosion risk already today.

For buried structures the dependence of the steel surface pH on current density \( J \) was reported by various authors, as shown in Figure 2. The EIR-free determined 0.1s after interruption of the cathodic current is linked to the steel surface pH according to the equilibrium line for hydrogen evolution shown in Figure 1. As a consequence, Figure 2 allows for relating the current density \( J \), the pH-value and the EIR-free, and the following conclusions are possible based on the data in Figure 2 with respect to Jref:

- 2 mA/m² will cause an increase of the steel surface pH above 9 and correspondingly result in an \( E_{\text{p}} \) more negative than -0.85 VCSE. The \( E_{\text{p}} \) in ISO 15589-1 for normal conditions is associated with a Jref of 2 mA/m².
- 20 mA/m² will cause an increase of the steel surface pH above 10.5 and correspondingly result in an EIR-free more negative than -0.95 VCSE. The

**Figure 2: Dependence of the current density \( J \) and the steel surface pH on the basis of literature data according to [15]. Additionally, the dependence of the EIR-free of the hydrogen electrode on the pH is shown on the right vertical axis.**

Unfortunately, there is usually no information available with respect to the diameter of the coating defects. This problem is directly associated with the installation of coupons, since conclusions with respect to the effectiveness of CP can only be drawn when the size of the defect is representative of those coating defects on the pipeline as discussed above and emphasised in [5] and described in ISO 22426 [16]. In Switzerland it is common practice to install coupons as follows:

- On modern 3LPE coated pipelines with a coating resistivity of at least 1 MΩm² coupons with a surface of 1 cm² are installed.

\[
\text{R} = \frac{1}{\text{A} \cdot \text{B}} = \frac{1}{2\pi \cdot (\text{d}/2)^{2}} = \frac{1}{2\pi \cdot \text{d}^{2}} \]

\[
\text{J}_{\text{ref}} = \frac{R \cdot A}{E_{\text{ref}} - E_{\text{p}}} \]

\[
\text{E}_{\text{ref}} = \text{E}_{\text{p}} - \text{J}_{\text{ref}} \cdot \pi \cdot d \cdot \rho \]

\[
\text{J}_{\text{ref}} = \frac{E_{\text{ref}} - E_{\text{p}}}{R \cdot A}
\]
On older PE coated pipelines coupons with a surface in the range of 10 cm² are installed.

On bituminous coated pipelines coupons with a surface of 100 cm² are used.

If the installed coupon sizes are considered to be relevant for the assessment of the effectiveness of CP on the pipeline, their surface can immediately be used for calculating E_ref as a function of the soil resistivity. A calculation example for defect surfaces ranging from 0.1 to 1000 cm² with a J_ref of 100 mA/m² is shown in Figure 3. According to Figure 2, this J_ref of 100 mA/m² is sufficient to satisfy the Ep of -0.95 VCSE on all coating defects well bedded in fine soil or sand. It immediately follows from Figure 3 that an E_ref of -1.5 VCSE is sufficient to ensure effective CP on coating defects of up to 100 cm² in the soil resistivities between 30 and 100 Ωm, as they are characteristic for lower altitude soils in Switzerland.

This approach allows for the calculation of E_ref for all possible conditions, provided J_ref is known. For pipelines well-bedded in fine soil and sand, or pipelines in water with increased hardness, the values for J_ref can be taken from Figure 2. For fixed steel offshore structures, EN 12495 requires in extreme cases values for J_ref of more than 200 mA/m² in sea water. In the case of coating defects in streaming soft water, significantly increased values of J_ref may be required, since the accumulation of alkalinity and to reach a sufficient surface pH is more difficult in such conditions as emphasized by [5].

Example of this application

In the following, an assessment of the effectiveness of CP based on a hypothetical application example is discussed in order to illustrate the procedure in a combined AC and DC interference condition. The increasing density of infrastructure today results in situations as shown in Figure 4, with combined high voltage and train interference. The discussed 3LPE coated pipeline with a wall thickness of 5mm is bedded in soil with resistivities between 30 and 100 Ωm and the coating defects are assumed to be smaller than 10cm². The coupons installed along the pipeline correspondingly have a surface of 10 cm². For the assessment of effectiveness three steps are required:

Firstly E_ref is determined. For the defect size of 10 cm² at the highest soil resistivity of 100 Ωm and a J_ref of 100 mA/m², an E_ref of -1.14 VCSE can be determined from Figure 3. This value is shown in Figure 5a with the vertical red line. Effective CP is accordingly established when E_on is more negative than E_ref. This will ensure sufficiently high current density and satisfying of the criteria given in EN ISO 15589-1.

Secondly, the contribution of stray current interference is assessed in accordance to DVGW GW 21 or ISO/DIS 21857. The average anodic interference ΔE_a,avg is determined from a 24-hour recording of E_on. The assessment of ΔE_a,avg is relative to E_ref. In the present case ΔE_a,avg is 0.3 V. and according to equation (5) given in DVGW GW 21 and ISO/DIS 21857 the requirements for the 24-hour average on-potential E_on,avg are:

\[ E_{on,avg} \leq E_{ref} - \Delta E_{a,avg} \] (5)

When equation (5) is satisfied effective CP is assured in the given DC interference situation. This value is marked in Figure 5b by means of the blue line. It follows that effective CP is present as long as the 24-hour average of E_on is more negative than E_on,avg. This procedure allows the demonstration of effectiveness of CP based on a comparably simple on-potential measurement in accordance to DVGW GW 21 and ISO/DIS 21857.

Finally, the limiting values for the acceptable AC interference must be taken from DVGW GW 28 B1. These U_ac values are based on the current density requirements given in ISO 18086. Since AC corrosion is a problem of over-polarisation there is a maximum acceptable DC current density given in ISO 18086. Correspondingly the maximum acceptable DC and AC current densities of 1 A/m² and 30 A/m² respectively may not be exceeded. For this reason, the lowest soil resistivity along the pipeline must be considered for the assessment, which is 30 Ωm in the present example. The limiting values are indicated in Figure 5c with the orange line for the acceptable U_ac.

Figure 3: Dependence of E_ref from the defect size and the soil resistivity for a J_ref of 100 mA/m² calculated according to equation (4).

Figure 4: Combined interference by high voltage power lines and traction systems.
This discussion illustrates the procedure for assessing the effectiveness of CP in a combined DC and AC interference condition in accordance to the requirements of DVGW GW 21, DVGW GW 28 B1 and ISO/DIS 21857. Clearly, the optimal operation of CP requires the consideration of all influencing factors. The present example illustrates that effective CP is ensured as long as the average \( E_{\text{on}} \) is more negative than -1.44 VCSE and the average \( U_{\text{ac}} \) is smaller than 4 V. This approach allows for a straightforward demonstration of effectiveness of CP in combined DC and AC interference conditions on the basis of readily accessible objective parameters.

Additionally, the planning of mitigation measures is readily possible by means of Figure 5c in the case of exceeding the AC interference threshold. An \( U_{\text{ac}} \) of 6 V can only be tolerated, when the average \( E_{\text{on}} \) is more positive than -1.6 VCSE as illustrated with the green dot in Figure 5c. In the case of significantly increased \( U_{\text{ac}} \) of for example 10 V, additional earthing measures are required. Under these conditions a further shifting of the \( E_{\text{on}} \) to more positive values is not possible due to the requirements for mitigation of stray current interference and the threshold of \( E_{\text{on,avg}} \) according to Figure 5c. However, in the practical application it is often difficult to decrease the level of AC interference to very low values.

In the example shown in Figure 5c the corrosion situation can be significantly improved at a \( U_{\text{ac}} \) of 10 V, when the level of stray current interference is addressed. Decreasing \( \Delta E_{\text{on,avg}} \) to 0.06 V results in a \( E_{\text{on,avg}} \) of -1.2 V CSE according to equation (5) as show in Figure 6. Correspondingly the average \( E_{\text{on}} \) can be adjusted to -1.3 VCSE which eliminates the AC corrosion risk even in case of strongly increased AC interference in the given configuration (green dot in Figure 6).

By means of this approach a demonstration of the effectiveness of CP and the planning of mitigation measures in the case of the interference conditions and considering the normative requirements is readily possible. The application of this procedure in the past years in Switzerland has revealed that it may not always be possible to meet the normative requirements over the entire length of a pipeline. This is particularly the case when heterogeneous soil resistivity is present along the pipeline. This may result in an exceeding of the threshold values on certain pipeline sections. These locations are readily identified by plotting the actual \( E_{\text{on}} \) and \( U_{\text{ac}} \) data in the corresponding diagram (similar to Figure 6). This allows for the determination of the operation conditions of CP that minimise the corrosion risk. The additional installation of coupons on these identified critical locations allows for further assessment of the corrosion situation, in particular when electrical resistance (ER) probes are used. They allow for real time corrosion rate measurement and further optimisation of the corrosion situation in these critical sections.
Conclusion

The discussed dependencies and the example presented illustrate the possibilities in assessing the effectiveness of CP based on today’s understanding of the underlying mechanism and interactions. The significance of this approach is to ensure effective CP on all coating defects on the pipeline while taking into account the conflicting requirements of sufficient polarization in the case of DC interference, while preventing over polarization in the case of AC interference. The analysis is based on the reference current density $J_{\text{ref}}$ that is required for establishing effective corrosion protection. This $J_{\text{ref}}$ and hence effective corrosion protection is ensured on all coating defects of the pipeline when $E_{\text{on}}$ is more negative than $E_{\text{ref}}$.

An increased level of DC interference can readily be addressed by shifting the average $E_{\text{on}}$ in cathodic direction according to ISO/DIS 21857. In contrast an increased level of AC interference can be mitigated by shifting the average $E_{\text{on}}$ in anodic direction. The presented procedure and example allow for the conflicting requirements associated with AC and DC interference to be taken into account, and hence adjusting the optimum level of CP. This optimum level of CP ensures effective CP with minimised risk of AC and DC interference.

Furthermore, since the assessment of effectiveness of CP with this method is based on the easily measurable values $E_{\text{on}}$ and $U_{\text{ac, on}}$ on the pipeline, it represents a unique procedure that is readily applicable on all pipelines. The problems associated with time synchronized interruption of rectifiers, DC drainages and AC decoupling devices are, therefore, resolved.

Literature

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The Future of Ship Painting – Part 2

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The first part of this article discussed the influence various parties have on the ship coating process and how the design of a vessel can affect this. It identified areas where change is needed.

This second part covers the coating specifications, inspection, and standards today, and what will be necessary in the future.

Coating Specifications

Specifications today

Many coating specifications in use today are “grandfathered”, that is they have been in use by a company for many years and have never been updated to reflect in-service experience and/or any technology developments.

The current approach to coating specification in most of cases is inadequate. At newbuilding, shipyards push standard specifications that take limited consideration of their production process preferences, their relationship with the paint supplier, and the price of the package offered.

At maintenance and repair, the usual solution is simply to repair and maintain the new building coating system with the same products that were originally supplied, or the equivalent as recommended by the coating company in the event of a change of supplier. This raises a range of problems, for example, if the vessel is built in Asia in the summer and then enters service in colder climates and/or dry-docks in colder climates, it is possible that the generic new build specification may no longer be suitable as surface preparation would be inferior and application may be by brush and roller as opposed to airless spray. Consequently, there is a great risk in simply adopting the new build specification as the standard Maintenance & Repair specification.

The generic specification

In general, when a specification is provided it usually divides the vessel in 8-10 key areas including the underwater hull, decks, tanks and holds, and the superstructure. It is prescriptive, and it will usually define the total area to be coated in square metres, the product type and possibly either mention a specific brand or provide a description that tends toward the selection from a limited range of available products, the number of coats of the product to be applied and the nominal dry film thickness, or in some cases a minimum/maximum range. It will then refer to the relevant Technical Data Sheets to enable further details regarding surface preparation and application requirements to be obtained. What it does not generally include is any reference to any specific application guides or procedures that may or may not be available.

However, the main problem hinges around the reference to the Technical Data Sheets. On nearly all technical data sheets there is a stipulation that indicates that the data included in it is a guideline, i.e. it is indicative. The implication is that the exact requirements will vary based on the project type and specific needs. As a result, the requirements on the data sheet are open to interpretation to some extent.

Specification tomorrow

The initial change is already taking place, as generic specifications are more frequently substituted by functional specifications (goal based) and the specification aspect is separated from the product selection aspect. Where functional specifications have been fully deployed on new build vessel and repair projects in recent years significant cost savings have been made in the range of 10-30% against the original budget and scheme selection [1]. Furthermore, through-life needs have been assessed and evaluated to understand how maintenance and repair will be carried out by also considering alternative solutions for these based on planned periods of ownership and operational requirements.

The functional approach breaks down specification into three distinct phases:

- The specification
  Understanding the needs of the project through-life area by area, prioritising the key areas and their required functions, and defining target values for the functions e.g. life expectancy.

- The specification
  Does not include the number of coats or type of product or brand, neither does it include dry film thickness. The paint supplier is therefore required to develop a project specific scheme from its own range of products. The functional specification does however include the known application and operational limitations, for example to be applied in China during winter months.

- Product selection
  Based on the functional requirements a template is issued for tender and paint suppliers are required to match the demands of the functional specification. Each proposed scheme can then be assessed against the required demands allowing for a best fit to be selected. The benefit of this approach is that while there is unlikely to be a solution that matches 100% of the functional needs, the areas of weakness, and hence risk, are identified and can therefore be properly assessed in selecting the options. This generates a very transparent product selection regime that is divorced from cost considerations for the paint itself.

- Risk assessment
  Developing a specification in this manner allows for risks to be assessed and quantification of the impact of any compromises made. It also provides a clear link between the needs of the construction process and the in-service performance requirements. Increasingly specifications will have to also consider interactions with other on-board systems.

Standards today

Any generic paint specification can list between 10 and 20 standards from different organisations e.g. ISO, NACE, SSPC, IMO, plus some shipyard or ship owner specific standards, and the paint manufacturers’ guidelines and recommendations.

Usually little attention is paid to standards until something goes wrong at which point these serve as a reference for how the project should have been carried out.

In marine work, most standards are inadequate as they are generally developed by a committee that could represent a range of industries with different requirements. As a result, the final output is a compromise. Also, the lack of applicability of many standards poses a problem, as do dedicated standards such as the IMO PSPC, which is the result of a negotiation rather than a technical assessment of the situation. For example, coatings can be tested on clean steel coated in laboratory conditions and then approved for real life application on a salt contaminated surface.
Standards in the future

There is a real need to “marinise” coating standards to make them suitable for these mega-structures and to ensure their technical integrity. There is a lack of a standard body that produces a uniform and comprehensive set of standards for this market, and the consequence is that many disputes arise from conflicting standards that may even be referenced in the same document [2]. The future requires a uniform set of standards agreed across the industry to produce a consistency in approach and to combine the theoretical and practical needs of marine mega-structures.

Coating product development

At present the dominant solutions are liquid based coatings (paints) of various limited chemistries (epoxy, alkyd, urethane and copolymer-based systems), that have their origins in technologies developed in the 1960's and 1970's. Despite attempts to grow the concept of bulk supply, marine paint is overwhelmingly delivered in 5, 10 and 20 litre cans that contribute to the high waste stream generated by the coating process, both at new build and repair. Hence, there is an urgent need for a paradigm shift in how vessels are protected from structural corrosion and fouling, and how cargoes are protected from contamination.

Product selection today

Over the last 20 years there has been an increase in coating manufacturing capacity, this together with a desire to increase efficiency of the manufacturing and distribution process of coatings for the marine market has resulted in increased rationalisation and a focus on reduction of SKU's (Stock keeping Units). This has forced paint suppliers to consolidate their offer/product range. As a result, new build and maintenance and repair products were merged eliminating aspects of the ranges, and together with a push from shipyards in pursuit of the concept of a universal primer, which could be overcoated by any given range of products from either the same supplier or competitor suppliers, has resulted in the number of coatings on offer declining.

What is clear given the current methods of coating specification is that in most of cases, selection is finally made on price by both owner and yard, rather than on technical merit.

Product selection tomorrow

While shipyards strive for standardisation and simplification [3], the in-line method of coating manufacture, rather that the batch method, would allow the development of an increased number of SKU's in smaller batches that would reduce the warehousing/distribution issue and allow specialist products to be developed to meet specific area needs. Key areas where specific functionality could be imparted would be for water ballast tanks and cargo hold/tank coatings, and on-board maintenance products/solutions.

Alternative materials could reduce reliance on liquid coatings to some extent, but it is unlikely that one technology can match the flexibility and utility of liquid coatings for all functions and areas. Increased use of plastics is a possibility for some aspects.

The Coating Process

The coating process comprises surface preparation and then application of coatings, the technology in use has not significantly changed for over 50 years. The existing processes are under pressure to meet the demands of the market for both the building and subsequent operation/repair and maintenance.

A shipyard has a focus on Time, Cost and Quality [4]. The key paint attributes of drying time and over-coating intervals have not progressed in line with the required speed of production and the quality of application still results in unacceptably high re-work levels and therefore, a review of possible technology solutions that may enable a positive change is worthwhile.

A comprehensive assessment of the coating process was made in the 1990’s which determined the key stages and costs associated with coatings, which during new construction comprise the following steps [5].

- Primary surface cleaning and preparation
- Shop primer application
- Weld line cleaning and coating

- Secondary surface preparation/cleaning
- Main coating scheme application at block stage
- Erection joints surface preparation/cleaning and coating

The relative cost of the coating process increases as it progresses through the production process, e.g. the cost of coating application for work carried out after the main scheme application can range from 6-14 times costlier per square metre than at the block stage. This shows that coating strategy and planning are critical to ensure that the coating work is integrated into the production process and that the specification should focus on, among other things, attributes of the coating that enable it to best survive the production process.

Coating Technology

The needs today

Today most construction facilities would identify the following as key attributes that they would target:

- Minimal surface preparation
- Minimum number of coats
- Speed of cure (at practical DFT)
- Over-coating intervals (both minimum and maximum) at practical DFT.
- Low temperature workability
- Low environmental impact

The ship owner is looking for longevity of the coating; anti-corrosive 15 years, anti-fouling 10 years, and chemical tank linings 10-12 years, as well as attributes such as colour match, ease of maintenance, universal application (e.g. one product for all areas), and anti-abrasion/toughness. The shipyard is generally interested in the achieving the 12-month warranty requirements, while the shipowner is generally interested in attributes through life of ownership.

Coating technology needs in the future

There are several features that are required in the future for new products and technologies. Perhaps the strongest driver for technological change in the future will be regulatory requirements. These have increased since the organo-tin ban of the 1990’s [6] that resulted in a dramatic change in fouling prevention technology solutions. The REACH directive [7] has had an ongoing impact on the chemical products that are considered safe to use and other legislation will cause further challenges, such as the BWT Convention [8] which has raised issues of compatibility between the treatment methods and the ballast tank coatings.

Based on the above, the key feature required of coatings is that of “predictability of performance”. The biggest challenge today is to get the coatings to perform in a predictable manner to allow newbuild and operating costs to be reliably accounted for. If the time to failure of a coating was understood then owners could plan and manage the costs of operation effectively and if the relevant performance criteria for new construction (drying time, overcoating intervals etc.) were predictable then production could also be optimised.

Progress on any of the required attributes is essential in the future, and some suggestions about technology developments required at the different stages are given below:

At new construction

- Weld line cleaning and coating
- Erection joints surface preparation/cleaning and coating
- Over-coating intervals (both minimum and maximum) at practical DFT.
- Low temperature workability
- Low environmental impact
- Minimal surface preparation
- Secondary surface preparation/cleaning
- Primary surface cleaning and preparation
- Shop primer application
For example, the use of UHP water (wet blast technology) to prepare steel surfaces could be adapted to produce a surface profile, and the use of lasers to remove paint for subsequent hot work, and use of localised chemical treatment for erection joints and seams.

**Through-life**
Laminates for colour match and improved barrier properties, self-healing coatings using bacteria technology [9], microencapsulation, or polymer memory, and anti-fouling based on living organisms or micro-structured surfaces [10].

**Inspection for quality control and assurance**
The current approach to coating work for ships appears to hinge around answering the question “have we done it correctly “, and while some shipyards do attempt to answer the question “can we do it better, and how?” their efforts are often restricted by the provision of a 12-month warranty and with little interest in through life performance.

Given the rate of ownership change of many ships it is the Classification Societies who are perhaps best placed to assess through life coating behaviour and performance, sadly, to date they have more often tended to focus on ensuring that documentation is audited and correct, rather than ensuring that the engineering of the coating system is carried out properly to match the build and operational needs of the vessel.

**Inspection today**
The current Inspector qualification is based around a 2-week course then the inspector gains experience either working contract to contract, or in some cases through a further on the job training programme.

In recent years, paint companies have taken to contracting out their paint inspectors (technical service representatives) to clients as a way of mitigating the cost of having this group of people.

to monitor coating application and to protect the paint company interests. This raises the issue of inspector loyalty.

At new building there can be several inspectors in attendance, and even more in the case of Water ballast tanks, i.e. ship owner inspector, shipyard production inspector/foreman, shipyard QC inspector, and paint company inspector. In addition, for ballast and crude oil tanks, a Classification Society production inspector/foreman, shipyard QC inspector, and paint company inspector may be present for verification purposes.

If the current belief that coatings fail because of poor surface preparation and application is true, then the conclusion must be that the current methods of inspection and assessment are inadequate. While this is not the root cause of failure (as this is not driven by these factors alone), but merely the symptoms of a poor engineering solution to the problem.

One major challenge of inspection today is the assessment of when a coating system has failed, using the IACS classification of ‘Good’, ‘Fair’ and ‘Poor’. Thus, even with a degree of defects where 20-50% of edges are showing corrosion and up to 20% of flat surfaces showing signs of corrosion (both classified as ‘Fair’), the coating system would not necessarily be considered to have failed.

Given that these are complex spaces and large areas, this judgement as to percentage is made by eye and is thus truly subjective. As ballast tanks must be in good condition after 15 years, there is a potential for considerable argument/dispute as to this subjective assessment of the degree of failure that could result in costly unnecessary repairs at one extreme, and loss of life-through structural integrity at the other.

**Inspection tomorrow**
Safety of shipping operation is reliant on an effective maintenance policy. Inspections today come at a high cost and are often perceived as onerous and inefficient by owners.

Shipping is slowly starting to embrace the idea of predictive/risk-based maintenance, and remote inspection solutions equipped with various sensors are being developed and tested by major companies. For example, the drone industry is booming, and since 2018 the R&D efforts have focused on innovations in autonomous flight, utilising big data, machine learning and computer vision. In terms of coating related applications, drones can be adapted to carry out visual inspections of external structures or enclosed spaces in a pre-planned, efficient and repeatable way. The capability of drones goes beyond visual inspection and it extends to more complex tests such as thickness measurements by using ultrasound probes for example. The presence of surveyors is still necessary, but with the advances in virtual and augmented reality technology, this may not be a requirement in the near future.

The challenge of inspection is not only what data is recorded but what is presented, and how it is presented, as well as repeatability of inspections to allow subsequent follow up to be meaningful. Reporting should include not only close-up photographs of issues but also fuller views to allow extent and severity of an area under consideration to be assessed. However more detailed representations are required that not only identify the areas being inspected but also, the location of defects etc. to allow subsequent follow up.

To remove subjectivity in the assessment of coatings, there is a need for the development of through-life performance data that could be presented as degradation curves to enable preventative maintenance to be conducted to prevent system failure. The industry must also consider if the current levels of failure acceptable under the Good-Fair-Poor assessment approach is meaningful and appropriate.

The delivery of inspection services will also change, with paint companies taking a more commercial approach to the supply of inspectors and the need from the market shifting more toward better coating work supervision and planning at both new build and dry-dock which will likely be suited to be delivered by independent third parties. There is already evidence in some market sectors of this approach being increasingly adopted.

**Maintenance or repair**
Now
Maintenance is defined as the ability to maintain a given area in its present condition i.e. if it is in FAIR condition all maintenance can do is sustain it in that condition, whilst a repair would be able to restore the area to a GOOD condition. While dry-dock work is generally considered repair work, work carried out by the crew is usually considered as maintenance.

For maintenance to be effective then the crew needs to be trained accordingly. There is considerable in-house evidence [11] that a properly trained crew uses less paint and performs better repairs, reducing costs.

In the future
Significant challenges will be faced to maintain vessels, and minimise down time, resulting from repairs while in service, and there are several possible scenarios:

- a. Coatings, coating processes or alternative technologies will need to be improved or will be required to provide a 25-year life.
- b. Vessel life will be reduced because of lack of maintenance or increased off-hire periods will be required to address all issues at Dry-Dock.
- c. Riding crews will be required on the unmanned ship to minimise downtime and hence vessels will be part-time manned.

**Conclusions**
As discussed in the both parts of this article, there is no doubt that the stagnation of the process technology and the increased regulatory burden, cost, and time pressures on new construction, as well as the increased number of vessels that require drydocking as the fleet grows, then it is unlikely that the current approach to coatings will remain sustainable, and is likely to be an increasingly significant cost driver for ship owners/operators and a significant man-hour and cost burden on ship builders and repair yards.

The challenge is that the cost of development against the market persistence of driving prices down to commodity levels as the added value that coatings can provide is not clearly defined or accessible to all. This limits the ability to increase revenues sufficiently to develop new technologies. Similarly, the dominant coatings companies are largely wedded to the supply of paint, meaning that novel solutions will likely emerge from smaller and more dynamic companies either alone or in collaboration with the established players. This will raise significant challenges to the current business model and may result in novel approaches (already being trialled) where in effect the underwater hull or ballast tanks etc. are rented by the owner from the paint company as long as they deliver the required performance and the through
life maintenance will rest with the paint company or suitable third. The range of ship owner types however will likely preclude a “one size fits all” solution.

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BRANCH DATES
Following advice by the government in the ongoing situation with respect to the outbreak of coronavirus, all ICorr meetings and events have been cancelled until further notice, with the exception of those held online.

ADDITIONAL DIARY DATES
At the time of going to press, IMechE Argyll Ruane has been temporarily closed and is scheduled to open on April 13. The range of online ICorr training courses is continuing. Online training courses provided by Corrodere are continuing, however the scheduled assessments have been cancelled for the time being. For all enquiries please contact Meena Tipson on 01252 732 234.

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