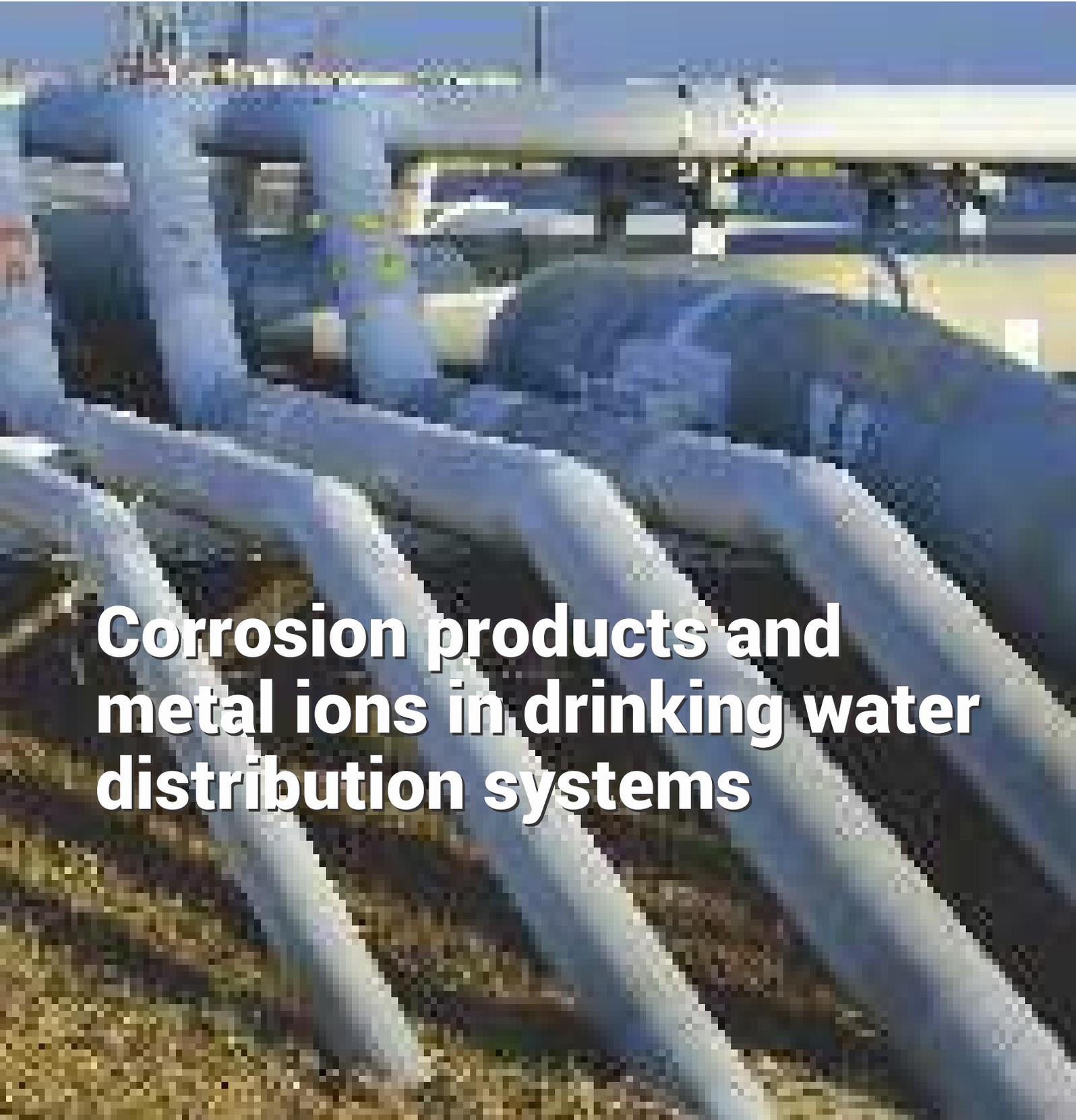


CORROSION COMBAT

January 2017

Quarterly Newsletter of  **NACE**[®] GATEWAY INDIA
INTERNATIONAL SECTION



**Corrosion products and
metal ions in drinking water
distribution systems**



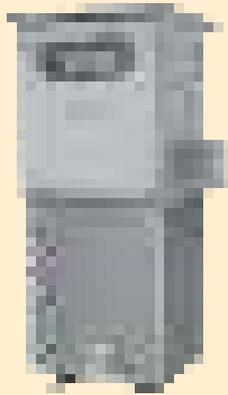
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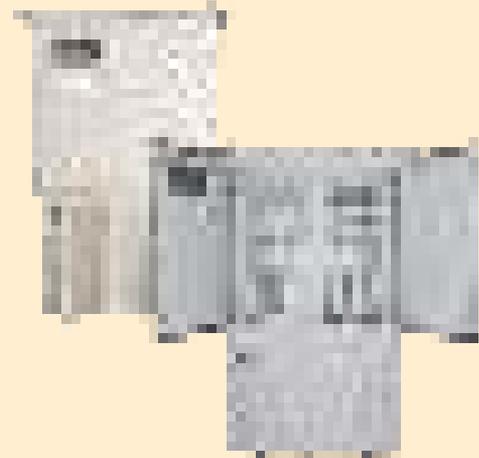


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INDEX

Editorial	
Anil Bhardwaj	3
Message from NIGIS India Chairman	
N Manohar Rao	5
The Relationship Between Iron Corrosion Products and Drinking Water Quality	
Brenda J. Little, Jason S. Lee and Tammie L. Gerke	9
CORCON 2016 –A Report	18
Development of Nanocontainer Impregnated Self-Healing Coatings for Active Corrosion Protection	
Arunchandran Chenan, R. P. George and U. Kamachi Mudali	22
Certification Program–A Report	28
MIC - Technical Interactive Exchange–A Report	30
Technical Activities - A Report	33
Foundation Day – A Report	35
Pipeline Corrosion – A Report	37
Selection of Suitable Superalloys for Industrial Applications	
I Gurrappa, T Sravan Kumar, I V S Yashwanth and N Das	38
Nace Headquarters - A Report	44
Corrosion Basics: Corrosion Potential	48

Corrosion Combat design & layout compiled by Rishikesh Mishra, Manager-Technical Services, NIGIS.

Letters to the editor are always welcome. We invite your suggestion, comments and views on the Newsletter as well as articles for publications. To publish your article, submit it to rishikesh@naceindia.org

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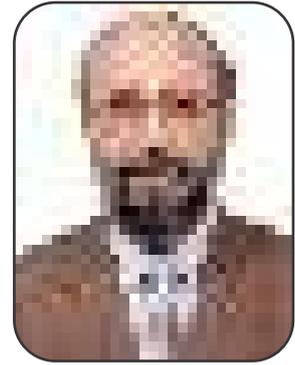
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Editorial



Dear Friends,

My heartiest greetings to all for the New Year.

Corrosion failures have repercussions in terms of safety and reliability of infrastructure, plants and assets. Corrosion failures also have a significant bearing on the insurance premiums paid by asset owners. An asset that is well maintained and well protected against corrosion, will attract a lesser premium from insurers whereas a badly corroded one may attract a high premium or in some cases may not even qualify for insurance coverage.

Damage to environment and loss of life resulting from failures due to corrosion failures has an adverse impact on image of an organisation and attracts heavy penalties from regulatory authorities. The adverse publicity and penalties are additional to the costs invested for remedial and updated measures for the asset to return to operational service.

Successful corrosion engineering application of corrosion control measures will save a significant sum of money for the industry and country. A highly trained corrosion workforce is needed to accomplish these goals. The current level of effectiveness of corrosion engineering curricula in the country is not sufficient to address the nation's need to address safety, reliability, and cost issues related to corrosion. The mission of NACE International equips society to protect people, assets and the environment from the adverse effects of corrosion is well addressed by increasing education and training on corrosion. But the issue can be comprehensively covered by incorporating corrosion engineering education, training, and research at multiple levels, viz. universities, government, and industry.

Anil Bhardwaj
Editor Corrosion Combat



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Message



On behalf of NACE International Gateway India Section, I wish you all A Happy New Year. New Year's Day marks more than just another turn of the calendar, and the symbolism of a new chapter in our lives. The start of 2017 promises to bring some real and substantial changes in our lives and work place.

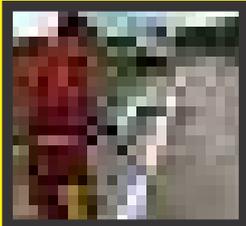
“If we do not learn from mistakes of history, we are doomed to repeat them”. The same we keep telling people about corrosion failures. Study the mistakes in the past to avoid repeating them in the future and learn from the positive things that have been done. If I were to select the major reason that progress is limited in corrosion control, I would have to say that the lessons of history are not reaching the right people – top management of industry and government. These are the people that make the final decisions of how and where money is spent, how manpower is used, where the major emphasis will be placed, and how much research will be done. After all, we have been dealing with severely corrosive environments all our professional lives. Our usual approach has been to minimize the effect of corrosion through protective coatings, CP etc.

I request you to attend CORCON 2017 Asia's largest Corrosion Conference on corrosion prevention and control to be held during 17-20 September 2017 at Mumbai. CORCON 2017 will provide an excellent opportunity for exchange of information on matters concerning corrosion and its control. Each year this premier event continues to grow in the number of valuable presentations and global leadership representation.

I would also like to thank you for all the support that you have given NIGIS. Please share your comments / feedback and let us all work together to build a Corrosion free planet.

N Manohar Rao
Chairman – NIGIS, 2016 - 2017

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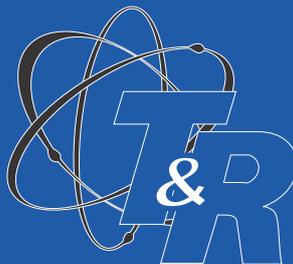
cable, the CI-50 is a stand alone interrupter which can be easily programmed with .1 second timing resolution. Additional current interrupters available with GPS timing synchronization.

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OBITUARY
IN THE MEMORY OF
P.F. ANTO
1941 – 2016

It is with sorrow that we inform you about the sad demise of Mr. P.F. Anto on 13 December 2016 in Kerala. He was born on June 9, 1941. He started his career with MES, worked for a few years with ONGC, then had a stint with Saudi Aramco. Mr Anto again worked with ONGC from where he retired as a General Manager. His area of work mainly covered cathodic protection of onshore and offshore pipelines and structures.

Mr. P F Anto was one of the oldest members of NACE International. After being inducted as a member of the executive committee of the India section in 1994, he served the section in various capacities including that of Trustee for the term 2000-03. His enthusiasm and zeal for NACE and the India section saw him make positive contributions for the growth and development of the section. For Mr. Anto, serving the India Section was a matter of pride and he was a constant source of motivation for his peers and colleagues. While his service to the section will be always remembered, his lively yet bold persona, his ability to use humour and his ringing laughter will be missed.

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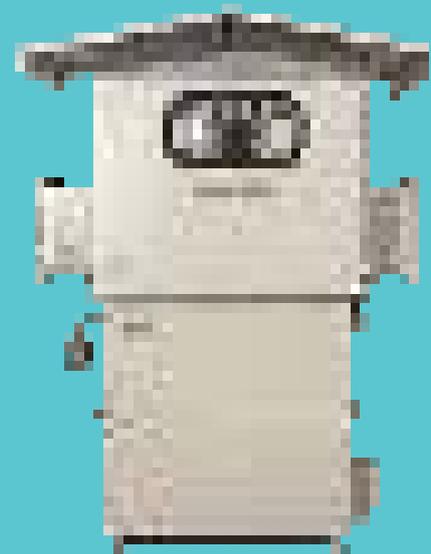
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The Relationship Between Iron Corrosion Products and Drinking Water Quality

Brenda J. Little and Jason S. Lee

Naval Research Laboratory
Stennis Space Center, MS 39529

Tammie L. Gerke

Department of Geology and Environmental Earth Science
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Middletown OH 45042

ABSTRACT

The relationship between iron (Fe) corrosion products and metal ions in drinking water distribution systems (DWDS) will be discussed. Specific adsorption and desorption mechanisms for divalent cationic strontium and pentavalent vanadium will be presented. Synchrotron-based techniques were used to characterize iron mineral phases and their concentrations and to map the distribution of metal ions associated with Fe corrosion products from DWDS pipes. DWDS Fe corrosion products are typically three-layered structures composed of a crust (exposed to drinking water), shell (an intermediate layer) and core (in contact with the iron surface). Lepidocrocite (γ -FeOOH) and goethite (α -FeOOH) are the predominant Fe oxyhydroxide minerals in the outer crust and core, separated by the shell composed of magnetite (Fe_3O_4). Fe oxyhydroxides have a high affinity for adsorbing metal ions, including vanadium, strontium, manganese, chromium, copper, lead, arsenic and uranium. Metal ions can be desorbed from Fe oxyhydroxides and reintroduced into drinking water via several processes including: change in flow, stagnation, switching source water, long distance water transfer, or change in water treatment chemistry.

Keywords: iron oxides, adsorption, desorption, vanadium, strontium

INTRODUCTION

Most drinking water distribution systems (DWDS) piping is iron (Fe), e.g., cast Fe, ductile Fe or carbon steel. Three problems are typically attributed to corrosion of Fe components in DWDS: 1) mass loss, 2) increased head loss and decreased water capacity and 3) release of soluble or particulate Fe corrosion products (i.e., red water phenomena).¹ An additional problem that has received little attention is the potential that Fe corrosion products are sinks for toxic metal ions that can be released back into drinking water.²⁻⁵ The following is a review of the relationship between toxic metal ions and Fe corrosion products in fully operational DWDS.

BACKGROUND

Fe components in DWDS are exposed to differing water sources, treatments and flow rates. The infrastructure of individual DWDS can be affected by changes in water sources and treatment regimes. In addition, primary transmission lines experience continuous flow; whereas, residential mains are subjected to periods of stagnation (low to no flow). Stagnation can cause localized changes in water quality, i.e., decreases in pH and disinfectant concentration.⁶

Source Waters

DWDS are maintained with surface waters, ground waters, reclaimed waters, desalinated waters and blends or combinations of sources. Each source water has a unique chemistry and contains a distinct microbial population. Toxic metal ions can be introduced into surface and ground waters as they flow through rocks or soils.

Source waters are routinely switched because of drought, contamination or increased demand (e.g., increased population). All source waters are corrosive to Fe components and changes in source waters can impact Fe release and the indigenous microbial community in the DWDS.⁷

Both transient and persistent biofilms in DWDS have been studied.⁸⁻¹² Li et al.⁷ evaluated the bacterial biofilm community in a DWDS that had been maintained with changing water supplies. They demonstrated that the microbial community and microbial diversity varied with source water and that switching source water had a substantial impact on the biofilm community in the distribution system. Mi et al.¹³ demonstrated that high concentrations of disinfectant could not prevent regrowth of biofilms in DWDS.

Water treatments

Water in DWDS is typically treated with oxidizing treatments, e.g., free chlorine, chloramines or both, to control water-borne pathogens. Free chlorine in drinking water is generated from chlorine gas (Cl_2), sodium hypochlorite solution (NaClO) and calcium hypochlorite [$\text{Ca}(\text{ClO})_2$] or from hypochlorous acid (HOCl). Chloramine, more specifically monochloramine (NH_2Cl), is formed when ammonia is added to chlorine.

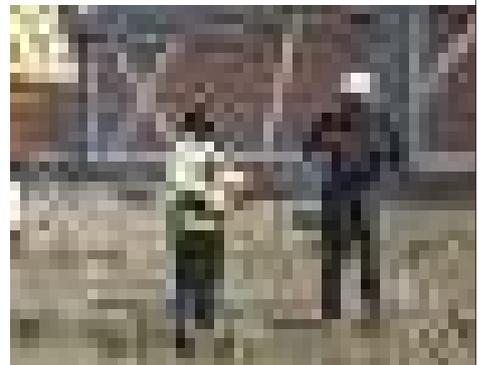
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- Consultancy On Rehabilitation Of CP Systems And Coating 1400 + Kms
- Cathodic Protection For Tanks & Bullets 250 + Nos And 500 + Nos Respectively



Chlorine compounds are highly reactive oxidizing agents that provide rapid disinfection by oxidizing microorganisms, organic compounds and pipe materials. The reaction with organic compounds produces disinfection by-products (DBP), some of which are potentially harmful to humans. In an attempt to avoid DBP, water utility operators may use chloramine for disinfection.

Oxidation Reduction Potential (ORP) and its Impact

ORP is the potential required to transfer electrons from an oxidant to a reductant. Oxidizing disinfectants increase the ORP in drinking water. Free chlorine produces a higher ORP than chloramines. All metals and alloys in DWDS infrastructures are susceptible to corrosion and in oxygenated water the corrosion products are typically composed of oxides, oxyhydroxides, or both. Free chlorine produces fairly stable corrosion products in most metallic pipes that can be disrupted with the transition to chloramines. Corrosion products formed in the presence of chlorine have higher oxidation states (e.g., Fe^{3+} and Pb^{4+}) than those formed in the presence of chloramine (e.g., Fe^{2+} and Pb^{2+}).¹⁴ Chloramine is more persistent in drinking water, leading to longer contact times with pipe materials. Gerke et al.¹⁵ demonstrated that Fe corrosion products formed in chloramine disinfected waters were porous and fluffy compared to compact, dense corrosion products formed in water treated with free chlorine. Chloramines can also cause nitrification if ammonia is allowed to remain in the DWDS. Differences in reactions of pipe materials with chlorine and chloramine become important when disinfectants are switched. For example, utilities have reported increased concentration of metal ions in the water system when the disinfectant was transitioned from free chlorine to chloramine.¹⁴ Mi et al.¹³ demonstrated that disinfectant type and dosage affected the bacterial communities in DWDS. Revetta et al.⁸ reported that nitrification due to chloramine caused an increase in nitrifying bacteria.

Fe Corrosion Products and their Properties

Fe oxides and oxyhydroxides can be produced in DWDS by corrosion processes, i.e., electrochemical reactions at the metal/water interface.¹⁶⁻¹⁸ Corrosivity of a specific drinking water depends on pH, alkalinity, dissolved oxygen, and total dissolved solids.¹⁸ Corrosion is also influenced by temperature and hydrodynamics. Sarin et al.¹⁷ identified goethite, magnetite and lepidocrocite as the primary minerals in dried Fe corrosion products. They reported high concentrations of readily soluble Fe^{2+} phases in wet Fe corrosion products. Yang et al.¹⁹ reported

that magnetite and goethite were the main constituents in Fe corrosion products in DWDS, but that the ratio magnetite/goethite varied with water source, i.e., surface water vs. groundwater. They stated that Fe corrosion products in systems using surface water had thick scales and densely distributed tubercles with high magnetite/goethite ratios (>1.0). Thin Fe corrosion products in systems using ground water contained comparatively less magnetite with higher surface areas and higher sorption capacities.¹⁹

Fe oxyhydroxides in DWDS can also be produced by FeOB during the oxidation of Fe^{2+} to Fe^{3+} . Miller and Tiller²⁰ indicated that FeOB, together with the ferric oxyhydroxide they produced, could form extensive deposits inside DWDS. Some FeOB, e.g., Gallionella, extrude abiotic polymeric structures, e.g. stalks or sheaths, upon which they deposit Fe^{3+} . The result is bacteriogenic Fe oxides (BIOS), fine grained (2 to 500 nm) Fe minerals that are mixed with live bacteria, cellular debris and extracellular polymeric substances. The dominant mineral phase in BIOS is 2-line ferrihydrite ($\text{Fe}_2\text{O}_3 \cdot 0.5\text{H}_2\text{O}$)²¹ that can convert to goethite over time.²² BIOS have the same physiochemical properties reported for other fine-grained Fe oxyhydroxides. BIOS act as sorbents of dissolved metal ions and enrichments of Cu, Pb, Cd, aluminum (Al), Cr, Zn, manganese (Mn) and Sr have been reported.²³⁻²⁵ Once deposited, BIOS surfaces have negative charges so that metal ion sorption can continue indefinitely without biological activity. The role of bacteria in the red water phenomenon has been documented by several investigators. Li et al.²⁶ reported that the most distinct difference between microbial communities in red water samples and control water samples was the abundance of FeOB.

Many authors have demonstrated the metal cation/oxyanion sorption capacity of Fe oxides using pure oxides.²⁷⁻²⁹ Because of their adsorbent properties, Fe oxide minerals, including goethite, hematite (Fe_2O_3), siderite (FeCO_3), limonite [$\text{FeO}(\text{OH})\text{nH}_2\text{O}$], ferrihydrite and magnetite, have been evaluated as commercial treatments for removing As from drinking water.³⁰ The relationship between metal ions and corrosion products in DWDS has been demonstrated in a limited number of studies.

Lytle et al.³¹ collected Fe corrosion products from an area in the United States where as in drinking water is acknowledged. The undefined Fe solids contained As concentrations of 10 to 13, 650 $\mu\text{g g}^{-1}$. One of the significant findings from their survey was the absence of a correlation between As concentrations in the drinking water

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- Systems Have Passed The Strictest Standards Of The Control Institutes Worldwide

and accumulation in corrosion products, i.e., significant amounts of As were found in solids where As concentrations in the drinking water were $<1 \mu\text{g L}^{-1}$.

Gerke et al.³² examined the potential for Sr^{2+} binding to goethite in four DWDS. The DWDS were maintained with waters having $\leq 0.3 \mu\text{g L}^{-1} \text{Sr}^{2+}$, i.e., all waters were within U.S. guidelines. Yet, average Sr^{2+} concentrations in the outer most layer of the Fe corrosion products ranged from 3 to 54 mg kg^{-1} . Synchrotron-based μ -X-ray adsorption near edge structure (μ -XANES) and linear combination fitting determined that Sr^{2+} was associated as a surface complex with goethite and incorporated into calcite (CaCO_3). Fe particulates from a filter inside a home in one DWDS had an average Sr^{2+} concentration of 40.3 mg kg^{-1} and the associated drinking water at a tap was 210 mL^{-1} .

Gerke et al.^{33,34} demonstrated discrete grains of vanadinite [$\text{Pb}_5(\text{V}^{5+}\text{O}_4)\text{C}_{13}$] associated with surfaces of Fe corrosion products composed predominantly of goethite. The total V concentration of the treated drinking water was 1.4 to $1.7 \mu\text{g L}^{-1}$; whereas the concentration in Fe corrosion products was $899 \text{ mg kg}^{-1} \text{V}$. Concentrations of Cr, Ni, Cu, Mn and Pb were also located in surface Fe corrosion products.

Reversibility of metal sorption, i.e., desorption, from goethite and other Fe oxyhydroxide is predictable and can be influenced by the transformation or aging of metastable sorbent phases. With aging, sorbed metal ions can be incorporated into the mineral structure or desorbed. Ion exchange, i.e., replacement of an ion in a solid phase in contact with a liquid by another ion, is typical for outer sphere complexes. In a model flow system, Gerke et al.¹⁵ demonstrated desorption of Sr^{2+} from newly formed Fe corrosion products. However, the conditions which cause re-suspension and dissolution back into drinking water have not been defined.³⁵

Sarin et al.³⁶ described the outermost layer of Fe corrosion products in DWDS (in contact with drinking water) as loosely held particles of lepidocrocite and amorphous $\text{Fe}(\text{OH})_3$ that could easily be transported to the bulk water, producing red water. Red water events have been triggered by alternating periods of stagnation, alternating aerobic and anaerobic conditions, changes in source water, changes in disinfectant, introduction of polyphosphates or orthophosphates and hydraulic entrainment due to changes in flow rate or direction. The association of toxic metal ions with Fe oxides and oxyhydroxides in red water has not been addressed.

CONCLUSIONS

Drinking water quality may be acceptable immediately after treatment, but the quality may deteriorate before the water reaches the tap. In the U.S. current testing methods for detecting toxic metal ion contamination specify testing the drinking water at the point of entry into the system and at the point of maximum residence time, not at the tap. Toxic metal ions of As, V and Sr can accumulate in Fe corrosion products in functioning DWDS. What is less understood is the potential for release of the toxic metal ions into the drinking water. Furthermore there has been little recognition that red water phenomena could be associated with toxic metal ions.

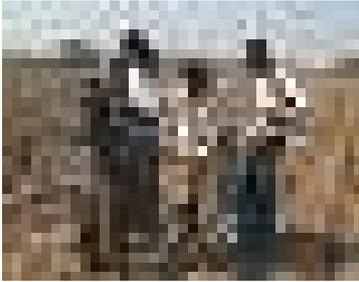
ACKNOWLEDGMENTS

NRL Publication number NRL/OT/7303-16-3275. Funding support from NRL Base Program.

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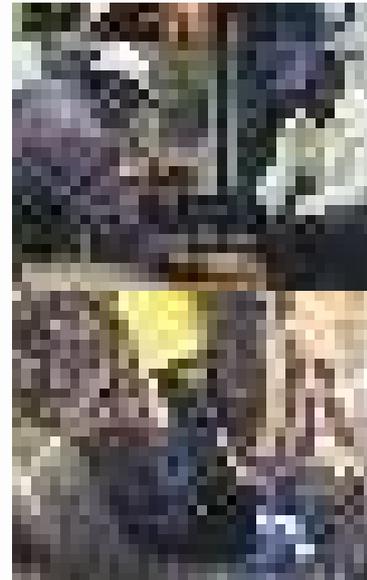
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CORCON 2016: International Corrosion Conference and Expo September 18 - 21, 2016

"A recent study has shown that 30 percent of failures on ships and other marine structures and assets occur due to corrosion," said Director General Indian Coast Guard Rajendra Singh, while speaking as the Chief Guest at the inaugural function of The 24th Annual Corrosion Conference and Expo (CORCON 2016) at The Leela Ambience Convention Hotel, New Delhi. "The cost of corrosion is estimated to be around 3.2 percent of the global GDP. Corrosion has an enormous impact on the military. There are direct costs like manpower and materials and indirect costs like vessels' downtime. The drag and propulsion power required due to marine fouling and corrosion can increase the consumption and cost of fuel by as much as 40 percent. Therefore, it is of prime importance to look at ways to prevent and mitigate corrosion."

CORCON is organized by NACE International Gateway India Section (NIGIS), one of the largest and the most active section of NACE International. CORCON is a unique event where the world corrosion fraternity comes together to present breakthrough research achievements, showcase latest technologies and products, conduct brain storming sessions to solve challenging issues in various industries and topping all to develop a network of corrosion professionals that soon evolves into fruitful international collaborations, control prevention and maintenance activities.

This year the event was held on September 18 – 21, 2016, and attended by over 800 delegates and 80 exhibitors from around the world. The theme of the conference was, "Managing corrosion prevention, inspection and mitigation from inside out".

CORCON is supported by the Department of Chemicals & Petrochemicals, Ministry of Chemicals and Fertilizers of Government of India, Federation of India Chambers of Commerce and Industry, Department of Commerce of the United States of America, Petrofed, Petrotech and the Australasian Corrosion Association.

Welcoming the guests and delegates, Dr U. Kamachi Mudali, Chairman, CORCON 2016 extolled the virtues of the discoveries made in India ages ago by kingdoms who had mastered the art of corrosion mitigation. "The centuries old Iron Pillar in Delhi and the bronzes of South India are some of the outstanding examples," he said.

Mr Anand Kulkarni, Trustee 2016-19, NIGIS, said: "Declining oil prices and global recessionary trends have forced organizations to seek ways to optimize costs. To this end, effective management of corrosion can in fact provide a competitive edge to asset owners. A critical component of effective corrosion management is proper training of our work force. Also important for creating a climate conducive to implementing corrosion management across organizations is government policy and legislation."

Mr B. Narayan, Group President (Procurement & Projects), Reliance Industries Ltd, said: "CORCON has always been a learning experience for me. Being a person from the refinery industry I would say that the cost of corrosion in this industry alone worldwide is estimated to be US\$ 9 billion. Ensuring a coatings and corrosion mitigation program right from the beginning itself will ensure that the plant has its run for its lifetime."

"It's exciting times for NACE International," said Mr Sandy Williamson, President, NACE International 2016-17, "as our strategic plan has continued to be challenged and optimized by the Board of Directors and now encompasses the areas of product and service diversification, member engagement, public policy, operational excellence, and board sustainability. These initiatives will ensure that NACE continues to grow in the right direction."

Robert H. Chalker, Chief Executive Officer, NACE International, noted that the organization is making a difference in over 100 countries. "The initiatives we started have started to blossom now. For example four years ago, we decided to invest heavily in education and certification programs. Next we decided to have outreach programs to reach out to government officials, lawmakers and regulators. We are working hard in regions such as the Middle East, China, Canada, Australia and looking at Europe. We are also looking at partnering with societies and organizations having common agendas. Today, we are now a 36,000 member organization with staff strength of 170 spread over 100 countries."

Dr Samir Degan, Vice President 2016-2017 noted that NACE International's recently released global cost of corrosion study – International Measures of Prevention, Application, and Economics of Corrosion Technologies (IMPACT) has found that the cost of corrosion world wide is over US\$2.5 trillion. "We at NACE International believe that at least 15 to 35 percent of this cost can be saved by using available practices and technologies in our routine working environments. Further costs can be reduced by incorporating corrosion prevention technologies and practices at the design stage of the asset. The IMPACT study also emphasizes the necessity of incorporating corrosion management systems in all organizations as a standard practice to maximize the benefits of reducing costs due to corrosion." CORCON 2016 also saw the launch of NACE International Gateway India Section's India focused IMPACT study for which participation and interactions were invited from the corrosion mitigating fraternity from all over the country.

Spread over four days, CORCON 2016 was a technical fest with six plenary lectures, 19 invited talks, 188 technical papers in 14 symposia including a poster and two student symposia, besides six technical interactive forums along with an innovative event '*Jung se Jung*,' (Fighting Corrosion) jointly organized with GAIL.

The six technical interactive forums had an excellent participation with purposeful discussions. The topics covered were: Delivering Performance through Optimum Coating Specifications; Water Treatment; Water Transmission Pipelines; Corrosion in Concrete; Regulations and Standards in Corrosion; and Corrosion in Refinery and Petrochemicals.

A cultural program was held on the first day of the event with a colorful and educative entertainment program.

22nd Annual Corrosion Awareness Awards were also presented CORCON 2016. The winners were: For Excellence in Corrosion Science and Technology in Research and Education, Dr Bharat Bhushan Jha, CSIR – Institute of Minerals and Materials Technology, Bhubaneswar; Excellence in Corrosion Science and Technology in Oil and Gas, Mr Shailesh D. Javia, SGB Scaffolding and Industrial Services Pvt Ltd., Ahmedabad; Distinction in Corrosion Science & Technology in Research and Education, Dr R. Balaji Naik, Naval Materials Research Laboratory, Ambernath; Distinction in Corrosion Science and Technology in an Industrial Organization, Mr Rituraj Mishra, Bharat Petroleum Corporation Ltd., Mumbai; Student Award for PhD, Dr L. Mohan, Anna University, Chennai; Student Award for M Tech, Ms Krishnaveni, PSGR Krishnammal College for Women, Peelamedu; Meritorious Contribution to Research and Education, Dr Rani P. George, Indira Gandhi Centre for Atomic Research, Kalpakkam; Meritorious Contribution to Industry, Dr Anil Bhardwaj, ONGC, Panvel; Excellent Laboratory Award, Tata Steel – Advanced Corrosion Research Centre, Jamshedpur; Lifetime Achievement Award, Prof K. A. Natarajan, Indian Institute of Science, Bangalore; and Recognition of Excellent Service of Late Shri R. P. Nagar, for the growth and development of the NACE International Gateway India Section. The awards were presented by Mr Sandy Williamson, President, NACE International.

The valedictory function was held on September 21, 2016 where the dates for CORCON 2017 were announced. It will be held in Mumbai, September 17 – 20, 2017.

Glimpses of CORCON 2016



Dr. U. Kamachi Mudali, Chairman, CORCON 2016 warmly welcoming the fellow delegates



Dignitaries during lighting the lamp to inaugurate the conference



Dignitaries on the Dias releasing the CORCON 2016 Souvenir



Delegates during the inauguration session



Director General Indian Coast Guard Rajendra Singh inaugurating the CORCON exhibition



Dr. Indranil Manna, Director, IIT Kanpur delivering the Plenary Talks

Glimpses of CORCON 2016



Panel Members during Technical Interactive Forum



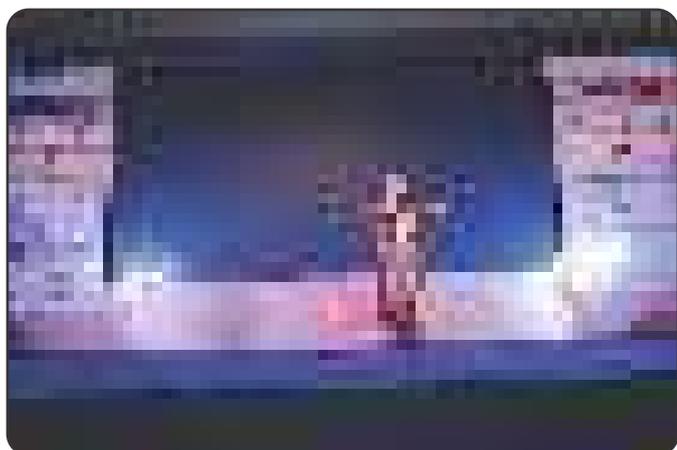
Sandy Williamson, President, NACE International addressing the delegates during Jung se Jung workshop



Dignitaries with the winners of Corrosion Awareness Award 2016



Exhibition premises of the conference



Cultural programme during the conference



Best Paper awards presented during the Valedictory function

Development of Nanocontainer Impregnated Self-Healing Coatings for Active Corrosion Protection

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Abstract

The article presents important results from studies carried out towards developing nanocontainer impregnated coatings with self-healing ability for active corrosion protection. Self-healing coatings were applied over modified 9Cr-1Mo ferritic steel which is widely employed in various fields such as nuclear, petroleum and chemical industries. A silane-zirconia hybrid coating matrix was used to impart passive barrier protection and the coating matrix was impregnated with inhibitor loaded nanocontainers to provide active functionality to the coating system. Three different nanocontainers, TiO₂ nanotube powders, hollow mesoporous silica spheres and hollow mesoporous zirconia spheres were synthesized and used as nanocontainers for loading corrosion inhibitors 2-mercaptobenzothiazole (2-MBT) and benzotriazole (BTA). Electrochemical Impedance Spectroscopy (EIS) was employed in this study as an effective tool for the investigation of active corrosion protection. A self-healing epoxy coating were also made and its long-term corrosion protection efficiency was studied using salt-spray analysis

Introduction

Corrosion of materials and structures is a hindrance to the development of society as it causes significant loss to the economy and hence its prevention and control is of great benefit for the humanity. Application of organic/polymeric coating system is one of the widely used strategies to combat corrosion of metals and alloys under service conditions. A typical protective coating system includes a pre-treatment layer or conversion layer, a primer and a topcoat. Chromate and phosphate conversion coatings are widely used strategies to obtain a pre-treatment layer to improve the adhesion of subsequent organic coatings for both ferrous and non ferrous alloys. But the extreme oxidation property of Cr (VI) causes several health problems to humans and it is carcinogenic in nature. Similarly, the corrosion protection performance of zinc phosphate coating is not good enough for outdoor exposure. Hence, there is a strong necessity for developing an environmentally- friendly surface pre-treatment for all coatings [1-4].

One of the most promising alternatives to the above mentioned toxic surface treatment for corrosion protection is sol-gel coatings [5, 6]. Corrosion protection provided by a barrier film, which avoids any interaction of metallic substrate with external environment, is known as passive protection. However, sol-gel coatings are not completely free from cracks and defects and this leads to the penetration of electrolyte and water into metal surface for initiating corrosion reactions. Hence, it is ideal to introduce active agents or corrosion inhibitors into the barrier coatings to enhance its anticorrosion property. Corrosion protection provided by active agents or corrosion inhibitors is known as active corrosion protection. In active corrosion protection methods, corrosion inhibitors are incorporated into the protective barrier layers which become active and decrease the corrosion rate when the passive barrier layer starts deteriorating [9]. Since the direct addition of inhibitors has negative effect on the barrier coatings, it is advised to load the inhibitors in micro/nano containers prior to mixing with the coating [5, 6].

Nano or microcontainers with sustained release properties can be used in a new class of self-healing coatings. The self-delaying and protection from corrosion activity of a defect causing corrosion in a coated material by any mechanism can be considered as "self-healing". When the environment around the coatings changes, nanocontainers sense the same and would release quickly the inhibitor for delaying corrosion activity. The present article is focused on the development of effective anticorrosion coatings for modified 9Cr-1Mo ferritic steels using active corrosion protection.

Design of Self-healing Coatings for Active Corrosion Protection

The selection of the proper nonmaterials which can act as a good container for loading inhibitors is the most important parameter for designing a self-healing coating. Moreover, the selected nanocontainers should be compatible with the organic-inorganic hybrid sol-gel film matrix used

as barrier coatings. Figure 1 shows the images of the nanocontainers.

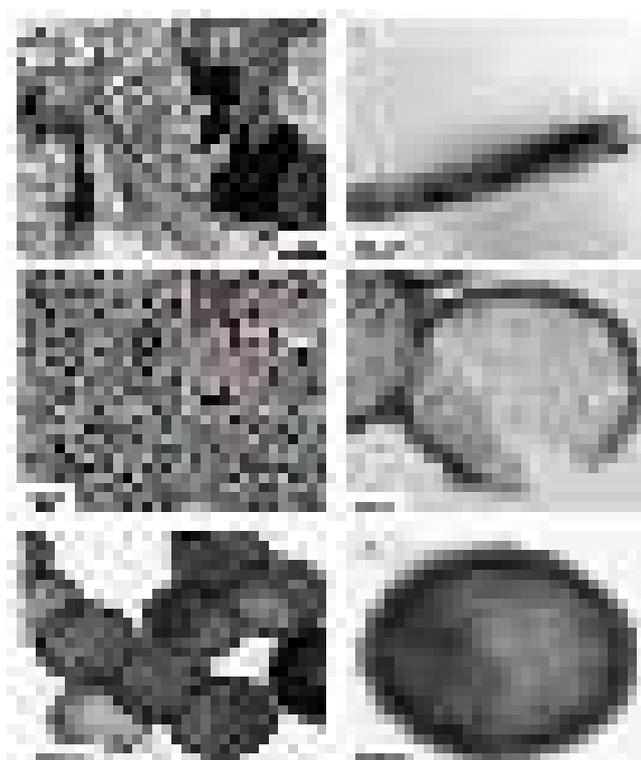


Figure 1: Images of synthesized nanocontainers; (A) SEM image of bundles of TiO_2 nanotubes, (B) HRTEM image of single TiO_2 nanotube, (C) SEM image of hollow mesoporous silica nanocontainers, (D) HRTEM image of hollow mesoporous silica nanocontainers, (E) HRTEM image of hollow mesoporous zirconia nanocontainers, (F) a single hollow mesoporous zirconia nanocontainers

The small size of the nanocontainers, generally less than 400 nm helps for homogeneous mixing of the nanocontainers in the coatings. Three different nanocontainers, TiO_2 nanotube powders, hollow mesoporous silica spheres and hollow mesoporous zirconia spheres were synthesized and used as nanocontainers for loading corrosion inhibitors 2-MBT. The details of the synthesis procedure adopted for preparing these three different nanocontainers was published elsewhere [6-9].

Inhibitor Loading and Releasing properties of Nanocontainers

Inhibitor molecules were dissolved in ethanol or acetone at desired concentration. For a typical loading process, about 100 mg of nanocontainers was added to 50 mL of inhibitor solution in a beaker and it was sealed in order to avoid any evaporation of solvent and stirred electromagnetically for 24 h. The loading of inhibitors into the nanocontainer was confirmed using UV-visible and Raman spectroscopic studies. The UV-visible and Raman spectroscopic studies for 2-MBT@ TiO_2 nanocontainer system are depicted in Figure 2.



Figure 2: UV-visible and Raman spectra of 2-MBT before and after loading in TiO_2 nanocontainer

The UV-visible spectra (Figure 2(a)) showed the successful encapsulation of 2-MBT into TiO_2 nanocontainers. This decrease in the absorption intensity of 2-MBT after the interaction with TiO_2 nanocontainers confirmed the decrease of the 2-MBT concentration in the solution as well as the successful loading of the 2-MBT molecules into TiO_2 nanocontainers. The loading efficiency of 2-MBT in the TiO_2 nanocontainer was found to be 73%. The loading of 2-MBT into TiO_2 nanocontainer was further confirmed using Raman spectroscopy. Figure 2(b) depicts the Raman spectra of pure 2-MBT, TiO_2 and 2-MBT@ TiO_2 . The characteristic peaks of both 2-MBT and TiO_2 were present in the spectra of 2-MBT@ TiO_2 . The presence of the peaks of 2-MBT in 2-MBT@ TiO_2 confirmed the successful loading of 2-MBT into TiO_2 nanocontainer

The continuous and sustained release of the inhibitor molecules from the nanocontainers on demand is the major functionality of the coatings to impart active corrosion protection. Figure 3 shows the release profile of TiO_2 nanocontainers.

The release behavior of inhibitor molecules from nanocontainers is demonstrated here using 2-MBT@TiO₂ system. The release profile of 2-MBT loaded TiO₂ nanocontainer system was investigated by UV-visible analysis of NaCl (0.05 M) suspensions of 2-MBT loaded TiO₂ at different pH values. The releasing of MBT from TiO₂ followed similar release kinetics at different pH values. The release of MBT was leveled off and reached equilibrium in 5 h at pH 10, however, amount of 2-MBT released was higher compared to that of pH 7. It was observed that higher amount of 2-MBT was released from the TiO₂ at pH 3 and 10 compared to pH 7. The amount of MBT released after 28 h under acidic and alkaline conditions were 0.30 mg mL⁻¹ and 0.27 mg mL⁻¹ respectively, while in neutral conditions it was 0.23 mg mL⁻¹ only. The difference in the release rate and quantity of MBT released from TiO₂ can be explained by the variation of solubility of MBT and the differences in the surface charge of both MBT and titania particles with pH.

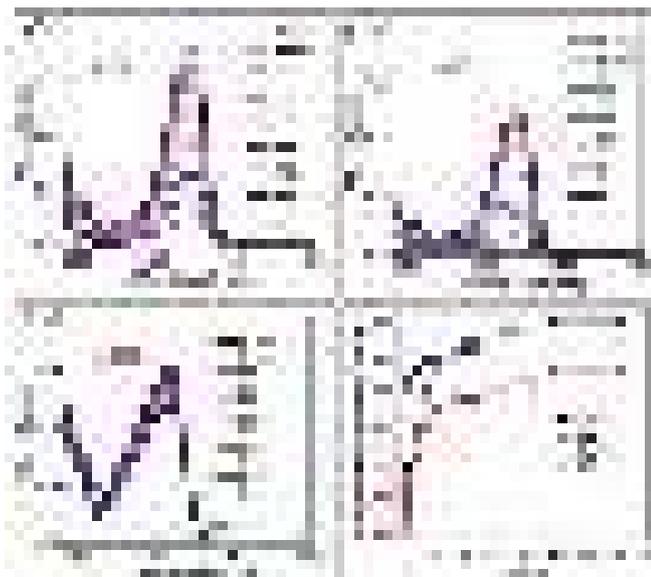


Figure 3: UV-vis spectra at different times of the 0.05 M NaCl media in which 2-MBT was released from 2-MBT loaded TiO₂ nanocontainers (a) at pH 3, (b) at pH 7, (c) at pH 10 and (d) corresponding pH-dependent releasing behavior of 2-MBT from TiO₂-MBT system

The solubility of 2-MBT is low in neutral pH, but relatively higher in alkaline and acidic conditions. Both the titania particles and the inhibitor molecules have the same surface charge when the pH vary from neutral pH values. This led to

electrostatic repulsion between the TiO₂ nanocontainers and 2-MBT, thereby facilitating the diffusion of MBT through the pores of TiO₂ nanocontainers and faster release. This dependency of inhibitor release on pH confirmed the stimuli responsive intelligent releasing property of TiO₂ nanocontainers. Furthermore, this observation can be extrapolated to a corrosion process, because corrosion of metals is always accompanied by changes in local pH.

Preparation of Coatings and Evaluation of Active Corrosion Protection

After successful synthesis of TiO₂ nanocontainers and loading of 2-MBT into the nanocontainers, the 2-MBT@TiO₂ system was mixed with silane-zirconia hybrid coatings. The 2-MBT@TiO₂ mixed coatings were applied on the metallic substrates through dip coating method. EIS is an ideal technique to investigate active corrosion protection based on self-healing of defects in a coating. Figure 4 shows the evolution of impedance response of scratched plain hybrid coating with and without inhibitor loaded nanocontainers for 1 week while immersed in 0.01 M NaCl solution for 2-MBT@TiO₂ system after making an artificial scratch on the coatings. After 1 h of immersion itself, three relaxation processes occurred on the surface of plain hybrid coating. The first relaxation process is the response of the hybrid coating due to its barrier property and it appeared in the high frequency region of the Bode plot. The second in the mid frequency range is due to the response of the oxide layer on the alloy surface and the third time constant at low frequency region is due to the corrosion activity. This indicates that within 1 h, the electrolyte could access the underlying metal surface and plain hybrid coating failed to give any protection. After 3 days of immersion, the second time constant disappeared from the EIS spectra and this could be due to the rupture of the oxide layer. All the previously mentioned observations indicated that plain hybrid coating was corroding continuously during immersion.

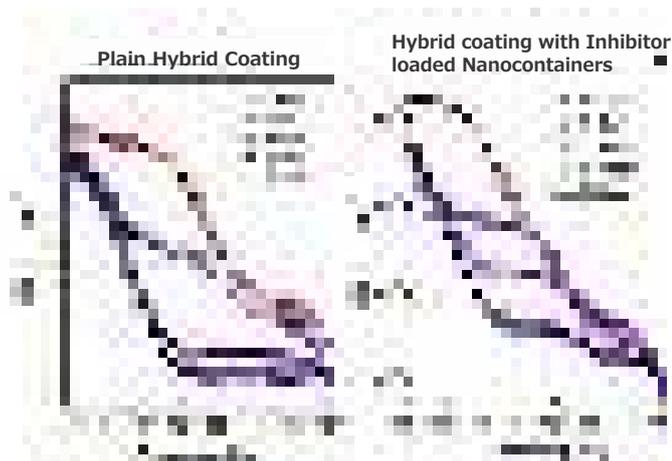


Figure 4: EIS response of plain hybrid coating and hybrid coating with inhibitor loaded nanocontainers (2-MBT@TiO₂ system) during immersion in NaCl solution after making an artificial scratch

However, the EIS response of the hybrid coating with inhibitor loaded nanocontainers was different. The EIS response of hybrid coating with inhibitor loaded nanocontainers after 1 h of immersion had two time constant; the relaxation process occurred at high frequency is assigned to the barrier property of the coating and the second time constant is due to the response of the oxide layer. No relaxation process due to corrosion was observed in the impedance spectra of hybrid coating with inhibitor loaded nanocontainers. During 1 week of immersion, from 24 h to 168 h the impedance value at low frequency almost remained unaffected and this suggests active corrosion protection. The relaxation process due to corrosion activity was not developed fully. The final relaxation process was more of capacitive in nature and less of resistive. The aforementioned results confirmed that the higher corrosion resistance rendered by hybrid coating with inhibitor loaded nanocontainers could be due to the release of the inhibitor from nanocontainers embedded in the coating, because plain hybrid coating did not show this effect.

In order to fabricate a model anticorrosive coating which can be used in marine as well as industrial environments, an epoxy coating with pretreatment layer containing inhibitor loaded titaniana nocontainers was also prepared and applied on 9Cr-1Mo ferritic steels. This Epoxy Nanocontainer Coating (ENC) was exposed to neutral salt spray along with Plain Epoxy Coating

(PEC) in order to evaluate its long term active corrosion protection efficiency. Both the Epoxy Nanocontainer Coating (ENC) and reference coating (Plain epoxy coating, PEC) were exposed to 1000 h of salt spray test. Two sets of coated specimens were exposed to salt spray test.

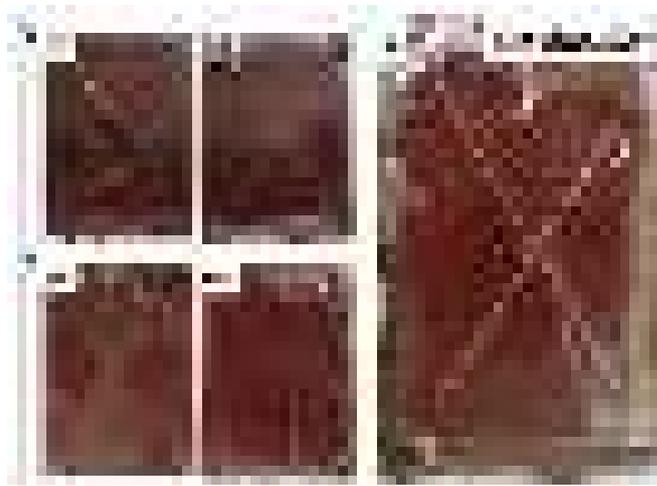


Figure 5: Photographs of the Epoxy Nanocontainer Coating (ENC) and reference coating (Plain epoxy coating, PEC) after 1000 h of exposure to neutral salt spray test; (A) first set, (B) second set; (C) Epoxy Nanocontainer Coating (ENC) after 2000 h of exposure to neutral salt spray test

Blistering of the coatings and under coat corrosion was clearly visible in the case of PEC after 1000 h of salt spray exposure. Moreover, a small flake of the coating was peeled off due to the loss of adhesion to the metallic substrate (Figure 5(a)). Conversely, no delamination of coatings was observed for ENC. Insignificant rust markings appeared on one side in the scratched area of the coating (Figure 5(a)). However, in the second set of tested samples, such rust markings were not observed on the scratched area (Figure 5(b)). The salt spray chamber test showed sufficient protection even after 1000 h of exposure for inhibitor loaded nanocontainer mixed epoxy coating compared to that of reference (plain top epoxy) coating. The salt spray test for ENC was further continued until 2000 h of exposure and the image of the 2000 h salt spray exposed specimen is presented in Figure 5 (c). It was observed that even after 2000 h of salt spray exposure, the coating was intact and significant damage due to corrosion had not occurred on ENC

Proposed Mechanism for Active Corrosion Protection based on Self-healing Ability

The initiation of corrosion process itself can act as a trigger for the release of the inhibitor molecules from the nanocontainer. The improved corrosion protection of the coating can be explained by a self-healing mechanism. A graphical illustration of the proposed mechanism is presented in Figure 6. If any local damage occurs in the coating, corrosion will initiate on the alloy surface. Localized corrosion of ferritic steels is commonly accompanied by change in pH at the micro anodes and micro cathodes. The enhanced corrosion resistance showed by the inhibitor loaded nanocontainer mixed hybrid coating can be explained as follows; as the immersion time increases, the water molecules and corrosive species enters to the coating through the pores and cracks of the coatings.



Schematic self healing mechanism:(a) Compact coating, (b), Controlled release of inhibitor from the nanocontainer in reply to corrosion activity which is accompanied by pH change.

Figure 6: Schematic self healing mechanism for active corrosion protection

This electrolyte solution could infiltrate into the nanocontainers through the pores and the inhibitor molecules could diffuse along this aqueous pathway. When any corrosion activity takes place low pH prevails around the micro anode and alkaline pH develops around the micro cathode area. This change in local pH will increase the release rate and quantity of the inhibitor released from the nanocontainers. The anticorrosive property of the organic inhibitor 2-mercaptobenzothiazole is based on producing a film on the alloy surface and this layer acts as physical barrier to aggressive corrosive ions. When pitting corrosion is initiated, these organic inhibitor molecules can form complexes with the

metal ions and form a protective layer and that stops further dissolution of the metal and alloys.

Conclusions

The present article contributes to the development of nanocontainer impregnated hybrid coatings for active corrosion protection based on self-healing ability for modified 9Cr-1Mo ferritic steels. Three nanocontainer systems were synthesized and loaded with corrosion inhibitor molecules of 2-MBT. The loading of inhibitors and its sustained pH-responsive release from the nanocontainers were demonstrated. Both the active and passive corrosion protection of the coatings were studied using EIS and salt spray analysis. Based on the evidences obtained from EIS studies, a possible mechanism for self-healing ability is proposed.

Acknowledgement: The author C. Arunchandran acknowledges HBNI and Prof. U. Kamachi Mudali at IGCAR, Kalpakkam for allowing to pursue PhD works. This work received Best PhD Thesis Award from NIGIS, Mumbai during CORCON 2015 at Chennai.

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U. Kamachi Mudali holds an M. Sc. in Materials Science, an M. Tech in Corrosion Science and Engineering, and a PhD in Metallurgical Engineering. He has 32 years of R & D experience in nuclear industry towards materials development and selection, corrosion engineering, surface modification & coatings, corrosion monitoring, and failure analysis related to steels & stainless steels, titanium, zirconium and their alloys related to fast breeder reactor and associated spent nuclear fuel reprocessing plants. He has been an outstanding scientist and the Associate Director of the Corrosion Science and Technology Group and Materials, Process, Equipment Development Group at IGCAR. He is a Fellow of NACE International, ASM International, Asia Pacific Academy of Materials, Indian National Academy of Engineering, Institution of Engineers (I), Indian Institute of Metals, Tamil Nadu Academy of Sciences, and Honorary Fellow of the Electrochemical Society of India. He has published 387 papers in journals, co-edited 15 books/proceedings, and holds an H-index of 30. He has guided/coordinated project works of 154 students for their undergraduate, postgraduate, and PhD degrees. He is a Senior Professor at Homi Bhabha National Institute University and an Adjunct Professor at the PSG Institute of Advanced Studies, Coimbatore. He has received several prestigious awards and honors including Meritorious Award for excellent contributions to corrosion science and Technology from NACE, India. Currently he is focusing on fast breeder reactor spent fuel reprocessing, with respect to: engineering development, nonmetallic materials development, process chemistry, modeling, equipment development and aqueous electrochemistry. (E-mail:kamachi@igcar.gov.in)

A Report - NACE International Certification Courses

For over 30 years, the NACE Coating Inspector Program has set the standard for inspections in the protective coatings industry and is the world's most recognized coating inspector certification program. CIP is the first international certification program designed to improve the overall quality of inspections performed, and it continues to provide the most complete training curriculum, producing top-notch inspectors for the industry.

CIP Level 1 course offers over 60 hours of instruction on the technical and practical fundamentals of coating inspection work for structural steel projects. This course provides students with knowledge of coating materials and techniques for surface preparation and application that prepares the student to perform basic coating inspections using non-destructive techniques and inspection instrumentation. Although specifically designed for coating inspector trainees, this course benefits anyone interested in gaining a better understanding of coatings application and inspection including project engineers, quality assurance managers, contractors, technical sales representatives, blasters, paint applicators, and maintenance personnel.

CIP Level 2 course focuses on advanced inspection techniques and specialized application methods for both steel and non-steel substrates, including concrete using both nondestructive and destructive techniques. Surface preparation, coating types, inspection criteria, lab testing, and failure modes for various coatings, including specialized coatings and linings are also covered. Classroom instruction is comprised of lectures, discussions, group exercises, and hands-on labs using destructive and nondestructive instruments and test methods. Students will also participate in case studies based on real-life situations and practices of a coatings inspector. The course concludes with both written and practical exams.

CIP Level 3 Peer Review examinations are conducted by contemporaries of the coating inspection industry and are experts in their field of work. There is no corresponding coursework, only an oral assessment. Peer review examinations are conducted by contemporaries of the coating inspection industry and are experts in their field of work. There is no corresponding coursework, only an oral assessment.

CP 1—Cathodic Protection Tester course provides theoretical knowledge and practical fundamentals for testing on both galvanic and impressed current CP systems.

CP 2—Cathodic Protection Technician course provides both theoretical knowledge and practical techniques for testing and evaluating data to determine the effectiveness of both galvanic and impressed current CP systems and to gather design data.

NIGIS organized following certification course during the year of 2016 in India.

Course No.	Course	Period	Venue	No. of Participants
1	CIP Level 1	25 - 30 April 2016	Kochi	24
2	CIP Level 1	02 - 07 May 2016	Mumbai	20
3	CIP Level 2	09 - 14 May 2016	Mumbai	14
4	CP 1 Tester	23 - 28 May 2016	Mumbai	10
5	CP -2 Technician	30 May - 04 June 2016	Mumbai	21
6	CIP Level 1	27 June - 02 July 2016	Bangalore	22
7	CIP Level 1	04 - 09 July 2016	Mumbai	21
9	CIP Peer Review	26 - 28 Sept 2016	Mumbai	21
10	CIP Level 1	26 Sept - 01 Oct 2016	Mumbai	27
11	CIP Level 2	03 - 08 Oct 2016	Mumbai	14
12	CIP Level 1	21 - 26 Nov 2016	Mumbai	24
13	CP 1 Tester	22 - 26 Nov 2016	Mumbai	12
14	CP 2 Technician	28 Nov - 02 Dec 2016	Mumbai	24
15	CIP Level 2	28 Nov - 03 Dec 2016	Mumbai	19

Photographs of Certification Courses



CIP Level 2 participants during 09 - 14 May 2016



CIP Level 1 participants during 27 June - 02 July 2016



CP 2 participants during 30 May - 04 June 2016



CIP Level 1 participants during 26 Sept - 01 Oct 2016



CIP Level 1 participants during 28 Nov - 03 Dec 2016



CP 2 participants during 28 Nov - 02 Dec 2016

A Report Technical Interactive Exchange (TIE) - Jung Se Jung III Seminar Microbiological Induced Corrosion (MIC)

Approximately 100 attendees were present for this 3rd Technical Interactive session under the series of "Jung Se Jung" which was the brainchild of Dr. A. K. Karnatak to jointly run a series of technical seminars by NIGIS and GAIL on a quarterly basis. This time the topic was on "Microbiological Induced Corrosion (MIC)" Seminar hosted at the GAIL, Noida, India offices for full day on May 30th, 2016. The conveners of the program were Mr. M. K. Sogani and Mr. Ashish Khara.

The MIC seminar and the inter-company valedictory session for the Technical Interactive Seminar were chaired by: Dr. A. Karnatak, Mr. E. S. Ranganathan, Mr. A. N. Pandey, Mr. N. Kumar, Mr. Patrick Teevens, Dr. Rolf Gubner, Mr. Gautam Chakorborty.

Objectives

To know the fundamentals of MIC mechanisms;

identifying different forms of MIC; determining the critical conditions causing MIC; analyzing and quantifying the impact of MIC; and to know the key control and mitigation measures for MIC.

Discussions

Discussions were led by the co-chairs, the panel and the participants. Key points are summarized as follows:

Shri E S Ranganathan of GAIL – Noida, India, introduced the topic of MIC and how the need to fight corrosion must continue. There is no winning this battle, but there is always a need to find new means to fight corrosion. With many more Jung se Jung seminars to follow, they offer a platform to share knowledge and experience so move the industry towards a field of corrosion experts.

Dr Samir Degan, Vice President, NACE International, highlighted the fantastic forum that is Jung se Jung as a means of exchanging views and knowledge. The exciting news that a NACE India IMPACT study was being started in collaboration with NACE International and GAIL.

Mr. Narender Kumar, NIGIS, discussed the state of the industry in India and its' interest in internal corrosion and MIC specifically. There is clearly interest from the whole industry, not just GAIL, and without this increased, things cannot improve. There is a need to know the mechanisms and mitigation strategies of MIC, and this understanding must start from the beginning, that is, understanding microbes, to be fully understood.

Dr. Ashutosh Karnatak, Director of GAIL – Noida, India, gave a very passionate talk on the need for corrosion control. Both the mind and pipeline need to be productive to have a productive company,

and thus seminars such as Jung se Jung are essential in engaging the minds of employees

Mr. Patrick Teevens, SME NIGIS, provided an excellent wrap up of the earlier Jung se Jung II, Pipeline Internal Corrosion Monitoring and highlighted the key points. He gave a brief over view of monitoring techniques and that integrity management can't be completed without understanding the corrosion threats. Mr. Teevens brought special attention to GAIL's unprecedented and rapid commitment from the top down to corrosion control, from the implementation of state-of-the-art monitoring equipment to developing in-house expertise. An excellent segue into Jung se Jung III's topic was provided when Teevens discussed corrosion mitigation and control starting with good sampling techniques, and the need to "engineer" the monitoring system to meet your needs rather than "piecemeal" it. There is no such thing as buying a canned solution for all systems therefore engineering a customized monitoring solution ensures effectiveness, a fact that hold especially true for MIC!

Dr. Rolf Gubner, SME NIGIS, was the invited MIC expert and provided a fantastic review of MIC, from the fundamentals of microbiology to specific impacts of microbes on corrosion. Dr. Gubner discussed the needs of microbes and emphasized that microbes must be active in the system to influence corrosion, their presence doesn't prove their influence. An important point made was the MIC is nothing new, it is not a new corrosion mechanism. Rather, MIC is the microbe's influence on corrosion kinetics or the modification of environments to be more corrosive. An important note that helps the mitigation and control strategies!

Dr. Gubner discussed growth characteristics of microbes, how microbes never exist in nature as single types, rather, aerobic, facultative anaerobic, microaerophilic, and anaerobic microbes exist in a consortium, growing in synergy with each other. Additionally, bacteria are not the only microscopy cells influencing corrosion. Bacteria, archaea and some yeast and fungi can also be implicated. MIC was identified as causing two different forms of corrosion, chemical and electrochemical corrosion. The causes of MIC were outlined as being:

- Metabolites
- Inorganic acids
- Organic acids
- Enzymes
- Differential aeration cells caused by different
- metabolic rates

The issue of proving MIC was brought to light, along with applicable technologies such as BioGeorge and BIOX which can detect the presence of biofilms and how these technologies can be paired with electrochemical noise pair well to assess if biotic corrosion is occurring. Dr. Gubner's closing remarks were focused on how the industry over complicates MIC and do a complete range of testing when all that is needed is monitoring specific indicators. He remarked that these indicators are different for each system and should be identified, but once identified, MIC monitoring can be a simple, affordable program.

Mr. B K Gupta and Mr. Rajesh Uperty, both of Oil Industry Safety Directorate (OISD) – Noida, India, gave talks on MIC being a neglected field of corrosion control and the need to bring it into the light. Mr. Gupta emphasized that collecting data is not enough, there must be expert review of the results and following recommendations while Mr. Uperty mentioned that biocides require extensive testing before using in order to optimize effects.

Dr. Anil Bhardwaj of ONGC, gave case studies on a water injection facility and on an oil line. In both cases, SRB were associated with failures during periods of low flow or stagnant flow and in one case, biocide treatment was ineffective.

Mr. L. S. Rao of GAIL, gave a case study of A LPG pipeline where ILI debris was analyzed using microbial culturing. In light of this case study, GAIL has come to realize the importance of training all

pipeline personnel to the awareness of criticality of oxygen and the presence of corrosive compounds.

Mr. Saheb Singh Gurjar of Cairn, gave a case study of determining optimal pigging frequency. Using advanced molecular methods on pigging debris, MIC risk was assessed and using internal corrosion direct assessment (ICDA), locations prone to MIC attack were identified.

Queries Raised by Attendees

Many excellent questions were brought up at the seminar. Some key questions are addressed below:

1. Culture methods are a thing of the past, industry needs to look at more advanced testing methods and observing multiple factors impacting MIC to better assess MIC threats and risk. There is a need to shift to molecular methods. It was indicated that molecular methods can be used simultaneously with culturing techniques to determine their relationship and thus aid in creating a continuation of data through the deployment of more advanced methods.

2. The testing method may be dictated by sample type. Liquid samples don't carry much value as there exists no correlation between planktonic cells and corrosion rates. This raises the issue of sample collection being incorporated into system design. Location high risk areas in the design phase and provide adequate sampling facilities to collect meaningful data.

3. It was stressed that high cell numbers do not correlate to high corrosion rates, they reflect a high risk. Consistent monitoring can be used to identify microbial upsets, which may reflect a period of increased MIC threat.

4. It was asked if an SOP be made for MIC with threshold levels, as a benchmark for when treatment must begin. Threshold levels cannot be made, as cell counts are not as important as how many cells are active and in contact with metal surface. Each system will be able to tolerate a different level of microbial activity before seeing MIC beginning to occur.

5. MIC testing can start as a prescriptive approach and move to a performance based approach once specific risks for each system have been identified. For each system, the need to determine key parameters to monitor using a full gamut of testing as early as possible to identify key parameters to monitor which provides the

“headlines of the newspaper”. Once the key parameters are identified, operators only need to “read the front page” of the newspaper, and only perform additional testing if there are concerning data.

Concluding Remarks

Jung se Jung III has demonstrated a great movement forward in recognition of the issue of MIC. GAIL has outlined the need for “Corrosion Doctors”, with expert understanding on corrosion to work in-house addressing corrosion issues throughout the system, from design through to threat assessment and mitigation strategies. This illustrates the huge amount of hard work and expertise being dedicated not only to MIC but to corrosion control as a whole.

Each system is different and there are no canned solutions applicable to every system. Monitoring of MIC is no different than other mechanisms, once the specific threats are identified, customized monitoring programs can be developed on a per-case basis to ensure valuable information is obtained. MIC monitoring must be meaningful, there is no need to run every test all the time if you know what you are looking for!

It was evident as the day moved forwards that MIC control can only begin with proper training of all personnel, and to that end, a sampling workshop and an Indian SOP for MIC testing was proposed should be developed.

It was concluded that more such Jung Se Jung dedicated workshops are essential for discussing industry's real concerns.



The last date for the receipt for applications at NIGIS office is 17 July 2017.
The application forms can be obtained from Email: rishikesh@naceindia.org or downloaded from www.naceindia.org

A Report – Technical Activities

NIGIS organised a one day workshop on “Microbiologically Influenced Corrosion” (MIC) on 28th May 2016 at Hotel Rodas, Mumbai. Prof. Rolf Gubner, Professor of Corrosion, Curtin University, Western Australia was the Subject Matter Expert (SME) and discussed various aspects of MIC. The topics covered were the fundamentals and diversity of MIC mechanisms and degradation forms applicable to your assets which key control measures to avoid and those which succeed at mitigating MIC under different conditions.

The workshop was attended by 40 delegates from BPCL, HPCL, ONGC, IOCL, NTPC, Welspun, L&T, Lucid Lb., Nalco, Dorf Ketal, Chembond, Ion Exchange, Heron Aqua, Boekhoff, GSFC etc.. The workshop commenced with a brief talk on IMPACT Study carried by NACE International and plans of NIGIS in this direction. This talk was delivered by Dr. Samir Degan, Vice-President NACE International.

The participants actively participated in discussions during the workshop and major points carried by them included determine the critical conditions, environmental factors, and likely causes for MIC analyze and quantify the extent of corrosion damage by MIC and its likely impact if MIC is posing a problem Integrate monitoring methodologies to assess MIC and biofilm development.

NIGIS organised a technical talk on The History of Protective Coatings in Nuclear Power Plants by Jon R. Cavallo, PE, FASTM on 26.11.16 at Hotel Rodas, Mumbai. Jon Cavallo is world renowned expert with almost 50 years' experience in Nuclear Coatings programs. He has worked around the globe in several countries and in his presentation he discusses the evolution of protective coating use in commercial nuclear power generating facilities, including the background and rationale for the technical and regulatory requirements which have evolved over the years. The function was attended by over 55 delegates.



Rolf Gubner during the technical Talk



View of attendance



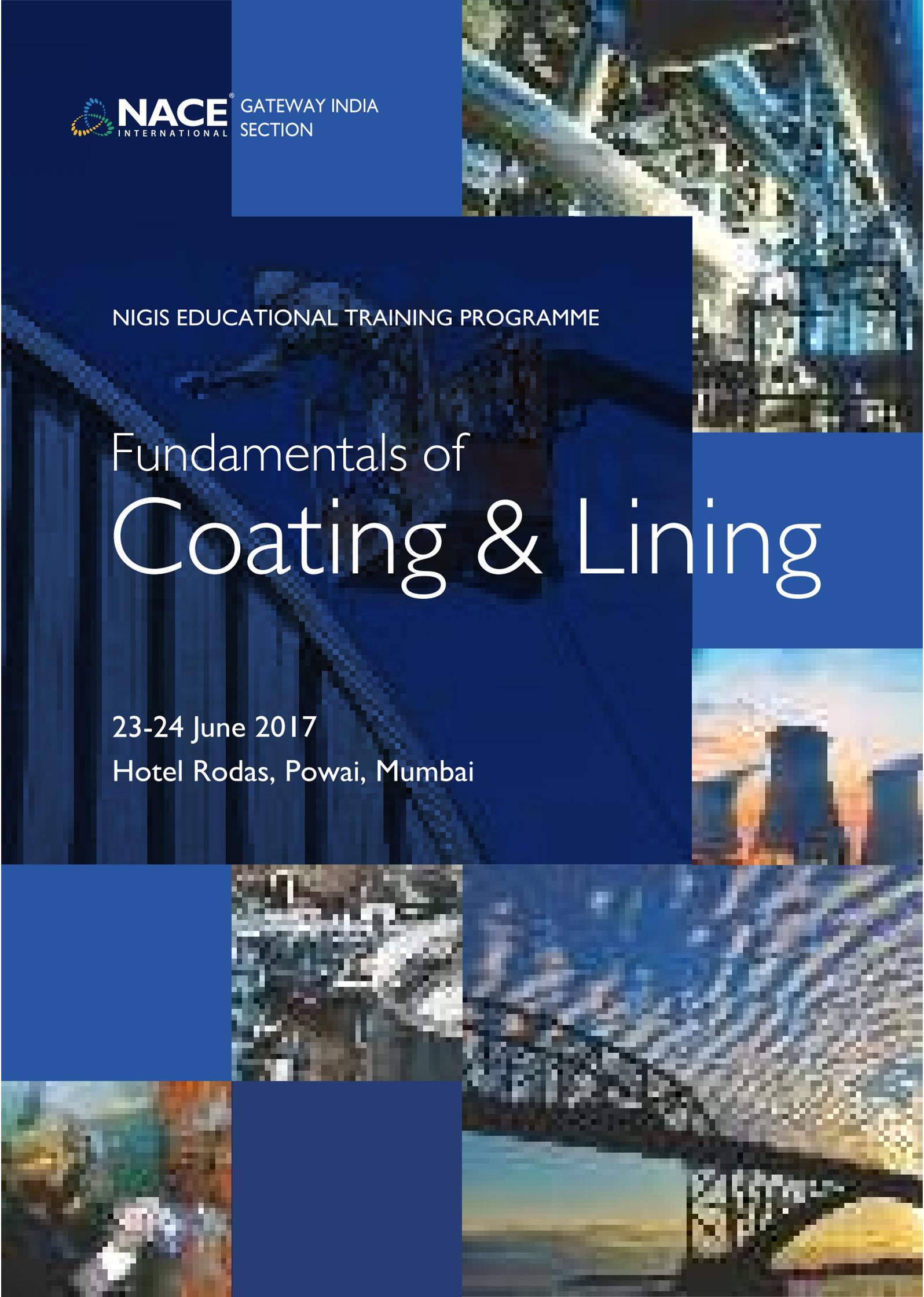
Jon Cavallo during the technical Talk

NIGIS EDUCATIONAL TRAINING PROGRAMME

Fundamentals of Coating & Lining

23-24 June 2017

Hotel Rodas, Powai, Mumbai



A Report - FOUNDATION DAY

NACE International Gateway India Section (NIGIS) celebrated FOUNDATION DAY on 30th July 2016 at Mumbai.

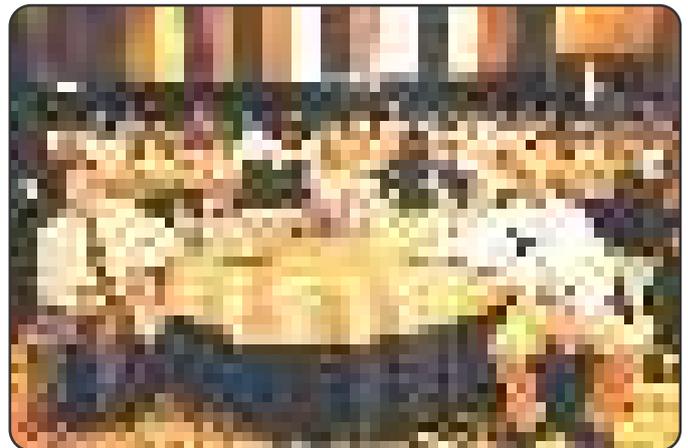
Mr. N Manohar Rao, Chairman, NIGIS welcome the NACE members and other dignitaries. Dr. Samir Degan, Vice-President, NACE International briefed about the IMPACT Study and activities of NACE International. Dr. U Kamachi Mudali updated the activities of NIGIS and CORCON 2016.

Mr. Anand Kulkarni, Trustee addressed the gathering and states his gratitude to his team members and office staffs for their support to make NIGIS a successful organisation. Foundation day was attended by more than 80 members and dignitaries from the industry.

The Foundation Day function ended with the felicitation of outgoing Section Governing Board Trustee Dr. Samir Degan by Mr. B Narayan, Group President (Procurement & Projects), Reliance Industries Ltd. The Programme ended with vote of thanks by Mr. Dipen Jhaveri, Secretary, NIGIS. Foundation Day ended with dinner.



N Manohar Rao welcoming the members



Members during the program



Dr. Samir Degan felicitated by B Narayan



Dipen Jhaveri giving the vote of thanks

CORCON

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Mumbai, India **2017**

Make plans to attend **Asia's largest conference on corrosion prevention and control in 2017.**

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A Report – Pipeline Corrosion

NIGIS conducted Educational & Training Programme on “Pipeline Corrosion” from 15-17 December 2016 at Hotel Rodas, Mumbai. It is one of the most popular programs of the section and earned a goodwill in the pipeline industry. Pipeline Corrosion training programme covers various aspects of **corrosion of pipelines** and methods available for prevention and **control of their corrosion**. The intention is to arm pipeline personnel with sufficient

knowledge on pipeline corrosion to maintain integrity of pipelines.

It provides a unique convergence of networking, learning, developing confidence and force one to grow and challenge oneself and bring fresh ideas back to the workplace as an investment in our own company. Faculty included eminent professionals from industry and academicians who all received high appreciation from participants.



Participants of Pipeline Corrosion

A Report - PETROTECH 2016

NIGIS has participated in PETROTECH-2016 an International Oil & Gas conference and exhibition during 05-07 December 2016 at New Delhi. NIGIS has an exhibition stall in the Pragati Maidan, New Delhi. The PETROTECH series of International Oil and Gas Conference and Exhibition is a biennial platform for national and international experts in

the oil & gas industry to exchange views and share knowledge, expertise and experiences. The visitors have shown interest in NACE Certification and educational program, CORCON 2017, JSJ workshop etc. appreciated its services in the field of corrosion awareness, protection and control of corrosion in India and globally.



Hon'ble Minister of State (I/C), Petroleum & Natural Gas, Dharmendra Pradhan at NIGIS Stall



NIGIS Section Chairman N Manohar Rao during his visit to the NIGIS Stall

Selection of Suitable Superalloys for Industrial Applications

I Gurrappa, T. Sravan Kumar, I. V. S. Yashwanth and N. Das

Defence Metallurgical Research Laboratory, Hyderabad and University of Texas at El Paso, USA

Abstract

Superalloys exhibit excellent mechanical properties at elevated temperatures, due to which they are used in aerospace applications. The major problem for superalloys is corrosion. The corrosion behavior of superalloy depends upon nature of alloying elements, environment in which they are exposed, temperature of the environment and exposure time. The current paper aims at selecting a suitable superalloy for industrial applications by studying the corrosion behavior of various alloys such as DMS- 31, CM 247 LC and Nimonic 75 in industrial environment at 25°C. The results showed that CM 247 LC and Nimonic 75 degrade due to pitting corrosion and DMS 31 through uniform corrosion. To evidence that corrosion current, corrosion rate and pitting susceptibility in simulated industrial environmental conditions were evaluated by different techniques and presented. The surface morphologies of DMS-31, CM 247 LC and Nimonic 75 were studied by Scanning Electron Microscope (SEM) and corrosion products with Electron Dispersive Spectroscopy (EDS) technique. Finally, based on the results obtained with different techniques, a suitable superalloy with appropriate surface treatment is recommended to fabricate different components for industrial applications.

Keywords: Corrosion, Superalloys, Industrial applications

Introduction

Superalloys exhibit excellent mechanical properties at elevated temperatures. The other materials, such as steels exhibit very poor properties, which make superalloys the only alternative for high temperature applications [1]. Due to their excellent mechanical properties, nickel-based alloys are used for a broad range of applications in an equally broad range of industries, including gas turbines, chemical and petrochemical processing, pollution control, oil and gas extraction, marine engineering, power generation, and pulp and paper manufacture. The alloys versatility and reliability make them the prime materials of choice for construction of

process vessels, piping systems, pumps, valves and many other applications designed for service in aqueous and high-temperature environments [2-3].

The nickel based superalloy DMS-31 has been recently developed by DMRL for gas turbine engine applications and showed considerably improved mechanical properties over the existing superalloys [4]. For any industrial application either high temperature or ambient, the alloy should exhibit not only the required mechanical properties but also corrosion resistance. The corrosion resistance of alloys depends on their chemistry such as nature of alloying elements and concentration of each alloying element. The major change is the addition of niobium and ruthenium. These are unique elements, which can increase high temperature creep properties significantly, but make the superalloys susceptible to high temperature corrosion i.e. hot corrosion and high temperature oxidation [5]. It is due to the fact that the superalloys cannot form corrosion resistant alumina or chromia scale because of the presence of rhenium and ruthenium but some Ni-based superalloys show good corrosion resistance in aqueous environments at ambient temperatures [6-7]. As mentioned above, for obtaining higher efficiencies, the components of industrial systems have to be fabricated from materials which satisfy both mechanical as well as corrosion resistance. In fact, corrosion determines the life of components in a variety of industries. Therefore, materials selection based on their corrosion resistance enhances the efficiency, reduces down time, which in turn improves the production significantly [8-10].

In the present investigation, an attempt was made to understand the corrosion behavior of different Ni-based superalloys like CM 247 LC, Nimonic 75 and DMS-31 in industrial environment at 25°C by using various advanced corrosion measurement techniques. The corrosion techniques are helpful in getting more information faster and powerful tools for researching a variety of materials under

simulated environmental conditions and temperatures and select appropriate material for different applications. Scanning electron microscope (SEM) was used to understand the nature of corrosion through which different nickel based superalloys degrade in industrial environmental conditions at ambient temperature.

Experimental

The compositions of superalloys evaluated in the present study are presented in Table.1. The test specimens of 3 mm thick and 14 mm in diameter were machined from the corresponding alloys, grounded up to 800 grit surface finish and then cleaned with distilled water followed by acetone.

Alloy	Cr	Co	Mo	W	Ta	Al	C	Ti	Ru	Re	Hf	Si	Cu	Fe	Nb
CM247 LC	8.0	9	0.5	10	3.2	5.6	0.07	0.7	-	-	1.4	-	-	-	-
Nimonic 75	21.0	-	-	-	-	-	0.08	0.2	-	-	-	1.0	0.5	5.0	-
DMS-31	7.0	10	2.0	6.0	9.0	5.6	0.02	-	2.0	1.0	0.1	-	-	-	1.2

Table 1: Nominal composition of studied superalloys (wt.%, Ni-Balance)

The corrosion behavior of DMS-31, CM 247LC and Nimonic 75 were studied in 0.5M solution of 90% Na₂SO₄ and 10% NaCl at 25°C by using CHI 680C potentiostat (CH Instruments, Inc.). Open circuit potential versus time, electrochemical noise measurement, AC impedance, potentiodynamic polarization and cyclic polarization techniques were used to evaluate the corrosion characteristics. The open circuit potential versus time curves was used to assess the protective nature of the superalloys. Potentiodynamic polarization technique was used to determine the active/passive characteristics of the alloy–solution system and to determine the corrosion rates. AC impedance curves were used to understand solution and polarization resistance. Electrochemical noise measurements and cyclic polarization techniques were used to evaluate the pitting and crevice corrosion resistance of the different Ni-based superalloys in the industrial environment at 25°C. Finally, scanning electron microscope was used to understand the degradation mechanism of various superalloys after corrosion studies in the industrial environmental conditions.

Results And Discussion

Open Circuit Potential vs. Time

The variation of open circuit potential as a function of time for CM247 LC, Nimonic 75 and DMS-31 in industrial environment at 25°C is shown in Fig.1. As can be seen, the open circuit potential of CM 247 LC alloy shifted towards more negative values while Nimonic 75 and DMS-31 to less negative values. Generally, a rise in potential in the positive direction indicates the formation of the passive film, and a steady potential indicates that the film remains intact and protective. A drop of potential in the negative direction indicates breaks in the film, dissolution of the film or no film formation. Therefore, any alloy for obtaining good corrosion resistance, the potentials should either shift to more positive side or maintain a steady value as a function of time under the chosen environmental conditions. The results CM 247 LC, Nimonic 75 and DMS-31 show that the alloys did not form a protective oxide scale for their corrosion resistance in industrial environment at 25°C. It suggests that effective measures are essential in order to use the alloys at ambient temperatures in industrial environments.

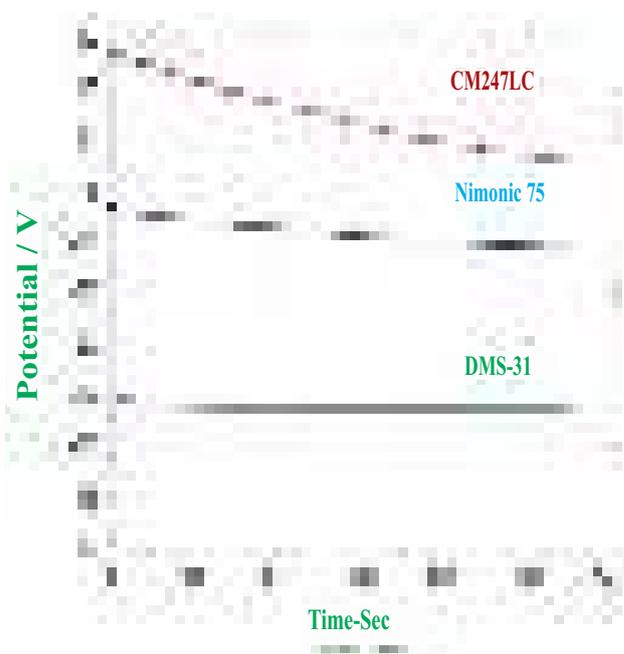


Fig.1 Open circuit potential as a function of time for different alloys in industrial environment at 25°C

Electrochemical noise measurements

The results obtained in the corrosion study, by industrial environment on CM247 LC, Nimonic -75 and DMS-31 alloys at 25 °C, come from analyzing the time series of current noise, to determine the electrochemical noise resistance (R_n) (Fig.2). There are some high frequencies and low amplitude transients for CM 247 LC and Nimonic-75 alloys, causing that these materials have a type of localized corrosion. The generic term 'localized corrosion' implies any corrosion process that is not uniformly distributed over a metal surface and these processes are associated with large fluctuations in the corrosion current, when compared to uniform corrosion. The current transients in time records are known to be closely associated with the initiation and repassivation of metastable pit, which provides useful information on the initial process of pitting corrosion. While for DMS-31, there are constant frequencies and amplitude transients during the entire experiment, indicating that this alloy degrades due to uniform corrosion. The magnitude of corrosion current noise is high for DMS-31 when compared to other alloys.

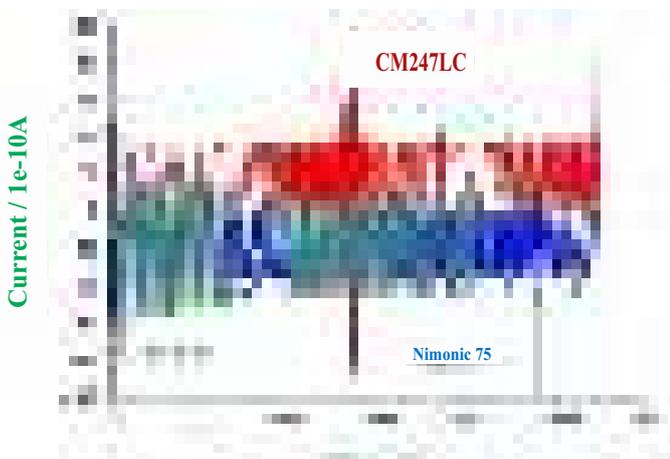


Fig.2 Electrochemical noise measurements for different alloys in industrial environment at 25 °C

A.C. impedance measurements

AC impedance offer further confirmation for the extent of surface reactivity of different alloys under open circuit conditions in industrial environment. The low frequency capability has led to probe and readily detect relaxation phenomena involving surface intermediates and thus studying electrochemical corrosion and passivation mechanisms. AC impedance measurements for CM247 LC, Nimonic 75 and DMS-31 in industrial

environment at 25 °C are shown in Fig.3. DMS- exhibits low impedance characteristics compared to Nimonic 75 and CM247 LC. The significantly reduced impedance recorded at 25 °C for DMS-31 afforded markedly faster charge transfer process that occurred on the alloy surface.

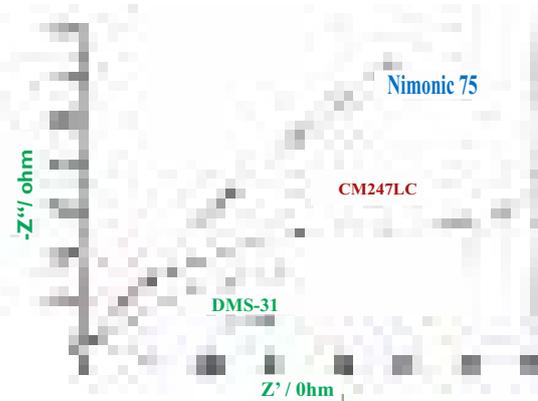


Fig.3: AC Nyquist plots for different alloys in industrial environment at 25 °C

The log Z vs. log (Freq) plot sometimes allows a more effective extrapolation of data from higher frequencies (Fig.4). The lowest surface resistance was observed at 25 °C for DMS-31 alloy. Phase angle as a function of log (Freq) showed that the corrosion resistance of CM247 LC is high compared to Nimonic 75 and DMS-31 (Fig.5).

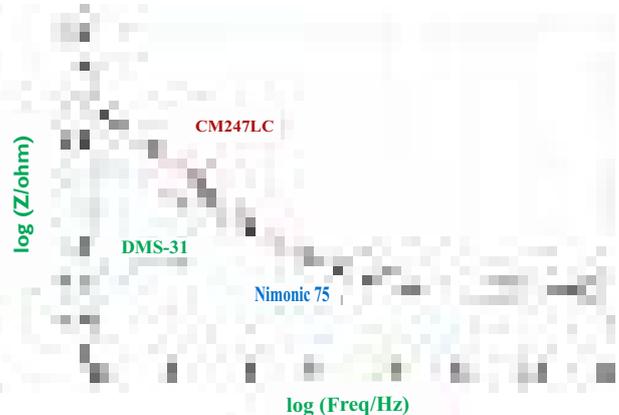


Fig.4 Bode plots for different superalloys in industrial environment at 25 °C

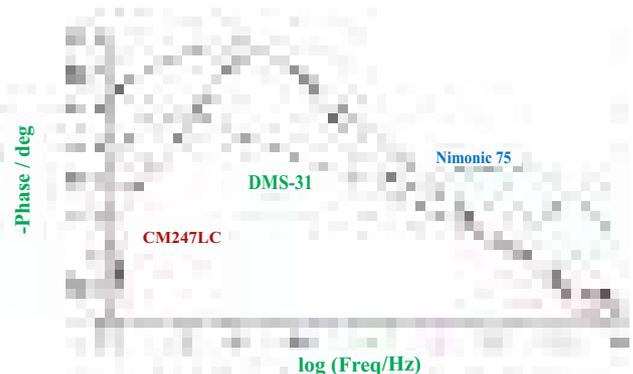


Fig.5 Phase angle measurements for different superalloys in industrial environment at 25 °C

Cyclic polarization measurements

The cyclic polarization curves for CM247 LC, Nimonic 75 and DMS-31 in industrial environment at 25°C are shown in Fig.6. The reverse scan came above the forward scan for DMS-31, indicating that the alloy is resistant to localized corrosion, whereas for CM247 LC and Nimonic 75, the reverse scan came well below the forward scan in the same environment. It is clearly indicating that CM247 LC and Nimonic 75 are susceptible to both pitting as well as crevice corrosion and DMS-31 is vulnerable to general corrosion at 25°C.

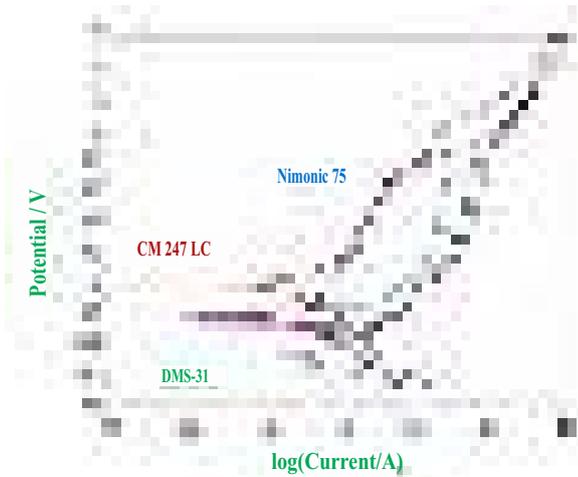


Fig.6 Cyclic polarization plots for different superalloys in industrial environment at 25°C

Potentiodynamic polarization

Corrosion potential (E_{corr}), corrosion current density (I_{corr}), anodic, cathodic Tafel slopes and corrosion rates measured for CM247 LC, Nimonic 75 and DMS-31 in the industrial environment at 25°C with the help of potentiodynamic polarization technique are presented in Table 2. The corrosion current density of CM247 LC is lower than Nimonic 75 and DMS-31 at 25°C in industrial environmental conditions. Consequently, the corrosion rate of CM247 LC is lower than Nimonic 75 and DMS-31.

Table 2: Corrosion data of different superalloys in industrial environment at 25°C

Alloy	I_{corr} ($\mu A/cm^2$)	$E_{corr}(V)$	Cathodic slope	Anodic slope	Corrosion rate (mils/year)	Linear polarization resistance, R_p (Ω)
CM247 LC	19.53	-0.009	5.097	5.657	8.637	2069.6
Nimonic 75	29.62	-0.232	4.996	2.330	13.36	2004.0
DMS-31	50.89	-0.501	7.234	4.416	26.99	733.3

Sem

The surface morphology of CM247 LC, Nimonic 75 and DMS-31 at 25°C in industrial environmental conditions revealed that DMS-31 degrades by uniform corrosion while CM247 LC and Nimonic 75 degrade by pitting corrosion

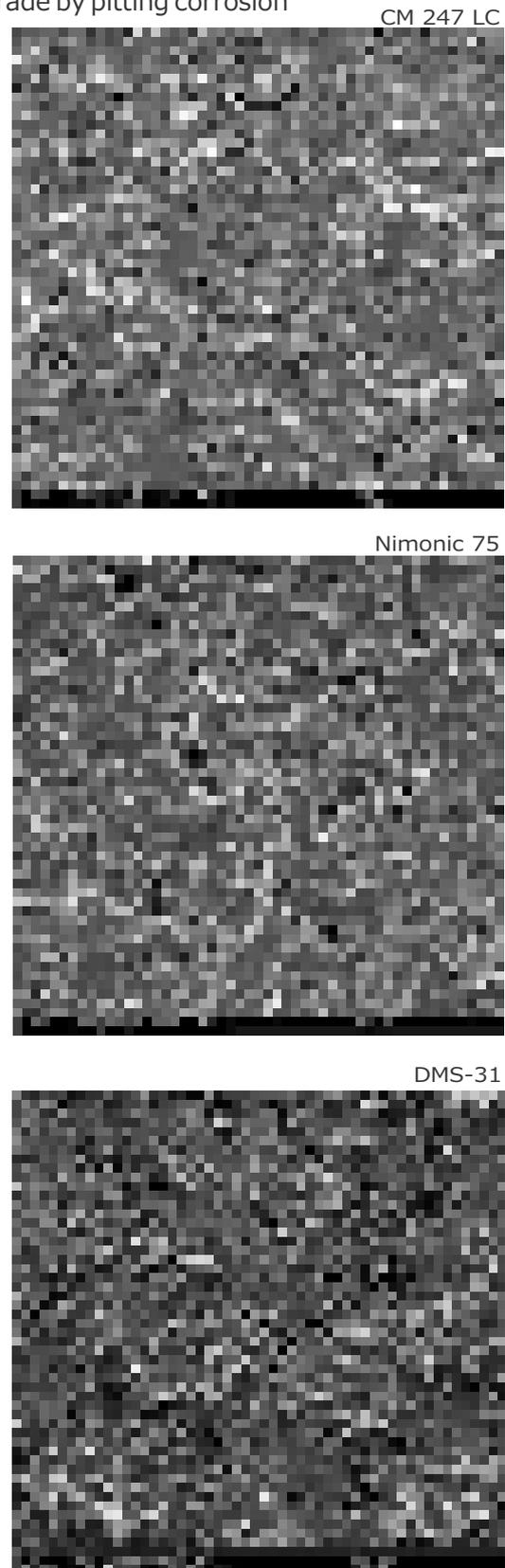


Fig.7 Surface morphologies of corroded superalloys in industrial environment at 25°C

Electron dispersive spectroscopic patterns of the three corroded superalloys in industrial environmental conditions are illustrated in Fig.8. The peaks corresponding to the base metal i.e. nickel, all the alloying elements, oxygen and sulphur were observed. However, the intensity of peaks varied from one alloy to another. The results are indicating that the superalloys form oxides and sulphides of nickel and alloying elements of superalloys during the corrosion process. The findings are similar to that of results obtained at elevated temperatures under hot corrosion conditions [11].

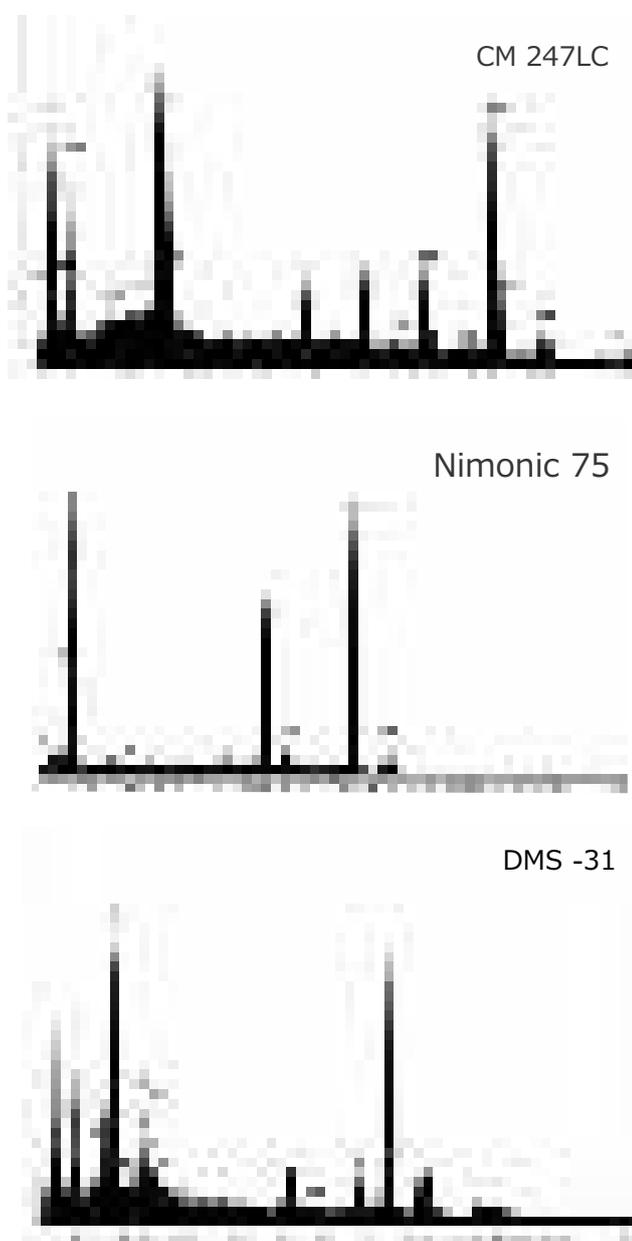


Fig.8 EDS patterns of corroded superalloys in industrial environment at 25°C

It is a general practice to choose the material which exhibits low corrosion rate in the given environmental conditions for fabrication of components. However, it is also important to consider the construction material that should be resistant to pitting corrosion as it is catastrophic and responsible for disasters during service. The present investigation revealed that the newly developed superalloy degrades due to uniform corrosion and other two alloys are susceptible to pitting corrosion. Therefore, it is recommended to use the new superalloy i.e. DMS-31 for fabrication of components used for industrial applications with appropriate surface engineering treatment.

CONCLUSIONS

1. A systematic corrosion study was carried out under simulated industrial environmental conditions on CM 247 LC, Nimonic 75 and DMS 31 superalloys by using advanced corrosion techniques and characterized using SEM and EDS with a view to select a suitable superalloy.
2. The superalloys could not able to form protective oxide scale on their surfaces.
3. CM 247 LC and Nimonic superalloys degrade due to pitting corrosion while the newly developed DMS 31 superalloy undergoes uniform corrosion.
4. The results suggest that the new superalloy DMS 31 with appropriate surface engineering treatment is more suitable to fabricate the components for industrial applications.

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Author:

Dr. Gurrappa has been working in the field of corrosion and its controlling technologies for the past three decades and playing a crucial role in defence (E-mail: igpl@rediffmail.com). He has been working in a variety of fields like corrosion evaluation, monitoring, high temperature corrosion of titanium and superalloys, design and development of smart coatings for superalloys and titanium based alloys, nanostructured materials, nanocomposite coatings, biomaterials, weldments, steels, coatings development for biomaterials, magnetic materials, powder metallurgy components, aluminium alloys and selection of appropriate materials for missiles & armour vehicles, cathodic protection design & development, modeling of cathodic protection systems etc. In addition to defence systems, he has been helping different industries in solving the corrosion problems and stressing the need of prevention of corrosion by using different advanced protective techniques. Dr. Gurrappa has been recognised globally, received a number of Prestigious Fellowships and visited Germany,

Japan, France, USA, UK, Belgium, Netherlands, Poland, Singapore, Israel and Malaysia. His list of numerous publications (two hundreds) both in international and national journals of repute provide sufficient support of his constant, successful and significant contributions in creating corrosion awareness and development of newer and novel protective systems and coatings to mitigate corrosion. He has received a number of best paper awards and delivered a number of invited lectures / talks, keynote addresses in various international / national symposia and chaired the technical sessions. Further, he was awarded a prestigious "Alexander Von Humboldt Fellowship" Of Germany, Marie Curie Individual Fellowship Of European Commission, Japan Society For Promotion Of Science Invitation Fellowship Of Japan, Royal Society Of Chemistry Fellowship And Andhra Pradesh Akademi of Sciences Fellowship For Recognition of His Meritorious contributions in the field of corrosion and related technologies. He was also awarded prestigious "16th NIIS Corrosion awareness Award in the year 2010 and "10th NIIS Corrosion awareness Award in the year 2004 by NACE International India section for his Meritorious Contributions to the corrosion field. Further, he was invited to submit "reviews" for internationally leading materials journals and books/ book chapters by reputed publishers. He published 9 books/ book chapters and edited two books on Gas Turbines. He is an elected Fellow of Royal Society of chemistry, London and Andhra Pradesh Akademi of Sciences, India.

Nace Headquarters Report- January 2017

CORROSION 2017 Highlights

Technical content

- 44 Technical Symposia – 7 of which are new for CORROSION 2017
- We currently have 495 papers in the system. Final count is expected to be ~ 480
- There are 5 Research in Progress (RIP) topics (7 total sessions, 2 are broken into separate two-day sessions) and 1 Research Topical Symposium this year. Nine submissions have been added to the Forum schedule and nine are going to be included in the Corrosive Chronicles Theater schedule in the exhibit hall.
- The Student Poster Session received 195 abstract submissions.

Exhibits

Companies – 411

Booths – 687

New Companies – 66

Social Media

- Advance promotion of specific activities such as poster sessions, pavilions, keynote, and Engaging Diversity event, are planned.
- During the conference some events will be live tweeted and in some cases live streamed such as Keynote (tweeted), Corrosive Chronicles (some tweeted, some streamed), attendee testimonials (mostly tweeted and shared on FB, may stream as appropriate).
- Rust Von Rust Campaign including photographed “sightings” and competition to defeat him.
- Articles will be written that will be used on social and in daily newsletter.
- Coverage of CP field, virtual spray booth, updates from exhibit hall, pavilions, MP awards, product showcase, and other highlights.
- Posts to recognize sponsors of conference and foundation events.

MP Corrosion Innovation of the Year Award

Have received 44 nominees for the 2017 MP

Corrosion Innovation of the Year Awards. Up to 10 winners, selected by a panel of corrosion experts, will be honored on Monday, March 27 just prior to the opening of the exhibit hall at CORROSION 2017.

The nominees are posted at :
www.nace.org/mpinnovationawards

CoatingsPro Contractor Award

CoatingsPro Magazine has received 26 Contractor Award entries. The program will award projects in the categories of Commercial Concrete, Commercial Roof, Industrial Concrete, Industrial Steel, Specialty Project, and Contractor/Crew MVP. Award winners will be announced in a special ceremony on Tuesday, March 28, 2017 at the Green Theatre (Corrosive Chronicles) from 11:30 a.m. to 12:30 p.m.

Executive Office

- NACE hosted the inaugural Asset Integrity Executive Council for Oil & Gas meeting at Headquarters. Senior technical leaders from BP, Chevron, ExxonMobil, Conoco Phillips and Shell attended. The meeting is designed to stretch the recognition of NACE as a valuable contributor to the industry into upper corporate management.
- We have learned that INGAA has passed a resolution requiring their members' pipeline inspectors to have NACE CIP 2 certification by the end of 2018.

Global Operations

- NACE P72 (Corrosion in Petroleum Refining and Gas Processing) was officially launched. This first working meeting was held in Beijing with around 60 participants, including representations from SinoPec, PetroChina, CNOOC among others.
- The annual technical gathering for Northern region of China was organized in Beijing. Members from Beijing, Shenyang and Tianjin enjoyed the occasion in which six technical presentations covering topics on refining equipment/corrosion management, pipeline, and CP were shared with the group.
- West Asia and Africa Area board has decided on the following activities for the year. Middle East Forum at Corrosion 2017 in New Orleans, LA – March 26 - 30, 2017. UAE

Conference in Abu Dhabi – May 2- 4, 2017
Egypt Conference in Cairo–August 12, 2017
Materials Performance & Welding
Technologies Conference in Dammam, KSA
– September 11 - 14, 2017 “NACE Process
Safety Management and Exhibition-2017” in
Kuwait – 21 to 23 November, 2017.

- The first issue of the LAA News was released this month to the excitement of members in the Latin American Area. The biannual newsletter features global trends, voice of the members and NACE International activities specific to the Area.

Maritime

- Served as chairman of Passenger Ship Safety Conference in Ft Lauderdale, FL.
Technical Activities staff partnered with
- NACE Chief Maritime Officer, and NACE CEO to visit the American Bureau of Shipping to meet with key staff and investigate some standards opportunities, etc.

Education

- Sponsored a NACE Basic Corrosion Overview class for staff, led by local instructors.
- 347 Instructors are under contract for 2017.
- Successfully completed our annual IACET audit, receiving very positive comments from the auditor.

Conferences

The first International Pipeline Coatings Conference was held in Houston with over 200 people in attendance. Highlights include:

8 Key Sponsors

25% International attendance with delegates from the following areas:

Europe

Asia

South America

Technical Program featured the following:

Presentations from authors representing seven different countries

End user panel that highlighted the challenges and issues of pipeline coatings

Two off-site plant tours:

Powder Fabrication

ID Coatings

Marketing

New NACE newsletters – 2017

NACE launched two new newsletters: the

CORROSION journal quarterly newsletter and the LAA (Latin American Area) newsletter. Both of these digital products were created to supply targeted editorial content to these two growing audiences. The introduction of the LAA newsletter brings our total of international newsletters to four: EAPA (English), EAPA (Chinese), WA&AA, and LAA.

LAA newsletter

This is the bi-annual newsletter of the NACE International News for the Latin America Area and features global trends, NACE International activities specific to the area, as well as general news about the association. Articles, in both Spanish and English, and photos are contributed by local NACE staff and members. The newsletter is published in January and July.

CORROSION Journal quarterly newsletter

The CJ quarterly newsletter includes editorial from staff and highlights/updates about the journal and new industry trends. The newsletter is published in January, April, July, and October.

Publishing

Books:

- Published CorrCompilations: Coating Failure Analysis. This compilation discusses various approaches that can be used in protective coating failure analysis. Both general and industry specific topics are discussed.
- Published CorrCompilations: Coatings for Marine Vessels. This compilation focuses on recent advances in outboard and inboard coating technologies, ballast tank solutions, and hull antifouling products. Developments in the properties, performances, and testing of new coatings are discussed along with examples of their practical application.

Journal:

CORROSION Journal:

CORROSION Journal integrated a plagiarism checker into the article submission program in November. All submitted articles are being checked prior to peer review for the percent they “match” published articles/books/ conferences. Overall, we are seeing a low rate of plagiarism. Features more “unlocked” content on its website, including Student Poster Research Letters, a monthly “Editor's Choice” Featured Open Access Article, and articles paired with MP's “The Science Behind It” quarterly feature. Additionally, authors may now post their unformatted articles in their institution's repository. Please see the attached Editorial by Dr. John Scully that ran in the December issue of CORROSION Journal.

Magazines:

Materials Performance:

MP now offers a platform for companies to display their white papers on materialsperformance.com. The fee-based program, part of MP's suite of digital advertising opportunities, allows web site visitors to view and download the papers for free. Each paper is promoted by MP in various venues over a six-month period and then archived. The first white paper will be posted in March 2017.

The first quarterly "Science in Action" series, a collaboration between MP and CoatingsPro, is launching in the February 2017 issue of MP. In this series, an MP technical article focused on a particular technology is supported with recommended articles in Coatings Pro describing job site applications.

CoatingsPro Magazine:

This January CoatingsPro Magazine celebrates fifteen years of covering industry trends, technological breakthroughs, and the people, products, and solutions that the high performance coatings industry relies on. For the anniversary issue CoatingsPro has included several special features including:

15 Years of CoatingsPro timeline, highlighting special moments since November 2001

15 Years of Industry Insight – a round table discussion with five industry experts. Available in print with bonus information available online only.

Special Industry Insight from long-time Contributing Editor Jack Innis CoatingsPro's "Greatest Hits," which follows up with 12 reader favorites (one each month). The first installment of this special series is "The Adventures of Overspray" and can only be found online.

CERTIFICATION

Delivered 3, 916 exams on the CBT platform since launch, which includes 600 exams delivered during January. Totals by program (for CBT examination delivery) are shown below.

- 3,261 CIP (Includes level 1 & 2) exams
- 614 CP (Includes levels 1,2,3 & 4) exams
- 7 Refining Corrosion Technologist exams
- 34 other exams

Processing time for new certifications continues its downward trend and is now at 4 weeks (as of December). This has exceeded our FY17 targets (set at 6 weeks). We will continue to monitor this and reset our benchmark if the trends holds steady at 4 weeks. NOTE – This number may fluctuate based on the volume of candidates who go through the various programs in any given month. The department has made great strides in improving the processing time due largely to team efforts and more automation driven by CBT and the supporting systems.

IMPACT PORTAL

Multiple work streams are underway supporting development, marketing and operations / support.

Internal NACE project team met in mid-January to address key areas of ownership and outstanding business questions. The meeting was successful and collaborative with all parties assuming ownership of critical areas to ensure project success. This has subsequently setup key points of contacts between NACE and APQC. Activities to date

- NACE and APQC marketing met to compare notes and identify areas of responsibility, messaging and expectations.
- Content management workshop is being coordinated between NACE and APQC to develop a strategy to ensure resource library is populated with quality content.
- Continued engagement with APQC to ensure that the customization required for the Mosia Q portal is aligned to NACE portal vision.

Next steps:

- Develop content management workshop agenda for upcoming 2 day event.
- Certification / Education to meet with APQC lead to focus on Certified Navigator training and certification development.
- Bi-weekly product management calls to ensure lock step between work streams to mitigate risks and meet target deadlines for launch.

Section 1

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Section 2

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Section 3

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NACE

Corrosion Basics: Corrosion Potential*

The potential of a corroding metal is most useful in corrosion studies, and fortunately, it can be readily measured in the laboratory or under field conditions. The corrosion potential is measured by determining the voltage difference between a metal immersed in a corrosive and an appropriate reference electrode. Examples of such reference electrodes are the saturated calomel electrode, the copper-copper sulfate electrode, and the platinum-hydrogen electrode.

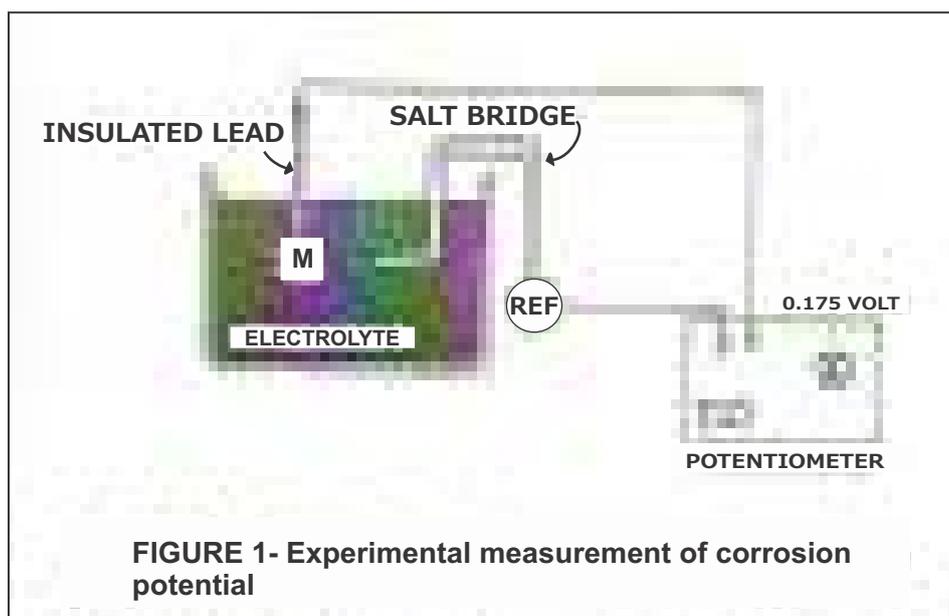
Figure 1 illustrates the experimental technique for measuring the corrosion potential of a metal M immersed in an electrolyte. This is accomplished by measuring the voltage difference between the reference electrode and the metal using a potentiometer. A potentiometer is used because it is capable of accurately measuring small voltages without drawing any appreciable current. Note that in figure 1 a salt bridge is used between the reference electrode and the corrosive solution. This is to prevent contamination of the reference electrode by the corrosive liquid.

In measuring and reporting corrosion potentials, it is necessary to indicate the magnitude of the voltage and its sign. In the example shown in figure 1, the corrosion potential of metal M is -0.175 V. The minus sign indicates that the metal was connected to the negative terminal of the potentiometer.

There is no need to worry about mixing up these connections, since the potentiometer cannot be balanced unless it is properly connected to the reference electrode and metal. Thus, in making a corrosion potential measurement, it is first necessary to experiment by connecting the metal to either the positive or negative terminal of the potentiometer, and finding which connection allows the potentiometer to be balanced.

In addition to recording the voltage and the plus or minus sign, it is also necessary to specify the kind of reference electrode used in making the corrosion potential measurement. For example, if a saturated calomel electrode is used, the experiment shown in figure 1 would be reported as " -0.175 V vs saturated calomel electrode."

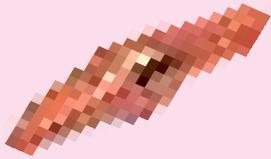
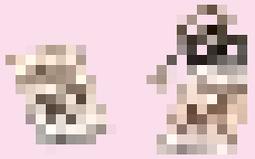
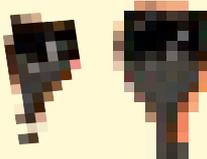
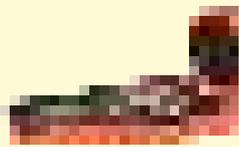
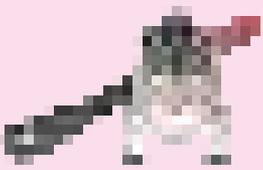
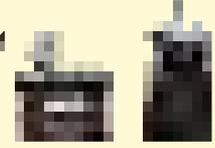
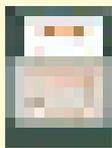
The magnitude and sign of the corrosion potential is a function of the metal, the composition of the electrolyte, and the temperature and agitation of the electrolyte.



* Adapted from Corrosion Basics – An introduction, National Association of Corrosion Engineers

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