Technical Sessions Descriptions

Technical Program Detailed Schedule

Monday, 18 September

0900 - 1030

Cathodic and Anodic Protection (CAP-1)

Hall-A

Corrosion Protection of Process Vessels by Galvanic Anode CP System - CAP11 (Invited)

Paper by: Pankaj Panchal, Corrosion Protection Specialist Pvt. Ltd., Ahmedabad

In petroleum industries, the extraction of crude oils goes through various processes in order to separate the residual impurities (gasses, water, and sludge) and then further processes to establish the different grades of extracted oil. During these processes different types of vessels are being used which need to be protected against corrosion as their internal surfaces are exposed to extreme corrosive environments.

Although these vessels are protected through internal linings, which are considered as a first line of defense from corrosion protection, the application of cathodic protection is still necessary as secondary protection because these linings cannot be 100% effective and the possibility of degradation with the passage of time always exists.

This paper is an effort towards; Providing information about the types and structure of the process vessels used in petroleum industries. Concepts for the use of cathodic protection. Various factors involved in designing galvanic anode protection systems.

Integrity Challenges & Control - Tank Bottom Corrosion - CAP12

Paper by: Shakeel Isak Girkar and Ajiv Mohan Nair, Renjith Vijayan Mangattu, ADCO, Abu Dhabi, United Arab Emirates

One of the leading Middle East Oil Operator has total 116 oil storage tanks. All crude oil tank and facility storage tank bottom plates are externally protected against soil-side corrosion with Impressed Current Cathodic Protection (ICCP) System.

Corrosion and subsequent failure, particularly on storage tanks bottom plates, is one of the main factors upsetting any upstream/ downstream production facilities. Maintaining adequate level of CP system is always a challenge for corrosion engineers due to complex corrosion phenomena. Failure of storage tanks during production stage due to corrosion can be catastrophic with following consequences:

- Loss of life(fatality)
- Safety and Environment(Fire, Toxic gases and Oil Spill)
- Resource and downtime cost impact
- Damage to asset/company reputation.

As per current industrial practice, above ground storage tanks' bottom plates are designed to be protected externally with ICCP system. However, the CP effectiveness often becomes challenging due to presence of air gap occurring between bottom plate and sand cushion. Such air gaps eventually lead to ineffectiveness of CP system due to restricted current flow. The situation aggravates when moisture ingress occurs through annular area of the concrete foundation and settles underneath the bottom plate surfaces.

This paper focuses on case study of crude oil tank bottom plate failure due to corrosion and discusses its causes, design and installation errors, analysis of CP effectiveness, inspection strategy, interpretation of damage mechanism and recommendations.

Over-Voltage Protection of Isolation Joints in Pipelines – CAP13

Paper by: Jay Warner, Dairyland Electrical Industries, Stoughton, WI USA

Isolation joints in pipelines may be subject to over-voltage failure due to lightning and, in some applications, AC voltage. When a pipeline is near an electric transmission line, it can be subject to significant AC voltage if a phase-to-ground fault occurs. Without proper protection, such over-voltage events can damage the isolation kit and/or the flange and possibly ignite flammable contents within the pipeline. Various types of isolation joints appear in pipeline facilities, including fittings in measurement tubing, threaded unions, flanged isolators, and monolithic isolators. All types can fail if not addressed, and should have over-voltage protection.

Over-voltage protection against both lightning and AC fault conditions is possible using appropriately rated products, and is required by many regulatory agencies for protection of equipment and personnel.

This paper will review safety regulations affecting pipeline isolation joints, provide a brief description of solid state over-voltage protection devices and their operation, compare solid state devices to other solutions for over-voltage protection and discuss device ratings and key application guidelines for these devices for use with isolation joints. Specific examples will be presented of damaged insulators, compromised CP systems and fire resulting from lightning and AC fault occurring on unprotected isolation joints on gas transmission pipelines and the over voltage protection solutions that were implemented following the failures.

Cathodic Protection System for Internal Surfaces of Piping/Pipeline - CAP14

Paper by: Gitesh Jha, Reliance Industry Limited, Mumbai

Metallic Pipelines transporting corrosive media (eg. Untreated sea water) would require internal corrosion protection by internal lining as primary protection supported by Internal Cathodic Protection System by suitable Galvanic Anodes or ICCP systems. This paper as case study discuss for various parameters involved for selection of system design calculations pertaining to the design of CP system for the internal surface of the underground lined metallic pipeline, Sea water pipeline & Brine water pipeline. Selection of anode system and installation configuration considering pipeline diameter and lengths is discussed in paper.

Foreign Pipeline Interference and Detection of Third Party Coating Defect by ACVG A-frame Survey - A Case Study - CAP15

Paper by: Ashok Kumar Khatik, GAIL (India) Ltd, Chittorgarh and G V GokulaKannan, GAIL (India) Ltd, Nasirabad-Ajmer

Company A operates cross country Liquid hydrocarbon P/L of 1440 Kms length, and crosses various utilities along its length at different locations. Company A pipeline is running parallel with a company B product pipelines in some areas. Company B pipeline is having coal-tar coating.

Due to poor quality of coating, Company B foreign pipeline is protected by CP units after every 8 Kms. At some locations anode bed of foreign pipeline are laid towards the affected pipeline of Company A, which is the common source of interference.

During quarterly On/Off PSP monitoring, at chainage 617.419 & 618.43 Km of affected pipeline, off PSP were found less electronegative than 850 mV. Since the low polarization is observed first time without any major change in the conditions of two pipelines and their CP system, It is suspected that total circuit resistance between two pipelines at pickup and discharge location is reduced considerably, may be due to coating damage.

This paper describes the problems faced in finding exact discharge location and the approach followed in resolving the issue. This paper deals with the case of third party coating damage; due to which interference gets aggravated in between two parallel running pipelines. The major concerns are:

- Challenges in maintaining pipe to soil polarized potential.
- Finding the exact location of current discharge.
- Rectification and mitigation measures.

Coatings & Linings (CL-1)

Hall-B

Future of Heavy Duty Coating Landscape- Prospects & Opportunities - CL11 Invited

Paper by: Dr. B P Mallik, Asian Paints Limited, Mumbai

The rapid increase in environmental severity across the globe due to climatic change, pollution, demographic pressure, industrialization etc. and consequent acceleration of corrosion rate has forced the facility owners to look for new generation coating systems and solutions which are capable of extending the service life of existing assets. During the past two decades, the technology landscape of heavy duty coating segment has witnessed the emergence of several new products and systems which are more durable, efficient both functionally and aesthetically as well as cost effective.

Between 1980-2000 the major technological shift in the PC industry was the transition from medium solid to high solids to solvent free products in both epoxy and PU chemistry to tackle the issue of VOC compliance in one hand and resolving the complexity associated with multi coat application practices on the other hand. Post 2000 attributes such as functionality, durability, green & sustainability, productivity and cost efficiency became the primary drivers for new technology evolution. While R&D efforts were directed on all these areas the core focus had been the designing of high durable long life anticorrosive systems. The other major initiative (post 2005) from the industry side was the efforts towards harmonization of system composition and testing protocol for various surfaces exposed in different environment zones under ISO / Norsoc umbrella to prevent dilution of quality. Post millennium the rapid increase in labour cost as opposed to material cost created new sets of demands for productivity enhancing technologies. The manifestation of this trend enabled the introduction of rapid cure technologies to ensure time saving during system installation leading to faster return to service. Progressively the industry started migrating towards high build dual purpose products to cut down one layer in the coating system. Elimination of mid coat in PC system is happening either via the amalgamation of primer and mid coat using high build DTM primer or mid coat & top coat using high build glossy top coat.

So far there is limited success in the adaptation of new chemistry based products such as Polyaspartics, polysiloxane in Indian PC market. The demonstration of superior value proposition on cost performance matrix against existing systems, application friendliness and workability under local environmental conditions are of critical importance for successful penetration of new technology. Therefore, the dominance of epoxy and PU chemistry as workhorse for heavy duty coating industry will continue. Major innovations are expected around the derivatization of proven chemistries, new cross- linking approaches, use of hybrid binders, performance enhancement through nano material reinforcements and partial changeover to waterborne systems. Intense research thrust is also seen in the anticorrosive zone to develop alternate technologies based on new environment friendly anticorrosive pigments, sol gel derived corrosion inhibitor, self-healing corrosion inhibiting capsules and ICP (intrinsically conducting polymer) based CP system with reduced zinc loading or zinc free anticorrosive system. Since corrosion related failures are far more intense on surfaces exposed to high heat zones and particularly on under insulation areas, industry needs more efficient solution to address this issue of high temperature corrosion.

Consumer concerns and pain points will continue to be the seeds for new innovation and triggers for new business opportunities. As of now penetration of high end coating system in Indian PC market is still not very high compared to developed countries. Coating suppliers have to catalyze this shift proactively by demonstrating superior value proposition of these prospective technologies to create new avenues for growth. This presentation will cover some of these upcoming technological trends and implementation challenges.

Technical Sessions Descriptions

Covalent Bonding of Si Coatings, Making Infrastructure Maintenance Easier - CL12

Paper by: Matt Saunders, CSL Silicones, Canada

A Pull-off adhesion test and a standard Atlas Cell test were used to evaluate the performance of an Epoxy-based storage tank coating system after curing for 1, 3, 8 days. Adhesion tests were conducted for triplicate samples under ASTM-D4541-09E1 standard at 20°C for the three curing times and results indicated that most of the failures were cohesive in nature. The standard Atlas Cell tests were based on NACE TM 0174 (Method A) with an internal and external temperatures of 60°C and 5°C respectively. Tests were conducted for coated carbon steel substrates at curing times of 1,3,8 days under gas, hydrocarbon and water (15% NaCl) phases for a period of 6 months. Results of the tested panels were made in the form of EIS Bode plots which indicated that the panels that were cured at 8 days had a higher impedance values that those that were cured at 1 and 3 day.

The Effect of Curing Time on the Performance of a Storage Tank Epoxy Coating System - CL13

Paper by: M. Dabir, Shabbir Mukadam and A. Al-Hashem, Kuwait Institute for Scientific Research, Kuwait

A Pull-off adhesion test and a standard Atlas Cell test were used to evaluate the performance of an Epoxy-based storage tank coating system after curing for 1, 3, 8 days. Adhesion tests were conducted for triplicate samples under ASTM-D4541-09E1 standard at 20°C for the three curing times and results indicated that most of the failures were cohesive in nature. The standard Atlas Cell tests were based on NACE TM 0174 (Method A) with an internal and external temperatures of 60°C and 5°C respectively. Tests were conducted for coated carbon steel substrates at curing times of 1,3,8 days under gas, hydrocarbon and water (15% NaCl) phases for a period of 6 months. Results of the tested panels were made in the form of EIS Bode plots which indicated that the panels that were cured at 8 days had a higher impedance values that those that were cured at 1 and 3 day.

Overcoming Challenges in Coating Application Using Simulators - CL14

Paper by: S. Ravichandran, Berger Paints India Limited, Kolkata and
Sabarinath C Nair, Skillveri Training Solutions Private Limited, Chennai

Coating a substrate with an objective to protecting it from corrosive influences of aggressive environments is as important as the coating research, formulation, specification, and installation. Technology developments are reported in all fields to protecting the infrastructure be it in process up gradation of the materials used or to its installing in the desired service. It is often stated that mimicking the service condition in controlled study at the laboratory is the most difficult, as conditions in actual service are quite different and the foremost of difference starts with the varying application standards adopted by the painters.

The industry has adequate knowledge and experienced personnel in all spheres of activity and do deploy competent professionals when it installs a project or while maintaining it during service; but when it comes to the crucial work in execution of a coating system, the worker who actually paints is the weakest link, with little or poor knowledge of the process or its requirements and it is at this phase of surface preparation and application, many a case study emanates to highlight premature failures.

This paper shall elaborate on the simulator tool developed for airless spray painter skill development training using a software supported spray gun that prepares a painter to learning it right, till one does not get it wrong.

Failure Analysis of Coatings - CL15

Paper by: Peter J. Engelbert, Level 3 Coating Inspection, LLE, USA

Failure analysis of coatings reviews several incidents from the USA. Through the review of individual case studies, the audience will see the utility of various analysis techniques, laboratory tests and equipment to determine the mechanism of failure of protective coating systems. Case studies will include examples from a global fast food chain's headquarters in the USA, Oil & Gas storage in California, Deminerlized water tanks in Indiana, Coal Process units in Oklahoma, High Rise (30+ floors) apartments in Chicago, MIC accelerated corrosion multiplying the rate of corrosion by a factor of over 40, Pipeline breach and explosion of a home in New York and heavy metals abatement on the US Capital Dome. Techniques will discuss the use of scientific methods in analysis. Use of test results from an overspray legal claim involving over 300 autos will also be discussed. The case studies will reveal related issues to coatings which are the unexpected results such as regulatory action and defense not often reported in journals.

Challenges of Coating Applications with Plural Component Equipment's and Zinc - CL16

Paper by: Denzil Dcosta, Graco India Pvt Ltd., Gurgaon

In today's worlds coatings are being formulated to provide longer durability of the Subtracts be it steel of concrete. Most protective coating have moved towards the 80-100% solids from 40-60% solids and with very lower pot life. Application is a challenge and using the correct equipment is critical to a good coating, Equipment s very critical to manage the higher solids coatings,

Plural component equipment are built to handle the coatings mixing material on demand and applying the coatings, there are many challenges towards mixing this material with plural component equipment's.

Application of Zinc Coatings is also a major challenge. Improper equipment being used for applying Zinc coatings. Most contractors use one sprayer for all the coatings, using the correct applications equipment's is also very critical and applications needs to be managed well.

Corrosion in Petrochemical Industries (CPI-1)

Hall-C

Digitalisation: Are We Ready to Leverage on it to Ensure Asset Integrity? - CPI11 Invited

Paper by: Anuar Shukri Khairol, PETRONAS, Kuala Lumpur

Humans evolve and adapt in order to survive. Where the First Industrial Revolution used water and steam to power machines for production, the Second Industrial Revolution harnessed electric power for the generation of mass production. The Third Industrial Revolution employed electronics and information technology for production automation and it is thought that a Fourth Industrial Revolution is the digital revolution, utilising artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials scienceand quantum computing to transform the global economy. The past few years have been particularly challenging for the oil and gas industry with low crude oil prices and it is expected to stay this way for a while longer. In addressing this "new normal" situation, PETRONAS is looking at digitalisation as ways and means to survive by transforming operations, boosting performance and creating additionalprofits from existing capacity. Published report by the World Economic Forum on digitalisation for the oil and gas industry found that digitalisation has the potential to create around $1 trillion dollars of value for oil and gas companies. The question that beckons now is, how ready are we to leverage on going digital to ensure asset integrity and remain relevant in the industry?

Corrosion Mitigation of The Furnace Feed Saturator System of Gail Pata Ethylene Plant - CPI12

Paper by: Srimanta Kumar Manna, Soumyajit Ghosh and Samik Mullick, GAIL (India) Limited, Auraiya

The petrochemical sector plays a vital role in the functioning of virtually all key sectors of the economy which includes agriculture, infrastructure, healthcare, textiles and consumer durables. Polymers provide critical inputs that enable other sectors to grow. India's petrochemical industry has been one of the fastest growing industries in the Indian economy. In order to ensure smooth and uninterrupted operations of process plants, it is imperative for field operators, control engineers, and designers to be corrosion conscious as lines and component fittings undergo due to corrosion.

This paper gives a comprehensive review of flow accelerated corrosion problems faced in the newly designed furnace feed saturator system and its successful mitigation in the 450000 MT per year ethylene plant-2 of GAIL (India) Limited, Pata, Uttar Pradesh, India. The chemistry of corrosion mechanism has been examined with the various types of corrosion and associated corroding agents in gas cracker unit-2. Factors affecting each of the various forms of corrosion such as furnace feed composition, circulating and make up water quality and blow down rate are also discussed. Ways of mitigating this menace with current technology of low costs have been discussed. This paper brings out the importance of the principles of corrosion that must be understood in order to effectively select materials and to design, fabricate, and utilize metal structures for the optimum economic life and safety of facilities in feed saturator operations.

Avoid Weld Overlay Failures - CPI13

Paper by: Savio Rebello, Reliance Industries Limited, Navi Mumbai, India

Corrosion resistant alloys (CRAs) are required for handling various corrosive fluids and process conditions in refinery and petrochemical plants. The high cost of CRA can be significantly reduced by fabricating equipment and components in dual metallurgy, especially for higher pressure / thickness applications. A lower metallurgy, carbon steel (CS) or low alloy steel (LAS), provides the required bulk pressure thickness, while the wetted surface - the surface in contact with the process fluid, is of a corrosion resistant alloy with much lesser thickness. This can be achieved by cladding, strip lining or weld overlay of the base material (CS / LAS) with CRA. Cladding or weld overlay is preferred over loose strip lining, as the CRA is well bonded to the underlying parent material.

However, proper quality assurance is critical to ensure that the CRA weld overlay functions as desired. This paper details three examples of loss of containment incidents due to weld overlay issues, emphasizing the need for proper specification and stage-wise inspection during execution.

Severe Under-deposit Corrosion Damage in Suction Headers of Compressor House in LPG Recovery Unit - CPI14

Paper by: Manoj Kumar, Swapnil Zodape and Saugata Sahu, Indian Oil Corporation Ltd, Guwahati Refinery

Corrosion plays a vital role in the petrochemical industries because of several factors, but it is mainly dependent on process parameters, equipment design, piping layout, metallurgy of the used component, and finally the age of the plant. At the same time, impact of corrosion severely impairs the economy and profitability of the plant. This paper deals with the corrosion mechanism due to sour water acid corrosion in the presence of coke fines deposits in the suction header of the compressor house in the LPG Recovery Unit (LRU); its damaging effect is also a major concern. Failures due to under deposit corrosion and sour water acid corrosion have also been reported worldwide in petrochemical industries. An attempt was made to investigate the cause and effect analysis by optimizing the critical design process along with its operating parameters and using better material selection. To facilitate the investigation process, analysis of collected deposits, failed equipment inspection, inspection history and process data /trends were carried out. This paper also highlights the possibility of design changes with respect to the knock out drum and its demister pad upstream of the compressor, in order to minimize the coke fines and moisture carry over along with process fluid in the suction headers, thereby leading to prevention of the corrosive effect in the inlet circuit of compressor house. The proposed remedial measures will be beneficial to improve the reliability and integrity of the compressor house and hence LRU.

Technical Sessions Descriptions

Hydrogen Blistering in Stabilizer Overhead LPG Condenser of Naphtha Splitter Facility - CPI15

Paper by: Swapnil Zodape, Manoj Kumar and Saugata Sahu, IOCL, Guwahati Refinery

Low-strength carbon steels are widely used in refining industries for manufacturing pressurized components such as pipes and pressure vessels. Hydrogen blistering is a common form of hydrogen damage which can occur in components when a wet H2S environment is present. Equipment operating in sour environment contain H2S are prone to deterioration by wet H2S damage mechanisms when particular process variables gets established within the prevailing operating conditions. Blistering and subsequent hydrogen induced cracking damage are strongly affected by the presence of inclusions and laminations that provide sites for the diffusing hydrogen to accumulate. The current study assesses the root causes of hydrogen blistering in a Stabilizer LPG overhead condenser of naphtha splitter facility. The paper discusses in detail the inspection findings, observations, prevailing process conditions for damage and remediation action plans to prevent further accordance and growth of hydrogen blisters.

Materials & Composites (MC-1)

Hall-D

Failure Analyses: In Retrospect - MC11 Invited

Paper by: Nurul Asni Mohamed, PETRONAS GTS, Malaysia

During a failure analysis assessment, the cause of corrosion is ascertained to enable the assignment of corrosion monitoring and mitigations. This paper aims to revisit past failure analyses to validate the damage mechanisms of hydrocracker reactor effluent airfin cooler tubes, sour water stripper reboiler tubes and lubricant unit feed bottoms pump-around exchanger tubes leading to loss of containments. The hydrocracker reactor effluent airfin cooler tubes were upgraded to duplex stainless steel for mitigation against ammonium bisulphide corrosion. The exchangers were found to be leaking upon starting up. Root cause of the leaks was attributed to Sulphide Stress Corrosion Cracking due to high hardness of the tube-to-tubesheet weldments. Sour water stripper reboiler is still considered as a corrosion bad actor for the refinery. Various metallurgy upgrades were applied and premature corrosion due to departure from nucleate boiling condition still manifested. The lubricant unit feed bottoms pump-around exchanger tubes were found to display localised corrosion on the tubes external surface. The material of construction for the tubes, TP316, was found to still be susceptible to Naphthenic Acid Corrosion.

Mitigation against corrosion usually employs the path of least cost in regards to capital expenditures. Hence, corrosion monitoring will be enhanced and inspection frequency will be shortened, where possible. In ensuring adequate attention is given to any particular equipment, a Corrosion Bad Actor list or also known as Critical Asset Integrity list can be compiled for prioritisation of efforts.

Material Selection for Oilfield Development – Narration of Practical Experience - MC12

Paper by: Subrahmanya Bhat, Freelance Consultant, Bangalore

The selection of suitable material of construction for oilfield development is an integrated complex process. The prerequisite is the clear understanding of corrosion mechanism and its severity and accordingly identify alloys that are resistant to this producing environment to sustain the life cycle. The vital data comes from the results of production testing and bottom hole reservoir analysis. Water analysis, gas analysis provides the fingerprinting of electrochemical environment, Synergism of CO2 and H2S mechanisms, Chloride & temperature impact on sour mechanisms, Pressure impact on sour mechanisms, Impact of deep water and HPHT scenario on alloy performance. Presence of significant quantity of volatile fatty acids and source of H2S impact the material of construction. If one has some flexibility in specifying corrosion mitigation protocols, cost savings could be feasible through less costly materials. Prediction of trade off between material selection and process changes during the life cycle of production regime, significant savings in capital cost of installation could be achieved through revision of materials and allowing option for less expensive materials at the design engineering stage itself. The prerequisite to selection of suitable material of construction involve the considerations of mandatory requirements of compliance to engineering codes and standards like ASME, NACE, API and ASTM. This technical paper is based on my long experience with oil and gas operations.

From Corrosion to Nanotechnology that Prevents Challenging Global Warming – MC13

Paper by: I.Gurrappa, DMRL, Hyderabad and I.V.S.Yashwanth, University of Texas, USA

Then the importance of Nanotechnology starting from the corrosion process through which highly ordered titania nanotubes, rods, wires and also the powders produced, are exlained with recent results. It also demonstrate the recent production of titania nanotubes, wires, rods of different dimensions using new titanium based substartes and the significance of selecting suitable substrate composition and optmisation of process parameters. The talk also demonstrate the importance of corrosion process and its superiority over other techniques in synthesizing nanostructured tubes and powders apart from their characterisation, properties and applications. Subsequently, the superiority of prepared nanotubes and the necessity of their use in effectively preventing global warming and in modern industries that allow the systems to be used safely at varied environmental conditions, which not only would enhance the efficiency of industrial systems but also their life span and consequently the profitability, are stressed.

On the Corrosion Behaviour of High Mn High N Stainless Steel: An Alternative Bipolar Plate Material for Proton Exchange Membrane Fuel Cells (PEMFCs) - MC14

Paper by: P. Saravanan, Bhawna Khalkho, S. Srikanth and S. Kumar, Steel Authority of India Limited, Ranchi & N. Lakshman and Raghuram Chetty, IIT Madras, Chennai

The high Mn and high N stainless steels have been successfully developed for the first time on laboratory scale in SAIL. The developed Mn stainless steel revealed an exceptional combination of properties: higher yield strength, higher elongation, superior Charpy V-notch impact toughness and remarkable corrosion resistance than that of commercial stainless steel (316L) both in aqueous and acid. Also the steel showed promising corrosion behaviour in terms of Ecorr, passive range and break down potentials, than 316L stainless steel in fuel cell environment. The prototype fuel testing results suggests that developed Mn stainless steel is a viable material to replace 316L for usage in bipolar plates of PEM fuel cells having higher power density of 118 mWcm-2 and low contact resistance of about 30 mΩ cm2.

Suitable Material of Construction for Tubular and Flow Lines for Deep Water - MC15

Paper by: Bipin Kumar and Anil Bhardwaj, IEOT, ONGC, Navi Mumbai

Corrosion mechanisms expected in deep water wells do occur in flow lines also, only difference will be fall in temperature and pressure. The major corrosion mechanisms experienced by deep water flow lines, other than one experienced in deep water wells is the vapour phase corrosion mechanism. In the deep water, there has been a trend towards the development of increasing severe oil and gas production environments, in terms of pressure, temperature, and aggressive fluids, and this is expected to continue into the future. Such severe conditions necessitate the use of corrosion resistant alloys (CRA). The material specifications for CRA are based on the combination of standard tests, fit for purpose testing and experience.

A recognized material selection procedure is to review the literature for corrosion data that applies to the anticipated field conditions. Then a group of candidate alloys is selected that represents a range of alternatives. A test program, simulating the subject field environment, is often carried out. The final CRA selection is made for a specific application based on available data, test results and an economic analysis of the alternatives. While more detailed testing and analysis is sometimes required, guideline tables and diagrams are often used. Pipe in pipe (PIP) concept is used where flow assurance is an issue. In such case the inner component can be solid CRA or CRA cladded carbon steel. The CRA depends on the CO2 and H2S level and in-situ pH. The outer component of pipe-in-pipe is usually of high strength steels as X 70, X80 or X100.

The most commonly and cost effective CRA downhole tubular material used for HPHT applications is API 5CT L80 type 13 Cr. Martensitic materials (13Cr and modified 13Cr steel) are highly susceptible to corrosion while in storage in a wet and saline atmosphere. Because of their high PREN index higher CRA materials can be considered to be corrosion resistant to atmospheric conditions. However, improper handling may result in affecting the material performances and by extension their corrosion resistance. It is highly recommendable to investigate the expected sequence of exposures of CRA to avoid occurrence of corrosion initiation before the commissioning in the oilfield.

Iron contamination of CRA surface shall be avoided to prevent pre-corrosion. If any contamination of CRA surface is observed, it requires to be cleaned by chemical or electrochemical process.

1030 - 1100
Tea/Coffee

1100 - 1130
Plenary Talk
Main Hall
U Kamachi Mudali, Chief Executive, HWB

1130 - 1215
Plenary Talk
Main Hall
Ananth Kumar, Union Minister of Chemicals and Fertilizers

1215 - 1230
Visit Exhibit Hall and Poster Area

1230 – 1315
Lunch

Technical Sessions Descriptions

1315 - 1415

Internal Corrosion in Pipelines (ICP-1)

Hall-A

Ensuring Safety and Quality in Pipeline Integrity Operations - ICP11 Invited

Paper by: Matthew Boucher, Clock Spring, USA

Industrial infrastructure is critical to the functioning of modern society. Upstream extraction, mid-stream transport, and downstream processing provide not only affordable energy that helps improve quality of life and lift people from poverty, but also many of the goods used to enhance and prolong life. From bio-degradable water bottles to life-saving medical equipment, the energy industry enhances and saves lives every day of every week of every year.

As an industry we are collectively and collaboratively committed to the safety and safekeeping of every individual working in this industry and to complete and uncompromising environmental stewardship. The capital investments of the energy industry represent trillions of dollars across the world. Properly maintaining these assets not only ensures their continued efficient and effective operation, but also enhances the safety of people working, living, or traveling near those assets and proactively protects the environment by preventing emissions and spills.

Tracking, measurement, and reporting requirements of safety statuses have increased over the years as these issues have become more prevalent. The good news is that the statistics are improving over time and that injury rates per measure of man hours have been decreasing. Fewer people are getting hurt and it is the result of purposeful effort on everyone in our industry's behalf.

We are all business people and, when given a set of metrics, we will work to manage them to maximum effect. Tracking and analyzing safety metrics results in understanding the most common injury types and a consequent focus on reducing the number of incidents of these types that occur. For example, common safety programs and tool-box talks often focus on hand injuries, slip-trip-and-fall injuries, or line of fire injuries from hand passed objects. Unfortunately, in our efforts to deliver great metrics, we can lose sight of less common injury causes that produce proportionally greater consequence.

We all note that no injury is acceptable, but the reality is that common injury root causes more often result in minor injuries. Less common injury causes, including crush injuries, falls from height, and injuries due to explosion often result in injuries for which the consequences are severe; where injuries can range from catastrophic and permanently life altering to fatal.

This paper will explore our industry's focus on safety during pipeline maintenance operations and explore the hazards that can lead to less common, but more disastrous injuries. It will introduce LEAN concepts for identifying the eight forms of waste to enhance safety program efficacy and quality. It will note that the best way to ensure safe operations is to remove safety hazards from the work environment and identify cases studies and maintenance and repair options that can be completed more safely while offering the same or better environmental protection and economic benefits to the companies that use them.

Inspection Methodologies and Tradeoffs for Inspection of Unpiggable Pipelines - ICP12

Paper by: Christian Openshaw, Quest Integrity, UAE and Dan Revelle, Quest Integrity, USA

Pipelines have become an essential part of the system to transport and supply of petroleum gases. Conventionally, gas pipelines are coated externally for anticorrosive properties. The inclusion of condensates, sour gases and other corrosive substance in traces cannot be ruled out during pipeline operation over a period of its intended usage. The External coatings are not able to provide resistance to corrosive substances present in gases and cannot be cleaned using pigs. The corrosion of pipelines through condensates, accumulated corrosive substances has caused severe damages to pipelines, mankind and economics worldwide.

This article reviews the benefits of considering an internal lining for gas transmission pipelines and the relationship between the internal surface roughness, the pressure drop across the pipeline and the maximum flow rate of gas through the pipeline

Failure Analysis of 6" Spool of Process Gas Compressor Cooler Outlet at Offshore Process Platform - ICP13

Paper by: Abhay Kujur, Maushumi K Talukdar, Sangeeta R. Prasad, Anita Sharma, A. Santra and Anil Bhardwaj, IEOT, ONGC, Navi Mumbai

In offshore process complex, process gas compressors are used to compress gases from 6-8 kg/cm2 to 90- 96 kg/cm2 in three stages. The compressed gas is cooled by passing it through inter coolers and the condensed water is removed through the knockout drums (KOD) at the respective stages. This case study pertains to failure of 6"Φ pipe spool segment of third stage cooler outlet line. PGC cooler outlet, after 3rd stage, have a pressure of 92 Kg/cm2 and it has 3.26% CO2, 90 ppm H2S along with condensate.

Laboratory investigations of failed PGC cooler outlet showed that chemical composition, tensile strength and hardness value of the tested sample were complying with the SSC resistant, ASTM A 106 Grade B material. The piping had an acceptable microstructure of normalized ferrite and pearlite.

Visual inspection of the failed surface showed the classic sand dune like surface contours oriented along the direction of fluid flow that is typical of erosion-corrosion. In metallographic studies, small pits were observed at several places. EDS analysis of pitted region on failed piping surface confirmed the influence of corrosive species like chloride and sulphides. Localized metal loss of cooler outlet piping led to its failure by erosion corrosion under corrosive environment. All the corrosion studies showed that existing metallurgy of piping was susceptible to CO2 corrosion. It was recommended to use UNS 31603, 316 L Stainless steels for PGC cooler outlet lines to avert such failures in future.

Corrosion in Chemical & Fertilizer Industries (CCFI-1)

Hall-B

Consultant Approach to Decision Making on Material of Construction for Chemical Industries - CCFI11 Invited

Paper by: Subrahmanya Bhat, Freelance consultant, Bangalore

The chemical plants consists of reactor vessels (HPHT), piping, valves, heat exchangers, evaporative cooling, evaporative and drying, distillation, mass separation, mechanical separation, Flue gas, effluent treatment and disposal. Understanding of Chemical reactions and operating conditions of flow dynamics, temperature and pressure and their impact on pH, electrochemical reactions are essential to decide on the most suitable Material of construction (MOC) for chemical plants. In pharmaceuticals wherein the quality of the medicines is vital and hence the corrosion resistance of alloy shall be very high to avoid any contamination by corrosion products. In fertilizer industry strong acids and strong alkali severely affect the corrosion behavior of alloys. In Agro industries MOC shall be corrosion resistant to nitration, ammonolysis, halogenations, polymerization, oxidation, hydrogenation, diazotization vapour phase catalytic reactions. In Biotechnology, low temperature to high temperature conditions is to be taken into considerations. Most of the chemical plants consists of combination of different type of equipments and process vary in different stages and hence always there is need of combination of alloy of different electrochemical potential which can lead to galvanic corrosion and therefore preventive measures are to be in built in design engineering stage itself. In a mixed gas environments it is the dominant process among possible oxidation, sulphidation, nitridation, carburization which can be assessed based on respective chemical potentials.

The Use of FRP (Fiberglass-reinforced Plastic) in Phosphate Fertilizer and Sulfuric Acid Processes - CCFI12

Paper by: Guy Schneider, Ashland Technologies GmbH, Germany and
Olivia Woerth, Ashland Technologies GmbH, 77694 Kehl, Germany

The demand for corrosion resistant composite equipment increased significantly starting mid 2000 when nickel prices raised very rapidly. With a 50-year reputation for low maintenance and relatively stable cost, Fiberglass-reinforced Plastic (FRP) made with Epoxy Vinyl Ester Resins provides process engineers with a reliable, cost effective construction material that can be employed in numerous applications that are corrosive to stainless steel, and at a much lower cost than high alloy clad steel. Although some other materials may be cost competitive with FRP, their use typically results in higher life cycle costs due to maintenance.

The purpose of this paper is to compare FRP made with Epoxy Vinyl Ester Resins with high nickel alloy in “wet process” phosphoric acid and sulfuric acid environments. Comparison of relative cost and corrosion data are presented to provide the information necessary for process engineers to facilitate future decisions concerning material of construction. Examples of equipment will be shown to demonstrate that it is an ideal product for the fertilizer industry.

Case Study - Crafting and Executing Corrosion Management Strategy at Multipurpose Sea Port - CCFI13

Paper by: D. Dubey, Adani Ports & SEZ Ltd, Mundra

Corrosion management for an operation is the systematic application of policies, practices and resources to control corrosion and provide reliable safe guard against unexpected failure and leaks that can jeopardize mechanical integrity, operation, health, safety and environment (HSE). In times of tight budget, the life cycle management of long time to fail component requires a comprehensive strategy for condition assessments, data management and standardized tasking for restoration during maintenance availability period.

While today’s sea port operational technologies are dramatically different from even half century ago , one issue remain fundamentally unchanged ; the impact of salt water environment & various chemical exposure on sea port infrastructure.

This paper uses examples from the Adani Ports & SEZ Ltd corrosion control program to execute corrosion management strategy. This paper also describes various successful continual improvements project to control corrosion & challenges way ahead.

Asset Management Through Corrosion Loss Prevention in a Urea Plant - CCFI14

Paper by: Dr. John Paul, Consultant, Chennai

In a large Urea plant in The Middle East a sudden failure was reported right after maintenance and return. A series of investigation and failure analysis showed startling information. A stainless steel component issued from the warehouse was found defective. In a modern Urea plant like that, about 54 different types of stainless steels (1)are used - some of them are patented and whose composition are not revealed. This is a unique plant that utilizes Natural gas as source of required Carbon di oxide. This called for a revamp on all previous failed cases of components - their origin, supplies, composition, warehouse and preservation methods etc. Is it wrong to expect the components to serve till suggested service life, or plan a proactive method to prevent failure – and if so on what basis? Some simple steps were introduced to avoid failures in future. This is a compilation of some case studies evoking active discussion.

Technical Sessions Descriptions

Microbial Corrosion & Inhibitors (MCI-1)

Hall-C

N-benzylidine-2(2-oxo-2-(10H-phenothiazine-10yl) amino) Acetohydrazide as Environmentally Benign Corrosion Inhibitor for Mild Steel in 1M HCl Solution - MCI11

Paper by: Mohammad Mobin and Saman Zehra, Aligarh Muslim University, Aligarh

In the present study, we are reporting the investigation of an environmentally benign compound, a glycine derivative N-benzylidine-2((2-oxo-2-(10H-phenothiazine-10yl) amino) acetohydrazide (BPAA), as potential corrosion inhibitor for mild steel in 1M HCl solution at temperatures 30-60°C. The investigation is accomplished by electrochemical polarization, electrochemical impedance spectroscopy (EIS), gravimetric, UV-visible spectrophotometry, FT-IR spectroscopy and scanning electron microscopy (SEM). The evaluated compound works as effective inhibitor for acid corrosion at substantially lower concentration and its adsorption on the MS surface was found to obey the Langmuir adsorption isotherm. Calculated thermodynamic parameters for adsorption unveiled a strong interaction amongst the inhibitor-mild steel surface. The electrochemical results revealed that the inhibitor act as mixed-type. The order of IE acquired from experimental results is successfully verified by theoretical calculations.

Antimicrobial and Anticorrosion Effect of Essential Oils of Medicinal and Aromatic Plants on Sulphate Reducing Bacteria Isolated from Oilfield Produced Water - MCI12

Paper by: Ranjan K.Bhagobaty and M.C.Nihalani, Oil India Limited, Duliajan

Medicinal and Aromatic Plants (MAPs) have been known to possess inherent anti-microbial properties. In the present study, locally available essential oils of Lemongrass (LEO) (Cymbopogon flexuosus), Citronella (CEO) (Cymbopogon winterianus) and Patchouli (PEO) (Pogostemon cablin) were analyzed to ascertain their antimicrobial and anticorrosion effects on a native strain of Sulphate Reducing Bacteria (SRB), isolated from produced water sourced from an Oil Collecting Station in India's North-Eastern state of Assam. The Minimum Inhibitory Concentration (MIC) for Lemongrass, Citronella and Patchouli essential oils were determined to be 50 ppm, 100 ppm and 450 ppm respectively, using microdilution susceptibility tests. The minimum concentration of the essential oils that not only inhibit SRB activity, but also kill the target bacterial cells was also determined using Minimum Bactericidal Concentration (MBC) assay. The MBC concentrations of LEO, CEO and PEO were found to be similar to their MIC levels. All the essential oils tested showed SRB biofilm inhibitory effects on glass and N-80 carbon steel coupons. The average rate of biocorrosion calculated based on the weight loss of N-80 steel coupons indicate that the essential oils tested were able to exhibit a significant anticorrosion effect on the treated N-80 steel coupons.

The Application of Electrochemical Impedance Spectroscopy (EIS) in Studying the Synergistic Behavior of Oilfield Chemicals for a Tubular Alloy under down hole Conditions in a Kuwait Formation Water - MCI13

Paper by: S. Mukadam, M. Dabir and A. Al-Hashem, Kuwait Institute for Scientific Research, Kuwait

A bubble cell test was used with an electrochemical impedance spectroscopy (EIS) system to study the synergistic effects of scale and biocide inhibitors on the performance of a corrosion inhibitor for L-80 tubular steel under simulated down hole conditions in one of Kuwait oil fields formation water. The EIS scan range of the frequency for the impedance tests was fixed between 0.1 to 20,000 Hz for all conditions and measurements were carried out at open circuit potential. The EIS results are in the form of Nyquest plots which indicated that all chemicals and their combinations show reduction of corrosion rate of L-80 in a simulated down hole condition. The levels of reduction vary for the chemicals and their combinations indicating different metal surface interaction mechanisms. The synergism between 250 ppm of biocide and 5 ppm corrosion inhibitor in the formation water exhibited the best protection of L-80 against corrosion.

Ethyl 6-amino-4-(methoxyphenyl) 3methyl2,4-dihydropyrano [2,3,C] pyrazole-5-carboxylate as Novel Corrosion Inhibitors for Mild Steel in - MCI14

Paper by: Hydrochloric Acid Solution useful for industrial pickling process, Parul Dohare, M. A. Quraishi, Banaras Hindu University, Varanasi

In the present work a new corrosion inhibitor namely Ethyl 6-amino-3-methyl-4-(methoxyphenyl) 2,4-dihydropyrano [2,3,C] pyrazole-5-carboxylate (MEP), was prepared, characterized and corrosion inhibition properties was investigated on mild steel using gravimetric, potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), Scanning electron microscopy (SEM), Atomic force microscopy (AFM) and theoretical methods. MEP exhibited highest efficiency of 98.8 % at 100 mg/L. AFM and SEM studies confirmed formation of adsorbed film on the metal surface and followed Langmuir adsorption isotherm. The DFT and MD which further corroborated the experimental results.

Corrosion in RCC Structures (RCC-1)

Hall-D

Controlled Permeable Formwork (CPF) Liner: Concrete Surface Quality Enhancer - RCC11

Paper by: S. Kothandaraman, Pondicherry Engineering College, Pondicherry

The durability of concrete structures primarily depends on the surface quality of the concrete, as it is the first line of resistance to penetration of aggressive agencies. Controlled permeable formwork (CPF) liner is an innovative material used for improving the quality of the cover surface zone of concrete. CPF liner drains mix water and entrapped air from the cover zone of concrete whilst retaining cement and other fine particles. This ensures triple benefit: (1) Reduced water-cement ratio, (2) Increased cement content, and (3) Decreased surface porosity in the surface zone of concrete. Though the CPF liner was introduced in Japan during the 1980s, its use and awareness are limited in Indian context, in particular. Most of the researchers have focused their attention to study the durability characteristics of CPF-lined-concrete. A critical review on the use of CPF liner is presented in this work. In addition, a comprehensive experimental study was conducted for the effect of CPF liner on the surface characteristics, depth of influence, and durability characteristics of CPF-concretes are discussed. In self-compacting concrete the synergetic effects add to the durability of concrete and eventually the sustainability.

Quinoxaline Derivatives for Rebar Corrosion in Simulated Pore Solution - RCC12

Paper by: J Saranya, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad and S Chitra PSGR Krishnammal College for Women, Coimbatore

Corrosion of reinforcing steel represents the most widespread form of deterioration of concrete structures resulting in significant costs for repair and replacement worldwide. Inhibitors, chemical substances that prevent or retard corrosion, are applied as concrete admixtures or as surface applied liquids either for preventive or for restorative applications. This work discusses the investigation of nitrogen containing heterocyclic compounds namely (3E)-3-(2- phenylhydrazinylidene)-3,4-dihydroquinoxalin-2(1H)-one (PHDQO) and 2,3-di(furan-2-yl) quinoxaline (FQ) as inhibitors, with potential remedial applications for concrete in pore solutions with chloride, in an attempt to develop an understanding the nature of the inhibition, the level of the inhibition and the ability of these chemicals to migrate through concrete. The electrochemical measurements such as potentiodynamic polarization and electrochemical impedance spectroscopy were performed in simulated concrete pore water solution, indicate that the inhibitor PHDQO showed excellent inhibition whereas FQ exhibited only moderate inhibition for steel.

Performance Evaluation of Silane/Siloxane Based Penetrating Sealer for Structural Applications in Marine Environment - RCC13

Paper by: R.Vedalakshmi S.Sathyanarayanan, S.Sreejakumari and T.Bharathidasan, CSIR-Central Electrochemical Research Institute, Karaikudi

Concrete cracking is considered as the most common type of distress observed throughout the structure and occurs from the stage of hardening itself. In a marine environment where bridges are subjected to seawater spray/splash, cracks of width as small as 0.05 mm could be significantly detrimental and they must be sealed to maintain durability. Penetrating sealers when applied on concrete surface, they form chemical bond with the pore walls, thus change the surface tension of the concrete. In turn, treated surface produces water repellancy and retards the permeation of aggressive ions such as chloride and sulphates enter into the concrete.

Silane and siloxane are common reactive sealers with low viscosity tend to penetrate deeper into the concrete. In the present study, a new silane based sealer has been formulated and tested using standard test codes. Various rigorous tests such as depth of penetration, water absorption and repellancy, pore size reduction (using MIP), chloride penetration (Rapid chloride permeability test) and scanning electron microscopic (SEM) studies were carried out.

From the studies, it can be inferred that developed silane/siloxane sealer penetrated up to 50 mm depth. Vapour transmission rate of sealer treated concrete surface was found to be in the range of 8-10 g/m2 over 24 hrs and indicated that the sealant remains breathable. The charge passed under RCPT test was 130 coulombs which is 10 times lower than that of untreated concrete. SEM studies showed the formation of acicular crystals throughout the concrete surface and confirmed the reaction of silane with Ca(OH)2. The detailed investigation revealed that concrete treated with low viscous silane /siloxane, performed better by a minimum factor of 10 than that of untreated concrete.

Sweet Corrosion Behaviour of Concrete by Utilizing Iron Dust as a Binding Material in Concrete - RCC14

Paper by: Han Seung Lee, Subbiah Karthick, Velu Saraswathy, Seung-Jun Kwon, Hanyang University, Korea and (CECRI), Karaikudi

Concrete is a boon to the construction industry. As the largest synthetic production in the world, concrete's annual demand is about 6 times the global human population (approximately 40BMT). Cement is the main binding material in the concrete. The demand for concrete increases with the demand for cement globally (approximately 4.1BMT). During the manufacturing of cement equal amount of CO2 is emitted into the atmosphere. It results in Green House Effect which in turn leads to the Global warming. So, the world needs a carbon negative concrete i.e., which absorbs the amount of carbon dioxide, quite more than it emits. To develop such a concrete, a newer approach of utilizing iron waste as a binding material has been attempted. Here, corrosion of iron in carbon dioxide environment is called as a sweet corrosion behavior (binding mechanism). The suggested mechanism is implemented in concrete and compared with the conventional concrete.

Technical Sessions Descriptions

1415 - 1430
Session Break

1430- 1600
Cathodic and Anodic Protection (CAP-2)
Hall-A

Effect of DC Interference on the Performance of Sacrificial Anodes Protecting a Pre-Stressed Concrete Cylinder Pipeline - CAP21

Paper by: Ezeddin Busba and Hussein Boshallah, The Great Man-Made River Authority, Libya

The protection level of a four-meter diameter Pre-stressed Concrete Cylinder water Pipeline of the Great Man-Made River was achieved by retrofitting vertical sacrificial anodes along its entire length. The sacrificial CP system was favored over impressed current CP system to avoid the risk of overprotection which can cause detrimental hydrogen embrittlement of the PCCP pre-stressing steel wire. A preexisting foreign oil pipeline protected by an impressed current CP system was intersecting with the PCCP pipeline. Interference testing and Close Interval Potential Survey (CIPS) performed at the pipeline crossing on both lines suggested that the sacrificial magnesium anodes may have rather enhanced the stray current pick up through the low resistance path. That effect presumably exacerbated the severity of interference with the adjacent PCCP pipeline at the stray current pick-up and discharge regions.

This work describes and evaluates the adverse interaction effect on the protection level of PCCP at the pipeline crossing and discusses possible interpretations of CIPS anomalies and likely mitigation measures.

Conventional AC Mitigation with Zinc versus, Engineered AC Mitigation System – Case Study - CAP22

Paper by: Ted Huck, MATCOR Inc, USA

High Voltage AC Transmission lines can adversely influence pipelines that are collocated along the same right of way by high Induced AC voltage and current, that can cause corrosion and safety issues of the steel pipelines. The conventional method used for the mitigation of the AC voltage is to install zinc ribbon anode and connecting it to pipeline through a decoupler.

Zinc when used for AC Mitigation on pipelines may have some concerns related to passivation and consumption. This paper will discuss the benefits of engineered AC Mitigation system, a packaged grounding system that combines the best of copper grounding with low resistance, corrosion-inhibiting backfill over conventional grounding using Zinc Ribbon. Engineered AC mitigation system provided superior performance over conventional grounding system that used Zinc. We shall discuss a case study where Zinc, Bare Copper and Engineered AC Mitigation system were installed and connected to a pipeline through decoupler to the pipeline under the severe influence of AC interference.

Instant OFF Measurements on Coupon: Practical Advantages of a Continuous Remote Monitoring - CAP23

Paper by: Ivano Magnifico, Automa S.r.l., Ancona, Italy

Stray currents increase and in some cases coatings improvement lead to more difficulties in evaluating Eon measurements than in the past. Switching remote monitoring to Eoff measurements let Cathodic Protection technicians lead better evaluations on CP efficiency by eliminating field voltage drop effects, thus letting them concentrate efforts only where really needed.

Moreover, rectifiers remote control based on Eoff measurements, allows resources optimization and injecting in the field no more current than that really needed. This work is focused on showing real advantages on leading cathodic protection efficiency evaluation on continuous Eoff remote monitoring and rectifier remote control Eoff based, presenting real cases where such kind of monitoring lead to huge advantages with respect to Eon remote monitoring.

Study On Trouble Shooting In ICCP Protected Underground Pipeline For Low Instant Off PSP Values - CAP24

Paper by: Santosh Gedam and Virendra Vastrakar, GAIL (India) Ltd

Successfully designed, installed and commissioned ICCP systems should demonstrate, a polarized PSP of -850 mV or more negative as measured w.r.t. saturated Copper/Copper Sulphate (CSE) Reference Electrode. Alternatively, A minimum of 100 mV of cathodic polarization. Either the formation or the decay of polarization must be measured to satisfy this criterion as per NACE RP-0169.

This paper is a case study related to identifying the probable causes of low instant OFF PSP values of pipeline. During ON-OFF PSP monitoring, it was observed that the instant OFF PSP values at many locations were less electronegative than protection criteria of -850 mV with respect to copper/copper Sulphate reference electrode. Pipeline was not getting adequate CP protection of -850 mV or more negative, but it was ensured that the P/L was protected by 100 mV cathodic polarization shift criterion.

Various efforts were made to identify the exact cause of low instant OFF PSP such as CAT survey, DCVG, checking of anode bed, data logging, faults in cables across IJ, checking of IJ with RFIT etc. After carrying out numerous surveys one of the probable causes was identified as shorting of IJ at one of the ends of pipeline. This paper describes the challenges faced in identifying causes of low instant OFF PSP values and various actions taken to rectify the same.

CP System for Aged Upstream & Downstream Oil & Gas Field Facility - CAP25

Paper by: Shaikh Harunor Rashid, Himoya Corrosion Technology (P) Ltd., Kolkata

Challenges for cathodic protection engineers especially for aged upstream and downstream oil and gas field facility, where accident, oil leak, production losses are common and routine. Cathodic protection is widely acceptable corrosion prevention technology in oil and gas industry. Every cathodic protection system design start with the first question whether to go with Galvanic/Sacrificial anode cathodic protection system or impressed current cathodic protection system. Effective designing of a CP system is a challenging task especially when the field is dying and production is reducing day by day; results have obtained for optimized design and life by cost effective cathodic protection system by experimental method with the compliance industry standard. In this paper 3 case studies will be discussed with the methods used, in accordance with NACE standard and industry norms. (1) Complex pipeline in oil field without an existing cathodic protection system (2) Onshore Gas Well Casing in a gas filed (3) Floating storage offloading facility (FSO).

The various methods adopted during pre-design survey, design engineering and in installation are discussed in this paper.

Microbial Corrosion & Inhibitors (MCI-2)

Hall-B

Suppression of Anodic Kinetics of Stainless Steels by Natural Seawater Biofilms - MCI21 Invited

Paper by: M. Eashwar, A. Lakshman Kumar, G. Sreedhar, S. Vengatesan, R. Ananth and V. Prabhu, CSIR – Central Electrochemical Research Institute, Karaikudi

The effect of biofilms on the anodic kinetics of three stainless steels, viz. UNS S31600, S44660 and N08367 in quiescent flowing natural seawater was investigated. Potentiodynamic anodic polarization showed two distinct passive regimes emerging with biofilm development. In the lower passive region near the ennobled open-circuit potential, biofilms produced dramatic decrease of anodic current densities ($p < 10\text{-}4$) accompanied by an increase of the breakdown potential by over 0.2 V for alloy S31600. Biofilms, however, led to significant broadening of the transpassive region on all the three alloys tested. Further, for alloys S44660 and N08367, biofilms altered the second passive region and amplified the peak current densities therein. These seemingly undesired effects, nonetheless, were detected far beyond practical realms. Potentiostatic current–time curves for alloy N08367 further confirmed the suppression of anodic kinetics in the lower passive region. Evans diagrams constructed from actual polarization curves provide fundamentally important insights that passivity promotion can be independent of microbially enhanced cathodic kinetics.

Microbiological Induced Corrosion in Newly Built Tanks - MCI22

Paper by: Ameer Hamza, Fluor Arabia Limited, Saudi Arabia, Neto Obasi, Fluor, United Kingdom

Localized (Pitting) corrosion in the annular plates of uncoated tanks was detected in newly built tanks sequel to hydrostatic testing. The causative factor was detected as microbiologically induced corrosion (MIC). This form of corrosion results from the activities of microbial colonies, normally a mix of possibly aerobic and anaerobic microbes that exist in both sessile and planktonic forms.

Stagnant and/or low flow conditions play a key role in MIC initiation. Sulfur, H2S, ammonia, hydrocarbon & acids also provide nutrient sources for sulfate-reducing bacteria (SRB). Carbon steel and stainless steel equipment including pipelines, piping and storage tanks face significant challenges from Microbiological Induced Corrosion (MIC) both prior to and during service due to several factors which are described in this paper.

This paper also outlines some of the major metallurgical, corrosion, prevention, mitigation and inspection issues that are commonly associated with Microbiological Induced Corrosion.

Biofilm Analysis on Cooling Waters of Fast Breeder Test Reactor Using Advanced Molecular Tools - MCI23

Paper by: B. Anandkumar, R.P. George, S. Lakshmanapandi, S. Ramamoorthy, C. Mallika, Indira Gandhi Centre for Atomic Research, Kalpakkam

Cooling water systems, particularly open recirculating systems, provide a favorable environment for the growth of microorganisms. Microbial growth on wetted surfaces leads to the formation of biofilms. If uncontrolled, such films cause fouling, which can adversely affect equipment performance, promote metal corrosion, and accelerate wood deterioration. These problems can be controlled through proper biomonitoring and application of appropriate cooling water antimicrobials. The objectives of the present study are to identify and isolate the predominant bacterial species present in the biofilms of fresh water cooling system of Fast Breeder Test Reactor (FBTR), Kalpakkam, using microbial analysis and metagenomic sequencing and to construct the Fluorescence in situ hybridization (FISH) probe for the predominant bacterial species. The microbial community in the FBTR sample annotated through 16S rRNA gene sequencing analysis indicated the presence of 70% of Bacillus sp. and members of Enterobacteriaceae family occupied 30% of the biofilm. The metagenomic studies revealed that 82% of the microbial community was populated by Pseudomonas species, 8.65% by Acinetobacter species, 4.74% by Shewanella species, 2.45% by Phyllobacterium species and 2.1% by Brevundimonas species. Further, FISH studies performed for the probe construction analysis had resulted in the construction of probes specific to Bacillus species and Pseudomonas species. The results of the present study would pave way for an efficient biofilm monitoring system. Though the cooling water in the test reactor is being treated with polyphosphate based corrosion inhibitor and commercial biocide, the presence of microbial groups indicates the treatment regime to be supplemented with antimicrobials to achieve the complete biofouling control. The molecular techniques (next generation sequencing and FISH probes construction/validation) employed in the present study facilitate to identify the biofilm forming and MIC causing microbes within a limited time.

Technical Sessions Descriptions

Microbiological Control and Successful Quality Maintenance of Reinjected Water in Onshore Operations, A Case Study - MCI24

Paper by: Veena Kothe, Archana, Harvir Singh, ONGC, Panvel, Navi Mumbai

The Effluent Treatment Plant of Kamalapuram (KMP) Karaikal, Cauvery Asset, generates 100 to 150 M3 per day quantity of effluent which is reinjected for enhanced oil recovery. The plant is operated once in two or three days and sometimes more than this. During this time the treated effluent is stagnant in treated tanks available at KMP, Effluent Treatment Plant (ETP). The effluent in Kamlapuram ETP plant was being treated with 10 ppm of aldehyde & amine type bactericides alternately, however, in spite of the treatment, blackening of water was observed in the water storage tank.

Since KMP effluent contains higher concentration of iron and sulphate (Iron:30-50 ppm and Sulphate:250-470 ppm), it was suspected that, this may have led to growth of sulphate reducing bacteria and may be the reason for turning the water to blackish colour, which was not desirable. Also, the design of the process has several ideal locations for bacteria to find niche and form colonies. The situation demanded detailed study, dose optimization of the amine and aldehyde type biocides used for treatment purpose at KMP, Karaikal.

Detailed study of samples from all the steps of the process revealed the actual microbial load and requirement of optimized biocide treatment of the system. High counts of SRB, General aerobic bacteria (GAB) were observed. Bactericide kill doses of the two types of biocides were ascertained against the different cultures (GAB & SRB) growing in these samples obtained from various phases of the process. The optimized doses were found to be higher than those being in practice. Implementation of the recommended doses of biocides in the plant evinced to bring the microbial problem under control and get the desired quality of injection water for enhanced oil production.

Establishing Microbial Contamination and Biocides Efficacy Evaluation in Cooling Tower Water Samples - MCI25

Paper by: Archana, Veena Kothe and Harvir Singh, ONGC, Panvel, Navi Mumbai

Cooling towers system is a critical unit in many industrial production processes, including oil industry, as they provide the most efficient means of rejecting heat from open re-circulating cooling systems. The basic objectives of a cooling water treatment program are to increase process efficiency, production output & maximize equipment service life.

Recirculating cooling water is susceptible to microbial contamination through incoming water and air. An inappropriate control of these microorganisms may lead to biological fouling in heat exchangers, which enhance scale formation and corrosion, impacting heat transfer efficiency and treatment, which affects overall process efficiency and result in the adverse effects on production.

The paper documents the results of investigations with respect to the degree of microbial invasion in the cooling water systems of LPG-I,II, C2-C3,APU units of Uran Plant. It also includes evaluation of biocides efficacy for effective control of the microbial proliferation against the presently used doses.

The study has revealed that the presently used doses of biocides were not effective to control heavy load of microbes present in the system. Therefore, efficient doses of biocides were evaluated through Minimum Inhibitory Concentration method. All the biocides were effective in the range of 50-100 ppm for LPG-I, II and C2-C3 whereas for APU it was above 150 ppm. It has been recommended to implement these doses for complete microbial control in the system.

Materials & Composites (MC-2)

Hall-C

Corrosion Issues in Molten Salt Reactor Systems Under Molten FLiNaK Salt Environment - MC21 Invited

Paper by: S. Rangarajan and Y.V. Harinath, BARC Facilities, Kalpakkam

Due to depleting uranium resources, nuclear energy vendors are now focusing on thorium (232Th) as breeder to get uranium (233U), a fissile material which will serve as nuclear fuel. India is the fourth largest country in the world with vast resources of thorium (~12.2 % of world thorium resources). Thorium, having a capacity to produce fissile 233U in thermal, intermediate and fast neutron spectrums, can be used as fertile material in molten salt reactors and other high temperature nuclear reactors. High temperature nuclear reactors for process heat production that can be used for electricity generation, hydrogen production and drinking water production are being currently pursued. In these reactors, molten salt eutectic mixture or molten lead will be used as coolant along with fissile components. A mixture of fluoride salts of lithium, potassium and sodium (FLiNaK) is one of the well suited eutectics for use with these high temperature nuclear reactors. In spite of several advantages over water cooled nuclear power reactors, material corrosion is one of the major problems in perusing molten salt reactor program, particularly in molten fluoride salts. In this presentation, the concept of high temperature nuclear reactors for process heat production is reviewed. The background for the selection of molten salt, the material and the physiochemical phenomena associated with the corrosion processes is described. The various methodologies for controlling the corrosion of structural materials, the significance of red-ox potential measurements and the designs of red-ox probes are discussed in detail. Finally, the experimental set up for molten salt corrosion testing and the corrosion studies made are presented in detail along with the future studies to be carried out for the understanding of materials behaviour in both static and dynamic loop facilities.

An Electrochemical Study of Polyvinyl Alcohol as Corrosion Inhibitor of Mild Steel in Sulphuric Acid - MC22

Paper by: Anita K Yadava, Rajdhani College and Gurmeet Singhb, University of Delhi, New Delhi

Corrosion being inevitable can cause deterioration not only in economic but health and safety areas too. The serious consequences of the corrosion process have become a problem of worldwide significance. Therefore, with the advances in technology, it has become quite important to take steps to prevent corrosion. The corrosion inhibition effectiveness of Polyvinyl Alcohol on mild steel in 1 N H2SO4 was investigated using electrochemical methods and surface analysis. The electrochemical impedance and potentiostatic calculations were done at various concentrations and temperatures. The data obtained showed that the inhibition efficiency increased with increase in the concentration of Polyvinyl Alcohol and also again showed an increase with increase in the temperature with the highest efficiency being 89.4% at 338K. Tafel polarization studies reveal that it acts as an efficient mixed type inhibitor. The temperature kinetics studies indicate monolayer adsorption of the inhibitor on the mild steel surface. The activation parameters governing adsorption show that the inhibitor is physically adsorbed. FTIR spectroscopy reveals the possible binding sites of polymer during adsorption on metal surface. The surface images recorded from Scanning Electron Microscope and Quantum chemical parameters such as highest occupied molecular orbital energy (E HOMO),lowest unoccupied molecular orbital energy (E LUMO), energy gap (ΔE), dipole moment (μ) etc. have been found to supplement the results obtained from electrochemical measurements.

Corrosion and Surface Film Characterization of TaNbHfZrTi High Entropy Alloy - MC23

Paper by: J. Jayaraj, Thinaharan, S. Ningshen, C. Mallika and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam

TaNbHfZrTi high-entropy alloy (HEA) was prepared by arc melting alloying elements, and the formation of single phase bcc structure was confirmed. The developed HEA alloy exhibited low current density values during potentiodynamic polarization in 11.5 M HNO3 at room temperature. The corrosion rate was negligible (0.002 mm/y) in boiling 11.5 M HNO3 and the X-ray photoelectron spectroscopic (XPS) analyses confirmed that the passive film was predominantly composed of Ta2O5. In contrast, the air formed native film consisted of ZrO2 and HfO2. On the other hand, the potentiodynamic polarization studies indicated high corrosion current values for the HEA in 11.5 M HNO3 + 0.05 M NaF at ambient condition. In boiling fluorinated nitric acid, the corrosion rate is high about 2.2 mm/y, and a severely corroded morphology was obtained. XPS investigations confirmed the presence of ZrF4, ZrOF2, and HfF4 along with un-protective oxides of Ta, Nb, and Ti on the film.

The Cavitation Erosion Behavior of UNS A96061 Alloy in Seawater - MC24

Paper by: H.Tarish, N.Tanoli and A.Al-Hashem, Kuwait Institute for Scientific Research, Kuwait

An ultrasonically induced cavitation facility was used to study the cavitation erosion behavior of UNS A96061 alloy in seawater. The work included measurements of free corrosion potentials, and mass loss in the presence and absence of cavitation. The cavitation tests were made at a frequency of 20 KHz and at temperatures of 250C. Cavitation conditions caused a noble shift in the free corrosion potential for UNS A96061 alloy. Cavitation also increased the rate of mass loss of this alloy by several orders of magnitude with respect to stagnant conditions. Another set of cavitation experiments was also carried out for this alloy in distilled water to distinguish between the mechanical and electrochemical factors that contribute to metal loss. Results indicated that the mechanical factor has an overriding role in metal loss of this alloy. Cavitation made the surface of this alloy very rough, exhibiting large cavity pits in the middle region of the attacked area as revealed by the scanning electron microscope (SEM). Cavitation attack was mainly observed at grain boundaries and matrix/precipitates interfaces. Mechanical factors are believed to be the leading cause of metal loss.

Low Cost Ferritic Stainless Steel with Superior Corrosion Resistance for Elevator Application - MC25

Paper by: P. Saravanan, Bhawna Khalkho, S. Srikanth, Santosh Kumar, Steel Authority of India Limited, Ranchi and T. Muthu Kumar, Salem Steel Plant, Salem

This work was taken to develop ferritic stainless steel with suitable alloy chemistry having mechanical properties and corrosion resistance equivalent to AISI 441 stainless steel, for elevator application. Accordingly, laboratory heats were undertaken with controlled additions of Cr (~ 19 wt.%), Mo (0.9 wt.%) and Ni (0.75 wt.%). These developed steels have been observed to be virtually immune to intergranular corrosion (IGC). Electrochemical corrosion results clearly reveal nobler corrosion potentials, lower corrosion & passive currents and higher pitting potentials for annealed ferritic stainless steels compared to 430 and 441 stainless steels indicating formation of more stable, tenacious and protective passive films on these steels. Superior Plastic Strain Ratio (rm ~1.0), lower 'Earing' tendency (□r) and favorable texture for formability can be achieved in modified 430 ferritic stainless steels with 65% cold reduction followed by annealing at 850oC. Hence, it can be concluded that Cr content can be increased up to 19% in the existing commercially produced AISI 430 SS for higher corrosion resistance and formability properties.

Technical Interactive Forum -1 Corrosion Monitoring & Testing

Hall-D

1600 - 1630
Tea/Coffee

Technical Sessions Descriptions

1630 - 1800

Corrosion Monitoring & Testing (CMT-1)

Hall-A

Corrosion Monitoring in Refinery and Petrochemical Plants – New Challenges - CMT11 Invited

Paper by: U. Anand, Reliance Industries Limited

Managing process side corrosion continues to be an evergreen subject of discussions in any refinery and petrochemical plants. The concerns never cease. Failures due to corrosion, resulting in unsafe condition and loss of production is a day to day problem for the operating crew. The demands of the business is same across the gamut, which are as follows.

- No loss of containment
- Safe and Continuous operation
- Longer intervals between turn around
- Increased production and yields
- Optimized maintenance cost

Ageing of assets and obsolescence add up to the list of challenges. Newer corrosion mechanisms are being revealed requiring extensive knowledge gathering, understanding and then resolution. Digital transformation in industry has increased the expectation from corrosion engineers to predict corrosion and also report corrosion as it occurs in operations, on-line, rather than discovering the same during a turnaround or shut down. This paper explores the possibility of making corrosion a process variable that can be simulated, predicted on line and help the operating crew to control the corrosion in real time. The demands of the business can be more effectively achieved. The advantages of prediction of corrosion in real time are many, but there are challenges.

Approach Towards Effective Coating Integrity Surveys - CMT12

Paper by: C.Gautam, GAIL (India) Limited, Vizag, Mallesh, GAIL (India) Limited, Cherlapalli GAIL (India) Limited, Noida

This paper highlights some of the major findings from the field experience while carrying out the Coating Integrity Surveys specifically Direct Current Voltage Gradient Survey (DCVG). Some of the major factors which are not identified during Close interval potential logging Survey (CIPS) are the small coating holidays near to the CP station where the CPPSM units are installed and secondly due to high rating of the CPPSM units, minimal potential dips observed at the smaller holidays. Since no abnormality is observed near and at the CPPSM installed stations, such locations are not considered for DCVG/CAT. After studying various maintenance practices across the globe (available in public domain) it was felt prudent to carry out DCVG for the entire section. After carrying out such surveys and correlating with ILI it was observed that DCVG survey would be more effective, if it is done for the entire pipeline.

Adverse Effect of Mn on the Corrosion Behavior of Offshore Platform Steel in a 3.5wt% NaCl Solution - CMT13

Paper by: Guanqiao Su and Xiuhua Gao, Northeastern University, Shenyang, China

Adverse effect of Mn on the corrosion behavior of offshore platform steel have been studied by cyclic wet/dry conditions in a 3.5wt% NaCl solution, in term of SEM, XRD, EPMA and analysis of corrosion process. The results showed that the offshore platform steel (medium-Mn steel) did not exhibit higher corrosion resistance than Q345 steel due to the presence of (Mn,Fe)xOy in the rust films. Moreover, the effect of small amount anti-corrosion elements on offshore platform steel was discussed.

Quinoline as Corrosion Inhibitors for Mild Steel: An Overview - CMT14

Paper by: K.Lavanya and J.Saranya, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad

Traditionally, controlling of corrosion has been managed by various methods like cathodic protection, process control, reduction of the metal impurity content, and application of surface treatment techniques, as well as incorporation of suitable alloys. However, the use of corrosion inhibitors has proven to be the easiest and cheapest method for corrosion protection and prevention in acidic media. These inhibitors slow down the corrosion rate and thus prevent economic losses due to metallic corrosion on industrial vessels, equipment, or surfaces. Many researchers have recently focused on corrosion prevention methods using organic inhibitors for mild steel in acidic solutions to mimic industrial processes. This paper provides an overview of types of corrosion, corrosion process, and mainly recent work done on the application of quinolone derivatives as corrosion inhibitors for mild steel.

Present Trends in Quality Assurance of Welded Components Through NDE Methods - CMT15

Paper by: Sanjivkumar Kharatmol, Kaushik Boral, K K Chattopadhyay, A T Mondal, Manoj Kumar Pal, Indian Oil Corporation Limited, Mathura

Welding plays the most important role in the fabrication of equipment for the pressurized process plants & its maintenance throughout the life cycle. To ensure reliability, a comprehensive health assessment program for the welded components using various Non Destructive Examinations (NDEs) is ensured during fabrication as well as in-service maintenance.

The two best-established NDE methods used for volumetric inspection of welds are Radiography Testing (RT) and Ultrasonic Testing (UT). Historically, Radiographic Testing has been the Non Destructive Examination (NDE) method of choice for inspection of critical welds in a variety of applications. However, with the advent of Automated Ultrasonic Testing (AUT) methods like Phased Array Ultrasonic Testing (PAUT) & Time of Flight Diffraction (TOFD), the code has allowed ultrasonic in place of radiography when certain laid down conditions are met. Although in thinner wall vessels, the Radiography Testing is still the most widely adopted technique for detecting both volumetric and planar indications, the PAUT & TOFD technologies have made rapid changes in inspection and reliability in various industries and are rapidly replacing the conventional radiography. A major advantage in replacing RT with PAUT & TOFD is reducing the radiation risks apart from increased production rate and better sizing of the discontinuities

Corrosion in RCC Structures (RCC-2)

Hall-B

Embedded Rebar Corrosion: Effect of Construction Practices and Quality of Rebar - RCC21 Invited

Paper by: Anup Kumar, Tata Steel, Jamshedpur

Many of the residential buildings in India, being non-engineered, show vulnerability to various construction related issues which results in the failure of the structure. In-situcorrosion of embedded reinforcement bar is amongst prevalent phenomena that can have disastrous consequences. The poor construction quality also affects the safety of structure and inhabitants. Several reasons such as: inadequate cover, inadequate water: cement ratio, improper usage of admixtures in concrete, improper evaluation of soil and water quality have been attributed to the phenomenon of corrosion of steel bar. In this paper we present the findings of the investigation of rebar corrosion observed in various parts of India. It is found that non-adherence to the stipulated construction norms, poor quality of concrete and reinforcement bar and poor design are mainly responsible for the corrosion of embedded rebar.

Innovative Corrosion Control Practices to Provide Long Term Durability of Concrete Structures -A Way Forward - RCC22

Paper by: Satander Kumar, Consultant, New Delhi

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking and spalling initiating from concrete cover. Steel corrodes because it is not a naturally occurring material. Rather, iron ore is smelted and refined to produce steel. The production steps that transform iron ore into steel add energy to the metal. Steel, like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural and original state—iron oxide, or rust. This process is called corrosion and for corrosion to occur, there must be at least two metals at different energy levels, an electrolyte, and a metallic connection.

In reinforced concrete, the rebar may have many separate areas at different energy levels. Concrete acts as the electrolyte, and the metallic connection is provided by wire ties, chair supports, or the rebar, pre-stressing cables itself. Corrosion is an electrochemical process involving the flow of charges (electrons and ions) when structure is moist.

Causes of concrete deterioration due to corrosion are discussed in the paper. The corrosion may be due to excessive permeability allowing ingress of chlorides and sulphates, abrasion/erosion, traffic, hydraulic pressure, fire/heat, volume changes, plastic and drying shrinkage cracking, loss of support, load impact etc. in/on reinforced concrete structures.

Performance of Corrosion Inhibitor Admixed Slag Cement Mortar Exposed to Aggressive Corrosion Environment - RCC23

Paper by: J. Sherin Mariya and M.S. Haji Sheik Mohammed, B.S. Abdur Rahman University, Chennai

The objective of the investigation is to study the effect of inhibitor addition on strength and durability performance of Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) mortar exposed to aggressive corrosion environment. The variables involved in the study are type of cement (53 grade PPC and PSC), type of corrosion inhibitor (sodium nitrite (SN) based and calcium nitrite (CN) based) and dosage of corrosion inhibitor (1%, 2% and 5% by weight of cement). The strength properties were studied by conducting compressive strength, splitting tensile strength, flexural strength and shear strength tests. The durability tests conducted are sorptivity test and chloride penetration test. It is found that there is a similar compressive strength values at the age of 28 day and 56 days for control and inhibitor admixed mortar specimens irrespective of type of cement, type of inhibitor and dosage levels. There is an appreciable increase in tensile strength, flexural strength and shear strength for inhibitor admixed mortar as compared to control mortar irrespective of type of cement. Sorptivity test results revealed an improved performance of SN and CN inhibitor admixed mortar specimens irrespective of type of cement. There is an appreciable reduction in chloride penetration depth in the range of 10-40% for inhibitor admixed PPC and PSC mortar as compared to control mortar. It is concluded that addition of sodium nitrite and calcium nitrite based inhibitor enhances the durability properties of PPC and PSC mortar without affecting the strength properties.

Technical Sessions Descriptions

Case Studies on Corrosion Testing in Concrete Structures - RCC24

Paper by: Dr. V.V.L. Kanta Rao, Dr. Lakshmy Parameswaran, CSIR-Central Road Research Institute, New Delhi

The case studies of non-destructive / semi-destructive investigations carried out on a RCC/PSC bridge and a RCC silo in the state of Kerala, India are presented in this paper. Both the structures were built during 1984-85. The substructure of the 12 span bridge had RCC piers and, its superstructure was built in PSC girders and RCC deck slab. The accessible piers of the bridge were tested non-destructively / semi-destructively using rebound hammer, UPV, concrete resistivity meter and core cutting. In-situ carbonation test was carried out and the chloride content of concrete was determined from powder samples. The RCC silo was in use for storage of water based slurry of thorium hydroxide. The walls of the silo were tested for rebar corrosion using Galvapulse, and concrete carbonation.

The results show that there has been no corrosion of reinforcement or concrete carbonation of both structures despite of the fact that these were exposed to aggressive environment for about 30 years. The possible reasons for no corrosion were attributed to good quality of construction and high / adequate concrete cover. The study highlights the importance of the above two factors which are essential for any durable concrete structure.

Corrosion Control of Reinforced Concrete in Corrosive Environment - RCC25

Paper by: Haixue Liao, Vector Corrosion Technologies Ltd., Canada &
Dhruvesh Shah, Vector Corrosion Technologies Ltd., Gujarat

Corrosive environments have caused tremendous damages, structural deterioration and failure of reinforced concrete structure. Corrosive environments include tidal zone and splash zone of marine piles, heavily chloride-contaminated concrete due to di-icing salts or cast-in chloride (such as sea-sands used as fine aggregates in concrete), and concrete repairs in which complete removal of chloride contaminated concrete is not desired such as prestressed concrete.

Current density of 1-7mA/m2 by galvanic anodes embedded in concrete has been found to effectively control the corrosion in many projects and studies (Gulis, Lai & Tharmabala, 1997). As a result of corrosion control, many existing structures have been conserved and their service lives have been extended, future repairs of many existing and new structures have been delayed.

This paper will discuss the corrosive environments, introduce the concept of corrosion control. Finally, case studies of service life extension are presented.

Corrosion in Petrochemical Industries (CPI-2)

Hall-C

Advances in Offshore Corrosion and Integrity Management - CPI21

Paper by: Dr. Binder Singh, PragmaticaGGS LLC, USA, Dr. Ananya Bhattacharya, Rice University, USA, Dr. Paul Jukes, The Jukes Group LLC, USA, Bob Wittkower, HSE Consultant, USA

Corrosion and integrity management (C&IM) techniques have evolved well over the past decade or so and are quite well established for the onshore sector, and are being continually updated as new knowledge is validated and accrued. This is largely because access and direct inspection to such assets is reasonable and not an overbearing issue. In difficult cases cost related issues can be challenging but rarely insurmountable. In stark contrast, offshore and in particular deep subsea assets can present near insurmountable challenges and in that case corrosion and integrity management techniques and methodologies must engage a different mindset. Here one needs to apply good science, robust engineering and carefully re-assess the impact on Health, Safety and Environmental (HSE) details with respect to people, the environment and property, and also for cost, practicality, reputation, and indeed revenue value added. As a result, such challenges are best addressed on a risk-tolerance basis, to maintain good business sense and return on investment (ROI), and here the ALARP (As Low As Reasonably Practical) criteria is utilized. The revenue side and HSE side are often in conflict, but can be managed if the major proponents are kept separate and under an independent leadership, prior to final company decisions at the highest level. NIGIS * CORCON 2017 * 17-20 September * Mumbai, India Copyright 2017 by NIGIS. The material presented and the views expressed in this paper are solely those of the author(s) and do not necessarily by NIGIS. Needless to say, with those decisions comes greater responsibility and accountability. This paper illustrates some of the multi-disciplinary approaches over the years. The case criteria and examples mentioned are from real world situations, and reveal the preferences of advancing and adapting existing technologies rather than implicitly brand-new ones. However, challenges still exist though with better knowledge management, and information exchange across assets and regions it is concluded that the industry overall will benefit. An 18 point check plan is offered to tackle the most prominent issues, plus direction and recommendations to facilitate fit for purpose solutions.

Failure Analysis of Extraction Steam Condensate Piping and Aldehyde Purge Lines in MEG (Mono Ethylene Glycol) Unit-A Case Study - CPI22

Paper by: Manindra Pratap Singh, Priyanka Mandawat and Bijay Kumar Muduli, Indian oil Corporation Ltd., Panipat, Haryana

In MEG (Mono Ethylene Glycol) unit, the products of the glycol reactor are mainly water (~ 89 Wt. %), traces of aldehydes and glycols (mainly MEG). This stream is treated in the evaporator columns at several stages. The overhead vapor of these evaporators is mainly steam with traces of process contaminants (aldehydes; such as acetaldehydes and formaldehydes), and it is used in re-boilers of columns for heating column bottom streams. In one installation, several failures have been observed in the condensate system of this process steam.

Each re-boiler that is connected with the evaporators is equipped with one purge connection for removal of occasional aldehydes. Failures have also been seen in this section of piping. The subject paper provides a brief description of the process section of the failure prone area in the evaporator section in the MEG unit, role of contaminants in the operation and its effect on integrity of equipment / piping and future actions taken to avoid such failures. The paper also discusses recent changes of philosophy in material selection of such services in this plant.

Failure of Kettle Type Condenser in Steam Condensate Service – A Case Study - CPI23

Paper by: Mayank Banjare, B. K. Muduli, Rahul Prashant and L. C. Gopalani, IOCL, Panipat

Kettle type condensers are the most troublesome condenser type in the chemical process industries. Several criteria and rules of thumb for kettle type exchanger operations are used, most popular of which is keeping the top row tube surface not less than 55 % of the shell diameter. Despite the significant demand placed on the condenser and exacting penalties for condenser leaks, the condenser often does not get the attention it deserves.

In the subject case the high boiler column of linear low density polyethelene (LLDPE) handles the tail gases from the low boiling column, which is composed primarily cyclo-hexane and separates the cyclo-hexane from the grease and high boiling impurities. The high boiling column overhead vapor is fully condensed in kettle type condensers that generate LP steam for distribution. Leakages in the tubes of these condensers cause cyclo-hexane slippage to the steam condensate system causing loss of cyclo-hexane and creating a hazardous environment in the steam system. This paper describes the methodology adopted to identify the root cause of tube failure in kettle type condensers, including remedial measures and precautions to avoid failure of such condensers

Corrosion Failure of SS 304L Tubes- A Case Study - CPI24

Paper by: Surendra Patle and Prashant Nikalje, Renu Gupta, Larsen and Toubro-Heavy Engineering Division, Mumbai

This paper covers a detailed investigation to understand the failure mechanism and probable causes of tubes failure. For one heat exchanger, SS 304L tubes were ordered from an overseas tube supplier. During manufacturing of equipment, an air leak test of tube to tube sheet joints was carried out wherein leakage was detected in some of the tubes away from the tube to tube sheet joints. These tubes were removed for analysis. Failure of the tubes were analyzed through non-destructive and metallographic examinations. Multiple pits along with corrosion product were observed on tubes OD and ID. Tube failure was attributed to the combined effect of microbiologically influenced corrosion (MIC) and chloride pitting due to water contamination.

Failure Analysis and Integrity Assessment of Aging Boiler Bank Tubes of HRSG - CPI25

Paper by: Maushumi Kakoti Talukdar, Abhay Kujur and Anil Bhardwaj, IEOT, ONGC, Navi Mumbai

In oil and gas processing plants, heat recovery steam generators (HRSG) continue to make great strides in efficiency and reliability for power generation. But tube failures continue to cause forced outages. To operate at peak capacity, it is necessary for a plant to find ways to avoid tube failures, as well as to quickly recover when forced outages take place. Finding the root cause for a failure is a very important step in preventing future failures.

A cogeneration plant installed in one of the gas processing plant was operating HRSG boilers that were in continuous operation for more than 20 years. In one of the boilers, boiler bank tubes failures had been reported a couple of times in a month. Lifetime of tubing was not mentioned by the manufacturer in the manual. Failed tubes were subjected to various laboratory investigations to understand the cause of failure.

Corrosion product analysis showed the presence of several ions like Fe, O, Ca, P, Si, Al, Mg, which were deposited on the internal surface of the tube. These deposits acted as an insulator and excessive deposits prevented efficient heat transfer through the tubes to the water. This caused the metal to become overheated. Long term heating caused distinctive microstructural change in both external and internal surface of the tubing due to decarburisation initially around pearlite then gradually spreading leading to intergranular metal loss. From laboratory investigations, it was found that the cause of the metal loss and eventual failure was flow accelerated corrosion (FAC) and erosion. FAC in consonance with microstructural changes resulted in the direct removal of iron from the internal surface of the tube and made it abrasive, thus accelerating the rate of metal loss from the tube surface by erosion.

A study was carried out on cut samples of otherwise healthy bank tubes of another HRSG to ascertain its health and make a comparison of the tube conditions of both HRSGs. The tube samples were subjected to similar analyses to understand the health, material integrity, morphology of the tube surface. From the laboratory investigations it was found that the tube surface of this HRSG exhibited morphology similar to the failed tubing. The tubes of this HRSG are susceptible to failure under FAC and erosion in a manner similar to the failed tubing, as inter-granular metal loss and similar microstructural change were observed in both tubing.

Technical Interactive Forum 2 Water Treatment

Hall-D

1800 - 1900
Visit Exhibit Hall and Posters

1900 - 2000
Cultural Programme

2000 - 2130
Dinner

Technical Sessions Descriptions

Tuesday, 19 September

0900 - 1030

Cathodic and Anodic Protection (CAP-3)

Hall-A

Findings from ECDA Performed on SPM lines- A CP Related Perspective - CAP31 Invited

Paper by: C. Haridas Anand, Vikalp Srivastava, Gokul Sarathy and Bhavesh Patel, Reliance India Limited, Jamnagar & Arvind Sahasrabudhay and Ashish Khera, Allied Engineers, New Delhi

Reliance India Limited's (RIL) Jamnagar Marine Terminal has nine (9) numbers of subsea pipelines catering to three Crude SPMs and two Product SPMs. SPM 1&2 were constructed in year 1999 whereas SPM 3, 4 and 5 were constructed in 2006. All SPM lines have underground portions from Marine Tank Farm (MTF) to Land Fall Point (LFP) except for SPM 05 and one (1) line of SPM-04 which is completely above ground and subsea. The underground sections are protected with coal tar enamel wrapping coating and cathodically protected with ICCP. To check the integrity of the wrapping coating, periodic indirect assessment surveys like DCVG (Direct Current Voltage gradient / CIPL (Closed Interval Potential Survey) is generally carried out. Intelligent pigging was also carried out in 2013 and in 2015 for SPM-1 & 2 revealing external corrosion of the underground sections of these lines.

As these SPM lines are lifeline for RIL refinery and any loss of containment may lead to serious environment damage and impact the business continuity, a decision was taken:

1. To review the effectiveness of current CP systems and indirect assessment surveys,
2. To find out the root cause of external corrosion and
3. To locate & predict susceptible areas where external corrosion have occurred or will initiate in the future

Hence it was proposed to carry out ECDA (External Corrosion Direct Assessment) of the underground segments of the SPM lines. The ECDA methodology as specified in NACE standard SP-0502-2010 & OISD-GDN-233 is a four-step procedure that requires the integration of historical data, multiple indirect field inspection surveys and direct pipe surface examinations with the pipe's physical characteristics to provide a more comprehensive integrity evaluation with respect to external corrosion. Allied Engineers was assigned to carryout turnkey ECDA.

The scope included five (5) underground portion of the SPM lines (SPM 1&2, SPM 3-01 & 3-02, and SPM 04 line 01 from MTF to Land Fall Point (LFP).

Role of Key Performance Indicators and its Evaluation in HPCL Transmission Pipelines - CAP32

Paper by: P. Anand Victor, Hindustan Petroleum Corporation Limited, Suryapet

Pipeline Integrity Management involves a series of activities, using systematic and comprehensive approach, to manage the safety and integrity of pipeline systems. Corrosion Control is an integral and major part of pipeline integrity management system.

Implementation of pipeline integrity management system is effectively tracked using key performance indicators (KPIs). The 5-M methodology (modelling, mitigation, monitoring, maintenance and management) implementation requires establishment of KPIs to track corrosion control implementation of an asset for its entire life. Fifty (50) KPIs have been identified to economically and efficiently control corrosion. This paper explains how to apply and implement the KPIs to control corrosion which will increase the capital expenditure, but will decrease operating expenditure during ideal stage and increase operating expenditure in normal operating stage but ensures immediate benefit to the asset.

AC Interference Study – Importance of Soil Resistivity – Case Study - CAP33

Paper by: Prashanth B G, Jef Techno Solutions Private Ltd, Bangalore

A Fusion bonded epoxy coated liquid hydrocarbon pipe line section 150 KM long was analyzed for AC Interference under steady state and fault conditions. The line has parallelism of 16 KMs with 765 kV and multiple crossings of 400 and 220 kV lines.

The area has high water table for 7 to 8 months in a year and goes dry in summer due to intense heat. Hence, the soil resistivity varies from 25 Ω-m in monsoon to 100 Ω-m in summer. Since current density varies inversely with soil resistivity, the AC corrosion effect is more pronounced in low soil resistivity conditions. The simulation for AC Interference under steady state conditions were done for 2 layer soil resistivity of 20/10 Ω-m and 36/10 Ω-m (measured value)

It was observed that the current density was about 320 A/m2 in 20/10 Ω-m and around 200 A/m2 for 36/10 Ω-m with all lines in steady state condition at full load.

Under fault conditions, the analysis showed 50 to 100% higher values of touch and coating stress voltages for high soil resistivity of 100/10 Ω-m as compared to low soil resistivity of 36/10 Ω-m. Since soil resistivity varies seasonally, it is imperative to consider lower soil resistivity values for evaluating AC current density and higher soil resistivity values under fault conditions for touch and coating stress voltages. Unless mitigation measures are designed for these worst case scenarios, the same may not be effective.

Case Study on Pipeline Under-protection Along with Mitigation Methods - CAP34

Paper by: Vipul Vilas Sawant, Mahanagar Gas Ltd, Mumbai

Mahanagar Gas Ltd is a City Gas Distribution Company engaged in the distribution of Natural Gas in and around Mumbai. We presently have around 400 Kms of steel pipeline. All our steel pipelines are coated with 3 Layer Poly Ethylene coating. As a supplementary protection against corrosion, we have also installed Cathodic Protection system over the entire network.

Since Mumbai is a congested city with a lot of underground utilities, our assets are prone to damage due to third party excavations in the vicinity of our pipeline. Coating damages on the pipeline and cable cuts in CP assets can subsequently lead to a failure of the CP system and cause under-protection of the Steel pipeline. If these issues are not resolved on priority it may lead to major hazards.

This paper deals with an issue of under-protection at two of our locations – Mantralaya and Andheri:

The under-protection at Mantralaya was due to the addition of many spur lines from the main pipeline over a period of time, coating defects on the pipeline and due to the high corrosive nature of the surrounding soil.

The under-protection at Andheri was due to coating defects on the pipeline which was difficult to repair as the pipeline is under a concretized road. This paper also includes the various measures and mitigation methods that were employed at site to resolve these under-protection issues.

Interference & Corrosion Due to HVAC Power Lines Running Parallel to Cross Country Pipelines: Computer Modeling vs. Field Monitoring - CAP35

Paper by: Sandeep Kerketta and G Narendranath Reddy, GAIL (India) Limited, Vijaipur

Pipelines paralleling or crossing high voltage power line in the same ROW, may be subject to electrical interference from electrostatic coupling, electromagnetic inductive and conductive effects. Predicting HVAC interference on pipelines is a very complex problem, with multiple interacting variables affecting the influence and consequences. In some cases, detailed modelling and field monitoring is used to estimate pipelines susceptibility to HVAC interference, identify locations of possible AC current discharge, and design appropriate mitigation systems to reduce the effects of AC interference

This paper addresses the technical background to high voltage interference with respect to collocated and crossing pipelines, and presents basic procedures, methods adopted in predicting and mitigating the HVAC interference i.e. collection of survey data, analysis of data, problems faced during survey and accordingly actions dealing with interference scenarios using computer modeling and field monitoring.

Coatings & Linings (CL-2)

Hall-B

Micro-Raman Spectroscopic Studies for Evaluation of Self-Healing Property of Corrosion Protection Coatings on Al and Mg alloys - CL21

Paper by: R. Subasri, S. Manasa, Swapnil H. Adsul and B.V. Sarada, International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Balapur, Hyderabad

Aluminum and Magnesium alloys have wide range of applications in aerospace and automobile industries due to their high strength-to-weight ratio. However, during their service, components made from these materials get corroded. Paints are generally used to render barrier type protection to the surfaces. Hexavalent chromium-based conversion coatings/primers are commonly applied prior to paint deposition. Due to their carcinogenic effect, chromate conversion coatings have been globally banned and hence, researchers are seriously developing chrome-free, self-healing conversion coatings. Sol-gel derived coatings are being evaluated, since they possess the necessary qualities to be a potential replacement to Cr6+-based coatings. In this context, cationic inhibitor loaded nanoclays were dispersed into an organic-inorganic hybrid silica sol-gel matrix. Coatings were deposited onto aluminum alloy A356.0 and magnesium alloy AZ91 using dip coating technique and thermal cured at 130oC. An artificial scribe was made on the coated substrate and immersed into 3.5 % NaCl solution for 120 h. Micro-Raman spectroscopic studies were carried out on these samples to study the localized self-healing property of the coatings. The results obtained from micro-Raman studies could confirm the inhibitor release on the scribed area and formation of a passive layer could be observed, thereby confirming self-healing effect. Nanoclay based sol coated substrates were found to be very promising for long term corrosion protection.

A Case Study on Blackening Effect of Thermal Spray Aluminum Coating - CL22

Paper by: Urvesh Vala, INOXCVA, Vadodara and Mihir Sheth, Sheth Corrosion & Coatings Pvt. Ltd, Vadodara

Pitting corrosion degradation has been observed on RVCM (Recovered Vinyl Chloride Monomer) tanks at petrochemical facilities. Generally, these pits are repaired by weld build up in order to stop further degradation. However, a more permanent solution is required to resolve these chronic pitting corrosion issues in RVCM tanks. The most efficient method to mitigate the pitting corrosion degradation is application of a protective coating or strip lining as the coating will isolate the material from the environment, and thereby prevent pitting corrosion degradation as well as stop the initiation of SCC (Stress Corrosion Cracking). The type of coating that should be used depends on the temperature, pressure and fluid composition of the system. This paper evaluates the feasibility of providing the strip lining method or coating method to stop the degradation of equipment due to pitting corrosion. Based on a further technical study, successful implementation of the coating application has been carried out on one of the RVCM Tanks, and subsequent inspections confirm satisfactory results of the coating application.

Technical Sessions Descriptions

Improve Equipment Performance Against Pitting Corrosion Degradation by Utilizing Corrosion Control Methods at Petrochemical Facilities - CL23

Paper by: Amit Jain, Khammas-Al, Saleh S, SABIC Petrokemya, Jubail, Saudi Arabia

The main tasks for Oil Gas pipeline transportation and equipments are fail-safe, timely, profitable and ecologically safe oil, gas and petroleum products delivery without quantity and quality losses not withstanding enormous distances between oil well and end point.

Due to Corrosion, Which is a very Serious Issue in Oil and Gas, Chemical, Pharmaceutical and Petrochemical companies, There is a massive damage to Equipments and Pipelines which sometimes accounts to thousands of dollars. For this reason, major metallic equipments and parts must be protected from corrosion resistance.

Fluoropolymer Coatings and Linings for Offshore, Oil Gas & Chemical Equipments - Meeting the Needs Under Harsh Conditions - From the Applicator's View - CL24

Paper by: Kirtan R. Dhami, Blinex Filter Coat Pvt Ltd, Mumbai

The main tasks for Oil Gas pipeline transportation and Equipments are fail-safe, timely, profitable and ecologically safe oil, gas and petroleum products delivery without quantity and quality losses not withstanding enormous distances between oil well and end point.

Due to Corrosion, which is a very serious issue in Oil and Gas, Chemical, Pharmaceutical and Petrochemical companies, There is a massive damage to Equipments and Pipelines which sometimes accounts to thousands of dollars. For this reason, major metallic equipments and parts must be protected from corrosion resistance.

Laser Ablation of Suspended Graphite Powder to Obtain Few-layered Graphene in Bulk Quantities - CL25

Paper by: Ravi Kiran Gadde, Chandu Byram, Swati G. Acharyya, Venugopal Rao Soma,Vadali V. S.S. Srikanth, University of Hyderabad, Hyderabad

Few-layered Graphene (FLG) has emerged as a unique material in various fields due to its outstanding mechanical, electrical, and optical properties. The main aim of this work is to synthesis the FLG in bulk with high quality in a simple method which can be applicable for the protective coatings as well as liners in oil refineries etc. Here, we report a simple technique for bulk synthesis of few layered graphene (FLG) from graphite powder (suspended in ethanol) by employing ultrafast laser ablation in liquids (ULAL) technique without the requirement of controlled environment. Graphite powder (average particle size of <20 μm) was suspended uniformly in ethanol and exfoliated at room temperature using a femtosecond laser (wave length is ~800 nm and beam diameter is ~8 mm) followed by ultrasonication to obtain few layer graphene with a lateral size of ~1 μm. Raman spectroscopy and high resolution transmission electron microscopy (HRTEM) confirmed the nature and morphology of the FLG. The quality and number of layers in FLG could be controlled by tuning the laser parameters.

Another Look to Rust Bullet - CL26

Paper by: Manojkumar V Sheladiya, Shailee G Acharya and Dr. Ghanshyam D Acharya, AITS, Rajkot, Gujara

In order to ensure the smooth and uninterrupted flow of liquid to the end users, it is imperative for the field operators, pipeline engineers, and designers to be corrosion conscious as the lines and their component fittings would undergo material degradations due to corrosion. This paper gives a comprehensive review of corrosion problems and its mitigation. The chemistry of corrosion mechanism had been examined with the various types of corrosion and associated corroding agents in the industry. Factors affecting each of the various forms of corrosion were also presented. It was noticed that the principles of corrosion and its prevention must be understood in order to effectively select materials and to design, fabricate, utilize metal structures, coating, and painting, etc. for the optimum economic life of facilities and safety in industries. Rust Bullet is a single component high solid coating. It is very different than the traditional rust conversion or rust encapsulation product. Rust Bullet is an advanced coating system which is far more than just Rust protection. This paper deals with unique feature and application of Rust Bullet to protect the metal.

Workshop- Women in Leadership

Hall-C

Corrosion Monitoring & Testing (CMT-2)

Hall-D

Corrosion Management System in Hydrocarbon Pipelines - CMT21 Invited

Paper by: Goutom Chakraborty, GAIL (India), Ltd.

Corrosion is a major threat to the integrity of pipelines. The problem is multi-faceted and has the potential to endanger life and property in addition to causing large scale disruption of operations with severe economic penalties. The conventional approach has always been detecting corrosion and carrying out repairs. However, rehabilitation or replacement of a corroded pipeline also involves expensive outages fraught with safety and other risks. A holistic Corrosion Management System is therefore essential for an effective monitoring and mitigation of corrosion problems.

Corrosion Management System sets out the CMS policy, implementation strategies and essential requirements for effective assessment, monitoring, control and mitigation of corrosion in pipelines and associated facilities during its entire life cycle spanning from planning, design, construction, operations, maintenance and decommissioning.

Corrosion management is a long-term, systematic, proactive, continuous, ongoing, technically and financially sound plan for managing corrosion over organization's assets life cycle by way of specific and measurable objectives. Corrosion management includes the following:

- Maintenance and dissemination of corporate strategy, regulatory requirements, finance, information affecting corrosion, and records on corrosion control activities.
- Establishment and implementation of organizational structure, resources, responsibilities, best practices, procedures, and processes to mitigate and monitor corrosion risks and to carry out maintenance activities.
- Evaluation and quantification of corrosion risks during design, construction, operation, shutdown and abandonment stages and identification of factors causing, influencing, and accelerating them.
- Review of the successful implementation of corrosion control, and identification of opportunities for further improvement.

Internal Corrosion Monitoring is an integral part of the Corrosion Management System of Pipelines which in turn is a critical component of the overall Pipeline Integrity Management System. Corrosion monitoring is particularly essential when carbon steel is used under potentially corrosive conditions. Even for corrosion resistant materials (CRAs), corrosion monitoring is useful.

Corrosion Monitoring mainly serves the following purposes:

- Integrity verification of piping or pipelines, at various intervals of time over the life of the pipeline
- Verification of effectiveness and optimizing corrosion control and mitigation strategies, such as corrosion inhibitors.
- Risk-based inspection planning system.
- Remaining Life estimation and extension.
- Lower operating costs:
- Reduces maintenance/inspection costs
- Minimizes unscheduled shutdowns

Assessment of an impact from operational changes/upsets.

Experimental Studies on Behaviour of Steel Tubular Compression Members Subjected to Accelerated Corrosion - CMT22

Paper by: Cinitha. A, Umesha P K, Palani G S, CSIR- Structural Engineering Research Centre, Chennai

The performance of steel structural components is strongly influenced by the damage due to atmospheric corrosion, whose control is a key aspect for design and maintenance of both new and existing structures. In extreme situations, it can lead to catastrophic failure of structural components. This paper presents experimental studies on corroded compression members under stressed and unstressed condition. The study is conducted by varying the corrosion rate of specimens under uniform corrosion. Experimental studies are carried out on corroded members with different percentage in thickness and weight loss. The failure modes and the ultimate load carrying capacity of the specimen are determined numerically and validated with experimental results. A significant reduction in load carrying capacity is observed for all corroded specimens compared to uncorroded control specimen. The failure modes and load carrying capacity of corroded members for uniform, corrosion are discussed. In the light of experimental results, it is inferred that the failure of the members is due to localized axisymmetric imperfections imparted to the tubular members due to corrosion.

EIS Investigation of Ammonium Chloride Corrosion on Carbon Steel Under Stirring Condition - CMT23

Paper by: Prince Kumar Baranwal, Abhilash Kumar, R. Prasanna Venkatesh,
Indian Institute of Technology Guwahati, Guwahati

Ammonium chloride (NH4Cl) corrosion has plagued the oil refineries. In the present work, the effect of NH4Cl on the corrosion behavior of carbon steel, under stirring condition, is investigated by potentiodynamic polarization, electrochemical impedance spectroscopy and other complementary techniques. It is found that the corrosion rate increases with the increase in the concentration of NH4Cl. The polarization measurement implies that the carbon steel is vulnerable to uniform corrosion. The impedance analysis performed at various overpotentials (+0.05 V, +0.15 V and +0.25 V w.r.t OCP) shows multiple time constants, corresponding to capacitance and inductance. The total impedance decreases with the increase in overpotential, suggesting that no strong passivation layer is formed on the surface of carbon steel. In addition, reaction mechanism analysis (RMA) is employed to investigate the mechanistic reaction pathway. From RMA, a multi-step reaction mechanism with three intermediate adsorbed species is propounded to elucidate the patterns observed in impedance measurements. The kinetic parameters and the surface coverage by the adsorbed species are also obtained from RMA. The surface morphology of carbon steel are also reported using field emission scanning electron microscope.

The Effect of Buffing on Different Surface Working Operations and to Study Microstructural Changes by Chloride Induced SCC on 304L Austenitic Stainless Steel - CMT24

Paper by: Pandu Sunil Kumar and Swati Ghosh Acharyya, University of Hyderabad, Hyderabad

Corrosion resistance and SCC susceptibility of austenitic stainless steel 304L will decrease, when it underwent different surface working operations like milling, turning, and grinding operations as, these are the last stages of industrial finishing operations. It induces tensile residual stresses on the surface of the material and due to higher surface roughness. It will undergo SCC when exposed to chloride environment which results in catastrophic failure. In the present study we report a simple machining process i.e. buffing, must follow as a last stage of industrial fabrication process after surface working operations in order to protect from SCC. The SCC susceptibility for these

surface finished samples when subjected to buffing operation was determined by using boiling magnesium chloride test as per ASTM G36 for 3 h. Microstructural changes in surface after SCC test was characterized by optical microscopy (OM) and Field emission gun electron microscopy (FE-SEM). Surface roughness measurements by surface profilometer (contact mode), phase confirmation by using X-ray diffraction technique and residual stress distribution on the surface due to surface working was measured by X-ray diffraction (sin2 χ) technique, The study reveals that buffing will improve the SCC resistance of austenitic stainless steel 304L by inducing compressive stresses on the material and having a minimum surface roughness which will helps in preventing from crack propagation. Buffing being a simple and effective method to increase the service life of the component.

Study of Hydrogen Embrittlement of API X65 & X80 Pipeline Steels using Short Fatigue Cracks - CMT25

Paper by: Dhiraj K. Mahajan, Randhir Swarnkar, Yashpal Singh, Rajwinder Singh, Indian Institute of Technology Ropar, Rupnagar, Kanwer Singh Arora, Mahadev Shome, Tata Steel Limited, Jamsedpur, Gurmeet Singh, University of Delhi, Delhi

Hydrogen embrittlement can often lead to degradation of tensile strength, yield strength, ductility, fracture toughness as well as fatigue life of linepipe steel. API 5L X65 and API X80 steels are commonly used high strength linepipe steels, thus, understanding their hydrogen embrittlement behavior is of great interest. Extensive literature is available on long fatigue crack growth behavior of hydrogen charged API steels, using conventional CT specimens, that shows the effect of hydrogen embrittlement. However, it is the short fatigue crack growth behavior (microscopic cracks propagating through 8 to 10 grains) that can provide fundamental understanding and correlation of the steel microstructure with hydrogen embrittlement phenomenon. To this end, a new experimental framework is developed to investigate the short fatigue crack behavior of hydrogen charged API 5L X65 & X80 steels involving in-situ observation of propagating short cracks coupled with image processing to obtain da/dN vs Delta K curves. Short fatigue crack growth behavior is characteristically different from long crack behavior showing high propagation rate as well as strong influence of microstructural barriers such as grain boundaries, phase boundaries and inclusions. Both the steels are compared for their short crack behavior after hydrogen charging and correlated with their hydrogen permeation behavior obtained using Devanathan-Stachurski cell thus giving detailed insight into the hydrogen embrittlement phenomenon observed for these steels.

Concept of an Intelligent Pipeline Internal Corrosion Prediction Model Using a Bayesian Network - CMT26

Paper by: Lewis Barton and Ian Laing, ROSEN Group, UK

Internal corrosion modelling within carbon steel pipelines is used to provide a better basis for corrosion risk analysis of pipelines. In particular corrosion modelling is most critical when inspection data is unavailable, lacking or cannot be conducted; to provide a sufficient basis for determining the possible corrosion rate. The combination of corrosion and flow modelling is a typical practice and provides detailed location specific corrosion predictions. However, the inherent variability of both flow and electrochemical parameters, combined with other data uncertainties can lead to highly conservative predictions in one scenario and highly accurate in others. The development of a self-learning corrosion model intends to remove this uncertainty, through utilizing ILI data as a reference source, and inferring by use of a Bayesian network the likely occurrence of corrosion and its severity, and location in both pigable and unpigable pipelines.

Through this approach, a model would close the uncertainty in a normally conservative corrosion prediction by analyzing and observing the changes of each input parameter against a database of many similar pipelines. Through doing this it would tune the prediction based on validated corrosion rates. This paper seeks to describe and outline the concept of the model prototype and what it could achieve.

1030 - 1100
Tea/Coffee

1100 - 1125
Plenary Talk
Main Hall
Prof Mark Alexander, Emeritus Professor, University of Cape Town

1125 - 1150
Plenary Talk
Main Hall
Dr. Brenda Little, Naval Research Laboratory, USA

1150 - 1215
Plenary Talk
Main Hall
John Healey, Regional Manager, Quest Integrity

1215 - 1230
Plenary Talk
Main Hall
Sandy Williamson

1230 - 1315
Lunch

1315 - 1415
Corrosion in Refineries (CR-1)
Hall-A

Understanding the Impacts of Crude Oil H2S Scavengers on Refinery Process Operations - CR11 Invited
Paper by: Michael Wagoner, Jamie McDaniels and John Jacobson, Athlon Solutions LLC, U.S.A

Sulfur compounds found in crude oil cause many problems. When hydrogen sulfide migrates from the liquid phase to the vapor phase, personnel, the environment, and equipment are put at great risk. H2S is corrosive to metals, especially at high concentrations and temperatures. H2S smells like rotten eggs at the part per billion level and is dangerous to life and health at 100 parts per million and above. Sulfur in crude oil is trending upwards. More than ever, processing companies need safe, cost-effective, and efficient handling methods with no negative impacts.

Hydrogen sulfide in crude oil is a result of natural processes occurring within the formation. Specification limits for crude oil vary widely between companies, industrial segments, and countries. Chemical scavengers such as triazines, containing nitrogen, or non-nitrogen scavengers, such as glyoxal, are often used to reduce H2S exposure. While triazines are relatively cost-effective and efficient, processing crude oil treated with triazines introduces corrosion and fouling risks to equipment. Glyoxal requires high dosage making treatment expensive, and its low pH can corrode feed equipment.

Athlon Solutions has developed a comprehensive line of non-nitrogen and non-glyoxal H2S scavengers for use in petroleum, each with their own unique properties. They have proven to be cost-effective and efficient at scavenging hydrogen sulfide without the long-term effects typical of triazine scavengers such as corrosion, fouling, and microbiological toxicity in wastewater plants. Crude oils treated with non-nitrogen and non-glyoxal scavengers have been processed safely, cost-effectively, and efficiently without operational restrictions or impact on finished product specifications. Safety, the chemical injection system, testing, and on-site support are also crucial for hydrogen sulfide scavenging projects in addition to chemical selection.

Optimization of Minimum Safe Pressurization Temperature (MSPT) for Hydroprocessing Reactor - CR12
Paper by: Gyananjan Mahanty and Kumar Dosi, Shell India Markets Private Ltd., Bangalore

Hydroprocessing units use thick wall low alloy steel materials (typically 1.25Cr-0.5Mo, 2.25Cr- 1Mo & 2.25Cr-1Mo-V) for the reactor and feed-effluent exchangers. These materials have superior high temperature strength and high temperature hydrogen attack (HTHA) resistance, but are susceptible to other damage mechanisms, such as temper embrittlement and hydrogen embrittlement, which are time dependent, and hence develop over years of exposure to high temperature and high pressure hydrogen environment. This causes a shift in the ductile-to-brittle transition temperature of these materials. In view of the above material degradation phenomena, pressurizing the equipment at low temperatures can result in catastrophic brittle fracture. To prevent this, Minimum Safe Pressurization Temperature (MSPT) is calculated and the equipment can only be pressurized up to 1/3rd of the design stress or 55 MPa (8 ksi), whichever is lower, until this temperature is reached. Normally, MSPT for the reactor is provided by the Process Licensor/Reactor Manufacturer during the design stage or manufacturing stage, and it has been invariably observed that this temperature is specified with lot of conservatism at a higher level. However, this MSPT can be optimized (lowered down) based on material degradation levels, and this change can bring in significant reduction in the startup and shutdown time of the reactor.

Material Solution for Sour Environment of Delayed Coker Unit in a Refinery - CR13
Paper by: Mitul Shah, Sandvik Asia Pvt Ltd, Pune

Wet H_2S cracking covers a range of damage mechanisms that can occur due to the effects of aqueous hydrogen charging in wet H_2S refinery process environments. Types of damage that can occur as a result of aqueous hydrogen charging include sulphide stress cracking (SSC), hydrogen induced cracking (HIC) and stress oriented hydrogen induced cracking (SOHIC). Due to the orientation of these cracks, the timely detection of these cracking phenomena remains a challenge to the NDT personnel as most of the conventional NDTs like radiography or ultrasonic flaw detection often fails to detect these types of damages.

Wet H_2S cracking phenomenon was experienced in a reboiler circuit in Once through Hydro Cracking Unit (OHCU) of a refinery due to accidental water carry-over. To detect the extent of damage, Phased Array Ultrasonic Testing (PAUT) was employed. The phased array system, in contrast to conventional ultrasonic system, uses a transducer assembly of multiple elements which can be pulsed separately in such a way that the individual wave fronts generated by each element in the array combine with each other to add or cancel energy in predictable ways that effectively steer and shape the sound beam. The Phased Array system could detect the cracks in welds and effective repairs could be carried out, thereby increasing the reliability of the equipments. The paper focuses on the consideration of operational upsets during the basic engineering design stage to avoid catastrophic failures in future. The paper also describes the effective use of Phased Array Ultrasonic Testing (PAUT) in detecting the wet H_2S cracking.

Technical Sessions Descriptions

Internal Corrosion in Pipelines (ICP-2)

Hall-B

Complexities and Nuances Associated with Using Advanced NACE International ICDA Standard Practices for Ensuring Regulatory Approved Pipeline Integrity Validations - ICP21 Invited

Paper by: Patrick J. Teevens, Broadsword Corrosion Engineering Ltd., Canada

The post-2009 publication of two specific NACE International Standard Practices for Internal Corrosion Direct Assessment (ICDA), resulted in a significant technical leap in the complexity and deliverables in performing ICDA for both wet gas and multiphase flow pipeline systems. With the publication of NACE International's SP0110-2010 (Wet Gas – ICDA) and SP0116-2016 (Multiphase Flow – ICDA), the determination of cumulative pipeline wall loss must be correctly computed and predicted using empirical, non-statistical analyses, with verifiable objective and factual operational and historic data sets. Over the past 8 years, the successful deployment of these Standard Practices has a common theme or requirement: the correct application of advanced engineering and science fundamentals. This paper underscores those fundamentals and discusses the successes achieved by doing it correctly every time.

Learning Experience from a Case Study on Failure of a Product Pipeline Due to Internal & External Corrosion Leading to a Massive Fire - ICP22

Paper by: Rajesh Uprety, Indian Oil Corporation Limited, Noida

This paper is a case study of a major fire which took place in a multi-product pipeline at Mumbai due to extensive internal and external corrosion. This pipeline was being used by multiple operators to transfer product from HPCL & BPCL Refinery to HPCL Marketing Terminal, Wadala-1; BPCL Khau Creek Marketing Terminal and IOCL Marketing Terminal, Wadala-2 for transfer of POL products. No health check-up such as thickness survey of the subject pipeline or hydro test of this pipeline was carried since its inception way back in 1984. There was no procedure for maintenance of this pipeline, which was passing along a busy road in Mumbai. There was no cathodic protection provided for the buried portion of the pipeline. Most of length of the pipeline was above ground and number of pipes were running parallel to each other alongside a busy road and on either side of the road were Marketing Depots of HPCL, BPCL & IOCL each of which were having product storage tanks. The pipeline was internally coated, however, the girth weld joints were not coated, only sleeves were provided on the external pipe surface.

The common notion in the industry is that if the length of the pipeline is less or if the operating pressure of the pipeline is less the risk of failure of the pipeline and consequent losses is less. This case study is a glaring example to deny such misconceptions. The basic purpose of this paper is to emphasize that the danger imposed by such multi-product low pressure pipelines may prove to be no less than a high pressure cross-country pipeline.

The practice of flushing the lines with sea water is detrimental to the health of the pipeline.

Impressed Current Cathodic Protection System for Water Pipeline Internal Surfaces - ICP23

Paper by: Shailesh Javia, MATCOR Inc., USA

As the water pipelines are getting older, the internal surfaces of pipeline experience corrosion issues as coating/painting deteriorate and conventional corrosion prevention system are no longer effective. Specially Designed Linear Anode System with access fitting for internal pipeline cathodic protection (CP) is the only impressed current, linear anode system for cathodic protection of internal pipeline surfaces to prevent corrosion and increase the life of water pipelines. Used for water and salt water pipelines, the system features entrance fittings spaced as far as two hundred feet apart. Other methods for cathodic protection of large diameter pipeline internal surfaces require closely spaced probe anodes. This paper will also discuss design, materials and installation requirements of Impressed Current cathodic protection System for water pipeline internal surfaces.

Corrosion in Chemical & Fertilizer Industries (CCFI-2)

Hall-C

CCFI21 Invited

Paper by: Sudhir Panadare, RCF, Mumbai

New Polyester Polyols for Two Component Coatings for High Performance Protective and Industrial OEM Coatings - CCFI22

Paper by: Dr. Geoffrey R. Webster Jr, Dr. Guianluigi Cassin, Stacey Marsh, Gary Whittaker, Dr. Curt Cleven and Dr. Robert Farina, Eastman Chemical Company, USA

Corrosion management for an operation is the systematic application of policies, practices and resources to control corrosion and provide reliable safe guard against unexpected failure and leaks that can jeopardize mechanical integrity, operation, health, safety and environment (HSE).

In times of tight budget, the life cycle management of long time to fail component requires a comprehensive strategy for condition assessments, data management and standardized tasking for restoration during maintenance availability period.

While today's sea port operational technologies are dramatically different from even half century ago , one issue remain fundamentally unchanged ; the impact of salt water environment & various chemical exposure on sea port infrastructure.

This paper uses examples from the Adani Ports & SEZ Ltd corrosion control program to execute corrosion management strategy. This paper also describes various successful continual improvements project to control corrosion & challenges way ahead.

Corrosion of CO_2 Absorbers – Whys and Wherefores - CCFI23

Paper by: Ramakrishnan Seshagiri, Viswanathan Venkateswaran and Deepashri D. Nage, L&T Hydrocarbon Engineering Limited, Mumbai

CO_2 absorber columns using Giammarco Vetrocoke (GV) solution are widely constructed from Carbon Steel, have reported to become a major concern for the sweetening units, corrosion being the major cause for the leakages. As a result of the leakage, the ammonia plants are taken for shutdowns leading to substantial losses in productivity. Various manifestations of corrosion are in the form of grooving, impingement, erosion-corrosion, deposition of GV solution on the internals viz. nozzles and tray supporting ring (TSR). The corrosion protection is offered by passivation treatment using Vanadium Pentoxide (V2O5), which when affected is predominant cause of corrosion of carbon steel. Various parameters like Iron content, solid contents, ratio of V5/Vt, gas velocity, inlet and outlet CO_2 concentration, solution concentration and temperature needs to be monitored to understand any disruption in the system.

Research on the factors affecting the meta-vanadate passive layer leads a path to arrive on the causes of failure. A few cases are addressed in the present study wherein the bottom portion of the absorber walls were found to be predominantly affected due to passivation layer destabilization. High velocity of inlet gas, higher CO_2 concentrations in inlet gas, high solution velocity, channeling and deposition of GV solution, Iron carbonate solid contaminants have found to cause depassivation and subsequent corrosion, erosion-corrosion of the absorber walls. Two case studies are discussed in this paper.

Corrosion Studies on Coated and Bare C-276 Material in Molten Cuprous Chloride Salt Environment - CCFI24

Paper by: Prakash S. Parhad, Ashwini B. Nirukhe, G. D. Yadav, Institute of Chemical Technology, Mumbai, D. Parvatalu, ONGC Energy Centre, Panvel & U. Kamachi Mudali, IGCAR, Kalpakkam

Hydrogen is one of the promising alternative energy carrier candidates and the Copper-Chlorine (Cu-Cl) cycle is a promising thermochemical cycle for hydrogen production, but its commercial viability is yet to be established and several bottlenecks need to be addressed. As Cu-Cl cycle involves high temperature reactions and corrosive chemicals, selection of suitable materials and the potential damage due to corrosion is an important concern for the implementation of technology in commercial scale. Thus, a study on these aspects is essential to realize the entirety of the cycle, including the development of high temperature anti-corrosion equipment materials and the system to evaluate the performance of the materials.

This paper represents preliminary investigation of C-276 and corrosion resistant coatings. Different types of coating materials were tested. Diamalloy 4006, YSZ (Yttria-stabilized zirconia) and alumina are the candidate materials selected for corrosion test. The test experiments were carried out on duplicate specimen, with and without coating and generation of corrosion data under static condition in high temperature molten cuprous chloride media at 550°C ±10°C for 100 h using quartz reactor system. After the immersion test, visual examination, weight loss analysis, SEM, and EDX were carried out to evaluate the specimens. The study showed severe corrosion of all the coated specimens.

Students Workshop on Corrosion Testing and Analysis

Hall-D

1415 - 1430
Session Break

1430 – 1600

Power Plants & Utilities (PPU-1)

Hall-A

Corrosion in Thermal and Hydro Power Plants - PPU11 Invited

Paper by: Dr. A. K. Maiti, BHEL R&D, Hyderabad

Thermal power plant situated in sea coastal region uses sea water as a cooling medium for condenser. As the sea water is corrosive in nature it causes saline water corrosion in condenser tubesheet. In order to overcome the corrosion problem, this carbon steel condenser tubesheet is cladded with titanium plate. Presently titanium cladded tubesheet is imported as it is not available locally. In this study an economical alternative to titanium cladding was envisaged. Accordingly, a number of coatings were made like Cupro- nickel, Molybdenum-steel, aluminium, etc. These coatings were deposited using twin wire arc spray technique (TWAS). Simultaneously polymer based epoxy coating was deposited after mixing the appropriate amount of resin and hardener. These coatings were exposed to salt spray testing as per ASTM B 117. For comparison, a mild steel, stainless steel and Titanium cladded rod were also put alongwith the other samples. After 20 days of exposure and 180 days of exposure, the samples were evaluated visually, it was found that most of the samples have corroded extensively whereas the polymer coated samples along with titanium cladded plates are intact. This study shows that polymer based coating can be a potential alternative to titanium cladding for condenser tubesheet.

Technical Sessions Descriptions

Boiler hopper panel also faces similar problem due to splash of sea water. In boiler, solid ash chunk falls in the sea water tank and water splash on the hopper panel walls causing severe corrosion. This problems force to replace those hopper panel bottom tubes very frequently. It is to note that the surface temperature of hopper panel is around 300-400 0 C. Because of high temperature, polymer coatings are not suitable and hence other high temperature coating was studied. Glass ceramic based coating which cures around 200 0 C and was found very suitable for that condition. This glass ceramic based coating is very cheap compared to other metallic coating like Cupro-Nickel, Molybdenum-steel, etc. This coating is applied by brush after thorough grit blasting of the steel surface.

Hydroturbine power stations situated in north east region faces acidic water corrosion. Because the water is highly acidic in nature and PH of the water is around 3.3. Due to acidic water corrosion the hydro components components (runner, labyrinth, guide vane, lower rings, etc.) get corroded and after some time its gets eroded. As a result, water leakage increase in the hydroturbine causing inconvenience to run the power house. As the temperature is very low (room temperature) polymer based epoxy/polyurethane coatings are being seen as a viable solution.

Cracking of AISI 321 Stainless Steel Welds in Solar Thermal Power Plant: Root Cause Analysis - PPU12

Paper by: Kamal Mankari and Swati Ghosh Acharyya, School of Engineering Sciences and Technology, University of Hyderabad

AISI 321 stainless steel (SS) tubes are commonly used in solar thermal power plant to transport the chloride ion containing thermic fluid at a temperature of ~ 400oC. It was noted that several of these SS tubes have failed in a short time after being exposed to the thermic fluid under service condition, which led to the leakage of the thermic fluid. The present study aims to understand the root cause of failure of these tubes, as these tubes were seam welded and also had spot welds on the surface. The seam welding had been done either by laser beam welding or by metal inert gas welding (MIG). Dye penetrant tests were performed to the tubes followed by microstructural analysis using optical microscopy, and field emission scanning electron microscopy (FESEM). Subsequently, X-ray diffraction studies were carried out to determine the phase of the tubes at the weld region. Microscopic analysis showed that the leakage of the thermic fluid occurred at different weld joints and adjoining area in each tube. In the case of laser welds, failure occurred due to knife line attack at the interface of weld and base material. In case of in MIG welded tubes failure occurred due to end grain corrosion caused due to high volume fraction of σ phase precipitation and attack at the interface of the σ phase and base material. Further, failure near spot welds occurred due to chloride-induced stress corrosion cracking (SCC) of 321 SS. Improper post weld heat treatment (for laser beam weld and spot weld) and high ferrite content in the filler wire (for MIG welds) was identified to be the root cause of failure of the tubes.

Microstrutural Characterisation and Corrosion Behaviour of 9Cr–1Mo Steel Based Metal Waste Form Alloys with Noble Metal Fission Products - PPU13

Paper by: R. Priya, S. Ningshen, C. Mallika and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam

Pyrochemical reprocessing technique based on electro-refining process is proposed for the extraction of uranium and plutonium from the spent metallic fuels, which would be discharged from future Fast Breeder Reactors (FBRs) in India. In electro-refining, the noble metal fission products (NMFPs), steel cladding hulls and zirconium from the alloy fuel that are not oxidized, remain in the anode basket as metallic waste. The solid metallic waste in the anode dissolution basket of the electro-refiner along with contaminated actinide elements is consolidated by melting to produce Metal Waste Form (MWF) alloys for disposal in geological repositories. The waste matrix to be produced for immobilizing the radioactive waste must possess excellent chemical stability and durability, besides its compatibility with the waste stream as well as the disposal environment. In the present work, the influence of NMFPs on the microstructure and corrosion behavior of 9Cr1Mo steel-12Zr MWF alloys in simulated ground water media was studied. Ingots of 9Cr1Mo steel-12Zr-NMFPs MWF alloy with different NMFP concentrations (1-4 wt.%) were prepared by vacuum arc melting. The XRD pattern of the MWF alloy showed the presence of α-Fe peak and the intermetallics phases Fe23Zr6, and Fe2Zr. The noble metal fission product intermetallics were found in 2.5 NMFP and 4 NFFP MWF alloys. Potentiodynamic polarization behavior showed improved corrosion resistance for 2.5 NMFP and 4 NMFP alloys than in 1 NMFP MWF alloy in simulated Rajasthan Ground Water (RGW) and Kalpakkam Ground Water (KGW) media. Electrochemical impedance spectroscopy (EIS) results revealed higher passive film stability for 2.5 NMFP and 4 NMFP MWF alloy in RGW and KGW media. Higher breakdown potential and polarization resistance values were observed in RGW than in KGW medium. Corrosion morphology showed more pits and corrosion attack at KGW than in RGW medium. The concentration of the NMFP played an important role in improving the corrosion resistance of the MWF alloy.

Case Study on Premature Failure of Super-Heater Tubes in Oil & Gas Fired Boiler - PPU14

Paper by: Vibhav Gupta, Harsh Vardhan and S.K.Yadav, Indian Oil Corporation Limited, Begusarai

Captive power plant (CPP) is a necessity of any refinery to provide uninterrupted supply of key utilities like steam & power. The CPP makes use of oil & gas fired boilers that produce steam by utilizing feedstock fuels to minimize fuel & loss of the refineries. As a consequence the boiler operators faces challenges to ensure reliable boiler operation by burning different blends of fuel oil(FO) & fuel gas(FG) with varying composition & calorific value. In this process both the radiation & convection zone tubes of the boiler are subjected to anomalous heat loads whenever there is a variation in the composition / calorific values of the FO & FG which is being used as fuel. This paper discusses a condition which led to the long term overheating & subsequent failure of pendant type super-heater tubes of a 150TPH capacity boiler. Critical design parameters, maintenance constraints and operating conditions of the boiler are highlighted that caused the failure of the super-heater tubes of MOC SS-347 & T-22. Metallographic analysis of the tubes and relevant chemical analysis of the deposits are discussed to determine the cause of failure along with measures taken to prolong the life of the boiler.

Surface Modification to Enhance the Properties of SA 210 Grade A1 Boiler Steel by Friction Stir Processing - PPU15

Paper by: Supreet Singh, Automobile Engineering Chandigarh University & Manpreet Kaur, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib

Friction stir processing (FSP) is used for localized modification and control of microstructure in near-surface layers of processed metallic components for specific property enhancement. In the current investigation, FSP was developed on a boiler tube material namely SA 210 Grade A1 which is commonly used in high-temperature steam generating plants. The FSP was carried out at the rotation speed of 900 rpm with feed rate of 70 mm/min and threefold pass of 100 % overlap. The microstructure, mechanical properties were studied in detail. It was observed that after FSP the microstructure and the mechanical properties of the steel like microhardness, tensile strength, and yield strength improved. Thereafter, high-temperature corrosion behavior of the unprocessed and FSPed materials was investigated at 900°C for 50 cycles in Na2SO4-82%Fe2(SO4)3 molten salt environments. Weight-change measurements after each cycle were made to establish the kinetics of corrosion. The FSPed specimen showed higher corrosion resistance than the unprocessed steel.

1430 – 1600

Internal Corrosion in Pipelines (ICP-3)

Hall-B

Internal Corrosion Management Strategies in Gas Pipelines - ICP31 Invited

Paper by: M K Sogani, GAIL (India) Ltd.

Corrosion is a naturally occurring phenomenon commonly defined as the deterioration of a material (usually a metal) that results from a chemical or electrochemical reaction with its environment.

Internal Corrosion Monitoring is an integral part of the Corrosion Management System of Pipelines which in turn is a critical component of the overall Pipeline Integrity Management System as 40% of all the corrosion failures shown are due to Internal Corrosion. Corrosion management is a long-term, systematic, proactive, continuous, ongoing, technically and financially sound plan for managing corrosion over organization's assets life cycle by way of specific and measurable objectives.

The properties and chemical composition of bulk fluids and gas transported through pipelines may greatly influence internal corrosion of pipelines and shall therefore, be monitored. For each pipeline network there should formulate a strategy to control internal corrosion of pipeline assets which may be divided into four broad categories, viz. development of Policy & Guidelines, Control Strategy, Monitoring & Analysis Strategy and Maintenance strategy.

Corrosion Control Strategy may include Corrosion Inhibition, selection of appropriate type and grade of the pipeline material, Process Improvement, Pig management, Cathodic protection etc. Liquid or gaseous hydrocarbons are by themselves not corrosive but the presence of water and the corrosive constituents, such as CO2, H2S, Chlorides, Volatile Fatty Acids (VFA) dissolved in it, significantly increases the likelihood of corrosion in the pipelines. Regular monitoring for corrosive constituents and moisture levels in gas shall be captured and stored in relevant databases. Sets of data will generate trends. Analysis of those trends will indicate the performance level of the upstream treatment facilities and corrosion mitigation program (if present).

Internal corrosion in the pipelines has complex mechanisms. The rate of corrosion is driven by a multitude of parameters. Despite the existence of abundant literature and reports in understanding of this mechanism, there are still no universal approach or established engineering principles to provide all the operating assets susceptible internal corrosion with just one deterministic solution. Hence there is need to develop a model that predicts the pipeline material degradation due to internal corrosion by incorporating the full range of key parametric effects that can be captured and modelled. The second role of a model is to identifying and prioritizing those parameters that have the strongest impact on the corrosion rate.

Further, for continual improvement in this direction, the organization should develop a process for training personnel on the organization-specific CMS processes and procedures. Additionally, competency evaluations for personnel, such as certifications, internal or external examinations, demonstrations of competence, previous job experience, or on-the-job evaluations, should be defined, implemented, and documented. It is important to consider the needs for re-training and evaluations, as well as the difference between training requirements for new and experienced personnel. Learning from both internal and external events is critical to the continuous improvement of Corrosion Management System.

Inspection, Monitoring, Model: Past, Present, Future - ICP32

Paper by: Sankara Papavinasam, CorrMagnet Consulting Inc., Canada

The title of the paper denotes two attributes:

Attribute #1: "Inspection" reveals "past" events, i.e., inspection technologies determine the corrosion rate "after" corrosion had caused loss of material

"Monitoring" reveals "Present" situation, i.e., monitoring techniques determine the corrosion rate at the time of monitoring

"Model" predicts the "future" situation, i.e., modeling predicts the "futuristic" corrosion rate based on system operating conditions.

Attribute #2: The paper discusses "past" developments, "present" status, and "future" advancements of inspection, monitoring, and modelling technologies.

The main objective of the paper is on Attribute #2.

Technical Sessions Descriptions

- In the past, the number of internal corrosion related incidences was more than 3 per 1,000 kilometers (KMs) of pipelines per year
- In the present, the number of internal corrosion related incidences hovers around 0.5 per 1,000 KMs of pipelines per year
- In the future, the industry's goal is to bring the number of incidences to "ZERO".

This paper explains "effective" and "economical" actions that are required to achieve the "ZERO" incidence goal.

In Line Inspection (ILI) Frequency for Cross Country Pipelines - ICP33

Paper by: Sahab Singh Gurjar, Cairn Oil & Gas, Vedanta Limited, Ahmedabad

In line Inspection (ILI) frequency are often based on conditions that are assumed constant over long sections of pipeline – perhaps entire pipeline systems. Many pipeline operators are following the fixed ILI frequency based on statuary requirement irrespective of different local corrosion growth conditions prevailing on the particular pipeline system. Scheduling the ILI based on maximum interval defined in statuary requirement may be very unrealistic and pose threats to the integrity of these pipelines.

This technical paper discusses the importance of ILI frequency, corrosion growth rate analysis, recent development to determine the ILI frequency, an engineering approach to calculate appropriate ILI-Run frequency, mitigation plan to extend the ILI-Run frequency for particular pipeline system. This technical paper would enhance the awareness among the pipeline operators to appropriately calculate the ILI-Run frequency which would cost beneficial to pipeline operators in long term without any integrity threats.

Root Cause Analysis of Internal Corrosion Related Failures in a Liquid Petroleum Pipeline Transporting Export Quality Crude Oil - ICP34

Paper by: Sridhar Arumugam, Patrick J. Teevens, Broadsword Corrosion Engineering Ltd., Calgary, Canada and Ashish Khera, Allied Engineers, New Delhi

The root cause of pre-mature leaks in a client's 34" crude oil pipeline due to internal corrosion was determined following the internal corrosion direct assessment Standard Practice for liquid petroleum pipelines (LP-ICDA: SP0208-2008). The 34" pipeline transports export quality crude oil with < 0.5% BS&W. The occurrence of pre-mature leaks prompted the operator to assess the extent of wall loss along the pipeline using an ultrasonic ILI tool which identified severe internal corrosion in selective pipeline regions. The root cause of these failures was then investigated using LP-ICDA methodology. In the LP-ICDA approach, the most probable locations of water accumulation and solids deposition along the pipeline were predicted as a function of the pipeline operating conditions. A comparison between the sites (i.e. locations along the pipeline) where internal corrosion was more severe and the sites where water and solids accumulation was more prevalent revealed the root cause of the failures at those selective locations in the pipeline. Advanced DNA sequencing of the filtrate of the water associated with the crude oil also provided significant insights into the role of microbiologically influenced corrosion (MIC) in causing internal corrosion of the subject pipeline where water and solids were observed to deposit. A mitigation plan was then suggested based on the root cause analysis of the internal corrosion.

Internal Coating –A Must in Gas Pipelines - ICP35

Paper by: Ranjit Sigh & Amrinder Singh, IOCL, Panipat

Pipelines have become an essential part of the system to transport and supply of petroleum gases. Conventionally, gas pipelines are coated externally for anticorrosive properties. The inclusion of condensates, sour gases and other corrosive substance in traces cannot be ruled out during pipeline operation over a period of its intended usage. The External coatings are not able to provide resistance to corrosive substances present in gases and cannot be cleaned using pigs. The corrosion of pipelines through condensates, accumulated corrosive substances has caused severe damages to pipelines, mankind and economics worldwide.

This article reviews the benefits of considering an internal lining for gas transmission pipelines and the relationship between the internal surface roughness, the pressure drop across the pipeline and the maximum flow rate of gas through the pipeline.

Water-based Corrosion Inhibitor for Sour Gas Production - ICP36

Paper by: Bhushan Sonchal, Sathees Kesavan; Seethalakshmi S, GE Water & Process Technologies, Bangalore, Lin Shaofeng, GE Water & Process Technologies, China & Nimeshkumar Patel, GE Water & Process Technologies, USA

In offshore process complex, process gas compressors are used to compress gases from 6-8 kg/cm2 to 90- 96 kg/cm2 in three stages. The compressed gas is cooled by passing it through inter coolers and the condensed water is removed through the knockout drums (KOD) at the respective stages. This case study pertains to failure of 6"Φ pipe spool segment of third stage cooler outlet line. PGC cooler outlet, after 3rd stage, have a pressure of 92 Kg/cm2 and it has 3.26% CO2, 90 ppm H2S along with condensate.

Laboratory investigations of failed PGC cooler outlet showed that chemical composition, tensile strength and hardness value of the tested sample were complying with the SSC resistant, ASTM A 106 Grade B material. The piping had an acceptable microstructure of normalized ferrite and pearlite.

Visual inspection of the failed surface showed the classic sand dune like surface contours oriented along the direction of fluid flow that is typical of erosion-corrosion. In metallographic studies, small pits were observed at several places. EDS analysis of pitted region on failed piping surface confirmed the influence of corrosive species like chloride and sulphides. Localized metal loss of cooler outlet piping led to its failure by erosion corrosion under corrosive environment. All the corrosion studies showed that existing metallurgy of piping was susceptible to CO2 corrosion. It was recommended to use UNS 31603, 316 L Stainless steels for PGC cooler outlet lines to avert such failures in future.

Students Session-1

Hall-C

Tailoring of Metallic Bio-implant Performance by Surface Engineering - SS11 Invited

Paper by: Jyotsna Dutta Majumdar, Indian Institute of Technology Kharagpur

Bioimplant refers to artificial materials (made of biosynthesis materials) used to replace the damaged part of human body. Implants made of metallic materials do enjoy prominent position due to their higher strength as compared to polymer based materials, and higher toughness as compared to the ceramic based implant. Commonly used metallic materials for bio-implant applications are AISI 316L stainless steel, titanium and its alloys, Co-Cr-Mo based alloy, etc. However, metallic implants often fail due to wear, corrosion, fatigue and bacterial infection in the human body. The failure of metallic implants may be circumvented by a suitable modification of surface microstructures and compositions, commonly termed as surface engineering. The surface engineering techniques, applied for improving the performance of implants may be based on microstructural modification (by mechanical, thermal or thermo-chemical routes) or coatings (developed by physical, chemical, electrochemical and thermal routes). In the present talk, the application of different surface engineering techniques on improving the properties of AISI 316L stainless steel, titanium and magnesium for bio-implant applications would be discussed in details. In addition, the future scope of research and development in surface engineering on tailoring of metallic implant will be recommended.

Corrosion Performance of Chemically Modified Polymer Coatings Applied on Mild Steel - SS12

Paper by: Punita Mourya and G. Udayabhanu, Indian Institute of Technology (Indian School of Mines), Dhanbad and Monika, Indian Institute of Technology (Banaras Hindu University), Varanasi

Corrosion resistant coatings are a promising solution to protect structural metals in severe corrosive environments. Modified polymer coatings made from PVC polymer are highly attractive due to the blood, cellular compatibility and the ability to work in various environments. This paper is focused on the use of modified PVC and PVC coatings for corrosion protection of mild steel (MS) in 0.5 M sulphuric acid. Their corrosion protection ability was examined by potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) measurements. The results of these study clearly reveal that both act as protective coating on mild steel and reduces the corrosion current density effectively. These coatings on metal surface were characterised by Atomic force microscopy (AFM).

Arabinogalactan as a Green Inhibitor for Carbon Steel Corrosion in 1M HCL Solution - SS13

Paper by: Marziya Rizvi and Mohammad Mobin, Aligarh Muslim University, Aligarh

Biopolymer arabinogalactan (AG) was investigated for its inhibition characteristics for carbon steel (CS) corrosion in 1M HCl. Gravimetric method, electrochemical impedance spectroscopy (EIS), potentiodynamic polarization measurements (PDP) and Atomic Force Microscopy (AFM)assessed the inhibition and adsorption of AG in the acid solution. The studies proved that the inhibition efficiency increased with elevating temperature and increasing AG concentration in acid solution. AG adsorption on CS favored Langmuir adsorption isotherm. Results of corrosion tests confirmed that AG could serve as efficient green inhibitor for CS corrosion in 1 M HCl with high inhibition efficiency and a low risk of environmental pollution. Monte Carlo simulation and theoretical quantum chemical studies were used to corroborate experimental results

Computational and Electrochemical Characterization of Synthesized Ionic Liquid as a Green Corrosion Inhibitor in 0.5 M H_2SO_4 Solution for Mild Steel - SS14

Paper by: Bhaskaran, Akshay kumar, Mansi Khera, Raj Kishore Sharma and Gurmeet Singh, University of Delhi, Delhi

The corrosion inhibition characteristics of 3-Butyl-1-methyl-1H-benzo (d)-imidazol-3-ium bromide [BMBIm]Br have been studied as eco-friendly green inhibitor for corrosion control of mild steel in 0.5 M H_2SO_4 solution by computational and electrochemical methods. The structure of the obtained [BMBIm]Br was confirmed by using 1 H, 13C NMR, and IR spectroscopy, which also confirms the absence of any major impurities. The corrosion data extracted from Tafel plots, electrochemical impedance spectroscopy and SEM, AFM, EDX indicate high inhibition effectiveness in H_2SO_4 solution. SEM and EDX observations confirmed the existence of protective inhibitor film on metal surface. The adsorption of an ionic liquid on the mild steel surface follows Langmuir adsorption isotherm. The effect of the temperature on the corrosion behaviour with addition of the different concentration of [BMBIm]Br was studied in the temperature range of 298 -328 K. Quantum chemical parameters such as highest occupied molecular orbital energy (EHOMO), lowest unoccupied molecular orbital energy (ELUMO), energy gap (ΔE) and dipole moment (μ) were also calculated. Quantum chemical calculations also supported experimental data and the adsorption of inhibitor molecules onto the metal surface.

Synthesis and Characterization Bio-based Benzoxazine Oligomer from Cardanol for Corrosion Resistance Application - SS15

Paper by: Ganesh A. Phalak, Deepak M. Patil and S. T. Mhaske, Institute of chemical technology, Mumbai

The Mannich-like condensation of a cardanol, paraformaldehyde and N,N'-Bis(2- aminoethyl)ethane 1,2-diamine were carried out to synthesized the amine functional benzoxazine(Bnz) resin. The amine functionality of Bnz resin was evaluated by physiochemical method and structure was characterized using Fourier Transform Infrared (FTIR) and 1H- Nuclear Magnetic Resonance (1H-NMR) spectroscopy. The added functionality into the Bnz resin backbone was utilized to modify the Bnz resin structure by glycidoxypropyltrimethoxy silane (GPTMS) in various proportions. The results revealed that the silane modified Bnz coatings have improved mechanical, chemical, and solvent resistance properties as compared to the neat Bnz coating. The gel and water absorption of polyamidecured coatings has been also evaluated. Furthermore, the cured films have been evaluated for glass transition temperature (Tg) by differential scanning calorimeter (DSC). The corrosion resistance properties were studied by salt spray and electrochemical analysis. It was observed that highly cross-linked structure of the GPTMS modified Bnz coatings enhanced the barrier protection to corrosive species.

Technical Sessions Descriptions

Technical Interactive Forum 3 Corrosion in Concrete Structures

Hall-D

1600 - 1630
Tea/Coffee

1630 - 1800

Cathodic and Anodic Protection (CAP-4)

Hall-A

Reliability of Coupons for AC/DC Interference Monitoring - CAP41 Invited

Paper by: Christophe Baete, Elsyca nv, Wijgmaal, Belgium

Coupons are available in different configurations, dimensions and shapes. Monitoring AC and/or DC interference requires a small surface area of the bare steel coupon sample with a reference electrode tip as close as possible to the steel surface for minimizing the IR-drop error in the measurement. Furthermore the effect of a coating surrounding the defect is often neglected or simplified which may have influence on the measured current densities, and thus corrosion rates.

Current standards such as NACE Standard SP0104-20141 does not address sufficient details to make AC/DC coupons sufficiently sensitive and reliable for interference monitoring. This article discusses results from a benchmark study on commercially available coupons. Deviations in the current density and IR-free readings through computational modelling are reported.

AC Interference, AC Corrosion & AC Mitigation - CAP42

Paper by: Jeffrey L. Didas, Matcor, Inc. Tucson, AZ USA

This paper will discuss AC Interference, AC Corrosion and AC Mitigation. The paper will cover each subject, provide some solutions and recent research on AC corrosion. The AC interference discussion will be about the three types of AC interference that is encountered in the pipeline industry. Discussion about the how-why-where-when of AC interference. This will be a general discussion. The AC corrosion discussion will explain AC corrosion, when-where-how-why of its occurrence and what it looks like. Several photographs of AC corrosion will be presented. Finally AC mitigation will be discussed. This will cover various methods for mitigating AC including modeling for designing the mitigation system. Systems will go from simple to complex and a case history for a 42" natural gas pipeline will be included.

Monitoring and Maintenance of MGL CP system - CAP43

Paper by: Pravin Vishvanathe, Mahanagar Gas Ltd, Mumbai

Mahanagar Gas Limited is a city gas distribution company based out in the city of Mumbai and around. MGL currently has around 400 kms of Steel gas pipelines for transportation of natural gas. The diameters of these pipelines are ranging from 2" to 18" and all coated with 3 layer poly ethylene coating (3LPE) .we are installing permanent Cathodic protection system for all commissioned pipelines and temporary Cathodic protection system having design life of 10 years for pipeline un-commissioned.

This paper shall basically outline the CP system in MGL along with various practices being followed in MGL to ascertain the effectiveness of CP. MGL has installed Various CP assets like CP stations, diode stations, external ER probes, corrosion coupons to ascertain the CP effectiveness. This paper shall outline the detailed monitoring procedure along with monitoring frequency of all the assets. MGL is also carrying out health adequacy surveys like DCVG,CIPL etc. over the steel pipeline network. Few case studies arising out of these monitoring results shall be presented in this paper.

1. Casing-carrier short at Taloja railway crossing .The detailed procedure of monitoring and rectification shall be presented.
2. Case study on CP under protection at Andheri which was resolved using a Flange isolation kit.

Interference & Corrosion Due to HVAC Power Lines Running Parallel to Cross Country Pipelines - Challenges in Mitigation and Way Forward - CAP44

Paper by: Mallesh G, Gail (India) Ltd-Cherlapalli, M. I. Md. Ammar, GAIL (India) Ltd-Noida, D. Phani kumar, GAIL (India) Ltd-G.Konduru

10"diameter, 3 layered PE coated LPG pipeline 8.7/6.4mm thickness & 300 km length was laid to transport the Liquefied Petroleum Gas (LPG).

During its first ILI run in year 2015, External corrosions was detected on 10" pipeline of 300kms. Nearly 350 no's of external corrosion defects were detected in which major defects were nearly 20 no's with a metal loss ranging from 10% to 50% and minor defects were 330 no's with a metal loss of below 10% of total pipe thickness. Dig verification was carried out at major defect locations for assesment. The defects observed were round shaped with holidays in coatings with 1 to 3 cm^2.

AC interference survey was under progress in the same pipeline few months before ILI run. Based on CP survey data, soil test at external corrosion site, lab test of corrosion material data and assessment of various factors such as presence of an AC voltage on the pipeline, presence of a coating fault (usually very small size – up to 3 cm2), the shape of the corrosion (rounded pit like), low/very low soil resistivity,

presence of a large disbonded area beneath the coating and calculations for Current Density found to be very much greater than> ~100 A/m2) , conclusion was made that external corrosion was due to AC interference.

A major factor contributing for the conclusion was the fact that HVAC power lines are running parallel to the pipeline approximate of 70 Kms and having HVAC power lines crossings at 30 locations.

Paper on Casing – Carrier Electrolytic Short Rectification - CAP45

Paper by: N. Ganesh, GAIL (India) Limited, Goa

As per standard practice, the pipeline across Rail and major road/highways crossings are provided with casing pipes. The purpose of casing is to avoid any mechanical stress to pipeline due to movement of rail/vehicle. Prior to insertion of carrier inside the casing, insulator rings are provided on the carrier pipe at every one meter distance & after insertion both ends of casing is provided with casing end seals to prevent ingress of water, mud/electrolyte. For proper cathodic protection of carrier pipe inside the casing pipe, usually Zn-ribbons anode are provided at 04 & 08 O'clock position at a distance of approximately two meters over the Carrier pipe.

Two Types of Casing – Carrier shorting is possible

1. Electrolytic Coupling: This can occur due to presence of moisture / liquid in the Annular Space (space between Casing and Carrier pipe). Moisture / Liquid enters through the Vent Pipe / Drain Pipe during heavy monsoon and it is comparatively easier to handle.ie to rectify
2. Electric Carrier Shorting means that carrier pipe get shortened with casing pipe by metallic interconnecting bolts of damaged insulator and sometimes the Zn-ribbon anode got detached from one end and provide an electrical path to flow of Cathodic protection current between casing & carrier pipes. These situations resulted drainage of CP current & sometimes the PSP of the effected zone goes below the protection level.

Corrosion in RCC Structures (RCC-3)

Hall-B

Critical Strategies for Mitigating Corrosion of Reinforcing Steel in Concrete - RCC31

Paper by: Vijay Kulkarni, Ready-Mixed Concrete Manufacturers' Association, Mumbai

Premature deterioration of reinforced and pre-stressed concrete structures is being witnessed all over the world. Amongst various factors affecting early deterioration, corrosion of reinforcing steel in concrete is one of the most widespread and serious governing factor. In fact, it has assumed a form of an epidemic in some parts of the world.

Contrary to general belief, a number of reinforced concrete structures in cities and metropolis located in the vicinity of the long coastal areas and industrial belts in India are witnessing considerable premature deterioration, most often owing to corrosion of reinforcing steel in concrete. Unfortunately, no reliable estimates of such deterioration are available. Unofficial reports however indicate that one cannot afford to ignore this phenomenon any longer.

Considering the experience of many advanced countries, where the premature deterioration has assumed the form of an epidemic, the author urges to take immediate steps to ensure long-term durability of the new concrete structures.

The paper presents a broad overview of the concrete durability scenario and highlights main factors which are responsible for the premature deterioration of structures. It briefly explains the salient features of both chloride-induced and carbonation induced corrosion.

Although a number of measures are available to ensure the long-term durability of concrete structures, the paper focuses attention on three critical measures, namely, the urgent need to undertake revision in the exposure class definitions of IS 456, use of concrete having low water-binder ratio along with higher percentage replacement of OPC by SCMs and specifying tests on durability in construction specifications.

The paper also presents the pros and cons of the Rapid Chloride Ion Permeability Test (RCPT), which in spite of many shortcomings, is now receiving wider acceptance as a reliable durability test

Corrosion Behavior of Dual Phase Steel in Different Pore Solution in RCC Structure - RCC32

Paper by: Subhadra Sahoo, Veer Surendra Sai University of Technology, Burla and Amit Sarkar, Jadavpur University, Kolkata

Dual Phase steels (DP) consist in a ferritic matrix with a fraction of dispersed in different percentage, which gives the material a good combination of strength and ductility, with a significant capacity to absorb energy and corrosion property. The purpose of this paper is to present results of an evaluation of dual-phase and different rebar steel reinforcements in corrosive environments. Low carbon steels were intercritically annealed at 7400C followed by iced water quenching to obtain dual-phase structures with different per cent volume fraction of martensite dispersed in ferrite matrix. Corrosion property of dual phase steel and rebar tested in different pore solution. Corrosion rate, tensile and macro as well as micro hardness tests were performed. From all of the tests carried out it was found that dual-phase steels exhibited better corrosion resistant properties and superior strength compared to rebar. The results reported show that dual-phase steel can be a good candidate for reinforcement in concrete especially in aggressive and corrosive environments.

Technical Sessions Descriptions

Determination of Corrosion Rates by Potentiostat and Weight Loss Measurement for Steels Embedded in Different Concretes Grades Developed with Different Cements - RCC33

Paper by: Rahul Ristav and Dinakar Pasla, Indian Institute of Technology Bhubaneswar

Corrosion behaviour of blended cements in structural concretes under aggressive exposure condition must be established. The present investigation was mainly directed towards investigating the corrosion behaviour of blended cements such as Portland pozzolana cement and Portland slag cement in structural concretes and compare it with ordinary Portland cement. The experimental investigations were carried out to arrive at the corrosion rates on three structural concretes 25, 35, 45 MPa. 8 mm cold twisted deformed bar (Fe 500 grade) was used in this study. The investigation was carried out for steels embedded in cubical specimens for a concrete cover of 20 mm. Chloride curing and mixing was done by 5% and 1% NaCl solution respectively. The idea behind categorizing this was to simulate the marine environment condition and to take a reference for comparison. The corrosion rates were assessed both by a potentiostat and from weight-loss measurements at the end of 500 days of exposure. The studies showed that the corrosion rates determined by gravimetric weight loss were less that the values determined by potentiostat. However, the corrosion rates are in the order M45<M35<M25 for the grade of concretes and for cements the corrosion rates are in the order PSC<PPC<OPC.

Calculation of Mass Loss on Corrosion of Reinforcement through Field Measurement - RCC34

Paper by: Dr. Sanket Nayak, Indian Institute of Technology (Indian School of Mines), Dhanbad and Narayan Chandra Moharana, KIIT University, Bhubaneswar, Odisha

Concept of reinforced concrete (RC) to be a durable material has been changed in last few decades as many RC structures are found showing distresses like cracking, spalling, de-laminations etc. The possible reason may be due to corrosion of reinforcement in costal chloride laden environment as well as in industrial CO2 laden areas. Corrosion of reinforcement inside the concrete is not visible unless there is crack formation. After the formation of crack in concrete the residual life of the structural member is hardly 5 to 10 years. But corrosion of reinforcement inside the concrete can be known instrumentally from early stage before making any structural damage. For calculation of residual strength of RC members for integrity appraisal, many models have been proposed. However, accuracy of the model depends on the amount and distribution of corrosion of reinforcement in existing structures. This is also a difficult process to assess the above parameters. Present study discusses various methods for corrosion measurement in the field to the real structures and calculations of corresponding mass loss. This mass loss can be utilized satisfactorily for calculation of residual flexural strength of RC member in flexure on bond loss as well as strength loss on corrosion.

Power Plants & Utilities (PPU-2)

Hall-C

Operating Experience of Nuclear Power Plants in the Context of Corrosion and Biofouling Issues - PPU21 Invited

Paper by: R. S. Sundar, Nuclear Power Corporation of India Ltd, Mumbai

Generally, extensive cooling water is a necessity for large nuclear power plants to cater to the essential processes. Problems emerge as outage of the systems need careful planning, due to its requirement including shutdown period and optimum outage period in an industrial unit. Hence it should be mandatory to have a thorough analysis of the important water quality parameter of the system from time to time so as to have a check on the system performance. Sea water based plants face corrosion related issues both internal due to sea water and external due to salinity in the atmosphere. The water quality (chemical and biological) inventory of an industrial unit should contain information about the quality of the source water it uses. Water is the preferred medium for cooling in many industries. A 1000 MW(e) nuclear power plant needs ~45 m3/sec of water for cooling purposes. Due to the continuous interactions between the constituents of cooling water and materials with which they are in contact, problems like scaling, corrosion and biological growth crop up. These may ultimately result in unscheduled plant shutdown and consequent production penalty. In view of the vital use in an industry, cooling water needs proper treatment for controlling of scale, corrosion and biofouling.

Biofouling problem is generally site-specific and the major conclusions reagarding the possibility of serious biofouling in an operating plant, need to be arrived at cautiously, because several factors, including water quality, hydrographic conditions, geographical location and cooling system configuration influence biofouling. Differences in the degree of colonization by biofilm bacteria or biofouling organisms on metal surfaces can generate corrosion potentials almost as large as that generated between incompatible metals. The impact of the distribution system corrosion can range from significant physical damage to pipes and other system components due to surface metal removal, localized or pitting corrosion. This presentation elaborates the operating experiences of nuclear power plants particularly in reference to seawater water cooled power stations.

Failure of HRSG Tubes During Pre-Commissioning Hydro Test - PPU22

Paper by: Mahesh.S, Bharat Petroleum Corporation Limited, Kochi Refinery, Kerala

At Kochi Refinery, GT (Gas Turbine) & HRSG (Heat Recovery Steam Generator) was being erected as part of Refinery expansion. During pre-commissioning, hydro test of entire integral piping including boiler banks was done and a leak was observed from tubes. Leak was observed on the fifth hydrotest (one at shop and four at site). During inspection, it was observed that leak was due to external corrosion. Severe pitting was observed. Samples were taken and analysed to identify the root cause for failure. This paper provides the details of failure (MIC & CUI combined) and the type of corrosion and the repair carried out. Paper highlights the importance of proper storage of equipment to avoid such premature failure to avoid moisture ingress.

Corrosion Behavior of Ni-based Superalloys in Molten FLiNaK Salts - PPU23

Paper by: Niketan S. Patel, Viliam Pavlík, Miroslav Boča, Institute of Inorganic chemistry, Slovakia

High temperature corrosion tests of alloys, Inconel 718, Inconel C-276 and Nimonic 80A, were performed at 680 °C in molten alkali fluoride salt (LiF–NaF–KF: 46.5–11.5–42%) environment. These experiments were carried out from 8 to 48 hours of immersion period in an attempt to understand the corresponding corrosion behaviour of the alloys at different times. Corrosion was noted to occur predominantly by dealloying of Cr from the alloys, an effect that was particularly pronounced at the grain boundaries of these alloys. Microstructural examination showed the depletion of Cr near surface of the alloys and also revealed mild intergranular corrosion at early stage of corrosion test. But in general all three alloys performed well and showed reasonably low corrosion rates in aggressive FLiNaK environments.

Corrosion Resistance System for the Steel Liner of Hydro-Electric Plant in Acidic Medium - PPU24

Paper by: Abhradip Pal and Chandan Das, Indian Institute of Technology, Guwahati, Assam

The Kopili Hydro-Electric Project (KHEP) of North Eastern Electric Power Corporation Limited (NEEPCO) is one of the pioneering Hydro-Electric Projects in the North Eastern Region (NER) of India. In recent years, it has been found that the low pH of the reservoir water has damaged plant equipment and metallic parts in KHEP due to corrosion. These parameters were tested according to the standard procedure of APHA (American Public Health Association). The metal parts used in power plant was characterized by field emission scanning electron microscopy (FESEM) energy dispersive X-Ray (EDX). The FESEM-EDX observation of the metal surface confirmed that the boiler quality (BQ) steel of ASTM (American society for testing and materials) grade A537 are used in the power plants. The corrosion rates were measured in sulfuric acid solution of different pH and molarity by potentiodynamic curves or Tafel extrapolation method. After that the metal surface was coated with silicon based super hydrophobic coating which has superior water-repelling effects and has received increasing attention as a promising solution to corrosion of metallic materials. The contact angle of super hydrophobic coating was more than 140^{0}. The corrosion rate of coated BQ metal plate was measured by Tafel extrapolation method and it had been observed that corrosion rate was reduced to more than 80 times compared to uncoated metal.

Corrosion of Nickel Alloys in Molten LiCl-KCl Medium Under Cl2 Environment - PPU25

Paper by: A. Ravi Shankar and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam – 603102, India

Pyrochemical reprocessing utilising molten chloride salt medium has been considered as one of the best options for the reprocessing of spent metallic fuels of future fast breeder reactors. Purification of molten salt is an important step, where chlorine gas is purged in molten LiCl–KCl eutectic salt at 873 K which is a highly corrosive environment. The materials used for fabrication of vessels and components of salt purification system should therefore possess adequate corrosion resistance. Corrosion studies on Ni-based alloys 600 (UNS N06600), 625 (UNS N06625), and 690 (UNS N06690) and their welds in molten LiCl–KCl eutectic salt at 873 K under Cl2 bubbling was carried out. The exposed surfaces were characterised using SEM, EDX and GIXRD. The results of the present study indicated that Ni-based alloy 600 and 690 offered better corrosion resistance compared to alloy 625. Localised corrosion and selective attack such as intergranular corrosion and preferential dissolution of precipitates within the grain were observed on the alloy 600 and alloy 625. However, weldments exhibited marginally higher corrosion rate compared to wrought alloy. Surface morphology of the tested weld metal surfaces revealed interdendritic corrosion on alloy 600 and alloy 625. The mechanism of degradation of Ni base alloys in molten LiCl-KCl salt under chlorine gas was found to be different from that observed in air and argon environment. It involved active oxidation process, resulting in accelerated corrosion under chlorine gas.

Technical Interactive Forum-4 Regulations and Standards in Corrosion

Hall-D

1800 - 1900
Visit to Exhibit Hall and Posters

1900 - 2030
Corrosion Awareness Awards - 2017 Ceremony

2030 - 2200
Dinner

Technical Sessions Descriptions

Wednesday, 20 September

0900 - 1030

Microbial Corrosion & Inhibitors (MCI-3)

Hall-A

Metal-Microbe Synergy Mechanisms in Localized Corrosion of Stainless Steels - MCI31 Invited

Paper by: R. P. George, U. Kamachi Mudali and B. Anandkumar, Indira Gandhi Centre for Atomic Research, Kalpakkam

Stainless steels (SS) are the favourite materials for industrial application due to its outstanding mechanical properties, weldability and general corrosion resistance. However, corrosion resistance offered by a few nanometer thick chromium oxide passive film is under threat from both the environmental and metallurgical variables. Stainless steels are susceptible to localized corrosion especially under the influence of chlorides and biofilms. Researchers worldwide have attempted to understand the critical factors involved in localized corrosion of SS. Earlier it was assumed that the quality of the passive film is the critical factor and the quality of the passive film depends on the metallurgical factors. However studies also showed that integrity of passive film is crucial only for pit initiations. The environmental factors play a major role in maintaining pit propagation especially chlorides and microbes. In many aqueous environments major localized corrosion damage were reported under biofilms formed by microorganisms. Advanced SS developed with high pitting resistance equivalent number (PREN) for sea water applications have failed due to crevice corrosion under biofilms. Even in fresh water environments where concentration of aggressive chlorides ions are below critical level anion-selective biofilms can cause pit stabilization and propagation. An attempt was made to come up with a metal-microbe synergy mechanism for the localized corrosion of SS by manganese oxidizing bacteria and presented in this paper.

Introducing a Comprehensive Pipeline Model System to Evaluate Biocides Based on their MIC Reducing Effects - MCI32

Paper by: Amit Bhattacharya, Nora Eibergen, KM Sreenivas, Subhash Nair, Geert M. van der Kraan, Dow Chemical International Pvt Ltd

Waters circuits, lodging at vessel bottom and water in the oil (crude as well in refined products) in the oil and gas industry in cooling tower, holding tanks and pipelines, pose a high risk of contamination with sulphate reducing bacteria (SRB), acid producing bacteria (APB) and associated biofilms. Contamination of the system may result in unwanted problems such as, Microbial Induced Corrosion (MIC) of pipelines and biofouling and in some cases flow disruption due to production of corrosive H2S gas and corrosive organic acids. Conventional methods for understanding of MIC dynamics may lead to the misleading results. The pipelines and vast infrastructure required for the production and transport of oil and gas are largely constructed of carbon steel. These assets often suffer damage and failure as a result of direct or indirect Microbial Influenced Corrosion (MIC). One approach to mitigate MIC is the periodic application of biocides to affected pipelines and other industrial assets such as tanks and separators. However, the highly localized nature of corrosion-associated biofilms does not allow an easy like for like comparison of the biocidal efficacy of existing products using common methods of biofilm cultivation. Corrosion causing biofilms found in oil and gas infrastructures typically grow under anoxic conditions where phase flow is present. Their ability to corrode the metallic substrate on which they grow causes corrosion products to be embedded in their biofilms. Here we present a developed method that allows for consistent corrosion measurements to be made for corroding biofilms grown on steel surfaces under flowing and anoxic conditions. The corroding culture was isolated from an anoxic sea sediment. This isolation process will be discussed. This culture can generate corrosion rates of up to 50 mpy after four weeks of growth. The detected corrosion is highly consistent, as corrosion rates measured for loops run in parallel have less than 10% variation. This consistency is of high importance to the acquisition of meaningful anti-corrosion data for a wide-range of biocidal actives. A comparison will be made between glutaraldehyde and THPS based formulations. Their ability to reduce corrosion in pipeline model systems will be discussed. The effects of these chemistries on corroding organisms grown under non-flowing conditions will also be reported.

Evaluation of Inhibition Efficiency of Pseudomonas Putida Over Mild Steel in the Presence of a Corrosion Inducing Microbe - MCI33

Paper by: Suma M.S, S.M.A. Shibli, Rubina Basheer, Sreelekshmy.B.R, Amina.S., Ardra Ravi

University of Kerala, Thiruvananthapuram

Microbial induced corrosion inhibition (MICI) is associated with the formation of biofilm over metal surface which is rather a novel technique that is less exploited so far. Pseudomonas putida is reported as an efficienct microbial corrosion inhibitor for industrial alloys whereas Shewanella putrefaciens as an inducer of corrosion. In this study, the inhibition efficiency of P.putida over mild steel (MS) surface is evaluated in the presence of a microbial corrosion inducer by setting a binary culture of P.putida along with S.putrefaciens in nutrient broth medium. OCP analysis and mass loss determinations were made preliminarily to examine the corrosion pattern of MS in binary culture and the results showed significant reduction in the corrosion rate. In order to understand the mechanism of inhibition, electrochemical analyses were done by Tafel polarization followed by scanning electrochemical microscopic (SECM) techniques. The exposed surface was examined using SEM and AFM and compositional analysis of scraped surface film was also carried out using FT-IR spectroscopy. Phases in corrosion products were analysed by XRD and the results suggested that P.putida suppressed the corrosion causing tendency

of S.putrefaciens by instantly forming a vivianite layer (Fe3(PO4)2.8H2O) over MS as an initial protection followed by a homogeneous biofilm over it. Variation of pH over a period of seven days showed that nature of bacterial metabolites was less acidic in binary culture. This study provided an insight into the application of P.putida as a versatile inhibitor of mild steel even in the presence of a corrosion-inducing microorganism.

Biological Souring of Crude Oil Under Anaerobic Conditions - MCI34

Paper by: Yasunori Tanji, Ryo Hasegawa, Kazuya Tohyama, Kazuhiko Miyanag, Tokyo Institute of Technology, Japan

Seawater injection into oil reservoirs for purposes of secondary oil recovery is frequently accompanied by souring (increased sulfide concentrations). Production of hydrogen sulfide causes various problems, such as microbiologically influenced corrosion (MIC) and deterioration of crude oil. Sulfate reducing bacteria (SRB) are considered to be major players in souring. Volatile fatty acids (VFAs) in oil field water are believed to be produced by microbial degradation of crude oil. The objective of this research was to investigate mechanisms of souring, focusing specifically on VFA production via crude oil biodegradation. To this end, a microbial consortium collected from an oil field water separator was suspended in seawater; crude oil or liquid n-alkane mixture was added to the culture medium as the sole carbon source, and the culture was incubated under anaerobic conditions. Physicochemical analysis showed that preferential toluene degradation and sulfate reduction occurred concomitantly in the culture containing crude oil. Sulfide concentrations were much lower in the alkane supplemented culture than in the crude oil–supplemented culture. These observations suggest that SRB are related to the toluene activation and VFA consumption steps of crude oil degradation. Therefore, the electron donors for SRB are not only VFA, but many components of crude oil, especially toluene. Alkanes were also degraded by microorganisms, but did not contribute to reservoir souring.

Hydrophobicity and Corrosion Inhibition by Self Assembling Nano Films on Metal Surface – An Over View - MCI35

Paper by: Susai Rajendran, St. Antony's College of Art and Sciences for Women, Dindigul

Self assembling nano films of surfactants on mild steel surface has been assembled by immersion method. These films have been analysed by AFM study. Contact angle measurement reveals the hydrophobic nature of the protective film. This film offers better corrosion inhibition efficiency as revealed by weight loss method.

Corrosion in Refineries (CR-2)

Hall-B

Impact of the Latest ASME B31.3 Revisions on PWHT of CS Piping in Oil and Gas Production and Refining Facilities - CR21

Paper by: Ameer Hamza, Fluor Arabia Limited, Al-Khobar, Saudi Arabia & Cathleen Shargay and Tina Tajalli, Fluor, USA

For oil and gas production and refinery services, carbon steel (CS) piping welds designed to the ASME B31.3 Code have traditionally had two possible reasons for postweld heat treatment (PWHT). One was if the weld exceeded the thickness limits given in B31.3, and the other was if the service resulted in a susceptibility to an environmental cracking mechanism. PWHT reduces both the residual welding stresses and any high hardnesses in the weld and/or heat affected zones, and hence lowers the risk of environmental cracking. In the 2014 Edition of B31.3, there were major changes made to the PWHT requirements that essentially resulted in no thickness requiring PWHT on CS. This paper will describe the impacts of this change in ASME B31.3 on new construction projects, with discussions of the advantages and precautions, including a list of the common environmental cracking services.

Remaining Life Assessment of Outlet Radiant Heater Tube of Naphtha Cracking Unit-a Case Study - CR22

Paper by: S P Singh, S Bhattacharya, Kannan Chandrasekaran & S K Mazumdar, Indian Oil Corporation Limited, Faridabad

Traditionally, the equipments were replaced after their design life or if found damaged mechanically or metallurgically degraded during routine shutdown and maintenance. However, in the present world economic scenario wherein industries are forced not only to take all possible measures e.g. minimum replacement cost and reduced down time to cut cost but also comply with the ever growing stringent safety norms. This gives an immense drive for continuous assessment of equipment's health and leftover useful life. Such assessments are now becoming a common phenomenon in chemical process and power generation industries.

The present case study pertains to an outlet radiant tube of heater of a Naphtha Cracking Unit. The tube has been in service of around 5.5 years ever since it's commissioning and subjected to 41 decoking cycles. As per licensor the tube replacement criteria is based on average service life of 6-6.5 years or 50 decoking cycles whichever is earlier. A cut tube sample was subjected to multiple laboratory tests including creep tests and was assessed for its suitability to further operation. The result of our study was in line to the general recommendations of the licensor.

Liquid Metal Embrittlement in Outlet Pigtails of Reformer of Hydrogen Generation Unit in Digboi Refinery - CR23

Paper by: K K Pandey, Sukla Mistry, S D Chaklader, R Gayen, Indian Oil Corporation Limited, Tinsukia

The focus on corrosion and integrity management in the refining industry today is increasing. Drivers for this are the need for improved operational safety for plant, personnel and the environment, as well as the need for increased plant uptime and extended equipment life. Finally, a good corrosion management program can increase the operating window. For example, it can allow the increased blending of low cost crudes, lower inhibitor consumption and reduce plants' operational costs.

Technical Sessions Descriptions

Refineries today have a range of corrosion challenges, such as naphthenic acid corrosion and sulfuric acid corrosion. Efficient monitoring requires a combination of monitoring technologies and solutions. This paper gives an introduction to intrusive and non-intrusive monitoring technologies applicable in a plant, and how they can be combined into an integrated solution. The paper will also examine other refinery monitoring applications and field data examples for different monitoring technologies will be provided.

The paper will also look at the challenges in data management and how the standardization of new communication solutions, such as WirelessHART offer a significant shift in the convenience, quality of data and real time information provided, allowing remedial actions to be taken before damage takes place.

Specifying Hardness Testing of Materials and Weldments on Vessels and Piping in Wet Sour Services - CR24

Paper by: Deo Borbor and Zesan Ardaniel, Fluor Daniel, Inc. – Philippines &
Cathleen Shargay and Kuntak Daru, Fluor Enterprises, USA

In oil and gas production as well as refining facilities, there are numerous services which are known to cause environmental cracking of steel components and/or weld zones if they have high hardnesses. The primary example is fluid services containing water and H2S. For equipment and piping in these services, hardness limits are recommended in various industry standards including NACE documents MR0175, MR0103, SP0472 and 8X194. Hardness is not a fundamental material property but a response to measuring technique. Hence, there have been occasions where the reported hardnesses were inaccurate due to application of incorrect procedure, incorrect correlations of different hardness scales or confusion on testing requirements, resulting in schedule delays and unnecessary costs. This paper gives a brief summary of the services wherein metals are prone to cracking and because of which, checking hardness is critically important. It also discusses the variations in industry standards and their specified hardness limits. The paper delineates different types of hardness testing practices and the various testing instruments, for both laboratory and field testing, and gives references to conversion charts for reviewing readings from the different scales (which vary by materials). The considerations of testing in different locations, i.e. base metals, weld deposits and heat affected zones, are also addressed.

Analysis of the Failure of the Ultrasonic Scanning of Bottom Plate of Storage Tanks to Detect Localized Corrosion - CR25

Paper by: Santanu Saha, Intertek – Inspec; United Arab Emirates

Metallic corrosion from contact with soil is mostly due to complex environment with moisture content of the soil. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects, depending on soil environment. In the Middle East countries, the weather is mostly hot, and the temperature will cross 45 degrees during the mid-summer i.e. in August. The amount of rainfall is also very less with less than 120mm. during the peak summer, the humidity sometimes are also very high contributing to the moisture ingress. Most of the above ground storage tanks in this region are situated along the coastal areas where the moisture is humid and contains salts. Although most of the storage tanks are based on processed sand bed like bituminous sand and Asphalt fireboard, the sealing at the tank annular plate outer edges sometimes breaks and thus paves the way for ingress of moisture. Over the time this moisture is collected at the bottom between the bottom plate and the soil and starts localized corrosion.

Here in this paper we have described a situation after all NDT and Inspection tasks as per API 653 guidelines have been completed, repairs have been attended satisfactorily and the tank released for Hydrotest, a very small leakage of water from the bottom plates was observed during the Hydrotest. Seepage of water have been noticed and after that the tank was emptied to verify and surprisingly two leakage spots have been identified adjacent to the shell to bottom plate welds. To find the cause of such failure, a portion of the bottom annular plate (1 meter x 500mm) from the affected portion including the shell to bottom weld has been cut and analyzed. The results of investigation and further possible ways to avoid such incident has been discussed in detail.

Corrosion of Monel Distributor of Caustic Scrubber in MSQ Unit - CR26

Paper by: K K Pandey, Sukla Mistry, S D Chaklader and R Gayen, Indian Oil Corporation Limited, Tinsukia

Motor Spirit Quality Upgradation (MSQU) unit of Digboi Refinery was commissioned in the year 2010. The purpose of the unit is to produce combined isomerate stream with an estimated RONC of 87.0 and reduction of sulfur and nitrogen content. Isomerization reactor effluent of MSQ Unit feeds the stabilizer column. LPG, H2 and HCl are stripped and sent to caustic scrubber column through stabilizer reflux drum. As the off-gas from the stabilizer reflux drum overhead contains HCl, it is caustic treated and water washed before being released. In the caustic solution, the NaOH composition varies from 10% wt to 2% wt as it reacts with HCl to produce NaCl and water. The Caustic Scrubber has been designed in order to ensure full neutralization of the stabilizer off-gas. MONEL alloy 400 (UNS N04400) has been used as material of construction of the distributor of the caustic scrubber. Several failures in the form of pin holes, cracks, thinning and perforation of connected flanges and distributor were observed since commissioning of the unit. Few of the failures were observed within short period of one year after commissioning. This paper presents the corrosion problem faced in the scrubber along with history and details of different failures in the system. The paper briefly covers the remedial measures taken to mitigate the corrosion problem.

Students Session-2

Hall-C

Corrosion Inhibition Behavior of Nonionic Surfactant Based on Amino Acid on Mild Steel in Acid Media - SS21

Paper by: Ruby Aslam, Mohammad Mobin and Saman Zehra, Aligarh Muslim University, Aligarh

Amino acid based surfactant N-alkyl cysteine, designated as (C12Cys) was synthesized and purified. The chemical structure of the synthesized surfactant was confirmed by FT-IR, 1H-NMR and elemental analysis. The inhibition efficiency of the prepared inhibitor on mild steel in 1M HCl was studied using potentiodynamic polarization, and electrochemical impedance spectroscopy. The synthesized compounds act as mixed type inhibitor and adsorb on MS surface in accordance with Langmuir adsorption isotherm. The EIS results revealed a greater charge transfer resistance in (C12Cys) solution compared to that in blank solution. The AFM results exhibited a lowering in the roughness of corroded MS surface in presence of (C12Cys) surfactant. Correlation between the quantum chemical calculations and inhibition efficiency was discussed.

Studies of Anticorrosive Performance of Ginger Extract in Epoxy Coating - SS22

Paper by: Aarti P. More and Shashank T. Mhaske, Institute of Chemical Technology, Mumbai

Extract of ginger has been prepared using dimethyl formamide (DMF) as a solvent. The major component of ginger which is obtained in extract also is gingerol, having –OH functionality as a structural part. The extract in solution form in DMF has been added into epoxy-amine system as well as in epoxy-Melamine formaldehyde (MF) system. With addition of the extract, corrosion resistance has been increases as compared to the plain epoxy system. It is observed as epoxy-MF system gives better anticorrosive properties as compared to the epoxy-amine system. The reasoning for the same is that in epoxy-amine system the gingerol remains as a physical constituent to improve the anticorrosive performance. Whereas, in case of epoxy-MF system, the –OH functionality of gingerol interacts with MF resin and hence while curing the gingerol becomes the chemically intact in resin backbone system. This chemical interactional in epoxy-MF system is additional benefit for it over epoxy-amine system. It affects the coating performance significantly hence epoxy-MF system shows better anticorrosive performance over epoxy-amine system.

Amino Acid Based Imidazolium Zwitterions as Novel and Green Corrosion Inhibitors for Mild Steel: Experimental and DFT Studies - SS23

Paper by: Jiyaul Haque and M.A. Quraishi, Indian Institute of Technology (Banaras Hindu University), Varanasi

Three novel amino acids based corrosion inhibitors namely 2-(3-(carboxymethyl)-1H-imidazol-3-ium-1-yl)acetate (AIZ-1),2-(3-(1-carboxyethyl)-1H-imidazol-3-ium-1-yl)propanoate (AIZ-2) and 2-(3-(1-carboxy-2-phenylethyl)-1H-imidazol-3-ium-1-yl)-3-phenylpropanoate (AIZ-3) were synthesized by condensing glyoxal, formaldehyde and amino acids, and characterized. The corrosion inhibition performance of synthesized inhibitors was studied by electrochemical impedance (EIS) methods. Among the studied inhibitors, AIZ-3 showed the maximum IE of 94.76% at a concentration as low as 0.55 mM (200 ppm). The results of potentiodynamic study reveal that AIZ-1 acts as cathodic inhibitor while AIZ-2 and AIZ-3 act as mixed type inhibitors. The results of EIS studies showed that in the presence of inhibitors, polarization resistance increased and Cdl decreased due adsorption of inhibitors at the metal surface. The result of scanning electron microscope (SEM) supported the formation of inhibitors film on the metal surface. The quantum chemical parameters were used to study the reactivity and adsorption behavior of zwitterions.

Oil Based Biocide Hybrids to Control MIC in Hydrocarbon Pipelines- A New Concept - SS24

Paper by: Jaya Chakraborty, Jaypee institute of information Technology

Microbiologically influenced corrosion (MIC) or bio-corrosion is blamed for causing serious failure of equipment, pipelines etc which leads to accidents in oil and gas industry, water treatment systems and sewer systems. Hydrocarbon pipelines are made up of carbon steel. Metal corrosion is anelectrochemical reaction between the environment and a metal, in which microbes play a very important role. The rates at which various types of metals corrode are dependent upon environmental conditions as well as on the type of metals.

The most well studied bacteria involved in bio-corrosion are the anaerobic sulphate reducing bacteria (SRB) and other bacteria such as methanogens, acid producers as well as the aerobic iron respires and manganese oxidisers. They may be introduced in a system via multiple ways, including secondary oil recovery, hydro test etc. SRB oxidise organic carbons to harvest electrons. The electrons are used for sulphate reduction that causes biogenic hydrogen sulphide release. Hydrogen sulphide gas is not only toxic to living organisms but also a corrosion threat to hydrocarbon pipelines. The biofilm produced by the microorganisms facilitates bio-corrosion by altering the chemistry such as pH, pressure, oxygen levels and nutrients at the interface between the metal and the bulk solution. Therefore, biofilms can be used to alter the conditions at a metal surface, and to accelerate or inhibit corrosion. Sessile cells in biofilms are notoriously far more difficult to treat than planktonic cells because biofilms can employ various defence mechanisms, including diffusional limitation, lowered metabolic rate to reduce intake, formation of persistent cells, up-regulation of resistance genes, efflux pumps, etc. Biofilms usually require 10X or higher antimicrobial concentrations to treat than planktonic cells. Considerable efforts have been directed toward controlling SRB growth and inhibition of corrosion induced by its activity. Although biocide treatments are widely used to decrease bio-fouling and MIC in steel pipes and in closed systems, the results are far from satisfactory. This is because biocides are much less effective against sessile microorganisms with biofilms compared to their effectiveness against planktonic populations. In addition, biocide resistance may be developed and biocidal action reduced by dilution. Now-a-days most of the bio cides available in the market are water based. Water acts as a nutrient to bacteria, which enhances the corrosion. So most of the hydrocarbon pipeline operators are not very keen to use such biocides, but as there is very limited alternatives available in the market, so they are compelled to use water bound biocides to control MIC in their hydrocarbon pipelines. In this presentation, the author is applying a new concept to control SRB sulfide production that can

be done by producing an oil based hybrids of biocide compounds and organic acids / chelating compounds/ nitrates etc. to mitigate bio-corrosion. Because of the various defence mechanisms adopted by biofilms, sessile cells in biofilms require 10 times the dosage of biocide for planktonic cells. The main aim is to limit the quantity of biocides and to increase its efficacy so that it can attack wide range of corrosion causing microbes.

Corrosion Control of Mild Steel Used in Oil and Gas Industries by Triazole Derivatives In 1m HCL - SS25

Paper by: Pratap P Kamble and R S Dubey, R.J.College of Arts, Mumbai-400086

Corrosion behaviour of mild steel and its control by benzotriazole and benzyl benzotriazole in1M HCl has been investigated by weight loss, open circuit potential (OCP) and potentiodynamic polarization techniques. Microstructure of surface was analyzed by scanning electron microscopy (SEM) and energy dispersive analysis by X-ray (EDAX). The polarization curves revealed that both compounds behave as mixed-type of inhibitors. The inhibition efficiency increases with increase in the concentration of inhibitors. The adsorption of inhibitor molecules on mild steel surface obeyed Langmuir adsorption isotherm. The presence of thin film formed due to adsorption may be responsible for decrease in corrosion rate of the mild steel.

Experimental Investigation of Erosion Corrosion Behaviour of Magnesium and Its Alloys - SS26

Paper by: S Jayabharathy, S.Pushparaj, P.Mathiazhagan, Pondicherry Engineering College, Pondicherry

Corrosion is the major challenge faced by Light weighting of automobiles has been an important issue in the transportation industries. Magnesium alloy seems to be the most promising substitute to Aluminium alloy and steel used in automotive and aerospace industries due to its low density of 1.74 g /cm3, high strength to weight ratio and good mechanical properties. In this present work, our aim is to study the erosion corrosion behavior of pure Mg, AZ31 and AZ91 in the 3.5% NaCl environmental condition. Various parameters that affect the corrosion behavior of the material are pH value, exposure time, concentration, temperature and velocity of the fluid. The specimens are exposed to continuous flow of 3.5% NaCl solution under 1 bar pressure in order to analyze their erosion corrosion behavior using the experimental setup. Further SEM analysis was done to study microstructure behavior. Weight loss method was performed .It was found that the corrosion rate increases as time of exposure increases. Comparative study of corrosion rate in static condition and erosion corrosion was done. It was found that the corrosion rate due to erosion corrosion is higher than corrosion rate due to weight loss method.

Materials & Composites (MC-3)

Hall-D

Intergranular Corrosion Behavior Of The Mig-Brazed Welds Of T6 Aa6061-Galvanized Mild Steel For Automotive Applications - MC31

Paper by: S. S. Sravanthi and Swati Ghosh Acharyya, University of Hyderabad, Hyderabad & K.V. Phani Prabhakar and G Padmanabham, International advanced research centre for Powder Metallurgy, Hyderabad

Automotive industry is increasingly adopting aluminium in the vehicle body, increasing the need for research on dissimilar metal welds of steel and aluminium alloys. However, due to the low solid solubility and differences in their thermal and electrochemical properties, microstructural inhomogeneities exist in the Al-steel joints in the fusion zone, raising the questions on durability of such welds. Hence, this paper aims to establish the corrosion behavior of aluminium alloy 6061- steel joints welded by Metal Inert Gas Welding-brazing (MIG-Brazing) as a function of different welding parameters such as weld speed and wire feed rate.

Chromium-graphene Composite Coatings: Microstructure and Electrochemical Properties - MC32

Paper by: Rekha M Y, Punith Kumar and Chandan Srivastava, Indian Institute of Science, Bangalore

The role of graphene in enhancing the corrosion resistant property of chromium-graphene composite coating as compared to pure chromium coating has been demonstrated. Cr and Crgraphene composite coatings were electrodeposited over mild steel substrate using Cr(III) electrolyte bath. A substantial reduction in the number of cracks in the coatings was observed after the addition of formic acid. Further addition of graphene with formic acid increased the coating compactness and produced globular morphology. Electrochemical studies revealed an enhancement in the corrosion resistant property of Cr-graphene composite coating as compared to pure chromium coating.

Corrosion Study of Ti-6Al-4V Alloy in Normal Saline Solution - MC33

Paper by: S T Vagge, Arpit R Patil, College of Engineering, Pune

The role of graphene in enhancing the corrosion resistant property of chromium-graphene composite coating as compared to pure chromium coating has been demonstrated. Cr and Crgraphene composite coatings were electrodeposited over mild steel substrate using Cr(III) electrolyte bath. A substantial reduction in the number of cracks in the coatings was observed after the addition of formic acid. Further addition of graphene with formic acid increased the coating compactness and produced globular morphology. Electrochemical studies revealed an enhancement in the corrosion resistant property of Cr-graphene composite coating as compared to pure chromium coating.

Control of Corrosion and Activation of the Mo Doped Mn Ferrite Based Electrode with Respect to Enhanced Power Generation in a Microbial Fuel Cell - MC34

Paper by: B.R.Sreelekshmy, Chinnu M. Lal, Suma M.S., S.M.A. Shibli, University of Kerala, Thiruvananthapuram

Iron oxide based magnetic nanoparticles have attracted enormous attention due to their biocompatibility and low toxicity and are being widely used in biological applications like controlled drug delivery, cell separation, magnetic resonance imaging and localized hyperthermia therapy of cancer. Among these, manganese ferrites are important members of ferrite family with a variety of application in science and engineering. This study reports the effects of Mo doping on Mn ferrite (Mo-MnF) to improve conductivity, active site accessibility and electrochemical stability for the electrode in Microbial fuel cell (MFC). As a promising material, Mo-MnF [Mn(1-x) Mox Fe2O4 (x = 0.0, 0.3, 0.5, 0.7,1) nanoparticles were prepared by thermal decomposition method and electrode prepared by electroless coating of Ni-P with Mo-MnF. The material structure and crystalline size of the prepared samples were analysed with XRD. The morphological characterization, surface structure, and electrochemical properties were studied using SEM, CSLM, AFM FT-IR, EIS, CV and polarization studies.

The results confirmed the formation of pure and cubic spinel structure, with the average grain size of 20-15 nm. SEM images clearly showed the agglomerated nature of nanoparticles. There was a significant increase in the stability of the developed electrodes, corrosion resistance and electrocatalytic activity towards the oxidation of microbial fermentation. MFC was constructed with these developed electrodes and run for about 3 months under aerobic condition and obtained a cell potential of about 0.78V and current density of about 0.4mA/cm2 on 7th day of operation and remained stable for 3200hrs. This study put forth a novel corrosion resistive composite with future potential for a biocompatible and cost effective electrode that is easy to synthesize.

Control of Corrosion and Tuning of Performance of Titanate Anode Under Bacterial Induced Environment - MC35

Paper by: Rubina Basheer, B.R. Sreelekshmy, Vidya K, Shabnam SN, S.M.A. Shibli, University of Kerala, Thiruvananthapuram

TiO_2 is a good candidate for use as anode in a Microbial Fuel Cell (MFC) owing to its excellent stability, mechanical properties and electrical conductivity. However, its biocidal properties and inability to capture electrons donated by Electrochemically Active Bacteria (EAB) hinders its performance as electrode in MFC. Tuning of phase characteristics of TiO_2 to enhance its biocompatibility and catalytic properties would be an ideal method to enable its use as a high performance anode in an MFC. Here, we report the synthesis of pseudobrookite Fe_2TiO_5 (FTO) by incorporation of Fe_2+ into TiO_2 lattice by thermal decomposition method, followed by electrode development employing electroless coating of FTO-Ni-P over cleaned, polished mild steel. The FTO composite coated mild steel electrodes showed high corrosion resistance, biocompatibility to different types of bacteria and improved photocatalytic and electrocatalytic activity. The performance and corrosion resistance of the developed FTO electrode was evaluated electrochemically using EIS and polarization techniques, microscopically by CSLM and AFM and microbiologically by biofilm formation studies

Results from UV spectroscopic analysis revealed reduction in band gap of FTO to 2 eV, a crucial factor determining biocompatibility of the composite. Uniform, compact, conducting biofilm were formed on the surface within 48 hours of inoculation on the anode. Performance of MFC in fed batch and flow chamber mode for more than 2200 hours showed a current density of 3 mA/m2 . The FTO composite also exhibited good anodic performance when exposed to solar irradiation, indicating the versatility of the electrode in generating electricity from biomass under electrochemical and photochemical conditions. Thus the control of anode corrosion by a suitable surface modification caused enhanced life of the anode under actual MFC condition.

1030 - 1100
Tea/Coffee

1100 - 1600
Hall-A
Jung se Jung

1100 – 1600
Hall-B
IMO

1100 - 1330
Students Session-3
Hall-C

Corrosion Behaviour of Prestressing Steel in Some Practical Scenarios - SS31

Paper by: Dyana Joseline and Radhakrishna G. Pillai, Indian Institute of Technology Madras, Chennai & Jayachandran Karuppanasamy, National Institute of Technology, Trichy

There is a tremendous increase in the construction of prestressed concrete (PC) structures worldwide. The most common cause of premature degradation of these structures is the ingress of chlorides through the concrete cover leading to initiation of corrosion of embedded reinforcement. However, there are no clear documentation of the corrosion initiation behaviour of prestressing steel in concrete exposed to chlorides. In this paper, the results of the preliminary investigations done on the pitting characteristics of prestressing (PS) steel in some practical scenarios are discussed. The first set of experiments in alkaline artificial pore solution were aimed at understanding the

pitting behaviour of passivated/ corroded PS steel in concrete with and without chlorides. Then, long term experiments (of about 5-month duration) were carried out to assess the effect of supplementary cementitious systems and corrosion inhibitors on the time required for initiation of corrosion in prestressed concrete structures, based on Fick's second law. Totally, 22 specimens of different kinds were tested. This paper highlights some of the salient findings of the investigation.

Bioresorbable Nano β-TCP Coatings on Titanium by EPD for Biomedical Applications - SS32

Paper by: S.P.Vinodhini, R. Manonmani, Rajalakshmi Engineering College, Chennai, B. Venkatachalapathy, SRM Eswari Engineering college, Chennai & T.M. Sridhar, University of Madras, Guindy Campus, Chennai

Biodegradable tricalcium phosphate [Ca3(PO4)2, β-TCP (whitlockite)] coatings were developed on titanium by means of electrophoretic deposition (EPD) to improve the corrosion resistance and biocompatibility. As a bioresorbable biomaterial, on implantation it would naturally be absorbed by the body resulting in the formation of new bone tissues. Nano β-TCP powder was synthesized by wet chemical precipitation method and coated on titanium surfaces by EPD. The coatings were carried out at various potentials ranging from 10-50 V and were followed by sintering in vacuum at 800°C for 1h. The optimum coating parameters were obtained at 30 V and 3 minutes by EPD. The crystallinity, vibrational states, and surface morphology were characterized by XRD, FTIR and FESEM respectively. The corrosion resistance of the coatings was further evaluated electrochemically to study the stability of the coatings using open circuit potential-time measurements (OCP), electrochemical impedance (EIS) and anodic polarization studies in Ringer's solution. The electrochemical studies indicate the stable nature of nano β-TCP coatings on the titanium substrate.

Electrochemical Performance of Graphene Oxide Deposits On 316l Stainless Steel - SS33

Paper by: J. Manovasuki, K. Ravichandran, T.M. Sridhar, University of Madras, Chenna & Rani P George and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam

In this study, we present the systematic investigation of a biodegradable amino acid based ionic liquid glutamic acid propyl ester lauryl sulphate (GluC3LS) as potential corrosion inhibitor and the investigation is accomplished by using the techniques including potentiodynamic polarization (PDP) and electrochemical impedance spectroscopy (EIS). The morphological characterization of the samples has been done by using scanning electron microscopy (SEM). The evaluated compound works as effective inhibitor for acid corrosion at substantially lower concentration and its adsorption on the MS surface was found to followed the Langmuir adsorption isotherm. The electrochemical results revealed that the inhibitor act as mixed-type. The order of inhibition efficiency (IE) acquired from experimental results, is successfully verified by theoretical calculations by using density functional theory (DFT).

Electrochemical Testing in Highly Resistive Steel-cementitious Systems - SS34

Paper by: Sripriya Rengaraju and Radhakrishna G. Pillai, Indian Institute of Technology Madras, Chennai

For new major infrastructure projects such as bridges, the desired design life is more than 100 years. However, many reinforced concrete structures experience premature corrosion either due to the presence of chlorides or carbonation in concrete. The use of pozzolanic material in concrete is widely practiced to delay the onset of corrosion and reduce the corrosion rate. Many new materials are being researched for their potential to be a Supplementary Cementitious Material (SCM). Literature reports lower chloride threshold and corrosion rate in SCM blended cements. Depending on the test method adopted, the estimated values of the chloride threshold and corrosion rate can vary, especially in the case of highly resistive concrete systems – but not much reported. This paper deals with the electrochemical testing of steel embedded in highly resistive cement mortar and challenges faced in data interpretation of such systems. Three lollipop type mortar specimens each with a Thermo-Mechanically Treated (TMT) steel bar were cast for OPC, FA30 (70% OPC + 30% Flyash) Limestone Calcined Clay Cement (LC3). The polarisation Resistance (Rp) was monitored using the Linear Polarisation Resistance (LPR) technique. Results reveal that the LPR measurements could not reveal any significant change in the Rp measured, although the specimens exhibited visible corrosion. The bulk resistivity of the mortar cover should be accounted in the analysis of electrochemical data. This paper demonstrates that techniques like Electrochemical Impedance Spectroscopy (EIS) can be used for this. For correct assessment of corrosion of steel embedded in SCM/blended cements, the data interpretation based on the combination of visual observation, microstructure, electrical properties and electrochemical phenomena is needed rather than an electrochemical phenomena alone.

Enhancement of Anticorrosive Performance of Epoxy Coating by Pistachio Shell Ash - SS35

Paper by: Shweta Amrutkar, Aarti More, Aparna Agrawal, Swapnil Kokate, Shashank Mhaske, Institute of Chemical Technology, Mumbai

Epoxy-amine is one of the popular systems for anticorrosive application. Here, anticorrosive performance was further enhanced by incorporation of pistachio shell ash. Calcination process was used for ash synthesis. Calcination was carried out in limited oxygen supply in the muffle furnace and the temperature was maintained at 800ºC for the duration of 2 hours. Surface of synthesized ash was coated with amino-silane to introduce amine group on its surface. The performance of ash in coating system was studied by varying its concentration at 1%, 3% and 5% (w/w) of total binder system. The confirmation of amino group on the surface of ash was done by FTIR and XRD analysis. Ash acts as filler which increases the hardness of the coating. Due to presence of inorganic elements such as Fe_2O_3 (~35%), SiO_2 (~8%), MgO (~3-4%), Al_2O_3 (~1.5%) in the ash increases the anticorrosive performance of the coating. Due to surface treatment the ash becomes a part of coating backbone. Hence inorganic elements and surface treatment these are the two prime factors to enhance the anticorrosive performance.

Corrosion in Refineries (CR-3)

Hall-D

Corrosion Control Strategies for Hydrotreaters and Fluidized Catalytic Cracking Unit - CR31

Paper by: Vivek Srinivasan, Prabin Chaudhary, Dorf Ketal Chemicals (I) Pvt. Ltd, Mumbai & Kelvin Chong Chee An, Desmond Tan Li Yew, Dorf Ketal Chemicals PTE Ltd, Singapore

Hydrotreaters and Fluidized catalytic cracker (FCC) units play a major role in modern refiners for meeting the stringent fuel specification and upgrading the bottom of barrel respectively. Corrosion in a refinery is not only restricted to primary crude units but also prevalent in these secondary units. Instances of severe corrosion have caused unnecessary unit shutdown and at times leakage/fire.

Overhead aqueous phase and under deposit corrosion has always been a concern in secondary units. Factors like feedstock quality, corrosive species and operational severity govern the intensity and location of corrosion in hydrotreaters and FCC. The corrosion is aggravated by ammonia and Hydrogen sulfide which is being abundantly generated in these units.

This paper will discuss on the type of corrosive species, corrosion prone location, mechanism, monitoring practices and corrosion mitigation strategies along with case studies.

An Application and Solutions Perspective on Refinery Corrosion and Integrity Management in India - CR32

Paper by: Vaibhav Mehta, Emerson Automation Solutions, Mumbai and R N Verma, Ex. IOCL Paradip, Jagatsinghpur, Odisha

The focus on corrosion and integrity management in the refining industry today is increasing. Drivers for this are the need for improved operational safety for plant, personnel and the environment, as well as the need for increased plant uptime and extended equipment life. Finally, a good corrosion management program can increase the operating window. For example, it can allow the increased blending of low cost crudes, lower inhibitor consumption and reduce plants' operational costs.

Refineries today have a range of corrosion challenges, such as naphthenic acid corrosion and sulfuric acid corrosion. Efficient monitoring requires a combination of monitoring technologies and solutions. This paper gives an introduction to intrusive and non-intrusive monitoring technologies applicable in a plant, and how they can be combined into an integrated solution. The paper will also examine other refinery monitoring applications and field data examples for different monitoring technologies will be provided.

The paper will also look at the challenges in data management and how the standardization of new communication solutions, such as WirelessHART offer a significant shift in the convenience, quality of data and real time information provided, allowing remedial actions to be taken before damage takes place.

Root Cause Analysis of Rupture in a Cross Country Crude Oil Transportation Pipeline - A Case Study - CR33

Paper by: G.C. Thakur, S P Singh, Sova Bhattacharya, C Kannan, S K Majumdar, Indian Oil Corporation Limited, Faridabad & S S Gupta, Indian Oil Corporation Limited, Noida

An API 5LX65 grade cross country crude pipeline of 24" dia. ruptured along the longitudinal seam after a service life of 18 years. Multiple failures have occurred in this line since last few years. Detailed failure laboratory investigation has been carried out on the cut spool piece from the failed pipe to establish the root cause of failure.

From the investigations, the failure has been attributed to the nucleation of micro cracks from pre-existing lack of fusion defects at pipe longitudinal seam weld and their growth by fatigue arising from the pressure cycles experienced in liquid pipelines. The growth of these cracks up to 80% of pipe wall thickness and the simultaneous interaction of similar such adjacent fatigue cracks has led to the axial defect dimensions exceeding the critical dimensions needed for longitudinal rupture.

Failure Investigation of Super Heater Tubes of a Boiler in Oil Refinery - CR34

Paper by: Aditya Divvela, S S Jha, Dr C. Kannan & Dr S K Mazumdar, Indian Oil Corporation limited, Faridabad

Ruptures were observed in the ASTM SA213 T22 & SS 347H super heater tubes of a boiler in an oil refinery after a service period of two years. Cut sample tubes from the failed regions were investigated for analysing the root cause of failure.

From the extensive Laboratory investigations carried out, tube internal deposits rich in 'Na' associated with the microstructural degradation of tube material was seen. The boiler feed water carryover to the steam side is seen to have led to the precipitation of 'Na' salts on the internal surfaces. The high heat flux regions of super heater coil tubes having localized Na deposits experienced reduced heat transfer and thereby overheating of tube causing rupture and leaks. The findings have been corroborated with the microstructural evidences. The detailed laboratory investigations carried out and the root cause analysis are enumerated in this paper

Case Study on Detection and Mitigation of Wet H2S Cracking in a Refinery - CR35

Paper by: Sukant Dev, K K Chattopadhyay, Kaushik Boral, A T Mandal, Indian Oil Corporation, Mathura Refinery

Wet H_2S cracking covers a range of damage mechanisms that can occur due to the effects of aqueous hydrogen charging in wet H_2S refinery process environments. Types of damage that can occur as a result of aqueous hydrogen charging include sulphide stress cracking (SSC), hydrogen induced cracking (HIC) and stress oriented hydrogen induced cracking (SOHIC). Due to the orientation of these cracks, the timely detection of these cracking phenomena remains a challenge to the NDT personnel as most of the conventional NDTs like radiography or ultrasonic flaw detection often fails to detect these types of damages.

Wet H_2S cracking phenomenon was experienced in a reboiler circuit in Once through Hydro Cracking Unit (OHCU) of a refinery due to accidental water carry-over. To detect the extent of damage, Phased Array Ultrasonic Testing (PAUT) was employed. The phased array

system, in contrast to conventional ultrasonic system, uses a transducer assembly of multiple elements which can be pulsed separately in such a way that the individual wave fronts generated by each element in the array combine with each other to add or cancel energy in predictable ways that effectively steer and shape the sound beam. The Phased Array system could detect the cracks in welds and effective repairs could be carried out, thereby increasing the reliability of the equipments. The paper focuses on the consideration of operational upsets during the basic engineering design stage to avoid catastrophic failures in future. The paper also describes the effective use of Phased Array Ultrasonic Testing (PAUT) in detecting the wet H_2S cracking.

1330 - 1430
Lunch

1430 - 1600
Microbial Corrosion & Inhibitors (MCI-4)
Hall-C

B3LYP-D3/6-311G(d,p) Level Of Theory To Reveal Corrosion Inhibitive Properties Of Five Cationic Gemini Surfactant - MCI41

Paper by: Sheerin Masroor, M. Mobin, M.J.Alam, Shabbir Ahmad, Aligarh Muslim University, Aligarh (U.P) 202002-India

Paper presents a comparative study of five synthesized cationic Gemini surfactants belonging to two series of tetradecyl (14-n-14) and hexadecyl (16-n-16) with methyl spacers, such as butane diyl-1,4-bis(dimethyl tetradecyl ammonium bromide), hexane diyl-1,6-bis(dimethyl tetradecyl ammonium bromide), butane diyl-1,4-bis(dimethyl hexadecyl ammonium bromide), pentane diyl-1,5-bis(dimethyl hexadecyl ammonium bromide), hexane diyl-1,6-bis(dimethyl hexadecyl ammonium bromide) as corrosion obstacle for acidic corrosion of mild steel via theoretical chemical calculations. The Quantum chemical calculations have been carried out at B3LYP-D3/6-311G(d,p) level of theory to obtain some structure based parameters that are relevant to corrosion inhibition efficiency as well as to supplement the experimental data for the present compounds. An empirical dispersion correction to hybrid functional (B3LYP-D3) has been incorporated in the present calculations due to presence of non-covalent interactions, Br……H, in the present compounds.

Synergistic Effect of l-proline Mixed with Sodium Benzoate as Sustainable Corrosion Inhibitor for Mild Steel in 1M HCl: Experimental and Theoretical Studies - MCI42

Paper by: Mosarrat Parveen and Mohammad Mobin, Aligarh Muslim University, Aligarh

Inhibition effect of L-proline (LPr) and LPr mixed with sodium benzoate (Lpr + NaBenz) on mild steel (MS) corrosion in 1M HCl at temperature 30°C was studied employing gravimetric method, electrochemical impedance spectroscopy (EIS), potentiodynamic polarization measurements and scanning electron microscopy (SEM). The concentration of Lpr was varied between 100-600 ppm. LPr inhibited the corrosion rate of MS at a considerable extent. Inhibition efficiency of LPr was synergistically enhanced on adding NaBenz at all concentrations. The change in impedance parameters indicated that LPr and Lpr+NaBenz molecules acted by adsorption at the MS/solution interface. Typically different surface morphologies for uninhibited and inhibited MS specimens verified the formation of adsorbed protective covering the MS surface. LPr alone and in combination with NaBenz acted as mixed type inhibitor and adsorbed on the MS surface in accordance with the Langmuir adsorption isotherm.

Unravelling the Corrosion Inhibition Mechanism of Carboxymethyl Cellulose on Iron Surface Using DFT - MCI43

Paper by: Dharmendr Kumar, Vinay Jain and Beena Rai, TCS ResearchTM, Pune

The use of corrosion inhibitors (CI's) is one of the most effective and economical means to combat corrosion. Owing to increased environmental concerns, there is a need for environmentally benign and green CI's. In this regard, although there have been several experimental studies reporting polysaccharides as promising green CI's for steels in various acidic media, the underlying mechanisms are not well understood. Molecular modeling methods based on the density fuctional theory (DFT) have been mostly limited to the computation of quantum chemical descriptors like the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) for the isolated molecule. We have employed DFT to model the adsorption of carboxymethyl cellulose (CMC) – an experimentally known polysaccharide CI for steels, with the Fe (001) surface. From the computed interaction energies, optimized structures and electron density difference plots, it can be inferred that the interactions are governed by chemical interactions between O-atoms of the OH-functional groups in CMC (rather than the hetero O-atoms as has been hypothesized earlier for another polysaccharide, guar gum) and the surface Fe-atoms. Thus, our computations provide important insights into the nature of CMC-Fe surface interactions which are difficult to gain experimentally. This approach, when used in conjunction with experiments, can help in the design and development of novel molecules for use as green CI's for metal surfaces.

Role of Tetramethylammonium Iodide on Control of Microbiologically Influenced Corrosion of Mild Steel Used in Oil And Natural GA Industries - MCI44

Paper by: Jitendra Girase and R.S.Dubey, R.J. College of Arts, University of Mumbai, Mumbai

Corrosion behaviour of mild steel was investigated by exposing mild steel coupons in Barr's medium inoculated with Desulfovibrio desulfuricans, sulphate reducing bacteria (SRB). Considerable loss in weight and deterioration of the microstructure of mild steel surface was observed during the investigations. Coupons were further exposed to culture media containing different concentrations of tetramethylammonium Iodide. The corrosion behavior of mild steel was measured by weight loss, corrosion potential and potentiodynamic polarization techniques. The surface analysis was performed by scanning electron microscopy (SEM). The corrosion current densities of both anodic and cathodic coefficients decreased in the presence of inhibitor, hence the inhibitor is of mixed type. The inhibitor exhibited its best performance at 500 ppm concentration. The inhibitor obeyed the Langmuir adsorption isotherm phenomenon since it is obtained as a straight line graph.

Microbiologically Induced Corrosion of Austenitic Stainless Steel Equipment in Coastal Environment - MCI45

Paper by: Subir Kumar Mitra and Ashish kumar Singh, Indian Oil Corporation Ltd, Paradip

Stainless steel materials are used in countless applications in Oil Refinery services due to their high corrosion and high temperature resistance properties. Material is extremely good in general, but they are susceptible to various damage mechanisms such as Stress corrosion cracking, MIC, pitting corrosion etc. Proper choice of stainless steel grade as per service conditions is also extremely important to avoid in-service failures. This localized dissolution of an oxide-covered metal in specific aggressive environments is one of the most common and catastrophic causes of failure of SS metallic pressure containments. The pitting process has been described as random, sporadic and stochastic. Prediction of the time and location of events remains extremely difficult.

The pitting corrosion in Stainless Steel equipment & piping is a big area of concern for the industries operating in Coastal environment. The presence of water/ moisture layer contaminated with sea salt aerosols, which are the main atmospheric pollutants in maritime coastal regions, makes very favorable condition for the growth of microbiologically induced corrosion.

This paper discusses the microbiologically induced corrosion that lead to severe pitting & perforation of the austenitic stainless steel equipment and piping which were kept in open environment during construction stage of plant. Paper also focuses on the preventive/ monitoring measures to avoid MIC of Stainless Steel equipment at construction site.

Effects of Reservoir Souring from Water Flooding and in an On-shore Oil Field - MCI46

Paper by: Saumya Mittal, Panneer Selvam V, Cairn Oil and Gas, Vedanta Limited, Gurgaon

Historical trends of bio-generated Hydrogen Sulfide (H2S) levels in an onshore oilfield have been determined based on field measurements to provide a basis for forecasting future H2S production using a mechanistic reservoir souring model. The reservoir is currently under produced water reinjection along with make-up water taken from an underground water reservoir. Such H2S production forecast is to plan mitigation measures for both short and long terms.

Sulfate is the limiting reactant in the H2S bio-generation process within the field. The reservoir souring model has shown that there is almost complete conversion of sulfate to H2S by the sulfate-reducing bacteria within the reservoir. The makeup water has high sulfate content and is the key source of sulfate for the bacteria. While the sulfate level produced water (which is re-injected) has been declining, the use of make-up water is increasing the concentration of sulfate injection into the field.

As the surface facilities have not been designed to handle H2S production, various mitigation measures have been put in place. A strict biocide program is being followed in the field along with down-hole H2S scavenger dosing. In order to minimize risks and mange within the available infrastructure, priority for treatment of wells was decided based on H2S production and weld hardness. H2S detection systems and H2S analyzers have been installed across the field.

Since limiting sulfate in injection water is the only certain procedure for mitigating H2S bio-generation and production in this field, sulfate removal in make-up water will dramatically decrease H2S production from the field within two years. The same is planned to be implemented in the field shortly.

1600 – 1630
Main Hall
Valedictory Function

1630 - 1730
High Tea

Poster Presentations

Visit the Exhibit Hall throughout to conference to view the following poster presentations.

Corrosion Inhibition of Mild Steel Used in Oil And Natural Gas Industries Using 5-Phenyl Tetrazole - PP1

Poster by: Pratap P.Kamble, Dr. R.S.Dubey, R.J.College, Mumbai

The inhibitive action of 5-phenyltetrazole on corrosion of mild steel in 1M HCl has been studied by weight loss and electrochemical techniques. The inhibition efficiency increases with increase in the concentration of inhibitor. Electrochemical studies support that the compound is efficient inhibitor for mild steel corrosion. The adsorption of compound obeys Langmuir's adsorption isotherm. Polarization study indicates that the inhibitor acts as mixed type. The protective film formed on surface was confirmed by SEM & EDX. Results obtained from weight loss technique are in good agreement with electrochemical and surface analytical results.

Probing Sulphur Speciation in Sea Water Exposed Concretes Using Raman Spectroscopy - PP2

Poster by: M. Premila, R. Rajaraman, R.P. George, U. Kamachi Mudali and G. Amarendra, Indira Gandhi Centre for Atomic Research, Kalpakkam and U. Sudha, Vinita Vishwakarma, D. Ramachandran, Sathyabama University, Chennai

Cooling water structures of nuclear reactors are continuously being exposed to harsh marine environment leading to corrosion induced damage. Flyash reinforced concretes (FA) are known to possess better resistance to corrosion as compared to normal concrete. Further improvement in corrosion resistance is brought about by selective nano phase modification of FA using nano titania (FAT), nano calcium carbonate (FAC) and a mixture of both (FATC). The present study is aimed at following the microstructural changes in FA and nanophase modified FA associated with prolonged

sea water exposure (SWE) using Raman and Infrared (IR) spectroscopy. IR on 365 days SWE concrete samples revealed a structural modification of both FAC and FATC, while FAT and FA were relatively unaffected. FAC, FAT and FATC revealed the presence of elemental sulphur on their surface, marking the onset of bio deterioration in concrete. Such clusters of sulphur are absent in FA indicating that all the sulphur formed has been oxidised by sulphur oxidizing bacteria to sulphuric acid, leading to extensive biodegradation. Thus, nanophase modification has improved biocorrosion

resistance of FA. Among the studied concretes, FATC is observed to exhibit superior bio corrosion resistance, although it also undergoes a structural modification on SWE.

Evaluation of Biodegradable Glutamic Acid Propyl Ester Lauryl Sulphate as Corrosion Inhibitor for Mild Steel in Acidic Solution - PP3

Poster by: Saman Zehra, Mohammad Mobin and Ruby Aslam, Aligarh Muslim University, Aligarh, U.P

In this study, we present the systematic investigation of a biodegradable amino acid based ionic liquid glutamic acid propyl ester lauryl sulphate (GluC3LS) as potential corrosion inhibitor and the investigation is accomplished by using the techniques including potentiodynamic polarization (PDP) and electrochemical impedance spectroscopy (EIS). The morphological characterization of the samples has been done by using scanning electron microscopy (SEM). The evaluated compound works as effective inhibitor for acid corrosion at substantially lower concentration and its adsorption on the MS surface was found to followed the Langmuir adsorption isotherm. The electrochemical results revealed that the inhibitor act as mixed-type. The order of inhibition efficiency (IE) acquired from experimental results, is successfully verified by theoretical calculations by using density functional theory (DFT).

Boswellia Serrata Gum: An Eco-Friendly Corrosion Inhibitor for Mild Steel in 1 M HCl Medium - PP4

Poster by: Megha Basik, Mohammad Mobin and Jeenat Aslam, Aligarh Muslim University, Aligarh

In present work, the corrosion behavior of mild steel induced by Boswellia Serrata Gum (BSG) was studied using different techniques such as weight loss, potentiodynamic polarization (PDP), electrochemical impedance spectroscopy (EIS) and atomic force microscopy (AFM) in 1 M HCl solution at different concentrations and temperatures (30-60° C). The result shows that BSG is good corrosion inhibitor for mild steel in 1 M HCl solution. The inhibition efficiency (%η) of mild steel in 1 M HCl increase with an increase in inhibitor concentrations. The highest percentage of inhibition efficiency was found to be 91.8% at 500 ppm concentration at the temperature 30°C. The adsorption of BSG on mild steel surface obeys Langmuir adsorption isotherm. Also, the electrochemical study exhibits that BSG acts as a mixed-type inhibitor in 1 M HCl medium. The AFM micrographs confirmed that inhibitor reduce the surface roughness in presence of 1 M HCl.

Short Term Test Methods to Determine Chloride Threshold Using Macrocell and Lollipop Type Specimens - PP5

Poster by: Deepak K. Kamde, Abdul Basit Peerzada, Radhakrishna G. Pillai, Indian Institute of Technology Madras, Chennai

Chloride induced corrosion is one of the serious mechanism of deterioration of reinforced concrete structures. Chloride threshold (Clth) is one of the important parameters to estimate the corrosion initiation time. Chloride ions from external/surrounding atmosphere travel into the concrete (mostly through diffusion process) and reach the rebar level. When sufficient amount of Clth reaches the rebar, chloride ions disrupts the protective passive layer on the steel surface. Though, Clth is an important parameter to be consider to estimate the service life; Practitioners/engineers generally do not evaluate the Clth before planning/construction. In other words, the performance based approach for durability design of reinforced concrete structure is not adopted. This conservative approach can be because of following reasons, i) the standard methods (say, ASTM G 109) requires a long time for determination of Clth of steel cementitious system,

ii) Chloride threshold cannot be generalized for steels; It also depends on many factors like steel type, concrete mix, water to binder ratio, and steel - concrete interface properties and iii) conservative approach of contractors and practicing engineers. This paper introduces the short term chloride threshold test methods for uncoated and cement polymer composite (CPC) coated rebar. For this, macrocell (similar to ASTM G 109) and lollipop type specimens (for linear polarization resistance technique) were cast for following set of steel specimens, i) 'as – received' steel, ii) CPC coating on 'as – received' steel, iii) rust free/sand - blasted steel surface, iv) CPC coating on sand – blasted steel. Chloride concentration near to the exposed steel surface was determined using guidelines given in SHRP – 330. Using both the test methods, chloride threshold determined for each steel type was found to be approximately same. The test duration to determine Clth was found approximately 30 - 90 days in case of Lollipop type specimens and 50-175 day in case of macrocell specimen.

Corrosion Behaviour of Nanophase Modified Fly Ash Concrete Reinforced with TMT Rebar for Seawater Applications - PP6

Poster by: U. Sudha, Vinita Vishwakarma, D.Ramachandran, Sathyabama University, Chennai-600119 & Manu Harilal, B. Anandkumar, R. P. George and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam

The corrosion of reinforced steel embedded in concrete structures is a universal threat to its integrity, finally leading to its failure. The steel reinforcement in concrete structures can be protected against corrosion using modification techniques. With the aim of increasing the durability and corrosion resistance property of concrete structures, supplementary cementitious materials and nanoparticles are being incorporated into the concrete. In the present work, four different concrete mixes were designed, fabricated and named as FA (fly ash concrete), FAT (fly ash with 2 wt% nano-titania), FAC (fly ash with 2 wt% nano-calcium carbonate) and FATC (fly ash with 1 wt% nano-titania and 1 wt% nano-calcium carbonate). All the specimens were reinforced with SAIL TMT steel rebar and tested under exposure to seawater for a period of 18 weeks. The corrosion parameters of the concrete with rebar was continuously monitored with techniques like Open Circuit Potential (OCP) monitoring and Linear Polarization Resistance (LPR) measurement. Test (RCPT). The detailed surface and phase analysis of the concrete specimens were carried out utilizing Scanning Electron Microscopy (SEM). Results confirmed that the incorporation of nanoparticles have greatly improved the corrosion resistance of the reinforced concrete specimens in comparison with fly ash concrete. The extent of degradation was observed to be the least in concrete specimen incorporated with nano-TiO2 and nano-CaCO3 (1:1 wt%) indicating its enhanced deterioration resistance

High Performance Concrete by Nanophase Modification and Sodium Nitrite Inhibition - PP7

Poster by: Manu Harilal, B. Anandkumar, R.P. George and U. Kamachi Mudali, Indira Gandhi Centre for Atomic Research, Kalpakkam & U. Sudha, Sathyabama University, Chennai

The development of high performance concrete (HPC) through the additament of mineral and chemical admixtures to concrete opened up the opportunities of engineering a concrete commix with enhanced properties and meeting the intended performance requisites. Flyash, the waste product in coal based power plants is a commonly used supplementary cementitious material in concrete in order to reduce the usage of cement and to enhance its durability. Though studies have shown that flyash has superior properties, there are some early-age performance issues of flyash concrete like low early-age strength, delayed setting time, high calcium leaching, more stringent curing conditions etc. Hence, this study attempts to overcome these drawbacks of flyash concrete by addition of nanoparticles and inhibitor. Four different mixes of concrete were prepared and designated as Control concrete (CC), Flyash concrete (CF), Flyash concrete with addition of 1% TiO2 and 1% CaCO3 nanoparticles (CFN) and Flyash concrete with addition of 1% TiO2, 1% CaCO3 nanoparticles and admixed with 2% sodium nitrite based corrosion inhibitor (CFNI). The samples were cured for 28 days in fresh water and the various mechanical properties such as compressive strength, split tensile strength and flexural strength were evaluated. Further, the durability properties like water sorptivity, penetration of chloride ions, water absorption capacity etc. were figured out. Scanning Electron Microscopy (SEM) was used to visualize the surface topography of the specimens. The results revealed that incorporation of nanoparticles together with inhibitor facilitated to overcome the shortfalls of flyash concrete and improved its early-age properties.

Chloride Monitoring Sensors for Civil Infrastructures - PP8

Poster by: Seung-Jun Kwon, Han Seung Lee, Hannam University, Korea, Velu Saraswathy, CSIR-Central Electrochemical Research Institute, Karaikudi and Subbiah Karthick Alagappa Government Arts College, Karaikudi

In the present investigation, a solid-state alkaline stable polymer coated Ag/AgCl sensor was fabricated for chloride monitoring in concrete environment. Ag/AgCl sensor was fabricated by sintering the AgCl powder with Ag wire. To validate the performance of the prepared polymer coated Ag/AgCl sensor in saturated KCl solution were evaluated by potentiodynamic polarization studies and open circuit potential (OCP) measurements. The alkaline stability of Ag/AgCl and polymer coated Ag/AgCl sensor in synthetic concrete pore solution (SCPS) was characterized by OCP measurements. The polymer coated chloride sensor was calibrated in saturated KCl, distilled water and synthetic concrete pore solution (SCPS) with various concentrations of chloride ions. The results revealed that the potential value remains stable in concrete environment.

Effect of Centella Asiatica Concentration as Green Inhibitors for 3% Chrome Steel in Produced Water Environment - PP9

Poster by: Jako Sibuea, Anggita Amilia, Sukma Azzah Kharisma, Yudha Pratesa, Patardo Lamindo, Universitas Indonesia, Depok, Indonesia

Corrosion is a common problem encountered in the oil and gas industry. It can lead to failure or degradation of metallic equipments used, such as pipe and tank, which are used to transmit oil, fluid and gas in exploration process. The usage of organic corrosion inhibitor is considered as an efficient and economical method to decrease corrosion rate and increases service life. The aim of this study is to investigate the effect of *Centella asiatica* leaves extract as an organic corrosion inhibitor for 3% Chrome steel in produce water

environment. The concentrations of inhibitor extract which were used in this study are 0 ppm, 100 ppm, 250 ppm, 500 ppm, and 1000 ppm. The corrosion resistance and corrosion inhibition ability were tested by electrochemical polarization measurements, Electrochemical Impedance Spectroscopy (EIS), and immersion tests in produced water solution. The compounds that inhibit corrosion in this inhibitor are identified using FTIR test. The characteristic of corrosion scales are investigated by Scanning Electron Microscopy (SEM). The result shows that *Centella asiatica* leaves extract can be used to inhibit corrosion for 3% Cr steel in produced water environment.

xCase Studies on Problem Faced In Cp System Due To Grounding Interconnections - PP10

Poster by: Navneet Kumar Sharma, Gail Gas Limited, Agra

Normally in an electrical circuit, the grounding circuit has an important role for maintaining safety concerns due to unintentional discharge of charge. All the equipments, structures and switchgear are needed to be grounded at regular distances to achieve the safety criteria and enabling functionality of Electrical circuit protection to address the safety concerns in abnormal conditions. However in Cathodic protection the grounding system is used for the conduction of current and help is achieving the corrosion protection criteria by controlling the flow of current in normal case. At most of the installations where CP system is in place will likely to have station grounding system for the Electrical system which must be in complete isolation to maintain intended charge flow.

In practical situation, the perfect isolation between the grounding system of the installation and CP system may not be possible and it may lead to serious issues which might affect the performance of the CP system. This paper includes two case studies which elaborate the effect due to interaction of station grounding system with the positive (Anodic) and negative (Cathodic) circuit of the CP system by using the designed electrical circuit of the CPPSM and modelling of the field circuit to get the better understanding of issues. Although these interactions happen in almost every CP site but their effects are just incremental whereas both of these cases caused serious issues affecting the reliable performance of the CP system and could be addressed by following a systematic approach in getting to the root cause of the problem. The endeavour is to sensitize about such issues and developing an approach to identify such problems during the routine preventive maintenance activities so that performance of the system can be ensured to achieve the desired result.