Meeting Materials Engineering Challenges in a Fast-Changing World

Materials Technology Institute

Today's engineers face many challenges that their predecessors in the chemical processing and oil & gas industries could never imagine. From shrinking budgets and staffs to growing concerns about environmental and safety regulations, to the management of aging plants, more is demanded of those with fewer resources at their disposal than ever before.

The modern-day process industries engineer must have reliable answers at his or her fingertips. Even the slightest misstep can cost a company millions of dollars in clean-up, repair or replacement costs, unplanned downtime, and in extreme cases, lives. With companies demanding the most from production equipment to keep up with market growth, engineering departments are forced to find ways to keep pace and ensure that their operations are efficient and safe.

Shrinking Range of Resources to Manage Growing Number of Challenges

New and seasoned engineers alike face difficult institutional issues daily as they take on increasing responsibility for their operations' success. They are often asked to handle expanding workloads as they manage multiple projects at different plant locations. At the same time, they are required to understand changing regulations and new developments in engineering, from new materials and design options to understanding and applying lessons from industry failures. Some of the challenges facing materials, reliability, chemical, and other Processing Industry engineers include:

- No Materials Engineering Expertise on Staff
- Need for immediate, reliable answers
- Loss of institutional knowledge due to retirement and other attrition
- Dearth of time and training resources for new engineers
- Rapidly changing regulations
- Aging plant challenges
- Lack of funding for critical research
- No time or human resources to update internal standards
- Need for an expert network of peers
- Outdated or no reliable reports or books to reference
- Difficulty in benchmarking (how do other companies address this issue?)

Unreliable Answers

When failure strikes and a critical pump or heat exchanger goes down at 3AM, who can engineering professionals turn to for answers that get equipment back up and running? Google? In-house experts? Even some of the world's best materials engineers don't have all of the answers. Not everyone has access to metallurgists, ceramists, and polymers experts — even during normal business hours. Try using a social network to locate and connect with a FRP or RBI expert, who has time to answer your questions within the next month let alone in real-time.

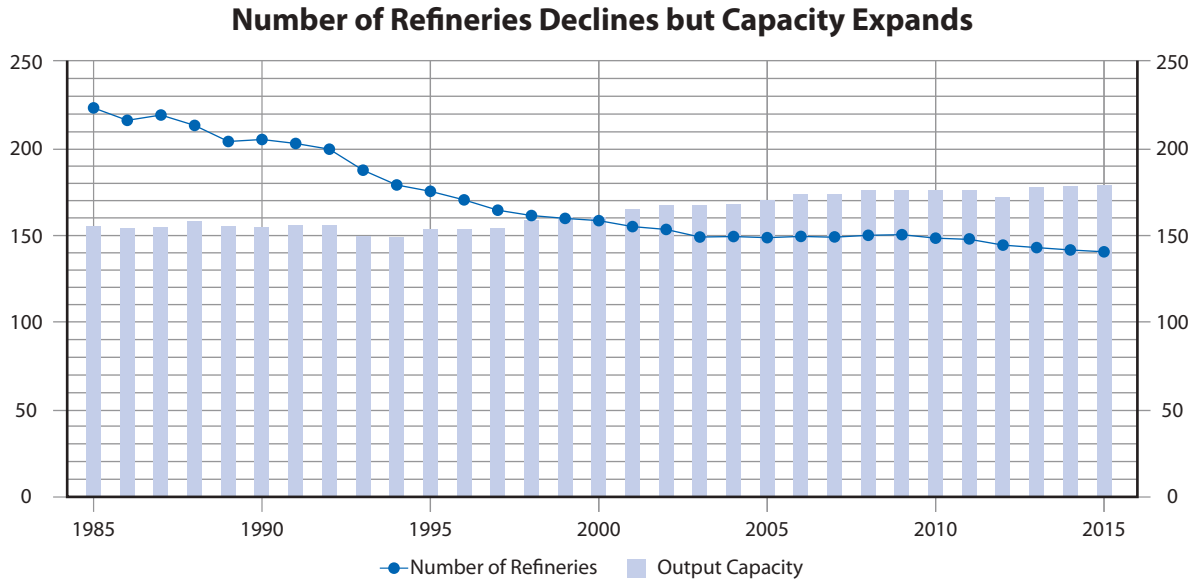
One potential solution is to find suppliers, consultants, and other resources at trade shows and conferences, then give them a try. It's possible to find help that provides dependable, long-term solutions — a "partner" you can trust. Of course, the challenge is that no single supplier or service provider has all of the answers. And they may not always be there for you. For example, a metals supplier might opt to change its business model at some point to focus on other industries. Or a talented fabricator might simply go out of business. Some of the best have failed to last as long as the plants that they helped design.

Aging Plant Challenges

Many chemical processing, oil & gas, and other industrial plants were commissioned in the 1950s, 60s, and 70s and designed to operate for 25-30 years. Although some have since shut down facilities or mothballed older equipment, many are still operating more than 50 years later. Materials, Reliability, Process and other engineers in those plants are tasked with ensuring that they continue to operate efficiently and safely.

Sometimes, equipment needs to be repaired, and the original supplier is no longer in business. Other times, lost documentation from the original manufacturer leaves engineering in the dark. Without these details, engineers are forced to find answers that they can trust. Many engineers are forced to turn to unproven options like the World Wide Web for answers. The problem is that an Internet search may or may not yield trustworthy advice or dependable solutions.

There are many other challenges associated with managing aging plants, including changing environmental and safety regulations. As cities expand, the buffer zones originally planned for processing plants shrink. This creates significant new challenges and potential risks that keep engineers and company management up at night. Failures, such as explosions, fires and chemical spills, are widely publicized by the media, and this puts further pressure on companies to carefully monitor and manage their aging equipment and infrastructures.



In 1982 there were 301 operable refineries processing about 17.9 million barrels of oil per day, according to Dan Eberhart, CEO of Canary. Today, there are less than 150 refineries processing 17.4 million barrels – less than in 1983, but more than any year since then. Materials, Reliability, Process and other engineers in these refineries are tasked with ensuring these plants continue to operate efficiently and safely.

Changing Workforce Issues

The engineers facing aging plant problems are often charged with tackling many other issues in their operations – namely managing an aging workforce. While navigating all the issues facing today's workforce, the generation that built and operated these plants for so many years is leaving the workforce. Although a few continue to consult, many are not available to answer their successors' most basic questions, leaving a dangerous vacuum at many plants. As these experts depart, organizations lose valuable institutional knowledge, and often don't know where to turn to when inevitable questions about materials selection, corrosion, and inspection arise.

Today's 'materials engineer' may or may not even have formal materials training. Those who are college educated in materials engineering often enter a chemical plant with little hands-on experience and practical knowledge. Although some start with useful skills picked up during internships, this is no substitute for years spent in a plant environment. The fortunate few are groomed for years under talented senior-level materials, reliability and process engineering experts, who have built their expertise through practice, failures, successes and interaction with their peers.

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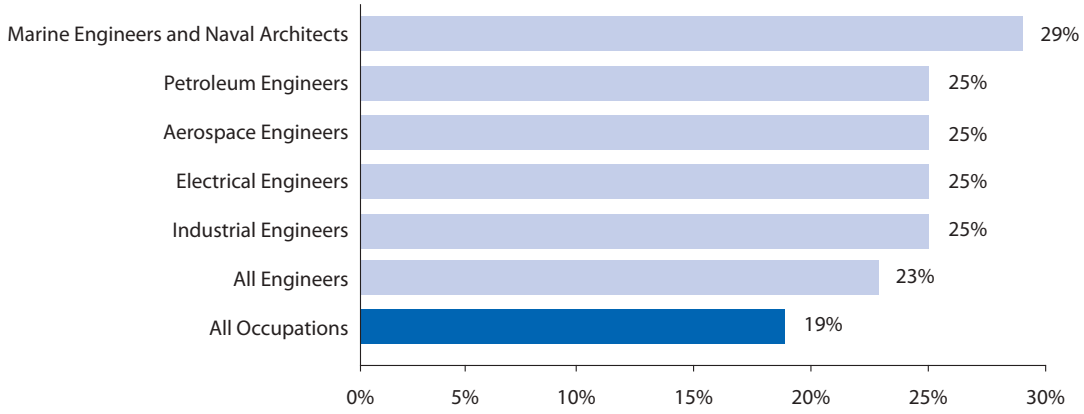
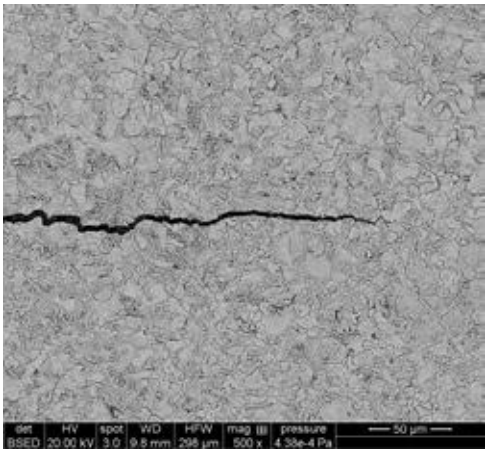
Unexpected changes in business conditions, workforce issues, and early retirements change the game for engineering departments. They are suddenly forced to work with fewer employees, and some of those critical team members might be fresh out of engineering school. Senior engineers who are still working in some of these plants, often have little or no time to train junior-level staff. These issues put the future operations at these facilities at risk from the standpoint of safety and reliability.

Share of Engineers in the Workforce 55 and Above



Source: EMSI Class of Worker 2014.2 (Employees)

Lack of Applicable, Practical Research



In a perfect world, every company would have limitless time and money to conduct materials, corrosion and other research to ensure that their plants operated efficiently, reliably, and profitably. The reality is that those programs are often the first cut from tightening budgets. Even though they might help make or save a company money, funding significant studies is often hard for a single company to justify. Joining a JIP or doing research through a university may result in a loss of control, schedule delays and insufficient output from the project.

Even if funding were available, many CPI, Oil & Gas, and other operations don't have the in-house expertise to conduct fast-track research that provides the kind of answers that they need to impact operations and show a return on investment. Universities, National Labs, and many so-called technical organizations aren't configured, nor are they resourced, to manage studies focused on the most critical industry challenges. Companies have few places to turn to affordably complete an important project to meet their immediate needs.

A Dependable Resource Developed by Engineers for Engineers

These are not all brand-new challenges. Engineers faced some of these same problems 40 years ago. To address many of them, five chemical companies joined together in 1977 to form the Materials Technology Institute. Today, MTI has grown to more than 60 member companies in 14 countries, creating a network of experts with more than 1,000 materials engineers worldwide. Our members represent 32% of the 2016 ICIS Top 100 Chemical Companies.

The chemical, oil & gas, pharmaceutical, and pulp & paper companies that have been members over the last four decades built the organization to meet their needs. They formed an association that they control and tailored it so that changes could be made quickly to address industry needs.

The original members wanted an organization that could share the cost and their expertise on non-proprietary research projects. The goal has always been to design practical studies that they are able to apply in their own plants. The group formed TAC Meetings to discuss these projects and new challenges in a dynamic face-to-face environment.

MTI's Investment in Research

MTI is addressing the challenges of industry research. As engineering and research personnel are tested to do more with less, the value of sharing essential, non-proprietary information increases. Many member companies continue to fund their own private, proprietary projects, but take advantage of MTI's deep pool of knowledge to help meet the challenges faced by the industry as a whole.

Through its 40 years, MTI has funded over $7 million worth of research, and since 2006 has funded more than $4.8 million worth of studies, with more projects in the pipeline. The average funding amount approved from 2006 through 2016 is $426,000.

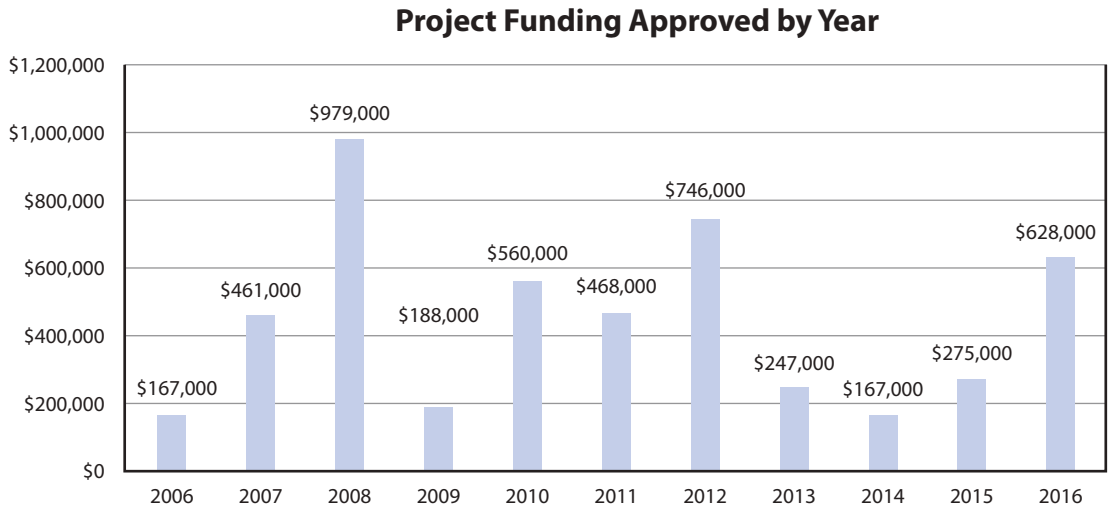
MTI's list of completed projects is extensive, and member company representatives have online access to a searchable database with all of the results. This includes everything from project reports to reference books and how-to guidelines.

A selection of a few of the many completed projects detailed in MTI's project reports, presentations and books includes:

- Metal Dusting
- Chemical Industry Corrosion Management
- How to Implement Risk-Based Inspection
- Statistical Analysis of NDE Data
- Reliability Manual
- Users Guide for Evaluating Polymer Systems
- Guide for Repair and Modification of FRP Equipment
- Atlas of Microstructures
- Incident Assessment
- Procedure for Evaluating Failure
- Repair and Damage Assessment of Glass-Lined Equipment
- Improving and Evergreening RBI
- Global FRP Standards
- Plastic Repair Welding
- Demolition of Obsolete Equipment

A partial list of MTI's current, active projects includes:

- Design for Inspection
- Reliability Manual for Fixed Equipment and Piping
- Corrosion Testing of Extruder Alloys
- Advanced SS Seminar on Fabrication and Welding
- CUI Mitigation through TSA at Pipe Mills
- State of the Art Review of Polymers NDE
- RFID Sensors to Monitor FRP Integrity
- Best Practices for Reactive Metals
- Guidance for Failure Mechanisms
- HTHA (High Temperature Hydrogen Attack) Lab Samples



In addition to these extensive lists, MTI Product Development Committees (PDC) are currently evaluating dozens of potential projects. Here are a few from the PDC files:

- Mechanical Integrity of Plant Civil Structures
- Carbonate Stress Cracking in Refinery Service
- Duplex Stainless Steels at Elevated Temperatures
- Best Practices for Furnace Tubes
- Guidelines for Industrial Coatings Maintenance
- Big Data Analysis of Inspection Data
- Drone Best Practices.

24/7 Q&A Forum

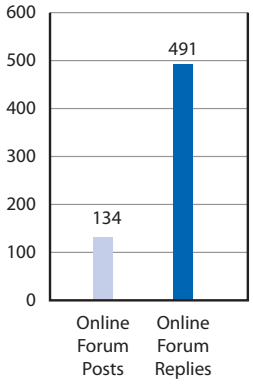
Members around the world have access to MTI's online Q&A forum. Engineers can post critical technical questions on a variety of topics and fellow members and leading industry experts provide feedback. The MTI forum is responsible for saving members time and money. Questions are broadcast by email to members who wish to participate. The forum acts as a virtual network of experts and can be accessed by members only. This helps ensure the quality of feedback, so that members are provided with information that they can trust.

On average, 45 questions are posted in the four to six months between meetings (there are two EuroTAC and AsiaTAC meetings per year). Many are answered within hours, providing pertinent technical answers by colleagues that MTI members know and trust. Many of these potential solutions include references, pointing the member to codes and relevant technical papers or speaking from personal experience having faced the same problems.

MTI also archives forum questions. Members are able to log-in and search by topic.

Many questions that come up have already been asked, and this resource provides and deep well of answers that stretches back more than a decade. This is a great tool for engineers performing materials research, from materials selection to failure prevention to mothballing of equipment, and some find it useful for benchmarking.

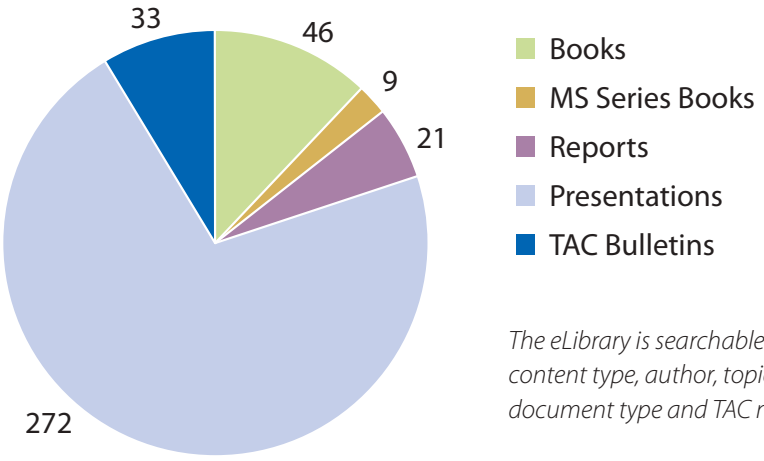
Online Forum Posts and Replies by MTI Members in 2016



Searchable eLibrary and Information Archives

MTI's members requested rapid access to reliable information, and the institute's brand new eLibrary meets that need. The database, which is available to members only, is searchable by topic, keyword, data, and other criteria. The archive contains books, reports, and other valuable downloadable information that is available 24/7. For example, references like MTI's MS Series, have helped processing industry professionals make critical equipment-related decisions based on instant access to reliable materials-chemical compatibility information. This has saved some companies millions in lost production, needless replacement, and other costs.

Total Publications on MTI eLibrary



The eLibrary is searchable by title, category, content type, author, topic, keyword, document type and TAC meeting.

Roundtables and Special Events

Each year, MTI hosts Roundtables and other special events for its members. The organization is currently planning a second Refiners Roundtable to address challenges specific to those environments. Roundtables include presentations from leading authorities on topics ranging from Risk Based Inspection to High Temperature Hydrogen Attack and much more. These events also include panel sessions, such as the recent High Temperature Furnace Tubes session held in Houston, Texas. Members tailor the subject matter to meet their specific needs. MTI maintains a small technical staff that report to the project teams and support these special efforts. In addition to Roundtables, MTI offers other opportunities to its members, including meetings for local materials personnel in Asia and eLearning and webinar training sessions available worldwide.

Structured Forums and Learning from Failures Luncheons

There is no downtime at MTI meetings. When participants aren't solving problems or networking, they are absorbing valuable information at one of the association's Lunch & Learn sessions. Presentations have focused on a variety of topics, including "Learning from Failures". Speakers often provide a case history of a plant failure, what they learned from those unfortunate challenges, and interact with the audience, which often provides valuable suggestions of their own.

MTI's TACs (Technical Advisory Councils) are always on the lookout for new ideas, and quickly adapts content to meet member needs. The organization continues to be driven and shaped by its member representatives, an agile model that has been effective for 40 years.

Managing Aging Plants Conference and Resources

Managing Aging Plants is an increasingly important topic to the Processing Industries, and MTI has taken the lead in providing information that helps its members. With well-known conference and media partner KCI (http://kci-world.com), MTI has co-hosted conferences in Asia, Europe, and the USA (more are planned) that have covered a broad range of issues facing today's engineers tasked with maintaining yesterday's facilities and equipment. A small sampling of the practical information shared at these unique events includes:

- 25 Years of Risk-Based Inspection;
- Managing Aging Plants: Non-metallics
- Cost-Effective Polymeric Heavy Corrosion Systems in Aging Plants;

- Risk Based Repair of Refinery Structures
- Management of Aged Equipment Lacking Documentation
- Management of Complex Facilities Using Robots
- Proactive Integrity Management of Aging Plant
- Current Principal Applications of 3D Laser Scanning in Plant Turnarounds
- Small Specimen Testing for Damage and Life Assessment of High-Temperature Components

In addition, many of MTI's projects are focused on aging plant issues. Members use these live forums to discuss contemporary problems and launch projects that address their most pressing concerns.

Education and Training Opportunities

New and seasoned engineers alike require training to provide them the information that they need to keep up with a rapidly changing technology, regulations, and other issues required to operate processing plants efficiently and safely. Recent engineering school graduates are often expected to provide valuable support immediately, but classroom experience doesn't prepare them for the realities that they face in a chemical, oil & gas, or many other industrial operations. MTI provides them with a platform to start learning practical information that they can often apply immediately.

One of MTI's most recent projects was a three-part FRP In-service Inspector Training session. The course was developed and taught by a senior team of engineering experts currently practicing their professions at chemical processing companies. The three-day session was also available to non-members for an elevated fee. Feedback has been positive, and MTI is planning to convert the course into an online eLearning module and an interactive webinar format.

Other training topics have included:

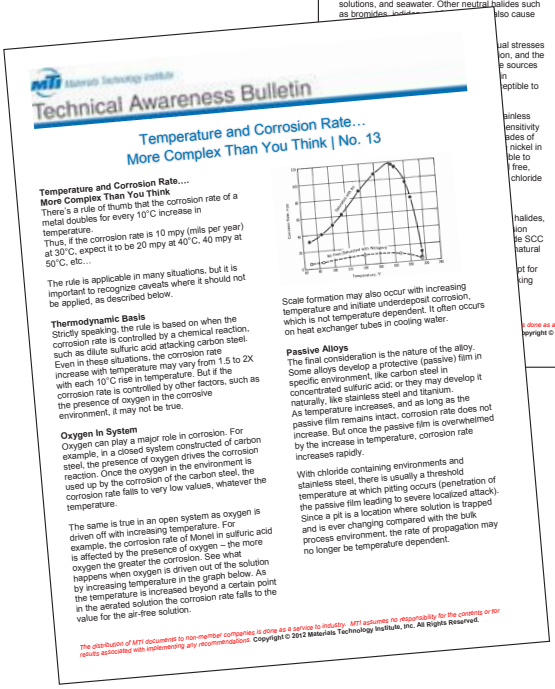
- Ceramics 101
- Welding and Weldability of Stainless Steel
- Clad Material Training
- Duplex Stainless Steel Training
- Fitness for Service
- Nickel Alloys
- Risk Based Inspection

TAC Bulletins and Safety Information

In a world where the next catastrophe could be tomorrow's headline, safety is paramount. MTI puts safety first with its Learning from Failures luncheons, Structured Forum Presentations and some of its safety-related TAC Bulletins. An MTI Project Team produces several bulletins each year, and its members are encouraged to copy and distribute them in-plant to their teams as reminders or use them for training. Current titles available in the members-only portion of MTI's website include but are not limited to:

- Focus on Stress Corrosion Cracking
- Preparing Plant Equipment Failures for Failure Analysis
- Before You Weld On It
- Storage and Handling of Molten Sulfur
- Reliability of Flexible Hoses
- What is RAGAGEP?

MTI has produced 33 TAC Bulletins and have translated 27 into Chinese and 5 into Spanish.



Technical Awareness Bulletin

Temperature and Corrosion Rate…
More Complex Than You Think | No. 13

Temperature and Corrosion Rate….
More Complex Than You Think
There's a rule of thumb that the corrosion rate of a metal doubles for every 10°C increase in temperature.
Thus, if the corrosion rate is 10 mpy (mils per year) at 30°C, expect it to be 20 mpy at 40°C, 40 mpy at 50°C, etc…

The rule is applicable in many situations, but it is important to recognize caveats where it should not be applied, as described below.

Thermodynamic Basis
Strictly speaking, the rule is based on when the corrosion rate is controlled by a chemical reaction, such as dilute sulfuric acid attacking carbon steel. Even in these situations, the corrosion rate increase with temperature may vary from 1.5 to 2X with each 10°C rise in temperature. But if the corrosion rate is controlled by other factors, such as the presence of oxygen in the corrosive environment, it may not be true.

Oxygen In System
Oxygen can play a major role in corrosion. For example, in a closed system constructed of carbon steel, the presence of oxygen drives the corrosion reaction. Once the oxygen in the environment is used up by the corrosion of the carbon steel, the corrosion rate falls to very low values, whatever the temperature.

The same is true in an open system as oxygen is driven off with increasing temperature. For example, the corrosion rate of Monel in sulfuric acid is affected by the presence of oxygen – the more oxygen the greater the corrosion. See what happens when oxygen is driven out of the solution by increasing temperature in the graph below. As the temperature is increased beyond a certain point in the aerated solution the corrosion rate falls to the value for the air-free solution.

Scale formation may also occur with increasing temperature and initiate underdeposit corrosion, which is not temperature dependent. It often occurs on heat exchanger tubes in cooling water.

Passive Alloys
The final consideration is the nature of the alloy. Some alloys develop a protective (passive) film in specific environment, like carbon steel in concentrated sulfuric acid, or they may develop it naturally, like stainless steel and titanium. As temperature increases, and as long as the passive film remains intact, corrosion rate does not increase. But once the passive film is overwhelmed by the increase in temperature, corrosion rate increases rapidly.

With chloride containing environments and stainless steel, there is usually a threshold temperature at which pitting occurs (penetration of the passive film leading to severe localized attack). Since a pit is a location where solution is trapped and is ever changing compared with the bulk process environment, the rate of propagation may no longer be temperature dependent.

Technical Awareness Bulletin

Focus on Chloride Stress Corrosion Cracking (CSCC) of 300 Series Stainless Steels | No. 8

Conditions for Stress Corrosion Cracking (SCC)

The conditions necessary for stress corrosion cracking are:
- Suitable environment
- Tensile stress
- Susceptible metal

Environment: The most common corrosive species that has caused failures of 300 series stainless steels in chemical plants is the chloride ion. Chloride Stress Corrosion Cracking can occur in hot acid chloride solutions, sodium chloride/peroxide solutions, and seawater. Other neutral halides such as bromides, iodi… also cause

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Except for particular cases involving sensitized metallic structure (containing chromium carbide precipitates in the grain boundaries) under particularly aggressive conditions, the morphology of chloride stress corrosion cracking involves multi-branched, transcrystalline cracking (through the grain). Figure 1 shows a photomicrograph of the transgranular lightning strike appearance of CSCC.

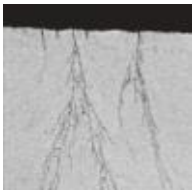

Figure 1. *Transgranular chloride SCC in 304L SS.*

Organic Chlorides

Organic chlorides themselves are not directly harmful to austenitic stainless steels. They will cause SCC only to the extent that they produce inorganic, ionic chlorides, by processes of hydrolysis or thermal decomposition (i.e. pyrolysis) or both.

A careful distinction must be made between organic chlorides that readily form inorganic chloride ions, and those that do not. For example, the symmetrical chain-like (aliphatic) chlorides do not readily hydrolyze. Ethylene dichloride (1,2

Network of Experts /Live TAC Meetings

Many MTI members appreciate the opportunity to interact with peers at one or more of the seven meetings held worldwide each year (two in Asia; two in Europe; and three in North America). Solutions are sometimes discovered during the live forums, break conversations, and evening receptions. Many of the industry's greatest technical minds attend these sessions, providing a fertile ground for advancing and sharing knowledge. Connections develop between this community of experts, that allows them to interact between meetings when they need trustworthy advice. Even new members have instant access to answers, via MTI's online directory and Q&A forum. At MTI, collaboration adds up to measurable value.

Meeting Materials Engineering Challenges in a Fast-Changing World

There are a multitude of materials engineering challenges in the chemical processing, oil and gas industries. Today's materials engineers need an organization to help them find solutions that they can trust. MTI shares resources and expertise that can make a measurable difference. Today, more than 60 companies in 14 different countries belong to the Materials Technology Institute because they believe MTI provides them rapid and efficient solutions to their company's problems. To inquire about membership, contact mtiadmin@mti-global.org or call +1 314.567.4111.