A Materials Technology Institute Publication

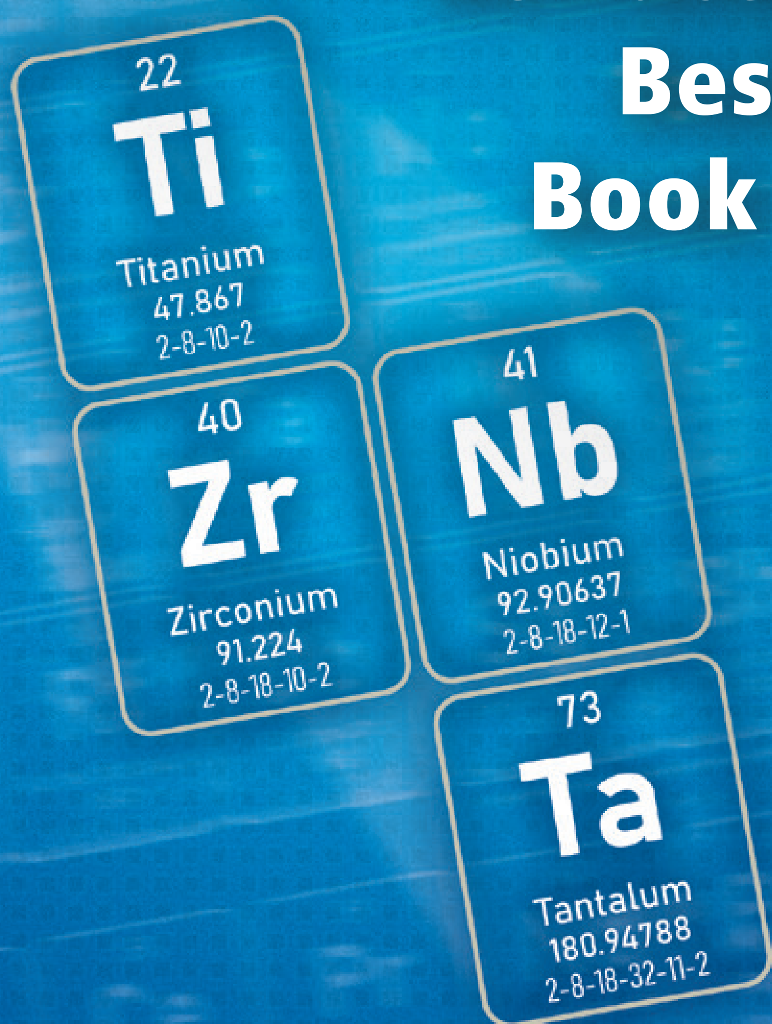
MTI CONNECT

GLOBAL CHALLENGES / TRUSTED SOLUTIONS

2021, ISSUE 1

Reactive and Refractory Metals Best Practices Book – A Unique Resource

Page 12



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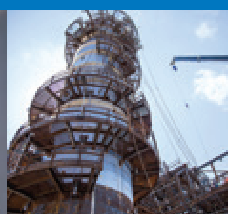
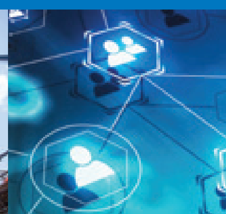
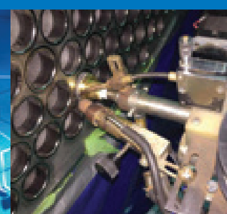

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ABOUT THIS PUBLICATION:

MTI CONNECT is published by the Materials Technology Institute, Inc. (MTI). MTI is a unique, cooperative research and development organization representing private industry. Its objective is to conduct generic, non-proprietary studies of a practical nature on the selection, design, fabrication, testing, inspection, and performance of materials and equipment used in the process industries.

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CALENDAR OF EVENTS:

Dual Laminate Training Course
May 4-5, 2021
Baton Rouge, LA

EuroTAC Virtual Meeting
May 18-19, 2021

AmeriTAC 135 – Hybrid Meeting
June 21-23, 2021
Louisville, KY

CURTIS HUDDLE APPOINTED TO MTI BOARD OF DIRECTORS

HOPES TO BRIDGE THE KNOWLEDGE GAP BETWEEN GENERATIONS

Curtis Huddle (Eastman Chemical) is the newest member of the MTI Board of Directors (BOD). He was nominated and appointed to the BOD in December 2020 to replace outgoing BOD member Eileen Chant who resigned from member company Becht in November.

Huddle began working at Eastman in 2008 as a co-op student and became a full-time employee in 2010. His participation in MTI soon followed when he attended his first AmeriTAC meeting in February that year in St. Petersburg, Fl.

Huddle vividly recalls that first encounter with MTI, "I could tell it was a very collegial organization as I was dragged around by Robert Sinko and Gary Whitaker, both MTI Fellows now, and met so many of the knowledgeable and respected names in the organization."

He immediately started participating in project teams and the TAC Forum. Encouraged by his mentors, he also promptly volunteered to champion projects. Huddle's activities have not gone unnoticed over the past 11 years.

"The BOD observed that Curtis has been very willing to contribute to MTI projects and the TAC Forum almost from his first TAC meeting," remarks David Barber (Dow), MTI BOD Chair.

"We expect that Curtis will bring that same energy and engagement to the BOD."

Although it's been an ongoing whirlwind of project involvement, Huddle says he is happy to take on another level of leadership to serve on the BOD.

"Since the beginning of my work with MTI, I have been very interested in the organization's role in supporting the people that work in the materials technology fields. I see the BOD as the main servants of MTI who influence the direction of the organization and, in the end, better serve our members so they can solve the issues they have day-to-day," Huddle explains.

Curtis Huddle (Eastman)

"By accepting my appointment to the BOD, I hope to also serve the organization in the best way I can so that current and future members get the best resources they can to go solve their companies' problems and best do their jobs. In this way, I hope I can have some small part in keeping our plants safer and more reliable."

Barber notes the BOD is especially looking forward to Huddle's input as a representative of the quickly growing younger age demographic at MTI.

"I expect that Curtis will bring a 'fresh eyes' perspective to the BOD. Curtis represents the newer

> CONTINUED ON PAGE 31

EILEEN CHANT RESIGNS FROM MTI BOD

Eileen Chant (Becht)

Eileen Chant resigned from MTI member company Becht in November 2020 to pursue other opportunities; thereby resigning from her position as an MTI BOD member.

MTI would like to recognize Chant for her involvement in MTI projects, Knowledge Management efforts, continual dedication to improve the MTI member website, and work to develop the MTI e-Library as a valuable member resource.

She served the MTI BOD from October 2011 – November 2020, where she was an active participant in several committees, including Chair of the Website Committee.

"Eileen was the driver who convinced the BOD to approve resources to support the excellent members-only website we enjoy today. Her commitment was persistent through multiple iterations of the website. During my BOD tenure, I observed that Eileen was a willing volunteer who would take on many different action items and deliver very useful results every time," concludes David Barber (Dow), MTI BOD Chair.

MTI appreciates and thanks Eileen for her dedicated service through the years. ▪

Global Solutions SYMPOSIUM 2022

WHY PART GLOBAL

March 1 – March 3, 2022
Grand Caribe Convention Center, Orlando

The Materials Technology Institute has announced the 2022 Global Solutions Symposium with the theme "Practical Knowledge and Innovative Solutions for the Process Industry." This Symposium follows on the heels of a successful, initial Global Symposium held in Baton Rouge in 2020 and will support MTI's mission to maximize member asset performance by providing global leadership in materials technology.

As Co-Champions for this Symposium, we would like to offer some guidance as to what valuable information and networking opportunities you may receive by participating in the 2022 Symposium in Orlando.

The Symposium will begin on March 1 with an opening reception, and the learning tracks will take place over two days – March 2-3. The schedule is slated to feature presentations by technical leaders in the processing industries, as well as experts from academia and peripheral support industries. The Call for Presentations is underway, and we invite you to submit an abstract associated with any of our session topics by June 30, 2021.

Technical tracks relating to Sustainability, Additive Manufacturing & Emerging Technologies, Reliability & Maintenance for Safety and High Temperature Damage Mechanisms, including High Temperature Hydrogen Attack, are included. In addition, the Symposium also includes a Knowledge Management Track emphasizing how to work with Subject Matter Experts to expand, maintain and preserve critical knowledge inside your company as changes in personnel and systems occur.

The global event will be preceded by an MTI Technical Advisory Committee (TAC) meeting. Member registration will include the TAC meeting and special invitations will be extended to non-member Symposium registrants to attend. During the TAC, details of current MTI technical projects and potential projects are discussed by experts in the industry, which adds tremendous value to attendance for the Symposium. Attendees will have the opportunity to network with key technical personnel from a wide variety of producer and supplier companies in the CPI and associated industries. There will be time for both formal and informal conversations on technical topics that are of interest to you and your company.

Of course, the Symposium will feature the Global Solutions Marketplace. The marketplace is the hub for breakfast, coffee breaks, receptions and a special Casino Night, where attendees can connect with exhibitors and other attendees throughout the event. Exhibitors (MTI members and non-members) from some of the premier suppliers to the processing industry will be available.

ICIPATE IN THE MTI SOLUTIONS SYMPOSIUM 2022?

A Note from Co-Champions Meghan Oaks and Chuck Young

Attendees will have the opportunity to network with key technical personnel from a wide variety of producer and supplier companies in the CPI and associated industries.

We are confident you will come away from the 2022 MTI Global Solutions Symposium with new information that will assist you and your company in meeting your technical and financial goals. Attendees at the MTI 2020 Symposium were universally positive about the value of their attendance; 93 percent of attendees surveyed indicated that the combination of high-quality technical presentations coupled with the ability to network with peers and SMEs in the industry made the 2020 Global Symposium a valuable event to attend.

We understand that your time is valuable and taking time away from your plant can be challenging, but the high-quality technical presentations and the opportunity to connect with other key subject matter experts will help you provide innovative solutions that improve the safety, sustainability, reliability, and profitability of your company. For people managers, the knowledge management track will help you ensure valuable technical knowledge, skills, and expertise are maintained while facing the challenges of an aging and increasingly mobile workforce.

So, why roll the dice with materials engineering technical challenges? Attend the 2022 MTI Global Solutions Symposium and discover possibilities that you haven't yet considered.

Please contact MTI if you have any Symposium related questions at mtiadmin@mti-global.org.

See you in Orlando!

Chuck Young
Tricor Metals

Meghan Oaks
BASF

2022 MTI Global Solutions Symposium Co-Champions

Global Solutions SYMPOSIUM 2022

MAKE A PRESENTATION

at the MTI Global Solutions Symposium 2022

REACH 200+ PROCESS INDUSTRIES ATTENDEES WITH YOUR LATEST RESEARCH, KNOWLEDGE AND TECHNOLOGY

The Materials Technology Institute (MTI) invites experts from the processing industries to submit abstracts for technical presentations or case studies applicable to any of our session topics at the MTI Global Solutions Symposium, March 1-3, 2022, in Orlando.

The event will broadly focus on Practical Knowledge and Innovative Solutions for the Process Industries, and features technical education tracks, a track dedicated to knowledge management, and the global solutions marketplace for the opportunity to meet with materials manufacturers, fabricators, and engineering experts who will be exhibiting.

Technical and knowledge management content, as well as case studies, focused around any of the session topics will be considered.

Presentations should be prepared to fill 30 minutes including questions. Speakers will receive discounted meeting registration to attend the event.

Emerging Technology

(emphasis on ASME and ASTM acceptance of the following technologies for use in chemical plants and refineries)

- Additive Manufacturing (3D Printing)
- Artificial Intelligence/Robotics
- Virtual Reality
- Other New Technology

High Temperature Damage Mechanisms

- Identifying In-situ
- Controlling to Minimize Occurrence
- Other High Temperature Problems

Sustainability in the Processing Industry

- Energy Conservation
- Recycling
- Life Cycle
- Processing Efficiency
- Materials of Construction Conservation

Safety/Maintenance

- Inspection or New Inspection Methods (Metals/Non-Metals)
- RBI
- Damage Assessment

Knowledge Management

- Working with SMEs
- Training Tools
- In-Person/Virtual Technical Training

Abstract Submission Requirements:

- 100-200 words (formal papers not required)
- Relevant title
- Clearly outline the presentation topic and scope
- Technical based, no commercial or marketing content
- Speaker contact information: name, title, company, email and phone

Please submit abstracts to mtisymposium@mti-global.org by Wednesday, June 30, 2021.

If you have any questions about the Symposium, please email mtiadmin@mti-global.org or call the MTI office at +1 314.567.4111.

March 1 – March 3, 2022
Grand Caribe Convention Center, Orlando

RESERVE EXHIBIT SPACE

for the MTI Global Solutions Symposium Marketplace

REACH KEY CPI INFLUENCERS

The Materials Technology Institute (MTI) is currently accepting reservations for the Global Solutions Marketplace (exhibit hall) at the Global Solutions Symposium, March 1-3, 2022, in Orlando.

The 2022 Symposium is expected to draw 200+ attendees, including top subject matter experts, from the areas of Specialty Chemicals, Commodity Chemicals, Refining, Mining, Fertilizers and Oil & Gas. MTI's technical community is comprised of key engineers, decision makers and leaders from world class chemical producers and suppliers. Our focus is on solving problems and improving the performance of materials of construction to enhance safety and reliability.

Exhibiting in the Global Solutions Marketplace will offer 13 hours of exhibition and networking to connect with attendees. Plus, the marketplace will remain open during a special Casino Night event for an additional three hours of networking with attendees.

MTI members receive booth reservation priority through June 30, 2021 – remaining space will be available to the public beginning July 1, 2021. Early bird reservations are $2,750 for MTI members and $3,750 for non-members through August 31, 2021.

Exhibit Hall Details

- 6 ft. table, 2 chairs, trash can, power and cords
- Only tabletop displays allowed. All displays must fit on top of the table – no crates, pallets or free-standing displays
- Tabletop dimensions 30″ x 72″
- Company logo and contact information will be included on the event app, MTI website and meeting materials
- One complimentary event registration per booth

Contact Kirk Richardson to reserve your booth while space is available! krichardson@mti-global.org +1 314.567.4111

If you have any other questions about the Global Solutions Symposium, please email mtiadmin@mti-global.org.

NEW MTI SUPPLIER MEMBER FLUOR EAGER TO COLLABORATE

FOCUSED ON PROJECT PARTICIPATION, SHARING KNOWLEDGE AND NETWORKING

Fluor is the latest addition to MTI after joining as a supplier member in the first quarter of 2021. The company was founded in 1912 and made its start in construction for a gas company. Throughout its more than 100-year history, Fluor has expanded into multiple industries, including chemicals and petrochemicals in the 1940s, as well as mining, petroleum refining, life sciences and several others, according to the company website. They offer services around the globe in engineering, procurement and construction for building refineries, chemical plants, infrastructure, offshore platforms and other projects.

Cathleen Shargay, MTI Designated Representative for Fluor, says they are eager to participate in MTI and plan to contribute to the vast technical knowledge of the organization.

"Although we are not a plant owner, fabricator or material supplier, we are both heavily involved with the new fabrication and construction phases of plants and reviewing the operating experience of many units when we are doing revamps or rebuilds after fires or other failures," Shargay explains.

"These are sources of data and experiences, which we can bring to MTI (when permitted by the owners). We hope to have our Materials and Welding experts from various locations around the world help contribute and participate in MTI and share the information within our Fluor community. Also, we work with almost all the MTI members as either our clients or suppliers, hence we are looking forward to this opportunity to network and work together to advance the industry knowledge."

Shargay has a history of participation and leadership roles in joint industry partnerships and is looking forward to the benefits Fluor will gain from the collaborative environment of MTI. As an example of the joint industry work she's been involved in while at Fluor, Shargay provides a case from 2008, which may be a bit dated, but it had a large impact on the industry. It involved critical, high pressure, high cost hydroprocessing reactors, where suddenly, fabrication on more than 30 2¼ Cr-1 Mo-V reactors at multiple fabricators came to an abrupt stop as the SAW welds started developing extensive amounts of microcracking.

"The cracking was in longitudinal, circumferential and nozzle welds, and always occurred after a heat treatment cycle such as PWHT or ISR. It was quickly identified as reheat cracking, but the root cause and solution eluded the industry for about seven months," she describes.

"It took a major team effort between the fabricators, steel suppliers, weld metal suppliers, owners and engineering contractors to pool information and solve this problem. My role was that as the chair of API 934-A committee, which became the central forum for sharing of this data and information. Testing by ArcelorMittal was the key breakthrough, which showed that the main cause was >1.5 ppm levels of lead and bismuth contamination in the welding flux. But our API 934-A work continued as we quickly issued an appendix on an inspection method and criteria for detecting and rejecting this cracking, and started a Joint Industry Sponsored Research project to develop a weld metal screening test to prescreen each batch of weld metal for reheat cracking susceptibility (from any type

Fluor provided preliminary services, front-end engineering and design, engineering, procurement, and construction (EPC) for Shell's Carbon Capture and Storage (CSS) Quest project in Canada. *Photo courtesy of Fluor.*

of contaminant). I also chaired the JIP sponsor group for developing this screening test, which finished the work within one year, and published the results as a second appendix to API 934-A. These documents are in wide use today and have prevented further cracking problems."

Fluor initially expressed interest in membership because of MTI potential project 357 – Corrosion in Bio-oils, which is currently targeted to better understand the corrosion associated with processing bio-oil feedstocks.

"MTI is well-positioned to become the central resource on biofuels processing plants materials and corrosion knowledge," Shargay points out.

"Fluor is currently designing and fabricating numerous biofuels units, which are revamps of refinery units so far. We would like to have an expertise in this topic to be able to best serve our clients."

She also discusses other MTI projects that could provide cost-saving ideas for company projects from materials or fabrication innovations and reliability improvements in their plant designs. Topics of interest include stress relaxation cracking mitigation, duplex SS fabrication (including ferrite testing), modifying CS standards to avoid low toughness issues, developing guidelines for thermal mix points and other topics. In addition, Shargay notes they are looking forward to accessing the e-Library to make use of the existing 40-plus years of MTI technical literature.

Although Fluor has only just begun exploring the MTI resources and benefits of membership, they jumped right in by attending the February virtual GlobalTAC meeting and providing an industrial technology demonstration during one of the sessions. Shargay also plans to make sure Fluor is contributing and involved in project idea development, and she is personally looking forward to networking opportunities and attending MTI meetings.

Welcome, Fluor! MTI is delighted to have your participation and contribution of technical knowledge. ▪

A Sadara integrated facility was designed to be the largest petrochemical facility to be built in a single phase. Fluor provided engineering, procurement, and construction management (EPCM) services for all utilities and offsites at the complex. *Photo courtesy of Fluor.*

ASIATAC AND EUROTAC CONTINUING MEETINGS AND PROJECT WORK AMID THE PANDEMIC

STATUS UPDATES AND FUTURE PLANS

AsiaTAC Activities

The Spring Conference originally scheduled last April to be held in DaNang, Vietnam was cancelled due to the outbreak of COVID-19. With the ongoing pandemic, AsiaTAC leadership opted for a virtual Fall Conference, which was held September 16 and 17. A total of 71 registrants participated in the two half-day sessions. Of the registrants, 17 were first time AsiaTAC attendees, 23 member companies were represented and five potential members (Allied Supreme Corp., CTCI, Formosa Petrochemical Corporation, Institute of Materials Science, and Wanhua Chemical Group Company, LTD) attended. This is the first time we hosted a region-wide virtual conference. Overall, attendance was good, and the program was well received.

Due to the continuing pandemic situation, the AsiaTAC leadership team concluded that the Spring Conference be held virtually April 7-8, 2021. The Fall conference is tentatively scheduled for face-to-face in mid-September in Shanghai, China. Looking ahead to 2022, Vietnam will be the host country for the in-person Spring conference next April.

PDC Project Review and Brainstorming Session

During the virtual Fall Conference attendees reviewed all current project ideas. Highlights are listed below:

#304 "Advanced Inspection Technology for Metal Process Equipment in Services" championed by Alex Chen of Dow to be developed into a one-day training class.

#322 "Translating MTI Documents to Chinese" Championed by Hulin Zhu / DuPont. Members discussed the needs and values of the project and decided to cancel the project.

#326 "Raw Material Specifications to prevent SCC and External SCC (Stress Corrosion Cracking) Control & Detection" was terminated due to lack of a project Champion and team members.

#327 "Bellows Gaskets/ Expansion Joint/Hose Training" (General Introduction & Material/ Type Selection & Maintenance & Inspection). Henry Ye of Chemours is the new Champion, he will lead the project team to propose a new project scope and action plan.

#367 Henry Ye, Chemours, reviewed the project SPS during the Fall conference (extending of Project 269 "Corrosion Data of the Most Commonly Used Corrosion-Resistant Nickel Alloys" to test another 10 different grades of Nickel Alloys). Henry Ye and Gary Coates, Nickel Institute, will be the Co-Champions of the project. The project went through the formal project RFP and vender selection (ITRI is the final contractor of choice). The project submitted a request for funding of $60,000, which was voted on by members during a special session of an AsiaTAC conference call and received funding approval from the MTI Board of Directors on November 2, 2020.

EuroTAC Activities

The 2020 year was obviously different for all organizations, including the EuroTAC group, because of the global COVID-19 pandemic. The in-person EuroTAC meetings were cancelled in Paris and in Ludwigshafen. All potential face-to-face meetings with the different project contractors were cancelled. But due to creative ideas and the faith of the MTI members in their organization, EuroTAC is still here and in good health.

To replace the in-person EuroTAC meetings, thanks to reliable IT communication systems, the members participated in the virtual GlobalTAC meetings, which included presentations from AmeriTAC and EuroTAC. This resulted in a wider recognition of the worldwide efforts of the organization. More European members attended the AmeriTAC projects updates and more AmeriTAC members joined the EuroTAC projects updates. In 2021, EuroTAC plans to hold an independent virtual meeting in May.

Despite the pandemic situation, 2020 was very productive for EuroTAC projects.

The Guidance for Failure Mechanisms book (Project 268) was completed and published. Thanks to the Champion, Lars Rose (DuPont), the contractor Becht, and all the project team members, it provides a valuable guide to the predominate failure mechanisms encountered in the chemical, pharmaceutical and food industries.

The projects on Evaluation and Simulation of HTHA Damage made important steps forward. At the end of Project 305, Institut de Soudure and its partner, Extende, demonstrated the validity of a process to artificially generate a representative HTHA damage distribution based on experimental metallurgy. This process will be improved by project 362 to consider the effects of non-metallic inclusions and welded areas. By the completion date of June 2021, members will be provided guidelines for the best procedures with the most reliable probes to detect HTHA damage, even at the earliest stage.

Project 291, Stress Relaxation Cracking (SRC) Mitigation Strategy saw some progress. In developing a test to detect SRC, the alloy 800H was not cracking as expected. The project team contracted with Lehigh University to perform Gleeble Testing to further the understanding of the 800H SRC behavior in the Julich Testing.

Finally, two new projects have been funded:

Duplex Stainless Steels at Elevated Temperatures (Project 364) will study the cumulative and sequential effects of temperature spikes above ASTM or European specifications on mechanical properties of Alloy 2205.

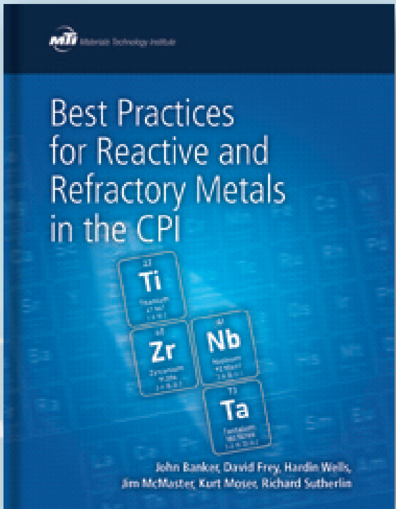
Pressure Swing Adsorption Structural Integrity Assessment (Project 353) is conducting a literature survey of the current fatigue models for H2 propagation in PSA units, including the FFS practices suggested by API 579 and ASME FFS-1 and BS 7910.

The success and productivity of MTI projects in 2020 illustrates the incredible work of the EuroTAC members even during these pandemic times. All members are looking forward to resuming the in person professional networking as soon as it is again allowed.

Regional TAC Announcements

Please watch for AsiaTAC and EuroTAC email updates as the status continues to change with the pandemic. If you have any questions regarding AsiaTAC, please contact Paul Liu, MTI Associate Director – Asia. For questions about EuroTAC, contact Patrice Houlle, MTI Associate Director – Europe. ▪

REACTIVE AND REFRAC
BEST PRACTICES BOOK



MTI takes great pride in the quality of its research, and there may be no better example of that than the work that is going into an upcoming book, Reactive and Refractory Metals Best Practices for the Chemical Processing Industry.

A Project Team, led by Co-Champions Hardin Wells (Albemarle) and Wendy McGowan (Neotiss), is in the process of making final improvements to the comprehensive guidebook. This will include the March 2021 addition of a new Tantalum-Niobium Equipment Design chapter, thanks to the assistance of SME David Frey, an industry consultant, who joined the team in 2019. Frey and Wells have also been able to reinforce the text in many chapters by providing more photos based on their recent experience in working with these materials.

Best Practices for Reactive and Refractory Metals, which will be released exclusively to MTI members in the 2nd quarter of 2021, includes sections covering Titanium, Zirconium, Tantalum and Niobium, and Clad Metals, in addition to the Safety, Welding, Casting, and Project Management Appendixes. There is no other all-inclusive reactive and refractory metals reference like it in the world.

"Much of this information has never been published," remarks McGowan.

"In fact, when our project editing team first began reviewing the authors' drafts, we questioned the fact that there weren't as many references as we had anticipated. Many of the best practices presented in this book are based on years of experience, which have not always been well documented."

She adds that the editing team has worked hard to ensure that the concepts are presented clearly and are supported by helpful graphs, tables and photos.

TORY METALS

A UNIQUE RESOURCE

The new reference will be a valuable resource for MTI's producer, engineering, and fabricator companies, especially those who may not have a lot of experience working with these materials.

"Some suppliers may know specifics in their area of expertise but may not have the full scope of knowledge associated with these materials," points out McGowan. "They will find this book a helpful tool."

With so many SMEs already retired or on the verge of leaving the workforce, the guidebook will help ensure that lessons learned during decades of working with these metals are captured and available for members.

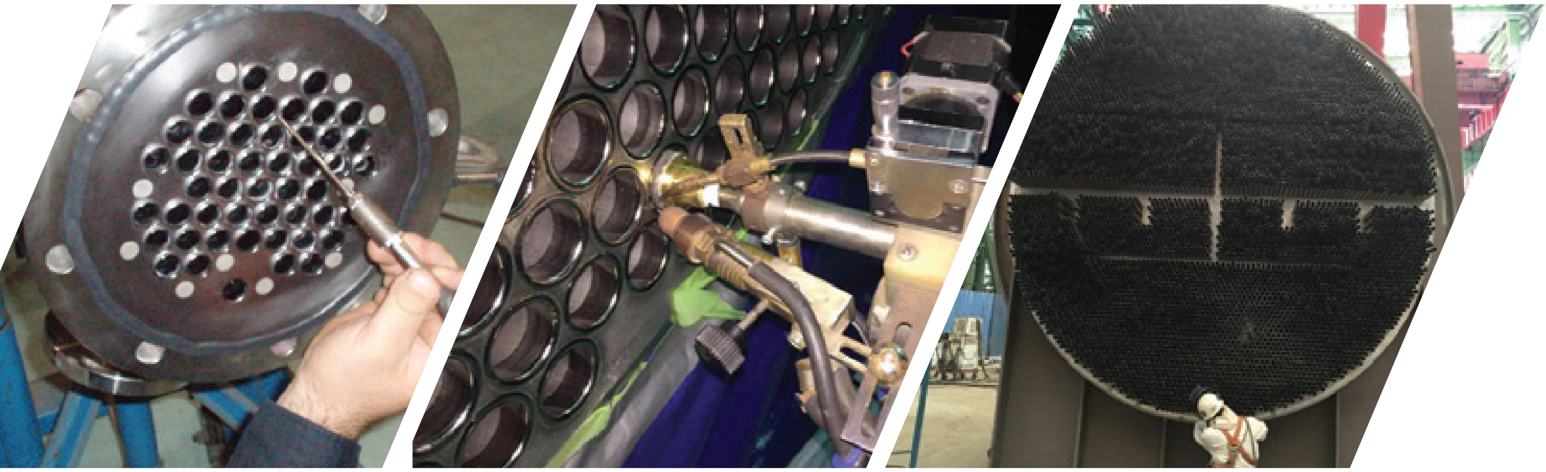
"This will also be an extremely valuable tool for incoming or junior engineers as a resource from SMEs in the field of reactive and refractory metals, especially since this information may not be available elsewhere," McGowan remarks.

"As our industry continues to shed subject matter experts, while also struggling to capture learned knowledge, this project couldn't come along at a better time," Wells explains. "This book is capturing an incredible range of experiential and even anecdotal information related to the use of reactive metals. Ranging from materials selection to equipment specification, design, sourcing, and fabrication, as well as inspection, quality controls, and failure analysis. Hopefully, this compendium will be a 'one-stop shopping' resource for the CPI.

"Perhaps as a testament to the breadth and unprecedented amount of technology, experience, lessons learned, and best practices captured, it has taken approximately a decade to evolve this particular project from an initial concept to a finished publication," points out Wells.

"While it is possible this is one of the more MTI labor-intensive projects undertaken, on the basis of the manhours committed by the author team, the MTI staff, and the MTI project champions, I think it has also been one of the most rewarding projects that I have had the honor of working on. In addition to forging long-lasting friendships among this group of folks, I am also confident that we are forging a perennial resource for our industry."

For further information on this project and future announcements regarding the release of the publication, visit mti-global.org. ▪



EXTERNAL CORROSION AND CRACKING

OF STAINLESS STEEL EQUIPMENT AND PIPES

HAIHUI (HENRY) YE, PH.D. – MATERIALS ENGINEERING CONSULTANT
THE CHEMOURS CHEMICAL (SHANGHAI) CO. LTD.

During the author's 15-year career as a materials engineer dealing with a large number of corrosion and cracking incidents of process equipment and piping in various Asian chemical sites, there are some commonalities that can be summarized from these incidents. One of the prominent findings is that most of the corrosion and cracking incidents of stainless steel equipment and piping were initiated at the external surface due to chloride concentration from the environment. This article tabulates 24 stainless steel related incidents, which were investigated during a 10-year period from 2007 to 2016. Some real images taken in the field are included to further illustrate these findings. Finally, recommendations and possible solutions to deal with these external corrosion and cracking issues are provided. The goal is that this review will be helpful to industry colleagues who may not be fully aware how frequently and significantly chloride stress corrosion can affect process equipment.

Please note that the failures and incidents described in this article are not directly relevant to the author's current company. In fact, they do not represent the performance of any specific company, because I collected them from a variety of different chemical sites in Asia during my career. So, no specific companies are identified, and the information provided in this article is applicable to all chemical sites, in general. Also, no proprietary information of any company is disclosed in this article.

The focus of this article is on process equipment and piping made of common austenitic stainless steels, including 304 SS, 304L SS, 316 SS, and 316L SS. These are commonly used in Asian chemical sites. Dual certified stainless steels 304/304L and 316/316L are more commonly used in the US industry, but since they have similar compositions, the findings as shown in this article are also applicable to these dual-certified materials.

The title topic of "corrosion and cracking" was selected to cover examples of general corrosion, localized corrosion, stress induced failure and the combination of both stress and corrosion, such as chloride stress corrosion cracking (SCC).

The environments covered here are in the chemical industry in Asia; however, the findings in this article are also applicable to other process industry environments and all other regions, because chlorides are almost everywhere and anywhere.

Table 1 lists 24 stainless steel related incidents that were investigated from 2007 to 2016. During this period, the author was providing technical support to 15 chemical sites throughout Asia, including China, India, Indonesia, Japan, Korea, Malaysia, and Singapore. These sites are typically not large, with each site having about 20-50 pieces of stainless steel process equipment. The sites only sent samples for failure analysis when there was a major incident, significant financial loss, prolonged shutdown, or injury resulted. Therefore, based on a rough calculation, about one percent of stainless steel process equipment or piping in each Asian chemical site will get a major failure every year. While this sounds like a small number, it is quite significant. If one site has 100 pieces of stainless steel equipment, there will likely be almost one major incident every year based on this ratio.

As summarized in Figure 1, among all these incidents, almost half of them (11 cases) were caused by external corrosion and cracking, which can be further attributed to chloride concentration at the external surface of the process equipment or piping where the chlorides came from the environment. In Asian chemical sites, not every site has a materials engineer, but there are always process equipment engineers or reliability engineers. They typically have some basic knowledge about the importance of avoiding the use of austenitic stainless steels in chloride-containing or other incompatible process conditions. However, many of them are not aware that the chlorides in the external environment can be just as problematic. And while some may be aware, they may not be sensitive to how significant external surface corrosion or cracking can be. As a result, these engineers may not give enough consideration to the prevention of external corrosion and cracking at the design, fabrication, and maintenance stages. The result is that chloride concentration at the external surface becomes the number one cause of the major stainless steel equipment and piping failures at their sites.

The second largest contributor to the failures is improper material selection or design for the corrosive process, totaling eight cases. Again, because of the lack of material engineering knowledge, the site engineers sometimes select stainless steels for chloride containing processes, HCl containing processes, or the processes that require high strength and high hardness. The incorrect material selection or improper design will likely cause major failures. Therefore, it is very important to consult with material engineers before

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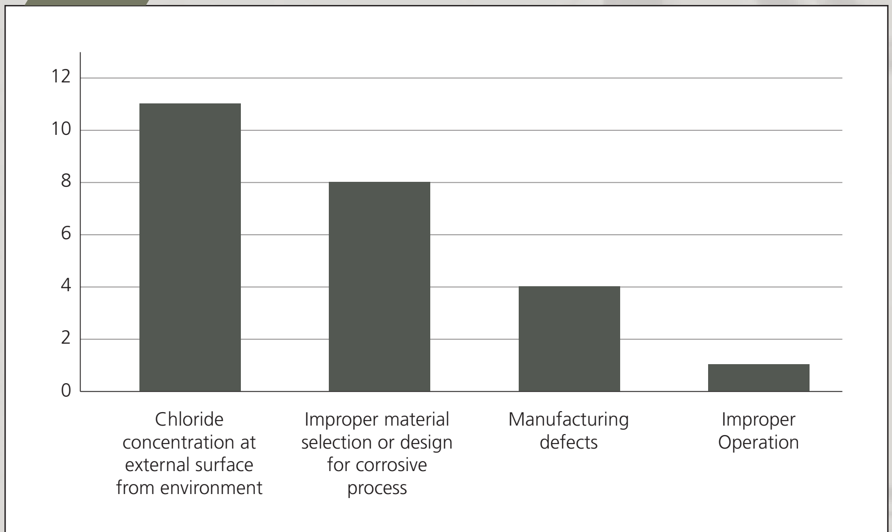
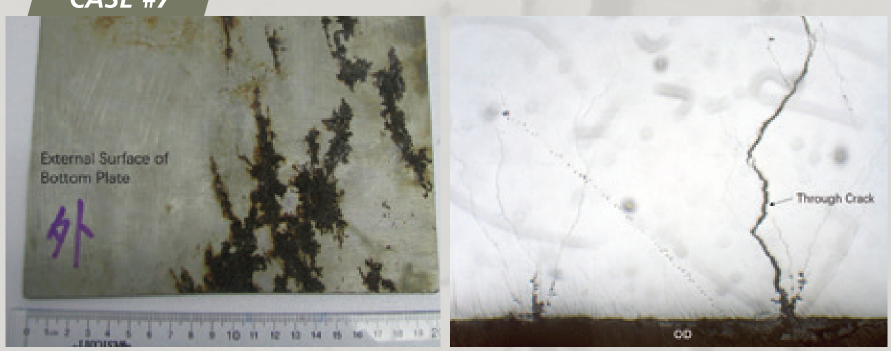
Figure 1 ***Number of Major Failures During 10 Years***



CASE #1

CASE #7



CASE #8

any new equipment fabrication or piping system construction.

The third cause of major failure in this study is attributed to manufacturing defects, including welding defects, casting defects, or iron contamination, which accounts for four cases. This should raise our attention to focus on the quality control of equipment and piping fabrications. The quality control process should include a thorough vendor audit at the beginning, a detailed prefabrication meeting, a comprehensive inspection and testing plan (ITP), and careful inspections at each hold point or witness point.

There is only one case in Table 1 where the failure was caused by improper operation. The operator used abnormally high-pressure water to clean a stainless steel pipe with one end plugged, and caused the pipe to rupture. Typically, in Asian chemical sites, operators follow the rules and regulations quite strictly. This type of failure is indeed uncommon.

The external corrosion and cracking described in this article is actually part of a hot topic being discussed by materials engineers during international conferences, which is corrosion under insulation, or CUI. In Table 1, among 11 cases of external corrosion and cracking, eight cases can be defined as CUI. This is because chloride concentration at the metal surface can be accelerated by the presence of insulation. This review provides some real practical evidence to confirm the significance of CUI and its relevant discussions.

The author's recommendations to deal with these external corrosion and cracking cases include:

1. Get involved in the design stage and specifying a proper coating to prevent the external corrosion and CUI. If it is critical service and the operating temperature is between 60 and 150 °C, the coating is mandatory for stainless steel equipment and piping. It is often difficult to convince the site managers to do this because of the cost, but it is often the easiest and most cost-effective approach when compared with other solutions such as upgrading materials of construction. You may meet resistance because they simply do not believe that external corrosion or CUI is a problem. Pointing to real examples of damage from external corrosion or CUI (such as those in this article) may be beneficial to help them to begin to understand its significance. Another common pushback from the site personnel is that coatings tend to cause pitting corrosion of stainless steels. This is true for some older types of coating, but for modern coatings, which are specially designed for stainless steels, this is no longer an issue. Of course, it is very important to select and apply the proper coating from qualified suppliers.

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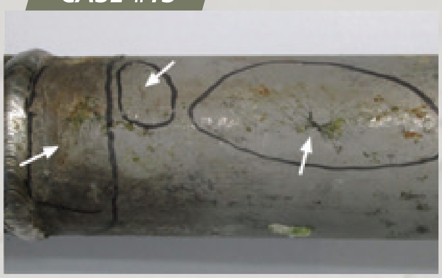
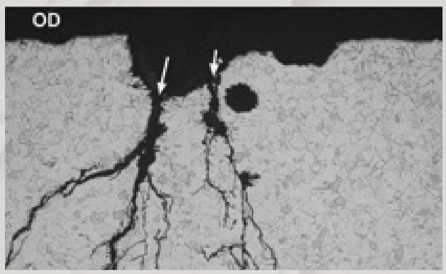
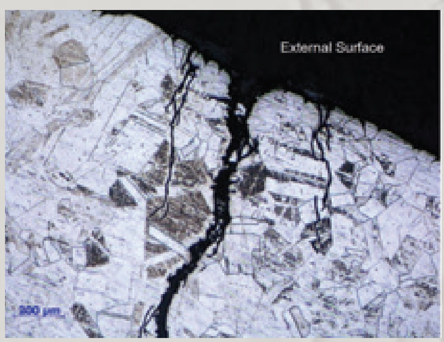
CASE #13





CASE #16



CASE #18

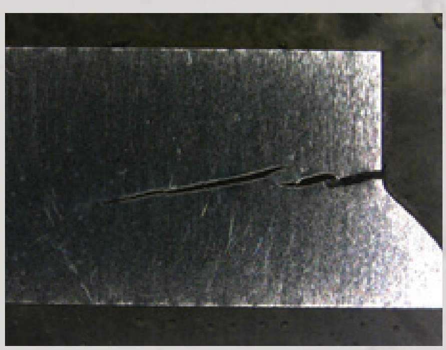


Table 1 Stainless Steel Failure Cases

Case	Year of Failure	Material of Construction	Equipment or Pipe	Internal Content	Operation Temperature, °C	Operation Pressure	Condition of Surroundings	Insulation	Failure Mode	Origin of Failure	Initiation Factor	Life before Failure
1	2007	304 SS	Pipe	City Water	60	120 bar	Indoor, Chemical Site	No	SCC	External Surface of Pipe	Chloride concentration on the pipe surface	6 years
2	2007	304 SS	Mixer	Organic Powder	40	1 bar	Indoor, Chemical Site	No	Pitting	Internal Surface of Shell	Improper material selection for chloride containing process	2 years
3	2008	304 SS	Reactor	HTF Oil / Organic Product	260	3 bar	Indoor, Chemical Site	Yes	Stress Cracking	T joint of heating coil	Manufacturing Defect during T Joint Formation	1 day
4	2008	304 SS	Container	Hot Water	90-100	1 bar	Indoor, Chemical Site	Yes	SCC	External Surface of Shell	Chloride concentration on the shell surface, under insulation	3 years
5	2009	304 SS	Boiler	Boiling Water	100	1 bar	Indoor, Chemical Site	Yes	SCC	External	Chloride concentration on the shell surface, under insulation	2 years
6	2011	304 SS	Condenser	Not used	NA	NA	Outdoor, Chemical Site	Yes	Iron contami-nation	Internal	Iron debris left by equipment fabricator	New
7	2011	304 SS	Large Storage Tank	Flammable Solvent	82	1 bar	Outdoor, Chemical Site	Yes	SCC	External	Chloride concentration under the bottom plate	7 years
8	2012	304 SS	Mixer	Organic Slurry with HCl acid	60	1 bar	Indoor, Chemical Site	No	SCC	Internal Screw Blade	Improper material selection for chloride and acidic condition	1 year
9	2012	316/316L SS	Tube	Organic solvent	20	10 bar	Indoor, Chemical Site	Yes	Pitting	External	Chloride concentration on the tube surface, under insulation	3 years
10	2012	304 SS	Reactor	lactic acid and others	50	10 bar	Indoor, Chemical Site	Yes	General Corrosion	Bolts of Agitator	Wrong material selection for the process	1 year
11	2012	304 SS	Heat Exchanger	HTF Oil/Organic Product	250	10 bar	Indoor, Chemical Site	Yes	Cracking due to Thermal Stress	Tube to tubesheet joint	Material selection not compatible with the high temperature cyclic operation	2 years
12	2013	304 SS	Plate Heat Exchanger	Boiler Water/ Cooling Water	90	4 bar	Outdoor, Chemical Site	No	SCC and Pitting	External	Chloride concentration between the gasket and the plates	3 years
13	2013	316L SS	Pipe	Water Solution of NaCl and Sodium Glycolate	120	5 bar	Indoor, Chemical Site	Yes	SCC	External	Chloride concentration on the pipe surface, under insulation	1 year
14	2013	304L SS	Pipe	Polymer	NA	NA	Indoor, Chemical Site	No	Stress cracking due to high pressure water cleaning	Internal	High pressure overload	3 year
15	2014	304 SS	Steam Condenser	Steam/Hot Water	80 - 100	1 bar	Indoor, Chemical Site	Yes	SCC	External	Chloride concentration on the shell surface, under insulation	5 years
16	2015	304 SS	Heat Exchanger	Steam	110	1.4 bar	Outdoor, Chemical Site	Yes	SCC	External	Chloride concentration on the shell surface (expansion Joint), under insulation	3 years
17	2015	304 SS	Centrifugal Separator	Slurry with 25800 ppm Cl-	60	10 bar	Indoor, Chemical Site	No	SCC and Pitting	Internal	Improper material selection for high chloride process	1 year
18	2015	304 SS	Valve	Polymer	100	5 bar	Indoor, Chemical Site	Yes	Stress Cracking due to Overload	Valve Stem	Improper material selection for the high stress condition	1 month
19	2015	304 SS	Mixer	Al(OH)3 Slurry	40	1 bar	Indoor, Chemical Site	No	Fatigue Cracking	Internal Screw Blade	Design and material selection not compatible with the slurry operation	1 year
20	2015	304 SS	Heat Exchanger	Organics/Cool-ing Water	170	10 bar	Indoor, Chemical Site	Yes	Cracking at the tube to tubesheet joint	Internal	Manufacturing defect during tube to tubesheet welding	3 months
21	2016	304 SS	Bolt	NA	Ambient	Ambient	Indoor, Chemical Site	No	Intergranular Corrosion Induced by Chloride	External	Chloride in the indoor environment	4 years
22	2016	304 SS	Valve	H2	Ambient	10 bar	Indoor, Chemical Site	No	Cracking due to internal voids	External	Manufacturing defect due to improper casting	4 years
23	2016	304 SS	Heat Exchanger	HCl/Cooling Water	90	2 bar	Indoor, Chemical Site	No	Intergranular Corrosion by HCl	Internal	Improper material selection for HCl service	1 year
24	2016	304 SS	Steam Condenser	Steam/Hot Water	90	1 bar	Indoor, Chemical Site	Yes	SCC	External	Chloride concentration on the shell surface, under insulation	1.5 years

FORTHCOMING CHANGES TO HIGH TEMPERATURE PROPERTY DATA

FOR FIRED HEATER TUBE MATERIALS IN API STANDARD 530 AND WRC BULLETIN 541

NATHANIEL G. SUTTON, MATERIALS & CORROSION STAFF ENGINEER II

E2G | THE EQUITY ENGINEERING GROUP

The Welding Research Council, Inc. (WRC) Bulletin No. 541 (WRC 541), entitled "Evaluation of Material Strength Data for Use in API Std 530," belongs to a series of WRC Bulletins containing detailed background information and material property data. These bulletins are used to support international codes and standards, including those of ASME and API. The first edition of WRC 541, published in 2013, was developed with API support for the 7th edition of API Standard 530, Calculation of Heater Tube Thickness in Petroleum Refineries (API 530). Although this title mentions refineries, the scope of the standard includes fired heaters in the petroleum, petrochemical, and natural gas industries.

Since the initial publication of WRC 541, various updates and expansions have been made. Throughout late 2020 and early 2021, the authors of WRC 541 have worked closely with the API 530 task group to incorporate recent changes. This article provides historical context and an overview of some significant upcoming changes. These updates are expected to be contained in Addendum 2 to the 7th Edition of API 530 when it is released.

API-WRC Interaction and Historical Background

Prior to API 530's use of the WRC 541 properties, they are reviewed by the API-ASME Fitness-for-Service Joint Committee (FFSJC, API 579). Once accepted, the material properties contained within API 530 are referenced from WRC 541. The all-important elevated temperature material allowable stresses shown in the standard are determined using the bulletin's properties. The task of reviewing and interpreting the bulletin's guidance and developing allowable stresses falls to the API 530 task group. Prior to the recent revisions, there was historically little direct interaction between the authors of WRC 541 and the API 530 task group.

The current collaboration has benefited both entities. WRC has received additional technical review and, as a result, is presently working on an Addendum to the third edition. API has had the opportunity to directly obtain clarification, interpretation, and implementation guidance from WRC.

Prior to the first edition of WRC 541, the allowable stresses in API 530 were mostly based on data compiled between the 1940s and 1970s. This effort was performed by the Metal Properties Council (MPC – later, the Materials Property Council) and its predecessor, the ASTM-ASME Joint Committee on the Effects of Temperature on the Properties of Metals. Data collected in the United States was published originally as ASTM Special Technical Publications (STPs) and later as ASTM Data Series (DS) documents. A major goal of the first edition of WRC 541 was to expand the database to include modern commercial heats from international data sources. To keep WRC 541 current, WRC has continued to support updates, revisions, and additions to the document since the first edition.

Recognition of New Alloys

Alloy manufacturers continually perform research and development work aimed at addressing and overcoming challenges encountered in operating facilities. In addition to creep, thinning damage mechanisms continue to limit heater tube service life. Such mechanisms include high temperature sulfidation, H2/H2S corrosion, high temperature oxidation, and others. Seemingly straightforward alloying element increases may not effectively mitigate these mechanisms. Moreover, increased alloy content may facilitate other, more complex damage mechanisms, such as thermal aging/embrittlement and stress corrosion cracking. New materials introduced in WRC 541 must already have ATSM and ASME approval prior to being recognized by WRC and API. ASME approval typically entails a Code Case, most commonly to Section I or Section VIII. ASTM approval involves adding the new alloy as a unique grade in an existing specification or publication of a new specification, as applicable. The following paragraphs describe two materials added in the third edition of WRC 541. A third material, Grade 921 (9Cr-2Si-1Cu), UNS K91201 is currently being considered for addition.

Two new alloys were recognized in the third edition of WRC 541. These alloys have recently gained interest for use in refinery fired heater applications. The first is Advanced 347AP (Nippon-Sumitomo Tradename) Stainless Steel, UNS S34752. This alloy is distinct from Type 347LN, UNS S34751, which has been recognized in ASTM and ASME for over a decade and listed in WRC 541 and API 530 for more than five years. 347LN aims to mitigate polythionic acid SCC (PASCC) through columbium stabilization ("347") and low carbon content (<0.02 wt%, "L") while maintaining creep strength through nitrogen additions ("N") – hence, "347LN". In fact, the tradename for 347LN, 347AP, is short for 347 Anti-Polythionic. Advanced 347AP similarly resists PASCC through low carbon and columbium stabilization, but also contains boron and copper in addition to nitrogen to match or exceed the creep strength of traditional 347H. WRC's analysis of Advanced 347AP is documented in WRC Bulletin 582.

The second alloy added in the third edition of WRC bulletin 541 is Alloy 115 (10.5Cr-V), Tenaris Tradename Thor-115, UNS K91060. This is a creep strength-enhanced ferritic steel, with increased chromium compared to traditional 9Cr-1Mo or grade 91 (9Cr-1Mo-V). The elevated chromium tends to provide better oxidation and sulfidation resistance over the 9Cr materials. However, chromium increases are limited to avoid metallurgical embrittlement (alpha-prime formation, 885°F embrittlement and rapid Z-phase

> CONTINUED ON PAGE 20

formation) experienced in higher-Cr materials. Carbide and carbo-nitride formers (vanadium, niobium) are added to provide similar creep strength to grade 91. WRC's analysis of Alloy 115 is documented in WRC Bulletin 576.

Introduction of the Creep Rupture Design Factor

The third edition of WRC 541 introduced the Creep Rupture Design Factor, F_{CR}. The intent of this factor is to allow greater flexibility in the use of materials when the high temperature rupture data are limited. Prior to the third edition, no margin was placed on the allowable stresses in the time-dependent regime. In other words, the API 530 allowable stresses were based on 100% of the minimum stress to produce rupture in the stated design life. The maximum temperature limits for alloys were set based on the temperature range of the available data. WRC recently published Bulletin 546, containing the guidelines historically used for evaluation of new materials for API 530. These include required number of heats, compositional and thermo-mechanical processing variability between heats, number, temperature, and stress range of tests, and requirements for minimum rupture time and maximum creep rates.

Generally, some data are available over the entire temperature range considered for a new material. However, available data perhaps may not meet 100% of the guidelines in WRC Bulletin 546, especially at the upper end of the temperature range considered. For example, if data at the top of the temperature range were limited, then historically, the stress curves were simply not extrapolated into that range. Thus, the alloy was not permitted for those design temperatures.

It is recognized that the process of collecting additional creep data is expensive and can require multiple years. Furthermore, our industry generally desires flexibility to allow early implementation of new alloy technology. Considering these views, the F_{CR} factor was introduced in WRC 541. Alloys can still be used in temperature ranges where the available data may not strictly meet the minimum WRC 546 requirements. At these temperatures, an F_{CR} factor of less than 1.0 is applied to the time-dependent allowable stresses to ensure appropriately conservative designs.

In particular, this factor impacts the use of the 300-series "L" Grade stainless steels (304L, 316L, 317L). Since the L-grade stainless steels were not originally developed with high temperature creep-limited service in mind, very little creep data were collected for them. Most large-scale creep testing and data collection efforts by ASME, ASTM, and others (e.g. the Japanese National Institute for Materials Science, NIMS)

have focused on the straight or "H" grades of the 300-series stainless steels. In the 6th edition (2009) of API 530, the maximum temperature for L-grade alloys was 1500°F. The first edition of WRC 541 (2013) listed a maximum use temperature of 1500°F for these alloys, with a note that the maximum temperature for creep-governed designs should be limited to 1100°F. This cautionary note is intended to warn designers against relying on 100% of the creep strength curve above 1100°F. The API 530 committee incorporated similar caution by lowering the maximum temperature for the L-grades to 1300°F in the 7th edition (2015), and further lowering this limit to 1100°F in Addendum 1 to the 7th Edition (2019). The progressive lowering of the temperature limit for the L-grades caused concern for companies presently using the alloys above this limit.

The F_{CR} factor of 0.8 was selected for the L-grades to match the ASME criteria of 80% minimum stress for rupture, used in determining ASME allowable stresses. This approach permits use of L-grades up to 1500°F, while maintaining conservatism in new designs. For some newly-recognized materials, the F_{CR} factor allows the alloy to be placed in service while the manufacturer continues to collect long-term creep rupture data. The F_{CR} factor is incorporated into the allowable stress tables and curves of API 530, meaning that no additional calculation/application by the user of API 530 is needed. This factor is not intended to be applied in fitness-for-service or creep remaining life assessments of existing heater tubes or other high-temperature equipment after installation.

Other updates, which are not discussed in this article, have been made to WRC 541. MTI members are encouraged to reach out to the author for additional details or with questions or comments. ▪

EXTERNAL CORROSION AND CRACKING OF STAINLESS STEEL EQUIPMENT AND PIPES

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2. Educate the site personnel to recognize the warning signs of CUI and take action at an early stage to prevent the catastrophic failures.
3. Provide maintenance guidance for stainless steel equipment and piping to reduce the potential for external corrosion and cracking.

In addition to common stainless steels, the author has been conducting failure analyses on many other common materials of construction for chemical sites, including carbon steels, duplex stainless steels, superaustenitic stainless steels, nickel alloys, copper alloys, wear resistant alloys, high temperature materials, and non-metals. Of course, different materials have very different failure mechanisms. The author hopes to have a chance to share these experiences in future articles. ▪

CASE #20

CASE #23

ATMOSPHERIC CORROSIO OF STAINLESS STEEL IN M

Results of a Field Exposure Program in Sweden

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AVESTA RESEARCH CENTRE, OUTOKUMPU STAINLESS AB, AVESTA, SWEDEN

N RESISTANCE
ARINE ENVIRONMENT

Stainless steels are often found in process industries because of their high resistance to many corrosive environments. While the main concern may be the corrosivity of different process streams, the risk for external degradation from atmospheric corrosion cannot be neglected. Atmospheric corrosion occurs in the presence of a thin aqueous layer on the metal surface combined with pollutants from the atmosphere. The type of corrosion is most commonly local in the presence of chlorides, i.e. pitting or crevice corrosion [1-5]. The grade selection must be adequate for the required performance. There are two main factors that affect atmospheric corrosion resistance of stainless steel: the characteristic properties of the stainless steel used and the actual environmental conditions. In marine environments, the conditions may be especially demanding. Selecting a suitable grade for such environments requires knowledge of the actual atmosphere of the application. This article is based on data from a 6.5-year atmospheric corrosion field study performed at a Swedish marine test site, Bohus-Malmön. This site was chosen because of the lack of relevant information for stainless steel used in a marine climate in Northern Europe. Results are discussed in the light of the current understanding of the factors affecting atmospheric corrosion of stainless steel.

Materials and Test Site

Welded and flat sheet rectangular coupons (size 150 x 100 mm) of nine different grades were used in this study. The characteristics of the materials and the welding parameters are given in Tables 1 and 2.

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Table 1 ***The Characteristics of Stainless Steels***

Stainless Steel	UNS Designation	Surface Finishes	Typical Chemical Composition, %wt						PREN*
			C	Ni	Cr	Mo	N	Other	
Ferritic	S40977	2E	0.02	0.5	11.5	-	-	-	12
	S43000	2B	0.05	-	16.2	-	-	-	16
	S44400	2B	0.02	-	18.0	2.0	-	Ti, Nb	25
Austenitic	S30403	2B	0.02	8.1	18.1	-	-	-	18
	S31603	2B	0.02	10.1	17.2	2.1	-	-	24
Duplex	S32101	2E	0.03	1.5	21.5	0.3	0.22	5Mn, Cu	26
	S32304	2E	0.02	4.8	23.0	0.3	0.10	Cu	26
	S32205	1D	0.02	5.7	22.0	3.1	0.17	-	35

Note: PREN = %Cr+3.3%Mo+16%N, 1D: Hot rolled, heat treated, mechanically descaled through shot blasting and pickling, 2B: Cold rolled, heat treated, pickled, skin passed, 2E: Cold rolled, heat treated, mechanically descaled through shot blasting and pickling

Table 2 ***Welding Condition of Welded Coupons***

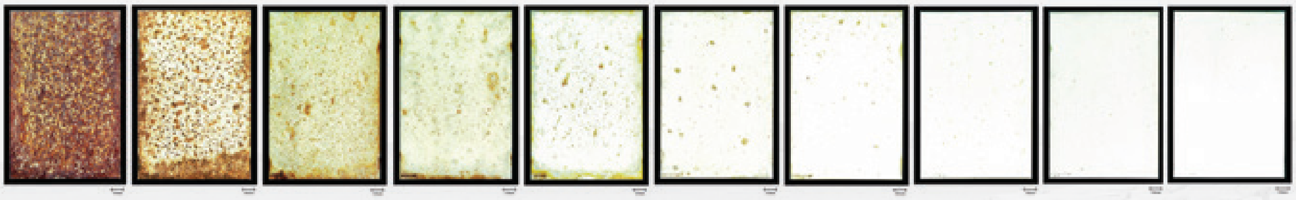
Base Material	Welding Method	Welding Wire (EN ISO designation)	Shielding Gas	Joint Design	Post-Weld Treatment
S40977	GTAW	W 19 9 L Si	Ar	Bead on plate	Mechanically polished
S43000	GTAW	W 19 9 L Si	Ar	Bead on plate	Mechanically polished
S44400	GTAW	W 19 9 L Si	Ar	Bead on plate	Mechanically polished
S30403	GTAW	W 19 9 L Si	Ar	Bead on plate	Pickled
S31603	GTAW	W 19 12 3L Si	Ar	Bead on plate	Pickled
S32101	GTAW	W 23 7 N L	Ar + 2%N2	Butt joint	Pickled
S32304	GTAW	W 22 9 3 N L	Ar	Bead on plate	Pickled
S32205	FCAW	T 22 9 3 N L R	Mison® 18	Bead on plate	Shot blasted and pickled

Note: GTAW: Gas tungsten arc welding, FCAW: flux cored arc welding, Ar: Pure argon gas, MISON® 18 (Linde): Ar + 18% CO2 + 0.03% NO

FIGURE 1 Test site and atmospheric coupons after 6.5 years of exposure.

(1a) Open condition | (1b) Sheltered condition

FIGURE 2



RN 0	RN 1	RN 2	RN 3	RN 4	RN 5	RN 6	RN 7	RN 8	RN 9
100%	69%	47%	32%	22%	15%	2.7%	0.41%	0.062%	0.0093%

Relationship between rating number (RN) and total area of rust and stains in accordance with JIS G 0595 and ISO/DIS 23721 standards [8, 9]

The cut edges were dry ground (320 grit) to minimize edge attack. The coupons were thereafter marked on the exposed side and cleaned before mounting [6].

The test site is located at the west side of Kvarnvik station in Bohus-Malmön on the west-coast of Sweden. The field test was performed from October 2009 to June 2016 (6.5 years). The racks were located less than 10 meters from the coast of the North Sea. The coupons were exposed in open and sheltered conditions at an angle of 45 degree and orientated to the south, facing the sea, see Figure 1. Duplicate coupons were exposed for most of the steel grades.

EVALUATION AND ANALYSIS OF CONTAMINATION

All tested coupons were cleaned with water, followed by a short rinse in acetone before evaluation. Two criteria were chosen for evaluation of atmospheric corrosion resistance [2, 3]. The first is the ranking of the corrosion resistance based on the number of pits and the maximum depth of pitting attack on the flat surface or welded area under a microscope. Corrosion attacks shallower than 25 μm are classified as surface etching and are therefore excluded [7]. Edge attacks have also been disregarded. The second criterion used was a visual rating of the aesthetic degradation in terms of the extent of rust and stains on the exposed surfaces in accordance with JIS G 0595 and ISO/DIS 23721 standards [8, 9]. The area around the welds were excluded when evaluating the appearance rating. The average RN was calculated from two values obtained from two different evaluators. The relationship between the RN and percentage of the specimen area with rust and stains is shown in Figure 2.

The deposited particles were collected before cleaning from some of the exposed coupons after 6.5 years exposure for evaluation of contamination of the stainless steel surfaces. The soluble contents of the deposits were dissolved in demineralized water by using ultrasonic cleaning. The resulting solutions were analyzed by ion chromatography for anions, such as chlorides, sulphates and nitrates [10,11].

The Presence of Contamination of Stainless Steel Surfaces

The analysis of the dissolved deposits shows that the amount of soluble species was higher in the sheltered condition than in the open condition, as shown in Figure 3. The difference is especially noticeable for the chloride ion which is about 30 times higher in the sheltered conditions. The main cause of this is most likely that there is no washing by rain in the sheltered condition, which often leads to higher levels of surface deposits.

Effect of Alloy Composition

The effects of alloy composition on the atmospheric corrosion performance of the various stainless steel grades are summarised in Table 3, while images of coupons are given in Figure 4. In this part of the article, the corrosion properties of the base material are in focus, so the welded areas were disregarded. Two types of corrosion morphology were observed on the exposed surfaces of base material: uniform corrosion and pitting corrosion. The uniform corrosion was noticeable on the S40977, which has a chromium content of only 11.5%wt. The uniform corrosion attack on S40977 has developed from severe pitting, which has merged into a uniform attack with time. Pitting corrosion was observed on all grades, except S32205, which exhibited the highest resistance to pitting corrosion of the different grades investigated. The number of pits was more than 20 for most of the grades, and the maximum pit depth depended on the alloying level and exposure condition. Three types of degradation were distinguished on the exposed coupons: discoloration, staining and red rust. Grade S40977 was covered with 100% red rust (RN 0) for both exposure conditions (see Figure 4). The grades S40977, S43000, S44400, S30403, S31603, S32101 and S32304 exhibited discoloration, red rust and stains on the exposed coupons. The spotty red rust and staining severely reduces the aesthetic appearance. For the more resistant grade S32205, discoloration is the main form of surface degradation in the sheltered condition. The chloride ions in the atmosphere were found to be the main cause of pitting corrosion and surface degradation. In the marine test environment, it is necessary to use high chromium and molybdenum containing stainless steel, such as grade S32205, to prevent corrosion and surface degradation. The results give good agreement with the corrosion resistance class (CRC) system in the Eurocode 3 standard (EN 1993-1-4:2006+A1:2015) and the Design Evaluation System tool-IMOA program [12, 13].

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FIGURE 3 ***The amount of soluble anions found in deposits on the exposed coupons after 6.5 years***

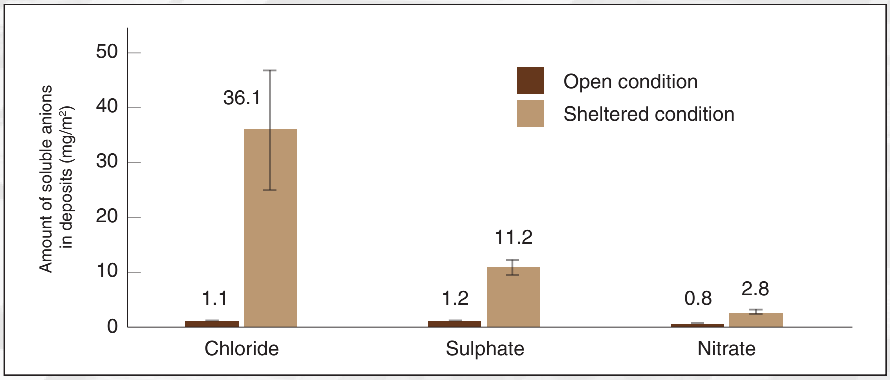
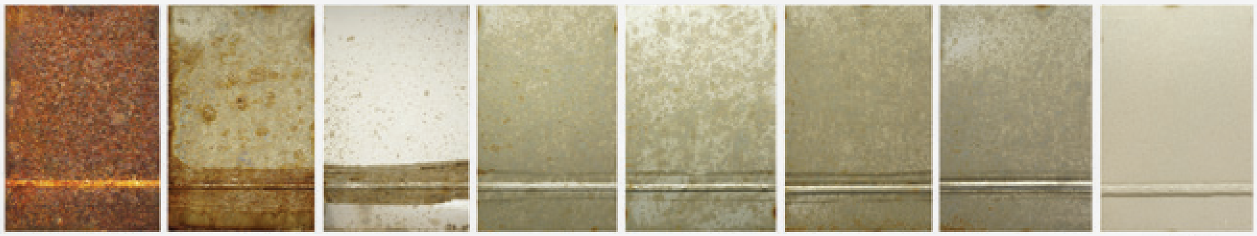


Table 3 ***Overview of Rated Test Results (p = number of pits)***

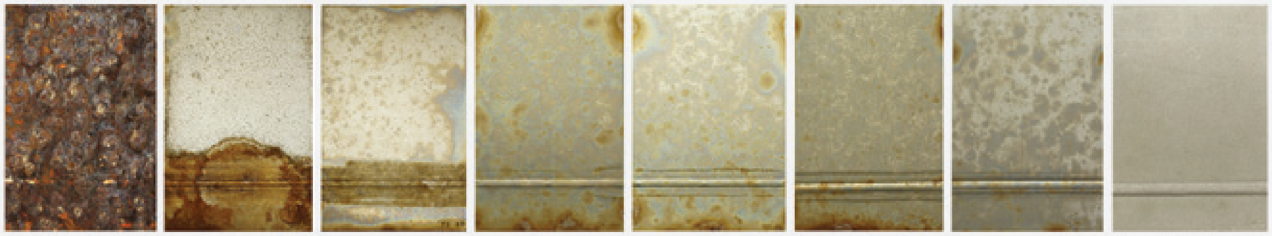
Stainless Steel	UNS Designation	Surface Condition	Corrosion Performance on Base Material				RN	
			Open Condition		Sheltered Condition		Open Condition	Sheltered Condition
			Max. Pit Depth	Max. Number of Attack	Max. Pit Depth	Max. Number of Attack		
Ferritic	S40977	2E	Uniform	Uniform	Uniform	Uniform	0	0
	S43000	2B	170 µm	>20p	150 µm	>20p	2	3
	S44400	2B	55 µm	>20p	54 µm	>20p	4	3
Austenitic	S30403	2B	70 µm	>20p	150 µm	>20p	2	1
	S31603	2B	85 µm	>20p	130 µm	>20p	3	2
Duplex	S32101	2E	90 µm	>20p	112 µm	>20p	2	1
	S32304	2E	85 µm	>20p	168 µm	>20p	2	3
	S32205	1D	No pitting	0p	No pitting	0p	9	9

FIGURE 4



S40977 Polished weld | S43000 Polished weld | S44400 Polished weld | S30403 Pickled weld | S31603 Pickled weld | S32101 Pickled weld | S32304 Pickled weld | S32205 Shotblasted and pickled weld

(4a) Open condition



S40977 Polished weld | S43000 Polished weld | S44400 Polished weld | S30403 Pickled weld | S31603 Pickled weld | S32101 Pickled weld | S32304 Pickled weld | S32205 Shotblasted and pickled weld

(4b) Sheltered condition

Appearance of the tested stainless steel grades after 6.5 years of exposure (The horizontal lines in the lower half of the images are welds)

Table 4 *Overview of Rated Test Results (p = number of pits)*

UNS Designation	Surface roughness, Ra (micron)	Corrosion Performance on Base Material				RN	
		Open Condition		Sheltered Condition			
		Max. Pit Depth	Max. Number of Attack	Max. Pit Depth	Max. Number of Attack	Open Condition	Sheltered Condition
S32101	0.2	45 µm	>20p	100 µm	>20p	5	4
	0.5	48 µm	>20p	98 µm	>20p	4	3
	0.8	38 µm	>20p	77 µm	>20p	3	1

Effect of Surface Roughness

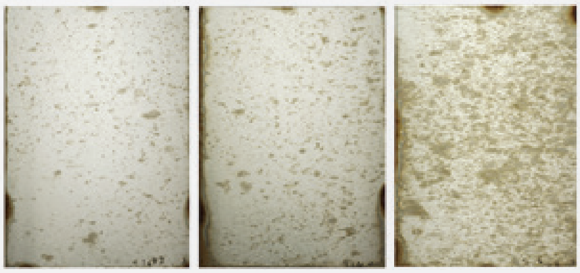
In order to understand the effect of surface roughness on the degradation of the stainless steel surface in the Swedish marine environment, three different surface roughnesses, Ra: 0.2, 0.5 and 0.8 µm, of duplex S32101 were exposed. A surface roughness of Ra ≤ 0.5 µm is often recommended for use in a highly corrosive environment [14]. The results demonstrate that a smooth surface has a beneficial effect on surface degradation. A smooth surface finish (Ra 0.2 µm) retains less rust or staining and provides a better appearance than a rougher surface (Ra 0.5 and 0.8 µm), see Table 4 and Figure 5. The higher degree of degradation of the specimens with a rougher surface became obvious, particularly when there is no cleaning (sheltered). In term of corrosion performance, no significant effect of surface roughness on depth of pit attack was observed. On the other hand, the difference in pit depth could clearly be seen between the open and sheltered exposures with deeper attacks for the sheltered. This supports the conclusion that a smooth surface can be used in combination with appropriate alloy selection to achieve the desired long-term corrosion performance.

Effect of Post-Weld Treatment

The effect of different surface treatments after welding on the corrosion resistance of stainless steel has been investigated on S31603, S32101 and S32205. Two different types of welded coupons were prepared: as welded and laboratory pickled weld for S31603 and S32101. For S32205, two different types of welded coupons were tested: as welded and post-weld cleaned by shot blasting and pickling in the laboratory. The results (see Table 5 and Figure 6) demonstrate that there is no significant difference in maximum pit depth in the weld

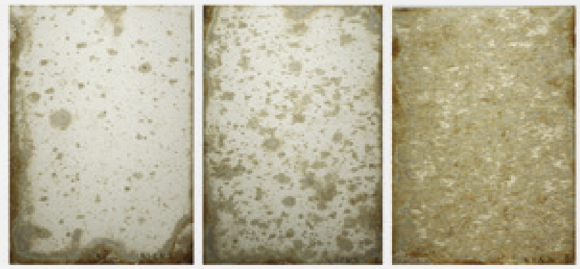
> CONTINUED ON PAGE 28

FIGURE 5



Ra 0.2 µm RN 5 | Ra 0.5 µm RN 4 | Ra 0.8 µm RN 3

(5a) Open condition



Ra 0.2 µm RN 4 | Ra 0.5 µm RN 3 | Ra 0.8 µm RN 1

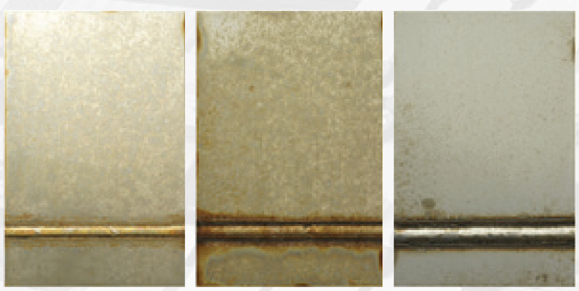
(5b) Sheltered condition

Appearance of the duplex grade S32101 with different surface roughness after 6.5 years of exposure.

Table 5 *Overview of Rated Test Results (p = number of pits)*

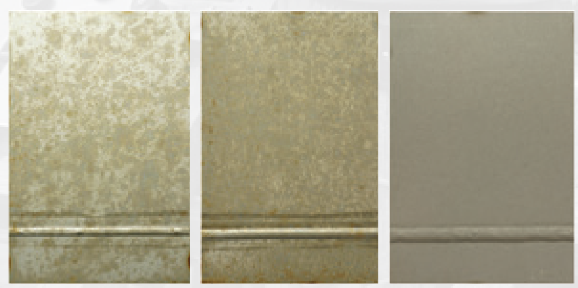
UNS Designation	Surface Treatment	Corrosion Performance in Welded Area			
		Open Condition		Sheltered Condition	
		Max. Pit Depth	Max. Number of Attack	Max. Pit Depth	Max. Number of Attack
S31603	As welded	90 µm	>20p	180 µm	>20p
	Pickled weld	85 µm	>20p	120 µm	>20p
S32101	As welded	160 µm	>20p	125 µm	>20p
	Pickled weld	75 µm	>20p	120 µm	>20p
S32205	As welded	No pitting	0p	No pitting	0p
	Shot blasted and pickled	No pitting	0p	No pitting	0p

FIGURE 6



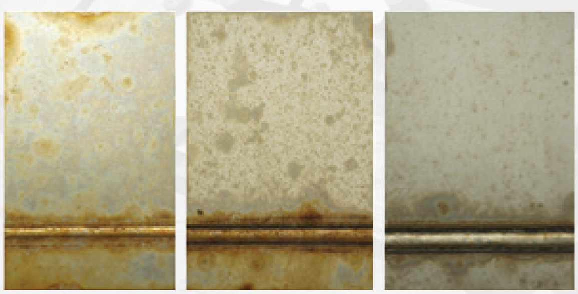
S31603 | S32101 | S3205

(6a) As-welded, open condition



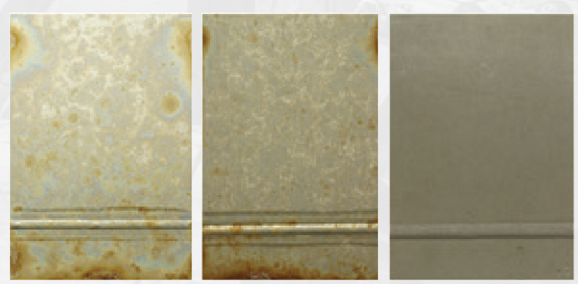
S31603 | S32101 | S32205

(6b) Post-weld cleaning, open condition



S31603 | S32101 | S32205

(6c) As-welded, sheltered condition



S31603 | S32101 | S32205

(6d) Post-weld cleaning, sheltered condition

Appearance of grade S31603, S32101 and S32205 after 6.5 years of exposure.
(The horizontal lines in the lower half of the images are welds.)

areas for S31603 and S32101. Significant difference in pit depth can be seen between the open and sheltered condition, with deeper pits for the sheltered one. For S32205, no pitting was observed in the weld areas for both as welded and treated surfaces. In terms of appearance, it can clearly be seen that the post-weld treatments are beneficial. Acid pickling removes the oxide scales formed during welding process from the steel surface. This will restore the passive layer and form a clean and corrosion resistant surface. In case of S32205 the sandblasting is used before pickling of the weld because the oxide scale is too thick and exhibits high chemical resistance. The sandblasted and pickled surface has a very rough surface (Ra ~6 μm) which can be compared with the original 1D surface (Ra ~3 μm). Even if the sandblasted and pickled surface is very rough, it still exhibits a higher corrosion resistance than the original 1D finish with the weld oxide left on the surface [2].

Effect of Exposure Condition

Stainless steel exposed in open or sheltered environments can give differences in corrosion performance and aesthetic degradation. Exposure condition must be taken into consideration when aesthetic performance is valued. A sheltered condition that is not cleaned accumulates dust and deposits of aggressive species, which can create a more aggressive environment. The obtained field results, as well as the analysis of the surface deposits, clearly indicate that the sheltered condition was more severe compared to the open condition, facilitating corrosion of susceptible stainless steels. This result is in agreement with the general observation from other European tests [5] showing that regular washing of exposed specimens by rainfall results in less staining than on those specimens which are sheltered.

CONCLUSIONS

- In the Swedish marine environment, it is necessary to use the higher alloyed grade S32205 for adequate atmospheric corrosion resistance, which give good agreement with the Eurocode 3 standard and the IMOA guide.
- Three types of aesthetic degradation were observed: discoloration, staining and red rust. Degradation mainly from red rusting and staining was observed for S40977, S43000, S44400, S30403, S31603, S32101 and S32304 and discoloration for the higher alloyed grade S32205.
- A finer surface finish in combination with appropriate alloy selection should be used to achieve the desired long-term corrosion performance. A surface roughness of Ra ≤ 0.5 μm is recommended for best aesthetic performance in Swedish marine environment.
- To achieve the best atmospheric corrosion performance, the surface should be clean and free of contamination. Post-weld cleaning gives an improvement against surface degradation in the weld areas.
- Stainless steels exposed in sheltered conditions showed less corrosion performance and a higher degree of surface degradation than in open conditions. The factors that contribute to this difference: no cleaning (no rain washed), and high deposition of chloride leading to corrosion in the sheltered conditions.

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RFID TECHNOLOGY FOR WEAR MONITORING OF NON-METALLIC PIPES

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In the Canadian oil sands industry, the bitumen-containing sand is mixed with water, and the resultant slurry is transported through pipelines. Due to the abrasive nature of solid particles in the slurry (slurry can contain solid particles up to five inches in size), pipeline wear has been a major issue. Due to excellent abrasion and corrosion resistance, the use of non-metallic pipe components, such as rubber hoses and elastomer-lined steel pipes, has increased. To achieve long wear life, thick elastomeric liner of 1-2 inches has been used in non-metallic pipes. Wear monitoring of pipeline is critical in asset integrity management; however, there are limited technologies available for non-metallic pipes. For example, embedded continuity wire system has been popularly used for rubber hoses, where copper wires are spirally wound to cover the entire rubber hose and embedded inside the liner at certain liner depths. As liner wear progresses, the embedded wire is exposed to coarse particles in the slurry, then the wire breaks with further progress in liner wear leading to loss of electric continuity. Therefore, if no electric current is detected through an embedded wire, it can be assumed the liner is worn out beyond the liner depth where the specific wire is embedded. However, this technology cannot tell the exact location of liner wear. Also, this technology can provide "go/no go" type of information only; once a wire is broken in one location, the entire wear monitoring capability is lost. In addition, the sensor system using continuity wires tends to break down often during handling and installation.

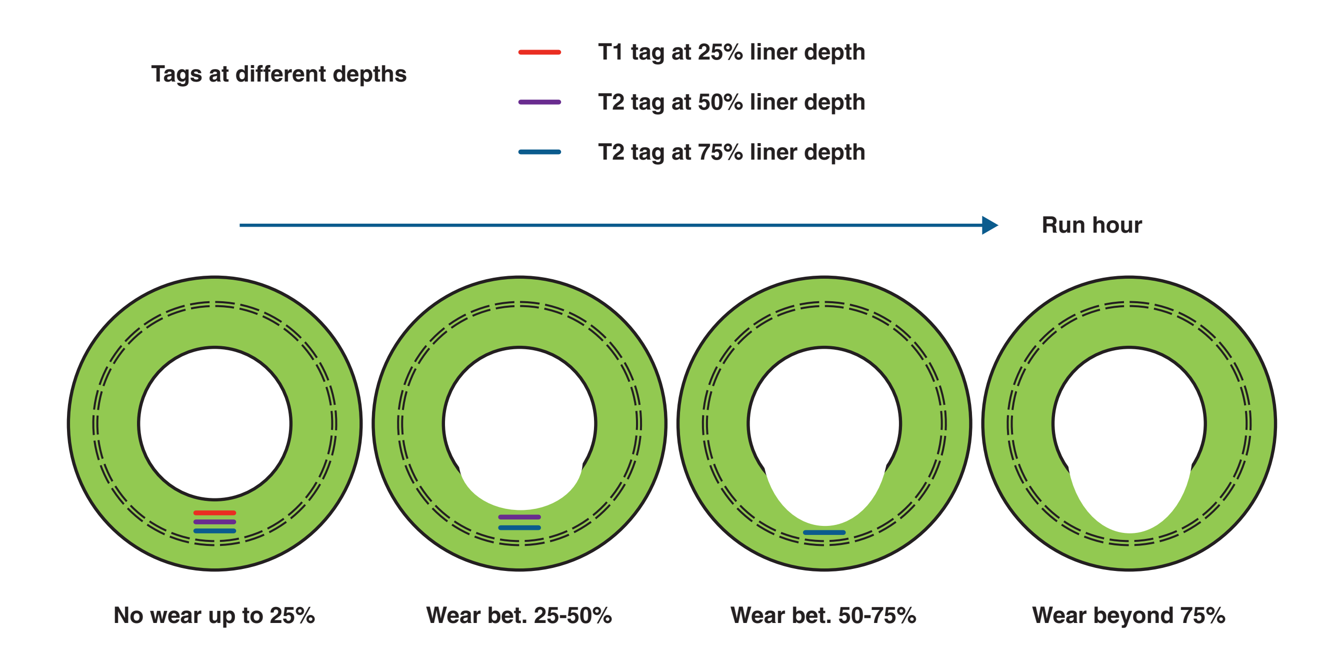
Radio frequency identification (RFID) is an automatic identification and data collection technology utilizing programmable tags. RFID technology has been used mainly for tracking and tracing purposes; however, Syncrude Canada Ltd. developed a novel wear monitoring concept by using RFID tags. RFID tags, which are programed with individual ID and location information, are embedded at different axial and circumferential locations inside the liner of non-metallic pipes. If a tag can be scanned, the specific location where the tag is embedded can be assumed intact. If a tag cannot be scanned, the specific

> CONTINUED ON PAGE 30

location where the tag is embedded can be assumed to have been worn out. Therefore, the exact wear location can be identified by checking existence or absence of the embedded tags. Tags can also be embedded at different liner depths at the same location, and by tracking the tags along the liner thickness, progressive wear monitoring can be achieved. Figure 1 describes the progressive wear monitoring concept, where three tags are embedded at three different liner depths (T1 at 25% liner depth, T2 at 50%, and T3 at 75%). If all tags are detected, it can be assumed the liner wear did not progress up to 25% liner depth. If only T2 and T3 tags are detected, it can be assumed the liner wear progressed between 25% - 50% liner depth, and so on. Wear monitoring of rubber hoses can be done by external or internal scanning since RFID signal can penetrate through rubbers and fabrics. However, RFID signal cannot penetrate through steel pipes, so wear monitoring of lined pipes can be done only by internal scanning (e.g. use of smart pigs). Syncrude Canada Ltd. was awarded a Canadian patent on this technology (CA 2922137).

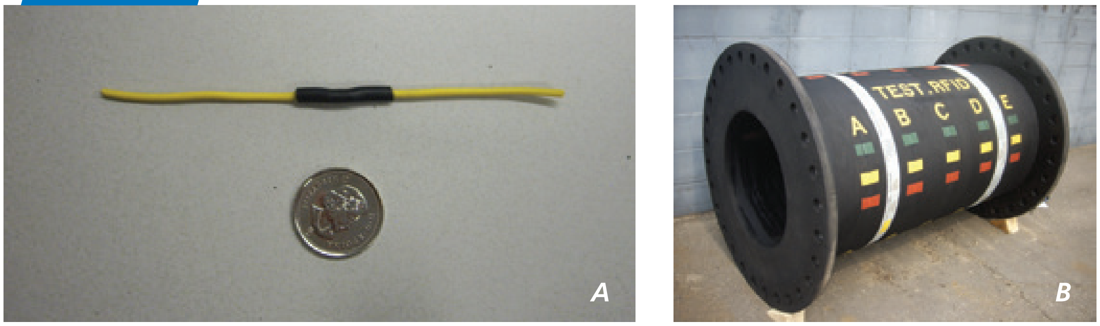
Rubber hoses were targeted for the development of external wear monitoring technology using RFID tags. RFID tags are categorized into two: active and passive. Passive tags, although they have shorter read range compared to active tags, are much smaller in size and more suitable to be embedded into rubber hoses. Therefore, passive RFID tags were selected. The following two uncertainties were identified. Manufacturing of rubber hoses requires a curing process, which is typically done at high temperature and pressure in an autoclave. The first concern was possible damage to the embedded tags during the hose manufacturing process. Slurry hoses being used in Canadian oil sands are thick-walled (in the range of 4 -7 inches depending on hose size, pressure rating, etc.) and significant signal attenuation was expected while RFID signal travels through the thick wall of rubber hoses. The second concern was lack of signal from external scanning as the result of signal attenuation. To rectify those concerns, prototype rubber hoses were manufactured and dipole-style ultrahigh frequency (a band from 860 MHz to 960 MHz) RFID tags were embedded in the hose. Tags could be read via internal scanning, suggesting tags were not damaged during the manufacturing process. However, the embedded tags couldn't be read via external scanning, which was partially due to serious signal attenuation while traveling through the thick-walled rubber hose. It was also found that carbon black, a filler being added to rubber compound, detuned the RFID signal. Dr. Patrick King from TROI suggested adjusting the length of the antenna to optimize the reading distance specifically for the environment surrounding the embedded tags. RFID tags with different antenna lengths were embedded into a prototype rubber hose and their reading distances were measured. As a result, an optimum tag design could be determined. When scanned from outside of the test hose, the modified tags produced the reading distance of one foot or more. The tag and the

FIGURE 1



Conceptual drawing showing progressive wear monitoring concept. By monitoring tags at different liner depths in the same location, timing for pipe rotation or replacement can be determined.

FIGURE 2



RFID tag (CC-71 from TROI) and prototype rubber hose, which were used to prove the concept and to optimize tag design. A penny was added for size comparison in A.

prototype rubber hose in use are shown in Figure 2.

To evaluate field performance of the RFID wear monitoring system, a total of 96 tags were embedded into a commercial rubber hose of 30 NPS, 42 ft. length, at eight locations along the length (A1 - A8), four locations around the circumference (12, 3, 6, and 9 o'clock positions), and three locations through the liner depth (25%, 50%, and 75%). All tags could be read during baseline scanning, which was conducted before hose installation, indicating the embedded tags were not damaged during hose manufacturing. The commercial rubber hose came with thicker wall (5 -7 in.) than the prototype hoses in the previous study, resulting in shorter reading distance of approximately 6 in. The test hose was installed in a S-shape configuration in a tailings line, as shown in Figure 3, and all the embedded tags could be scanned, suggesting tags were not damaged after significant bending during installation. Successful in-service RFID scanning demonstrated reliable wear monitoring of rubber hoses could be done by using the developed RFID technology. Further development is on-going in collaboration with National Research Council (NRC) in Vancouver, BC for the development of remote RFID wear monitoring system (Figure 4). This novel technology is expected to resolve the previous issue of limited wear monitoring capability of non-metallic pipes, contributing to improved asset integrity management through enhanced monitoring capability of the liner wear. ▪

FIGURE 3

The layout of the test spool in the field, showing eight tag locations along the spool length in yellow (A1 - A8).

FIGURE 4

Researchers at NRC in Vancouver, BC demonstrating remote RFID wear monitoring system in a laboratory (The picture was taken before the COVID-19 pandemic).

CURTIS HUDDLE APPOINTED TO MTI BOARD OF DIRECTORS

> CONTINUED FROM PAGE 3

generation of materials engineers and can advise the BOD on how to transfer knowledge most effectively to that generation," he states.

As part of that approach, Huddle plans to keep his eyes and ears open within the membership to stay abreast of current issues in the organization, as well as look into the root causes of issues to serve MTI more productively as a whole. He specifically would like to devote some time to the issue of knowledge management, which is affecting not only MTI, but the industry in general.

"I hope to give some insight into this issue and see it from a whole career perspective, from student to retiree, so that we can bridge the many gaps that are starting to open in our fields," he remarks. "If you have an issue that you need fixed, I hope you feel free to come to me or anyone on the BOD to let that issue be known," he concludes. ▪

Q&A WITH MARICELA JOHNSON

PROJECT CHAMPIONS

MTI is at the forefront of providing global leadership in materials technology to improve safety, reliability, sustainability and profitability. Technical research projects play a vital part in the success of the MTI mission. While the goal and outcome of each project varies, the overarching commonality is member leadership to develop and nurture each project from inception to completion. These member leaders, dubbed MTI Project Champions, have the unique opportunity to grow leadership skills, network and create tangible solutions alongside other industry professionals.

In this issue, CONNECT spoke with Maricela Johnson (Chevron) to learn more about her roles within MTI, her company and how her leadership experience of potential project 357 – Corrosion in Bio-Oils is progressing.

Q: ***Please describe your role at Chevron Corporation.***

A: I have been a Chevron Materials Engineer for 13 years and held numerous technical roles across different Chevron operating companies, including the central technical group supporting both upstream and downstream business units, site refinery materials engineer, and project materials engineer. I have also served as the program manager for Chevron's materials and reliability training for engineers and inspectors.

Q: ***How long have you been a member of MTI and how have you benefited from your involvement?***

A: I joined MTI as the TAC Representative and Designated Representative in February 2018. Technically, I have benefited immensely from the resources and technical support within the MTI community.

Q: ***Have your fellow MTI members helped you grow in your career and/or in your involvement with MTI? If so, how?***

A: I immediately felt an overwhelming sense of community. As a new TAC Rep and DR, I was unsure of how to approach my new role, but I immediately found mentors among my fellow MTI members and MTI staff. There is never a shortage of someone to talk to, share technical perspectives with, or have a meal with during the AmeriTAC meetings I have attended. I have built strong working relationships that have helped me develop both my technical and project management skills.

Q: ***How did you become a project champion? Please tell us how you came to take on this role and what skills and/or experience you believe can help the project and team succeed.***

A: During one of the PDC meetings, I proposed a potential project idea to have MTI help fill the industry knowledge gap on the topic of bio-oil corrosion. As alternative fuels and ways to lower carbon emissions become more widely explored by member companies, I thought MTI could help lead the industry

SPOTLIGHT

effort to bridge knowledge gaps. The idea was well received, and I was happy to volunteer to Champion the project.

I hope to help the project succeed by bringing my field materials engineering perspective to the table. My goal for the project is to have a better understanding of the impact that bio-oil processing and co-processing will have on the long-term reliability of process piping and equipment.

Q: *Tell us about the Corrosion in Bio-Oils (357) Project.*

A: The purpose of the project at its current potential stage is to better understand the corrosion associated with processing bio-oil feedstocks. This can affect both an existing unit looking to co-process or a newly designed unit. The project has a strong interest from owner/operators, consulting engineering companies, and suppliers. As processing alternative fuels becomes more common, understanding proper materials selection will become important across member companies.

Q: *How was the project idea conceived? Is the current state of the project the same as the original idea or how has it changed?*

A: The project is still in the potential phase with a strong interest from many member companies. We had a successful meeting in February 2021 and have started the process of bounding the frame for the scope of the initial phase of the project. Because bio-oil corrosion is a complex topic with many paths to research, the project team will start with a literature search focused on identifying free fatty acid corrosion data for lipid feed stocks. I am confident that as we learn more and develop project deliverables this will become a multi-phase project with many avenues available to explore.

Q: *Please explain what you have learned from your experiences as a team member of other MTI projects and how it has helped you as a project champion.*

A: As a team member in other MTI projects, I have observed how willing the MTI community is to offer insight and guidance to the projects every step of the way. I have been impressed at how different perspectives are respectfully and openly shared. As a project champion this has helped me develop my confidence in bringing my ideas to the table. I know I don't have to be an expert on the topic to offer my perspective, be a valued contributor or help lead the discussions. For the bio-oil topic, I am eager to develop both technically and as a project champion.

Q: *What are you gaining from this experience as a project champion?*

A: This is my first time as a project champion. Thus far, I've gained a more detailed understanding of how ideas become projects and look forward to going through the entire funding proposal process to provide a valuable deliverable to member companies. I have built a strong working relationship with Dr. Robert Freed (MTI) and with other members, and I know that I have strong support for a successful project.

Q: *Just for fun, so we get to know you outside of MTI: What is the best city you have ever visited and why?*

A: While in college I had the opportunity to spend a summer internship in Spain. I had friends interning all over Europe and we would plan weekend trips together to visit each other. By far my favorite city to visit was Rome, Italy. I immediately fell in love with the sights, the food (I had so much gelato), the rich and beautiful history. I had the opportunity to take a guided tour through the Vatican and still remember the awe I felt. I went to visit with my husband years later and it was great to experience it again through his first-time vantage point. I hope to visit again someday.

Q: *Briefly talk about one exciting/proud moment in your professional career.*

A: During my career I have had the opportunity to support two major capital projects. The first one was the installation of six new Coke Drums that were fabricated in Spain. The second major capital project was the fabrication of an entirely new hydrogen manufacturing unit. Both projects resulted in a strong feeling of accomplishment and allowed me to see projects through from early stages of planning, fabrication, and finally to feed in.

CONNECT thanks Maricela for taking the time to speak with us and for volunteering to champion the Corrosion in Bio-Oils project. MTI members interested in learning more information about the project or joining the team can visit the Corrosion in Bio-Oils Project 357 community at www.mti-global.org/communities. ■

Technical Awareness Bulletins (TAC Bulletins) published by MTI are brief industry-related topics that have evergreen value. The TAC Bulletins Committee develops ideas to produce new bulletin topics that will have an impact on MTI members and the industry, as well as regularly reviews and revises past bulletins to keep them up to date with best practices and industry standards.

In this issue of CONNECT, MTI is releasing Bulletin No. 7 – Corrosion Under Insulation and Bulletin No. 14 – Metal Specifications. Bulletins released to the public can be downloaded by visiting www.mti-global.org/participate/tac-bulletins.

Materials Technology Institute

Technical Awareness Bulletin

Corrosion Under Insulation | No. 7

1. What is Corrosion under Insulation?

Corrosion under insulation (CUI) is, as the name indicates, the corrosion or corrosion-related cracking that occurs under insulation and/or fireproofing. It is a major problem in all parts of the chemical processing industry, and constitutes a major portion of many plants' maintenance budgets. The corrosion can take the form of general corrosion, crevice corrosion, pitting or stress corrosion cracking. In carbon and low alloy steels, CUI is almost always general or localized corrosion in which there is a significant amount of metal loss. In stainless steels, general corrosion is unusual. Crevice corrosion or pitting can occur, but the most common problem is stress corrosion cracking, especially at welds and cold worked areas, without significant metal loss.

2. Why does it occur?

CUI occurs because of the combined action of three factors:

- Water and moisture penetrate and accumulate between the insulation and the equipment
- Other corrosive components dissolve in the water/moisture that collects
- The mixture of aqueous corrosives are held in place by the insulation allowing the corrosion to continuously progress.

A fourth factor that occurs in most cases is the elevated temperature of the insulated equipment that increases the rate of corrosion. However, elevated temperature is not always a factor: Carbon and alloy steel equipment with an operating temperature below the dew point or which cycles above and below 32°F (0°C) often suffers CUI even though the metal temperature may never rise above ambient. In all cases, the corrosion is hidden under the insulation and progresses unnoticed for long periods of time.

3. How is it prevented?

There is really no way to guarantee with 100% certainty that CUI can be prevented. However, two techniques can be employed to minimize and/or delay CUI (1) Stop the water and moisture from penetrating and accumulating in the insulation and (2) Use a coating or other protective barrier to stop the corrosive fluids from contacting the bare metal surface.

Prevent moisture from penetrating the insulation –

- Design insulation sheathing so that water runs off the insulation.
- Improve insulation system designs, especially on horizontal sections or at changes in direction where openings in the insulation often occur.
- Maintain caulking on joints.
- Avoid using insulated surfaces for walking, ladders, valve access, maintenance, etc.
- Use insulation that does not retain moisture, e.g. cellular glass or perlite in place of fiberglass.
- Use insulation that is free of potentially harmful substances, e.g. chlorides in fibrous insulation or halogenated expanding agents.
- In moderate temperature applications, operate the equipment without insulation. (Consider heat losses and personnel protection before adopting this method.)

Use a barrier coating to protect the equipment –

- Use a conventional paint on steel subject to CUI. Typically epoxies or epoxy-phenolic coatings are used. The upper temperature limit of the coating should be at least 250°F (120°C), but 300°F (150°C) or even 350°F (175°C) is preferred.
- Use aluminum foil wrap around on stainless steel piping or equipment beneath insulation. This provides both galvanic protection and a barrier protection for the metallic substrate. Consider one of the many insulating paints available today that might both protect the substrate and provide modest insulating properties.
- Use thermal-spray aluminum (TSA) on piping or vessels as a barrier coating and galvanic protection. It can be competitive or slightly more initially, but its life cost might be less expensive than conventional paints and coatings which have shorter service lives.
- Use galvanizing or other coating for structural steel under fireproofing. Avoid using galvanized steel in areas where the environment can be alkaline. Zinc and zinc-based coatings will corrode in alkaline environments.
- Build cages or physically restrict access to equipment in lieu of insulation and personnel protection.

4. How is CUI detected?

Plant personnel may consider two categories of inspection techniques, visual and the more sophisticated NDT techniques, usually performed with the insulation system still in place.

- Visual Inspection – Removing insulation for inspection is the simplest technique and most commonly used. It can be done rapidly and usually inexpensively, but areas of CUI can be overlooked. The inspector needs to be alert for staining and evidence of rusting as shown in the following photo. The inspector must also look closely at water ingress locations such as attachments, nozzles and structural supports which often penetrate the insulation weather barrier. In severe cases, corrosion of the aluminum weather barrier, as evidenced by pitting and white deposits, are indicative of CUI.

- The more sophisticated techniques involve the use of radiography, ultrasonic testing, infrared thermography and eddy current testing. These techniques have been used with varying degrees of success. The capability of these techniques and the associated costs are rapidly changing.
- Insulation removal is usually required for definitive confirmation of CUI. Guidance on defining the severity of service and the corresponding extent of insulation removal is included in the prevailing piping and equipment inspection codes API 570 and API 510, respectively.

References

NACE Standard RP0198-2004, “The Control of Corrosion under Thermal Insulation and Fireproofing Materials – A Systems Approach”

European Federation of Corrosion – Information is available on their Website under the topic, “Corrosion in the Refining Industry” and Working Party (WP) 15 http://www.efcweb.org/WP_on_Corrosion_in_the_Refinery_Industry.html

American Petroleum Institute API 570 Piping Inspection Code: In-service Inspection, Rating, Repair and Alteration of Piping Systems

American Petroleum Institute API 510 Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair and Alteration

Reviewed/Revised 2018

Materials Technology Institute

Technical Awareness Bulletin

Metal Specifications | No. 14

Metal Specifications…. Get it Right or Get the Wrong Stuff

When ordering material, it is important to use a complete designation that accurately describes that material. For example, the high strength precipitation hardening stainless steel designation, 17-4PH, comes from the commercial designation used by the inventor, Armco Steel. Inconel and Hastelloy are trade names commonly associated with two specific alloys, however these names can describe a family of alloys. Using just that "family" name can lead to costly errors. Any name can be given to an alloy, but if the UNS # or EN is given then it will meet the specific chemical composition requirements unique to that alloy.

We need also remember that while metal designations describe materials, these designations do not include product form or quality level.

Grain flow produced by forging influences its properties

Product Form

To specify the correct material, chemical composition alone is not enough. The product form is also a requirement because product form (casting forging rolled plate, tube etc.) might have an effect on end use, service life and availability. See photo.

For convenience, product form specifications usually combine a group of similar materials. ASTM A240 is a standard that outlines the requirements for stainless steel plate. It references **over 270** different alloys **by UNS number & chemistry**.

Because product form specifications can be general, like ASTM A240, the user must indicate not only the specification number, but also the name or UNS# for the stainless steel needed, for example, 304 (S30400) or 316L(S31603). This is known as the embedded alloy within the standard. Just as specifying type 304 stainless steel is not sufficient; specifying ASTM A240 alone will not ensure that you will receive the correct material.

Quality Levels

Specifications for metals must meet the needs of commerce and the requirements of different industry segments. The quality level required by the aerospace or nuclear industry is significantly higher than that of a standard structural material.

ASTM and other standards usually describe a host of requirements for a product, such as heat treatment condition and mechanical properties. Consequently, referencing the standard is a shorthand way of obtaining these requirements.

Other information may also be required when identifying materials in a procurement database, for example dimensions and finish. Many specs have other specifications referenced within them. ASTM A480 is listed within A240, as are full chemistries for each alloy listed. Specifiers need not duplicate that information in their order requirements, but for each specification, all requirements must be adhered to.

Quality levels are often referenced in standards as optional requirements, which the user selects at extra costs, so it is important to analyze the requirements for additional quality before indicating it in the specification.

ASME material specifications for pressure vessels use only ASTM standards that meet quality requirements for pressure equipment. To recognize the material as suitable for the more demanding service, ASME modifies the standard ASTM designation. ASTM A240 for stainless steel pressure vessel plate becomes SA-240 in the ASME system. Even though these specifications may seem to mirror each other, ASME includes additional modifications to the ASTM standard to ensure that the material has a quality level suitable for pressure vessel applications.

Material requirements may include a specification published by the customer as well. Customer specs often include existing product form information, and quality level specifications. Customer specifications may also supersede requirements for many attributes already covered in other referenced specifications. Care should be exercised up front to ensure which applies.

Getting it Right

In today's chemical companies, emphasis on process safety management is crucial. It is necessary to avoid getting less than the desired material on a requirement. When there are 20 or more alloys associated with one trade name, getting material fully specified can prevent failures. A requirement for "Inconel plate" is not sufficient to get the proper product into your equipment. Order "alloy 600, to ASTM B168".

Making sure the correctly specified material is obtained for an application is of the highest priority in procurement. This means paying attention to all the levels of specification and using them all, if needed:

- Material name (use embedded designation in applicable product form standard when applicable)
- Material standard for product form and other features, with relevant referenced specifications
- Material quality level for cost effective procurement, when applicable
- Specifications unique to the customer where any of the above can be augmented or superseded.

Review/Revised August 2019

This report is subject to later revision. MTI assumes no responsibility for the contents or for results associated with implementing any recommendations.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MTI MENTOR MATCH OFFERS VIRTUAL NETWORKING

A VALUABLE MEMBER RESOURCE FOR PROFESSIONAL DEVELOPMENT

After months with limited access to networking events and face-to-face meetings, MTI and its members needed to find a way for the network of materials engineers to stay connected and continue their personal and professional development.

The Mentor Match Program was one solution, allowing members to stay connected through one-on-one mentoring relationships.

"Informal mentoring is common at MTI, and we wanted to provide a more formal program that allows mentors and mentees to meet more frequently and help these connections to flourish," explains Daniel Rasmussen, Mentor Match Program Coordinator.

Registration is open on the MTI website at mti-global.org/mentoring. After completing your MTI profile with a picture, detailed biography and work history, you can choose from one or more of the six mentorship categories:

- Ceramics
- Metals
- Polymers
- Knowledge Management
- MTI Champions
- DR/TAC Representatives
- MTI Resources.

Members can sign up to be a mentor, mentee, or both but whichever direction you choose, you will be sure to gain valuable knowledge and guidance. Don't just take our word for it. Maria Jose Landeira Oestergaard (Haldor Topsoe) signed up to participate as a mentor and has already gained value from the relationship.

"Being a mentor is as much giving as it is getting; it is a benefit for both parties and a golden opportunity to grow," she remarks.

Rasmussen says MTI hopes the program will ease the struggles of

limited one-on-one professional development and feelings of isolation during these uncertain times, but that it also continues to serve as a valuable member resource beyond when the world reopens and we can all meet in person again.

"If you have any questions about the Mentor Match Program or need help registering please contact me at drasmussen@mti-global.org or +1 (314) 567-4111," he concludes. ▪