A Materials Technology Institute Publication

MTI CONNECT

2023, ISSUE 3

GLOBAL CHALLENGES / TRUSTED SOLUTIONS

SUSTAINABLE PROCESS INDUSTRIES

MTI GLOBAL SOLUTIONS SYMPOSIUM 2024 PREVIEW

Page 3

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CONNECT

Inside This Issue

2023, ISSUE 3

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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SUBSCRIPTIONS:

For a free subscription, visit www.mti-global.org/about/connect-magazine.

CALENDAR OF EVENTS:

EuroTAC Spring Meeting
May 22–24, 2024
Gent, Belgium

AsiaTAC Spring Meeting
Joint Conference with Japan Society of Corrosion Engineering
June 5, 2024
Sonic City Omiya, Japan

AmeriTAC 144
June 24–26, 2024
Denver, CO

MTI Global Solutions SYMPOSIUM 2024

SUSTAINABLE PROCESS INDUSTRIES

February 26–29, 2024
Crowne Plaza Hotel
Baton Rouge

2024 MTI Global Solutions Symposium Co-Chairs Invite You to Baton Rouge

Dear Readers:

We are excited to return to the Gulf Coast region for the MTI Global Solutions Symposium, February 26-29, 2024, in conjunction with AmeriTAC 143. As Co-Champions for the Symposium, we are pleased to provide a comprehensive preview in this special Symposium Spotlight issue of MTI CONNECT, which includes information for our two highly anticipated keynotes, more than 35 technical presentations and a growing list of key industry experts in the Global Solutions Marketplace.

The Symposium Steering Committee has worked tirelessly to develop a valuable program with five education tracks, including Non-metallics, Emerging Technology, Sustainability/Reliability, Bioprocessing and Corrosion Mechanisms, and Knowledge Management.

The Symposium does come with several exciting changes this time after the excellent feedback from past attendees:

1. Participants are eligible to receive a certificate worth 12 professional development hours for attending!
2. The AmeriTAC 143 meeting will take place Monday afternoon and extend to Thursday morning for a Symposium wrap-up and MTI project ideas discussion.
3. Several education sessions have been expanded to 45 minutes to cover more in-depth topics.
4. We're offering an optional event to "Tee-Off" the Symposium at TOPGOLF Monday evening in lieu of the traditional opening reception.
5. We've added a Closing Celebration on Wednesday, including dinner, drinks, music, networking and door prizes to conclude the Symposium in the Global Solutions Marketplace after two full days of learning!

We understand that your time is valuable and taking time away from your job can be challenging, but we hope you register to join us. We are confident you will come away from the 2024 MTI Global Solutions Symposium with new information that will assist you and your company in meeting your technical and financial goals.

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

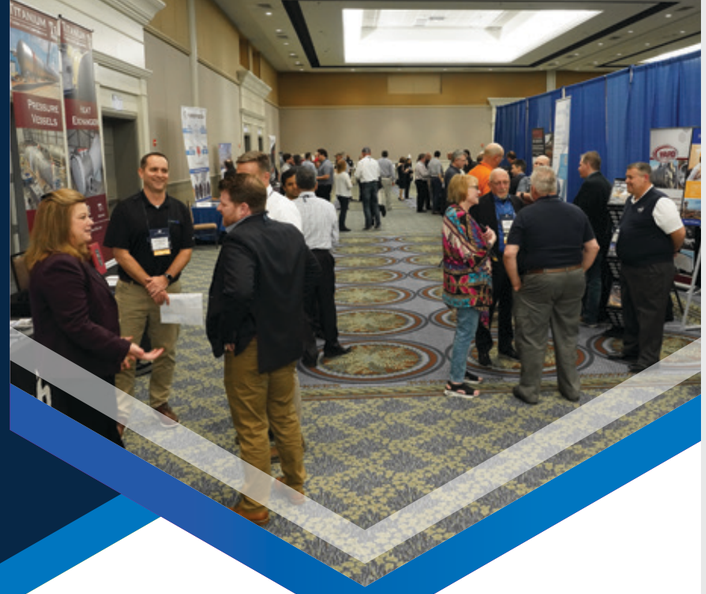
See you in Baton Rouge!

Meghan Oaks
BASF

Chuck Young
Tricor Metals

Global Solutions SYMPOSIUM 2024

SUSTAINABLE PROCESS INDUSTRIES



GLOBAL SOLUTIONS MARKETPLACE

The Global Solutions Marketplace provides access to processing industry professionals who will be showcasing their companies' innovative products and services.

AEI · AkzoNobel · Alleima · APEX · CORROCOAT USA · Corrosion Materials · Curran International · DURALOY Technologies · enerfab Excellence Through Execution · FLO-SPEC · Frontier Plastic Fabricators · HATCH · Marks Brothers Incorporated · mersen Expertise, our source of energy · New Castle Stainless Plate, LLC · NORAM · outokumpu sustainable stainless steel · pai · Pfaudler Defining the standard · RMB Products · Rolled Alloys · sij americas · Southern Heat Exchanger · Stress Engineering Services Inc. · Taprogge · TEADIT · Titan Metal Fabricators · Titanium Fabrication Corporation · Tricor Metals · Ward Vessel & Exchanger · Webco Industries

Limited space is still available – visit www.mti-global.org/mtisymposium/exhibit to reserve your space, or contact Kirk Richardson, Director of Sales and Marketing at krichardson@mti-global.org.

SYMPOSIUM KEYNOTES

Dawn of the Energy Transition Era—Early Observations

Curt Graham, Vice President Office of Technology, Fluor

The opening Keynote will cover the Energy Transition technologies that are being built and going into operation, those that are on the near-term horizon, and those that will be needed, but are not yet commercial. We'll then discuss how these trends will impact the industry, and some observations on both the challenges and opportunities inherent to this dramatic change in technology.

Curt Graham, Fluor

About the Speaker

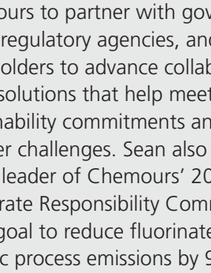
Curt Graham has more than 30 years of industry experience. In his role leading the Office of Technology, he is responsible for Fluor's licensed technologies, interfacing with other licensors, companywide technology strategy support, and responsibility for Fluor's Fellows Program. Since joining Fluor in 1996, Graham has worked on a wide range of Energy and Chemicals projects with extensive experience in Gas Processing – LNG Regasification Terminals, Turboexpander Plants (C3+ and C2+ recovery), Residue Gas Compression, NGL Fractionation, Propane Refrigeration Systems, Amine Treating, Physical Solvent Treating, Scavenger Treating, Ryan-Holmes, Membrane, and Gas/Oil Separation. Refining – Hydrogen Plant, Hydrotreater, Coker, Amine Treating, Merox, C3 Splitter. He has significant experience with the use of process simulation as a design tool. His expertise includes petroleum, petrochemical, power, and gas processing applications. His experience also includes field assignments in refineries, including two-unit start-ups, extensive operator training, and Process Lead on major grass roots gas plants, gas plant debottlenecking and gas plant fire rebuild projects.

Driving Sustainability in Chemical Manufacturing

Sean Uhl, Sustainability Technology Director, Chemours

Sustainability is increasingly a business imperative – essential to long-term growth and success. However, what is often underrepresented is the importance of materials and material science in powering the energy transition, enabling decarbonization, and reaching global climate goals. The world needs more than effective and advanced chemistries – it also requires that these essential materials are produced with an unwavering commitment to safety, sustainability, and end-to-end product stewardship, all for the benefit of our shared planet.

This session will unpack Chemours' approach to responsibly manufacturing critical chemistries, sharing advances in analytical and abatement technologies that support meaningful reductions in emissions, the role of carbon in business strategy, and detailing areas where innovation in sustainable solutions can advance sustainability.



Sean Uhl, Chemours

About the Speaker

Sean Uhl has more than two decades of experience in the chemical industry with deep expertise in site operations, process development, and continuous improvement activities. In his role, Sean works collaboratively with Chemours' three businesses – Titanium Technologies, Thermal & Specialized Solutions, and Advanced Performance Materials – to ensure the company continues to lead in sustainability and is well-positioned for the future. Additionally, Sean actively seeks opportunities for Chemours to partner with government, regulatory agencies, and other stakeholders to advance collaborative solutions that help meet its sustainability commitments and solve broader challenges. Sean also serves as the leader of Chemours' 2030 Corporate Responsibility Commitment goal to reduce fluorinated organic process emissions by 99% or more. In addition, he leads the field engineering program for Chemours, a rotational development program for early-career engineers.

Global Solutions SYMPOSIUM 2024

SCHEDULE OF EVENTS*

MONDAY, FEBRUARY 26	
8:00 AM – 6:00 PM	Registration/Check-in Open
8:00 AM – 12:00 PM	MTI Board of Directors Meeting
12:00 – 1:00 PM	Lunch
1:00 – 5:00 PM	AmeriTAC 143 Project Team Breakout Sessions
6:00 – 8:00 PM	Symposium "Tee-off" Networking Event | Location: TOPGOLF *OPTIONAL Not Included with Registration

TUESDAY, FEBRUARY 27			
5:00 - 10:00 AM	Exhibitor Set-up		
7:00 AM – 5:00 PM	Registration/Check-in Open		
7:00 – 8:00 AM	Breakfast		
8:00 – 8:45 AM	**KEYNOTE:** Dawn of the Energy Transition Era – Early Observations Curt Graham, Fluor, VP Technology		
	TRACK: EMERGING TECHNOLOGY	**TRACK: NON-METALLICS**	
9:00 – 9:30 AM	Digital Gasket Trainer (Page 8)	Gasket Evaluation for FRP Flanges (Page 10)	
9:30 – 10:00 AM	Development and Properties of a New Titanium Alloy for Geothermal and Oil & Gas Well Casing (Page 8)	Condition Monitoring of Metallurgical Furnace Refractory Linings (Page 10)	
10:00 – 10:30 AM	Break & Exhibits in the Global Solutions Marketplace		
10:30 – 11:00 AM	Corrosion Performance of Additively Manufactured Alloys (Page 8)	Embedded RFID Sensors for FRP Corrosion Barrier Monitoring (Page 10)	
11:00 – 11:30 AM	Times They are A-Changin' – An Overview of Recent ASME Boiler and Pressure Vessel Code (Page 9)	Non-Metallic Materials Selection for High-Pressure Hydrometallurgical Applications (Page 10)	
11:30 AM – 12:00 PM	Nano Bubble Vapor Infusion to Mitigate the Fouling of Heat Exchangers (Page 9)	Thermoplastic Welding: Its Methods and Uses for the Chemical Processing Industry (Page 11)	
12:00 – 1:30 PM	Lunch & Exhibits in the Global Solutions Marketplace		
1:30 – 2:15 PM	Engineering Diagrams for Material Selection in Water-Based Environments (Page 9)	Non-Metallic Resistance to Anolyte and Catholyte S ervice Environments Explored (Page 11)	
2:15 – 3:00 PM	Corrosion Performance of the Austenitic Grade UNS N08935 in Harsh Chemical Environments (Page 9)	EU PFAs Update (Page 11)	
3:00 – 3:30 PM	Break & Exhibits in the Global Solutions Marketplace		
3:30 – 4:15 PM	Inspection and Remaining Life Assessment of Hydrogen Reformer Hot Outlet Systems (Page 9)	3:30 – 4:00 PM	Polymers and Ceramics; Old Art and Current Science (Page 11)
4:15 – 5:00 PM	High-Temperature Stable, Hydrophobic Coatings for Antifouling Applications (Page 10)	4:00 – 4:30 PM	Best Practice: PFA Sheets for Sulfuric Acid Production at OMV Refinery in Schwechat (Page 12)
		4:30 – 5:00 PM	Topic TBA
5:00 – 8:00 PM	Networking Reception in the Global Solutions Marketplace		

* Subject to Change

Plan to Join Us for the "Tee-off" Networking Event at Topgolf

WEDNESDAY, FEBRUARY 28			
7:00 AM – 5:00 PM	Registration/Check-in Open		
7:00 – 8:00 AM	Breakfast & Exhibits in the Global Solutions Marketplace		
8:00 – 8:45 AM	**KEYNOTE:** Driving Sustainability in Chemical Manufacturing Sean Uhl, Chemours, Director of Sustainability		
	TRACK: KNOWLEDGE MANAGEMENT	**TRACK: SUSTAINABILITY/RELIABILITY**	
9:00 – 9:30 AM	Instructional Delivery Options for Effective Training (Page 12)	Heat Treatment of U Bent Exchanger Tubing (Page 15)	
9:30 – 10:00 AM	From Traditions to Work Instructions, Does Your Daily Focus S upport your Knowledge Management Goals? (Page 12)	Asset Integrity Management Challenges of Critical Piping and Pipelines (Page 15)	
10:00 – 10:30 AM	Break & Exhibits in Global Solutions Marketplace		
10:30 – 11:15 AM	Good Knowledge Management Practices in the Process Industries (Page 13)	10:30 – 11:00 AM	Evolution of Reliable Designs for Acid and Oxygen Feed Lances for Demanding Applications (Page 15)
	TRACK: BIOPROCESSING & CORROSION MECHANISMS	11:00 – 11:30 AM	Sustainability through the Lens of a Materials Engineer in Process Design and Construction (Page 15)
11:30 AM – 12:00 PM	Corrosion and SCC Risks and Mitigations in Renewable Unit Recycle Gas Systems (Page 13)	Contributions of Pressure Hydrometallurgy to Reduce Energy Consumption and CO_2 Emission for Ni and Co Battery Chemical Productions (Page 15)	
12:00 – 1:30 PM	Lunch & Exhibits in Global Solutions Marketplace		
1:30 – 2:00 PM	Application of Advanced Metal Cladding Technology for Upgrading Existing Refining Equipment for Renewables Co-Processing (Page 13)	Successful Repairs and Field Welding of Corrosion Resistant Alloy Equipment On-site (Page 16)	
2:00 – 2:30 PM	Static Mixers Uses and Benefits from a Materials Engineer's Viewpoint (Page 14)	2:00-2:45 PM	The Impact on Life Cycle Carbon Footprint of Using Different Materials in CPI Equipment (Page 16)
2:30 – 3:00 PM	Applying Corrosion Engineering Principles to New Technology: Predicting Damage Mechanisms in Molecular Recycling Units (Page 14)		
3 :00 – 3:30 PM	Break & Exhibits in Global Solutions Marketplace		
3:30 – 4:15 PM	Common Corrosion Mechanisms and Laboratory Testing for Hydrometallurgical Applications (Page 14)	Planning to Fail: Some Unexpected Developments (Page 16)	
4:15 – 5:00 PM	Systematic Approach Toward Damage Mechanism Reviews and Mechanical Integrity Improvements for Ammonia Synthesis Facilities (Page 14)	4:15 – 4:45 PM	Overview of Applications with Increased Equipment Reliability Using UNS N10362 and UNS N06035 Alloys (Page 17)
5:00 – 8:00 PM	Closing Celebration in Global Solutions Marketplace Exhibitor Clean-up Begins Upon Conclusion at 8 PM		

THURSDAY, FEBRUARY 29	
7:00 – 8:00 AM	Breakfast
8:00 AM – 12:00 PM	AmeriTAC 143 • PDCs • Brainstorming Session: Discuss project ideas from Symposium • Project Completion Reports • Project Funding Proposals
12:00 PM	Meeting Adjourns

EDUCATION TRACKS & SESSION DESCRIPTIONS

MTI Global Solutions SYMPOSIUM 2024

TRACK: EMERGING TECHNOLOGY

Digital Gasket Trainer

Alton Jamison, Teadit

The Digital Gasket Trainer (DGT) has been developed to simulate the behavior of a bolted flanged connection in real time. DGT is a specialized software that simulates the bolt interaction when you tighten a flange with either a torque wrench, a short wrench or a long wrench. In addition, the software allows you to select from multiple gaskets to be used in between the flange along with two different friction factors. The software connects to a bench in which you can use an actual torque wrench or hand wrench that will communicate to the program as force is applied. This program uses a training tool to show what happens in the field when we tighten up a flange and the interaction between the bolts. The software also shows when the bolts have been yielded. The convenience of this digital gasket trainer is that it is portable and can be used to train engineers and maintenance staff from the convenience of a laptop or iPad.

Development and Properties of a New Titanium Alloy for Geothermal and Oil and Gas Well Casing

Bill MacDonald, Special Metals

A new titanium alloy, Ti-475, has been developed for challenging geothermal wells as found in California's Salton Sea in the hypersaline, low pH and high chloride environment. The alloy is a leading candidate for supercritical steam fields as being developed in Iceland. The development process will be presented including corrosion testing, manufacturing and connections. As the alloy has been found to be a suitable replacement for ASTM Ti Grade 29, other applications will be discussed including sub-sea components, including stress joints and risers.

Corrosion Performance of Additively Manufactured (AM) Alloys

Suresh Divi, Stress Engineering Services

As the use of additive manufacturing (AM) expands into more critical applications, establishing confidence in the expected performance and reliability of AM components also becomes more critical. However, very little information has been presented regarding the use of AM within the chemical process industry (CPI). The harsh and demanding environments of chemical process industries present unique and challenging conditions for AM components to withstand. To help address this lack of information, a case study of AM components was created to showcase the types of features that can be made using the AM process while designing for chemical processes and marine applications. Immersion corrosion testing of AM and wrought alloys were performed in a reducing inorganic acid, an oxidizing inorganic acid, and an organic acid. Immersion tests were also performed in the marine environment for AM materials to traditional wrought materials. Corrosion rates of AM alloy vs wrought alloys in above mentioned conditions and the effect of microstructure due to exposure to the acids and salts will be presented.

Times They are A-Changin— An Overview of Recent ASME Boiler and Pressure Vessel Code

Josh Masters, Tricor Metals

The ASME Boiler and Pressure Vessel Code (BPVC) sets the standard for the safe design and manufacture of boilers and pressure vessels. Every two years this code is revised to keep up with current technology and information available. Some of the changes have little effect on industry while other seemingly small changes can cause a large ripple effect. It is important that all who are involved in working with the ASME BPVC know the current code changes and updates, understand why the revisions were made, and determine how they will affect their company business. Join us to hear: A brief history of the origins of the ASME Boiler and Pressure Vessel Code (BPVC) and the National Board Inspection Code; A brief overview of the current sections of the ASME BPVC; Recent revisions and updates in the last few years of the ASME BVPC, with a main focus of changes in ASME Section II and ASME Section VIII, Division 1; and a summary of possible future changes to the ASME BPVC.

Nano Bubble Vapor Infusion to Mitigate the Fouling of Heat Exchangers

Michael Radicone, HTRI

Preventing or minimizing fouling within a heat exchanger is paramount to achieving its expected performance functionality. Fouling occurs when tube or plate surfaces are covered by organic or inorganic deposits from the source cooling water. As this chronic condition develops, there are resultant inefficiencies and damage that occur, such as diminished heat transfer, pressure drops, MIC and system shut down. These are costly, laborious and energy consumptive for the facility that impacts a company's Net Zero goals. Many facilities will use tear down and biocides as an acute response to fouling. These methods are used in an emergency or as a preventative treatment. Although they can return a heat exchanger to desired functionality, once fouling has begun, there is an immediate, sustained, and progressive loss in performance. Vapor infusion has been proven to be effective for both remediating and maintaining a potentially fouling exchanger. The technology uses application specific vapor treatments, presented through a timed bubble emulsion within the cooling water stream, to provide foul prevention while minimizing environmental impact. The presentation will provide an understanding of vapor infusion technology, current research on the benefits of nano bubbles and a discussion of current commercial applications.

Engineering Diagrams for Materials Selection in Water-Based Environments

Bjorn Helmersson, Outokumpu

Water can seem a simple medium to consider from a material selection point of view, but any materials engineer knows that there are many factors that can affect the corrosivity. The influence of pH, temperature, chlorides, oxidizing contaminants, and different alloys and surfaces means that the result can be rather challenging to predict. Today there is a vast body of literature and material selection tools available, but many are outdated, too conservative or otherwise difficult to fully utilize. Furthermore, several modern alloys are often missing. This work covers the development of new engineering diagrams for stainless steels in chloride containing water, based on recent test data, and covering several steel grades, both classic and modern. The ambition has been to facilitate material selection in water-based systems to increase cost efficiency and operational reliability. New data will be presented and the thought process behind the development of the diagrams will be explained.

Corrosion Performance of the Austenitic Grade UNS N08935 in Harsh Chemical Environments

Bjorn Helmersson, Outokumpu

For the highly corrosive environments that may be found in chemical process industries, it can be a challenge to select the most appropriate material when it comes to both cost efficiency and reliability. Oftentimes advanced Ni-based alloys are required to battle the harsh conditions. UNS N08935 is a highly alloyed austenitic material with a high resistance to corrosion. With a nickel content of 35% it is a relatively lean alternative to conventional nickel-based alloys, while in many cases it offers similar corrosion resistance. This work focuses on the performance of N08935 in acidic and chloride containing environments and looks to identify environments and applications where this grade can offer an advantage over established materials, which focuses especially on its resistance to uniform corrosion. Different product forms will also be discussed, and explosion bonding to achieve thicker gauges is provided as an example.

Inspection and Remaining Life Assessment of Hydrogen Reformer Hot Outlet System

Carl Jaske, HSI Group

This presentation will review the key aspects of inspection and remaining life of hydrogen reformer hot outlet systems, including manifolds and pigtails. State-of-the-art methods for identifying and quantifying cracking and creep damage of base metal and welded joints will be described with emphasis on providing appropriate data for remaining life assessment. The latest procedures for evaluating

> CONTINUED ON PAGE 10

fitness-for-service and remaining life will be covered. These procedures will address high-temperature creep, low-cycle thermal fatigue, and creep-fatigue damage in a manner consistent with the requirements of API 579-1/ASME FFS-1. The main materials covered will cast 20Cr-32-Ni-Nb alloys and wrought Alloy 800H and Alloy 800HT.

High-Temperature Stable, Hydrophobic Coatings for Anti-fouling Applications

Brandon Dooley, Chevron

This presentation will highlight a rare-earth based process for use in antifouling applications. Rather than a traditional coating, the surface of the alloy is modified with rare earth nanoparticles, yielding a very thin oxidized layer that is integral to the alloy. This treatment has no measurable thickness, does not impose any operating temperature limits, protects from high temperature oxidation, and decreases surface energy and polarity leading to low fouling and coking rates. Successfully treated materials include stainless steels, superalloys, and carbon steel. The process is water-based and nonhazardous and has successfully treated both the inside and outside surfaces of heat exchangers, including those with finned tubes. Laboratory tests conducted to simulate operating conditions in a Coker furnace show 316 stainless tubes experience about 80% reduction in coke formation compared to the untreated tubes. Testing in water-based systems on low alloy steel also demonstrated decreased fouling. Data collected in refinery applications in Coker furnace tubes and vacuum column wash beds are promising.

TRACK: NON-METALLICS

Gasket Evaluation for FRP Flanges

Tim Rice, VSP Technologies

Gasket selection for FRP flanges is critical to prevent leakage of corrosive chemicals; however, the stress limitations of the flange material create problems that make this uniquely challenging. In this presentation, we will discuss an empirical method of evaluating the sealing performance of gaskets used in FRP flanges and compare commercially available gaskets geared toward low bolt load applications based on this testing.

Condition Monitoring of Metallurgical Furnace Refractory Linings

Afshin Sadri & Maria Tibbo, Hatch Engineering

Acousto Ultrasonic Echo (AU-E) is a non-destructive method of measuring refractory thickness and condition in operating metallurgical furnaces. Reliable monitoring and control of metallurgical furnaces is essential to ensure safe furnace operation and optimize furnace campaign life. Careful monitoring of the thickness and condition of refractory lining can allow preemptive detection of refractory wear, avoid sudden furnace failures and unscheduled shutdowns. This lining information plays a critical role in allowing furnace operators to confidently prolong reline dates. Recent technological breakthroughs have allowed for more accurate measurements of refractory lining than ever before and given insight into the change in physical properties of the refractory brick.

Embedded RFID Sensors for FRP Corrosion Barrier Monitoring – Update on Implementation in Chemical Process Applications

Brian Linneman, RL Industries

FRP vessel integrity monitoring with MTI RFID sensors continues to advance. Sensor arrays have been installed in several new FRP vessels to support plant equipment integrity programs. Practical application and observations will be discussed based on recent experience. Topics will include pre-installation testing, sensor installation arrangements in secondary bonds, sensor installation arrangements in primary corrosion barriers, fabrication techniques and challenges, sensor interrogation, post-curing and material additives.

Non-Metallic Materials Selection for High Pressure Hydrometallurgical Applications

Ian Donohue, Hatch Engineering

There are hydrometallurgical applications in which metallic materials are either unsuitable or uneconomic for process reactor vessels. In these applications, non-metallic corrosion-resistant lining systems consisting of refractory materials and impermeable membranes are used to protect the vessel pressure boundary from corrosion. This presentation highlights the suitability of various chemical-resistant refractory materials, including aluminum oxide-based bricks and mortars, silica-based bricks and mortars, carbon or graphite bricks, and silicon carbide materials for hydrometallurgical processes. This presentation also focuses on non-metallic membranes, including vinyl ester resin FRP, synthetic rubber, polymer (e.g., PFA, PTFE, ECTFE), and bituminous mastics.

Thermoplastic Welding: Its Methods and Uses for the Chemical Processing Industry

Jason Knapp, Arkema

The presentation will give an in-depth discussion of welding thermoplastic materials. The presentation will have a short but detailed description of the different methods to weld plastics and will also explain benefits and drawbacks of each method. It will also discuss the most commonly welded plastics in the chemical processing industry and will discuss the strengths and limitations of welding each material. Finally, the presentation will show how plastic welding is growing and essential for the chemical processing industry with examples, giving examples of industries where plastic welds are common. The presentation is intended to inform engineers that plastic welded components and systems can be a viable and beneficial alternative to metallic ones. Engineers who are unfamiliar with plastic welding will hopefully be educated and consider areas where plastic welding could increase the safety and efficiency of their business.

Non-Metallic Resistance to Anolyte and Catholyte Service Environment Explored

Bryan Hutton, Composites USA

We are exploring why amorphous thermoplastics can provide good resistance to concentrated anolyte and combat the attacks of the catholyte environment. Robust brine solutions, sodium hydroxide, hypochlorous acid, sodium hypochlorite, and hydrochloric acid are some of the contributors common to Chlor-Alkali facilities. We will discuss polymer chain chemistry while looking at historical performance environments in the Chlor-Alkali industry. Costs of corrosion, poor fabrication, and installation can be enormous, affecting the bottom line of plant productivity. We must help facilities address essential design, fabrication, and installation issues to prolong the service life while maintaining a safe operating environment. The discussion will walk the participants through a historical progression of thermoplastics and explore the physical characteristics, polymer chemistry, and typical application range while relating the materials to recent updates in the ASME NM.1, NM.2, and ASME RTP-1 standards. American Welding Society standard, B2.4, is a crucial document that we will address on the qualification of welders, which helps us connect the theoretical with the practical. Participants will leave the presentation with a better understanding of thermoplastics and how they may improve their equipment performance in their respective facilities.

EU PFAs Update

Johannes Derfler, AGRU

On 14th October 2020, as part of the EU's zero pollution and circular economy ambitions, the European Commission published a Chemicals Strategy for Sustainability (CSS). The strategy includes several "key actions," one of which is to phase out per- and polyfluoroalkyl substances (PFAS) in the EU, unless their use is proven to be essential for society. At the time of publication of the CSS, the REACH competent authorities of Denmark, Germany, the Netherlands, Norway and Sweden had also started preparatory work on a broad REACH restriction, covering all uses of PFAS. Based on the ECHA procedures, a draft proposal for an EU PFAS restriction was published on 7th February 2023, and the proposal also targets to ban fluoropolymers. The EU PFAS restriction proposal will be subject to a review process over the next two years. The first major milestone was on March 22, 2023, when the restriction proposal was opened for a 6-month public consultation based on ECHA procedures. The public consultation closed on September 22, 2023. In the following few months, the first feedback from ECHA is expected. The purpose of this presentation is to provide a brief overview of the current situation and actions. It remains to be seen whether the results of the public consultation are already available or whether further measures are already known at the time of this conference.

Polymers and Ceramics; Old Art and Current Science

Dale Heffner & Phillip Hypes, Knight Material Technologies

Polymers and Ceramics: MTI places such a high importance on these materials of construction that they have a separate, specific project development committee (PDC) for each of the two materials along with a metals PDC. The ceramics PDC has developed numerous ceramic training courses and covered technical subjects such as inspection techniques. The Polymers PDC has completed projects on topics such as permeation, plastic welding, repair manuals and numerous inspection and training programs. One tank lining technology that has been a workhorse in the chemical process industry combines these two materials of construction. It is commonly known as the art of chemical resistant masonry. Chemical resistant masonry is extremely durable, and

> CONTINUED ON PAGE 12

Global Solutions SYMPOSIUM 2024

EDUCATION TRACKS & SESSION DESCRIPTIONS

when properly designed, handles the harshest chemical and thermal conditions. In addition, it is a reliable method of tank lining construction and has been around for a long, long time. Unfortunately, the use of chemical resistance masonry gets little attention in academia. Materials engineering students receive little or no exposure to the combined use of ceramics and polymers to provide chemical resistance in chemical process vessels. Their first experience often comes when faced with replacing a vessel that has been in service for, perhaps, 30 to 40 years or more. This presentation will reintroduce some of the basics of chemical resistant masonry and much more. The combination of membrane, mortar and brick that make up the system will be explained. The use of ceramics and polymers for the internals, such as supports, packing and distributors, will also be discussed.

Best Practice: AGRU PFA Sheets for the Sulfuric Acid Production at the OMV Refinery in Schwechat

Michael Krauss, AGRU

The OMV refinery in Schwechat, Austria, operates a wet sulfuric acid plant with a production capacity of about 2.5 - 9.5 t/h. The plant area in which the sulfuric acid is produced by condensation, is subject to high corrosion, in which regular steels and stainless steels would be destroyed quickly. To achieve sufficient resistance to these highly aggressive application conditions, a multi-layer structure consisting of four layers was used. However, the structure was chemically attacked and leaked for quite a few years. Due to the apparent downtimes and the increasing repair costs OMV decided to fundamentally redesign the condenser area. The new development mainly focused on the selection of a suitable lining system that will withstand the harsh operating conditions. In the selection process, seven different products were evaluated and analyzed. Based on the available long-term references and the investigation carried out (exposure testing with 98% H_2SO_4 at 260°C), the PFA fixed-point lining system was specified as the optimal solution for flue gas desulfurization units at OMV. The first condenser at OMV was relined in 2018. Due to the success, the remaining three units followed in 2019, 2021 and 2022. All of them are successfully in operation until today.

TRACK: KNOWLEDGE MANAGEMENT

Instructional Delivery Options for Effective Training

Mark Harmody, Equity Engineering

Over the last three years, different types of technical training delivery have been used. Before the pandemic, instructor-led training (ILT) was the mainstay of most technical learning. Throughout the pandemic, with travel restricted or banned entirely, virtual ILT (VILT) became the norm using video conferencing apps. Currently, ILT and VILT are still the most popular ways to engage in training and career development, but other instructional delivery such as on-demand and hybrid learning, have proliferated. This presentation will focus on the advantages and disadvantages of these training delivery options, what works and what doesn't, examples of good instructional design, and central tenets of effective training that must be present no matter what instructional delivery is performed.

From Traditions to Work Instructions: Does Your Daily Focus Support Your Knowledge Management Goals?

Tara Sheldon, Tricor Metals

While the idea of knowledge management isn't new, the focus on knowledge management is appearing more and more in our day-to-day business. In an industry where specialized knowledge isn't easy to find it is more important than ever to harness that knowledge to build for your future. Does your company focus on building your knowledge management? Do you use a system and processes to support information and knowledge retention? Is the knowledge from within your key employees being shared and captured for the future? Join us to hear about best practices to use your ERP system and processes to better integrate your leadership team.

Good Knowledge Management Practices in the Process Industries

Cory Cannon, Knoco

The industrial processing sector is a complex and diverse ecosystem of companies both large and small, both national and global, and with interdependencies between them. Smaller, more specialized companies serve the requirements of larger, bulk processing and manufacturing companies. Underpinning all of this is a common foundation in materials technology. For interoperability of components and products across this ecosystem, and for effective service provision, the sector must work to a common knowledge base in the properties and behaviors of materials from raw materials to the processed forms of those materials as needed for specific industry applications. Deep technical knowledge and expertise must be sustained across an array of specialized scientific and engineering domains. Knowledge management practices in the Processing Industries focus on people-oriented approaches, such as communities of practice, nominating subject matter experts (SMEs) as knowledge leads, programs for knowledge retention from more experienced to younger employees, organizational learning, and best practice development and application.

This presentation is based upon MTI's Business Cases for Knowledge Management Continuous Improvement (Project #369). It will cover the project findings, a synthesis of responses from 17 companies, gathered through surveys and in-depth interviews, supplemented by additional materials drawn from the practitioner literature and the author's own experience.

TRACK: BIOPROCESSING & CORROSION MECHANISMS

Corrosion and SCC Risks and Mitigations in Renewable Unit Recycle Gas Systems

Cathy Shargay, Fluor

When a hydroprocessing unit is revamped to process biofuel feeds, one of the areas that needs to be analyzed for a possible increased risk of corrosion is the recycle gas system. This gas is primarily hydrogen, and in renewables units will have a much higher water content compared to the previous refinery hydroprocessing service. Even downstream of the compressor, which adds some superheat to the stream, factors such as the piping not being insulated, low flow rates in some branches, cold climates, etc., can lead to water condensation in the lines. The risk of corrosion on carbon steel due to this water formation then depends primarily on the carbon dioxide content in the gas. Recent units have required tracing and insulating of this line to avoid corrosion. A unique scenario which can lead to stress corrosion cracking of stainless steel piping sections in recycle gas quench spools close to the reactor is also described.

Application of Advanced Metal Cladding Technology for Upgrading Existing Refining Equipment for Renewable Co-Processing

Nate Sutton, Equity Engineering

Corrosion concerns in refineries are significant, often leading to extended turnarounds, unplanned shutdowns, and pressure boundary failures resulting in costly and complex shell and infrastructure replacement. High-Velocity Thermal Spray (HVTS) cladding technology, with alloys developed specifically for thermal spray application, have over twenty years of reliable service record in amine processing units in upstream equipment. This technology has now been expanded into more chemically aggressive and elevated temperature environments in both caustic and sour conditions in refining and petrochemical facilities. With the repurposing of equipment for new feeds and biofuel processing, alloy upgrades are required to prevent enhanced corrosion rates associated with fatty acids. A combination of process technology, procedure and materials needed to be addressed to obtain the performance required for more challenging conditions. These modified superalloy systems are resistant to both basic and acidic conditions at elevated temperatures. They are effective in providing an impermeable metallurgical barrier, protecting the underlying substrate, and can be efficiently applied without metallurgical impact to the existing shell or the need for vessel post thermal processing (PWHT). Testing with crude and biofuel feed from facilities, and full field applications have been undertaken, validating recent advances in HVTS and materials technology for protection in reactors, separators, crude distillation units (CDUs), high concentration sulfuric acid drums, fractionators

> CONTINUED ON PAGE 14

among others. These advancements with high protective layer density provide robustness for a longer, maintenance-free service life while reducing installation time associated with other mitigation methods. Complexities and costs associated with weld overlay are avoided, and organic coatings with limited performance can be replaced by HVTS Cladding systems for long term durability.

Static Mixer Uses and Benefits from a Materials Engineer Viewpoints

Shahab Soltaninia, Fluor

The use of static mixers seems to be growing – in part due to process configurations and corrosive components present in some renewable fuels hydroprocessing and pre-treatment units, which result in numerous applications of static mixers. Static mixers are used at various injection or mix points, including some water wash injections, hydrogen quench and/or cold feed injections into hot reactor streams, acid/water mix points, and dehydrating glycol additions into natural gas streams. This presentation highlights the benefits of static mixers in scrubbing contaminants and increasing mixing efficiency to mitigate corrosion and/or thermal fatigue risks and discusses how the corrosion risks being mitigated can be either at the injection / mixing point or in downstream piping and equipment. The presentation also gives a description of static mixers' various types of elements, materials and design options, and lists typical applications in refining, renewables units, and chemical plants.

Applying Corrosion Engineering Principles to New Technology: Predicting Damage Mechanisms

Nate Sutton, Equity Engineering

Significant energy is already focused on scaling up molecular recycling technology. MTI's Roundtable in early 2023 demonstrated interest in this area and highlighted challenges associated with managing feed stream contaminants, which affect various areas of molecular recycling process units. Materials and Corrosion Engineers are tasked with identifying damage mechanisms, selecting materials, and developing mechanical integrity strategies for these units. Application of known damage mechanisms from conventional refining, petrochemical, and chemical processing units is a useful starting point. This presentation will discuss the application of corrosion engineering principles (i.e. chemical engineering, electrochemistry, metallurgy, etc.) to predict damage mechanisms in advanced molecular recycling units. Case studies regarding HTHA, NH_4Cl salt point and acid dew point corrosion, various forms of SCC, and other mechanisms will be presented.

Common Corrosion Mechanisms and Laboratory Testing for Hydrometallurgical Applications

Masoumeh Naghizadeh, Hatch Engineering

This presentation addresses common corrosion degradation mechanisms in pressure hydrometallurgical applications, including general corrosion, pitting corrosion, stress corrosion cracking, crevice corrosion, and intergranular corrosion. It focusses on the effect of halides, presence of secondary phases, and alloying elements on corrosion performance of materials and briefly describes the use and limitations of iso-corrosion curves in estimation of corrosion rates. Assessment of the long-term durability of materials for hydrometallurgical applications often requires exposure and/or accelerated laboratory testing. This presentation covers experimental design and protocols, laboratory qualifications, standard procedures (e.g., ASTM, ISO), and elaborates on test parameters (e.g., pressure, temperature, agitation), solution and coupon considerations, test durations, and techniques for solution and coupon post-test analysis for effective materials selection. The application of accelerated electrochemical techniques in durability assessment is also highlighted in this presentation.

Systematic Approach Toward Damage Mechanism Reviews and Mechanical Integrity Improvements for Ammonia Synthesis Facilities

Daniel Benac, Baker Engineering

Damage Mechanisms for Oil Refinery Operating units have been well documented for over 20 years and MTI has recently published a book containing CPI focused DMs. The successful application of this methodology is the cornerstone of Risk Based Inspection and other predictive Mechanical Integrity technology that have proven improvements in equipment reliability. The emphasis of this presentation is identification of DMs for ammonia and other related processes (i.e., Urea and Nitric Acid Plants). This presentation provides an overview of the some of the potential damage mechanisms based on known process parameters, selects the appropriate inspection methods, and communicates relevant factors and possible mitigation options as a resource for the ammonia production sites. This methodology has been implemented in numerous facilities worldwide and is being used in mechanical integrity programs.

TRACK: SUSTAINABILITY/RELIABILITY

Heat Treatment of U-Bended Exchanger Tubing

Yong-Joo Kim, Webco Industries

When the heat exchanger design requires the use of U-bend tubes, these can be subject to U-bend heat treatment per design code. Requirements are typically based on the steel grade, bend radius and special applications, such as sour or wet hydrogen sulfide service. API 660 specification states that heat treatment shall be completed by electric resistance or furnace methods. In some cases, vendor specification may further define the temperature range by the heating method and holding time at the temperature. One of the main purposes of the U-bend heat treatment is to limit the residual stress, which can induce susceptibility to stress corrosion, there is no clear recommendation of the actual stress limit or measurement methods other than annealing requirement. This paper provides the fundamental information for stress distribution pattern during bending, temperature ranges by U-bend section during resistance heat treatment. Indirect residual stress measurement methods are reviewed which can provide an option of using variable data to define stress limitation rather than using process parameter requirement of temperature and time. The experimental test also provides residual stress amount measured by hardness per bend radii and by the heat-treating temperatures for the alloys of carbon steel, austenitic stainless, duplex and nickel copper alloy.

Asset Integrity Management Challenges of Critical Piping and Pipelines

Qurban Ali Lashari, Saudi Aramco

Asset Integrity Management associated to corrosion. This presentation will discuss key elements and integrity efforts, a condenser tube failure case study, visual and metallograph examination, hardness testing, chemical analysis, and SED/EDS analysis.

Evolution of Reliable Designs for Acid and Oxygen Feed Lances for Demanding Applications

Evan Hinshaw, APEX Engineering

This paper and presentation will provide examples of applications of acid injection and oxygen injection equipment and the evolution of their designs that resulted in use of reactive and refractory metal alloy solutions. Many Mineral Processes and Chemical Processes require injection of high concentrations of Acids and Oxygen to create and maintain chemical reactions that create or liberate certain elements and/or compounds. Precise delivery of either of these media into the reaction chamber is key to the efficiency or effectiveness of the reactions that occur. Continuous as well as batch process that utilize injection lances are required to withstand non-steady state upsets in the process as well as long life during operation of the chemical reaction. Methodic material selection and customized mechanical designs are usually required depending on the specific chemical interactions. Velocity, concentration, temperature, and type of fluids or gases must be considered for proper selection of the most optimum materials that provide the equipment reliability and longevity requirements. Reviewing specific case history examples and the thought process for each injection lance application will provide Engineering insight into how these designs evolved over the past two decades.

Sustainability Through the Lens of a Materials Engineer in Process Design and Construction

David Cole, Marathon Petroleum

The intent of this presentation is to outline a possible forward-thinking approach for materials engineers and process design teams to use ESG metrics in the selection of materials for process equipment as a reportable metric within FEED packages, Materials of Construction changes, and/or bidding out to contractors. One of the biggest challenges is that we currently have info on physical material properties (stress, temp limits, chemical compatibility) but not an accompanying database for ESG. The future may include CO_2 and other trackable ESG metrics attached to the Material Test reports, GMNs, or as part of bid packages.

Contributions of Pressure Hydrometallurgy to Reduce Energy Consumption and CO_2 Emissions for Ni and Co Battery Chemical Productions

Cinziana Sist and Frank Cheuk, Hatch Engineering

First commercial use of pressure hydrometallurgical processes in North America started with the invention by Frank A. Forward and

> CONTINUED ON PAGE 16

subsequent U.S. Patent 2,576,314 (1948) for extracting of nickel values from nickeliferous sulfide material, using ammonium carbonate solution, and later implemented by Sherritt Gordon Mines Ltd. at Fort Saskatchewan, Alberta, Canada. Acid pressure leaching and sulfide precipitation processes were developed later and implemented at Moa Bay in 1964 for production of mixed (nickel and cobalt) sulfide from laterite ore. The commercial use of pressure hydrometallurgical processes expanded greatly between 1990-1995 with the development and implementation of high-pressure acid leaching of laterite ores in Western Australia. This was followed by pressure oxidative leaching of copper sulfide by Phelps Dodge (2003), and chloride-assisted pressure oxidative leaching of nickel, cobalt, and copper sulfides by INCO Ltd. (2005) and Cominco Engineering Services Ltd. (2006). Most recently, the use of these hydrometallurgical processes has been of interest to companies looking to produce high-purity chemicals used in cathode active materials and electrolytes for solid-state electric batteries with a low emissions footprint. This presentation outlines some conventional hydrometallurgical process options to intermediate products, major reagent requirements, unit energy consumption and key CO_2 emissions, with of the objective of comparing the overall environmental footprint of such processes relative to conventional smelter/refining operations.

Successful Repairs and Field Welding of Corrosion Resistant Alloy Equipment On Site

Pete Philippon, Tricor Metals

Managing a successful repair or new construction of corrosion resistant alloy equipment on site requires planning and preparation. The author covers lessons learned over the years and discusses steps that have led to successful projects. Topics include making sure the scope of work is well understood by all parties, who is responsible for what facet of the project, timing, and best practices criteria for selecting the qualified vendor. Does the company have a history of successful on-site fabrications? Does the safety culture meet yours? Do they have a well-established safety program with the latest electronic protocols (ISNetworld, DISA for example)? Are they open to pre- and post- project visits and walk-throughs? Are they easy to work with? These and other items will be discussed in detail.

The Impact of Life Cycle Carbon Footprint of Using Different Materials in CPI Equipment

Claes Tigerstrand, Outokumpu

There is an increasing focus on the environmental emissions generated by different industrial processes and possible measures to reduce them. This may result in new production processes being put into use and lead to more demanding conditions for its equipment, i.e., process vessels and piping systems. Higher or lower temperatures, the presence of more corrosive solutions, calls for more resistant materials. Initially, the sustainable transformation mainly concerns emissions in the production process (Scope 1), and secondly emissions from electricity (Scope 2). But ultimately, every component with significant influence on the emissions, such as raw materials and purchased goods (Scope 3) must be considered to reduce the overall carbon footprint of a produced product. Hence, a greener process calls for greener material solutions for its process equipment. The challenge hereby is how the material specifier can compare different material solutions and draw unbiased conclusions of their respective environmental performance throughout the whole life cycle of the equipment, including potential recycling. The existing tools (LCA) and data inventory to accomplish this task will be presented and limitations in its use will be discussed.

Planning to Fail: Some Unexpected Developments

Matthew Bell, IRISNDT

Operating facilities have varied and challenging processes; they require damage resistant materials at low and high operating temperatures. Failures are prevented by using specialized mechanical design and materials. However, substantial corrosion and cracking damage can occur due to many reasons, such as unforeseen contaminants, severe service, service condition changes, material characteristics not covered in basic specifications, and effects of long-term service. Vigilant inspections are essential since these demanding processes can develop dangerous leaks and potential explosions. This presentation summarizes case studies illustrating common forms of process equipment damage for various materials used in industry and the inspection and non-destructive testing (NDT) techniques used to identify them. Case Studies include corrosion, cracking, and degradation failures from carbon steels, austenitic stainless steels, commercially pure titanium, high temperature alloys, and non-metallics. The intended audience is for any operating facility that handles cooling waters, has hydrogen production, puts materials in high temperature service, or insulates piping and components.

Overview of Applications with Increased Equipment Reliability Using UNS N10362 and UNS N06035 Alloys

Javier Guerrero, Haynes International

This presentation is an industry overview of key applications where latest-generation Ni-based Corrosion Resistant Alloys N10362 (HASTELLOY® HYBRID-BC1® alloy) and N06035 (HASTELLOY® G-35® alloy) have improved equipment reliability and service life after adoption. Examples include heat exchangers, vessels, valves, piping, etc. N10362 has excelled as a versatile alloy with excellent corrosion resistance in HCl, H_2SO_4, and organic acid solutions. It typically outperforms other Ni-Cr-Mo alloys in reducing acids and can tolerate oxidants up to a certain limit. On the other hand, N06035 has exhibited outstanding performance in highly oxidizing environments, like wet-process phosphoric acid production, compared to other Ni alloys and stainless steel. The cases presented outline the advantages of using well-selected material, which depend on application, in equipment reliability and service life. ▪

HEFFNER NAMED MTI'S 20TH FELLOW

HONORED AT 2023 AWARDS BANQUET IN ST. LOUIS

Left to Right: Debra McCauley (Chemours), Becky Heffner, Dale Heffner (Knight Material Technologies), and Heather Allain (MTI)

When MTI Chair and long-time friend Debra McCauley invited fellow member Dale Heffner out for lunch in October, he wondered what she might want to discuss. Polymers projects? Dual laminates? As exciting as that sounds, McCauley had bigger news to share, an announcement that made Heffner's jaw drop and left him speechless for the first time in quite a while (rare for those who know Dale). While he worked his way around the gravy-smothered turkey and potato stuffing special at The New Pennsburg Diner near Quakertown, PA., McCauley revealed that Heffner had been named MTI's newest Fellow.

"Pinch me," he later texted (and not to wake him from a food coma). "I am thinking it was a dream." Heffner said he had no suspicion whatsoever as they sat in the diner. "It was one of those things where it takes a few moments to sink in. Then I was just completely honored. I only know of one other supplier member company Fellow on the list, and that is Galen Hodge. So to be a supplier and be recognized in this way, I was completely shocked!"

Teased about being speechless again during the MTI Awards Ceremony at AmeriTAC 142 in St. Louis, he chuckles. "What really sank in is that it is an honor for me, but I would not have been there without Becky at home taking care of the kids and raising the family while I was traveling on business and going to MTI meetings," he explains. "And I would not have been there without all of the people who served on project teams, on the Board, and the PDCs. Without everyone else, there is no Fellow Award. So I felt it was neat that the members and Becky were sharing in that with me."

One of Heffner's endearing traits is that he is humble. While he chooses to focus on what others bring to the table, he has put on his "MTI hat" and served the organization for many years. Heffner has represented Electrochemical (now part of

> CONTINUED ON PAGE 42

MTI VIRTUAL GLOBALTAC MEETING A SUCCESS

FACILITATES WORLDWIDE PROJECT COLLABORATION

MTI Project 357 Corrosion in Bio-Oils Phase 1 Testing - flow-through and max wall shear stress.

The return to in person meetings has restored opportunities for collaboration that the pandemic helped us to particularly value. However, virtual meetings have advantages as well that MTI wants to continue to capitalize on. The GlobalTAC 2023 was designed so that members across time zones, who may otherwise not be able to attend an in-person meeting, could connect and learn about the projects and topics from each TAC region. Jeremy Nelson (Koch Industries) spearheaded the meeting planning and was well-equipped to handle two days of online MTI meetings after his success as the AmeriTAC Chair during the global shutdown.

"GlobalTAC meetings bring the MTI community together to focus on projects," Nelson explains. "We renewed the virtual format set in place out of necessity during the Covid era, with a change in focus to an increase in the speed of technology development on projects. This virtual format has the potential to become a semi-annual event depending on the need and reception from members."

Thanks to Jeremy and the rest of the GlobalTAC planning team's hard work the meeting was well received with 74 participants on day one and 94 on day two. Of the total participation, 33 attendees were able to join us for the first time to experience MTI in action and learn more about the collaborative projects MTI funds and how those can provide valuable knowledge. With a deeper reach into member companies, the meeting was able to broaden the knowledge shared and improve the collaborative efforts within MTI.

Ross Dupre (NobelClad) was among the first-time attendees and offered a glowing review from his experience and impression of the meeting.

"As a first-time attendee of MTI (virtually or in person) it was nothing but impressive. Virtual meetings can be a challenge for a simple one-on-one meeting much less several attendees. MTI executed this meeting professionally and made it user friendly," he shares. "The organization made it so attendees knew what was happening and weren't left in the dark. The topics of discussion were meaningful and worthwhile for anyone that handles materials, from an SME to someone that may wear many hats within an organization. I look forward to becoming more involved within MTI and the next AmeriTAC meeting!"

Attendees from across each TAC region were able to tune into project reports and learning sessions that they otherwise may not have been aware of, including reports on Bio-Oils Phase 0 and Phase 1 (357), Reformer Outlet Manifolds (375), Alloy 625 Atlas (335), and a case study on Considering Suppliers for FFKM.

As the world has shifted, MTI remains agile in disseminating knowledge to its members. With travel restrictions lifted, we have been able to return to in-person meetings but continue to look for ways to provide additional value. The 2023 GlobalTAC meeting was an example of that and with the positive feedback we hope to be able to bring more successful meetings to our members across each region in the future.

Don't miss out on these valuable learning and networking opportunities! Visit the MTI website www.mti-global.org for our upcoming events list. ▪

OCTOBER MEETING DELIVERS TECHNICAL CONTENT, PROJECT DEVELOPMENT AND BOD STRATEGIC VISION

AmeriTAC 142 Update

MTI members convened October 23-25, in St. Louis, MO for AmeriTAC 142, the Alloy Castings for Critical Applications Forum, MTI Annual Membership Meeting, Annual Awards Banquet (see page 36) and MTI's first ever trivia night. Although total attendance only reached 75 participants, which is historically lower for an MTI October meeting, there were 43 member companies represented and five first-time attendees.

The TAC 142 meeting content, technical meetings, and networking were a success under the leadership of the TAC Chair, Andrew Rentsch (Huntsman) and Vice Chair, David Cole (Marathon Petroleum). The first day included a special tour of the local MetalTek foundry prior to the Castings Forum, which was a full afternoon session of expert presentations and discussions. With the addition of the Annual Meeting on the 24th, the leadership team still managed to pack the agenda with 15 project team meetings, the Ceramics, Polymers, Metals and Knowledge Management Project Development Committee meetings, three technical structured forum speakers, and a project funding proposal presentation. The official executive summary, including where to find presentations, is available in the AmeriTAC library.

For a bit of fun to conclude the busy, but productive event, approximately 35 attendees stayed for the MTI Trivia Night following the awards banquet. MTI members teamed up at tables, named their team and tested their knowledge over 10 rounds of questions while MTI staff hosted the game. Although it was a close start between all the groups, team "Sneaky Leakies" crept ahead and took first place by a notable margin. The consensus: MTI should host another trivia night in the future, so be sure to join us next time if you missed out!

Above: Attendees participate in a local foundry tour of MetalTek. Left: AmeriTAC attendees engage the speaker in a discussion during a structured forum presentation.

2023 Annual Meeting Results

The 2023 Annual Membership Meeting took place Tuesday, October 24, in St. Louis, Mo., in conjunction with AmeriTAC 142. Members voted and approved the 2023 Board of Directors slate and the slates for TAC leadership:

2024 Board of Directors

- Debra McCauley, Chemours (Chair)
- Andrew Rentsch, Huntsman (Vice Chair; Ex Officio)
- David Barber, Dow
- Bill Bieber, Webco Industries
- TP Cheng, ITRI (Ex Officio)
- David Cole, Marathon Petroleum
- Anette Hansson, Topsoe (Ex Officio)
- Dale Heffner, Knight Material Technologies
- Curtis Huddle, Eastman Chemical Company
- Meghan Oaks, BASF
- Maria Jose Oestergaard, Topsoe
- Maurice Wadley, DuPont
- Chuck Young, Tricor Metals
- Nina Young, Chevron Phillips Chemical Company

AmeriTAC Leadership

- Chair: Andrew Rentsch, Huntsman
- Vice Chair: David Cole, Marathon Petroleum

AsiaTAC Leadership

- Chair: TP Cheng, ITRI
- Vice Chair: Alex Chen, Dow
- Vice Chair: Jan Li, Outokumpu

EuroTAC Leadership

- Chair: Anette Hansson, Topsoe
- Vice Chair: Lars Rose, DuPont

Members also voted and approved a three percent increase for the 2025 dues schedule over the 2024 dues.

MTI Chair Debra McCauley (Chemours) presents the new strategic direction during her report at the Annual Meeting.

Board of Directors Shares New Strategic Direction

Debra McCauley (Chemours), MTI BOD Chair, presented the new plan during the annual membership meeting, which was adapted, updated and expanded over the past year from the 2018 Strategic Plan. The new Strategic Vision has five overall objectives, with actions to achieve each and KPI's to measure the success of the actions taken.

The new objectives where the BOD focuses strategically now include Engage Membership, Generate Technical Resources, Transfer Knowledge, Maintain Financial Stability, and Retain and Grow Membership. The complete plan for 2023 and beyond, including mission, vision and guiding principles, can be found by navigating to About > Organization and clicking the blue "Access" button for the Governance Library. If you have any questions about the new strategic direction, please reach out to Debra McCauley (Chair), Andrew Rentsch (Vice Chair) or Heather Allain (Executive Director).

Materials Technology Institute

Objectives	Actions to Achieve	Key Performance Indicators
Engage Membership	• Increase Membership Participation • Rapidly integrate new members (both new member companies and individuals new to MTI) • Maintain open and respectful culture focusing on the best for MTI	• Collective Engagement Score increases by 5% annually • Meeting Attendance increases by 5% average annually
Generate Technical Resources	• Provide resources that solve technical issues by: - Funding and Executing Projects - Developing Training, TAC Bulletins, and Webinars - Ensure MTI Forum provides valuable technical exchange • Organize TAC meetings to share knowledge on state-of-the-art technologies that offer clear benefits to members	• Annual Project Spend at least 90% of budgeted amount • Ensure projects have broad support among member companies – *All projects have a minimum of 5 participants from separate member companies*
Transfer Knowledge	• Effectively distribute MTI information to DRs and VDRs • Effectively distribute MTI information within Member Companies • Provide continuing education in materials technology • Distribute MTI knowledge and increase MTI reputation and visibility outside of MTI	• Collective Engagement Score increases by 5% annually • Manage as a regular Knowledge Management PDC Agenda item • Website download requests from non-members increase 10% • Linked In Followers, Social Media impressions growth 10% annually • Non-member attendance/participation (webinars+training) • Are other organizations referencing MTI content as relevant
Maintain Financial Stability	• Generate sufficient revenue to operate and fund projects • Operate with fiscal responsibility	• Operate within budget • Admin Expenses maintained <=25% Annual Revenue • Communicate MTI Financial Status to membership globally • Manage cash reserve in accordance with MTI policy
Retain and Grow Membership	• Provide a Global network for materials experts to exchange non-proprietary information on materials performance issues • Increase MTI's profile outside of the organization	• 95+% Membership Retention • 2 new Producer Members added annually • 10% increase in first time attendees annually in each region

Participants convened in Shanghai, China for the Fall 2023 AsiaTAC meeting, September 25-27, 2023.

ASIATAC UPDATE

FALL MEETING GENERATES POSITIVE VIBES AND SIX NEW PROJECT IDEAS

As the old saying goes, patience, persistence, and perspiration make an unbeatable combination for success. Such was the case when the Fall 2023 AsiaTAC meeting convened in Shanghai, China, September 25-27. "This is the first time we were able to host a full-blown face-to-face meeting in Asia in four years," according to Paul Liu, MTI Associate Director. Although the Fall 2022 AsiaTAC Meeting took place live in China, participation was limited due to travel restrictions related to the COVID-19 Pandemic. The Spring 2023 AsiaTAC Meeting, which was to be held in Da Nang, Vietnam, was canceled due to extenuating circumstances.

Moving beyond those challenging situations and holding a productive in-person session made the recent successful fall meeting feel all the sweeter for the 36 participants. In total, sixteen member companies and three potential member companies were represented in Shanghai.

"I had the privilege of attending the Fall AsiaTAC meeting and seeing the true spirit of MTI collaboration at work in the group," says Heather Allain, MTI Executive Director. "The agenda was packed with technical content, as well as members sharing case histories of failures for everyone to learn from." In addition, MTI member company Stress Engineering Services led a virtual training session on "Reliable High Temperature Materials for Heaters and Furnaces".

AsiaTAC's leadership team also facilitated a brainstorming session, identifying 11 new topics for training opportunities, and six potential project ideas. Liu adds that the AsiaTAC PDC will follow up virtually and start developing the highest potential ideas into new projects.

Overall feedback from attendees was overwhelmingly positive. "Everyone appreciated being able to meet in person," points out Allain. "Hybrid and remote meetings can be effective, but they don't come close to replacing the relationships developed and synergistic conversations that occur when members are able to meet in person."

Toward that end goal, the AsiaTAC leadership committee, led by Chair T.P. Cheng, is already hard at work planning a face-to-face 2024 Spring AsiaTAC Meeting. MTI Distinguished Service Award winner and Designated Professional, Maso Nakahara (retired from Asahi Kasei), has been in communication with the Japan Society of Corrosion Engineers (JSCE) to arrange a one-day joint international meeting in Omiya, Japan next June (2024). Please watch for further details in subsequent issues of CONNECT and at mti-global.org. ▪

A Brainstorming Session Identifed
11 Topics for Training Opportunities
6 Potential Project Ideas

EUROTAC UPDATE

FALL MEETING FOCUSED ON PROVIDING TECHNICAL INFORMATION AND DEVELOPING PROJECTS

The Fall 2023 EuroTAC meeting convened November 8-10, at member company TOPSOE's campus, in Lyngby, Denmark—a suburb of Copenhagen. Anette Hansson, EuroTAC Chair, led the meeting, assisted by Lars Rose, EuroTAC Vice Chair, Robert Freed, MTI Associate Director and Heather Allain, MTI Executive Director. Although he was unable to attend, Rolf Kirchheiner, MTI Associate Director—Europe, played a key part in helping the planning team organize the two and a half-day event.

Attended by 25 representatives from 17 member companies and nine countries, the meeting was packed with excellent technical presentations from invited speakers pertinent to MTI member interests, status reviews of funded projects, discussions of newly proposed projects, a project brainstorming session, and an informative tour of Topsoe laboratory facilities at the meeting site.

One topic of particular importance in the industry was the Update on EU Regulations & Hearing (PFAS) by Cedric Triquent (Chemours). Triquent indicated there were more than 5,600 responses, regarding the proposed regulations, received by the EU from all industrial sectors. The responses point to the understanding that individual derogation for fluorochemical use and application will not be effective or practical for controlling PFAS release into the environment. It also shows that different areas of the world have different approaches to PFAS regulation:

- Japan had the largest response to the proposed EU regulation since Europe is a significant business market for it. The new regulation could have a significant impact on their economy if enacted.
- Great Britain has very much a scientific approach.
- In the US there is a federal initiative, and many states have their own initiatives on PFAS control. At the federal level, the approach is to focus on the control of specific compounds, not the overall ban of PFAS materials. The U.S. Department of Defense issued a document stating that without PFAS materials it would not be viable to have a modern army and has done a thorough technical analysis that finds PFAS essential for national security.
- China and India have not instituted any significant control of PFAS materials.

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Peter Nielsen lectured on Drones in Confined Spaces.

2023 MTI TECHNICAL PROJECTS REVIEW

MTI technical research projects are thriving. The magnitude of collaboration, rapid development and communication have all been key this year in working to continue addressing members' industrial processing industry challenges. Here is a quick review of this year's potential projects that formed and newly funded projects.

POTENTIAL PROJECTS FORMED

#399 – 2nd Dual Laminate Training for the US
Champions: Lisa Desai (Pfaudler) and Avery Boyer (Chemours)

#400 – Ceramics Refresh Training
Champion: Jay Schickling (Chemours)

#401 – Inspection Basics for API 2024 Inspection Summit
Champion: Jeremy Nelson (Koch Industries)

#402 – Process Equipment Fabrication Roundtable
Champions: Wendy McGowan (Neotiss) and Adam Renstrom (Ward Vessel and Exchanger)

#403 – High Purity Processing Roundtable
Champions: Andrew Rentsch (Huntsman) and Hisham Samra (Pfaudler)

#404 – Fracture Mechanics, MTI Pub No. 8 Update
Champions: Jan-Willem Rensman (Fluor) and Ed Richey (Linde)

#405 – Cracking Susceptibility, Mapping for High Temperature Austenitic and Ni-base Alloys
Champion: Jan-Willem Rensman (Fluor)

#406 – Guideline for Preservation of new Equipment & Piping During Plant Construction, Commissioning, and Maintenance Replacements
Champions: Jan-Willem Rensman (Fluor) and John Houben (ExxonMobil)

#407 – Surface Modification Guide:
Champion: John Houben (ExxonMobil)

#408 – Fiber Optics for High Temperature Applications
Champions: Richard Samson-Ovia (Air Products) and Mark van den Broek (Fluor)

#409 – Equipment Evaluation and Preparation for High Purity Service
Champion: Cameron Morelock (Eastman Chemical)

#410 – Guidance for Failure Mechanisms — Pulp and Paper Processing
Champions: Jeremy Nelson and Matthew Richardson (Koch Industries)

#411 – Extractables in Polymers
Champions: Michael Krauss (Agru) and Jenell McCall (Chemours)

#412 – AI for Knowledge Management
Champions: Maria Jose Oestergaard (Topsoe) and Andrew Rentsch (Huntsman)

For updates and information on all potential projects, please visit mti-global.org/teams--groups/potential-projects.

FUNDED PROJECTS

#310 – New Test Method for Titanium Hydriding
Champion: Curtis Huddle, Eastman Chemical
Amount Funded: $12,000
Project Scope: Inspect a heat exchanger at an Eastman Chemical site that is believed to be failing due to Ti hydriding. The cost of this project proposal includes: ECT inspection of the heat exchanger with the modified procedure for 100% of 187 tubes in the heat exchanger; All travel expenses by ProQual personnel to the Eastman site, per-diems, etc.; Initial Preliminary Field Report prepared by ProQual; Final report completed within two weeks following heat exchanger inspection.

#385 – MTI Podcast
Champion: Marc Cook, Dow
Amount Funded: $23,500
Project Scope: An aging workforce presents an economic impact to companies that lose knowledge. Maintaining and transferring this knowledge is crucial to limit interruptions to business operations. MTI has a vast repository of knowledge both in the MTI library and among its members. The MTI podcast will aid in capturing knowledge that is not currently recorded as well as improve accessibility to existing knowledge through distribution as an audio format. Beyond the main purpose as a knowledge management tool, the MTI podcast may serve as marketing material to attract new members and as a potential source of revenue if highly downloaded. This project focuses on the establishment of the podcast after which it will be moved into an ongoing committee.

#394 – Summarizing Requirements of ASME PCC-2 Composite Repairs
Champions: Avery Boyer and Debra McCauley, Chemours
Amount Funded: $82,000
Project Scope: Develop a guide via process map based on the requirements of ASME PCC-2 and ISO 24817 to assist in understanding the requirements for composite repairs on metallic equipment. Supplemented with a webinar outlining use of the process map. Develop some scenarios and walk through each from start to finish.

#399 – Dual Laminate 2nd Training U.S.
Champions: Avery Boyer, Chemours and Lisa Desai, Pfaudler
Amount Funded: $28,000
Project Scope: Repeat training that MTI conducted in Baton Rouge Nov 2022 – includes video and audio for Matchbox to complete the BR training sessions missed (Module 4). A comprehensive three-day Dual Laminate Training Course will be provided. This Training Course will use MTI company subject matter experts to thoroughly cover dual laminate materials and design fundamentals, manufacturing techniques for pipe and equipment, applicable codes and testing, inspection, and repair options.

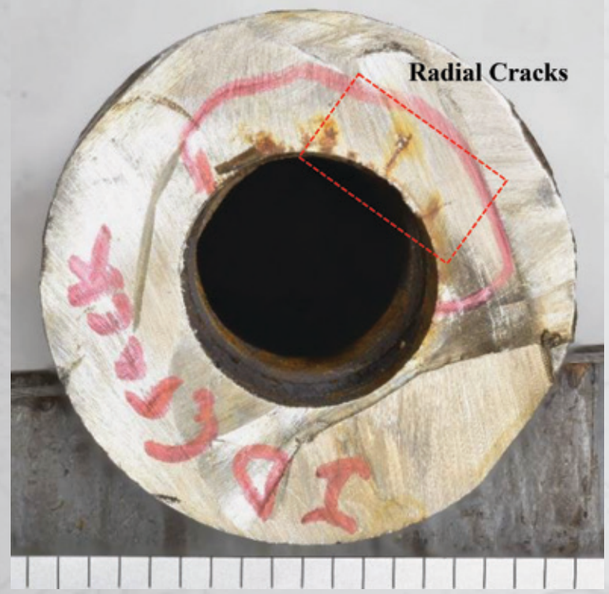
#401 – API Inspection Summit 2024
Champion: Jeremy Nelson, Koch Industries
Amount Funded: $1,500
Project Scope: Work with Brent David Ray and Mark Carte (Vice Chair API IMI Summit, Training Coordinator) to develop and offer a training program on inspection of FRP and Dual laminate at the 2024 API inspection summit.

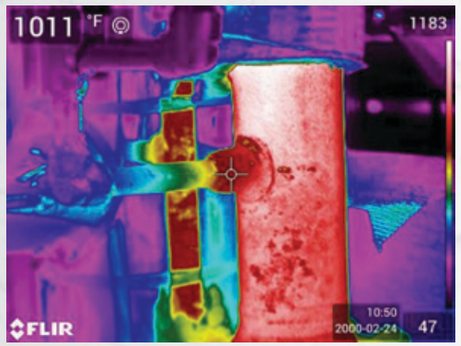
#410 – Guidance for Failure Mechanisms — Pulp and Paper Processing
Champions: Jeremy Nelson & Matthew Richardson, Koch Industries
Amount Funded: $147,550
Project Scope: Create a guideline for failure mechanisms in the pulp and paper industry. Leverage the template of the book "MTI Guidance for Failure Mechanisms in the Chemical Process Industries." This is required because it is an efficient and accessible means for conveying the most important information to a field-oriented audience.

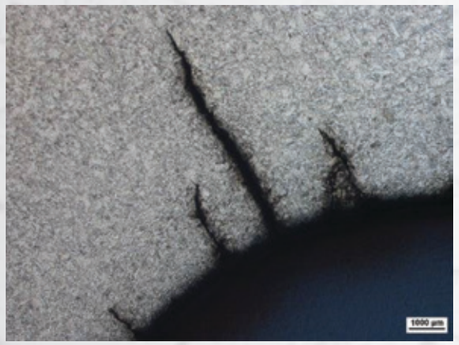
For updates and information on all other currently funded projects, please visit mti-global.org/teams--groups/funded-projects.

FAILURE OBSERVED AT CROSSOVER PIPING OF PYROLYSIS FURNACE AND PATH FORWARD

BHADRESH PRAJAPATI, JIMMY CLEAVINGER
CHEVRON PHILLIPS CHEMICAL COMPANY







ABSTRACT

304H Stainless Steel has long been known as the material of choice for furnace convection sections. However, exposure to elevated temperatures for long durations can lead to higher temperature degradation. In this case study, we represent the unique failure observed at the crossover piping, 304H metallurgy, at small bore connections after four and half years of service. This systematic failure was observed on 100+ small-bore connections at the same process location on three furnaces. The location of cracks on individual small-bore connections was between the 5 o'clock position and the 7 o'clock position. The crossover piping was operating in the range of 1300°F to 1350°F (704°C to 732°C). The failure analysis has indicated presence of thermal as well as mechanical stresses, however, without sensitized microstructure. Cracks were observed in all three directions: longitudinal, circumferential, and radial. At the toe of the weld, cracks were stepwise, however were not interconnected. Thermal fatigue is identified as the principal root cause. In addition, unexplained chromium dilution in the weld was observed. The probable cause of the chromium dilution is "Self-healing". This study is is intended for inspectors, engineers and managers explaining the complex failure mode, root cause assessment and effective resolution.

INTRODUCTION

The ethylene cracking furnace is a core equipment in ethylene production units in the petrochemical industry. These furnaces are operating at a wide range of temperatures from 450°F (200°C) at the inlet of the convection section and up to~2000°F (1150°C) at the furnace radiant outlet section. The convection section is recovering heat from the exhausted flue gas. The piping connecting the convection section to the radiant section is called crossover piping. This crossover piping is operating in the range of 1100°F to 1450°F (600°C to 800°C) and is insulated to conserve the heat. For crossover piping, austenitic stainless steel 304H is a popular choice of material because of its excellent combination of high temperature mechanical properties, high temperature corrosion resistance, and superior structural stability [1] [2]. Figure 1 shows a schematic view of the furnace arrangement.

The failure analysis investigated in this study was identified as a hydro-

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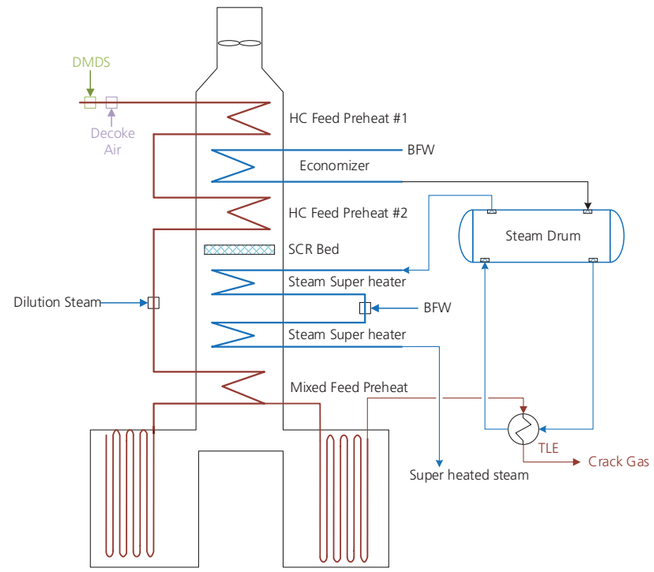

Figure 1: Schematic View of Ethylene Cracking Furnace (Drawn by Author)

FAILURE OBSERVED AT CROSSOVER PIPING OF PYROLYSIS FURNACE AND PATH FORWARD

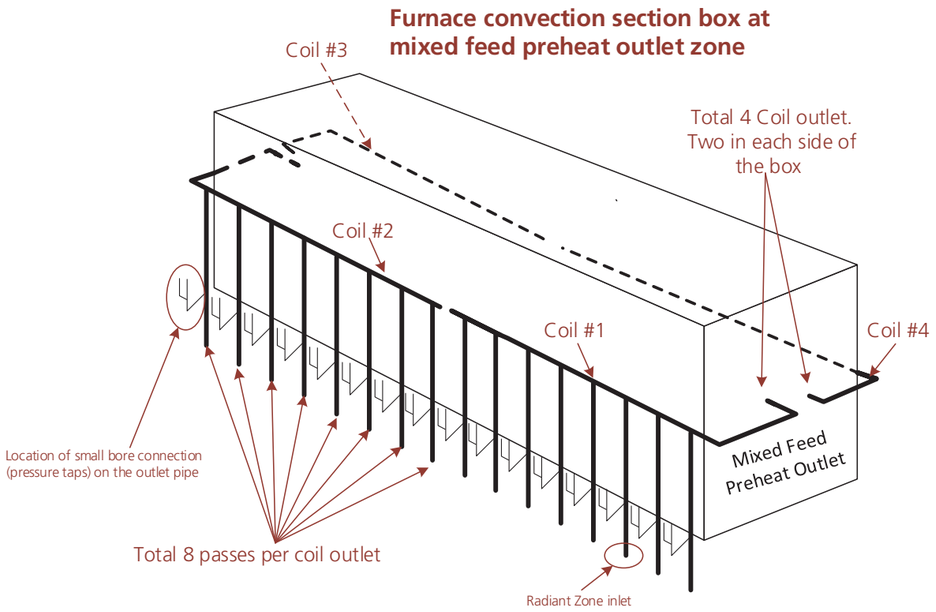

Figure 2: Schematic shows the location of the Small-Bore Connection (Pressure Taps) above the "Arch", inlet to Radiant Zone. Total 32 inlet going into the furnace and each inlet has a pressure measuring device above the venturi. (Drawn by Author)

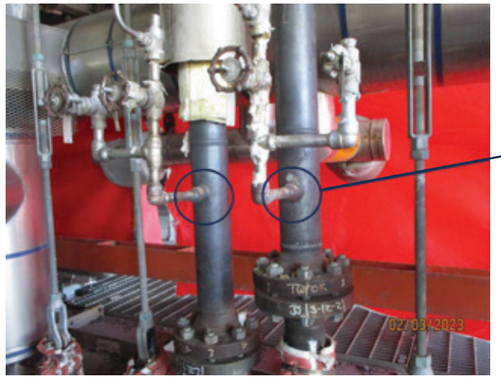

Figure 3: Location of pressure taps in the field

Figure 4: Location of cracks on pressure taps

was systematic and chronic in nature. These pressure taps are insulated to minimize the thermal gradient; therefore, it was difficult to identify cracks while in operation. Design review of the furnace reveals the outlet manifold from the convection section is Nominal Pipe Size (NPS) 8" SCH 80 pipe size and each vertical outlet of the manifold is NPS 4" SCH 40 pipe size. These pressure taps were socket welded NPS ¾" small bore connections. The crossover piping was operating in the range of 1300°F to 1350°F (704°C to 732°C) at operating pressure of 35 to 50 PSIG. Figure 2 shows the schematic view of mixed feed preheat to the convection outlet section and the relative location of the pressure tap, Figure 3 shows the joint configuration and Figure 4 shows the location of the crack. The observed failure was the "first in kind" failure at the location after approximately four and a half years of service.

LABORATORY RESULTS

Due to the nature and extent of the concern, several failed small-bore connections were submitted for failure analysis. The small-bore connection at Coil #3 outlet #1, which experienced the wisp of fire, was investigated in detail.

Visual Examination

The close-up visual examination, Figure 5, revealed a crack on the toe of the weld on the nipple side, jagged and following the contour of the weld toe. After removal of oxide from the internal and external surface, the outer diameter side (OD) revealed multiple fissures oriented circumferentially parallel to the principal cracks, Figure 6 and Figure 7. The inside surface, after splitting in half, showed a network of longitudinal cracks intersecting the circumferential cracks and creating the appearance of "mud cracking," Figure 8. At the leak site, the toe of the weld, the fractography shows the crack initiated from the outer surface, progressing towards the inside.

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Figure 5: Close-up visual examination

Figure 6: Visual examination after removal of oxide

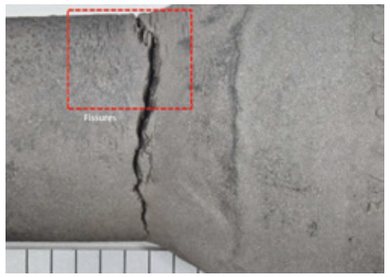


Figure 7: Closeup view of fissures OD

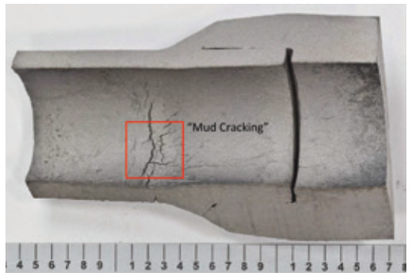


Figure 8: "Mud Cracks" in ID

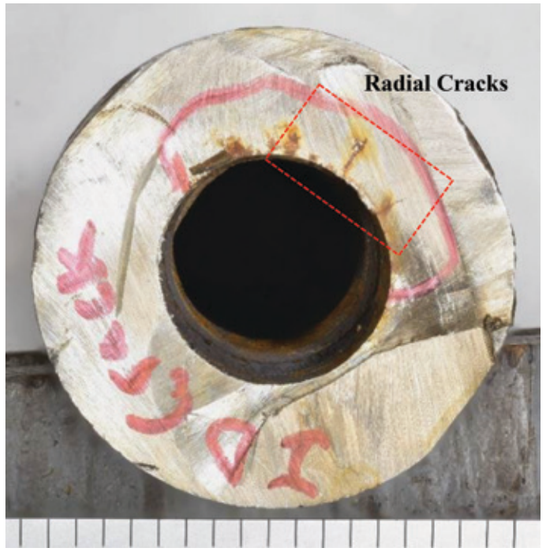
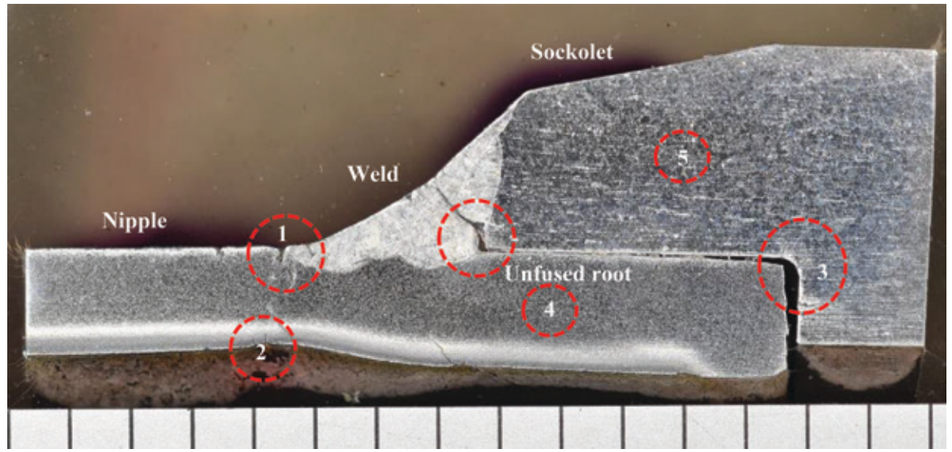
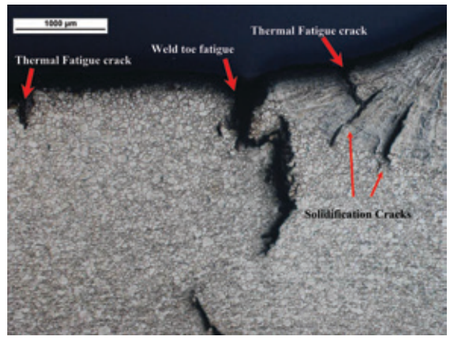
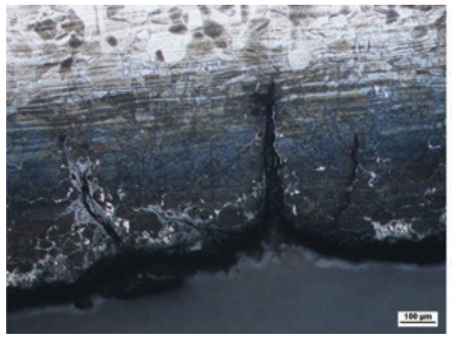


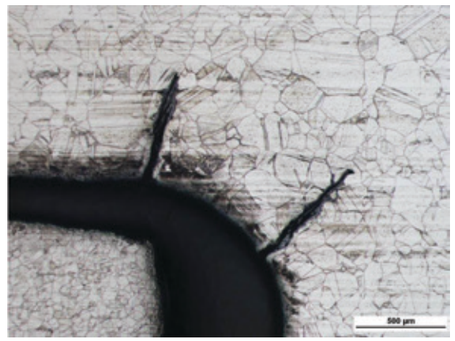
Figure 9: Radial Cracks on Sockolet®

FAILURE OBSERVED AT CROSSOVER PIPING OF PYROLYSIS FURNACE AND PATH FORWARD









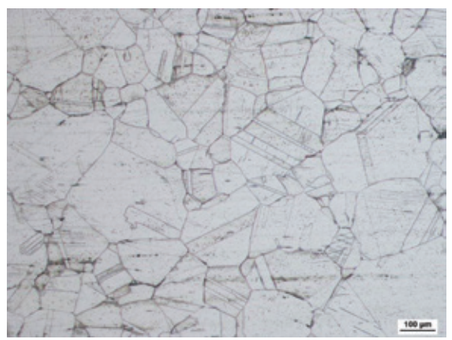


Figure 10 (top): *Etched macro section by Kallings solution.*
Figure 11 (middle row, left): *Toe of the weld at 25X, Killings solution, magnified section at location #1 of Figure 10.*
Figure 12 (middle row, right): *Magnified view at location #2 of Figure 10, etched with Killings solution.*
Figure 13 (bottom row, left): *Magnified view of location #3 of Figure 10, etched with Killings solution. Cracks are evidence of Thermal fatigue. Viewing at 25X.*
Figure 14 (bottom row, right): *Micrograph of location #5, shown in Figure 10, electrolytic oxalic acid etched, ASTM A262 Method A, magnification 100X.*

Metallographic Examination
A metallograph of a portion of the fracture surface is shown in Figure 10. A higher magnification view at the location of the through-wall crack, is shown in Figure 11. The micrograph revealed the presence of intergranular and trans-granular cracks with distinguished crack morphology. Cracks were stepwise, growing at slightly different elevations and were mostly transgranular in nature. The ID of the nipple shows evidence of carburization, Figure 12. The base of the socket showed evidence of thermal fatigue cracks, Figure 13, as well as

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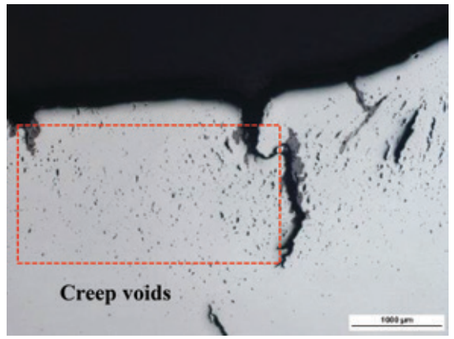

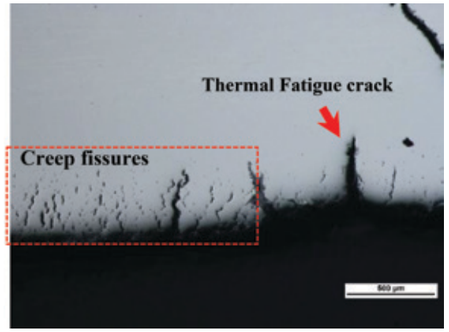

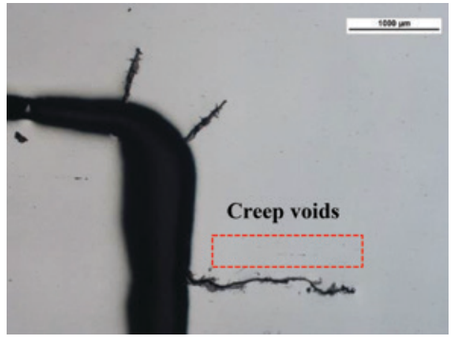

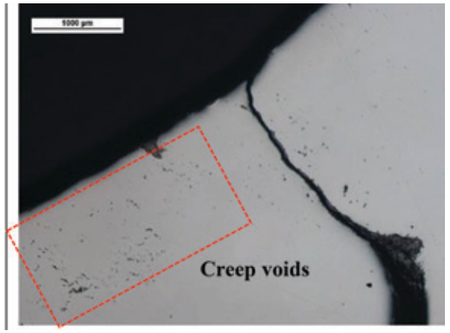

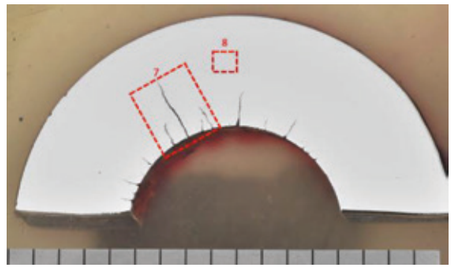

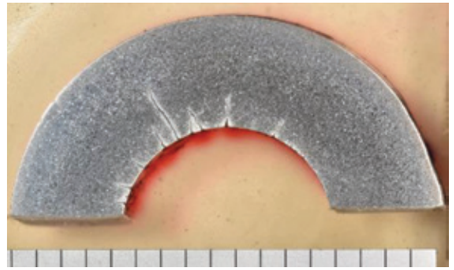

Figure 15 (top row, left): *Creep voids at location #1 of Figure 10. As polished condition.*
Figure 16 (top row, right): *T*Creep fissures at location #2 of Figure 10. As polished condition.
Figure 17 (middle row, left): *Creep void nearby crack, on location #3 of Figure 10.*
Figure 18 (middle row, right): *Creep voids at weld, showed in Figure 10.*
Figure 19 (bottom row, left): *Radial cracks at Sockolet®, As polished.*
Figure 20 (bottom row, right): *Radial cracks, Killings etchant.*

solidification cracks in the fusion zone of the weld, Figure 10. An optical micrograph of the section away from the defect zone, Figures 14 and 15, show small grain surrounds the large grain with twin boundary arrested within the grain. Figures 15, 16, 17 and 18 are the metallograph in as-polished condition (without etchant) of all marked areas in Figure 10, shows creep voids.

The radial cracks on the Sockolet® have also been metallographed to determine the type of cracks. The polished section for the radial cracks at the Sockolet® is shown in Figure 19. The magnified view of location #7 identified in the Figure 19, shows transgranular cracks appear to be thermal fatigue cracks driven by thermal stress in the hoop direction, Figure 22. The microstructure at mid-wall for the Sockolet® (Figure 23) shows evidence of aged austenitic microstructure. Similar to Figure 14 and Figure 15, Figure 23 shows small grain surrounded by large grain and twin boundaries.

The metallographs shown in Figure 14 and Figure 22 are taken from the zone away of the defect zone, to understand the base microstructure. Both samples were prepared in compliance with ASTM A262 Method A [3] showing a typical austenitic stainless-steel microstructure.

Chemical Analysis

Chemical analysis of the nipple (small bore pipe) and Sockolet® was performed using optical emission spectroscopy (OES) (Table 1). The results indicate that the chromium and molybdenum content were out of range for the weld deposits, and the chromium content of the Sockolet® was lower than the minimum required.

Elmnt.	Nipple (P1C3)/[%w]	A312 TP304H/[%w]	Weld (P1C3)/[%w]	AWS A5.9 ER308H/[%w]	Sockolet /[%w]	A182 F304H/[%w]
C	**0.06**	0.04 – 0.10	**0.05**	0.04 – 0.08	**0.04**	0.04 – 0.10
Si	**0.28**	≤1.00	**0.33**	0.30 – 0.65	**0.33**	≤1.00
Mn	**1.68**	≤2.00	**1.5**	1.0 – 2.5	**1.47**	≤2.00
P	**0.028**	≤0.045	**0.02**	≤0.03	**0.034**	≤0.045
S	**0.003**	≤0.030	**0.00**	≤0.03	**0.012**	≤0.030
Cr	**18.4**	18.0 – 20.0	**16.8**	19.5 – 22.0	**17.9**	18.0 – 20.0
Mo	0.29	-	**0.68**	≤0.50	0.27	-
Ni	**9.8**	8.0 – 11.0	**9.4**	9.0 – 11.0	**9.2**	8.0 – 11.0
Al	<0.0020	–	<0.0020	–	<0.0020	–
Co	0.687	–	0.0744	–	0.114	–
Cu	0.372	–	**0.24**	≤0.50	0.386	–
Nb	<0.0030	–	<0.0030	–	<0.0030	–
Ti	0.0082	–	0.0072	–	0.0020	–
V	0.0587	–	0.0652	–	0.0608	–
W	0.0274	–	0.0246	–	0.0501	–
Pb	<0.0030	–	0.0033	–	<0.0030	–
Sn	0.0154	–	0.0078	–	0.0075	–
B	<0.0010	–	<0.0010	–	<0.0010	–
Fe	68.89	Balance	70.78	Balance	70.11	Balance

Table 1: Chemical Analysis Results for Nipple and Sockolet®.

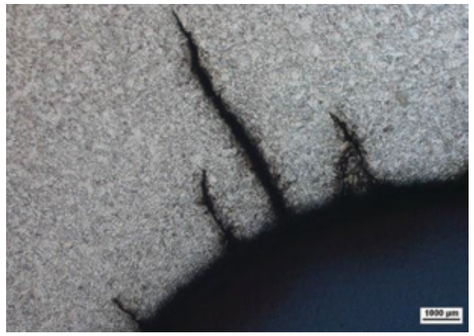

Figure 21: Magnified view of location 7 in Figure 19

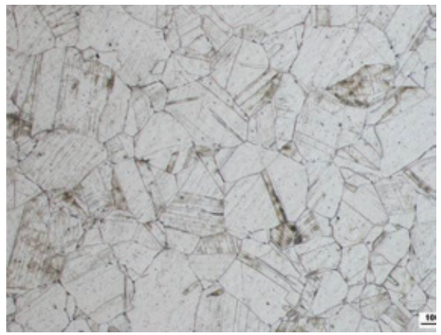

Figure 22: Micrograph of location no 8, shown in Figure 19, electrolytic oxalic acid etched, ASTM A262 Method A, magnification 100X

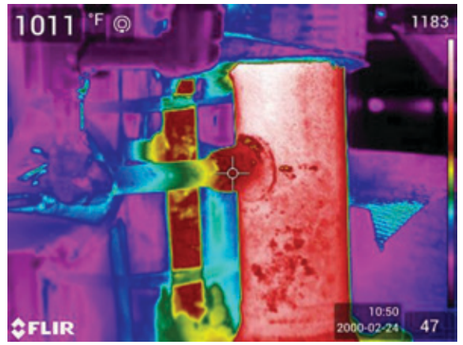

Figure 24: IR-Scan of one of the connections in identical service

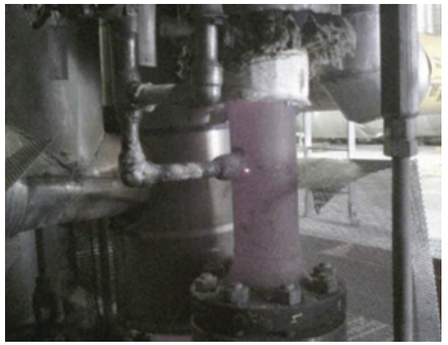

Figure 25: Picture shows location of the IR-Scan and pointer's direction

DISCUSSION

Metallographic examination revealed three distinct damage mechanisms, namely,

1. Carburization of internal surface.
2. Creep damage (expressed by presence of creep void and fissure) to external and weld connection.
3. Thermal fatigue at Sockolet® and nipple weld joint.

The leading contributor for the failure is combination of thermal fatigue and mechanical stresses (tensile) at bottom of the Sockolet® to nipple weld. The metallography shows the absence of sensitization or corrosion product, which was unexpected.

To better understand the sources of the thermal stresses, field walks and IR-Scans of similar connections on other furnaces were conducted. Figure 24 and Figure 25 show the image of one of the IR-scans, and Figure 26 summarizes the observed temperature phenomenon at the 32 pressure taps while in service. The extreme temperature gradient was observed within approximately 8" of the nipple connection. One end of the nipple was experiencing about 1000°F (538°C), whereas the other end was experiencing around ambient temperature. This extreme thermal gradient was observed in a relatively small section. This drastic temperature change is due to a combination of two factors, 1) minimum to low flow in a stagnant zone, and 2) presence of water (process water, often referred to as either quench water or dilution steam).

The field survey also revealed manufacturing/construction practices that potentially had induced the bending stresses at the bottom of the pressure tap connection. Figure 27 and Figure 28 show the operating condition of the

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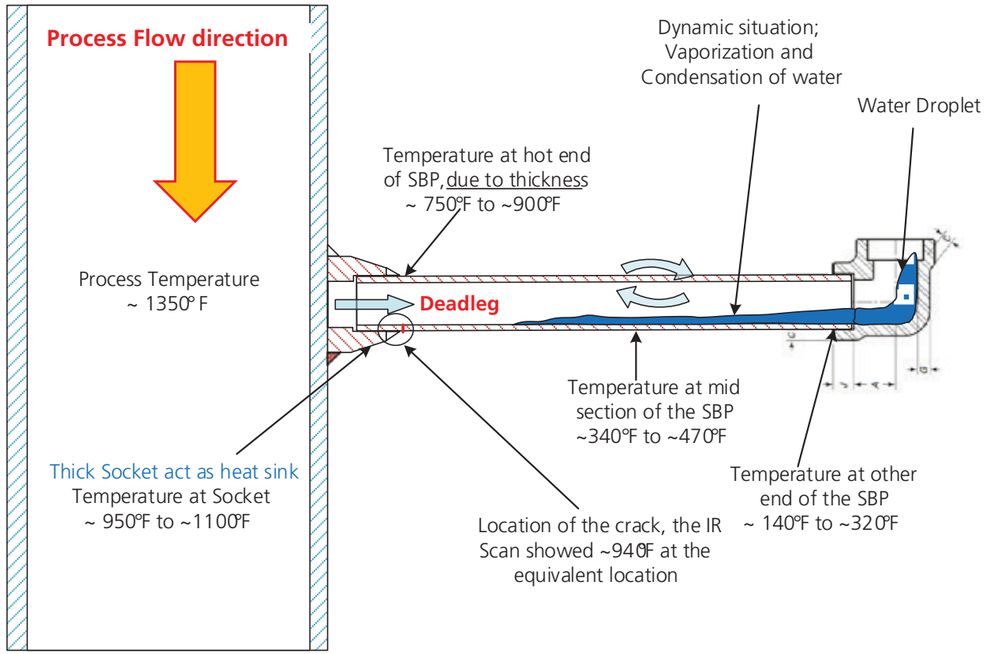

Figure 26: Summarized operating temperature survey. (Drawn by Author)

pressure taps. The metallic screen was installed as a safety measure to prevent accidental exposure to the hot piping in the vicinity of the bolted flange connection. During operation, this location expands due to the thermal movement of the radiant coil. However, the screen restricts the downward movement causing excessive stresses on the connection.

The microstructure of the intact area, Figure 14 and Figure 22, is mainly composed of larger sized equiaxed austenite grains along with small grains in between and twin crystal lamellar grow throughout most of the austenite grains. This is a typical microstructure of annealed stainless steel after work hardening (plastic deformation) indicating recrystallization of work hardened grains. Along with a typical microstructure, Figure 14 shows irregular lamellar structure, intercepted within the grain due to grain growth. This structure is indicative of the grain growth, as more activation energy is required for twin boundary migration versus austenite grain boundary migration. This crystal structure manifests an early stage of creep [2].

To better understand the absence of the sensitized microstructure, a literature review was conducted, revealing the absence of sensitization identified by ASTM A262 method attribute to phenomenon called "Self-healing," the enrichment of chromium depleted zone by diffusion of chromium from interior of grain to chromium depleted zone [4] [5] [6]. The phenomenon has been known to nuclear power and sulfuric acid production industries for more than three decades; however, it has not been documented extensively. A study done by Nagashima et al. [4], and Kolli et al. [6], has demonstrated that, 304H operating above ~1300°F (700°C) could start experiencing the "healing effect" after 120 hours of service. This study provides a reasonable explanation of our findings.

RESOLUTION

The Sockolet® connection was considered the root cause of the failure, as the significant difference in the thickness of Sockolet® vs. nipple causes excessive thermal stress on the connection. In addition, the restricted movement, due to the installation of safety barrier, induced bending stresses beyond the design capabilities of the metallurgy. To resolve the issue, without making significant changes in the design of the connection, including the safety barrier and piping geometry, the pressure tap connection has been upgraded to extruded piping per ASME B31.3 section 304.3.4. The metallurgy of the extruded piping is Alloy 800HT, due to availability.

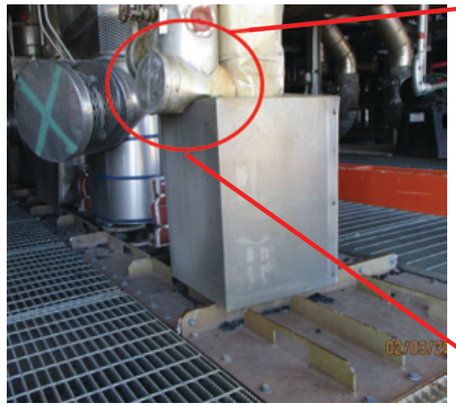

Figure 27: Field walk showed potential source of bending stresses. An obstructed movement of pressure taps

Figure 28: Magnified view of the obstructed movement

CONCLUSIONS

1. The fracture on the pressure taps was initiated as a mechanical fatigue at socket to nipple weld connection. The cracks have propagated in different elevations in transgranular fashion due to the stress concentration mechanism. The stress concentration mechanism is due to relatively lower mechanical strength at higher temperature and the differential thickness at socket connection causing excessive stresses on the relatively thin nipple (small bore pipe).

2. The chemical composition of the socket to nipple weld did not meet the requirements for ER-308H. However, the information is inconsequential as the failure started at the toe of the weld, remains at the toe, and has not propagated in the weld. The failure of the weld (that had not leaked) was due to the thermal stresses at the socket connection.

3. Other degradation was observed, such as carburization on the ID of the nipple, the radial cracks on the pressure taps are important but are not contributing factors.

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2023 AWARDS CEREMONY SHOWCASES

COLLABORATION IN ACTION

SHELL TAKES HOME GLOBAL VALUE AWARD

The rewards of MTI's collaborative model were on display again at AmeriTAC 142. Members gathered for a special evening the led off with a presentation of Value Awards by Chair Debra McCauley and Executive Director Heather Allain. Among the many highlights, Shell accepted the Global Value Award for leveraging MTI's "High Temperature Behavior of Weld Joints in the Cast 20Cr-32Ni-1Nb Alloys" report in steam methane outlet headers welds material selection, failure analysis efforts, and repair activities in its hydrogen manufacturing units.

According to Jorge Penso, a Principal Inspection and Integrity Engineer with Shell, the company used information included in the Project 227 report on weld filler metal options. This enabled them to maximize creep life based on proper filler metal selection, support failure analysis of SMR outlet manifold weldments, and provided guidance for welds filler metal selection in new projects and repairs. "This is an example of report we have referenced multiple times," he emphasizes.

Penso says that he submitted an application for the award to support MTI and show a win-win example. He also took the opportunity to suggest that the "value to members" should be an introductory section in MTI reports.

Despite a busy travel schedule, Penso was able to rearrange his trips and fly to St. Louis on Awards Day to participate in the AmeriTAC Meeting and Awards Ceremony. It was worth the extra effort. "Information gathered in the meetings was very useful and, I was very proud and honored to have received this MTI award in Shell's name," he concludes.

OUTOKUMPU, ALLEIMA, AND NOBELCLAD SHARE JOINT VALUE AWARD

Collaboration was on full display, as members from Alleima, Outokumpu, and NobelClad took the stage to receive a Value Award for leveraging the MTI network in developing new product forms for a super austenitic alloy called Sanicro 35. This product had previously been available to the market in only bars and seamless tubes. According to Luiza Esteves, Technical Marketing Engineer with Alleima, end users had expressed a need for the alloy in other product forms.

To meet this demand, Alleima partnered with fellow MTI members Outokumpu and NobelClad to develop sheets, plates, and explosion-bonded products. "This partnership was initiated at the Global Symposium in 2022, where the three companies discussed the idea," reports Esteves. "The project's development was discussed over several subsequent AmeriTAC Meetings."

She adds that Sanicro 35 is now available for various applications beyond heat exchanger tubing, such as pressure vessels, tanks, and tubesheets. It also can be manufactured in multi-metal products, where the alloy can be used as the corrosion resistant layer, and other materials, like carbon steel, can be used for structural materials.

According to the Esteves, this collaborative effort helped each of the companies improve their processes and procedures. She finishes by providing a great example of one of the many benefits of membership: "The networking within MTI and the technical contacts within this organization have been the basis for identifying a need and developing a wider offering of product forms of this alloy. As single companies, we would not have been able to make this technical development and to be offering this to the market."

> CONTINUED ON PAGE 38

> CONTINUED FROM PAGE 37

HURST RECEIVES DISTINGUISHED SERVICE AWARD

One of the unsung heroes at MTI finally found his way into the limelight at the 2023 Awards Ceremony. Bob Hurst who has worked at Monsanto, Shell, Becht, and other companies during his long association with MTI, was presented with a well-deserved Distinguished Service Award. "This is a great honor," says the humble materials engineer. "Just to be mentioned in the same category as past recipients is an honor in itself.

Hurst's resume of achievements at the Materials Technology Institute is far too long to include in anything short of a book, but Associate Director Bob Freed took a stab at it. "Bob has a long, significant track record for contributions to the membership in every aspect of MTI activities," he notes. "One very visible aspect of his contributions is the fact that he demonstrates an outstanding presence at AmeriTAC meetings. Out of the last eighteen meetings, Bob has been present for 15!"

Freed adds, "Another perspective of Bob's MTI contributions is his high activity responding to MTI Forum posts. Since 2018, he has provided input to 57 Forum posts, a very high number. This is an outstanding example of his willingness to share his valuable information with the MTI community which has incredible benefit to early career and experienced personnel from MTI member companies."

But the impressive numbers don't stop there. Consistent with all his contributions is his ongoing commitment to project teams. He has been an active participant on 13 project teams since 2018, according to Freed.

The hardworking Hurst says that the two projects he is most proud of are the update to the materials engineering section of Perry's Handbook and the CPI Learning Modules projects. "With Perry's Handbook, we had a tremendous team of subject matter experts that included four who are now MTI Fellows," he reports. "Instead of just a revision, we did an entire rewrite. Even with this we met every goal set by the handbook publisher McGraw-Hill and the timeline set by the handbook editors. Just to be involved with such a prestigious engineering textbook was an honor.

"For the CPI Leaning Modules I think we produced a very valuable product that was needed by the industry. We had a lot of challenges along the way but, with the work of Jennifer Larimore, Bob Freed, along with the rest of the project team, we were successful."

In his opinion, MTI is the premier materials engineering technical organization for the chemical process industry, both in the U.S. and worldwide. "It is driven by its membership," he notes. "The way to keep its current status is for people to be involved and keep it moving forward. Just seeing projects move forward and achieving results gives a real sense of accomplishment."

Hurst isn't planning on cutting back on meetings, forum posts, or project activities anytime soon. "I still hope to be able to contribute to MTI into the future," says MTI's latest Distinguished Service Award recipient. "The award is an honor but so is being able to work with the entire MTI membership and administrative staff. Being involved with MTI is an enriching experience."

SAMRA EARNS CHAIR'S LEADERSHIP AWARD

Hisham Samra is a blur at most AmeriTAC Meetings, giving it his all from the live AmeriTAC forum discussions to providing guaranteed correct answers during trivia night. Wherever he happens to be, from project team meetings to hallway discussions, Samra has something of value to add to the conversation. So, other than to Hisham himself, it was no surprise that he was presented with the Chair's Leadership Award at AmeriTAC 142 in St. Louis.

"Hisham was an incredible supporter, contributor, and leader of the High Purity Roundtable session at AmeriTAC 141," notes Andrew Rentsch, Huntsman, who nominated Samra for the award. "His participation and involvement included many hours of collaborative planning sessions to design and select topics, suggesting and soliciting speakers, and reviewing of presenter content. He even contributed a presentation of his own, all while remaining entirely technical and non-commercial. Hisham is a true professional with a huge heart and love for MTI."

Samra demonstrates that love for the organization in his own unique way, diving deep into materials science. "The interplay between practical engineering and theoretical science is what continually captivates me as a materials engineer," he explains. "Delving into the science behind material behavior not only deepens our understanding of development across various materials classes and the significance of fabrication methods but is also key to predicting and mitigating safety risks in our operations. Working with MTI colleagues to blend theory with practice has been extremely rewarding. I eagerly anticipate furthering this work, bringing new ideas, and driving innovation in our field."

When Hisham first heard that he was receiving the Chair's Leadership Award, he recalls that he jumped around the office for a few minutes, then called his wife to tell her the good news. That good mood seemed to carry all the way to the podium at awards night, where Debra McCauley, MTI Board Chair presented him with the honor. "Receiving the Chair's Leadership Award was more than a personal milestone," shares Samra. "It was a reflection of the collaborative spirit and supportive environment nurtured by the MTI community. This honor highlights our collective expertise and the inclusive, forward-thinking ethos of our members and staff."

MTI Awards were created to celebrate members who showcase their accomplished leadership, participation, industry expertise and value gained through membership.

HANSSON RECEIVES MTI CHAIR'S LEADERSHIP AWARD

HONORED AT EUROTAC GROUP DINNER

MTI EuroTAC meetings include the tradition of a group dinner, and this fall the EuroTAC participants gathered at MadKlubben in Lyngby, Denmark. This time there was cause for a special celebration in honor of Anette Hansson (Topsoe), who was recognized with an MTI Chair's Leadership Award during the evening event.

"I think so many people are contributing to the MTI community by answering questions on the MTI Forum, being involved in project teams, or in the board work," Hansson reflects days after being recognized with the award. "Thus, I feel very honored and thankful to receive this award."

Left to Right: Heather Allain (MTI), Anette Hansson (Topsoe), Robert Freed (MTI)

Although gracious and humble in her words, Hansson is known for her active and strong leadership, and effectively representing the European membership. She is the Topsoe Vice Designated Representative, and her major leadership contributions include Project Champion, EuroTAC Chair (recently re-elected to another term), member of the virtual Global TAC planning team, and Ex-Officio Member of the MTI Board of Directors (BOD).

Since participating in a BOD role, she notes an appreciation for the global focus of the organization rather than regional as once perceived. The virtual Global TAC meetings, as a result of COVID-19, especially seem to have helped shift that perspective of being more inclusive of members around the globe.

"Being part of the GlobalTAC planning team and bringing information from the other TACs and the board into the EuroTAC community is very important for me," she shares.

Robert Freed MTI Associate Director, who began supporting EuroTAC and working more closely with Hansson as part of his MTI responsibilities in 2021, has observed Hansson's qualities and shares that she is an outstanding EuroTAC Chair.

"I have personally seen her skillful leadership of EuroTAC from the planning stages through conducting the meeting," he explains. "She has an inviting but decisive presence that engages all attendees and results in productive meetings."

Hansson also holds a solid track record for reliable technical contributions to project teams. Since 2018 she has championed four projects, including Duplex Stainless Steel Welds at Elevated Temperatures (364 & 391), Stress Relaxation Cracking Heat Treatment Alternatives (378), Stress Relaxation Mitigation Strategy (291), and Polymers in Biofuels (397). Currently, she is an active team member on 12 other MTI projects as well.

"Anette is a consistent contributor of her technical expertise to numerous project teams where her input is sought and valued," Freed concludes.

Hansson simply attributes the passion she exhibits to participating on behalf of her company as a member of MTI.

"Involvement is important. MTI is nothing without active members," Hansson describes. "Furthermore, I believe that the benefit of MTI to our companies is correlated to our participation. The more we get involved, the more knowledge we bring back to our company."

Congratulations, Anette, on this well-deserved award! ▪

CLASSICS CORNER

HIGHLIGHTING RESOURCES FROM THE MTI ARCHIVES TO PROMOTE KNOWLEDGE TRANSFER

Members at MTI have access to a treasure trove of technical information 24/7 (select content is available to the public). To encourage knowledge sharing and provide more learning opportunities, MTI CONNECT will highlight past resources, including publications, webinars, technical bulletins or training, in each issue. This effort from the MTI Knowledge Management Committee is intended to help new and long-time members alike realize membership benefits through the reliable collection of MTI research and education.

Implementing and Evergreening RBI in Process Plants
Ricardo Valbuena, John Aller, Michael Renner and Gene Feigel
Published 2005

Risk-Based Inspection (RBI) is a systematic approach to the management of inspection programs by prioritizing equipment inspection activities. The approach consists of a detailed inspection, corrosion, material, process, plant operations and consequence analysis to identify and mitigate risk and to make informed decisions on inspection frequencies, level of detail, and methods of nondestructive evaluations.

Leaks of flammable/hazardous material may originate from a variety of causes. Material related damage that can be detected by inspection is only one of these causes. Other important causes for leaks can be directly or indirectly associated with process upset, failure of control systems, operator errors, incorrect operation, improper job training, lack of procedures for maintenance, bad weather conditions, etc. Inspection cannot prevent leaks associated with these causes, but it can identify material degradation before failure. Statistics provided by companies contributing to this publication show that 30% to 50% of losses due to leaks in the Process Industry can be attributed to some form of material degradation, making inspection and RBI an essential activity to prevent failure.

RBI is used in the Chemical Process and the Petroleum/Refining industries with vendors offering a wide variety of services in connection with RBI. There is a significant amount of confusion and misunderstanding about this work process and technology. The purpose of this book is to present a tutorial or "how to" on Risk-Based Inspection Program Implementation and Evergreening for the Process Industry. This tutorial will enable operating companies to better understand Risk-Based Inspection – both its benefits and limitations.

The document presents instructions on a variety of topics including:

- How Do You Demonstrate the Value of RBI vs. Conventional Inspection Strategies to Your Company?
- How to Implement Risk-Based Inspection
- RBI Considerations in Plant Design
- RBI – An Insurer's Perspective
- "Maintaining or Evergreening RBI Programs After Implementation" an important topic since RBI should not be viewed as a one-time exercise but rather an on-going process that helps us manage inspection and mechanical integrity in our facilities.

Risk, in the context of RBI, is the combination of Likelihood of Failure and Consequence of Failure. Likelihood of Failure (also called Probability of Failure) is driven by material damage mechanisms, their rate of progression, the tolerance of the equipment to damage, and the amount and type of inspection activities that have been performed in the past. Consequence of Failure is the outcome of a failure that may

> CONTINUED ON PAGE 43

HEFFNER NAMED MTI'S 20TH FELLOW

> CONTINUED FROM PAGE 18

Knight Materials Technologies, LLC) at MTI since the 1900s, notes McCauley, with a hint of a smile. He was the Board of Directors Vice Chair from 2005 to 2007, Chair from 2008 -2010, and has been a continuous member of the BOD since 2004. Dale also served as the Polymers PDC Chair from when it was formed in 2004 to present.

Asked what keeps him coming back for more, Heffner replies, "MTI takes on real life problems. They're not just a standards-writing organization, but a problem-solving organization. And I've thoroughly enjoyed being involved with a real, nimble organization that could attack problems together and solve them."

He digs a little deeper, back to his early days at MTI: "When I started, the polymers people were a RAG, a Resource Advisory Group," he laughs, setting up his punch line. "So when we went from RAGs to PDCs, it was a "rags to riches" story. The Polymers Group blossomed after that with many polymers projects. We tackled complex things, such as permeability, studying things like spark testing, and developing repair manuals for all sorts of materials. And the training programs, being involved with those has been fantastic! I like passing along knowledge. I like mentoring people, and with the trainings, we get to do that."

It's easy to understand why people follow Heffner's lead. "My philosophy is: treat people with respect, treat people like I would like to be treated, and then expect something in return," he says. "And that something in return is being fair, being reasonable, listening to the other person's point of view and working toward compromise."

Heffner's wisdom is reflected in his official nomination for the prestigious Fellow Award. "Dale is

Left to Right: Dale Heffner (Knight Material Technologies), Debra McCauley (Chemours)

frequently the voice of reason in the room during direction-setting discussions at both TAC and BOD meetings, with a deep understanding of the history and intentions of the organization," wrote Marc Cook (Dow). "He is a true gentleman in the way he always conducts himself, which helps to bring the energy level back down in heated discussions. He is also a major promoter of the MTI culture, seeking out new attendees, fostering connections and finding ways to engage new members."

McCauley calls him a "Pillar of MTI organization, Historian, Advisor and Mentor to many, including myself." She adds, "he has a passion for polymers – has run the PDC for as long as any of us can remember and has always encouraged new ideas, quickly engages new participants and could put a clinic on how to run a good meeting! He embodies the MTI tight knit culture—friendly and accepting of new and different projects."

If all of that isn't enough to make Dale blush, then the festivities at the live ceremony in St. Louis checked that box. Friend, colleague, and MTI Staff Member Dale Keeler came to the front and unveiled a bright red "Dale 2" t-shirt as he spoke of their friendship and polymers projects. He then handed Heffner a duplicate shirt but with "Dale #1" plastered across the chest. "Since the award, I have had a lot of fun now knowing how to sign all of the emails when Dale Keeler is included: I get to use Dale #1 without anything else," he laughs.

Heffner closes his mandatory Fellow article interview in usual fashion, focused on his colleagues, and… well… dessert. "The collage of photographs and all of the kind words from Marc Cook, Maria Ostergaard, Jay Schickling, Deb McCauley, Ed Naylor, Dale Keeler and others (on the video), they were a bunch of voices that I recognized and appreciated," he recalls. "But the one that stuck out was Jay, saying the next Cold Stone ice cream cone is on him. I don't want him to forget that one."

Aside from holding Schickling to his promise, our latest Fellow looks forward to a bright future for the Materials Technology Institute "I am amazed at the next generation coming up at MTI," he shares. "MTI is doing a terrific job of putting their very best people in the very best positions. I see the next generation stepping up to the plate, the likes of the Curtis Huddles, the Andrew Rentschs, the Meghan Oaks, and the David Coles. One of the most rewarding things about becoming an MTI Fellow is that I will continue to be associated with the organization beyond my career and get to see what the next generation is going to do." Here's the deal Dale: not only will we share MTI's successes with you but we'll even pick up your ice cream (note: limited to one treat per AmeriTAC Meeting), as you as long as you keep coming back to share your wisdom. And once again, congratulations! ▪

EUROTAC UPDATE

> CONTINUED FROM PAGE 23

Another status update on this topic is scheduled for the 2024 MTI Global Solutions Symposium. Please see the Symposium Spotlight section for more information (page 3).

Other topics of interest addressed in the lectures by invited speakers included Inspection by Drones in Confined Spaces by Peter Nielsen (Multidroner), The Use of Big Data to Reduce Materials Degradation by Professor P. Schempp (TH Cologne Department IWA), Tube-to-Tube Sheet Weld Scanner by Ole Nørrekær Mortensen (FORCE Technology), and Hydrogen-assisted Fatigue by Professor Christian F. Niordson (University of Denmark, DTU).

There was also lively discussion among four potential MTI projects, Relaxation Cracking Susceptibility Mapping (405), Guideline for Preservation of New Equipment and Piping (406), Equipment Surface Modification Guide (407), and Corrosion of Extruder Alloys. Work will continue to move these projects forward before the EuroTAC Spring 2024 meeting that will be hosted by Victaulic near their facilities in Nazareth, Belgium. Details of the project discussions can be found in the EuroTAC Fall 2023 Executive Summary in the EuroTAC library at www.mti-global.org. In addition, four more project ideas were proposed at the short brainstorming session, which will be further investigated at the meeting in Belgium.

Peter Nielson, Multidroner, demonstrates how the drones work and could be beneficial for inspection.

MTI thanks Topsoe for their gracious hospitality, excellent facilities and the welcoming environment for the EuroTAC meeting! Be on the lookout for the Spring 2024 meeting announcement details at www.mti-global.org/about/events/eurotac-meeting. ▪

CLASSICS CORNER

> CONTINUED FROM PAGE 41

be expressed, for example, in terms of safety to personnel, economic loss, or damage to the environment. Risk can be represented in the form of a matrix displaying the level of likelihood and consequence.

The key to understanding Risk-Based Inspection is the fact that unexpected failures due to damage always occur where the damage is worse than what was expected. Inspections increase the knowledge of the amount of damage, which is used to prevent such events from occurring. RBI may use techniques to evaluate the statistical likelihood that damage severe enough to cause failure could exist given the amount of appropriate inspection activity that has been performed. Also, when damage progress is time-based, future inspections can be planned based on the amount of damage expected at some point in the future. Thus, RBI establishes a proper balance between advancing damage and increased knowledge of the amount of damage to assure that the equipment is always safe to operate.

Visit www.mti-global.org and navigate to the Resources menu for access. ▪

MEMBERS:	Download a **free PDF copy** from the Technical Resource Library as a benefit of membership or purchase a copy from the member bookstore – **$55**
NONMEMBERS:	Purchase a copy from the MTI bookstore – **$203**

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NEW MTI WEBSITE FEATURE ALERT

STUDENT & RECENT GRADUATE JOB BOARD

The MTI Website and MTI Scholarship and University Outreach Committees would like to inform or remind members and soon-to-be graduates or recent graduates and recent graduates of the MTI Job Board, which launched earlier this year!

The job board is intended for use by college students preparing to graduate or recent graduates seeking entry level engineering positions in the Process Industries, and MTI members seeking to post materials and engineering related job opportunities for entry level positions. The board is publicly available; however, all resumes or job posts made to the board are first reviewed by MTI before approval is granted. Only resumes that meet the upcoming or recent graduate requirements and only member entry-level positions will be approved.

Access to the job board is available 24/7 at www.mti-global.org under the Resources menu, so be sure to take advantage of this opportunity. Questions? Please contact mtiadmin@mti-global.org. ▪