A Materials Technology Institute Publication

# MTI CONNECT

2023, ISSUE 2

GLOBAL CHALLENGES / TRUSTED SOLUTIONS

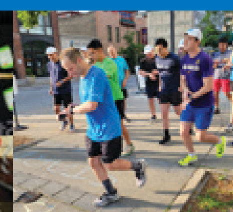
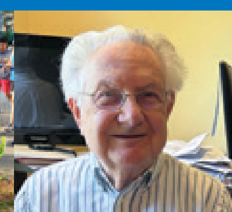
## PROJECT UPDATES

TAC Meetings Yield New, Potential & Completed Projects

# CONNECT

## Inside This Issue

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### ABOUT THIS PUBLICATION:

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

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## CALENDAR OF EVENTS:

**Global TAC Meeting**
September 6–7, 2023
9 AM–12 PM EDT each day
Virtual

**AsiaTAC Fall Meeting**
September 18–20, 2023
Shanghai, China

**AmeriTAC 142**
October 23–25, 2023
St. Louis, MO

**EuroTAC Fall Meeting**
November 8–10, 2023
Lyngby, Denmark





# VIRTUAL GLOBALTAC MEETING SCHEDULED FOR SEPTEMBER

## ENABLES COLLABORATION ACROSS TECHNICAL ADVISORY COUNCILS

Virtual project meetings have been a long-standing function of MTI, which allowed the organization to quickly transition to an entirely virtual format at the onset of COVID-19. Since then, MTI has been back on track with face-to-face Technical Advisory Council (TAC) meetings, but both members and the leadership recognize one aspect of the pandemic that only strengthened MTI further—global collaboration. As a result, a virtual TAC meeting scheduled between other TAC events was proposed to facilitate broader member involvement and additional project work.

"We are excited to offer this Virtual Meeting to allow all those who cannot attend our in-person meetings regularly the chance to connect with MTI's unique network," remarks Heather Allain, MTI Executive Director.

"We hope that materials engineers, inspectors, reliability and design engineers and others involved in plant integrity and maintenance will be able to join and find this to be a valuable way to connect with MTI's resources."

The Virtual GlobalTAC event is scheduled September 6-7, 2023. The meeting will be conducted via Microsoft TEAMs and held from 9 AM - 12 PM EDT each day. Jeremy Nelson (Koch Industries), former AmeriTAC Chair, volunteered to lead the virtual meeting planning and hosting, and Kevin Ganschow, MTI Associate Director, as well as Allain and the TAC leadership teams, are supporting the development of the program.

"The Virtual GlobalTAC meeting is designed to allow broad participation within MTI member companies to network and benefit from the MTI community," Allain explains.

"There will be technical presentations and recent progress on current projects presented, as well as opportunities to develop and scope out new projects."

All MTI members are encouraged to attend the sessions and be part of MTI's collaborative efforts. This opportunity is available to members as a benefit of membership and is open to nonmember producers by invitation. To request an invitation, please email mtiadmin@mti-global.org. Visit www.mti-global.org for meeting details and registration. ▪

# MTI WELCOMES NIPPON STEEL TO ITS WORLDWIDE TECHNICAL COMMUNITY

## SEEKS TO SUPPORT MTI ACTIVITIES BY SHARING KNOWLEDGE

NIPPON STEEL

MTI, which is made up of many of the top chemical and energy companies in the world, recently became even stronger with the addition of supplier member NIPPON STEEL. Headquartered in Tokyo, the largest steel manufacturer in Japan and a major supplier of corrosion resistant materials worldwide provides a wide range of carbon steel, stainless steel, and nickel alloy products, including tube, pipe, plate, sheet and bar. In addition, Nippon Steel's engineers and researchers have developed new grades of alloys and solved materials issues by working with customers, a collaborative business model that should benefit the MTI technical community.

With offices in Japan, Germany, Singapore, Qatar and the United States, Nippon Steel plans to contribute to each of MTI's three Technical Advisory Councils (TACs), according to Masaki Ueyama, Designated Representative (DR) for the company. "Each representative will join TACs and communicate with MTI members," he says.

That worldwide participation will certainly help MTI's Metals PDC and associated projects. MTI's newest member brings a wealth of materials knowledge with it. In 2012, NIPPON STEEL and Sumitomo Metals merged, creating a company with an extraordinarily deep pool of expertise. At the time they combined resources, both organizations had over 100 years of history and experience in steel manufacturing.

Like the metals that it manufactures, Nippon Steel brings many strengths to the table. "Our experts specializing in manufacturing, welding and corrosion, etc. can share their knowledge through meetings and papers," explains Ueyama, a Senior Manager based in Houston, Texas. "Some of us have already registered in MTI, so we are glad to help to solve material issues at online MTI Forum, as well."

Ueyama notes that Nippon Steel's seamless tubes and pipes are used for various applications, such as refineries, chemical plants, thermal plants, nuclear plants and OCTG (Oil Country Tubular Goods), etc. "That means Nippon Steel has experiences and know-how, especially for stainless steels and nickel alloys," he points out. "We believe we can support MTI activities."

The former Technical Services Engineer knows that joining the Materials Technology Institute also presents a learning opportunity for he and his colleagues. "Nippon Steel would like to know trends or issues for materials used in refineries, chemical plants and other plants," explains Ueyama. "We think that MTI is one of the best communities in which our requirements will be fulfilled, because many end-users are joining and discussing various kinds of material topics deeply."

One such activity of particular interest to Ueyama is Project #357. "NIPPON STEEL is interested in 'Corrosion in Bio-Oils' especially because renewable diesel and SAF is one of the expanding markets recently," he says. "We believe that our materials can solve material issues or improve operation for these plants."

After already attending two AmeriTAC meetings and presenting at one EuroTAC meeting, Nippon Steel is off to a fast start participation-wise. In fact, plans are in the works for a presentation on a new austenitic stainless steel with resistance to polythionic acid stress corrosion cracking and stress relaxation cracking at high temperature, which will be part of technical program offered at the AsiaTAC meeting in Shanghai, China this September. MTI welcomes its valuable new member and contributor, Nippon Steel! ▪

# CURT GRAHAM TO DELIVER KEYNOTE AT MTI GLOBAL SOLUTIONS SYMPOSIUM 2024

## DAWN OF THE ENERGY TRANSITION ERA – EARLY OBSERVATIONS

The MTI Symposium Committee is excited to announce Curt Graham, Vice President for Fluor's Office of Technology, as the Keynote Speaker for the MTI Global Solutions Symposium 2024, in Baton Rouge, LA. In relation to the event theme, "Sustainable Process Industries," Graham will discuss 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. He will also discuss how these trends will impact the industry, and some observations on both the challenges and opportunities inherent to this dramatic change in technology.

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 responsible for Fluor's Fellows Program. Prior to that, he was the Manager of Engineering and Department Manager of Process Engineering for the Southern California (SoCal) offices (Aliso Viejo and Long Beach), and the leader of the Fluor Gas Processing Technology Group.

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

*Curt Graham — Fluor*

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 plant, gas plant debottlenecking and gas plant fire rebuild projects.

Graham received a Bachelor of Science degree in Engineering from Harvey Mudd College. He also holds 13 U.S. Patents in gas processing and treating, is a Fluor recognized Subject Matter Expert in Gas Processing and is an author of over 25 industry papers.

Please save the dates, February 26-28, 2024, to attend the keynote, the excellent technical sessions the Symposium Committee is developing and the Global Solutions Marketplace to connect with industry partners! Registration will be available this fall. Visit www.mti-global.org/mtisymposium for details. ▪

# TUBE TO TUBE

# JOINT APPLICATION FOR SHELL AND TUBE HEAT EXCHANGER

BY YONG-JOO KIM – WEBCO INDUSTRIES, USA


## Abstract

Material selection of tubing material for a heat exchanger unit is dependent on the operating environment, the available material options, and the cost. However, if the operating environment condition is different within a designed unit (such as pressure, temperature, stress, etc.), then the design and material selection can be problematic. One option to overcome this issue is to use a "Standard tubing material to higher alloy tube joint" (or so called "Safe Ending") design. This experimental study evaluated and documented the proper orbital weld joining design, various qualification testing methods and corrosion performance at the fusion/HAZ (Heat Affected Zone) of the dissimilar alloy joints. Test results were used to support the application of the ethanol processing Kettle boiler unit, which have been experiencing crevice corrosion at the tube-to-tubesheet location of the higher temperature section of the unit. The base material was S30403 (304L) stainless steel and considered higher alloys joint options of S32205 (2205), S32750 (2507), and N06625 (625). Each type of high alloy tube was orbital welded to a base grade tube at one end of the length. Each weld was flushed at the outside surface and radiographically inspected before any testing. Corrosion performance was compared at the fusion/HAZ and the effect of the metallurgical microstructure at the fusion zone was reviewed. Test results are summarized with discussion of the potential issues by the welding procedures, recommended qualification testing and expected corrosion performance at the fusion zone.


## I. Background

A heat exchanger unit located in a kettle reboiler used for an ethanol biorefining process failed prematurely due to leaking from the tubes located at the steam inlet side, which operates at 204°C (400°F), 150 psi (10.34 bar) pressure. It was a horizontal unit with U-bend tubes. The steam inlet is on the top side of the tubesheet and the outlet is on the bottom side. The investigation concluded that the root cause of the leaking tubes was crevice corrosion (Figure 1) occurring at the back face of the tubesheet on the steam inlet half of the unit and temperature was the main contributor of corrosion failure. Please note that, although the root cause was crevice corrosion, all corrosion tests were performed as pitting corrosion based on several different grade comparison options.

> CONTINUED ON PAGE 8

***Figure 1.*** *Crevice corrosion failure.*


***Figure 2.*** *Dissimilar metal weld joint schematic.*

| GROUP | FILLER WIRE | AUTOGENOUS |
|---|---|---|
| 304L(S30403) to 625 (N06625) | 625 filler wire - AWS A5.14 ERNiCrMo-3 | No filler wire |
| 304L(S30403) to 2205 (S32205) | 2507 filler wire - 25.10.4.L EN 25 9 4 N L | No filler wire |
| 2205 (S32205) to 625 (N06625) | 625 filler wire - AWS A5.14 ERNiCrMo-3 | No filler wire |
| 304L (S30403) to 2507 (S32750) | 2507 filler wire - 25.10.4.L EN 25 9 4 N L | Not Planned |

***Table 1.*** *Listing of grades and weld combinations used for this study.*

To overcome the issue, an option of orbital welding a higher alloy dissimilar metal to the base tube at the steam inlet side of the U-bend tube was chosen to conduct in-situ experimental review. (See Figure 2.)

For the proper welding of dissimilar metals, development of an acceptable welding procedure specification (WPS) is an essential part. However, other factors should be understood between dissimilar metal welds, which can affect the specific application, such as the corrosion potential due to the variation of temperature difference or chloride content of the fluid. This study establishes basic knowledge of metallurgical review of chemical homogeneity at the dissimilar metal weld/HAZ area between various dissimilar metals and corrosion performance at the weld/HAZ compared to the lower alloy grade side of the metal.

## II. Study Summary

For the mock-up testing, four grades were utilized as shown in Table 1 with tube size of 1.000 in. OD x 0.065 in. W (25.4 mm OD x 1.65 mm W). The study was conducted with/without filler wire matching the higher alloyed grade of the given pair.

Using an automatic GTAW orbital welding unit, welding procedures were developed and verified by the qualification methods of guided bend, tensile, hydrostatic burst test, dye penetrant inspection at OD and a whole body radiographic inspection. Welding parameters were documented including heat input, shielding, backing gas and welding wire, if applied. Before testing the OD side weld reinforcement was removed by smooth grinding to make a clear pass to the opening of the tubesheet holes. (See Figure 3.)

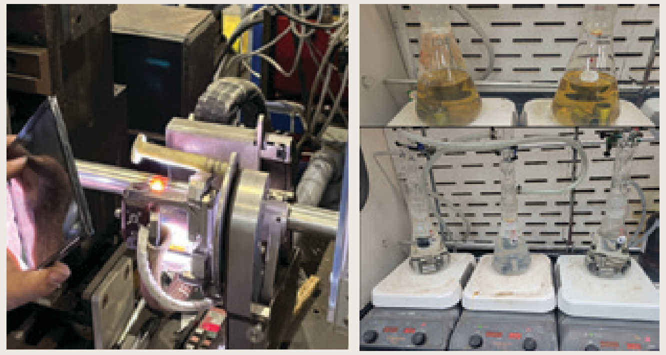

***Figure 3.*** *Automatic orbital welding and Corrosion test.*

To determine the corrosion rate differences between dissimilar metals and welds, ASTM G28, G48 and A262 Method C corrosion tests were performed. These tests deviated occasionally from the requirements as listed by the ASTM specification considering dissimilar metals, geometry, and testing apparatus. Due to the variations, the results were used as qualitative data to compare the relative corrosion rates of the different grades and orbital weld to each other.

| BASE METALS | JOINTS | FILLER WIRE | PASS | SHIELDING/ BACKING GAS | HEAT INPUT |
|---|---|---|---|---|---|
| 304L to 625 | J-Bevel | 625 filler wire | 2 | 100% Argon //100% N2 | 0.495 KJ/mm |
| | Square Butt | No filler wire | 1 | 100% Argon //100% N2 | 0.186 KJ/mm |
| 304L to 2205 | J-Bevel | 2507 filler wire | 2 | 97%Ar./3%N2//100% N2 | 0.530 KJ/mm |
| | Square Butt | No filler wire | 1 | 97%Ar./3%N2//100% N2 | 0.200 KJ/mm |
| 304L to 2507 | J-Bevel | 2507 filler wire | 2 | 97%Ar./3%N2//100% N2 | 0.530 KJ/mm |
| 2205 to 625 | J-Bevel | 625 filler wire | 2 | 97%Ar./3%N2//100% N2 | 0.630 KJ/mm |
| | Square Butt | No filler wire | 1 | 97%Ar./3%N2//100% N2 | 0.212 KJ/mm |

***Table 2.*** *Summary of the orbital weld plan and heat input*

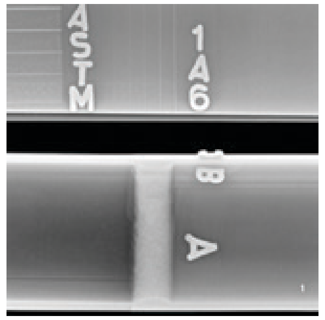

***Figure 4.*** *X-Ray images. 304L to 625*

| GRADE | MELTING TEMP. | SPECIFIC HEAT CAPACITY (J/(g*°C) |
|---|---|---|
| S30403 | 1,400° C (2,550° F) | 0.48 |
| S32205 | 1,400° C (2,550° F) | 0.48 |
| S32750 | 1,400° C (2,550° F) | 0.48 |
| N06625 | 1,290° C (2,350° F) | 0.44 |

***Table 3.*** *Reference physical properties of the grades*

## III. Test Results

### *Welding Procedure Specification*

Following Table 2 and Figure 4 are the summary of the heat input and an example of the X-Ray image. Other destructive qualification tests were conducted, including a burst pressure test.

Thermodynamic properties of the metal are one of the key factors which can influence the welding metallurgy between dissimilar metal welding. Table 3 shows the example melting points and specific heat capacity. The melting temperature of N06625 is 110° C (230° F) lower than others and has a lower specific heat capacity, which requires less thermal energy to be brought to the same temperature.

### *Metallurgical Analysis of Welds*

304L Welded to Duplex 2205 With or Without Filler Wire

With similar thermodynamic properties between two grades, both sides of the weld showed complete weld penetration. The weld metal near the 304L side appeared to be more equiaxed and dominated by the austenitic phase. This is likely due to the abundance of austenite stabilizers from the 304L causing increased austenite stability and grain growth. The only notable difference was the phase balance of the weld that extended along the length of the weld S32205 duplex base metal of a sample without filler wire weld. (See Figure 5.)


***Figure 5.*** *Cross-sectional welding image of dissimilar metal of 304L - 2205 joint with no filler wire.*

304L Welded to Nickel alloy 625,
With and Without 625 Filler Wire

Regardless of whether autogenous or with filler wire where 304L samples were welded to 625 nickel alloy, some remnant of the 304L base metal remained. This is due to the difference in thermodynamic properties between 625 and 304L. The fusion line and HAZ

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microstructures of the weld with 625 showed similar features both autogenous and with 625 filler wire, which shows that melting occurred in these areas. (See Figure 6.)


***Figure 6.*** *Cross-sectional weld image of dissimilar metal of 304L - 625 joint with 625 filler wire.*

Energy-dispersive X-ray spectroscopy (EDS) analysis of the weld fusion line (Figure 7) showed a chemical gradient proportional to the observed microstructural weld boundary, especially Fe and Ni content percent. Materials of differing chemical composition will likely have a different tribological response from polishing causing the base metal to appear raised/lowered with respect to weld.

2205 Welded to 625 with and without 625 Filler Wire

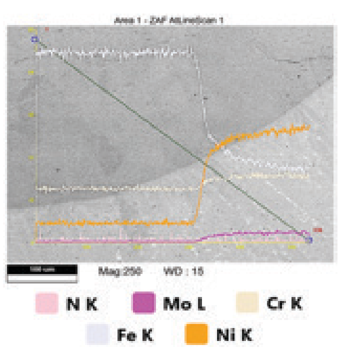
Both samples showed similar features as previous welds involving 625 in contact with 2205 and had partial re-melting of the 2205 base metal side. Ferritization of the 2205 base metal and austenite formation at melted contact points was shown between the 2205 base metal and weld.

Corrosion

Table 4 above shows all the samples used during testing and which tests were applied to the respective orbital welds / base metals.

G28 Method A Testing Analysis: 2205 – 625 Weld With and Without 625 Filler Wire

Two ASTM G28 tests were performed, with one bath containing the orbital weld samples and the other bath containing the base metal samples. Figure 8 and Table 5 show the samples after the test, where dotted lines in the image show the location of the orbital weld center (the label below the image dictates the side of the orbital welds which is that grade). On the welded section, there was a clear boundary of color difference between the transitions from base metal welded to base metal. However, no pitting was present at the fusion lines.




**eZAF QUANT RESULT – ANALYSIS UNCERTAINTY: 3.51%**

| ELEMENT | WEIGHT % | MDL | ATOMIC % | ERROR % | NET INT. | R | A | F |
|---|---|---|---|---|---|---|---|---|
| N K | 0.0 | 0.00 | 0.0 | 100.0 | 0.0 | 0.7951 | 0.0941 | 1.0000 |
| Cr K | 20.3 | 0.05 | 22.0 | 2.9 | 1236.0 | 0.8885 | 0.9373 | 1.1835 |
| Fe K | 56.7 | 0.07 | 56.9 | 2.5 | 2323.2 | 0.8988 | 0.9188 | 1.0545 |
| Ni K | 20.6 | 0.09 | 19.7 | 3.2 | 611.9 | 0.9099 | 0.8712 | 1.0362 |
| Mo L | 2.3 | 0.07 | 1.4 | 7.7 | 99.2 | 0.8502 | 0.5572 | 1.0083 |

***Figure 7.*** *EDS analysis of fusion line (Diagonal crossing blue line is the direction of EDS analysis).*

| SAMPLE | ASTM G28 METHOD A | ASTM G48 METHOD A | ASTM A262 PRACTICE C |
|---|---|---|---|
| 304L/625 w/625 filler wire | | | X |
| 304L/625 w/o filler wire | | | X |
| 304L/2205 w/2507 filler wire | | X | X |
| 304L/2205 w/625 filler wire | | X | X |
| 304L/2205 w/o filler wire | | X | X |
| 2205/625 w/625 filler wire | X | X | X |
| 2205/625 w/o filler wire | X | X | X |
| 304L/2507 w/2507 filler wire | | | X |
| 304L base metal (Reference) | | | X |
| 2205 base metal (Reference) | X | X | X |
| 2507 base metal (Reference) | | X | |
| 625 base metal (Reference) | X | | X |

G28-A Detecting Susceptibility to Intergranular Corrosion in Wrought, Nickel-Rich, Chromium-Bearing Alloys

*Method A – Ferric Sulfate—Sulfuric Acid Test*

G48-A Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

*Method A – Ferric Chloride Pitting Test*

262-C Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steel

*Practice C – Nitric Acid Test for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steel*

***Table 4.*** *Samples and applied testing regimen.*

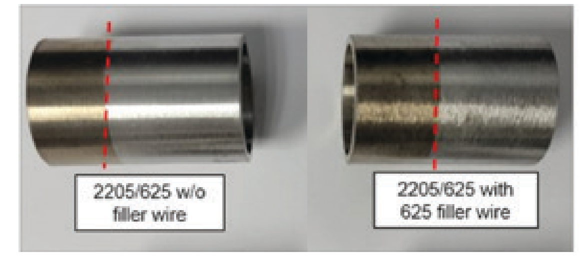



***Figure 8.*** *G28 Method A samples, post test.*

| SAMPLE | CORROSION RATE (MPY: MILS PER YEAR) | PITTING |
|---|---|---|
| 2205/625 w/o filler wire | 10.1 | No |
| 2205/625 w/625 filler wire | 11.2 | No |
| 2205 base metal | 10.1 | No |
| 625 base metal | 10.0 | No |

***Table 5.*** *G28 Corrosion Test Results.*

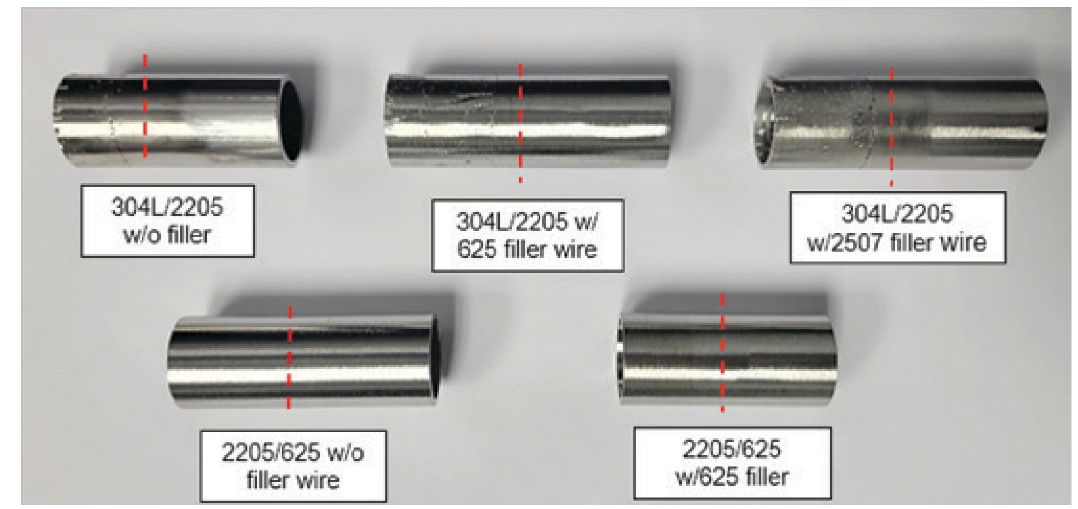



***Figure 9.*** *G48 A post test samples.*

| SAMPLE | TEST TEMPERATURE | CORROSION RATE (G/M²) | PITTING |
|---|---|---|---|
| 304L/2205 w/2507 filler wire | 50° C (122° F) | 350 | Yes |
| 304L/2205 w/625filler wire | 25° C (77° F) | 275 | Yes |
| 304L/2205 w/o filler wire | 25° C (77° F) | 204 | Yes |
| 2205/625 w/625 filler wire | 25° C (77° F) | 0.10 | No |
| 2205/625 w/o filler wire | 25° C (77° F) | 0.13 | No |
| 2205 base metal | 25° C (77° F) | 0.24 | No |
| 2507 base metal | 50° C (122° F) | 0.16 | No |

***Table 6.*** *G48 Corrosion test results.*

G48 Method A Testing Analysis: 304L - 2205 & 2205 – 625 Weld With and Without Filler Wire

Two base metal G48 Method A tests were performed on the duplex base metal samples to verify their pre-welded condition, with the 2205 sample being tested at 25°C (77°F) and the 2507 being tested at 50°C (122°F). The results can be seen in Figure 9 and Table 6.

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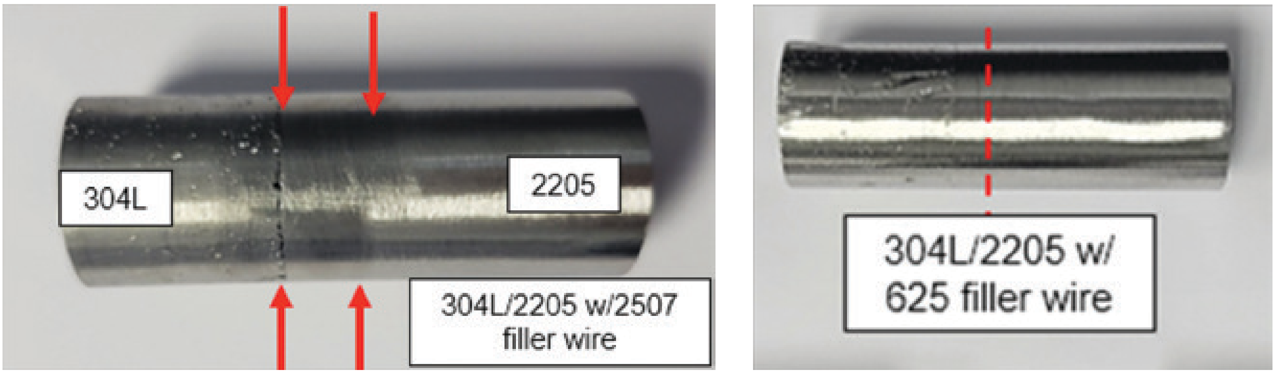


***Figure 10.*** *304L - 2205 Weld with 2507 filler wire and 625 filler wire.*

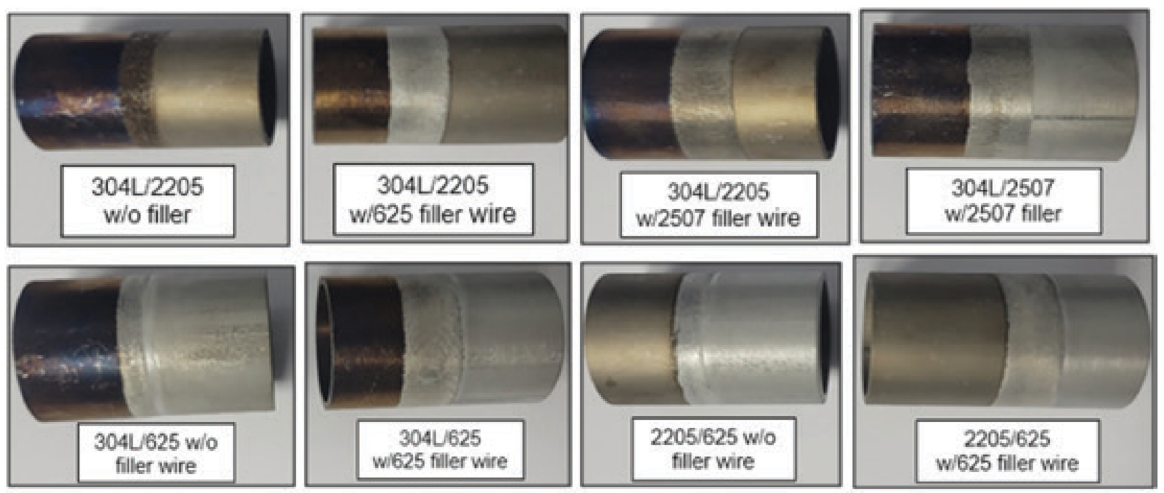


***Figure 11.*** *A262-C post test samples.*

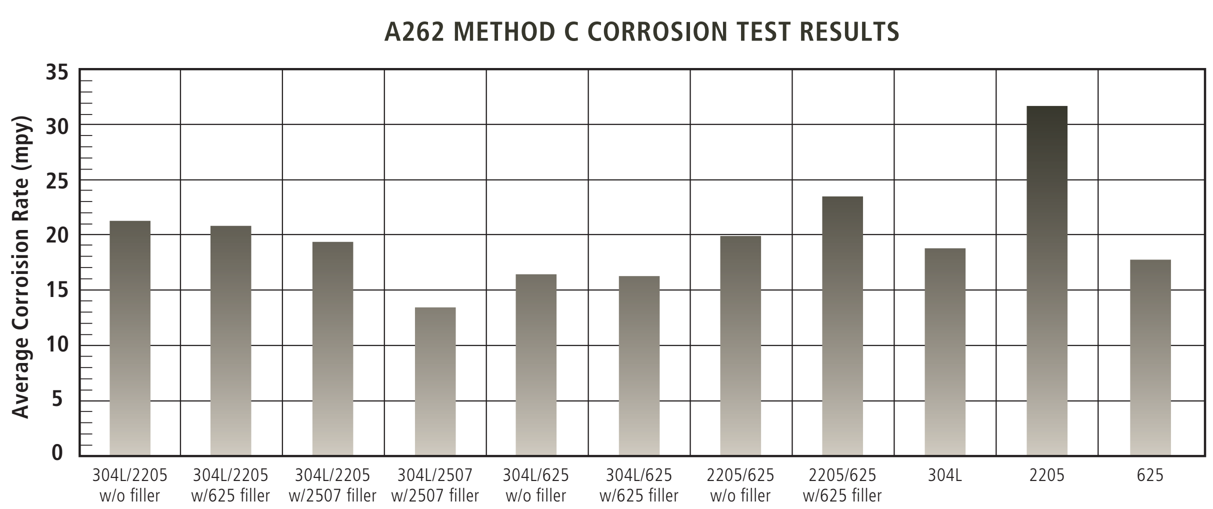


***Table 7.*** *A262 Method C corrosion test results.*

The high corrosion rate in the sample containing 304L can be attributed to the fact that a standard G48 Method A test is not designed for austenitic alloys and the critical pitting temperature for 304L is below the typical testing temperature of 25°C (77°F). However, the orbital weld samples that were 2205 and 625 experienced corrosion rates equal to or less than that of typical duplex stainless steels.

Visual inspection of the OD surface showed that the nickel and duplex portions, as well as the fusion zone of each weld joint were easily able to pass the test while the 304L portions corroded heavily and had pitting corrosion at the joint of the weld. The dotted lines in the image show the location of the welding centers. Also, it is noted that, even without filler wire, the fusion zone will create a higher alloy due to the mixing of both base metals that is a "higher" grade than 304L and is superior in terms of corrosion resistance. Figure 10 represents an example of the location of the pitting line to the actual location of the orbital fusion line boundary. The 304L side of the base metal shows general pits and the 304L side of the HAZ shows circumferential lined deep pitting.

### A262 Method C Testing Analysis

The austenitic test samples (304L orbital weld halves and base metals) experienced discoloration, while the duplex and nickel samples (2205, 2507, and 625 orbital weld halves and base metals) had a dulled surface finish. While the 304L samples stained on the surface more than any other grade, they only experienced a little more corrosion than the 625 samples and retained a smooth surface (no pitting corrosion). Figure 11 shows examples of the weld samples after testing and the corrosion tests can be seen in Table 7, which includes the average corrosion rates for each tested orbital weld and base metal.

The orbital weld samples containing 2205 performed more poorly than those that only contained some combination of 304L, 625, and 2507, having a corrosion rate roughly equal to that of standalone 304L.

Additionally, the 2205 base metal had the worst performance out of all the tested materials. The best performance was seen in the 304L/2507 w/2507 filler wire sample, followed closely by the 304L/625 samples. The addition of filler wire almost always increased the corrosion resistance except for the 2205/625 samples.

### Summary of Corrosion Testing

Testing the corrosive resistance of a dissimilar metal orbital weld is a challenging task, as the different grades react with acids in separate ways.

G28 Method A testing seemed to work well for the selected grades, except acid bath may be too aggressive to austenitic grades. G48 Method A testing would likely behave similarly for austenitic grades. The A262 Method C testing yielded valid results and were directly applicable to austenitic grades and uncertain for duplex and nickel grades since the test is not designed for these grades, but the general trend of "more corrosion resistance the higher the alloy content" could still be seen.

The fact that every dissimilar metal weld performed better than the average of its base metals shows that the corrosion resistance of the material is not compromised by the orbital welding process; it is in fact improved.

## IV. Conclusion

Proper welding procedure of dissimilar grades of steel tubing can be developed with high performance results. Metallurgical analysis did not show any detrimental phases between dissimilar metal joining by a GTAW welding process. Corrosion resistance of the dissimilar metal was not compromised by the GTAW welding process and improved compared to the lower alloy base metal.

With proper automatic welding and inspection/testing capability, the consistency of the orbital welding quality between dissimilar metal can be maintained. ▪

# ASIATAC UPDATE

## FALL MEETING TO FEATURE PANEL SESSION ON STAINLESS STEELS FOR CHEMICAL INDUSTRY

MTI's AsiaTAC Leadership Team is pleased to announce that the Fall 2023 Meeting is being held in Shanghai, China. The Planning Committee, led by AsiaTAC Chair TP Cheng (ITRI) and Paul Liu (MTI Associate Director), has already arranged a full agenda of technical presentations and panel sessions, as well as special training and networking opportunities for the September 18-20 meeting.

"All members from Asia, the Middle East, Europe, and North American are welcome to attend," says Cheng (ITRI). "This September, we are going to have 15 presentations, which cover lots of materials and case studies. It is worthy of spending a couple of days for exchanging experiences and widening knowledge."

AsiaTAC's preliminary agenda includes presentations on a variety of topics, including: Quality Sources of Information to Assist in Selection of Materials for Industrial Applications; Stainless Steels for Chemical Industry (panel session); New Alloy Developed for Metal Dusting Environment; New and Established High Performance Alloys for Severe High Temperature Applications; Corrosion and Material Selection for Biofuel Production Equipment; UNS S34752 for High Temperature Environment (anti-polythionic acid SCC and stress relaxation cracking); Welding Metallurgy and Weldability of Nickel Alloys; Severe Corrosion of 2205 Duplex Stainless Steel Heat Exchangers in HCl Service; Failure Analysis of FRP Tank; Failure Analysis of Bearing Housing Welds of Cooling Water Pump System; Case Study of Stress Corrosion and In-service Inspection; Fitness for service (TBD); Q&A Based on Actual Corrosion Cases; Corrosion in Acid Roast Kiln and Material Improvement; and N08935, A New PRE 52 Alloy for Corrosive Environments.

The three-day meeting will also include MTI activity updates, a special presentation on MTI's vast knowledge resources (and how to find them), project highlights and a project development committee brainstorming session, led by three moderators.

Education is always an important component of AsiaTAC Meetings, and the team has put together a session on a topic of particular interest to Process Industry companies around the world: High Reliability Materials for Heaters and Furnaces.

"This training session is a big plus for elevating your professional skills," notes Cheng. "Several trainers will cover frequently used heat resisting alloys and provide some case study examples."

Of note, the organizing team hopes that AsiaTAC representatives from around the world will participate in the Fall Meeting, since COVID-related travel restrictions have been lifted in China.

"I would just like to stress that this is the first time in four years that we are able to conduct face-to-face meeting in China with colleagues from other countries," reports Liu. "We are looking forward to a successful event and would like to extend invitations to all member company employees inside and outside the Asia Region."

To register, visit mti-global.org/about/events/asiatac-meeting. ▪





# EUROTAC UPDATE

## STRONG FOCUS ON TECHNICAL PROJECT DEVELOPMENT AT SPRING MEETING

The Spring 2023 EuroTAC meeting, held May 10-12, in Munich, Germany, saw good attendance with 28 registrants. Of the attendees, 15 member companies were represented, and four individuals were first time participants. The meeting was hosted at Linde Engineering's modern Angora conference center, and MTI would like to extend recognition and thanks to Linde for hosting and helping to organize the event.

The meeting consisted of several new technology lectures to inform and educate participants. The presentations included: Research Results on the Effect of Gas Composition on Metal Dusting of Ni-based Alloys from DECHEMA; High Pressure Gas Transmission of Hydrogen by Open Grid Europe; Duplex Stainless Steel Performance in Alkaline Hydrogen Electrolyzers by Alleima; The Effect of Inert Gases on 3D Metal Printing by Linde; and The Groove System for Tube and Flange Design by Victaulic. The event also offered a special structured forum session on the PFAS materials restriction proposal in Europe. Discussions were open to all participants and included current status updates on the issues companies are facing, along with the opportunity to share how companies are addressing the new European regulations.

In addition to the presentations and general session discussion, the EuroTAC Spring meeting placed a significant emphasis on MTI projects. There were several MTI project updates and reports, and a productive Project Development Committee (PDC) session to identify new technical project ideas. The PDC session resulted in three new potential projects and two co-champions for each to facilitate the project process.

For additional information or to join any of the project teams, please visit www.mti-global.org/communities/potential-projects

Looking ahead to the Fall 2023 EuroTAC meeting, the leadership team is already making progress. Topsoe has volunteered to host the meeting at its facility in Denmark and the planning stages are underway. Be sure to save the dates and attend November 8-10, 2023, and check www.mti-global.org/about/events/eurotac-meeting for details as they become available! ▪

### EuroTAC Project Development Committee (PDC) Identifies Three Potential Projects

**Reheat/Relaxation Cracking Susceptibility Mapping for High Temperature Austenitic / Ni-base Materials (405)**

*CHAMPIONS: Jan-Willem Rensman (Fluor), Josef Poellmann (Linde)*

The scope draft of this project is to create "Nelson curve style maps" that delineate SRC conditions for certain alloys or alloy families. The necessary data will be obtained from open literature and member company information. This should result in a guideline for members on when PWHT is likely needed.

**Guideline for Preservation of New Equipment and Piping During Plant Construction, Commissioning, and Maintenance Replacements (406)**

*CHAMPIONS: John Houben (ExxonMobil), Jan-Willem Rensman (Fluor)*

The proposed scope is to create a "Guideline for Prevention of Equipment and Piping Degradation During Plant, Equipment Construction, Testing and Commissioning." End-users are often confronted with equipment and piping leaks during plant commissioning, at start-up or within the first year of operation, which is frequently caused by residual hydrotest water causing corrosion, often Microbiological Influenced Corrosion (MIC).

**Surface Modification Guide (407)**

*CHAMPIONS: John Houben (ExxonMobil), Matthias Grundwuermer (Linde)*

The project scope is to develop a Surface Modification Guide that will focus on surface modification applications pertinent to the process industries. It will include conventional and new techniques, as well as laser cladding, high velocity oxygen fuel, and diamond-like PVD coatings. Suggested content includes wear mechanisms common in the process industries, a general overview of surface modification techniques, key surface modification techniques for new equipment or new parts, key surface modification techniques for repairs and refurbishing, upgrades of worn parts, QA/QC guidelines, and relevant examples and case studies.

# AMERITAC UPDATE

## TAC 141 AND HIGH PURITY ROUNDTABLE DELIVERS VALUABLE INFORMATION

MTI members convened June 20-23, in Milwaukee, WI for AmeriTAC 141 and the High Purity Roundtable. Organized by TAC Chair Andrew Rentsch (Huntsman) and Vice Chair David Cole (Marathon Petroleum), the event included a full day session on Meeting High Purity Industry Expectations and two days of project meetings and technical presentations during the TAC 141 sessions.

The meeting ranks among the highest attendance records for a June TAC, recording 99 participants, including individuals from 41 member companies and 17 speakers/guests. The Roundtable was a large draw with 11 presentations on this industry subject:

- **Rhyme and Reason for Higher Purity Now and in the Future in Semiconductor Applications** — Koh Murai, Mega Kinetics Fluid Systems
- **SEMI Standard** — Bob McIntosh, Enviro-Energy Solutions
- **Effects of Contamination on Semiconductor Yield** — Johan Desimpelaere, JSR Micro
- **Material Contaminants and Their Impact on Fabrication** — Meredith Green, Brewer Science
- **The Challenges of High Purity in a Commodity Environment** — Juventino Uriarte, Huntsman
- **PTFE and PFA Design Considerations for High Purity** — Jenell McCall, Chemours
- **PVDF Design Considerations for High-Purity Applications** — Saeid Zerafati, Arkema
- **Design and Fabrication of High-Purity Vessels vs Conventional** — Hisham Abu Samra (Dr.-Ing.), Pfaudler (Edlon)
- **How to Detect and Measure Sources of Contamination, Leachable, Extractable Testing** — Hugh Gotts, Air Liquide Electronics U.S. LP - Balazs Analytical
- **Testing and Evaluation Methods for Ensuring the Cleanliness of High-Purity Process Liquids** — Gary VAN SCHOONEVELD, CT Associates, Inc.
- **Surface Preparation Techniques for High-Purity Industry Requirements** — Bradley Hostetler, AstroPak

*Top: Participants of the 5k Fun Run take time for a group photo before the race begins.*
*Left: AmeriTAC Representatives raise company table tents to vote in favor of funding MTI project #394.*
*Right: Attendees network and enjoy snacks during a break at AmeriTAC 141.*

During the TAC sessions, two structured forums were offered, including CrystalView Laser Microscopy—A Novel Alternative to EBSD by Brian Hoover, Advanced Optical Technologies, Inc. and a PFAS/PFOS (per-and polyfluoroalkyl substances/perfluorooctane sulfonic acid) Panel Session with Jay West (American Chemistry Council), Jenell McCall (Chemours), and Jaana Pietari (Ramboll). All presentations are now available to MTI members in the Technical Resource Library.

Projects were another focal point throughout the week. MTI members voted to support sending three projects to the Board of Directors for funding, one new project formed, and a project completion report was delivered (see sidebar).

Last, but not least, participation in the networking and entertainment offerings at this event was notable. Approximately 35 people attended the Brewers baseball game, 15 individuals participated in the 5K Fun Run, all attendees engaged during the breaks, meals and receptions, and around 50 people enjoyed a selection of food vendors and connected in friendly games of shuffleboard, bags/cornhole, and a golf simulator at 3rd Street Market Hall.

Overall, it was a successful meeting, and the TAC leadership would like to thank everyone for their participation. Be sure to save the dates and "Meet us in St. Louis," October 23-25, for AmeriTAC 142 and the Annual Meeting! ▪

## AMERITAC PROJECTS UPDATE

*Projects a Focal Point throughout AmeriTAC 141*

**Funded Projects**

***#394 – Summarizing Requirements of ASME PCC-2 Composite Repairs***

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.
CHAMPIONS: Avery Boyer & Debra McCauley, Chemours
AMOUNT FUNDING REQUESTED: $82,000

***#399 – Dual Laminate 2nd Training U.S.***

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.
CHAMPIONS: Lisa Desai, Pfaudler; Avery Boyer, Chemours
AMOUNT FUNDING REQUESTED: $23,500

***#401 – API Inspection Summit 2024***

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.
CHAMPION: Jeremy Nelson, Koch Industries
AMOUNT FUNDING REQUESTED: $1,500

**New Project**

***#408 – Fiber Optics for High Temperature Applications***

CHAMPIONS: Richard Samson-Ovia, Air Products, and Mark van den Broek, Fluor
MTI members are welcome to participate in the project team. Scan the QR code, login and join now.

**Completed Project**

***#368 – Best Practices for Working with SME's***

CHAMPION: Pat McSharar, DuPont
The completion report is available in the AmeriTAC Library under TAC 141 meeting documents. The final deliverables from the project will be available to members this fall and announced via email.

*__Figure 1 (left).__ Touch point corrosion under a pipe support*
*__Figure 2.__ Fillet welded patch plate repair at a CUPS location*

# FEA USED TO VERIFY FILLET WELDED PATCH PLATE REPAIRS FOR CORROSION UNDER PIPE SUPPORTS

*VITALY DRAMARETSKIY CENG*

## Introduction

Corrosion under pipe supports (CUPS) is a variation of touch point corrosion, which is a damage mechanism that many industrial facilities have to continuously fight with as they age. Contact points between pipes and their supports create areas for dissimilar metal and oxygen concentration cell corrosion, leading to a rapid and highly localized external wall loss (see Figure 1), which ultimately poses an inherent integrity threat as this type of corrosion is difficult to avoid, identify, measure, and remediate.

Facilities having long runs of off-plot piping, such as tank farms, have to spend millions of dollars on inspection campaigns, aiming to timely detect and quantify the damage before it is too late. As a result, it is often found that numerous lines are no longer fit for service and have to be repaired or replaced. Off-plot pipes typically run for hundreds of meters without a single isolation valve. Taking them out of service for a partial or complete replacement is a major exercise, which leads to significant financial losses. On the other hand, a permanent repair on the run, such as restoring the wall by a local weld buildup, is rarely possible due to the surface roughness, corrosion scale, lack of remaining wall thickness or uncertainties in estimating the extent of metal loss.

Out of all possible permanent repair options, one economically attractive solution is fillet welded patch plates (see figure 2), described in ASME PCC-2. Article 212 provides a conservative method to design such repairs; however, its analytical design rules are based purely on hoop and longitudinal loads resulting from pressure. While the code requires an additional consideration to be given to external loads, it provides no specific guidance on how it shall be approached. For CUPS locations, a reaction force from the underlying support is an additional load that must be taken into account as its magnitude may have a significant effect, especially in large diameter lines.

To tackle this issue, a large scale stress study was conducted using finite element analysis in accordance with rules laid down in ASME BPVC Section VIII Div. 2, Part 5 (2019) to assess the stress levels in patch plate repairs underneath a range of off-plot pipes between DN 203 mm (8 in) and 914 mm (36 in) in a variety of most common schedules.

## Elastic Stress Distribution Analysis

As a first step in the study, a stress distribution analysis was carried out based on a 508 mm (20 in.) carbon steel (C ≤ 0.3%) pipe in its standard schedule, operating at 20 barg (290.075 psig) / 50 °C (122 °F), with a fully welded 60° wide / 400 mm (15.75 in) long / 10 mm (0.4 in) thick patch plate. (see Figure 3 on page 20). Pipe support was initially excluded from the analysis to assess the effect of its presence on the stress distribution at a later stage.

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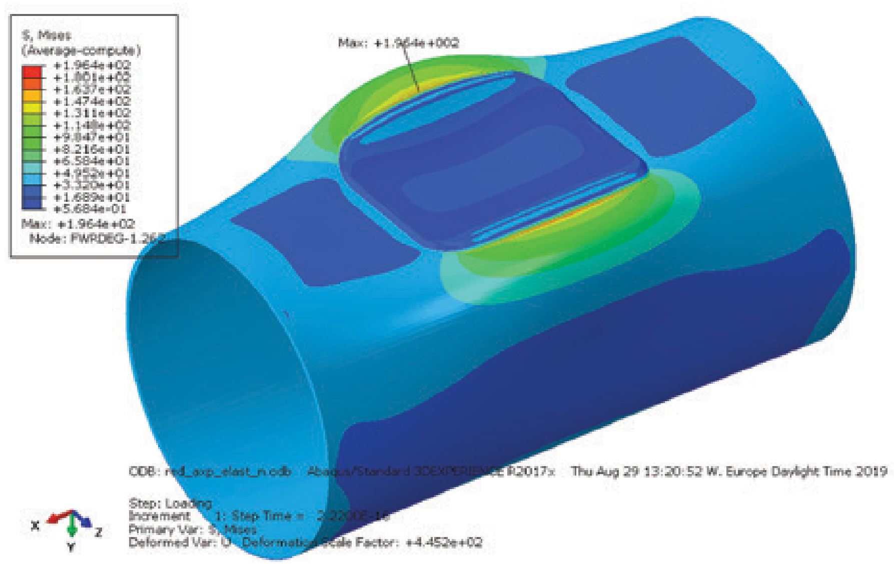


***Figure 3.*** *Von Mises Equivalent stress distribution on the deformed shape (deformation is magnified to enhance appearance).*

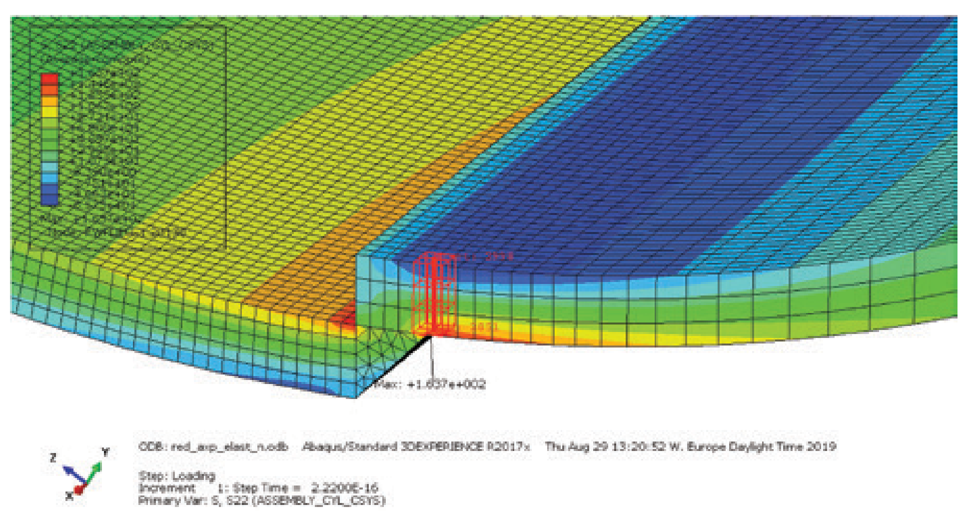


***Figure 4.*** *Transformed hoop stress around the weld and a stress classification line at the weld's toe (midplane cut view).*

Also, as it is virtually impossible to monitor the remaining pipe's wall thickness underneath the patch plate after it is installed, it was conservatively assumed that the wall is completely corroded away up to the edges of the patch, ultimately making it part of the pressure boundary. (See Figure 4.)

The following observations were made in this part of the study:

- Maximum principal and equivalent stresses were highest at the axial midplane on the longitudinal sides of the plate and the peaks were at the weld's toe on the pipe's side;
- Hoop stress peaked at the corners of the plate at the weld's toe and the linearized average membrane stresses were slightly higher than at the plate's center, while the computed membrane + bending invariants were significantly lower;
- ASME PCC-2 method significantly overpredicted the maximum membrane + bending stress at the weld compared to the Finite Element Analysis (FEA) results.

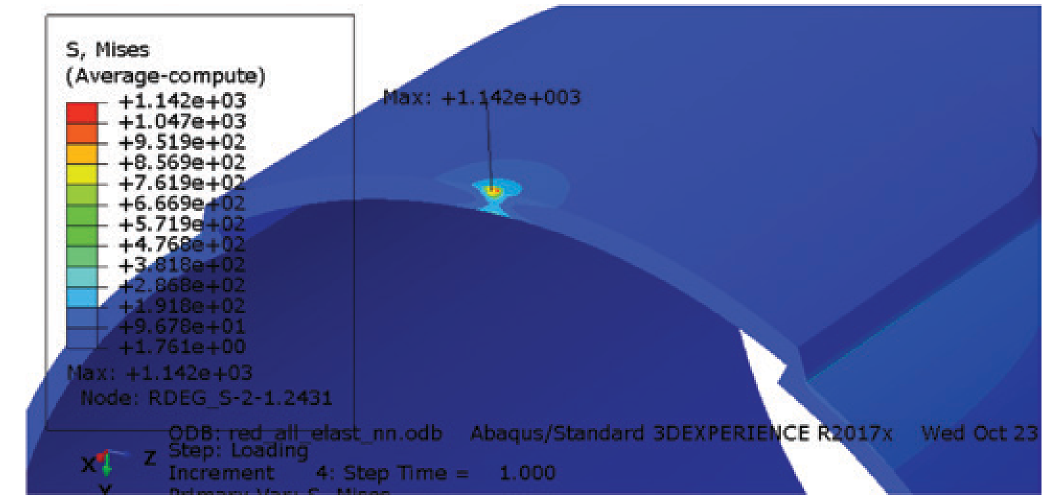


***Figure 5.*** *Von Mises equivalent stress at the contact point (midplane cut view, rod is hidden).*

## Pipe Support Effect

To model the effect of a pipe support, a fixed 25 mm (0.98 in) steel rod representing a typical sleeper was brought in contact with the pipe underneath the patch plate. Shear forces and bending moments were applied to the pipe's ends to represent the free hanging spans up to the next supports six meters (20 feet) away. The immediate finding was that the maximum equivalent stress raised to an extreme value of >1000 MPa (145038 psi) at the contact point, despite the fact that the contact pressure was spread over a number of nodes. The stress field; however, was highly localized and did not interact with the plate's welds. (See Figure 5.)

The second major finding was that both maximum principal and transformed hoop stresses coincided at the midplane, hence aligning with the axial position of the support.

To further assess how the pipe with a patch plate would fail, an elastic-plastic analysis was carried out assuming isotropic hardening. The main conclusions were as follows:

- No structural instability was observed even for the highest load factor. No local failure was identified and the maximum equivalent plastic strain capped at 6.4%;
- Redistribution of stresses at the contact point due to local yielding did not affect the overall load transfer and stress levels at the patch plate's welds;
- Maximum equivalent plastic strain was observed at the axial midplane at the weld's toe on the pipe's side, pointing towards a potential failure initiation at this location in case of overload;
- Pressure is the failure-driving load, while the support's reaction / bending moment led to the concentration of the prevailing stresses at the midplane. (See Figure 6.)

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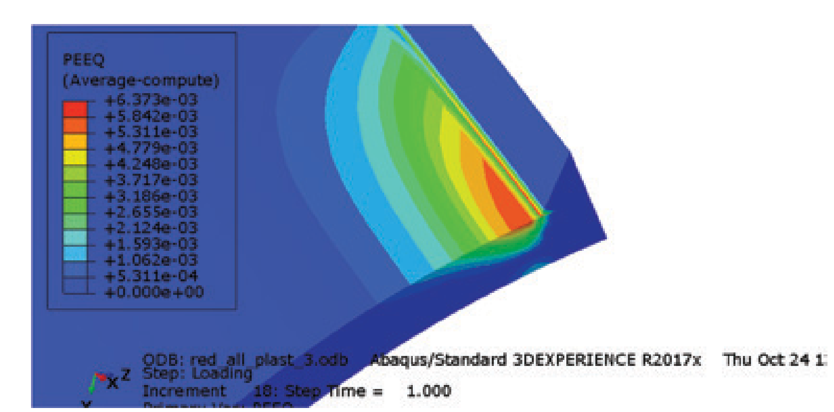


***Figure 6.*** *Plastic equivalent strain at the weld for the load factor of 3 (midplane cut view, plate is hidden)*

### Parametric Analysis

In order to study the effects of changing geometrical features, several additional models were run. An increased plate thickness / weld leg, longer / wider patch plates and effects of a pinhole / undamaged pipe wall on various pipe sizes / schedules were analyzed. The findings can be summarized as follows:

- Presence of the pipe wall underneath the patch plate majorly reduces the bending stresses at the weld; however, that effect is significantly diminished when a pinhole is made in the wall;
- Increasing the patch plate thickness / weld leg reduces the bending stresses at the weld, although it may lead to the shift of stress peaks to the weld's root;*
- Increasing the length / width of the patch plate had no effect on stress levels.*

* Pipe support was omitted from these models.

### Bulk Verification

After analyzing the findings, a bulk verification using the elastic stress analysis method was done for various pipe sizes and schedules. The following stress allowables were used:

- Average membrane stress – 138 MPa (20015.2 psi);
- Membrane + bending stress – 207 MPa (30022.8 psi);
- Triaxial stress limit – 552 MPa (80060.8 psi).

The above limits were set assuming ASME B31.3 as the design code and ASTM A106-B steel as the base material. Design conditions were 20 barg (290.075 psig) / 150 °C (302 °F), and the span length was six meters (20 feet). It shall be noted that the allowables did not include a weld efficiency factor.

| PIPE (ASME B36.10) | | PATCH PLATE | | | |
|---|---|---|---|---|---|
| DN (in) | Wall Thickness (mm) | Wall Thickness (mm) | Weld Leg (mm) | Axial Length (mm) | Cold Forming Strain (%) |
| 8 | 6.35 | 8 | 6 | 400 | 3.52 |
| | 8.18 | 10 | 8 | 400 | 4.36 |
| | 12.7 | 14 | 12 | 400 | 6.01 |
| 10 | 6.35 | 8 | 6 | 400 | 2.85 |
| | 9.27 | 10 | 8 | 400 | 3.53 |
| | 12.7 | 14 | 12 | 400 | 4.88 |
| 12 | 6.35 | 8 | 6 | 400 | 2.41 |
| | 9.53 | 10 | 8 | 400 | 3.00 |
| | 12.7 | 14 | 12 | 400 | 4.14 |
| 14 | 7.92 | 8 | 6 | 400 | 2.20 |
| | 9.53 | 10 | 8 | 400 | 2.74 |
| | 12.7 | 14 | 12 | 400 | 3.79 |
| 16 | 7.92 | 8 | 6 | 400 | 1.93 |
| | 9.53 | 10 | 8 | 400 | 2.40 |
| | 12.7 | 14 | 12 | 400 | 3.33 |
| 18 | 7.92 | 8 | 6 | 400 | 1.72 |
| | 9.53 | 10 | 8 | 400 | 2.14 |
| | 12.7 | 14 | 12 | 400 | 2.97 |
| 20 | 9.53 | 10 | 8 | 407 | 1.93 |
| | 12.7 | 14 | 12 | 410 | 2.68 |
| 22 | 9.53 | 10 | 8 | 447 | 1.76 |
| | 12.7 | 14 | 12 | 450 | 2.44 |
| 24 | 9.53 | 10 | 8 | 487 | 1.61 |
| | 12.7 | 14 | 12 | 490 | 2.24 |
| 26 | 9.53 | 10 | 8 | 526 | 1.49 |
| | 12.7 | 14 | 12 | 529 | 2.08 |
| 28 | 12.7 | 14 | 12 | 569 | 1.93 |
| 30 | 12.7 | 14 | 12 | 609 | 1.80 |
| 32 | 12.7 | 14 | 12 | 650 | 1.69 |
| 34 | 12.7 | 14 | 12 | 690 | 1.59 |

***Table 1.*** *Patch plate dimensions that* ***passed*** *the assessment.*

During the analysis, stresses at the midplane were linearized at the weld's toes, both through the pipe and the plate. Patch plate dimensions that satisfied the criteria are tabulated in Table 1.

All patch plates analyzed had the circumferential width of 60° and were centrally positioned at the low point of the pipe. Forming strains are given for reference, it shall be noted that above 5% it is required to carry out appropriate postforming stress relief prior to installation, as per ASME PCC-2.

During the analysis, a number of patch plates also failed the assessment (see Table 2).

More than 90% of these failed due to the exceedance of the membrane + bending stress levels while the few remaining models showed exceedance of the average membrane and triaxial stress limits. In all cases, the highest stresses were located at the weld's toe on the pipe's outer surface.

All weld leg sizes were equal to the plate thickness minus 2 mm (0.08 in) to avoid melting of plate's edges and creating a stress riser. Further increasing the thickness of the plates that failed the assessment was not seen appropriate as it would end up with a weld throat thicker than the pipe's wall. For large diameter lines, it was also discovered that while increasing the thickness reduces the bending component, it also causes the average membrane stress to rise due to the shift of the neutral line relative to the pipe's axis, which is caused by the increased plate thickness.

### Implementation Risks

The patch plates described here were intended to be welded to live equipment, which is a high risk activity on its own and a thorough assessment shall always be done to confirm that it can be executed safely (e.g. see API RP 2201) and no burn through will occur during the process.

Apart from that, welding a plate under a support implies that the pipe will need to be lifted, which also requires an engineering assessment, especially in view of the reduced wall thickness due to corrosion.

The other issue is the level of non-destructive examination that one can do at the touch point location itself and the weld around the patch. Even a tiny leak of a flammable substance during welding may have disastrous consequences. Thus, one needs to gain certainty around the amount of wall thickness left at the corrosion patch.

| PIPE | | PATCH PLATES | | |
|---|---|---|---|---|
| DN (in) | Wall Thickness (mm) | Wall thickness (mm) | | |
| 20 | 6.35 | 8 | 10 | • |
| 22 | 6.35 | 8 | 10 | • |
| 24 | 6.35 | 8 | 10 | • |
| 26 | 7.92 | 8 | 10 | 12 |
| 28 | 7.92 | 8 | 10 | 12 |
| | 9.53 | 10 | 12 | 14 |
| 30 | 7.92 | 8 | 10 | 12 |
| | 9.53 | 10 | 12 | 14 |
| 32 | 7.92 | 8 | 10 | 12 |
| | 9.53 | 10 | 12 | 14 |
| 34 | 7.92 | 8 | 10 | 12 |
| | 9.53 | 10 | 12 | 14 |
| 36 | 7.92 | 8 | 10 | 12 |
| | 9.53 | 10 | 12 | 14 |
| | 12.7 | 14 | 16 | 18 |

***Table 2.*** *Patch plate dimensions that* ***failed*** *the assessment.*

On the other hand, the lack of possibility to execute volumetric inspection on the welds and the fact that the calculations assumed a geometrically perfect weld without a weld efficiency factor, calls for a careful approach to welding quality and NDE. Remedies such as multilayer MT/PT and job-specific qualification of welders are some options that may help mitigate the risks.

Last, but not least, installing a patch plate may create an internal crevice corrosion risk, so an appropriate inspection and monitoring strategy may be needed for such cases.

### Conclusion

Viability of patch plate repairs for CUPS locations in off-plot piping has been demonstrated and the results of this study have already been successfully used to carry out numerous repairs, saving millions of dollars in replacement costs. However, engineers shall always assess the limitations of applying this repair method and the risks it carries versus advantages of other permanent repair types and/or replacing the corroded lines, either partially or completely. ▪

# INDUSTRY ICON SALOT STILL TURNS TO MTI FORUM FOR ANSWERS

## MAINTAINS HIGH PRAISE FOR THE MTI TECHNICAL NETWORK

An active member of MTI at 92 years old, Bill Salot, a Senior Reliability Engineer at Advansix, wakes up most mornings, reads scriptures, has a little breakfast, and gets to work. It's a routine that he has followed religiously for most of seven decades, one that has turned him into a candidate for a GOAT (greatest of all time) award in his field of reliability engineering.

As you might imagine, Salot is quite a character. He is a pragmatic pro who gets to the point quickly. He has certainly earned a big ego for his many achievements, yet he displays humility and a wry sense of humor that can be self-deprecating at times. When asked what he was looking forward to next as he lives his best life in his 90s, he quipped, "tomorrow and the next day." Inquire about retirement, and it's a non-starter for him – inconceivable at this point in his long career. He jokes that he'll probably be buried under Advansix's Learning Center or his own private parking space at the plant, both which have signs posted that already bear his name.

Delving back to his introduction to the Materials Technology Institute, remarkably, Salot is able to start with the organization's founding.

"After MTI was conceived, my company, then known as Allied Chemical, was one of the first to join," he recalls. "Allied Chemical already had an in-house mini-MTI, represented by an active group called AIMEC (Allied Interdivisional Materials Engineering Committee). So, we hit the ground running. My early attendance was as a representative of a division facility where I am still employed, not of the corporation, which has changed corporate (once Honeywell) or division names more than a dozen times."

Bill Salot, Senior Reliability Engineer – Advansix

In addition to the recognition he has received at Advansix, Salot has also made a name for himself at MTI. Among his industry honors are MTI's Distinguished Service Award, established by the Board of Directors in 2018 to recognize extraordinary service to the organization. He's made many significant contributions to numerous projects, but perhaps more notable, Salot began participating in the MTI Forum (formerly TAC Forum) in January 1988. His Forum activity is approaching 600 posts, in which he has offered insight on the full range of issues faced by operating plant personnel. A review of his comments reveals contributions on metallic and non-metallic materials and equipment in a wide range of circumstances.

Although Salot has amassed a vast amount of materials engineering knowledge over 70 years, he continues to seek answers from MTI's deep well of resources. For example, he recently posted a forum question on the Corrosion Under Insulation resistance of a product called Pyrogel. The post generated five responses within the first 30 minutes, three more within the second 30 minutes, and a total of 12 in less than a week. Salot thought that quick and helpful response was solid evidence of the Forum's potential benefits.

"There is an art to asking "answerable" questions on the Forum," he points out. "A recent question of mine received no response at all until it was re-worded."

> CONTINUED ON PAGE 35

BOB HURST, BECHT

# 200 SERIES STAINLESS STEELS IN THE CHEMICAL PROCESS INDUSTRY

## Consider for Use in Specific Applications

200 series stainless steels have not found widespread use in the chemical process industry, but deserve more consideration because they could offer the economic material of construction for specific applications.

### What Is A 200 Series Stainless Steel?

200 series stainless steels are not new or exotic materials. They have been available for decades. What characterizes them from the much more common 300 series stainless steels is that manganese is substituted for part of the nickel content as an austenite stabilizer. Higher contents of nitrogen are also used to stabilize the austenite. They were first used in North America in the 1950's. A post World War II nickel shortage led to their development and use.

Table 1 below shows a comparison of two grades of 200 series stainless steels, 201L (UNS S20103) and 201LN (UNS S20153) and 304L (UNS30403). Because manganese is not as strong an austenite former as nickel, the chromium content has to be somewhat lower. The lower chromium affects the corrosion resistance of the alloys. Also, molybdenum, a ferrite former, cannot be used in the typical 200 series as its inclusion would make it very difficult to maintain the austenite crystal structure. Because of the lower chromium and lack of molybdenum, 200 series stainless steels are, as a rule, not as corrosion resistant as 300 series.

### Why Consider A 200 Series Stainless Steel?

If the corrosion resistance of 200 stainless steels is lower than 300 why should they be considered? The substitution of manganese for nickel will lower the price of the alloys. The cost advantage is determined by the spread between nickel and manganese prices. As nickel becomes more expensive compared to manganese the cost advantage increases. An additional price consideration is that nickel is an important component of many lithium-ion batteries. As demand increases for electric vehicles and electricity storage batteries, it will put upward demand and price pressure on nickel.

### Possible Applications For 200 Series Stainless Steels

Even with the lowered corrosion resistance of 200 series stainless steels, the resistance may be adequate for mildly corrosive conditions. An application may be too corrosive for carbon steel but can be economically handled with a 200 series negating the need for the more corrosion resistant and expensive 300 series.

Some suppliers have corrosion data on their websites comparing 200 and 300 series. The standard corrosion guides do not normally list 200 series. However, The NACE Corrosion Data Survey has corrosion data tables for 17 Cr stainless steels. These can be used as a proxy for 200 series to give approximate corrosion resistance to the environments listed in the survey. Corrosion testing, either field or laboratory, may be more essential in determining the adequacy of 200 series than with 300 series. The lack of molybdenum in the alloys is a drawback with environments containing chlorides or other halogens.

In addition to mildly corrosive conditions, another use are applications where there is a need for product purity. If iron contamination in even small amounts needs to be avoided, 200 series may be the economic choice. Even in non-corrosive systems, carbon steel equipment will still have some rust from down times. This can get into the process and may contaminate the product and/or cause unacceptable discoloration of the final product. 200 series may perform just as well in preventing this as 300 series.

| TABLE 1 (CONCENTRATION IS IN WT%.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| UNS | TYPE | FE | C MAX | CR | NI | MN | N | SI |
| S20103 | 201L | Bal. | 0.03 | 16.0-18.0 | 3.5-5.5 | 5.5-7.5 | 0.25 max | 0.75 max |
| S20153 | 201LN | Bal. | 0.03 | 16.0-17.5 | 4.0-5.0 | 6.4-7.5 | 0.10-0.25 | 0.75 max |
| S30403 | 304L | Bal. | 0.03 | 17.5-19.5 | 8.0-12.0 | 2.00 max | 0.10 max | 0.75 max |

Per ASME SA-240

| TABLE 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| UNS | TYPE | TENSILE STRENGTH | | YIELD STRENGTH | | ELONGATION % | HARDNESS | |
| | | KSI | MPA | KSI | MPA | | BRINELL | ROCKWELL |
| S20103 | 201L | 95 | 655 | 38 | 260 | 40 | 217 | 95 HRBW |
| S20153 | 201LN | 95 | 655 | 45 | 310 | 45 | 241 | 100 HRBW |
| S30403 | 304L | 70 | 485 | 25 | 170 | 40 | 201 | 92 HRBW |

Per ASME SA-240

200 series stainless steels are approved for products administered by the Food and Drug Administration. Conditions in the food and beverage industries are often only mildly corrosive but product purity and color are essential. No one wants to see rust particles in their soup or aspirin. For these reasons, these materials have gained wide acceptance compared to the CPI.

A common use for austenitic stainless steels is low temperature and cryogenic services because of their superior low temperature fracture properties compared to most ferritic steels. Austenitic stainless steels do not have the sharp ductile to brittle transition temperature of carbon and other ferritic steels. 304L is a common choice for these applications. 200 series are a possible alternate. 201LN is cited as a stainless steel suited for low cryogenic applications. Section VIII Division 1 of the ASME Boiler & Pressure Vessel Code covers the use of 200 series stainless steels for cryogenic service. Specific requirements can be found in para. UHA-51. 200LN can be used to -320° F (-195.6° C) without impact testing. It has been used for liquid gas storage tanks.

### Availability

200 series stainless steels are readily available as plate, sheet and strip. Pipe may be more difficult to procure. This should not present a problem in the fabrication of process equipment. For example, a tank or process vessel can be constructed of 200 series plate. If 200 series pipe and forgings cannot be found, nozzles and flanges can then be constructed from 300 series.

In recent years the use of 200 series have become more common in Asia. This has caused some quality issues to be raised. One should always purchase any corrosion resistant alloy or other material from reputable suppliers that have well established and followed quality control programs.

### Mechanical Properties

Because of the higher nitrogen contents, 200 series stainless steels normally have higher tensile strength, yield strength and hardness than 300 series. Table 2 compares 201L and 201LN to 304L. The higher tensile strength allows thinner sections to be used in fabrication. This also represents a cost advantage over 300 series.

### Design And Fabrication

201L and 201LN are included in the B&PV Code Section II-A. Plate is covered by ASME SA-240. Allowable design stresses are in Section II-D. Because of the higher strength and hardness, formability will be lower than with 300 series. This should not present a major problem to rolling or other forming processes. Per Section IX of the Boiler and Pressure Vessel Code, 200 series have the same P and F numbers as 300 series. A welding procedure and welder qualified to weld 300 series will also be qualified to weld 200 series. Considering all of this, there is no major fabrication obstacle to fabricating process equipment from 200 series.

### Summary

The purpose of this article was not to suggest that 200 series stainless steel is a complete substitute for the more traditional stainless steels. The purpose is to suggest they can be the economic engineering choice for particular applications and should be considered. ▪

# 2023 SCHOLARSHIP RECIPIENTS ANNOUNCED

## AWARD HELPS STUDENTS PURSUE PROCESS INDUSTRY CAREERS

*BY DANIEL RASMUSSEN, MTI*

MTI is pleased to announce the recipients of the 2023 Bert Krisher and Robert Sinko (established 2022) Memorial Scholarships. Madison Pixler (Notre Dame) and Jake Hughes (University of Akron) have been selected to receive these prestigious awards for demonstrating a strong desire to enter the Process Industries supported by academic achievements, work experience and enthusiasm for their chosen degrees. Both students received a $5,000 award toward their academic expenses and were recognized at the MTI AmeriTAC Meeting in June.

*Madison Pixler, Notre Dame (left), Jake Hughes, University of Akron (right)*

### Madison Pixler, Notre Dame

Pixler's journey into the field began when her grandfather was diagnosed with cancer. She pursued a degree in Chemical Engineering in hopes of making a positive impact in the world through pharmaceutical improvements.

"Although I may not be working directly in pharmaceuticals, I still will carry my grandfather's legacy with me as I engineer solutions to society's greatest needs," Pixler explains.

Instead, Pixler will carry on his legacy as a Process Engineer at ZAP Engineering and Construction Services, Inc. where she will work on several projects from engineering studies and maintenance repairs to full-scale designs of large facilities.

"I am excited to combine my Notre Dame education, previous internships and polymer research experience to apply it within this dynamic role," she shares.

With the financial assistance granted by this award, Pixler notes that she was able to participate in undergraduate research focused on polymer membranes for use in gas separation at high temperatures to increase energy production sustainability.

Dedicated to advancing toward a career in the industry, Pixler also held two internships during college. She began at EVRAZ Rocky Mountain Steel as a Quality Control Engineering Intern, where she led data analysis projects to refine the overall steel-making process, improving the quality of the final products by identifying process variables related to defects in the final steel product and developed a plan to mitigate these effects.

"It was estimated by the financial department that these changes would result in saving the company millions of dollars!" Pixler proudly proclaims.

She then went on to intern at TotalEnergies Polypropylene Plant and led a team briefing of over 30 engineers and managers on flare emissions to link causes determined from an analysis of data trends.

Outside of the field, Pixler has a passion for sports and staying active. She played club basketball at Notre Dame and captained her dormitory's flag football and basketball teams. She expects this recreational experience to make her transition to Colorado for her new career very smooth.

"I cannot wait to take advantage of the beauty of the Rocky Mountains. Hiking 14ers, biking on local trails and skiing with loved ones are some of the activities I plan to fill my time off from work with."

### Jake Hughes, University of Akron

Hughes' path into the industry began with a passion for materials science, due to its nature as a field that every industry is reliant upon. This later developed into an interest in corrosion engineering to study the dangers that corrosion presents to the public so he could have a hand in preserving the infrastructure that communities rely on every day.

"My interest in corrosion engineering and the protection of metals began when learning about the Silver Bridge collapse of 1967, which collapsed due to stress corrosion cracking and a lack of redundancy in the design," Hughes shares.

"I hope to earn my degree and spend my career ensuring that no additional loss of life happens due to the degradation of metal infrastructure."

This directly impacted his decision to study corrosion inhibitors, a widely used method for the prevention of corrosion in many industries, for a year-long undergraduate research project. Spending so much time on this topic, Hughes learned significant laboratory procedures that are used to determine the effectiveness of compounds in corrosion inhibition. He says he considers it as one of the most memorable moments of his educational career.

"The results from the numerous experiments allowed me to calculate the inhibition efficiency for the compound that I studied and by making variations to the temperature and inhibitor concentration, I was also able to make conclusions about the effects these parameters had on inhibition efficiency," he explains.

With his passion for corrosion and relevant experience to back it up, Hughes plans to finish his degree and enter the workforce near his hometown in the development of protective coatings or corrosion resistant alloy manufacturing. He shares that the scholarship awarded allows him to focus on school and accomplish his objectives without the stress of accumulating debt.

"This award will go a long way in helping me achieve my academic and professional goals. While furthering my education is something that I find very important, the costs associated with college can be overwhelming at times," he admits.

This scholarship will allow him to take time away from work to not only focus on classes, but to pursue his interests outside of his rigorous work schedule. Hughes has a workshop where he enjoys tinkering and crafting, including leather wallets, cases, stained glass windows and building model cars.

"I like to spend my time building and creating things, and I believe this is part of what led me to study engineering," Hughes remarks.

Keep an eye out one day for a "Jake Hughes Original"!

Congratulations and best wishes to our 2023 scholarship recipients! MTI looks forward to watching you grow in your careers. For those interested in applying for the 2024 scholarships, be sure to read the accompanying sidebar. ▪

# Scholarships

## MTI 2024 SCHOLARSHIP APPLICATION PROCESS OPENS SEPTEMBER 1— TWO $5,000 AWARDS AVAILABLE

The Materials Technology Institute seeks college students who show an interest in pursuing a career related to Materials Engineering in the Process Industries to apply for the prestigious 2024 Bert Krisher and Robert Sinko Memorial Scholarships. Each scholarship is valued at $5,000 and two applicants selected by an MTI committee will be awarded to help cover educational expenses.

Winning also offers the unique opportunity to network and build future working relationships with some of the most notable engineers in the Process Industries. Having the chance to attend one of MTI's global Technical Advisory Council (TAC) meetings is also a highly regarded benefit of receiving an MTI scholarship.

Students may begin applying September 1, 2023.

Qualified applications will be accepted from undergraduate students enrolled in Materials Engineering, Materials Science, Corrosion Engineering, and other relevant programs. The following information is required for submission:

- Completed application
- Academic transcript
- Three recommendation forms from educators or employers familiar with applicant's background
- Résumé
- Supplemental essay

Scan the QR code for complete details or visit www.mti-global.org/about/scholarships! Applications must be received no later than January 2, 2024, for consideration. ▪

# Refractory Reliability and Life Cycle Strategy of Process Furnaces and Vessels

## *Establishing Best Practices*

*BY MANABENDRA MAITY, SAUDI BASIC INDUSTRIES CORPORATION*

### Introduction

Fired heaters, olefin furnaces, reformers, reactors, gasifiers, calciners, incinerators, boilers, and a host of other high temperature equipment items (herein after called furnace) are amongst the most expensive and essential assets in the hydrocarbon and petrochemical process industries. Operating conditions and process dynamics of furnaces vary widely, ranging from hot-oxidizing atmospheres to processes that contain hot acidic and alkali gases or gases with entrained solid particles or extremely reducing conditions, or highly corrosive and erosive slags, molten salts, and ashes. Typical operating temperatures in furnaces could be as low as 250°C (482°F) to as high as 1950°C (3542°F). Some of the equipment operates at pressures as high as 8MPa (1160.3 psi) or more.

Refractory materials are used in furnaces as thermal insulation linings and/or to contain heat and provide necessary protection to the furnace containment structure against thermal damage, corrosion, erosion, and many other operational stresses (Figure 1). Each furnace has a somewhat different combination of temperature, pressure and operating environments and campaign life. Therefore, lining objectives could be completely different between furnaces and between various zones of the same furnace. For example, fired heaters are designed to have substantial insulating capability in their linings, while others (e.g. Refinery FCCU) designed to withstand severe erosion caused by flowing catalyst. Typically, different hot and cold wall lining systems range from 20mm to 450mm thick or more could be designed depending on operating severity. In many services, a furnace containment shell includes an external water-cooled jacket or external insulation or air shroud as well as internal linings. In addition, many other internal structures and functional components are made of refractory-like catalyst bed supports, domes, flue gas tunnels, partition walls, bridge walls, etc. Furnaces in process plants usually are required to operate two to five years or more, uninterrupted between planned shutdowns. Process furnaces are rarely built with backup units. Therefore, refractory linings, structures, and associated components (RLSC) must be fit for service and maintain their structural integrity and functional performance during designed lifetime.

Typically, RLSC are susceptible to aging and degradation by several mechanisms including overheating, melting, shrinkage, chemical wear, melt impregnation, thinning due to corrosion, abrasion & erosion, mechanical abuses, thermal shock, cracking, thermo-mechanical stresses, fatigue and creep, acid gas dew point corrosion, etc. [1]. Some damage mechanisms could be accelerated due to design deficiencies, poor material quality, inadequate anchoring, installation deficiencies, operational upsets and inadequate maintenances. Refractory degradation left unchecked or undetected could cause a serious impact on mechanical integrity, reliability, run-length, productivity, safety and maintenance costs. Damage to a containment structure may take several weeks to repair and restore integrity. A major share of financial losses could be due to plant shut-down, rather than refractory or structural repairs or replacement costs themselves.

Over the years, refractory integrity management (RIM) practices have enhanced progressively with operational experiences and technological advances. However, premature failures still occur. Many of these problems could be avoided by implementing a systematic refractory reliability and life-cycle

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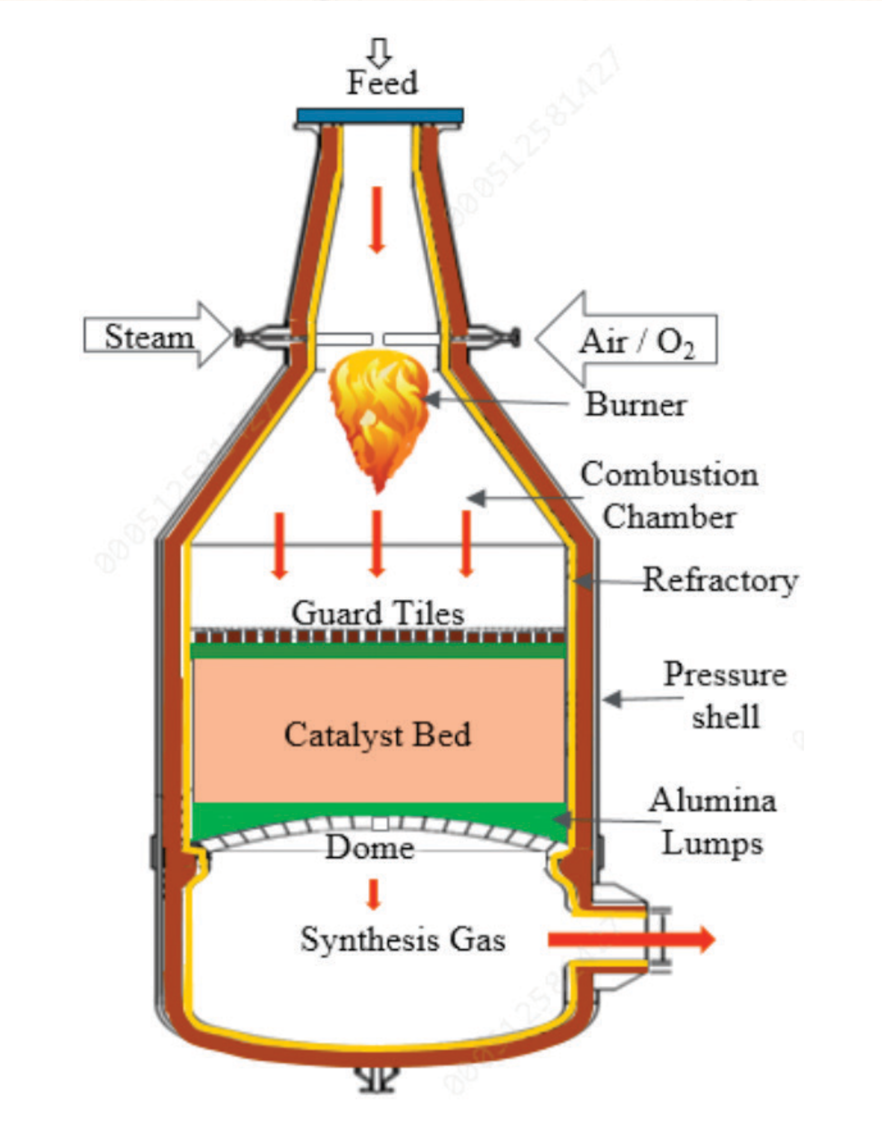
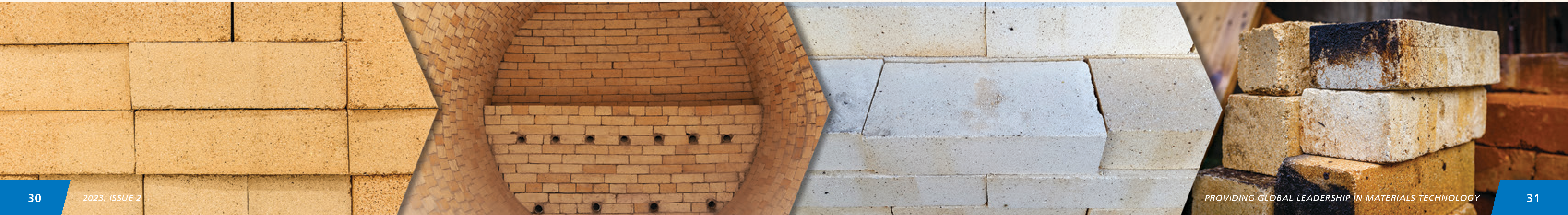



***Figure 1.*** *Typical reactor with internal refractory systems.*



management (RLCM) program. Each individual process furnace is unique to its operational environment and performance demand. No "one size fits all" refractory design and maintenance philosophy would be rarely applicable uniformly to all assets. Further, standards and codes for refractory RLCM practices are limited. Therefore, strategies should be formulated to a more proactive and tailored approach towards RLCM strategies backed and driven by experiences, appropriate technologies and techniques. This paper highlights the typical practices of implementing RLCM strategies.

## Refractory Reliability and Life-Cycle Management—Key Requirements

Refractory performance is made up of all activities that go into different stages [1]. The refractory life cycle is typically comprised of two stages:

- Pre-operational stage—this includes planning, detailed designs, material selection, procurement, installation, and commissioning of the furnace.
- Operational stage—this includes a comprehensive system of inspection, monitoring, assessment, maintenance, and repair or upgrades to ensure continued fitness for service.

RLCM should include a documented program of standards, specifications, guidelines and procedures to perform the tasks systematically. Important life cycle stages and associated tasks that are critical to performance are described briefly.

## Refractory Work Scope and Technical Specification

The wide-ranging nature of refractory activities and their management requires involvement from multiple stakeholders, including plant owners, project specialists, and external agencies (involving specialists from project, purchase, engineering, operations, inspection, maintenance, planning, quality management, safety) and external agencies (e.g., licensor, equipment manufacturer, refractory manufacturers, designer, installer, dry-out contactor, experts, etc.). Often, stakeholders both internal and external may have different or even conflicting priorities. Further, many of the refractory critical tasks are open-art technologies and could suffer due to oversights, misunderstandings, ignorance and conflicting priorities among stakeholders. Refractory engineering and integrity management is often about compromises related to various technical and economic factors. Thus, quality of as-installed refractory and its performance is one way or another dependent on the inclusiveness of job specification. Plant owners should take care of their specific interests by being involved during the project stage to ensure a proper specification. The complexity of the refractory contract, scope of work, duration and budget varies widely. Accordingly, a detailed descriptive and performance based contract specification should be tailored by exclusively defining scope of work and specific requirements. Specification and instructions should include but are not limited to:

- Scopes, roles, responsibilities and deliverables among stakeholders;
- Furnace engineering datasheet and drawings;
- Furnace process and operation practices, design and service conditions;
- Refractory design basis, performance requirements (e.g., casing temperature limit, thermal insulation efficiency, expected life);
- Material: Acceptable materials, selection and procurement criteria;
- Installation and dry-out: Specific methods and quality control program;
- Execution strategy: on-site or modularized shop installed refractory;
- Shipping and storage requirements of shop lined assets;
- Data / information requirement from contractors and suppliers;
- Applicable specification, standards, and EHS and regulatory codes;
- Post order engineering document submittals and approval protocol;
- Pre-qualification criteria of manufacturers, installers and others;
- Recommended contractors and manufacturers;
- Schedule for design, supply and installation;
- Quality control requirements for design, material and installation;
- Any other specific requirements;

Refractory design, installation, inspection, maintenance and associated tasks require a specific set of skills, expertise, experience and resources. The agencies should have the right competencies, capabilities and resources to perform the tasks safely and reliably. Refractory products are heterogeneous in nature; therefore, quality could vary both as manufactured and as-installed. The refractory manufacturer should have a system to ensure a sufficient level of quality and reproducibility. The plant owner should not leave key engineering and construction decisions up to the discretion of contractors and suppliers without a review. Usually, refractory life-cycle costs, including those of inspection, repair, replacement and management, as well as the risk costs associated with potential production interruptions, could be more significant than the initial as-installed acquisition cost. Also, be sure to consider the life-cycle cost of a refractory system while selecting a solution from alternative designs and sources.

## Refractory Selection, Design and Detail Engineering

RLSC systems are often complex designs consisting of many individual materials and components that must be integrated into a single system to perform together and meet design objectives. Initial decisions on design and material selection could affect long-term reliability and performance negatively. It would be extremely difficult to perform a major change or modification later in an operating plant. Therefore, design and material selection should include:

- Careful analysis of service conditions and associated stresses that are active, such as temperature, pressure, corrosion, thermal shock, abrasion, erosion, furnace gas and feed composition, mechanical movement, vibration, etc.
- Embedding adequate safeguards in design, material quality and installation against potential damage mechanisms of materials and RLSC system as a whole in the anticipated services.
- Ease of constructability, future maintenance and repair.
- Robust refractory system for inaccessible sections (e.g. Heater convection section) where maintenance could be difficult.

Detailed engineering documents typically include: details of lining, structure, sub-structure and components; material types; lining thickness and geometry; engineering calculations of structures (e.g. dome, arch); heat transfer & thermal profile calculations; anchoring systems (material, design, spacing, and welding-attachment details); dimensions of shaped items and tolerances; laying and bonding pattern of bricks; type of mortar; support systems (e.g., shelf flat, retainer plate); expansion gap details; installation and dry-out procedures, shuttering details for monolithic applications, etc.

Material procurement should include guaranteed specification, inspection, tests and acceptance criteria, packing and marking requirements, and shelf life.

## Installation, Dry-out and Commissioning

Installation and dry-out of refractory is as equally important as material selection and design. Installation and dry out procedures should be written in a mixed instructional and checklist format to ensure that steps taken are followed up by physical checks in the field. Common installation errors could be minimized by implementing a comprehensive quality assurance and inspection and test plan (ITP),

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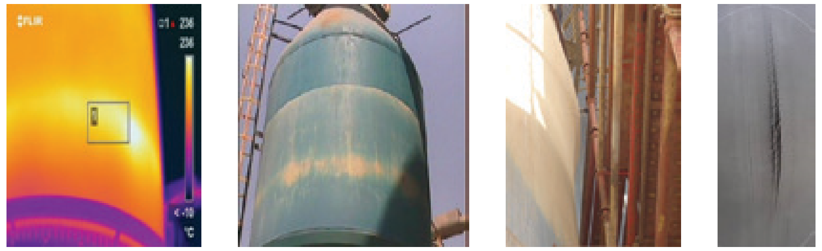
## Refractory Deterioration Leading to Shell Overheating



*Left to Right: Thermography, Paint Discoloration, Bulging, and Cracking*

***Figure 2.***

inspection hold and witness points. The procedures should include:

- Materials control, installer qualification control, installation process control, curing procedure, and acceptance criteria;
- Storing and preservation of lined equipment to avoid potential damage (e.g., alkali –hydrolysis);
- Heat dry-out details of newly installed refractory;
- Heating rate and temperature control during commissioning of furnace with new linings.

A post commissioning thermography survey could be performed to verify and confirm design and installation quality.

### Inspection, Condition Assessment and Maintenance

A systematic in-service and off-line inspection program should be developed and deployed for each furnace. The inspection plan should include what, how, where and when inspection must be conducted and what, how, where and when the appropriate action or emergency responses must be taken to address the concerns (e.g., hotspots) that may affect safety, reliability, and productivity.

In-service inspection has several benefits including:

- Timely identifying anomalies (e.g., hotspot) and reducing uncertainties;
- Avoid catastrophic failure and ensure safe shutdown;
- Extend run-length (e.g., hot spot temperature control by steam sparging);
- Proactively schedule and prioritize maintenance rather than reacting to a catastrophic failure;
- Allow advanced shutdown scoping, planning, resourcing, and spare management.

Common in-service inspection practices include (Figure 2):

- Casing temperature measurement and trending (e.g., Infrared thermography, skin thermocouples, thermo-indicating paint).
- Visual inspection of casing (paint burning, bulging and deformation, corrosion, cracks, leaks, etc. caused due to overheating)
- Visual inspection of fired furnaces interior through peepdoors to check flame patterns, impingement on walls, broken, missing or displaced refractory.
- Ultrasonic thickness (UT) measurement of casing at suspected areas where erosion or corrosion could occur due to refractory damage.
- Interior refractory wall-temperature measurements (e.g., infrared spot pyrometer, contact thermocouples).
- Furnace operation and control: A well-established integrity operating windows (IOW) program would allow monitoring key parameters (e.g. temperature, pressure, heating and cooling rate, burner malfunctioning, operational upset, etc.), which have direct effect on refractory damage mechanisms.

Inspection during a shutdown involves a combination of activities, including visual inspection, dimensional measurement, hammer test, photographing, sample testing, and engineering analyses. These help in validating findings of in-service inspection.

Periodic inspection along with design and construction information, historic failures, and changes and modifications form the basis of scheduled maintenance programs. The maintenance scope, schedule, resources (materials, contractors, workforce, and other resources) should be planned accordingly. Repair scopes of safety critical parts should be prioritized based on identified risks and criticality. Repair jobs, whether permanent or temporary, should be treated like a new job with adequate quality control.

### Continuous Improvement

There are several things to consider:

- Failure investigation: Address unusual refractory failures, chronic problems and deficiencies with a comprehensive investigation and scientific approach instead of "replace in-kind" practices.
- Upgrading aged assets: Explore possible improvement opportunities of aged assets by adopting state-of-the-art design practices, improved materials, and installation techniques to keep furnaces synchronized with ever-changing performance demands.
- Management of change (MOC): Validate fitness for service of a refractory system through an effective MOC process when considering a furnace revamping leading to potential changes in process and operating parameters that might negatively affect refractory integrity.
- Communicate and share unusual incidents to relevant stakeholders to avoid reoccurrences.
- Update standards and procedures periodically based on lessons learned and latest engineering practices.
- Train to enhance competency and awareness of plant engineers responsible for refractory tasks.
- Adequacy check of current RLCM program: A gap assessment or audit, typically by an experienced specialist, can identify inadequacies and risks present in a RLCM program of a plant versus industry best practices. Periodic gap assessment could help in benchmarking and deploying corrective measures.

### Final Remarks

There are a number of factors that could affect refractory performance. From time to time, unpredictable failure could occur even with the use of the best designs, materials and installation practices. Each furnace and associated refractory system is unique with respect to its design, operational severity and performance requirements. Therefore, the life cycle of refractory of individual assets should be addressed in all its complexity over the entire life cycle; from design and material selection, installation to commissioning, through inspection, monitoring, shutdowns, maintenance, upgrades and finally to replacement. ▪

### Reference

1.M.Maity: Updates on improving refractory lining service life; Hydrocarbon Processing. March 2011, Vol. 90. No.3 (29-37).

## INDUSTRY ICON SALOT STILL TURNS TO MTI FORUM FOR ANSWERS

> CONTINUED FROM PAGE 24

The flip side of the coin, answering questions, is part of the forum's unwritten rule of quid pro quo. But you had better know what you are talking about, according to Salot. "If a question expresses a need for guidance, rather than for a solid solution, and I have a related opinion, it is hard for me not to express that opinion," he confesses. "Express enough opinions, and questioners will seek you out. It will assure that you are either an expert or a fool."

To ensure his considerable materials-related expertise doesn't become stale, Salot continues to participate in the MTI forum and keeps up with the latest technology and techniques. "Knowledge rapidly becomes outdated," he notes. "MTI involvement helps us stay abreast of trends in a number of engineering fields."

Over its 46-year existence, MTI has launched many projects that have garnered Salot's attention. He shares an initiative that was particularly interesting. "MTI sponsored the first ever symposium on Mechanical Integrity, just a few months after OSHA passed its PSM Rule in 1992," he recalls. "From that sprang numerous, still-thriving enterprises, introducing new inspection programs, systems, and techniques, and an acronym called RAGAGEP."

Having access to other talented peers through the MTI network has also been helpful to Salot over the years, and he provides one example. "I do recall the discovery, by long-ago surveying my network, that industry practices widely favored both welded tubes and welded pipe over seamless in most instances," he says. "It helped us justify changing our standards, resulting in large, continuing savings over many subsequent years."

MTI recently completed a Knowledge Management Project, Best Practices for working with SMEs. Salot and his treasure trove of materials engineering knowledge is exactly the type of subject matter expert that the project team had in mind as it worked to build the new guidebook and its interview templates. Not only is he an icon at Advanxix (his colleagues revel at the simple yet elegant solutions that he often comes up with), but he is a highly respected member of the MTI technical community. Although Salot doesn't travel to AmeriTAC meetings these days, we hope that he continues to contribute questions and answers to the MTI Forum—as long as his daily routine and Father Time allow him to keep up the good work. ▪

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# LAST CALL FOR 2023 MTI VALUE AWARD SUBMISSIONS

## SHARE HOW YOUR COMPANY APPLIED MTI RESOURCES

Has an MTI project, forum post, seminar, networking event or some other MTI resource improved safety, sustainability or reliability within your company's plants or helped you support a fellow member's operations? If the answer is 'yes,' then the MTI Awards Committee encourages you to apply for the 2023 MTI Value Awards!

The contest is open to all MTI members, and joint company applications are welcome. Value cases must be original and unique to your company or the collaboration between multiple member companies. The awards are a great way to recognize your company's successes related to the value received through MTI membership.

The Global Value Award will be presented at the Annual Awards Banquet following the AmeriTAC 142 meeting, October 25, 2023, in St. Louis, MO.

The deadline to apply is September 1. Scan the QR code or visit www.mti-global.org/membership/awards. ▪