



Cover story:

TEADIT: Optimizing sealing in energy waste heat recovery



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Heat Exchanger World is the global magazine connecting those working in the heat exchanger supply chain

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Evolving with purpose

As autumn approaches, the September issue of Heat Exchanger World highlights the often-unseen yet absolutely essential factors that make our industry resilient, efficient, and forward-looking. From the silent role of sealing technology to the transformative power of service excellence and the lasting impact of advanced coatings, this edition is a reminder that true innovation often lies in the details.



Our cover story focuses on TEADIT®, a global leader in gasket technologies, whose solutions are proving indispensable in the energy transition. While much of the attention in waste heat recovery falls on exchangers and boilers, TEADIT® shows that sealing systems are just as vital. With applications ranging from refineries to combined heat and power plants, their materials helping industries cut emissions, extend asset life, and achieve real energy savings.

Equally engaging is our visit to Tranter's global service hub in Monza, Italy, where we were given a rare behind-the-scenes look at how service has become a differentiator in the heat exchanger sector. In candid conversations with Franco Langone and his team, we learned how Tranter is blending standardized global procedures with local adaptability. From flexible maintenance strategies to predictive AI-driven diagnostics, Tranter is reshaping what it means to be a true lifecycle partner. Read all about it on page 16.

Turning to this issue's technical feature on page 18, we spotlight the coating system developed by G.M.A. Srl. With more than three decades of field-proven success, this epoxy-phenolic coating is demonstrating its worth in extending the lifespan of shell-and-tube exchangers while simultaneously improving efficiency. Laboratory and field studies confirm its ability to mitigate fouling and corrosion, particularly in aggressive seawater and process environments.

Finally, as we look beyond this issue, we are excited to share the Advance Conference Program for Heat Exchanger World Americas 2025, set to take place on 15 & 16 October in Houston, Texas. This event promises to bring together manufacturers, end users, engineers, and researchers from across the region for two days of high-level presentations, technical exchange, and networking. From decarbonization strategies to digitalization, hydrogen integration to lifecycle management, the program reflects the challenges and opportunities shaping our industry. Learn more on page 31.

As this issue shows, innovation in heat exchange is never just about the "big" equipment, it is about the gaskets that prevent leaks, the service models that sustain reliability, the coatings that fend off corrosion, and the people who make all of it possible. These are the quiet revolutions that enable our industry to meet the twin goals of performance and sustainability.

I hope you enjoy exploring these stories as much as we enjoyed bringing them to you.

All the best,
Iryna Mukha
Editor
i.mukha@kci-world.com

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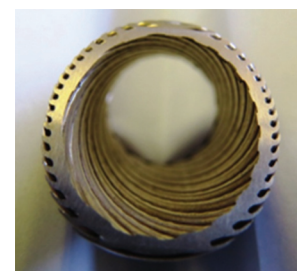
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This article explores the multifaceted considerations that influence these crucial maintenance decisions, providing industrial practitioners with detailed insights for optimizing heat exchanger reliability and performance.



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CALENDAR

15 – 16 October 2025

HEAT EXCHANGER WORLD AMERICAS CONFERENCE & EXPO

» Location: Houston, Texas, USA

Url: <https://heat-exchanger-world-americas.com/>

18 – 20 November 2025

STAINLESS STEEL WORLD CONFERENCE & EXPO

» Location: Maastricht, the Netherlands

Url: <https://stainless-steel-world-event.com/>

6 – 7 May 2026

HEAT EXCHANGER WORLD EUROPE CONFERENCE & EXPO

» Location: Rotterdam, the Netherlands

Url: <https://heat-exchanger-world-europe.com/>

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Community Update

Sharing good news from the heat exchanger community and wider industry...

Alfa Laval names Martijn Bergink President of Marine Division



Alfa Laval has appointed Martijn Bergink as President of its Marine Division, effective September 1, 2025. Bergink, who will join the company's Group Management, currently serves as President of the Business Unit Pumping Systems within the Marine Division and Managing Director of Framo, an Alfa Laval-owned company—roles he will continue to hold.

Having joined Alfa Laval in 1998, Bergink has spent most of his career in senior leadership positions within the Marine Division. CEO and President Tom Erixon praised his extensive industry knowledge and track record in driving growth and innovation. The appointment follows the retirement of current Marine

Division President, EVP Sameer Kalra, who has led the division since Alfa Laval's acquisition of Aalborg Industries in 2011. Kalra has been instrumental in advancing decarbonization initiatives and guiding the division—which accounts for 40% of Alfa Laval's order intake and employs 6,300 people—through the global energy transition.

Hexonic appoints Mariusz Grelewicz as Sales & Marketing Director



Hexonic Heat Exchangers has announced the appointment of Mariusz Grelewicz as Sales & Marketing Director. Grelewicz brings extensive experience in industrial, energy, and infrastructure projects across Europe, with a proven record in international project development, strategic growth, and building high-performing teams.

His career includes delivering complex projects in Poland, the European Union, the UK, Australia, and Ukraine, spanning the energy, chemical, and construction sectors. He has worked with R&D partners on advanced energy storage solutions and has led significant organizational changes, including post-merger integrations and sales transformations, aimed at streamlining processes, enhancing efficiency, and empowering teams. Grelewicz expressed enthusiasm for joining Hexonic, citing the company's strong engineering foundation and growth vision. A graduate of the University of Physical Education in Warsaw and the University of Economics in Katowice, he is recognized for his commitment to innovation, collaboration, and responsible leadership.

Tranter appoints John Kruep as Vice President of Human Resources



Tranter has announced the appointment of John Kruep as Vice President of Human Resources, effective July 31, 2025. Kruep brings over 25 years of international HR leadership experience with prominent organizations such as BP, Chevron, ExxonMobil, and most recently, Commonwealth Fusion Systems.

Known for driving organizational transformation, cultural evolution, and leadership development on a global scale, Kruep will be instrumental in advancing Tranter's people and communications strategy. His focus will include fostering a people-first culture, strengthening talent pipelines, and empowering teams to grow and excel. These initiatives aim to enhance Tranter's ability to serve its markets and customers effectively while supporting the company's ongoing global expansion. The company expressed enthusiasm for Kruep's leadership, emphasizing the strategic importance of his role in shaping the future of Tranter's workforce and sustaining its competitive edge worldwide.

BTL joins JPM Group, expanding EPCM capabilities

JPM - Automação e Equipamentos Industriais S.A. acquired 100% of BTL – Indústrias Metalúrgicas S.A., reinforcing synergies and enhancing the group's EPCM solutions for demanding industries including food, chemical, pharmaceutical, petrochemical, and environmental sectors. Based in Ossela, Oliveira de Azeméis, BTL operates from 18,000 m² facilities and builds pressure equipment up to 1,000 bar, with volumes of 355 m³ in-factory and up to 50,000 m³ on-site. The company is recognized for its expertise in stainless steel, carbon steel, titanium, and special alloys,



as well as its turnkey engineering, automation, and supervision solutions through its NewPower brand. JPM management emphasized that the integration will strengthen production capacity, innovation, competitiveness, and international reach while maintaining quality, trust, and sustainability. AECOA congratulated BTL on this strategic step and reaffirmed its support. This acquisition positions the JPM Group as a stronger player in the metallurgical sector, with expanded capabilities to deliver complex, high-quality industrial solutions worldwide.

Exchange what matters...



HEAT EXCHANGER WORLD EUROPE CONFERENCE & EXPO 2026

*6 & 7 May, 2026
Rotterdam Ahoy, the Netherlands*



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TEADIT: Optimizing Sealing in

In modern industrial plants, energy efficiency has shifted from a secondary consideration to a core operational imperative. Across refining, petrochemical, and chemical processing, the drive to reduce energy consumption and emissions has placed heat recovery and waste heat reclamation at the forefront of engineering strategies.

While discussions often focus on major equipment like advanced heat exchangers, high-efficiency boilers, and integrated plant networks, one often overlooked factor is the sealing system.



By Iryna Mukha, Heat Exchanger World

TEADIT® is uniquely positioned as a global sealing manufacturer with a complete portfolio of gasket technologies to address critical pain points experienced in these high-profile applications. Its range of engineered solutions enables TEADIT® to use effective sealing to optimize industrial energy efficiency by maximizing uptime, minimizing emissions, and extending the life of heat recovery assets.

The Intersection of Heat Recovery and Sealing Performance

Whether in refinery heaters, waste heat boilers, or combined heat and power (CHP) systems, energy is only as valuable as the system's ability to capture and retain it. Industrial waste heat is the result of energy produced during industrial processes that

is not utilized, as it is lost through exhaust gases, hot products, or heated equipment. Studies estimate 20–50% of industrial energy becomes waste heat. While some losses are unavoidable, facilities can reduce them by improving efficiency with engineered technologies.¹

Gaskets directly affect the reliability, safety, and efficiency of heat exchangers and related equipment. Leaks, pressure drops, and fugitive emissions diminish system gains. Selecting the right gasket material is, therefore, a strategic decision with operational and environmental implications.

The value of a gasket

A gasket's role is deceptively simple: maintain a tight seal under fluctuating pressures, thermal

Energy Waste Heat Recovery



adapts to flange irregularities, sealing corroded faces or uneven surfaces with minimal leakage. In condensate recovery and low-pressure exchangers, it delivers reliable performance with negligible cold flow when installed correctly.

2. Restructured PTFE (rPTFE)

Tealon® sheets offer superior creep resistance and mechanical stability under fluctuating temperatures. Available in multiple styles, rPTFE balances conformability, recovery, and sealability without sacrificing chemical compatibility, ideal for waste heat exchangers under thermal cycling.

3. Compressed Fiber Sheets

Blending elastomeric binders with aramid or inorganic fibers, these sheets withstand moderate to high pressures and temperatures. They provide reliable sealing in economizers, air preheaters, and auxiliary exchangers, with excellent blowout resistance and stability.

4. Flexible Graphite Sheets

Essential in high-temperature applications with steam, hydrocarbons, or oxidizing gases. TEADIT® graphite gaskets maintain seal integrity under cycling conditions, resist creep relaxation, and handle temperatures beyond most gasket materials, making them indispensable in boilers and ducting. For demanding services in oxidizing environments, TEADIT® also offers oxidation-inhibited graphite, extending service life where conventional graphite would otherwise degrade.

5. Metallic & Semi-Metallic Gaskets

For extreme pressures and temperatures, TEADIT® spiral wound, corrugated, jacketed, and kammprofile gaskets combine metal strength

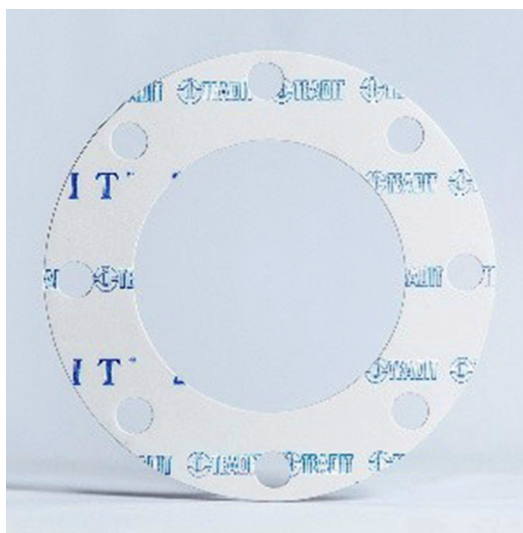
cycling, and chemical exposure. Achieving this requires materials that withstand creep, vibration, and process media without degradation, aligned with a plant's operating conditions, maintenance strategy, and compliance goals.

Waste heat applications are particularly demanding. High temperatures accelerate creep and relaxation, reducing gasket stress and leading to leakage. Pressure fluctuations, thermal expansion, and corrosive condensates compound these issues. Here, TEADIT®'s breadth of materials provides critical value.

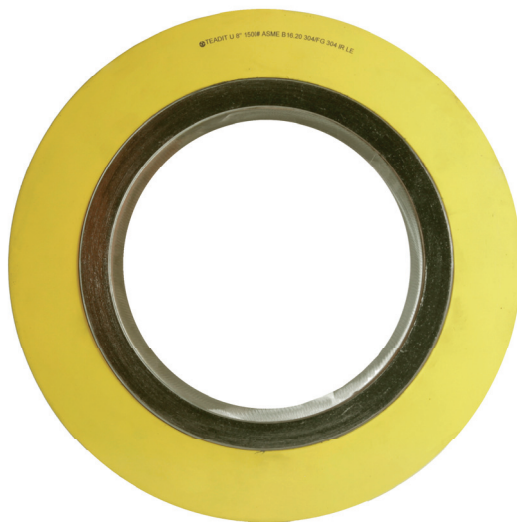
TEADIT® gasket materials for energy optimization

1. Expanded PTFE (ePTFE)

Ideal for low-torque applications where chemical resistance and conformability matter. ePTFE



≈ TEADIT® 24SH gasket.



▲ TEADIT® 913M Spiral Wound Gasket.



with soft material sealability. Used in large exchangers, heaters, and waste heat boilers, they resist vibration, flange rotation, and thermal expansion.

Sealing and energy efficiency: A direct correlation

Energy loss is not always visible. Micro-leakage or pressure decay across flanges reduces thermal efficiency, forcing plants to burn more fuel or run auxiliary systems harder. This raises costs and emissions.

Deploying gasket solutions tailored to each service yields measurable gains:

- Improved thermal efficiency by eliminating leakage paths.
- Reduced downtime through longer maintenance intervals.
- Lower emissions via reduced fugitive leakage.
- Increased safety by preventing hazardous leaks.

When gaskets are treated as commodities, energy recovery projects can fall short. Addressing this with engineered material selection, application

support, and testing to validate performance under real-world conditions is a viable solution for energy conservation.

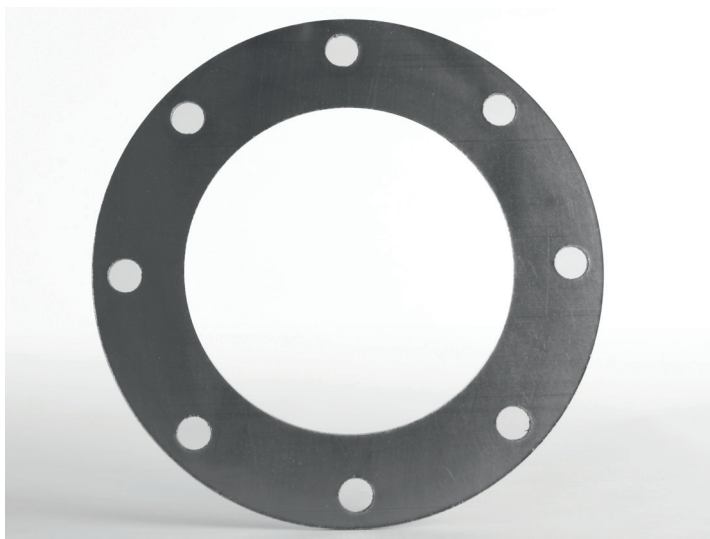
Case study: Waste heat recovery in a petrochemical plant

A Gulf Coast petrochemical facility sought to expand its waste heat recovery network, expecting 5–7% fuel savings. Early commissioning revealed flange leakage, particularly in units exposed to thermal cycling. A TEADIT® survey found non-optimized gasket materials lacking creep resistance and recovery. The plant adopted a multi-material sealing strategy:

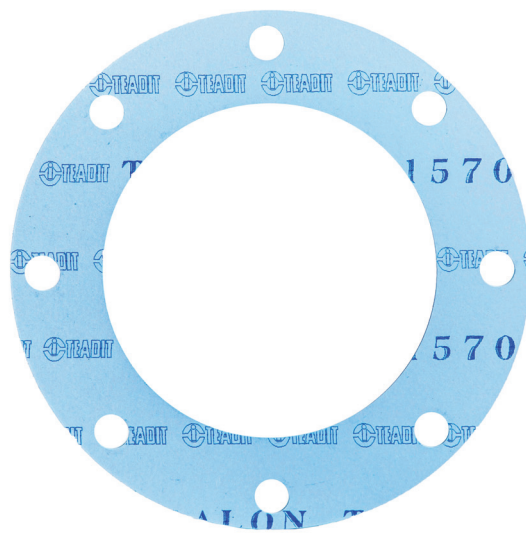
- Spiral wound gaskets with oxidation-inhibited graphite for high-pressure, high-temp headers.
- Tealon® rPTFE sheets for condensate return flanges under frequent cycling.
- ePTFE sheets for corroded or low-bolt-load flanges requiring a highly conformable seal on irregular surfaces.

The result: a leak-free startup, achieved an estimated annual fuel savings of 25,000 MMBtu, and reduced CO₂ emissions by over 1,000 metric tons.





TEADIT® GR1701. High Temperature Graphite Sheet with Multiple Foil Inserts.



TEADIT® Tealon TF1570 gasket.

The TEADIT® advantage: From material science to operational value

TEADIT®'s broad manufacturing capability enables holistic solutions, unlike suppliers limited to one material type. Supported by API, ASME, and EN testing, TEADIT® offers:

- Tailored solutions across ePTFE, rPTFE, compressed fiber, graphite, metallic, and semi-metallic gaskets.
- Versatility for low-pressure lines to extreme-temperature headers.
- Lifecycle optimization through longer service life and fewer leaks.
- Sustainability with verified low-leakage performance.

TEADIT® also provides engineering support, bolted joint analysis installation training, and post-installation monitoring to ensure long-term sealing reliability.

The silent contributor to a sustainable future

As industry pushes toward net-zero, heat recovery and reclamation remain vital pathways to reduce

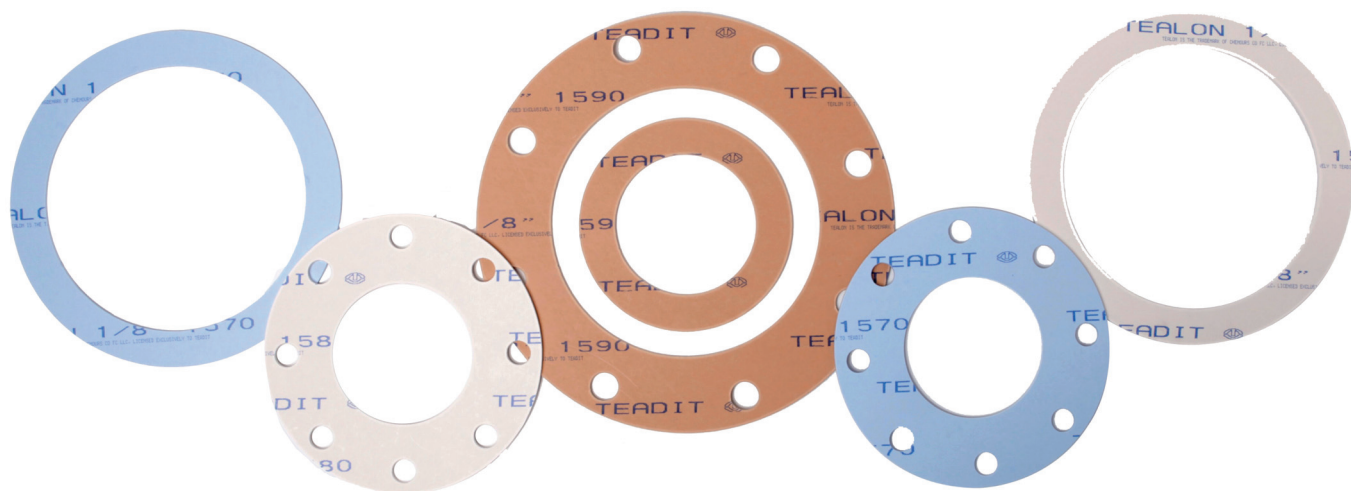
fuel use and emissions. Success, however, depends not just on major equipment but also on sealing systems that ensure integrity.

A single gasket failure can negate a multi-million-dollar energy investment. A properly selected gasket, by contrast, can operate for years without incident, conserving energy and preventing leaks.

TEADIT® is committed to helping industry realize the full value of heat recovery through diverse materials, engineered solutions, and proven performance, ensuring sustainability is built on reliability at every joint. ■

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Industry News

Dover acquires Site IQ LLC



Dover Corporation (DOV) has acquired Site IQ LLC (SIQ), which is now part of the Dover Fueling Solutions (DFS) business unit within Dover's Clean Energy & Fueling segment. Headquartered in Lombard, Illinois, SIQ is an industrial Internet of Things company with a focus on remote monitoring of fueling sites. SIQ's hardware and software products expand Dover's ability to deliver a comprehensive solution that brings actionable intelligence

and remote hardware service to retailers and service companies. "SIQ fulfills a need in the industry for an end-to-end solution that connects retailers and service companies with fuel dispensers," stated David Crouse, President of DFS. "This acquisition provides us with industry leading remote monitoring and analytics capabilities, which can reduce operating costs and improve the efficiency of maintenance for our customers."

Anytherm invests in stronger leadership



Anytherm is pleased to welcome Nermin Beganovic as the new Managing Director of Anytherm Bosnia and Herzegovina, further strengthening leadership and ensuring continued progress in quality and reliability. The company sincerely thanks Lorenz Schaffner for laying the foundation with a dedicated and reliable team, and it looks forward to the next chapter with Nermin on board. A warm welcome also to Flurin Guyer, further strengthening its energy consulting team in Switzerland. Nermin Beganovic brings extensive leadership experience in production and team management, gained through various roles in the industrial sector, including as Executive Director of Technology and QA, Head of Technology, and Head of PM & Technology Department. He holds a Bachelor's degree in Mechanical Engineering, an MBA, and is a certified ISO

9001 Lead Auditor with a strong focus on practical implementation, process reliability, and quality assurance. Nermin ensures that its stainless steel exchangers and equipment are manufactured to the highest standards, reliably and on schedule. Flurin Guyer holds a Master of Science in Mechanical Engineering, with a specialization in Energy and Environment, Renewable Thermodynamic Energy Technologies, and Thermochemical Grids. He also brings hands-on experience as a certified polymechanic (EFZ), complemented by several years of CFD experience in fluid flow and heat transfer optimization. At Anytherm, Flurin leads energy consulting projects—advising the clients on how to cost-effectively improve energy efficiency and reduce CO₂ emissions, for example, by analyzing how to optimally recover excess process heat.

Baker Hughes to acquire Chart Industries

Baker Hughes (BKR) and Chart Industries (Chart) have entered into a definitive agreement under which Baker Hughes will acquire all outstanding shares of Chart's common stock for USD 210 per share in cash, equivalent to a total enterprise value of USD 13.6bn. "This acquisition is a milestone for Baker Hughes and a testament to our strong financial execution and strategic focus as we continue to define our position as a leading energy and industrial technology company," said Baker Hughes



Chairman and CEO Lorenzo Simonelli. "We know Chart well, having worked

alongside them on many critical energy infrastructure projects. Their

products and services are highly complementary to our offerings and strongly aligned with our intent to deliver distinctive and efficient end-to-end lifecycle solutions for our customers across their most critical applications. The combination positions Baker Hughes to be a technology leader that can provide engineering and technology expertise to meet the growing demand for lower-carbon, efficient energy and industrial solutions across attractive growth markets such as LNG, data centers, and New Energy.

Arabelle Solutions to supply Turbine Island equipment

Arabelle Solutions is pleased to be supplying an SMR nuclear steam turbine, TOPAIR generator, and associated heat exchanger for the first GE Vernova Hitachi Nuclear Energy BWRX-300 small modular reactor project at Ontario Power Generation's Darlington Nuclear Generating Station in Canada. The equipment will form key components of the Darlington SMR turbine island. Once operational, this SMR will deliver enough

electricity for approximately 300,000 homes. The supply chain for the turbine hall will include specialist providers from Canada, including Ontario-based Chemetics Inc., which will manufacture components for the heat exchangers. In total, the full-speed steam turbine generator shaftline for the Darlington SMR will be 34 metres long and includes a single-flow high-pressure module and two double-flow low-pressure modules



to improve cycle efficiency. It will be coupled with an air-cooled TOPAIR

generator rated up to 370 MVA for the 60 Hz Canadian grid.

Alleima's partnership with Bångbro Strip Steel in Sweden



Alleima is pleased to have entered a new distributor partnership with Bångbro Strip Steel. Through the partnership, Bångbro will process, sell, and distribute Alleima's premium strip steels to ensure even better local access to high-quality strip steel on the Swedish market. Bångbro Strip Steel, part of Scanstrip Group and based in Kopparberg in Sweden, is a distributor of cold-rolled strip steel and has a long-standing reputation for its expertise, with a wide range of carbon steel, stainless steel, and special steel grades available directly from its efficient steel service center.

With a large warehouse, modern processing equipment, and deep technical knowledge, Bångbro Strip Steel is a trusted partner for Alleima, a leading global manufacturer of advanced steels and special alloys. Alleima brings to the partnership a long history of metallurgical expertise and depth of know-how. Its comprehensive steel portfolio includes ten premium knife steel grades with the latest generation Damascus steel - Damax, Austenitic and Carbon Spring steels, Precipitation Hardening steels, Nickel alloys, and an extensive range of hardened and tempered products. The partnership enables local stockholding, faster delivery times, and direct access to Alleima's wide portfolio of high-performance precision strip steels. With this partnership, Alleima continues to expand its global distributor network, making high-performance strip steel more accessible and supporting customers with both technical expertise and reliable local deliveries.

LNG Alliance selects Chart Technology and Modular Solution



LNG Alliance Pte Ltd, an integrated provider of LNG export terminal infrastructure and LNG supply, has announced its strategic decision to select Chart IPSMR® process technology and modular liquefaction solution for its Amigo LNG export facility with a capacity of 7.8 MTPA in Guaymas, Sonora, Mexico. IPSMR® process technology sets the industry standard for efficiency and performance in liquefaction and enables customers and operators to tailor their liquefaction systems to meet site-specific conditions. This flexibility allows for optimal

matching of compression power with single cold box capacity, maximizing operational efficiency and reducing costs. Furthermore, LNG Alliance will leverage Chart's mid-scale modular solution that incorporates Mega Bay air-cooled heat exchangers, Tuf-Lite IV fans, process vessels, valving, brazed aluminum heat exchangers, and cold boxes. The modular solution addresses the challenge of achieving the best balance between large-scale LNG facility economics and high operational efficiency.

THUNDER project wins the best post award



The THUNDER project received recognition at the 42nd UIT International Heat Transfer Conference, held in Florence, Italy. The University of Florence (UNIFI) presented a poster showcasing the

research work developed within the THUNDER project framework. The company is pleased to share that the poster was awarded Best Poster of the Conference, a significant achievement that

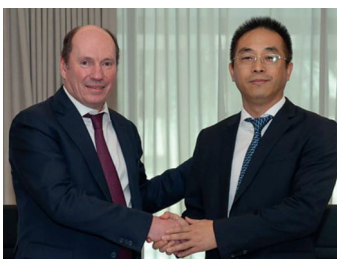
highlights the quality and relevance of the research being carried out under THUNDER. The UIT Conference is a key event for the heat and mass transfer community, bringing together researchers from universities, research institutions, and industry. It provides a platform to present and discuss advances in experimental, analytical, and numerical work related to topics such as thermal conduction, radiation, convection, multiphase flows, and energy system applications. This recognition reinforces the impact of the THUNDER project within the broader scientific and engineering communities and underlines the valuable contributions of the academic partners.

Stainless reproductions



A company dedicated to manufacturing equipment for the food industry has standardized on SACOME's supply of special expansion joints for its equipment. After a multi-year testing period, these expansion joints have proven their worth, durability, and ability to perform under the most demanding operating conditions. This equipment has successfully passed the validation period.

Sinosteel wins ArcelorMittal TPJ expansion project



ArcelorMittal Tubular Products Al-Jubail (ArcelorMittal TPJ) has issued a letter of award to Sinosteel Equipment & Engineering Co (Sinosteel MECC) for its Heat Treatment and Finishing Line (HT/FL) capacity expansion project in Saudi Arabia. This strategic investment underscores the kingdom's

growing industrial leadership and supports Vision 2030 by localising advanced technologies, strengthening supply chains, and unlocking long-term value for the energy and infrastructure sectors. Sinosteel MECC will lead EPC execution, while Tenova (Tenova Italimpianti) will supply cutting-

edge finishing technology for the new facility. The project is set to break ground in December 2025, expanding the kingdom's capacity in OCTG and line pipe heat treatment, and firmly positioning ArcelorMittal TPJ as the regional gatekeeper for premium seamless steel solutions, said a statement

Vallourec secures Sinopec supplier certification



Vallourec Tianda has once again been selected for Sinopec Group's 2025 list of non-API casing suppliers, marking the fourth consecutive year the company has earned this recognition. This continued inclusion reinforces

Vallourec's strategic role in China's energy sector and highlights its consistent performance within Sinopec's supply chain. Sinopec's annual tender process for oil well pipes is a key benchmark in China's energy industry. Over the past four years, Vallourec has supplied several Sinopec subsidiaries, with its products widely recognized for their reliability and technical excellence. This collaboration has evolved into a long-term, trusted partnership within the Sinopec ecosystem. This achievement also reflects Vallourec's strong internal coordination. The sales team led the market development efforts, supported by seamless cross-functional collaboration across finance, HR, quality control, and equipment teams — a collective effort that continues to drive the company's competitiveness in a demanding market.

Radco Industries partners with West BioFuels

Radco Industries, a manufacturer of high-performance heat transfer fluids, is proud to announce a strategic partnership with West Biofuels, a pioneer in renewable biomass energy technologies. As part of this collaboration, Radco's XCEL THERM line of synthetic heat transfer fluids will be integrated into West Biofuels' cutting-edge biomass conversion systems to improve operational efficiency and thermal stability. West Biofuels, known for its innovative approach to converting woody and herbaceous biomass into renewable energy, is incorporating XCEL THERM in its proprietary thermal conversion technology

to ensure optimal heat transfer, system longevity, and reduced environmental impact. The use of XCEL THERM in high-temperature bioenergy processes helps West Biofuels maximize energy recovery from biomass feedstocks while maintaining safety and compliance with rigorous environmental standards. Radco's fluids are formulated to perform under extreme conditions, minimizing system downtime and reducing the total cost of ownership. This partnership underscores both companies' commitment to driving innovation in clean energy and delivering dependable solutions for a greener future.

Baxi expands heating and hot water portfolio



Heating and hot water solutions provider Baxi has expanded its AquaHeat Heat Interface Unit (HIU) range with the launch of the AquaHeat HD/HWI direct HIU. The introduction strengthens Baxi's product portfolio to deliver direct heating without the need for a plate heat exchanger. Additionally, the new solution can provide indirect, instantaneous hot water to residential and commercial buildings in low-rise multi-occupancy and communal heat network developments. The AquaHeat HD/HWI is the first Direct HIU to pass BESA V3 2023, a mandatory HIU requirement with the

incoming Heat Network Technical Assurance Scheme (HNTAS) Technical Standard and current requirement of CIBSE CP1 Heat Networks: Code of Practice for the UK. Achieving this certification positions the new HIU as best-in-class for heat loss and strong VWART performance. With the new model, the AquaHeat range can now provide solutions across the whole HIU market, supplying models suited to both high and low-rise apartments, and communal and campus heat networks. This is in addition to utility and commercial spaces within these developments. Furthermore, Baxi can offer HIU users Heat Meters and its Mercurius connected platform, a secure and responsive web portal that's accessible from any device, anytime and from anywhere. This service offers a range of benefits, including remote fault diagnostics, increasing first-time visit success, and remote monitoring and control of each individual HIU settings to prevent heat network performance drift.



Iconic Manchester building retrofitted with Mitsubishi heat pumps



Mitsubishi Electric has announced the retrofit of a ten-story office building at Manchester's Exchange Quay campus with 12 air source heat pumps. The upgrade to building eight — the largest in the complex — has increased its energy performance certificate to B, in line with changing regulations which will require all office buildings to have a B rating by 2030. The landlord, Till Asset Management (Tillam), said it would go on to upgrade building one of Exchange Quay later this year, and building five after that. The asset management firm now intends to remove the previous gas

system entirely as part of plans to decarbonise its entire portfolio. Mitsubishi said it had used 12 40kW CAHV-P500YB-HPB heat pumps, installed in a cascaded configuration for optimal performance. It said the system delivered hot water of up to 70°C without the need for additional heaters. It provided heating through a pre-existing system of four-pipe fan coil units. The system was installed by air conditioning contractor Austin Broady, whose eponymous managing director said he would be bringing landlords from other parts of the country to see the project.

China commissions first steam extraction molten salt storage project



The 600MW Subcritical Thermal Power Unit Flexibility Retrofit Project with Steam Extraction Heat Storage, developed by Yantai Longyuan Power Technology Co., Ltd. (a subsidiary of CHN Energy Technology & Environment Limited), successfully passed CHN Energy's acceptance inspection. This project represents the largest operational "steam extraction heat storage" molten salt thermal energy storage facility in China. Based at Hebei Longshan Power Plant's 600MW unit, the project utilizes molten salt energy storage technology to provide grid peak regulation and frequency modulation services. Operational data confirms the system reduces

the boiler's minimum stable combustion load by an additional 100MW, enabling continuous peak shaving for over 4 hours. Under rated conditions, it boosts unit output by 30-60MW for peak support durations exceeding 6 hours, while improving Automatic Generation Control (AGC) performance by 150%. The successful implementation of this project provides valuable practical experience and technical support for the large-scale integration of molten salt energy storage with coal-fired power units, establishing significant demonstration value for wider industry adoption.

H C Coils joins the Bergman & Beving Group



Bergman & Beving (B&B) has acquired all shares in H C Coils Ltd, a company that produces made-to-order heat exchangers, used for temperature control, air conditioning, and refrigeration. H C Coils is situated in Fareham, United Kingdom. The company has over 70 employees and a turnover of approximately MGBP 10 with good profitability. "H C Coils is a niche producer of bespoke coils on the UK market. It has an efficient and flexible production process and produces made-to-order, customer-adapted products. This, combined

with their short delivery times and high standards of quality and service, distinguishes H C Coils in the market and is something that is highly valued by its customers.", says Mats Gullbrandsson, Head of Division Core Solutions.

"Having developed H C Coils for over 40 years, it is time to hand the company over to a new owner, and I am very pleased that B&B will now lead the company going forward. I was impressed by B&B's extensive experience and decentralized culture. With B&B's ownership approach, there are strong prerequisites for achieving success, and I am convinced I have found the appropriate owner for H C Coils", says former owner Paul Galloway. H C Coils will be part of the Core Solutions division, and closing will take place with immediate effect. The acquisition is expected to have a marginally positive impact on Bergman & Beving's earnings per share during the current financial year.

Global OTEC and Makai Ocean Engineering sign MoU



In a positive development for the Ocean Thermal Energy Conversion (OTEC) industry, Global OTEC has signed a Memorandum of Understanding (MoU) with Makai Ocean Engineering (Makai), under which Makai will supply its proprietary Thin Foil Heat Exchanger (TFHX) technology for integration into Global OTEC's most recent solution, the OTEC Power Module®. This agreement reflects growing momentum toward technology commercialisation, bringing together Global OTEC's modular and modern approach and Makai's advanced TFHX to sustainably power the tropical area of the world. Makai Ocean Engineering, based in Hawaii, has been a leader in OTEC

research and development for over four decades, including the design, construction, and operation of one of the only two grid-connected OTEC demonstration plants in the world. This extensive experience highlighted both the technical and economic challenges of scaling OTEC systems, particularly the high capital costs driven by large, titanium heat exchangers. In response, Makai developed the TFHX to reduce system cost without sacrificing performance. The TFHX features compact geometries and corrosion-resistant materials that significantly lower the cost while maintaining high thermal efficiency, durability, and fouling resistance, making it purpose-built for the unique demands of OTEC.

Westcome Heat Exchangers

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20 years

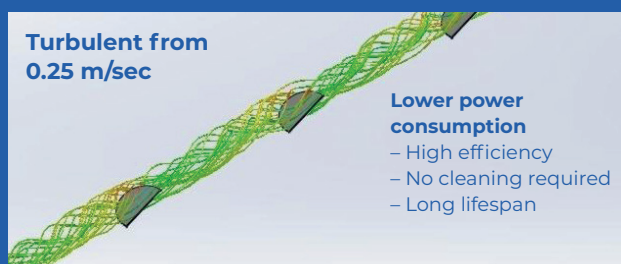
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Beyond the plates: Tranter's global service edge



Earlier this year, Heat Exchanger World was invited to Tranter's advanced facility in Monza, Italy. It was both a privilege and an opportunity to witness firsthand the intricate work behind their global service operations.

In an exclusive conversation with Franco Langone (Aftersales Director), Mirko Radrezza (Aftersales Manager), Bruna Reis Amanai (Global Service Projects), and Madeleine Sestan Bach (Global Marketing Manager), Tranter offered a behind-the-scenes look at how it is building a customer-centric, globally scalable maintenance strategy, one that blends agility, expertise, and digital transformation.

By Iryna Mukha, Heat Exchanger World

Standardized yet tailored

Tranter has built its service model around one principle: global capability, local adaptability. This isn't merely about having service centres in multiple countries, it's about harmonizing standards while responding flexibly to regional and customer-specific needs. For global clients, notably in the marine shipping industry, this level of reach is critical.

Franco emphasized, "We are often called to support a vessel in China, while the operations manager is based in Denmark. If we don't have an agile and responsive global network, we can't meet these demands."

Each Tranter service centre follows unified procedures, ensuring consistency across its operations, but retains the freedom to adapt to country-specific regulations and logistical hurdles. Bruna, who oversees coordination across regions, plays a central role in maintaining this balance: "Planning a service job might include customs clearance, special permits, and managing technician schedules across multiple time zones. It's a daily challenge, and we thrive on solving it."

Built around the customer

In a landscape where service is often reactive, Tranter positions itself by making flexibility and customer proximity core to its maintenance philosophy. "Our size is a strategic advantage," Madeleine noted.

"We're big enough to be global, but small enough to be accessible. Customers can reach out and speak directly to someone who understands their system." Franco expanded on the importance of this customer intimacy: "Every plant is different, even when the equipment is the same. One might use hard water in Italy, another soft water in Benelux. These variables change everything, and if you don't tailor your service to those factors, you're failing your customer."

This bespoke approach extends to training programs. Tranter doesn't assume what the client needs, it listens first. Some customers want to handle routine maintenance in-house; others lack the resources and prefer full service. "We offer training, tools, and even plate pack rotation programs, depending on their needs," said Franco. "It's all about making their job easier and minimizing their downtime"

Scaling service with a multinational mindset

Maintaining consistent quality across continents is no small feat. Tranter's network includes a growing number of strategically located service centres, including recent expansions in Shanghai and ongoing developments in Turkey. But scaling global service doesn't mean just copying and pasting operations, it means building expertise, infrastructure, and trust at every touchpoint.

"We use the same processes everywhere," Franco confirmed. "Whether it's Italy, China, or the US, we clean and rebuild heat exchangers following the same multi-step protocol. Our technicians are trained not only on Tranter's equipment but also on competitors' models. That flexibility is why customers trust us with multi-brand fleets."

Regional differences still matter, especially when it comes to regulations, customs, and documentation. Bruna explained how Tranter uses both internal staff and vetted local distributors to manage high-demand seasons or remote requests. "We sometimes send Italian technicians to China for a project because the customer trusts that specific person. That speaks volumes about our service culture."

And while the company prefers to rely on its internal network, it is also cautiously expanding its ecosystem of trusted local service partners. "These relationships are carefully managed," Franco said. "We train and monitor third parties because we know that handing over the service interface is a serious responsibility."

Digital ambitions

One of Tranter's most forward-looking strategies lies in the development of AI-powered predictive and prescriptive maintenance systems. While the current offering focuses on analysis and planning, the company is working on integrating historical and real-time data to anticipate and prevent failures, especially for high-stakes applications like marine or energy generation. Madeleine outlined the vision: "Imagine global clients with many plants and operations having visibility into exactly when each unit needs servicing, not too soon, not too late. That's the goal: a fully optimized maintenance cycle based on real operating conditions." This is not just tech for tech's sake, it's a way to align service with value. "We're looking to integrate this with our ERP and CRM systems," Franco said. "Eventually, we want to dispatch technicians automatically based on real-world triggers." But implementing this globally is complex. "Each country and customer has its own tech infrastructure, documentation standards, and security regulations," Bruna added.

The human factor

Even the most sophisticated digital system is useless without skilled people behind it. And finding those people is one of Tranter's greatest challenges. "Service work isn't for everyone," Franco admitted. "It's demanding, it's global, and it doesn't stick to a 9-to-5 schedule."

To meet these needs, Tranter invests heavily in its people, pairing senior engineers with new recruits, offering in-field training, and creating career paths within the service organization. "We build our team from the ground up," said Franco. "This work can't be learned in a classroom alone. It's experience-based." Tranter is also trying to inspire younger generations by collaborating with universities and engineering programs. "The industry has a reputation for being niche," Madeleine observed, "but we're trying to show that heat exchangers are a vital part of green energy, healthcare, and infrastructure. That makes the work both relevant and rewarding."

Maintenance as a selling point

One surprising takeaway from our visit was how often maintenance influences purchasing decisions. Tranter



➤ From left to right: Tranter's Mirko Radrezza, Bruna Reis Amanai, and Madeleine Sestan Bach, Franco Langone.

is positioning itself not just as a product vendor, but as a lifecycle partner. "More and more customers are asking about service before they even buy the equipment," Mirko shared. "They want to know how we'll support them 5, 10, 15 years down the line." This is especially true in industries with mission-critical operations, where downtime means lost revenue or safety risks. For example, in energy production, even a brief disruption could halt electricity supply to an entire city. "We've had calls at midnight, asking for a technician on-site the next morning," said Mirko. "And we deliver." The trend is clear: service is no longer an afterthought, it's a differentiator. Tranter's ability to provide global consistency, rapid response, and deep technical insight has made it a preferred partner even for customers with competitors' equipment.

A new era of service leadership

Tranter isn't trying to be the biggest player in the market, it's aiming to be the smartest, most reliable partner for global customers who need more than just equipment. "We're not the cheapest," Franco admitted, "but when our customers call, they know we'll be there, anywhere, anytime, with the right solution."

In an industry increasingly driven by data, efficiency, and sustainability, Tranter's focus on service is both prescient and strategic. With growing investments in digital tools, specialized personnel, and AI-enhanced diagnostics, the company is laying the foundation for what modern heat exchanger maintenance should look like.

Their Monza facility isn't just a hub for repairs, it's a symbol of what's possible when customer-centric service meets global capability. For the Heat Exchanger World team, the visit was a rare look into a company that sees maintenance not as an afterthought, but as a pillar of innovation.

As the world transitions to more sustainable and resilient infrastructure, Tranter's message is clear: it's not just about selling heat exchangers. It's about keeping them running efficiently, intelligently, and everywhere. ■

Phencote coating system to optimize durability and energy efficiency of heat exchangers

Shell and tube heat exchangers are vital to industrial plant operations, and their efficiency can be improved through integrated solutions for both new and existing systems. Over the years, various methods have been developed to address corrosion and erosion, enhancing equipment longevity and material selection. Research has also focused on coatings that reduce fouling and improve energy efficiency, with studies conducted alongside industry partners. These patented solutions have been successfully applied in major oil & gas facilities over the past 30 years.

By Lorenzo Comel, Project manager, G.M.A. Srl

Years of research and applications in the field of anti-corrosive coatings for the prevention and elimination of corrosive and erosive phenomena of plant components including condensers and heat exchangers, have led to the development of patented technologies for the coating of tube bundles, including high thickness cladding of tube sheets, epoxy or composite lining of water boxes and internal lining of tubes using epoxy phenolic systems (tube ends or full-length lining).

Corrosion in heat exchangers

Heat exchangers are exposed to a dirty and aggressive environment and are susceptible to fouling and corrosion of tubes. Fouling increases resistance to heat exchange, decreasing the performance of the equipment and triggering corrosive processes under deposit. Fouling also requires expensive shutdowns to allow hydrodynamic or chemical cleaning of tube bundles.

Tubes are made of different materials, ranging from carbon steel to copper alloys, to stainless steel, up to titanium. Problems related to poor design are many, including generalized corrosion, quick pitting, erosive phenomena...

In case of even just one small leakage, the process might be stopped to identify the issue and plug the damaged tube. For example, in the case of a hole of even a single tube of the steam condenser serving the turbine of a power plant using sea water, the presence of chlorides on the steam side requires timely actions that may lead to an unplanned shutdown of the plant.

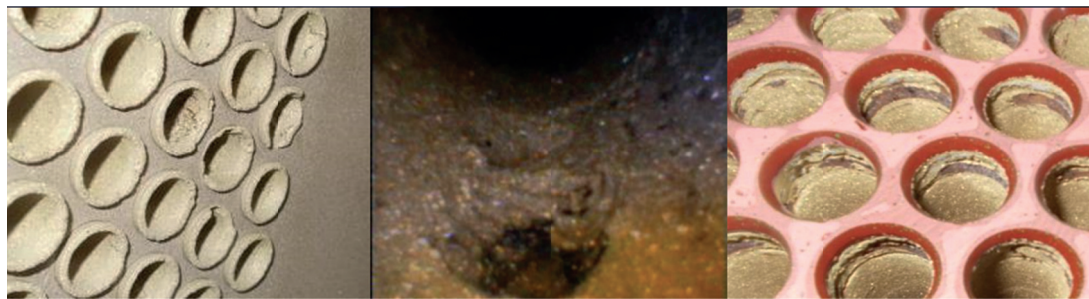


Figure 1. Erosive phenomena related to over velocity in combination with particles in Al-brass/copper tubes.



Figure 2. Overvelocity damage in copper tubes of a chiller condenser. Note how the presence of the fragment of plastic material (coming from an evaporative tower) stuck in the spiral of the pipe was the cause of the problem.

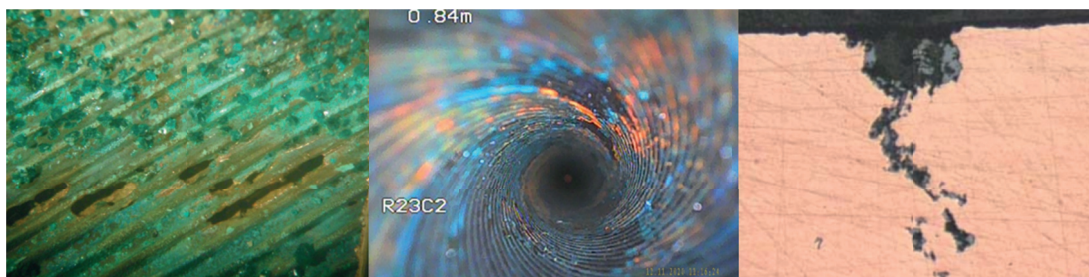


Figure 3. Antnest (formicary) corrosion in copper tubes a chiller unit. Type of damage difficult to identify.



Figure 4. Erosion/corrosion problems in Cu-Ni tubes. Presence of dispersed sand in cooling water.

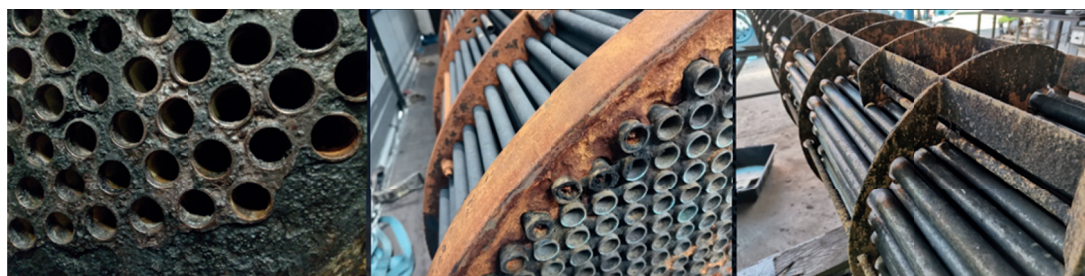


Figure 5. Galvanic corrosion due to interaction between materials with different electronegativity.

Also, if a microscopic hole occurs in a condenser tube serving a refrigeration unit, this causes the loss of large quantities of refrigerant gas and consequently the system will go out of service.

Figures 1-5 show some critical conditions identified over the years during onsite inspections.

Methods

Technologies for the coating of heat exchangers

Over the years, solutions capable of solving problems on the tube side have been developed, preventing damage caused by fouling, corrosion, erosion and cavitation, through the application of epoxy or phenolic resins on the surfaces of the tube plates, inside the tubes and water boxes of heat exchangers or condensers.

Resins can be used both for cooling water circuits (even with steam cleaning) but also in the presence of aggressive media, with maximum operating temperature of 180°C.

A patented semi-automatic system has been developed for full-length painting of tube bundles, that can be used for interventions both in the factory and on client sites.

The internal tubes painting machine is made up of four spraying probes which are inserted inside the tubes; the probes, using a radial nozzle, spray the paint product uniformly over the entire internal surface of the tube using air-mix technique with a thickness of approximately 50 microns per pass.

Studies of efficacy and durability

Durability tests have been carried out over time at accredited laboratories, including immersion tests in various solutions and salt spray for up to 2000 hours.

In particular, long-term immersion tests in fresh water and brackish water according to ISO 2812 were carried out on the various formulations of resins, applied to samples of various base substrates.

Further tests were carried out according to ISO 9227 to verify the resistance of the material to salt spray for up to 2000 hours.

These tests are periodically repeated, to confirm the resistance of the materials following compositional variations (linked, for example, to regulatory requirements on a European basis) or in the case of formulation of new materials before their introduction into the painting procedures.

Laboratory and field tests were also carried out to verify the influence of the application of the coating on the heat exchange ratio of tube bundle, with reference to the application on the full length of the tubes.

Field applications are periodically monitored, allowing for the creation of a history of the

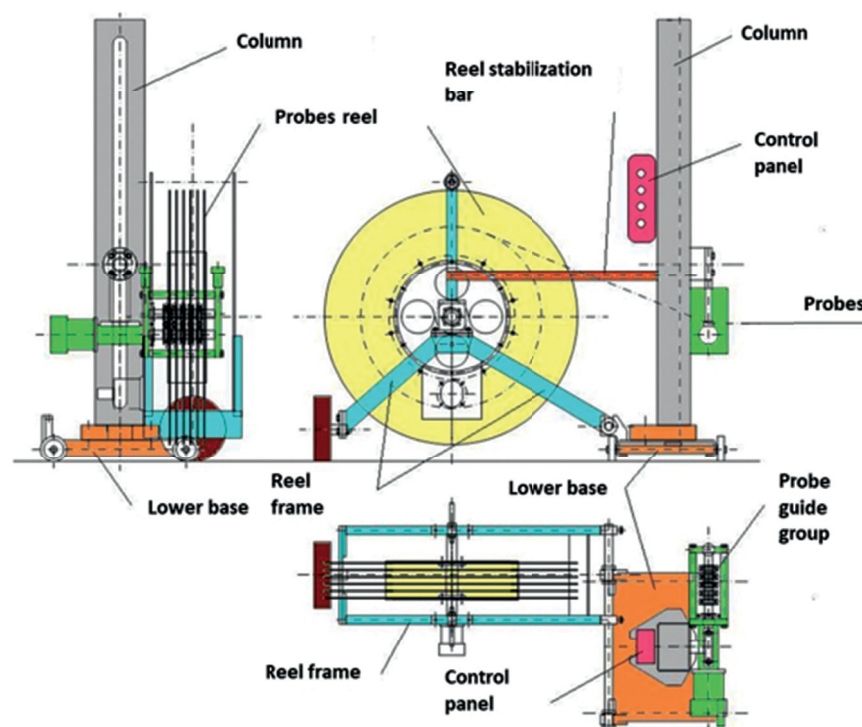


Figure 6. Schematic drawing of the internal tubes painting machine.

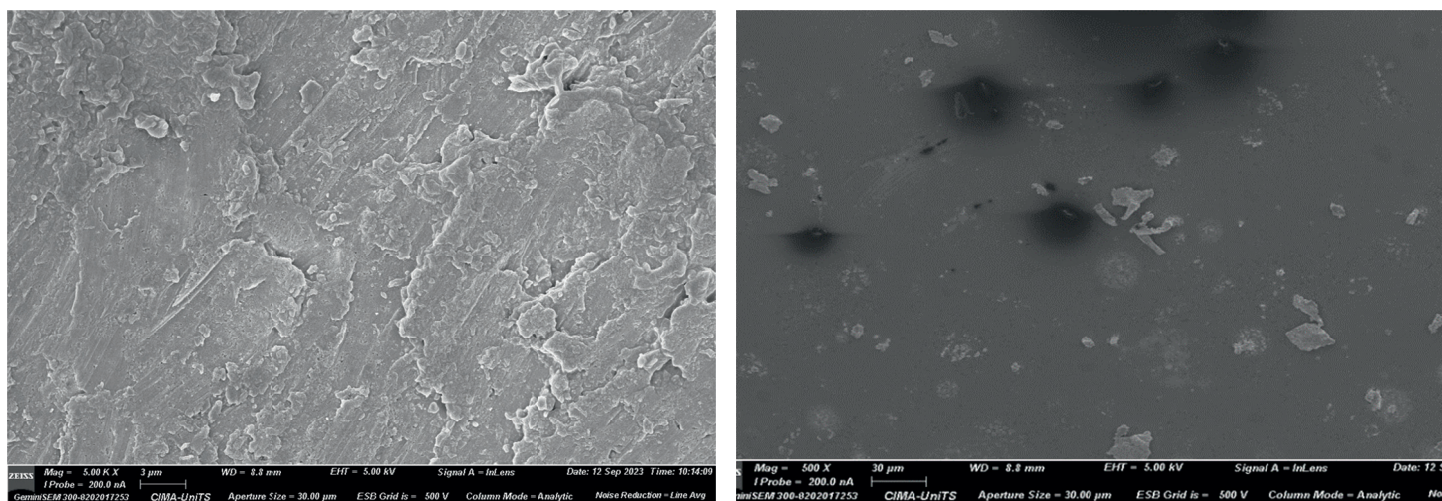


Figure 7. Scanning electron microscope comparison between uncoated Cu-Ni sample and epoxy-coated tube.



Figure 8. Test setup for seawater flow simulation in coated and uncoated tubes.

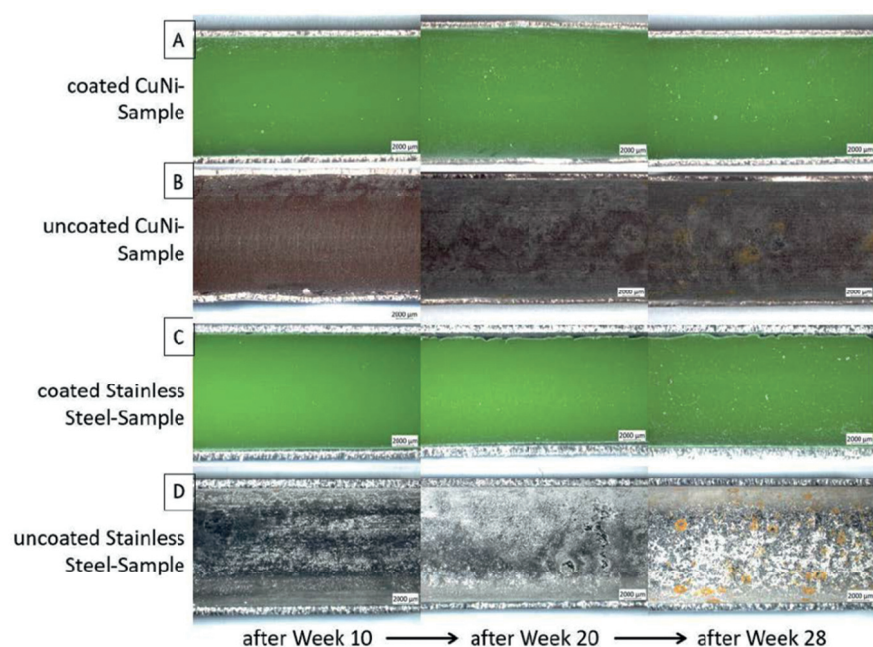


Figure 9. Visual comparison over the time between coated and uncoated tubes.

durability of the coatings under various operating conditions.

Anti-fouling effect

Over the last few years, with the background of energy efficiency, the request from clients to identify solutions to reduce the adhesion of deposits on the internal walls of pipes has increased significantly, to limit or eliminate the need for costly cleaning interventions.

Fouling is a rather complex issue to study as there are no standardized test methodologies to measure the influence it has on the energy performance of a heat exchanger: it is therefore essential to determine the mechanisms of formation of biological deposits to scientifically evaluate the fouling resistance characteristics of coatings.

Experimental studies on Cu-Ni and stainless-steel pipes inserted in a tube bundles model aimed at recreating the fouling conditions present in their industrial plants fed by river water have been carried out in collaboration with an important international partner. G.M.A. has recently completed under a POR FESR 2021-2027 Fund the CLEAN project – Coating Life Extension for Anticorrosive applications, which focuses on the following topics: in-depth analysis of the antifouling and heat exchange properties of the Phencote system for the coating of heat exchangers, optimization of the application system, LCA analysis of the process and creation of the related standards. The research phases have been performed with the collaboration of the Department of Engineering and Architecture of the University of Trieste and MaterialScan S.r.l.

Based on this project, an experimental study has been completed, reproducing the effect of the coating on stainless steel, Cu-Ni and brass pipes with sea water circulation. In parallel, in-depth surface characterization studies of the materials, coated and not, have been carried out.

Results

Laboratory tests

The morphological and instrumental analyses on the surface of the materials are aimed at verifying the

Test duration [weeks]	Total cell counts (1.000/cm ²)								
	A-1	A-3	A-5	C-1	C-3	C-5	D-1	D-3	D-5
10	0	0	0	0	97	54	5.500	5.600	5.900
20	36	36	60	86	220	140	2.400	3.200	2.600
28	14	130	48	280	230	270	3.300	2.900	1.300

Coated CuNi

Coated SS

Uncoated SS

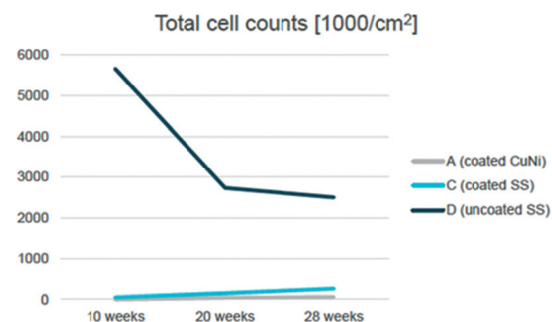


Figure 10. Time evaluation of cells count on coated and uncoated tubes.

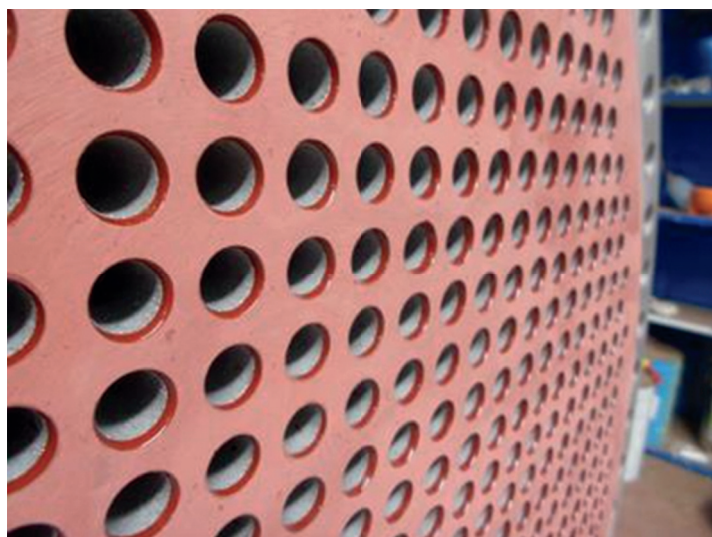


Figure 11. Coating application process.

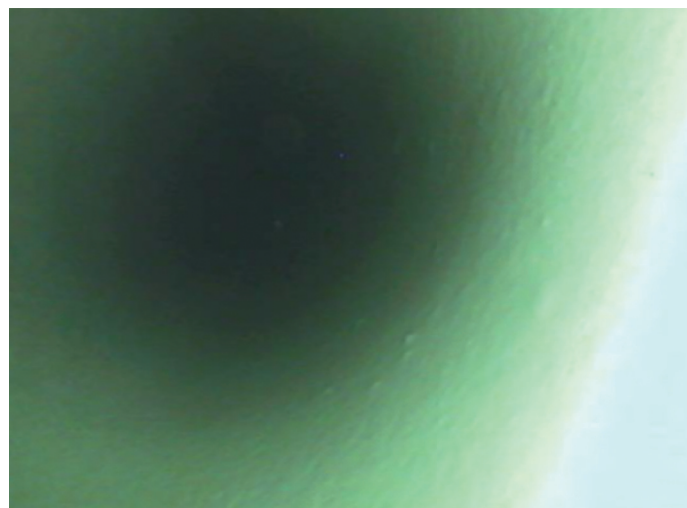
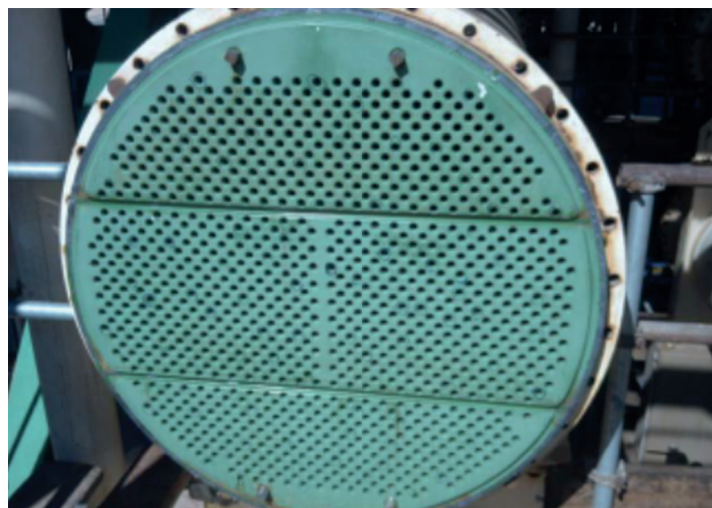


Figure 12. Visual and endoscope inspection of a coated bundle after 4 years of operation.

possible role of the coating in terms of reducing the fouling effect.

The results of the investigation show in general a significant reduction in roughness due to the presence of the coating compared to bare metal, in addition to a clear decrease in wettability, in particular compared to stainless steel and Al-brass.

Visualization under the scanning electronic microscope allows to appreciate the greater uniformity of the surfaces in the presence of the coating.

The conditioning tests in river and sea water in the long term (up to 28 weeks) show a significant beneficial effect of the coating in the adhesion of carbonate deposits.

Regarding the formation of biological film, the cell count on stainless steel pipes shows values up to 60 times higher in uncoated pipes compared to coated ones.

Case study: Heat exchangers in a refinery

In 2013, 8 newly built tube bundles were coated, destined for installation at an Oil &



Figure 13. Uncoated tubes bundle after 4 years in the same operating conditions.

Gas site in Libya. In previous years, the tube bundles, made of carbon steel and not coated, already showed significant problems in the short-medium term, both of a corrosive nature and of fouling, significantly affecting the efficiency of the plant. In synergy with the client, a coating cycle is implemented, which involves the application of an epoxy coating on the full length inside the tubes, completed by a high thickness coating (3 mm) on the tube sheets, designed to protect the tube/plate interface.

Four years after commissioning, the exchangers are opened and subjected to a visual and endoscopic inspection. A comparative assessment is also made between the coated tube bundles and bundles of similar construction and same service, but without coating. The report, issued by the client, highlights the great difference in the presence of corrosion products and deposits in favor of the coated bundles, with the coating appearing perfectly preserved.

Conclusions

The use of epoxy and epoxy-phenolic coating systems on heat exchangers is a consolidated solution that allows to increase the performance and the life of the components, thanks to the anti-corrosion effect and the possibility of optimizing the metallurgical choices and avoiding any operational problems or design errors. Less known, but of primary interest in terms of energy efficiency and reduction of maintenance interventions, is the beneficial effect of the coating on the adhesion of deposits to the walls of the tubes, whether they are organic (biofouling) or inorganic (typically carbonates).

Experimental studies have been carried out to measure this effect, confirmed by the experience in the field in the coating of tube bundles for the power and oil & gas sectors.

Furthermore, a study, co-financed by the POR FESR 2021-2027 Fund has been completed, giving a deep analysis of the dynamics underlying the antifouling and energy efficiency effect related to the application of coating systems on tube bundles. ■

About the author



Lorenzo Comel holds a master's degree in Materials Engineering. After a short experience in Biomedical field, he joined G.M.A in 2010, working in R&D department and getting qualifications as a coating inspector and NDT technician. Lorenzo currently works as a Project Manager, organizing anticorrosion coating activities in oil & gas, chemical and power plants.

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Alabama Heat Exchangers, Inc. is an Engineered-to-Order fabrication and repair company in business to meet the highly specialized process equipment needs of our clients. We've been serving various industries as a small business with an unwavering passion for quality and excellence since 1986. We've earned a reputation from our customers as a "go-to" source for pressure vessels, heat exchangers, specialty welding, machining, and industry knowledge.

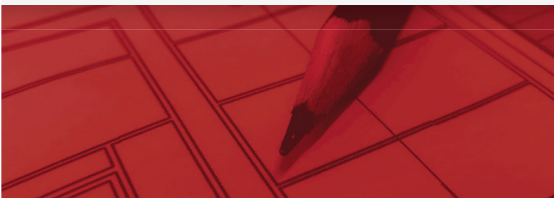
Core Capabilities

- Shell & Tube Heat Exchangers
- Plate & Frame Heat Exchangers
- Air-fin Heat Exchangers
- ASME Pressure Vessels
- Heat Exchanger and Tank Components
- Fabricated Piping Assemblies
- Heat Exchanger re-tubing & repair
- Process equipment repairs in house & onsite

Certifications & Specifications

- ASME – "U" designation
- NBIC – "R" certification (repairs)
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Bio-based cooling tower water treatment:

A sustainable alternative – Part 3

In this 3-part series of articles, ODYSSEE Environnement presents feedback on using a bio-sourced product for anti-scaling treatment in cooling tower water, compared to conventional products.

By Amaury Buvignier, Frédéric Bertrand, Fabrice Chaussec, Xavier Labeille at ODYSSEE Environnement and Logan MANARANCHE at ODYSSEE USA INC.

I. Introduction

In the previous 2 articles, we highlighted the importance of identifying tracers correlated with the antiscalant effectiveness of a plant extract, addressing the major challenge inherent in using a natural raw material of agricultural origin, namely, the variability in the quality of the supply. We presented the optimization approach of the industrial extraction process, developed by ODYSSEE Environnement, aimed at reducing the environmental impact of ODYLIFE as well as the regulatory limitations regarding the use of bio-sourced chemicals. In this article, we will discuss the experience gained from transitioning from a polyacrylate-based antiscalant treatment to ODYLIFE in a Cooling Tower (CT).

II. Experience feedbacks

II.1 Site selected

ODYLIFE having been validated in the R&D laboratory, the final step is to test it at a 1:1 scale by applying it to real operating cooling towers.

To do this, we began by substituting ODYLIFE for its "operational" equivalents in our formulations

to validate the compatibility of the solutions. The substitution led to the presence of a very low proportion of fine particles in solution but did not alter the stability of the different formulations containing ODYLIFE, nor their aspect.

Several sites in France with water cooling applications and different water qualities have been chosen to deploy ODYLIFE industrially. The selected installations all have circuits that can be assimilated to the schematic diagram represented in Figure 1. On each of the tested circuits, the same observations were made, leading to the same conditions. Therefore, this article will focus on one site only, site G.

The conditioning strategies follow the guidelines of the regulatory French framework ICPE 2921, which emphasize the need to maintain surface cleanliness, performance, and equipment integrity while controlling microbial activity in the fluid.

As monitoring indicators, we use the Ryznar Index (I.Rz) and the Saturation Index (SI). Although highly debated, the I.Rz is often indispensable in the profession as an indicator, and its association with SI provides a very good characterization of water's scaling potential.

The temperature used for calculating the two indices is the most important measurement taken from the water network. Generally, it is located at the top of the evaporator, where a high skin temperature induces parameters particularly favorable to scaling (low I.Rz).

Water analyses were conducted every 2 weeks, from 13 weeks before the switch from the conventional product to ODYLIFE until 11

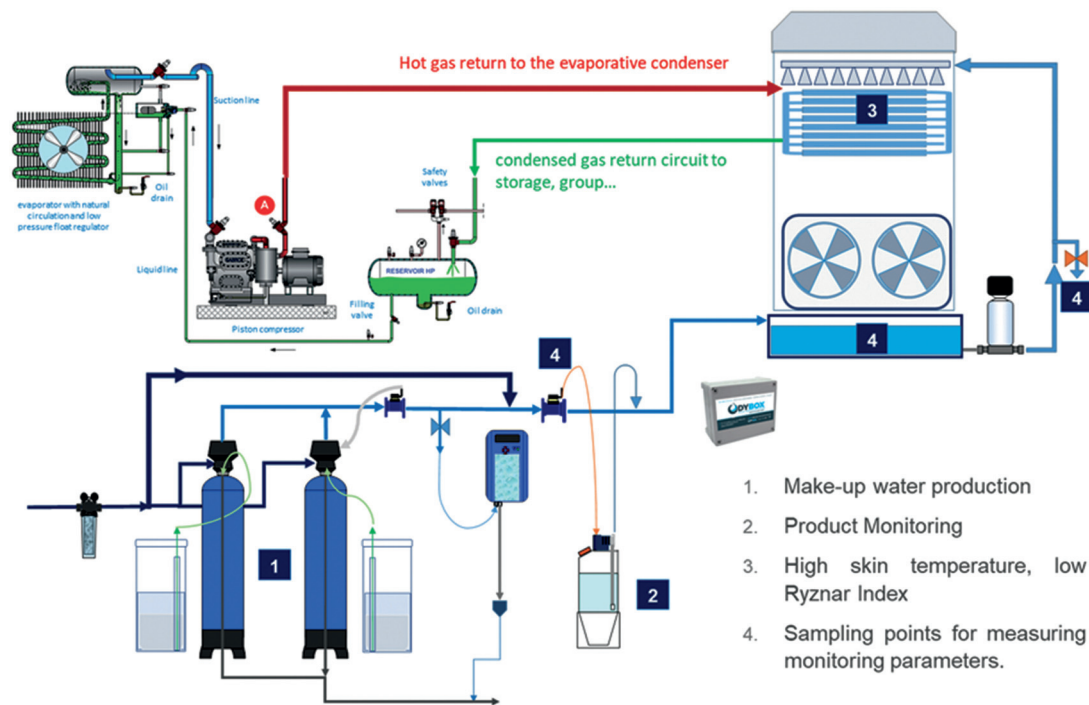


Figure 1: Schematic diagram representing the installations tested at site G.

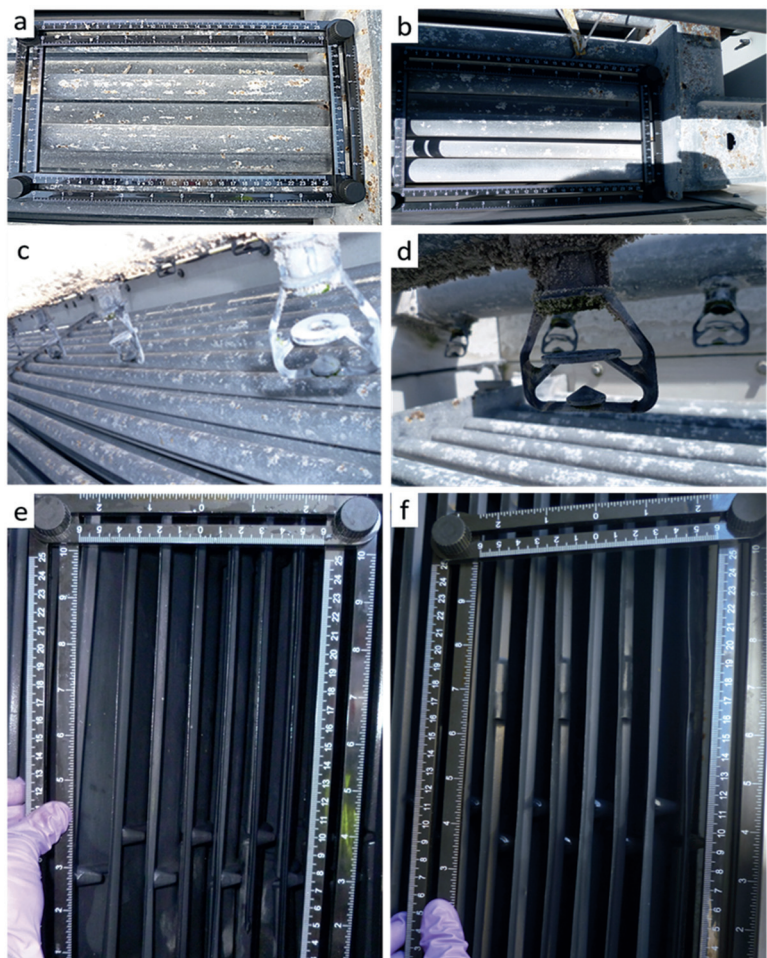


Figure 2: Surface condition evolution between the technical shutdown in November 2019 (left) and June 2020 (right) at site G. a and b: view of the upper tubes (point 3 on the schema in Figure 9); c and d: view of the spray ramps and a set of nozzles (point 3 on the schema in Figure 1); e and f: view of the packing's trickle lamellas.

weeks after the substitution. Surface conditions were also regularly monitored. Analytical monitoring was reinforced and supplemented by the surveillance of key parameters (measurement of additional parameters such as BOD₅, COD, etc.) continuously and remotely using the dedicated ODYBOX-ODYSECURE solution.

Table 1 presents the characteristics of the installation at site G.

Table 2 presents the water analysis of the makeup water and the circuit with the conventional product for site G.

The calculations of I.Rz and SI in the TAR depend on the fluid temperature, which was considered to be

60°C (140°F), the maximum value recorded in the network.

II.2 Surface condition before and after substitution

On this site, the towers are cleaned twice a year, this biannual scheduling ensures detailed monitoring of the evolution of surface conditions. The switch from the conventional product to ODYLIFE took place on March 16th, 2020. Technical shutdowns occurred in early December (4 months before the change of conditioning product) and early June (3 months after). The evolution of surface conditions during the technical shutdowns at site G is presented in Figure 2.

Table 1: characteristics of the installations at site G.

Tower Power	Network Volume	Half-Life Time (T ½)	Materials
800 kW	2.5 m ³	8 to 9 hours	Galvanized steel

Table 2: Water analysis of the makeup water and the tower during normal operation with the conventional product.

	pH	TH (ppm)	M-Alk (ppm)	Conductivity (µS/cm)	Chlorides (mg/L)	Iron (mg/L)	Copper (mg/L)	N	I.Rz	IS
Make-up	7.8	31	204	608	32,8	< 0,1	< 0,1	-	-	-
Cooling Tower	8.7	57	380	1098	63,9	< 0,1	< 0,1	~2	~5	~50

(Absence of Suspended Solids)

Table 3: Water quality for the makeup water and the cooling tower at site G. The highlighted delineation corresponds to the switch from the conventional product to ODYLIFE.

Date		12/17/19	01/13/20	02/25/20	04/09/20	04/29/20	05/18/20	06/02/20
Product		Conventional			ODYLIFE			
Temperature fluid (°C)		60	60	60	60	60	60	60
pH	Make-Up	7.7	7.5	7.7	8.3	7.8	7.8	7.6
	CT	8.7	8.4	8.6	8.8	8.8	8.7	8.7
TH (ppm)	Make-Up	32	34	42	37	29	23	21
	CT	69	50	59	71	64	46	40
	N	2.2	1.5	1.4	1.9	2.2	2.0	1.9
M-Alk (ppm)	Make-Up	185	205	201	209	212	208	209
	CT	404	286	321	420	415	413	402
	N	2.2	1.4	1.6	2.0	2.0	2.0	1.9
Cl ⁻ (mg/L)	Make-Up	31.3	32.5	33.3	33.2	33.1	33.0	33.0
	CT	72.5	45.7	53.8	75.1	69.1	67.4	63.4
	N	2.3	1.4	1.6	2.3	2.1	2.0	1.9
SO ₄ ²⁻ (mg/L)	Make-Up	36.0	37.0	36	38	40	40	41
	CT	83.0	52.0	59	78	80	80	78
	N	2.3	1.4	1.6	2.1	2.0	2.0	1.9
Conductivity (µS/cm)	Make-Up	559	587	591	651	631	612	626
	CT	1189	806	925	1203	1223	1176	1167
	N	2,1	1,4	1,6	1,9	1,9	1,9	1,9
NO ₃ (mg/L)	Make-Up	15,0	13,6	12,4	13,0	13,8	13,6	14,0
	CT	34,8	19,2	20,1	27,6	33,4	27,8	27,3
	N	2,3	1,4	1,6	2,1	2,4	2,0	2,0
Na ⁺ (mg/L)	Make-Up	160	120	120	130	140	136	140
	CT	250	160	190	260	270	278	270
	N	1.6	1.3	1.6	2.0	1.9	2.0	1.9
DOB ₅ (mg O ₂ /L)	Make-Up	< 0.5	<0.5	1.7	0.6	<0.5	0.7	0.9
	CT	0.9	0.5	1.4	0.5	0.7	1.2	1.3
COD (mg O ₂ /L)	Make-Up	11	<10	<10	<10	<10	10	<10
	CT	44	22	20	19	19	20	17
I.Rz	CT	5.0	5.8	5.4	4.8	4.9	5.3	5.5
SI	CT	62.6	17.2	34.9	81.5	70.9	44.8	35.1

We observe in Figure 2a (Nov. 2019) and b (June 2020) the maintenance of surface conditions, with no deposition formation observed on the upper tubes. In Figure 2c (Nov. 2019) and d (June 2020), surface conditions are maintained with no deposition formation on the nozzles (historical deposits, in place, non-evolving). Figure 2e (Nov. 2019) and f (June 2020) show very clean surfaces with no deposition formation and absence of salts between the trickle lamellas of the packing.

In conclusion, three months after switching from the conventional product to ODYLIFE, there is no

significant modification in surface conditions. The system's integrity is maintained.

II.3 Monitoring

Water quality at the installation was monitored throughout the in-situ test. In addition to standard parameters, concentrations of sulfate, nitrate, BOD₅, and COD were measured. Table 3 shows the evolution of water quality based on the analysis date.

Figure 3 shows the evolution a) of the concentration factor (TH, TAC, Chlorides, Sulfates), b) of the I.Rz

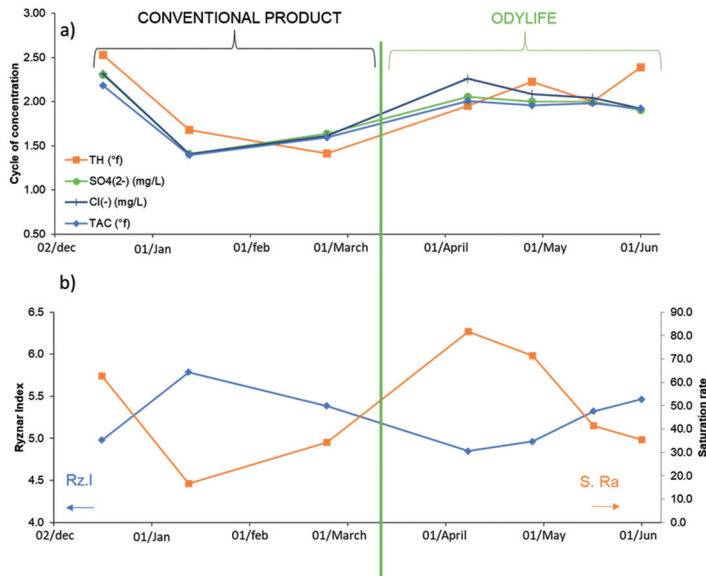


Figure 3: Evolution of a) concentration factor, b) I.Rz and SI, over time for site G. The central vertical line corresponds to the switch from the conventional product to ODYLIFE.


and SI, over time for site G. The central vertical line corresponds to the switch from the conventional product to ODYLIFE (March 16th 2020). We observe from Table 3 constant values for the makeup water. Between the first and second analysis, the client decreased the concentration in the tower, which explains the decrease in concentration factors (N) (Figure 3a) between early December and early January. During the analyses with the conventional product, the concentration factors were around 1.5 to 2.0 when switching to ODYLIFE. Despite the increase in system concentration between February 25th and April 9th, the system integrity was preserved with ODYLIFE conditioning. Additionally, in Figure 3b, we see an I.Rz oscillating between 4.8 and 5.8 for the TAR. The SI, on the other hand, oscillates between 20 and 80. The tests show that a simple substitution of the petrosourced antiscalant with ODYLIFE, without changing the operating conditions of the network, remains transparent to operation. The next step for this site will be to increase the concentration rate to reduce the I.Rz to values close to 4.2.

III. Conclusion


During the deployment of ODYLIFE on industrial sites, the integrity of the networks was maintained despite an increase in the concentration factor. Surface conditions are also preserved, even in the most vulnerable areas. One difference resulting from the substitution of conventional products by ODYLIFE is the slight increase in the proportion of readily biodegradable DBO₅ in the effluent water.

The deployment of ODYLIFE is part of a concept that respects industrial ecology: offering industrialists a technical solution that is equivalent but in line with today's environmental challenges. Through the ODYLIFE program, Industrial Water Companies continue to reflect globally on the field of water conditioning and advances in the creation of industrial sectors in green chemistry.

These sectors are founded and organized according to the principles of the circular economy, and it is this approach that has enabled the networking of French actors, ranging from farmers to users of the commercial product. The green revolution is now underway, integrating the knowledge of sectors engaged in this evolution, tools from the digital world, eco-design, biosafety: it is the approach of hydroethics, allowing us to progress and concretely envision the objectives of ecological transition in the industry. The path we are forging is taking shape with ODYLIFE. ■



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Custom skived fin HEX: High-efficiency thermal solutions you've never heard of



▲ Welder at work on a skived aluminium profile during assembly. Image courtesy of SAG.

The world is rapidly shifting due to climate, political, and economic crises, impacting all industries. New data highlights the need for more efficient operations in process industries. For example, the U.S. Department of Energy reports that 20–50% of industrial energy is lost as waste heat – yet heat recovery solutions are often overlooked. One such solution is the skived fin (SKF) aluminium heat exchanger, which offers outstanding performance but remains little known. Let's explore its technical features and uses.

*Maxime Blondin, Marketing & Communication Officer,
SAG Industries*

Unique technology with unique attributes

Designed and made by only a few companies in the world, skived fin heat exchangers provide top notch performance thanks to the material used as well as their fabrication process.

SKF exchangers are made by skiving fins directly into an aluminium frame profile, preventing most material loss as opposed to machining and avoiding any soldering which could decrease the heat transfer coefficient and create fragility areas. This fabrication method offers the following benefits:

- Excellent pressure resistance, above 60 bars, thanks to a multi-channel geometric profile
- Excellent vibration and shock resistance
- Very high exterior surface/interior profiled air section compared with classic finned tubes

The aluminium used also plays a big part in their high efficiency, offering high thermal conductivity as well as the following advantages:

- Lightness
- Flexibility (easy to shape by folding or bending)
- Increased corrosion resistance with various coatings

Altogether, these strengths also offer a light, compact and durable product, thanks to its malleability and heat transfer coefficient, which makes it easy to integrate into many machines.

Versatility meets efficiency

Despite remaining relatively unknown, the skived fin technology is already playing a critical role in multiple industries where heat must be managed under pressure, vibration, and tight space constraints.

In air compressors, particularly oil-free or high-performance units, these exchangers are used to efficiently dissipate heat from the compression process. The skived fin structure allows for a high surface area within a compact volume.

In industrial refrigeration, HVAC, and heat pump systems, where rapid, efficient, and reliable heat extraction is essential, skived fin exchangers enhance the system's COP (Coefficient of Performance), directly reducing energy consumption and ensuring stable temperatures under varying loads.



✦ *Tailor-made skived fin heat exchanger showcasing fin geometry and tube inlets. Image courtesy of SAG.*

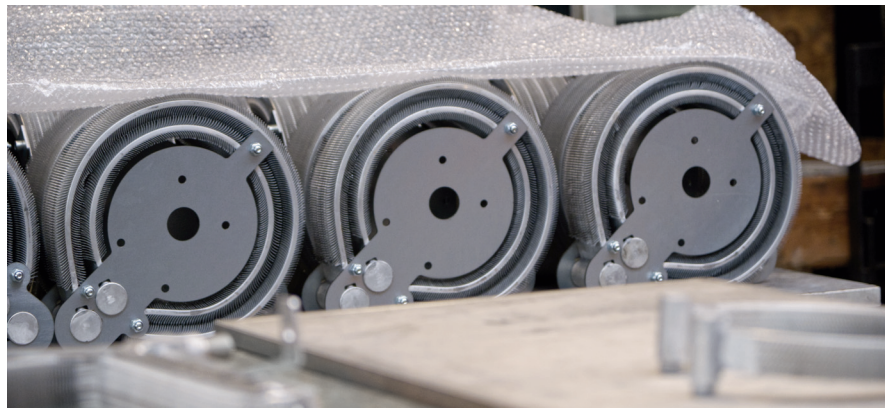
In heavy-duty applications, such as in off-road trucks, the railway industry, construction equipment, and specialized vehicles from manufacturers like MAN, these devices are often integrated into charge air cooling (CAC), oil cooling systems or intercoolers to handle extreme thermal loads, ensuring optimal engine performance and extended service life. The high vibration resistance of these exchangers is also a key advantage for that sector.

Taking advantage of aluminium's shaping capabilities and high-precision manufacturing, customized skived fin exchangers meet the exact requirements of various thermal management needs. Whether in stationary industrial units or mobile heavy machinery, they provide a reliable and durable solution for maximizing heat transfer and minimizing operational risk.

Tailored to your needs

You may have noticed the repeated emphasis on "custom" skived fin exchangers throughout this article, and for good reason. While OEM solutions are available, they often come with limitations. In contrast, custom-designed exchangers are tailored to your specific process requirements, unlocking the full performance potential of this unique technology.

Whether used in industrial machinery, military vehicles, or commercial and medical refrigeration, custom skived fin exchangers consistently deliver superior results. Now that you're familiar with their advantages, you may agree that it's time to consider a bespoke solution for your application. ■



✦ *A set of finished, custom skived fin heat exchangers ready for delivery. Image courtesy of SAG.*

About the author

With a degree in marketing and a background in science, Maxime joined SAG to highlight the company's expertise in customized heat exchangers through modern, technical B2B marketing and communication.



About SAG Industries:

SAG Industries is a Belgian designer and manufacturer of custom heat exchangers and related process equipment. The family-owned group is structured around four business units: industry, pharma, air coolers, and special equipment. SAG serves a wide range of sectors including pharmaceuticals, nuclear, oil & gas, chemicals, renewable energy, defense, and more.



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Conference and Exhibition Information

DATES AND VENUE

The two-day Heat Exchanger World Americas Conference & Expo 2025 is being held on Wednesday, October 15th, and Thursday, October 16th, 2025, at the NRG Center in Houston, Texas. The venue is fully accessible.



The NRG Center

NRG Park, 1 Fannin St, Houston, TX 77054, United States
Tel. 832-667-1400 | <https://www.nrgpark.com/>

HEAT EXCHANGER WORLD CONFERENCE 2025

The Heat Exchanger World Americas Conference will be held in conference rooms located in the back of the exhibition floor. Conference delegates are required to collect their badges from the main registration counter and proceed to the conference sessions.



Conference Hours

WEDNESDAY, **October 15th** › 9:45 a.m. – 4:00 p.m.

THURSDAY, **October 16th** › 9:45 a.m. – 4:00 p.m.

SOCIAL PROGRAMS

To make the Heat Exchanger World Expo & Conference 2025 a complete experience, we will also host a special evening networking event.



Post-Event Reception with Local Live Entertainment

WEDNESDAY, **October 15th** › 4:30 p.m. – 6:30 p.m.

All conference delegates and visitors are invited to our post-event reception in the exhibition area. Enjoy live music from The Royal Dukes Band, drinks, and a selection of food in a relaxed setting designed to encourage networking and socializing among industry professionals.

CONFERENCE AND EXHIBITION HOURS

The Conference and Exhibition Registration Counter is located at the main entrance of the Expo Hall. All registrations and collections from Exhibitor Passes, Conference Delegate Badges, and Information will be processed from this counter.



Registration Counter Hours

TUESDAY, **October 14th** › 2:00 p.m. – 5:00 p.m.

WEDNESDAY, **October 15th** › 8:30 a.m. – 4:00 p.m.

THURSDAY, **October 16th** › 8:30 a.m. – 4:00 p.m.

HEAT EXCHANGER WORLD EXPO 2025

More than 70 exhibitors are set to welcome you to their displays, where experienced technical and sales representatives will be on-hand to answer any questions, provide information, and showcase their company, products, and services.



Exhibition Hours

WEDNESDAY, **October 15th** › 9:00 a.m. – 4:00 p.m.

THURSDAY, **October 16th** › 9:00 a.m. – 4:00 p.m.



EXPOFLOOR



CONFERENCE

Welcome To The Heat Exchanger World Americas Conference & Expo 2025!



MESSAGE FROM THE CHAIRMAN

It is my great pleasure and honor, as the Chairman of the Heat Exchanger World Americas Conference and Expo 2025, to WELCOME YOU ALL with enthusiasm and excitement.

The Gulf Coast—Texas and Louisiana—are recognized as major players in the U.S. energy sector, with Houston serving as the energy capital of the world. Houston's vibrant economy and surrounding areas host a high concentration of major EPC companies, heat exchanger fabricators supporting leading Oil & Gas companies, refineries, petrochemical and chemical plants, midstream and pipeline operations, LNG export terminals, offshore production, and more.

This is the only conference devoted specifically to heat exchangers and related cleaning and maintenance industries. It provides a unique platform for individuals to connect, share knowledge and expertise, and learn about new and emerging technologies and products.

The conference includes expert panels and sessions with presentations, discussions, and workshops that highlight the most relevant topics in the heat exchanger industry. The Expo will showcase sponsors' and manufacturers' products, along with service providers, suppliers of raw materials, and tooling. You will also have the opportunity to enjoy interactive discussions with experts as you walk the floor.

I assure you that attending this conference will provide a unique opportunity to learn from exhibits featuring specialized heat exchanger technologies, troubleshoot equipment, and explore ways to increase operating efficiency. I look forward to meeting all of you at the conference over the next two days.

Sincerely,

Jack Piparia,
Engineering Consultant
retired Technip Energies



MESSAGE FROM THE VICE CHAIRMAN

I am looking forward to being the Vice Chairman of the Heat Exchanger World Americas Conference & Expo 2025. This wonderful event provides endless opportunities to allow the heat transfer community to come together, partake in new ways of thinking through extensive knowledge transfer, learning of the latest innovations in heat transfer equipment, cost-saving initiatives, practical solutions, and technical demonstrations. This event will serve as a stage for networking opportunities with some of the most talented individuals in this diverse industry.

Throughout my career, I have gained a wealth of knowledge and expertise in sealing, bolting, training, and technical support. My position at TEADIT in Pasadena, TX has allowed me to oversee its Commercial Team and Application Engineers here in North America. As one of the nation's leading SMEs in Bolted Flange Joints subject matter, I have authored and maintained standards for the assembly of bolted-flanged connections and valve packing installations. During my career, I have had the opportunity to assist end users and OEMs in providing the necessary training to understand bolted flange joints, sealings and gaskets, which is necessary for understanding their connection to heat transfer equipment. Having the opportunity to educate and train is vital to ensuring your heat transfer equipment meets maximum performance; this way, users extend the life expectancy of their assets, improving processes and mitigating common challenges.

As we anticipate meeting one another this October, we invite you to join us at the NRG Center, with your ideas and topics focused on heat exchanger costs, design, performance, maintenance and efficiency in the oil and gas industry. I am confident that there is something for every professional from all levels of expertise at the Heat Exchanger World Americas Conference and Expo 2025. I am looking forward to seeing you all there!

Mark Ruffin,
Vice President of Sales
Teadit North America



October 15th & 16th 2025

NRG Center
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October 15th | Day 1

WEDNESDAY

ROOM 1

9:00 AM	Exhibition floor opens
9:45 AM	Welcome by Conference Chairman Jack Piparia
10:00 AM – 10:30 AM	Keynote 1: Title pending, <i>Naomi Jabbari</i> , S&B Engineers & Constructors
10:30 AM – 11:00 AM	Keynote 2: Title pending, <i>Bill Ashenart</i> , Engineering consultant
11:00 AM – 11:30 AM	COFFEE AND NETWORKING ON THE EXHIBITION FLOOR

ROOM 1

11:30 PM – 1:00 PM SESSION:
Heat exchanger design

- Performance enhancement in heat exchanger with various type of tube inserts, *Jack Piparia*, **Engineering consultant**, **retired Technip Energies**
- Changes in ASME Section VIII, div 1 requirements in 2025 edition for HX design, *Ramesh Tiwari*, **CoDesign Engineering**
- The science of vapor infusion nanobubbles and their application in heat exchanger foul elimination, *Michael Radicone*, **HTRI**

ROOM 2

11:30 PM – 1:00 PM SESSION:
Corrosion & materials

- Decoding corrosion: Understanding and controlling iron oxides in closed-loop systems, *Logan Manaranche*, **ODYSSEE USA INC.**
- Alloy 59® and its applications in the oil & gas industry, *Cristian Degano*, **A.D. Tubi Inossidabili SpA**, *Dr. Bill MacDonald*, **VDM Metals USA**
- Introduction of 316A: A unique cost effective grade to replace 316L, *Audrey Allion*, **Aperam Stainless France**

1:00 PM – 2:30 PM **LUNCH BREAK AND NETWORKING ON THE EXHIBITION FLOOR**

ROOM 1

2:30 PM – 4:00 PM SESSION:
Sustainability & emerging technology

- Replacement of old MWK bayonet boiler with latest generation vertical floating head boiler in ammonia plants, *Uma Sankar Khan*, **KBR**
- Feedback on using a bio-sourced product for anti-scaling treatment in cooling tower water, compared to conventional products, *Logan Manaranche*, **ODYSSEE USA INC.**
- Advancements in direct steam injection technology for industrial process heating, *Alex Kolb*, **Pick Heaters**

ROOM 2

2:30 PM – 4:00 PM SESSION:
Fabrication & testing

- How tube-to-tube sheet welds impact wall reduction, *Brandon Fultz*, **Elliott Tool Technologies**
- Supplier quality surveillance process for shell and tube heat exchangers, *David Gonzalez*, **Aramco Americas**
- Understanding reaction forces in hinged and gimbal expansion joints, *Ibere Souza*, **Teadit**



October 16th | Day 2

THURSDAY

ROOM 1

9:00 AM Exhibition floor opens

9:30 AM – 10:00 AM Keynote 3: Vice Chair's Welcome, *Mark Ruffin, Teadit*

10:00 AM – 11:00 AM Panel discussion:
Heat exchanger design & specification: TEMA, API 660 & 661, PIP, ASME, ISO, PCC-1, and end user specs

Panel moderator: *Dinesh Bakshi, Brask*

Panelists: *Mark Ruffin, Teadit; Sangeeta Bakshi, TEMA; TBA; TBA*

11:00 AM - 11:30 AM

COFFEE AND NETWORKING ON THE EXHIBITION FLOOR

ROOM 1

11:30 PM – 1:00 PM SESSION:

Heat exchanger design

- Enabling high-aspect ratios, thin walls, and production scalability for critical microchannel heat exchangers via pulsed electrochemical machining (PECM), *Daniel Herrington, Voxel Innovations*
- Heat recovery with twisted tube® technology upgrade of feed/effluent heat exchanger at Saraland, *Prashant Jadhav, Metalforms Heat Transfer*
- Case studies in applying dual enhanced finned tubes to improve shell and tube heat exchanger efficiency, *Craig Thomas, Neotiss*
- Hybrid plate heat exchangers transform sugar evaporation, *Osama Olabi, VAU Thermotech*

ROOM 2

11:30 PM – 1:00 PM SESSION:

Design & leak prevention

- Advancing tube plugging: Digital solution to improve reliability, conformance, and traceability, *Danko Kobziar, Curtiss-Wright – EST Group*
- Modernizing bolted joint performance in new and aging heat exchanger systems, *Noah Detjens, AW Chesterton*
- Investigation of steam leak due to material failure of primary reformer HP steam coil manifold, *Muhammad, SABIC*
- Sealing performance of various pass bar rib gasket styles, *Robert Taylor, 3S Superior Sealing Services LLC*

1:30 PM – 3:00 PM

LUNCH BREAK AND NETWORKING ON THE EXHIBITION FLOOR

ROOM 1

3:00 PM – 4:00 PM PANEL DISCUSSION:

Best heat transfer practices: Managing aging plants & equipment upgrades

Panel moderator: *Javier Martinez, Teadit*

Panelists: *Dale Norman, Teadit; TBA; TBA; TBA*

ROOM 2

2:30 PM – 4:00 PM SESSION:

Maintenance & cleaning

- Addressing the limitations of HEX maintenance with safe and cost-effective organic descaling solutions, *Ken Marko, Wheelhouse Industries LLC*
- Continuous online cleaning of heat exchangers, condensers and evaporators, *John Panarese, Taprogge*

CONTACT US

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Ms. Iryna Mukha Conference coordinator
i.mukha@kci-world.com | +31-651-492-699

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Get more out of your heat exchangers with heat transfer enhancement: Part 5 – Case studies in applying dual enhanced tubes for boiling

In this series of articles we will look at the idea of heat transfer enhancement. The benefits of enhancement are that your heat exchangers will provide the same performance at a lower cost or provide better performance at the same or smaller overall size and footprint.

About the authors

Himanshu Joshi retired from Shell in 2021 after 34 combined years with ExxonMobil and Shell, during which he specialized in heat exchangers and fouling. He was part of a team that was granted a patent related to fouling deposit analysis at ExxonMobil, and led applied fouling R&D projects at both companies. He has made several presentations about the field aspects of fouling and fouling mitigation, and deployed many mitigation technologies in the field. He can be reached by email at alph.hmj@gmail.com.



Lou Curcio has over 30 years of experience in design, troubleshooting and repair of all types of heat exchangers. Leader of technology development projects and advisor for ExxonMobil's global manufacturing teams. Co-inventor of two U.S. patents and co-author of papers on enhanced heat transfer and fouling of heat exchange.



Craig Thomas is currently the Director of Technical Sales for NEOTISS, Inc., a manufacturer of high-performance heat transfer tubing with operations in USA, France, China, and India. Craig has over 33 years of experience in applications engineering related to shell and tube heat exchangers. He is a member of the National Association of Corrosion Engineers, The Materials Technology Institute, Heat Transfer Research Inc., and The American Society of Heating, Refrigerating and Air-Conditioning Engineers. Craig has a degree in Engineering Science from Loyola University Maryland. He currently resides in Nashville TN.



By Himanshu Joshi, Heat Exchanger Specialist,
Lou Curcio, Heat Transfer Advisor, and Craig Thomas,
Director of Technical Sales, NEOTISS Inc.

The use of finned tubing in the process industry has been a common practice for over 50 years. The criteria for when to consider this has been covered by Part 4 in this series. Dual-enhanced tubes, with both OD and ID fins, have been in common use in the AHR (air conditioning, heating, and refrigeration) market, especially refrigerant condensers and evaporators. However, it is only in the last ten years that dual enhanced tubes have entered the hydrocarbon and chemical processing industries. This article will explore three examples of how dual enhanced tubes are used in the Refining, Petrochemical and Chemical Process Industry to improve heat transfer efficiency and reduce capital expenditure. Refer to Parts 2-4 of this series of articles for background on controlling resistance, finned tubes, and dual-enhanced tubes.

Case 1: Petrochemical plant fractionator feed chilling

A typical petrochemical manufacturing facility is comprised of a series of fractionators tasked with separating hydrocarbon mixtures according to their boiling points. Prior to entering a fractionator, process feed streams are commonly cooled with heat exchangers, maximizing efficiency in downstream separation. In this context, engineers were challenged to debottleneck an existing plant. The solution demanded innovative retrofitting of previously installed heat exchangers, making use of enhanced tube designs to extract greater performance from the existing equipment footprint, and thus minimizing capital expenditure.

Comparing tube bundle designs showed that upgrading from plain tubes to the Thermo-B dual-enhanced tubes (Fig. 1) delivered a substantial boost in process throughput. Thermo-B tubes feature a modified fin structure on the outside diameter (OD) to enhance nucleate boiling at low temperature differences. This configuration allowed the plant to achieve a 12% increase in feed rate, illustrating that appropriate tube enhancements can improve heat exchanger efficiency by replacing only the existing tube bundle.

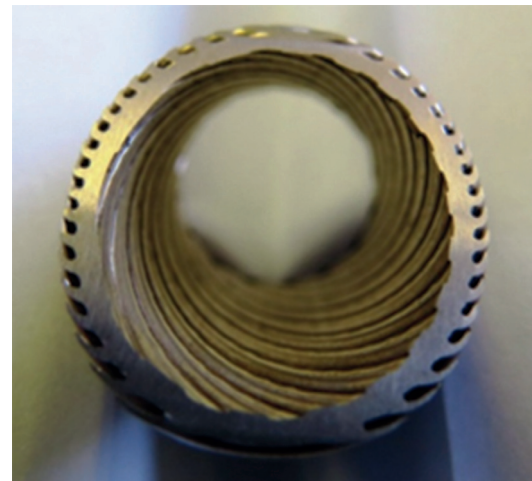


Fig. 1. Thermo-B tube with internal helical microfins and outside boiling enhancement. Image courtesy of NEOTISS.

Let's take a closer look at the Thermo-B nucleate boiling tube. Reshaping low-fins to form micro-channels or cavities creates nucleation sites that allow bubbles to form at lower temperature differences than on smooth or standard low-fin surfaces. The resulting rapid movement of liquid and vapor at these nucleation sites provides for very high boiling heat transfer rates at a relatively low Mean Temperature Difference (MTD). The Thermo-B type of boiling surface was selected for this case in part because it has undergone rigorous third-party testing so the end client could perform their own design evaluation using commercial software tools.

Case 2: Refinery feed effluent exchanger

This case study is for a reactor feed vs reactor effluent (feed/effluent) heat exchanger with hydrocarbon streams on both sides. The feed vaporizes to 100% vapor on the shell side and the effluent condenses from an all vapor state to about 50% vapor on the tube side, with both streams containing noncondensable gases. The heat exchanger is oriented vertically and has a single tube pass. With plain tubes, the size and weight of large or multiple shells present problems of maintenance, installation, and capital cost investment. Heat transfer enhancement can be used to improve on all of the above aspects. This particular service is prone to fouling and in a future article we will address how that might affect the selection of enhanced surfaces.

The differences between a plain tube heat exchanger, one enhanced only on the outside, and one with dual

Table 1. Heat duty and feed rate improvement using dual-enhanced Thermo-B tubes (Case1).

TEMA type BKU	Existing plain tube	Thermo-B dual enhanced upgrade
Feed rate increase, %	–	11.7
Heat duty, Fouled, MW	5.77	6.44
MTD, C°	5	5
Tube OD, mm	19.05	25.4
Fixed Shell Size, Effective area, m ²	1600	3780

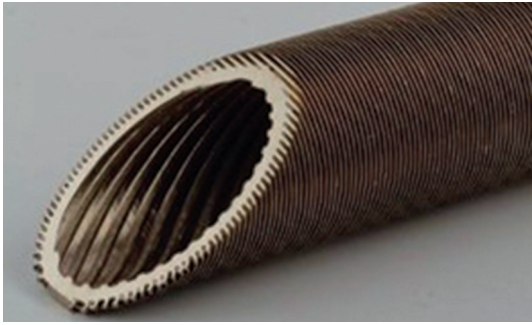


Fig. 2. Dual enhanced low-fin tube. Image courtesy of NEOTISS.

enhancement, are presented in the tables 2 and 3. The comparison assumes that the same 35% margin on surface area (for fouling plus other purposes) is provided for all cases.

Case 3: Chemical plant recuperative heater

A typical recuperative heater uses waste heat from a furnace or reactor and recovers that energy to improve the efficiency of the reactor or furnace by preheating the feed gas. In this case, the end client had already installed a conventional plain tube heat exchanger but needed to achieve a higher feed gas temperature from the recuperator to improve efficiency and uptime on the reactor. Two improvement options were considered, one with low-fins and one with dual enhancement. Given that this was a gas/gas exchanger with roughly equivalent heat transfer coefficients on both the shell and tube sides, the dual enhanced tube option proved to be the optimal solution. Figure 3 shows the recuperator process and the Table 4 shows the increase in heat recovered achieved - a feed outlet temperature of 354 C° vs 335 C°.

Summary

This article has highlighted three examples of common heat exchange services that can benefit from the application of dual enhanced tubes in place of conventional plain and low-fin.

- In the case of a Petrochemical plant chiller, the Thermo-B tube enabled a 12% increase in feed rate, retaining the same heat exchanger size

Table 2. Summary of improvements using dual enhanced low-fin tubes for feed/effluent heat exchanger (Case 2).

Benefits of Double enhancement

- The dual enhanced tube (Fig. 2) has the best design - smallest size and the lowest weight, 800 mm shell diameter (column C)
- A plain tube design with a single shell requires a 2.3 m diameter shell with >8000 tubes (column A)
- A reasonable plain tube design requires two shells in parallel of the same diameter as the dual enhanced, but a 50% greater tube length (column B)
- A finned tube without internal enhancement requires a shell diameter of 1300 mm (62% larger) and weight 2.4X times the dual enhanced design - columns C vs D. But note that the "Only OD" enhanced case (column C) is still a substantial improvement over plain tubes (columns A & B).

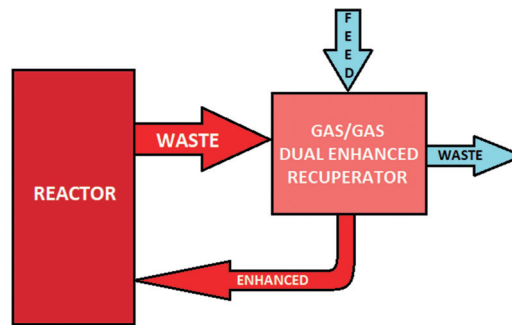


Fig. 3. Use of recuperator to improve reactor efficiency

- In the case of a refinery feed/effluent heat exchanger, dual-enhanced tubes resulted in the smallest design and the lowest weight.
- In the case of a recuperative heater, dual-enhanced tubes gave an 11% increase in heat duty and a 19 C° increase in feed preheat temperature.

There are numerous other opportunities to apply similar benefits. It should also be noted that the range of tube sizes (OD and wall) and material types available with dual enhanced tubes is more limited as compared to smooth or low-fin tube.

Upcoming in this series

In the next few articles we will look at other boiling enhancements, enhancements for condensing services, and how fouling might affect finned tube selection. ■

Table 3. Details of improvements using dual enhanced low-fin tubes.

		A	B	C	D
		Starting design, one shell-Plain	Starting design, two shells-Plain	Only OD enhanced, one shell	Dual enhanced tubes, one shell
Shell ID	mm	2350	800	1300	800
No.of tubes	–	8122	833 (x2)	2364	833
Tube Length	m	12.2	18.5	12.2	12.2
Area, outside	m ²	4717	739 (x2)	4167	1434
UA	kW/C°	406	392	396	390
Weight, empty	tons	151.6	22.5 (x2)	39.77	16.76

Table 4. Recuperator comparison table for heat recovered in a recuperator (Case 3).

Temperatures	Plain tube existing design	Low-fin tube design	Dual enhanced tube design
Hot gas from Rx, In/Out (C°)	393/136	393/121	393/115
Cold feed gas, In/Out (C°)	76/335	76/349	76/354
MTD (C°)	53.6	37.0	30.8
Heat duty (MW)	16.4	17.3	18.2

Stop flash corrosion in heat exchangers during hydrotesting

While hydrostatic testing ensures heat exchanger integrity, the water used can cause flash corrosion during testing and transport. This guide explores how adding corrosion inhibitors to hydrotest water prevents costly equipment damage and project delays.

By Julie Holmquist, Content Writer, Cortec® Corporation

Imagine being an employee at an LNG company. You have been waiting three months for your order of new heat exchangers to arrive from overseas. The shipment finally comes, and you unpack the equipment to get it ready for installation. Suddenly, your heart sinks. As you inspect the heat exchangers, you do not find shiny new tubes. Instead, the internals are covered with a layer of flash corrosion that has formed sometime between manufacturing and arrival. Not only is the appearance marred—the corrosion must either be removed or the equipment replaced before the heat exchangers can be commissioned. With your project on a deadline, you will lose valuable time while installation is delayed. Is there any way to avoid these corrosion surprises and the headaches they bring? Fortunately, the answer is yes! One excellent way to start is by adding corrosion protection during hydrostatic testing (hydrotesting).

The irony of hydrotesting

The main purpose of hydrotesting is to ensure the integrity of a metal vessel—to confirm that it will not leak or burst when filled with fluids at high pressures. Hydrotesting may be done to individual tubes or the entire tube bundle after it has been assembled. Hafish Alfarizy, an application engineer at PT Tiga Ombak, an Indonesian company that provides preservation products and engineering services for the oil and gas industry, summarized the purposes of hydrotesting this way: “integrity assurance, certification, customer requirements.”^[1] He explained that hydrotesting is often done by the manufacturer or supplier according to ASME standard BPVC VIII.1.^[2] PT Tiga Ombak together with the manufacturer or supplier has performed such hydrotesting for air cooled heat exchangers at the manufacturer’s site after assembly and before shipment.^[3] Another time hydrotesting may be desired, according to Scott Bryan (Certified Water Technologist and Technical Sales Manager at Cortec® Corporation), is just before commissioning the final equipment at the installation site.^[4] While hydrotesting is intended to make sure that equipment is reliable, the introduction of hydrotest water into the system simultaneously brings a corrosion risk. “Hydrotest[ing] uses water and it will definitely cause corrosion,” Alfarizy explained. Corrosion could occur during hydrotesting as the



▲ Measuring Corrosion Inhibitor for Hydrotesting. Image courtesy of Tiga Ombak, Cortec® Case History 852.

water courses along the shiny new metal surface and causes flash corrosion. The residual moisture remaining in the system could also foster corrosion at any time between hydrotesting and installation, including during the long journey from one plant to another. This corrosion creates a weak point in the system where further deterioration and thinning of the metal walls could occur, eventually leading to potential leaks and failures. Other repercussions could include clogging of the system with corrosion products or “poisoning” of the water by high iron levels. As Bryan explained, some performance requirements for industrial equipment (not limited to heat exchangers) include flushing a system until the iron levels are acceptable. He noted that in one case, workers had to fill and flush a system 10-12 times before they could achieve this, wasting tens of thousands of gallons of water in the process. Switching to the right corrosion inhibitor enabled them to pass the fill and flush requirements on the first try.^[5] In each situation, the water intended to verify the system’s integrity can ironically be the very instrument that causes it to lose its integrity, interrupt projects and processes, and waste time and money. That is why having a corrosion prevention strategy during and after hydrotesting is critical.



➤ Closeup of pressure gauges for hydrotesting of heat exchangers. Image courtesy of Tiga Ombak, Cortec® Case History 852.

Benefits of adding a corrosion inhibitor during hydrotesting

The presence or absence of a corrosion inhibitor during hydrotesting makes a stark difference. Alfarizy noted that PT Tiga Ombak first added corrosion inhibitors to hydrotest water in 2024 when hydrotesting air-cooled heat exchangers on their way to an LNG project in another country. He said that without a corrosion inhibitor, corrosion starts quickly, while with the right corrosion inhibitor, it will not appear for a long time—or perhaps not at all, depending on how long the corrosion inhibitor is active. He also mentioned that, while nitrogen purging is a very common strategy for corrosion prevention after hydrotesting, adding a corrosion inhibitor to the hydrotest water was less expensive and more effective.^[6]

The ideal corrosion inhibitor contains a blend of “contact” and “vapor-phase” corrosion inhibitors that leave behind a thin film of corrosion protection as they are circulated through the system. The “contact” corrosion inhibitors offer protection only when in direct contact with metal surfaces, while “vapor-phase” corrosion inhibitors have the ability to migrate through void spaces and attach to metal surfaces as a molecular protective layer. During hydrotesting, when the system is flooded with water at high pressure, contact protection is the main mechanism as the treated water leaves behind a thin film of corrosion inhibitors. However, once the water is drained, the remaining film will release corrosion inhibiting vapors that protect surfaces where the corrosion inhibiting film is not present and will continue to protect the system as long as they remain trapped inside. Bryan explained that at this point, it is normally necessary to dry the

vessel internals to minimize the amount of water in the system; however, with the right corrosion inhibitors, treated residual water can have the added benefit of leaving behind a greater “reserve” of corrosion inhibitors for an enhanced level of ongoing protection.^[7] These corrosion inhibitors can provide protection for up to two years, depending on the dosage used.

Ideally, corrosion inhibitors will be dosed at a rate that provides enough chemistry to provide ongoing protection during the shipping stage and any storage periods that may follow at the installation site. Alternately, another form of vapor-phase corrosion protection, such as fogging fluid, can be applied to provide interim protection between hydrotesting and installation instead of the higher cost option of nitrogen blanketing with its inherent challenges.

Hydrotesting best practices

Picking any corrosion inhibitor and adding it to the hydrotest water is not an end-all for corrosion problems. As mentioned above, an appropriate film-forming corrosion inhibitor with contact and vapor-phase protection is best, especially if it has a good history of hydrotesting success. Secondly, it is important to have an application where both the water and the corrosion inhibitor can be reused. As Bryan noted, using excess water is “cost prohibitive.” Instead of sending thousands of gallons of water and corrosion inhibitor down the drain, recycling the water allows both the water and the corrosion inhibitor to be used more than once, as long as the corrosion inhibitor stays at the right concentration and the solution remains free of contamination. A little corrosion inhibitor may need to be added each time to maintain the proper dose; however, recycling hydrotest water that is still in good condition can reduce overall costs by wasting fewer resources. Another important step to ensure best results during hydrotesting is to make sure the system is clean.



➤ Heat exchangers being prepared for shipment. Image courtesy of Tiga Ombak, Cortec® Case History 852.



➤ Shrink wrapping heat exchanger with corrosion inhibiting film.
Image courtesy of Tiga Ombak, Cortec® Case History 852.

Alfarizy noted, "If there is visible dirt and flash rust, it is better to perform surface preparation...."^[8] This may require the use of a basic alkaline cleaner with flash corrosion protection, or it may call for a rust removal step followed by cleaning and neutralization. Either way, removing contaminants is critical to enabling the corrosion inhibitors to do their job effectively.

The right dose and application procedure is also critical. In one case, a heat exchanger supplier was having corrosion problems despite using an extremely popular corrosion inhibitor during hydrotesting. The manufacturer of the corrosion inhibitor stepped in to examine the problem and found out the supplier needed to revamp their application method. First, they needed the proper dosage, a number that is variable depending on the water type. Another critical step was adequate mixing to ensure that a homogeneous blend of corrosion inhibitors and water was reaching every part of the system. One technique was to mix the solution in a large tank and test to validate the right concentration of corrosion inhibitors. Another option was to inject corrosion inhibitors into the water as the vessel filled, making sure to complete the dose by the time the vessel was 80% full. Sufficient dwell time was also critical to allow the corrosion inhibitors to be fully applied to the system (in this case, the treated water was left in the vessels for at least two hours). Although the heat exchangers were drained, they were not force-dried, and the absence

of corrosion complaints indicated that the problem had been solved.^[9]

Multi-national success story

In 2024, PT Tiga Ombak was involved in a cross-national effort to deliver heat exchangers corrosion-free to an LNG customer in Malaysia. This customer was concerned about corrosion because of a previous negative experience from an overseas supplier and enlisted VCI Technology (M) Sdn Bhd to help avoid the problem on this shipment. This time, corrosion protection started before the heat exchangers were even assembled. Since the tube manufacturer was located in South Korea, VCI Technology (M) Sdn Bhd coordinated with Cortec® Korea to provide corrosion protection at the fabrication site. This involved adding a corrosion inhibitor to the water when hydrotesting each tube. The tubes were drained, inspected, and fogged with a waterborne vapor-phase corrosion inhibitor for shipment. The tubes were capped to trap the vapor-phase corrosion inhibitors inside and wrapped in corrosion inhibiting film. Thus protected, they were ready for an eight to nine week journey by sea to Indonesia. Corrosion risks from fluctuating temperatures and condensation were high during this time, but the tubes successfully reached the heat exchanger manufacturer in good condition.^[10]

Once in Indonesia, responsibility shifted to PT Tiga Ombak, who conducted hydrotesting with corrosion inhibitors. This time, the intention

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Heat Exchanger Application

SHENSHI has been committed to the development of heat exchanger in the LNG marine and shipbuilding fields, continuously providing efficient heat exchange technology for various maritime applications, which can be applied to LNG offshore oil and gas platforms, various LNG floating platforms, and FGSS systems for various ships.



Vacuum diffusion welding equipment

Vacuum Diffusion Bonding Technology

The diffusion bonding is a solid-state welding process that bonds two contacting surfaces (faying surfaces) through the application of heat and pressure in a vacuum. Its welding strength can reach over 95% of the base material, ensuring excellent product performance.

Natural gas cooler Heat exchanger



was to provide internal corrosion protection after hydrotesting, and the product selected was found to be an economical and convenient alternative to nitrogen blanketing. The process included hydrotesting with water at three different pressures and took an hour and a half to complete.

^[11] The external surfaces of the tubing in the assembled heat exchangers were protected by spraying them with a water-based rust preventative that dried into a thin clear film. The final stage was to shrink wrap the two units in film containing vapor-phase corrosion inhibitors. The training and execution of this stage of the project were handled in just a few weeks, allowing the heat exchangers to reach the LNG site on time and protected, thanks to sound products and practices and the cooperation of multiple parties scattered across South Korea, Indonesia, and Malaysia.^[12] The case history above underscores the need for hydrotesting and corrosion protection at multiple points in the product life cycle and supply chain. If the tubes had corroded during hydrotesting or shipment, the appearance would have reflected poorly on the tube fabricator while presenting extra challenges to the heat exchanger manufacturer. If the assembled heat exchangers had rusted during hydrotesting or delivery to the customer in Malaysia, the LNG company would have been back where they started with compromised goods that could have delayed installation and put their entire project on hold. By preempting these problems at

every point, both the manufacturers and end user ended up with a happy result.

Special thanks to Scott Bryan, CWT, of Cortec® (<https://www.cortecvci.com/>) for advising article content and structure; Hafish Alfarizy of PT Tiga Ombak (www.tigaombak.co.id) for sharing his experiences; and Jay Zhang of Cortec® (<https://cortec-sea.com/>) for facilitating communication. ■

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Say goodbye to harmful refrigerants and hello to natural alternatives

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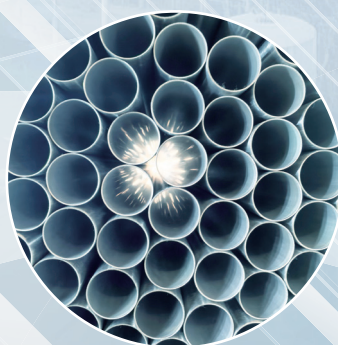
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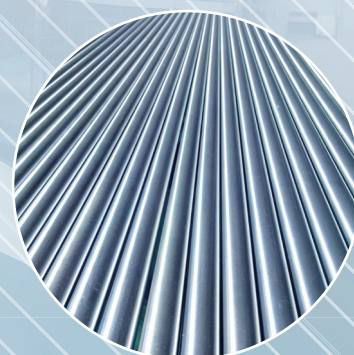
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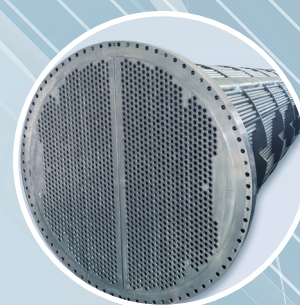
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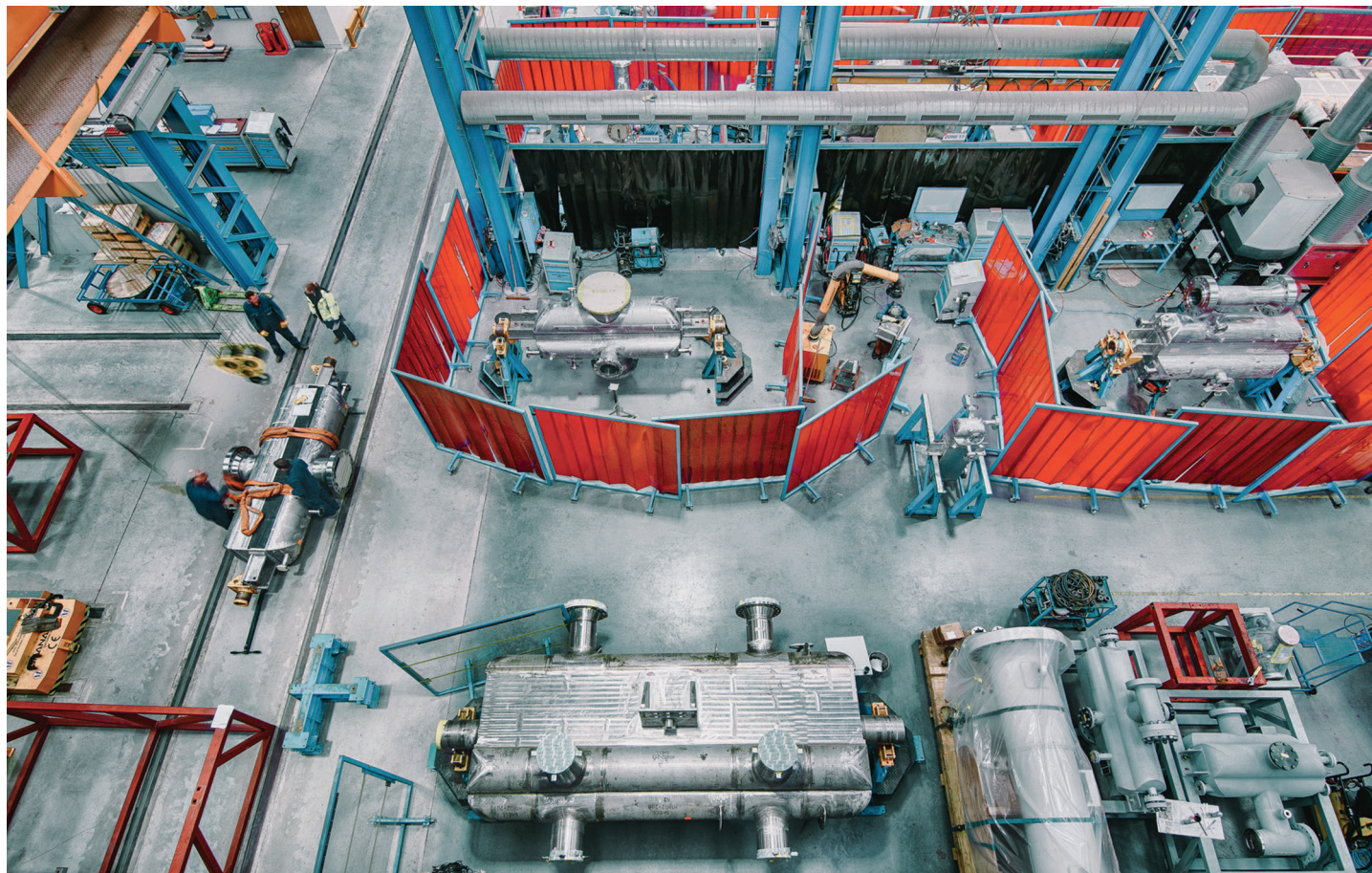
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Stepping up with sCO₂ power cycles



➤ The main Heatric PCHE manufacturing facility in Poole, UK. The Heatric Poole site is a 20,000m² facility dedicated to bonding, fabricating and testing Heatric PCHEs.

In the push to deliver greater energy efficiency, supercritical CO₂ is now emerging as an alternative to steam in power generation. Key to turning the concept into a successful industrial technology are unique printed circuit heat exchangers which are helping to enable its success.

By Renaud Le Pierres, Heatric Business Development Engineer, and Shaun Askew-Jones, Marketing Manager, Filtration & Energy Solutions Division, Parker Hannifin Filtration Group

For more than 140 years, steam has been the working fluid of choice for thermal power generation cycles. In the drive for ever greater efficiencies, alternatives to steam are being developed, with one promising choice now being supercritical carbon dioxide (sCO₂). The physical properties of supercritical CO₂ being a gas with very high power-density make it an attractive solution, particularly in the increasing desire to deploy smaller, distributed power plants.

In an exciting breakthrough on the journey to more efficient power generation, a pilot project recently began operations in San Antonio, Texas. The Supercritical Transformational Electric Power (STEP) Demo project aims to prove an indirect-fired supercritical CO₂ Brayton cycle concept with a \$169 million demonstration plant led by GTI Energy and underway at the Southwest Research Institute

(SwRI). The process has completed the first phase of testing, having generated electricity at around 4 MWe while also being synchronised to the grid. However, the journey to reach this milestone meant achieving technical breakthroughs with many key components – including the high temperature heat exchangers.

Supercritical CO₂

While the steam cycle has dominated power generation for modern history, CO₂ in a supercritical state, has advantageous physical properties that make it behave close to a liquid – allowing the compressor to act closer to a pump – but has the characteristics of a gas in terms of its thermodynamics offering advantages over steam. The benefits of sCO₂ power systems include higher efficiencies, reduced emissions from less fuel use, compact turbomachinery, reduced plant size, rapid response to load transients, reduced water use, heat source application flexibility, and overall better potential economics. Given these potential benefits, the use of supercritical carbon dioxide was recognised and first explored in the 1950s. However, limitations in materials and equipment, including the shell and tube heat exchangers in use at the time, curbed the thermal performance and stalled its development.



➤ The Heatric “HTR” (High Temperature Recuperator) PCHE at the Heatric manufacturing facility in Poole, UK before shipment.

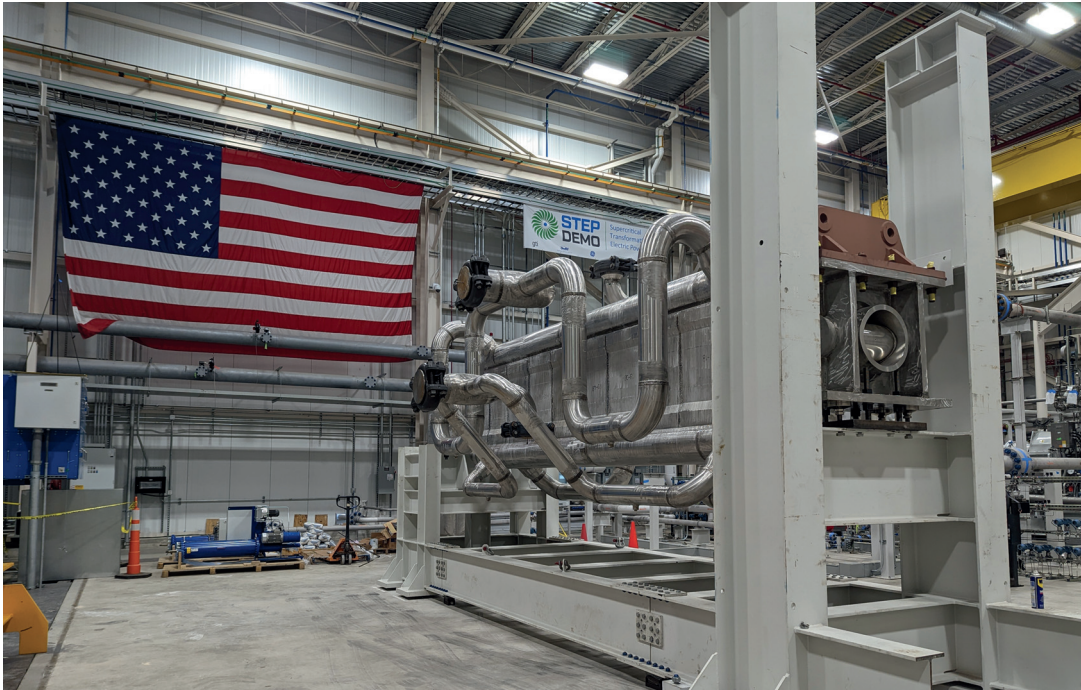
Decades later in 1985, the printed circuit heat exchanger (PCHE) was developed which enabled compact, efficient, and cost-effective heat transfer at the higher temperatures and pressures associated with sCO_2 cycles. PCHE's consist of flat metal plates in which fluid flow channels are chemically etched. The etched plates are stacked with plates of alternating hot and cold flow channels and are diffusion bonded together to make a strong heat exchanger block with a large heat transfer surface area. Initially, while PCHE's had helped to enable the use of supercritical carbon dioxide in power conversion cycles experiments, it was still limited to a relatively small scale ranging from a few kilowatts to a few hundred of kilowatts. For targeted industrial-scale applications, something on the megawatt scale was required, and when the PCHE technology became available and proven at commercial scales in O&G it supported cost effective sCO_2 -based power plants and contributed to the decision to proceed with the 10 MWe STEP Demo project.



➤ The Heatric “LTR” (Low Temperature Recuperator) PCHE awaiting installation at the 10 MWe STEP Demo project in San Antonio, Texas.

STEP into the future

In 2015, under a US Department of Energy/National Energy Technology Laboratory programme, a cooperative grant funding solicitation was issued to design, build and operate a 10 MWe supercritical carbon dioxide demonstration loop – the STEP Demo project (www.STEPdemo.us). The project was won by GTI Energy, a technology development and training organization, who became project lead working in partnership with GE Vernova, and fellow non-profit organisation SwRI, along with power cycle specialists including Heatric and others. Fundamental to the power cycle is the need for large amounts of heat recuperation and among the key components for the STEP Demo project are three high efficiency heat exchangers based on PCHE technology. These exchangers are the High Temperature Recuperator (HTR), the Low Temperature Recuperator (LTR), and the Main Cooler (MC). Heatric won the contract for the design, engineering, manufacturing, and supply of all three heat exchangers in August 2018. In terms of design, the MC is a relatively conventional PCHE similar to those widely used and well-proven in the oil and gas industry over many decades. The LTR design is slightly more customised for the duty but still close to conventional PCHEs in its layout, whilst the HTR is a heavily customised PCHE to manage more aggressive process conditions while still using regular austenitic stainless steel. This HTR design led to many collaborative work activities and iterations between GTI Energy, SwRI and Heatric to facilitate its integration within the STEP Demo process loop. Design conditions for the main cooler are 150 °C temperature and 175 barg pressure. For the low temperature recuperator, design conditions are higher than those found in the MC at 290 bar and 250 °C, although still easily managed by conventional PCHE technology. However, for the high temperature recuperator, a design temperature of 600 °C and pressures of the order of 290 bar make for much more challenging conditions that had to be addressed and required some design changes for the plant even post-contract.



▲ Heatric "HTR" (High Temperature Recuperator) PCHE in a support frame at the 10 MWe STEP Demo project in San Antonio, Texas in 2023 (www.STEPdemo.us).

The difficulty of this sCO₂ cycle is the combination of high pressure and high temperature; and whilst that is advantageous from a thermodynamic point of view, it is a major challenge from a thermal-mechanical design point of view. To manage this high-temperature and high-pressure CO₂, the necessary pipework needed to use thick walls leading to very high thermal stress / loads on the recuperator as the thermal expansion of thick sections can deliver substantial mechanical forces. The design of the pipework to bring the working fluid into and out of the heat exchangers and turbines thus became a complex problem. Secondly, a fully bonded and fully welded compact heat exchanger with a large heat gradient results in high bending stresses. This thermal expansion issue presented substantial engineering challenges that had to be overcome.

A collaborative road to project success

Heatric had worked with several of the partner organisations in the design of the thermal loop and to establish equipment sizing considerations even prior to the STEP Demo project's call for suppliers of equipment. Subsequently, during the detailed design and implementation phases, collaborative working practices between Heatric, SwRI and GTI Energy were critical to addressing these challenges. This was despite the impact of COVID restrictions, which limited the opportunities for face-to-face discussions and work. The site was still being built, and the main equipment was in the delivery phase when the COVID global pandemic hit, which slowed down the project tremendously. Ultimately, though, the collaborative relationship was key to the success of this unique project. As a first-of-a-kind development, it is only when physical development starts that some of the issues that may not have been known or identified during the project

definition stage emerged. It is at these most challenging times that the relationship is most important to be able to address those issues constructively. Sadly, many first-of-a-kind projects have historically failed and fallen by the wayside as they got closer to execution, but the foundation of a solid collaborative relationship between Heatric, GTI Energy and SwRI was there to help overcome these difficulties.

The HTR was delivered in 2021, with electricity first produced mid-2024 and subsequently tested successfully in a simple cycle configuration, using the HTR and the main cooler and generating some 4 MWe net in late 2024.

John Marion, Senior Director for Carbon Management & Conversion at GTI Energy, summarises the importance of the project success. "We are delighted with the project achievements to date. The STEP Demo facility is a driving force in power cycle technology development, establishing



▲ The 10 MWe STEP Demo project in San Antonio, Texas, USA in 2023. In October 2024, the STEP Demo facility accomplished the phase 1 testing milestone: achieving full operational speed of its turbine at 27,000 RPM operating at 500°C. It generated 4 MWe net of grid synchronized power.



▲ The Heatric "Main Cooler" PCHE after on-site delivery to the 10 MWe STEP Demo project in San Antonio, Texas.

the groundwork for future sCO₂ applications. GTI Energy is proud to be leading this collaboration enabling future low carbon power generation processes."

Commenting on the project, Dr. Tim Allison, director of SwRI's Machinery Department, highlighted the pioneering nature of the technology and the role of close collaboration in achieving this remarkable energy sector breakthrough. "The success of phase 1 of STEP Demo is a major advancement of the commercial maturity of these transformative power systems which represents many technical firsts. Overcoming the challenges associated with the combination of operating temperatures and pressures while generating power highlights the tenacity and perseverance of STEP Demo's engineering and project teams," said Dr. Allison.

The sCO₂ opportunity

The characteristics of sCO₂ offer around a 10% increase in efficiency when compared with conventional steam cycles. This is a substantial advantage over existing steam cycle approaches. In addition, though, the use of sCO₂ allows a far more compact power block to be deployed. The turbomachinery components in the STEP Demo project are approximately one-tenth the size of a conventional steam power plant. The turbine has a diameter of about 18 cm, for example, while the heat exchangers are also far more compact than conventional shell and tube type designs. This not only reduces the footprint, the environmental impact and construction cost of a new generation asset but also favours the deployment of sCO₂ in multiple retrofit applications. Once installed, simple cycle gas turbine power plants typically face severe restrictions on the available space that would rule out the subsequent addition of a steam cycle. The compact footprint of the sCO₂ power conversion island alleviates that issue, making it well suited for use with aero derivative gas turbines such as the LM2500 from GE, for example. There is also scope for installing these devices aboard offshore oil and gas platforms, which typically use

simple cycle gas turbines. Both these applications – converting a simple cycle machine into a sCO₂ combined cycle – creates a very high efficiency yet compact unit, making operations more efficient and burning less gas.

Furthermore, the sCO₂ Brayton cycle device can be applied to many different heat sources, including concentrated solar power, advanced nuclear reactors, industrial waste heat, thermal energy storage and geothermal heat.

The next STEP

Currently, GTI Energy, SwRI, and GE Vernova are reconfiguring the STEP Demo pilot from a simple cycle to a Recompression Closed Brayton Cycle (RCBC) system configuration. This advancement will allow the installation to reach higher efficiencies for the overall loop by including the LTR. In this second phase that is taking place this year, the project will further increase the operating temperature to 715 °C, raise the output to the full 10 MWe net, and increase net plant efficiency.

The project is hailed as a success story having generated electricity and is operating as expected. With a design rating of 10 MWe net, STEP Demo is the largest such facility to be operational in the world. Having proven its ability to meet initial performance targets, including its full operational turbine speed of 27,000 rpm and achievement of the initial target turbine inlet temperature of 500 °C, the STEP Demo project marks a critical shift in the technology's development and puts it on a firm footing for future commercialisation. It might even be said that STEP is a supercritical breakthrough for energy. ■

About the authors

Renaud Le Pierres is responsible for assisting in the development of Heatric (Parker Filtration and Energy Systems) business within new markets, with specific focus on power generation, energy storage, carbon capture, and waste heat recovery applications. Since joining Heatric in 2005 as a design engineer in the nuclear department, Renaud has been involved in various new power conversion cycles and has been involved in many advanced gas power conversion cycles and energy storage projects.



Shaun Askew-Jones is the Marketing Manager at Filtration & Energy Solutions Division, Filtration Group, Parker Hannifin Corporation. Shaun started his marketing career as a Marketing Analyst at Heatric in 2018, rising to Marketing Manager in 2020. Since 2024, Shaun has overseen marketing activities for all brands and products within the new Filtration & Energy Solutions Division within Parker Hannifin, covering heat exchanger and air inlet filtration product lines.

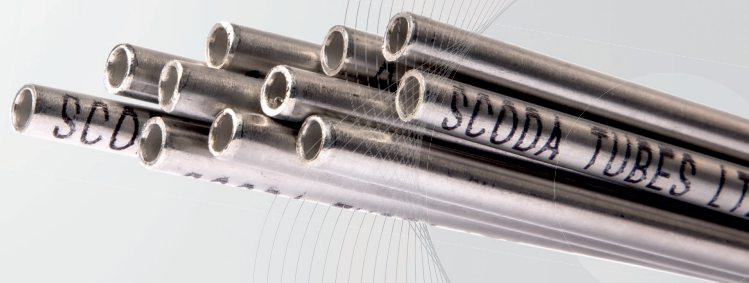




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How smarter filtration saves heat exchangers and the systems that rely on them



Water Filtration for Protection of Heat Exchanger 90 m³/h x 2 nos filters, 500 micron. Photo courtesy of Filternox.

In industrial plants, data centers, chemical refineries, and even historic hotels, heat exchangers are the silent heroes ensuring thermal balance, energy efficiency, and smooth operations. However, their vulnerability to fouling—caused by particles, organic matter, and biological growth—poses a persistent threat. The solution? Mechanical filtration.

By O. Oğuz Tameroğlu, CEO, Filternox

Why heat exchangers need protection

Whether it is a plate or shell-and-tube design, heat exchangers rely on clean, uninterrupted fluid flow to operate efficiently. But water drawn from cooling towers, rivers, lakes, or the sea often carries solid particles, sediment, algae, and corrosion byproducts. These contaminants reduce heat transfer, cause blockages, and increase pressure loss. Fouling—whether due to biofilm formation, mineral scaling, or particulate deposition—is not only a performance problem but also a cost and sustainability issue. According to studies, even a thin layer of fouling as small as 0.25 mm can reduce heat transfer efficiency by over 10%. As efficiency declines, energy consumption increases, which in turn raises operational costs and carbon emissions. That's where mechanical filtration becomes essential. By capturing unwanted solids before they enter the system, filters preserve the integrity and performance of heat exchangers.

Understanding the numbers

Choosing the correct filtration level is both a science and an art. For example, if a plate heat exchanger has a plate gap of 2 mm, the filtration rating should ideally be at least five times finer, approximately 400 microns. However, to provide a higher safety margin and account for particle variability, Filternox typically recommends a filtration degree of 200 microns in such cases.

In general, filtration degrees ranging from 50 to 500 microns are selected based on the risk of fouling, the water source, and the exchanger design. Even small particles can significantly affect performance in plate exchangers or form insulating layers inside tubular systems. Also critical is the flow rate. For example, in systems handling flows above 100 m³/h, filters must be designed to handle the volume without creating pressure drops or requiring frequent manual maintenance. This is where automatic self-cleaning filters become indispensable.

Reliable cooling at the water's edge: From iconic hotels to industrial strength

Overlooking the shimmering waters of the Bosphorus, the Çırağan Palace Kempinski in Istanbul is more than a symbol of luxury and history — it's a testament to innovative engineering. Its seawater-cooled HVAC system, like many others near the coast, faces significant fouling risks, particularly in the summer months. Since 2004, Filternox® automatic self-cleaning filters have been the invisible



By maintaining clean heat transfer surfaces, companies can significantly reduce their carbon footprint.
Photo courtesy of Filternox.

guardians behind the scenes, ensuring uninterrupted performance even during peak tourist season. But Çırağan is just one example. Prestigious properties such as the Four Seasons, Mandarin Oriental, Les Ottomans, Vakko Hotel & Residence, as well as leading institutions like Galatasaray and Bahçeşehir Universities, also rely on Filternox's patented double-effect filters to protect their heat exchangers. These advanced filters capture not only fine particles but also large debris up to 5 centimeters in size, effectively eliminating the risks associated with seawater fouling.

And the result? Zero system failures in over 20 years of continuous operation — a record that speaks for itself. From five-star luxury to critical infrastructure, Filternox ensures that cooling systems run smoothly, efficiently, and without compromise.

This is achieved using patented double-cleaning technology that doesn't interrupt the system or require manual intervention—the result: uninterrupted cooling, reduced maintenance, and a sustainable approach to energy efficiency.

But the benefits go beyond comfort. In industrial environments like petrochemical facilities and food processing plants, efficient filtration extends equipment life, reduces cleaning intervals, and ensures consistent product quality.

What makes a filtration system smart?

Innovative filtration isn't just about particle size. It's also about:

- Filter placement: Proximity to the heat exchanger matters. Filters should be installed inline, as close to the source as possible.
- Inlet pressure: Based on Filternox's 30 years of experience, a minimum inlet pressure of 2 bar is recommended for efficient filter operation.
- Backwash interval and duration: Efficient automatic filters must be able to clean themselves without excessive water loss or interruption to the flow.
- Material selection: Filters operating in corrosive environments (like seawater) should be made of high-grade stainless steel, titanium, or duplex materials.

Cooling towers and surface water: A double challenge

Cooling towers bring their own set of problems. Airborne contaminants—such as leaves, insects, and microbes—accumulate in the water. Surface water sources, such as rivers and lakes, carry a wide variety of pollutants, including sediment, organic matter, and aquatic organisms. In coastal or offshore applications, shell fragments and algae blooms are common.



⚡ Since 2004, Filternox® automatic self-cleaning filters have quietly ensured smooth operation, even during peak tourist season. Photo courtesy of Filternox.



⚡ From five-star hotels to vital infrastructure, Filternox keeps cooling systems running smoothly and efficiently. Photo courtesy of Filternox.

In these challenging environments, dual-stage automatic self-cleaning filters make the difference. They help reduce chemical usage, energy consumption, and the frequency of manual cleaning. Their long-term benefits include:

- Less frequent chemical dosing (antiscalants, biocides).
- Lower risk of emergency shutdowns.
- Reduced pump wear and tear.
- Stable thermal exchange capacity.

These savings translate not only into lower operational costs but also into environmental benefits. By maintaining clean heat transfer surfaces, companies can significantly reduce their carbon footprint.

Integration matters

Another often-overlooked factor is system integration. A filtration system must be appropriately integrated into the plant's automation network. Features such as remote monitoring, differential pressure control, and alarm signaling allow for proactive maintenance and optimize

filter cleaning cycles. Filternox filters, for example, can be directly connected to SCADA or PLC systems, enabling maintenance teams to respond before fouling causes system degradation.

Additionally, filters should be designed for easy inspection and minimal replacement of spare parts. Modular configurations make it easier to scale up or adapt to changing process requirements.

Why it matters more than ever

As the demand for energy-efficient, climate-resilient cooling systems grows, mechanical filtration plays a more strategic role than ever before. Industrial operators, facility managers, and engineers are realizing that a small investment in proper filtration upfront can prevent significant downstream losses, both financial and environmental.

In today's world, where sustainability is no longer a trend but a necessity, filtration has become a core component of responsible industrial design.

By implementing reliable, automatic self-cleaning filters, operators can extend equipment lifespan, optimize heat exchange, minimize unplanned shutdowns, and support their ESG (Environmental, Social, and Governance) goals.

Conclusion

Filtration is no longer a secondary concern—it's a frontline defense. In high-demand environments, protecting heat exchangers means protecting productivity and efficiency. With the right system in place, heat exchangers can perform as intended: run cleanly, efficiently, and continuously.

More about heat exchanger applications:
<https://www.filternox.com/pdf/en/Filternox-Sea-Water-Heat-Exchanger.pdf> ■

About the Author

O. Oğuz Tameroğlu graduated from the Department of Environmental Engineering at Istanbul Technical University in 1983. He worked at an RO facility Construction in Saudi Arabia between 1983 and 1986. He returned to Türkiye and founded Antel Treatment System Construction Industry & Commerce Co. in 1986. Since then, he has been leading the development and global promotion of advanced water filtration technologies, with a particular focus on automatic self-cleaning filters. As the CEO of Filternox®, he has overseen the design, production, and international deployment of filtration systems in over 80 countries.



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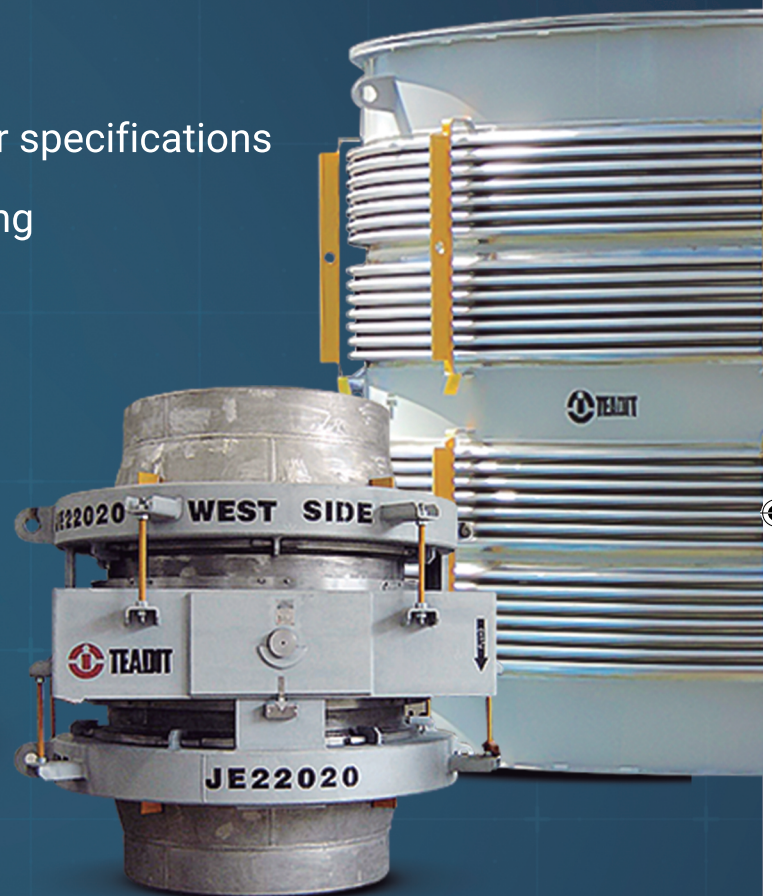


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9 most common mistakes in the installation and commissioning of a heat exchanger

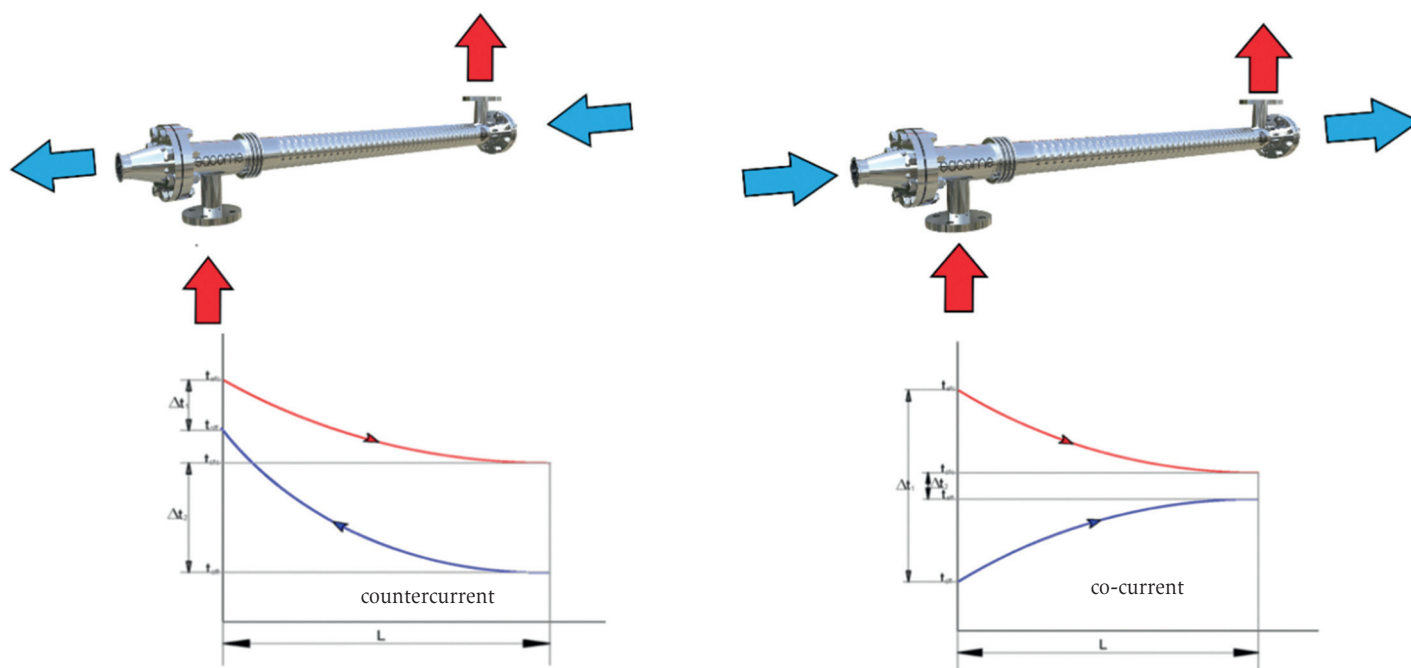


Figure 1. Countercurrent and co-current arrangement.

In over 40 years of SACOME's history, the company has supplied thousands of equipment for multiple and various applications. This article outlines some of the most common mistakes made during the installation and commissioning of heat exchangers that can negatively affect equipment performance and, in some cases, lead to complete failure.

By Fernando Vera, Technical Department, SACOME

1. Wrong flow configuration of the fluids in the heat exchanger

According to the flow directions of the hot and cold fluid flow in a unit, there are 2 ways to install a heat exchanger, as shown in Figure 1.

Except in some very specific applications, a heat exchanger has higher efficiency when installed in countercurrent configuration, since this arrangement results in a higher logarithmic mean temperature difference (LMTD) between the hot and cold fluid, resulting in higher thermal efficiency and, therefore, a smaller required heat exchange surface. However, in some specific processes a co-current arrangement may be preferable, so at the design stage, the Technical Department will recommend to the client the best solution for their particular case.

When the customer proceeds with the installation and commissioning of the equipment, they may arrange the service inlets and outlets incorrectly by mistake. In that case, the equipment may finally be installed in co-current instead of countercurrent, which, for the reasons explained above, may have a

negative impact on the performance of the heat exchanger.

2. Overpressures due to a close water loop with a bad design

There are numerous reasons why unusual overpressure may appear during the operation of a tubular heat exchanger, such as water hammer or overheating of one of the fluids, among others. This overpressure can lead to plastic deformation, partial or total failure of the shell or inner tubes, or collapse of the bellows, which can render the equipment completely useless.

On Figures 2, 3, 4, and 5 you can see typical failures of heat exchangers by collapse of the shell side, particularly of the expansion joint, due to overpressures in the service side.

In the case of overpressure in a poorly designed hot water circuit, it is essential to install an expansion vessel or tank in the closed water loop. This component has the function of absorbing the pressure increase of the heat transfer fluid (for instance water or glycol/water solutions) when it heats up. This fluid, as its temperature increases, tends to increase its volume, and if the liquid is in a closed circuit and there is no component that can absorb this expansion, significant overpressure will appear, which can lead to the collapse of elements such as the expansion joint or the inner tubes of the heat exchanger.

Figure 7 shows a typical diagram of a closed water loop where, among other necessary components such as pumps, pressure gauges, valves, drains, and sight glasses, the expansion vessel or tank can be seen.



Figures 2, 3, 4 and 5. Examples of expansion joints collapsed and cracked by an overpressure in shell side.

This is a typical installation for the heat recovery section of a process plant.

3. Blocking of supports

Depending on the disposition of the equipment (horizontal, vertical installation, one or several modules in series, etc.), the heat exchanger may be supported on the foundation in various ways. For example, in the case of a single module with horizontal layout, it can be supported on 2 cradles or support legs, as shown in Figure 8.

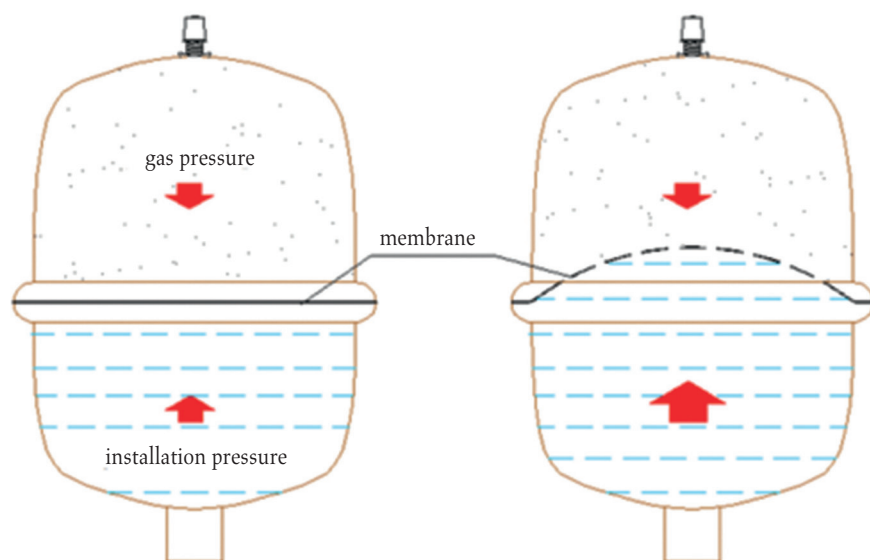


Figure 6. Operation of an expansion vessel.

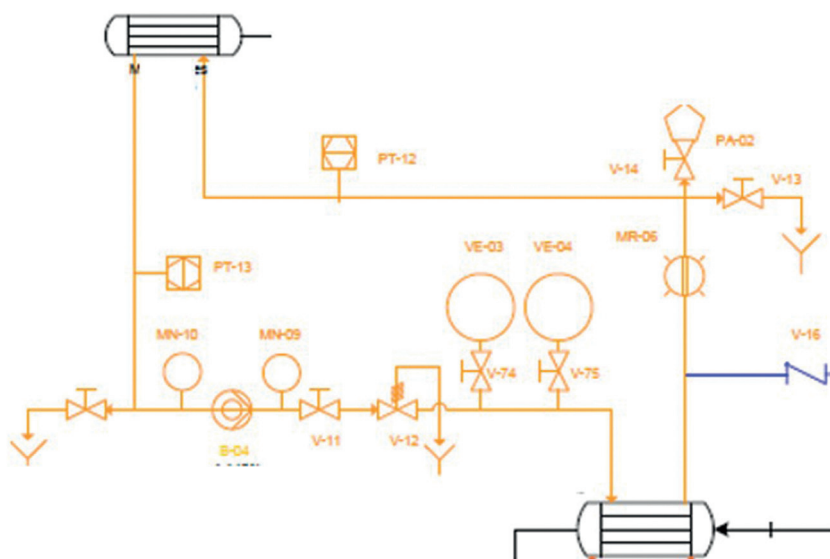


Figure 7. Elements of a close water loop.

If the anchor bolts are anchored to the floor in such a way that they do not allow movement of the equipment, there will be additional stresses in the expansion joint as well as in the tube-to-tubesheet weldings, thus leading to cracking in the welds. With this in mind, if the heat exchanger is fixed at 2 points, it is advisable to leave one of them sliding or allowing free expansion.

In many projects the support or frame is part of the scope of supply, in which case this type of construction detail must be taken into account. However, if this is not the case and the customer decides to construct it themselves, it is essential that the installation company in charge of the frame take this type of detail into account, in order to avoid additional stresses (and possible breakage) in the equipment.

4. Poor design of the condensates pipeline

In a condenser or water/steam exchanger, if the condensate removal is not carried out properly, the shell side may start flooding, causing the steam stream to hit the liquid layer, thus causing loud noises and vibrations. To detect this malfunction, it is sufficient for the operator to touch the top and bottom of the heat exchanger in operation. If the top part is hot while the bottom is cold, the shell side is probably flooded up to the level where the surface temperature changes. This malfunction is known as water hammer, and it is one of the typical cases in a process line.

5. Excessive fouling

Fouling is a phenomenon that has a negative impact on the heat transfer coefficient, increases pressure drop, and can even activate and accelerate corrosion attacks. There are different fouling mechanisms: crystallization (typical in very hard water with high mineral salt contents, such as calcium carbonate and lime), sedimentation (deposition of sand, rust, or other suspended solids), chemical (in processes where the product can be degraded by temperature), freezing (when a fraction of the product is frozen by the process temperatures), biological (when untreated water is processed, thus enabling the proliferation of different types of organisms or microorganisms), and protein precipitation (typical in milk by-products), among others.

Given the complex nature of this phenomenon, the solution is often not trivial either and usually involves different aspects. With the aim of minimizing the problem and increasing the running time between CIP, the following actions can be taken:

- When doing the thermal calculation, a high oversize can be considered or fouling factors can be introduced as a safety factor. This will give the equipment a margin to become fouled and still reach the required temperatures.
- Make the more fouling fluid flow through the tube side, as it is easier to clean than the shell side.
- Design the equipment to ensure a high process velocity for the process fluid, thus minimizing fouling.
- Provide a flanged tubesheet design so that the reducer or header can be easily removed with the aim of inspecting the tube side.
- In case a dirty fluid is flowing through the shell side, a solution with removable tube bundle can be suitable.

6. Corrosion attack due to the use of very aggressive cleaning agents

Fouling in a heat exchanger is a complex phenomenon that can lead to different types of dirt build-ups and deposits, such as oil and grease deposits, lime scale, different types of organic deposits, sludge, or metal oxides. In case of chemical cleaning (Cleaning-in-Place or CIP), cleaning solutions with different agents and concentrations can be used, such as hydrochloric acid (HCl), phosphoric acid (H₃PO₄), nitric acid (HNO₃), citric acid (C₆H₈O₇), caustic soda (NaOH), and different polyphosphates (such as NaPO₄ or Na₃PO₄).

Figure 8. Heat exchanger with 2 support saddles.



Figure 9. Detail of sliding holes in the supports.

Some of these agents are very aggressive and, in addition to the temperatures at which such chemical cleaning is usually carried out (typically between 60°C and 80°C), can lead to corrosion problems (uniform or localized, such as pitting or crevice corrosion) in the construction material of the heat exchanger.

The following are some basic guidelines to keep in mind when it comes to CIP cleaning:



Figure 10. Condensates pipeline with a poor design.



Figure 11. Example of fouling in shell side.

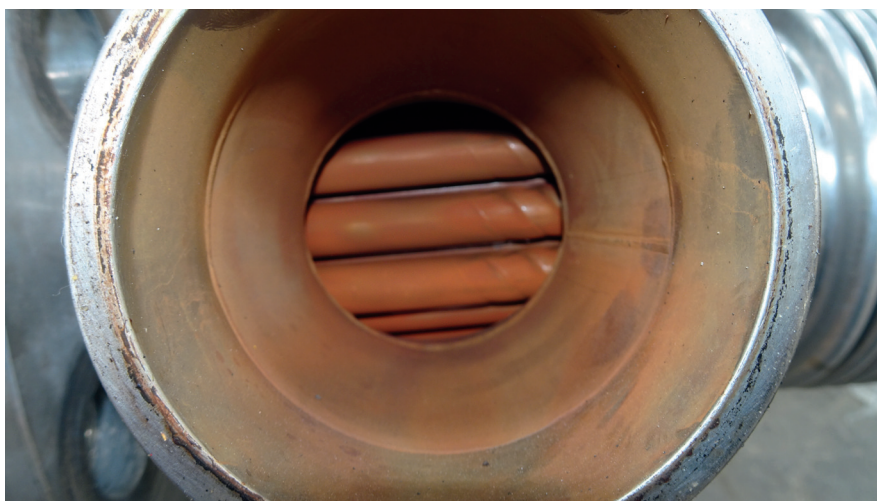


Figure 13. Detail of the service inlet nozzle of a unit with untreated water.

- Check with a specialist company about the cleaning agents and concentrations to be used, as well as the cleaning procedure, taking into account the construction material of the heat exchanger, both tubes and gaskets.
- Only circulate cleaning agents and concentrations according to the recommendations of this specialist company. Products such as hydrochloric acid (HCl), phosphoric acid, and nitric acid, among others, can be very aggressive at high temperatures.
- At the end of the chemical cleaning cycle, the heat exchanger should be rinsed with water. Otherwise, the solution may settle and in certain areas of the equipment the concentration of the cleaning agent may increase, raising the risk of corrosion.

7. Corrosion due to use of service water with high chlorides content

Sometimes the customer uses untreated or poor quality service water with high ppm of salts and chloride ions, which, together with elevated process temperatures, can lead to localized corrosion if the quality of the used stainless steel is not suitable.

On Figure 13 you can see the shell side inlet nozzle of equipment with hard service water having high ppm of Cl⁻, which has caused high fouling as well as initiated corrosion of the pipes.



Figure 14. Collapse of a pipe due to freezing of retained water.



Figure 12. Beginning of corrosion attack.

8. Freezing of product

During the shutdown of the installation, if the units are not completely drained, leaving fluid inside, and the ambient temperature drops below 0°C, there is a risk of freezing of the stagnant product, which can damage the heat exchanger tubes. This is the reason why it is recommended to place drain valves at the lowest points of the installation. On Figure 14 you can see a heat exchanger collapsed by water that has been retained inside and that has frozen when the temperature drops below 0°C.

Another possible alternative is to use propylene glycol solutions in a suitable proportion, with a lower freezing point than water. ■

About the author

Fernando Vera is an Industrial Engineer from UPCT (Polytechnic University of Cartagena). With over 20 years of experience in process engineering at SACOME, where he has been part of the Technical Department and has held various roles since 1998, Fernando is an expert in the thermal and mechanical design of tubular heat exchangers. He works closely with both European and global markets, providing technical support and engineering solutions tailored to international clients. Fernando is fluent in 6 languages, which enables him to communicate effectively and build strong professional relationships worldwide. You can contact Fernando Vera directly by email at fvera@sacome.com or through his LinkedIn profile.



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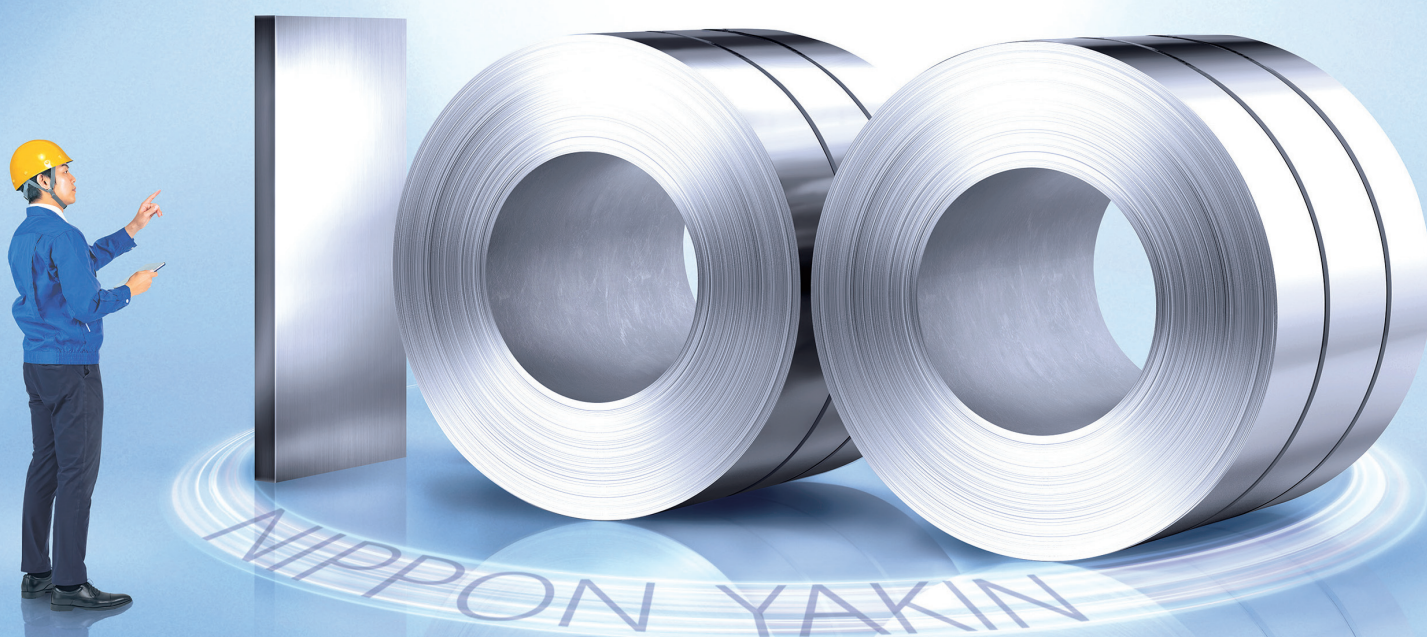
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Acceptable loss and tube replacement in heat exchangers



▲ Inside view of the carbon steel tube bundle within a heat exchanger.

Heat exchanger tubes represent the cornerstone of thermal transfer efficiency between fluid streams. These critical components, while engineered for durability, inevitably face degradation through various mechanisms including corrosion, erosion, fouling, and mechanical stress. The challenge lies not merely in identifying tube failures, but in making informed decisions about acceptable levels of tube loss and implementing strategic replacement programs. This article explores the multifaceted considerations that influence these crucial maintenance decisions, providing industrial practitioners with detailed insights for optimizing heat exchanger reliability and performance.

By Omari Hussein Sabuni, Mechanical Engineer,
Kinyerezi Power Plant

The efficiency paradigm: Understanding performance impact

The relationship between tube loss and heat exchanger performance presents a complex dynamic that extends far beyond simple thermal transfer calculations. When tubes are removed from service or plugged, the impact ripples through the entire system, creating a cascade of operational challenges. The reduction in heat transfer surface area directly diminishes the exchanger's capacity to achieve desired temperature differentials, leading to increased approach temperatures that can significantly impact process efficiency and product yield. These efficiency losses manifest in multiple ways throughout the system. Energy requirements typically increase as the system attempts to compensate

for reduced heat transfer capability, driving up operational costs and potentially straining other process components. The flow distribution within the exchanger becomes increasingly unpredictable, with plugged or failed tubes creating flow imbalances that can result in localized hot spots and accelerated tube degradation in remaining active tubes. Perhaps most concerning is the self-reinforcing nature of these efficiency losses. As fluid velocities change due to tube loss, the likelihood of increased fouling rises significantly. Reduced flow rates in remaining tubes can create conditions favorable for sediment deposition and biofilm formation, accelerating the fouling process and further compromising heat transfer efficiency. This creates a challenging scenario where each lost tube potentially accelerates the degradation of remaining tubes.

Service duration: The time factor in tube integrity

The duration of service emerges as a critical factor in determining tube integrity and replacement strategies. Material degradation follows complex patterns influenced by both operational time and service conditions. Extended exposure to process fluids and thermal cycling can lead to subtle changes in material properties that may not be immediately apparent through standard inspection techniques. The impact of service duration manifests differently depending on operational patterns. Heat exchangers operating under steady-state conditions typically experience more predictable degradation rates compared to units subjected to frequent thermal cycling. These

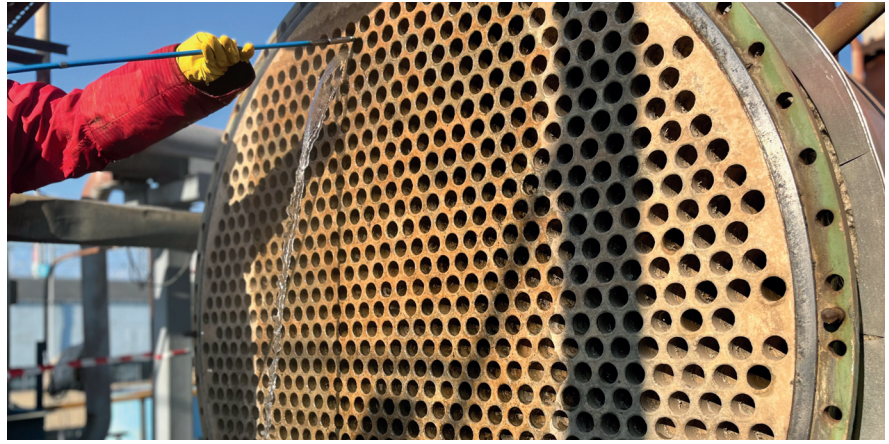
thermal cycles, particularly during startup and shutdown operations, can induce significant stress on tube materials, accelerating fatigue mechanisms and potentially leading to premature failure. Modern inspection protocols have evolved to address these time-dependent degradation mechanisms. Regular maintenance checks now incorporate sophisticated wall thickness measurements, detailed fouling assessments, and corrosion rate evaluations. The integration of predictive analytics has revolutionized this process, allowing operators to leverage historical performance data and machine learning models to anticipate tube replacement needs with unprecedented accuracy.

Strategic planning: The outage timeline perspective

Maintenance planning for heat exchangers requires careful consideration of outage schedules and operational constraints. The time remaining until the next planned outage significantly influences decisions regarding temporary repairs versus complete tube replacement. When facing imminent outages, engineers often employ strategic temporary measures such as tube plugging to maintain operational continuity while minimizing immediate downtime. However, these short-term solutions must be balanced against long-term reliability concerns. Extended periods between planned outages necessitate more thorough evaluation of tube condition and may warrant comprehensive replacement programs to ensure continued reliable operation. This decision-making process requires careful analysis of current performance metrics, degradation rates, and potential risks associated with delayed maintenance. Successful maintenance strategies typically incorporate robust condition monitoring systems that provide real-time performance data. This information, combined with detailed analysis of historical trends, enables operators to optimize maintenance scheduling and resource allocation while minimizing impact on production schedules.

Criticality assessment: Risk-based decision making

The role of a heat exchanger within the broader process system fundamentally shapes maintenance and replacement strategies. High-safety impact units, particularly those preventing process upsets or maintaining critical temperature controls, demand immediate attention when tube failures occur. These exchangers often operate under stringent regulatory requirements that mandate specific inspection protocols and maintenance intervals. Operational criticality extends beyond safety considerations to encompass production impact. Exchangers integral to maintaining throughput or product quality require particularly careful monitoring and rapid response capabilities. This often necessitates maintaining comprehensive spare parts inventories and developing detailed contingency plans for potential failure scenarios. Risk management strategies for critical exchangers



▲ Cleaning of heat exchange equipment with a high-pressure hydraulic unit.

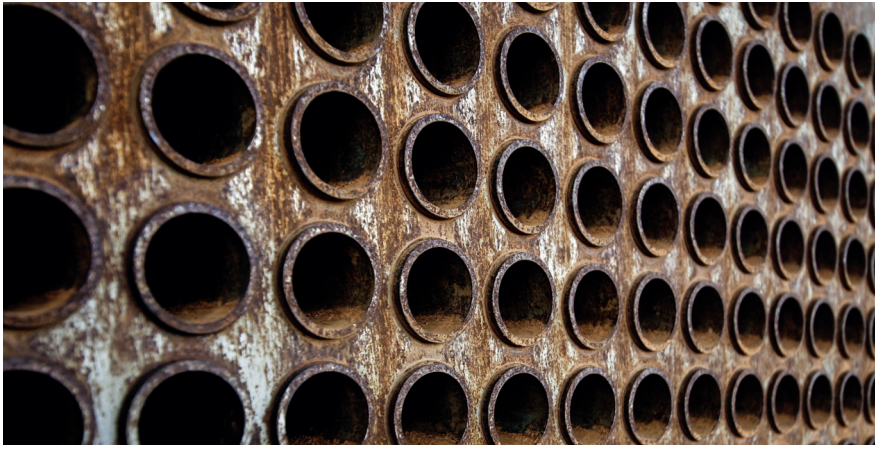
increasingly incorporate sophisticated analysis tools such as Failure Mode and Effects Analysis (FMEA) and risk-based inspection (RBI) programs. These systematic approaches help optimize maintenance resources while ensuring appropriate attention to high-risk scenarios.

Understanding damage mechanisms: The technical foundation

Effective tube replacement strategies begin with a thorough understanding of underlying damage mechanisms. Corrosion remains one of the most significant challenges, manifesting in various forms from uniform material loss to highly localized pitting attacks. The complexity of corrosion mechanisms often requires sophisticated inspection techniques and careful analysis to determine appropriate intervention strategies. Erosion presents another significant challenge, particularly in systems handling high-velocity fluids or those containing particulate matter. The interaction between erosion and corrosion can create particularly aggressive degradation scenarios that require careful monitoring and potentially modified operational parameters to manage effectively. Thermal fatigue, resulting from repeated expansion and contraction cycles, demands particular attention in systems with significant temperature variations. Understanding these damage mechanisms enables the selection of appropriate inspection techniques and the development of targeted maintenance strategies.

Historical analysis: Learning from past performance

Understanding historical failure patterns provides invaluable insights for developing proactive maintenance strategies. Trend analysis of tube failures often reveals subtle patterns that might otherwise go unnoticed in day-to-day operations. When failure rates show an increasing trend, this typically signals accelerating degradation mechanisms that require immediate attention. Conversely, decreasing failure rates might indicate the success of previous maintenance interventions or improvements in operational practices. Modern data collection and monitoring systems have revolutionized the approach to failure analysis. Advanced sensors and monitoring equipment now



➤ Rust tube sheet of the heat exchanger due for maintenance.

provide continuous streams of performance data, allowing operators to track key indicators such as pressure drops, temperature profiles, and heat transfer efficiency in real-time. This wealth of data, when properly analyzed, can reveal early warning signs of developing problems long before they manifest as actual tube failures. The integration of machine learning and artificial intelligence has further enhanced the capability to predict future failure events. These sophisticated analytical tools can process vast amounts of historical data to identify subtle patterns and correlations that might escape human observation. This predictive capability enables maintenance teams to move from reactive to proactive

maintenance strategies, potentially preventing failures before they occur.

Consequence analysis: Understanding the stakes

The potential consequences of tube failure extend far beyond immediate operational disruptions, encompassing safety, environmental, and economic impacts. In systems handling hazardous materials, tube failures can lead to dangerous fluid mixing or releases, potentially creating severe safety hazards for personnel and surrounding communities. These safety considerations often drive the development of comprehensive containment systems and emergency response protocols.

Environmental impacts present another critical dimension in consequence analysis. Modern regulatory frameworks impose stringent requirements regarding the release of process fluids, making it essential to consider potential environmental consequences when developing tube replacement strategies. This often involves implementing sophisticated leak detection systems and establishing detailed response procedures for potential release scenarios.

The economic consequences of tube failure can be particularly far-reaching, especially in integrated process systems where the failure of a single heat exchanger can force the shutdown of entire production lines. These economic considerations must be carefully balanced against the costs of preventive maintenance and planned replacement programs.



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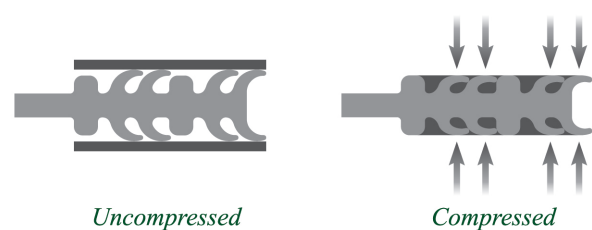


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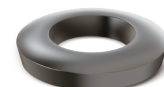
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Inspection excellence: The role of advanced technologies

The accuracy and effectiveness of inspection techniques play a pivotal role in tube replacement decisions. Modern inspection technologies have evolved significantly, offering unprecedented insight into tube condition and degradation mechanisms. Eddy Current Testing (ECT) has emerged as a particularly valuable tool, capable of detecting subtle changes in tube wall thickness and identifying developing corrosion or erosion damage before it reaches critical levels. Ultrasonic testing technologies have also advanced considerably, now offering high-resolution imaging of tube walls and the ability to detect both surface and subsurface defects. These capabilities are particularly valuable in identifying stress corrosion cracking and other challenging failure mechanisms that might be missed by conventional inspection methods. Thermal imaging has introduced new capabilities in performance monitoring, allowing operators to identify flow distribution problems and localized hot spots that might indicate developing tube problems. When combined with traditional hydrostatic testing, these advanced inspection technologies provide a comprehensive picture of exchanger condition and reliability.

Integration of maintenance strategies

Successful tube replacement programs require the integration of multiple maintenance strategies and technologies. This integrated approach begins with

establishing clear performance criteria and acceptable loss thresholds based on system criticality and operational requirements. Regular inspection programs, utilizing appropriate combinations of available technologies, provide the data necessary for informed decision-making. Maintenance planning must consider both immediate operational needs and long-term reliability goals. This often involves developing staged replacement programs that allow for the systematic renewal of tube bundles while minimizing impact on production schedules. The development of detailed maintenance procedures and quality control protocols ensures consistency in replacement operations and maximizes the reliability of repairs.

Conclusion

The management of tube loss and replacement in heat exchangers represents a complex challenge that requires balancing multiple technical, operational, and economic factors. Success in this area demands a comprehensive understanding of degradation mechanisms, careful analysis of operational data, and the application of appropriate inspection and maintenance technologies. The key to success lies in maintaining a proactive, data-driven approach to tube management while remaining flexible enough to adapt to changing operational requirements and emerging technologies. By carefully considering all aspects of tube loss and replacement decisions, organizations can optimize heat exchanger performance while minimizing both planned and unplanned downtime. ■



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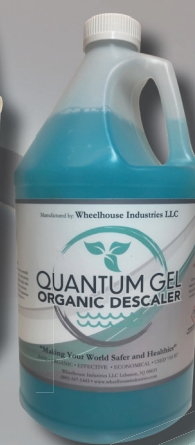
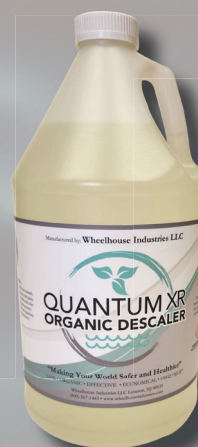
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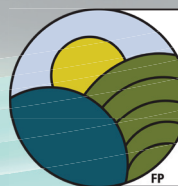
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Product News

Sanhua's AI-driven path toward reliable data center cooling solutions



As the data center cooling market heats up across the world with the onset of AI technology, Sanhua has introduced a flurry of new product offerings designed to meet the exacting requirements of equipment manufacturers and service technicians alike. Data center cooling refers to the various methods and technologies used to maintain optimal temperature and humidity levels in data centers. This is crucial to prevent overheating of servers, storage devices, and other networking equipment, ensuring they operate efficiently and reliably.

Cooling systems can include air conditioning units, liquid cooling solutions, raised floor designs, and advanced techniques, such as free cooling, which uses external cold air. The market includes a wide range of products, including air conditioners, precision air conditioners, liquid cooling, air handling units, chillers, and others.

Among the newest Sanhua products used in this segment are 2-way and 3-way electric ball valves, which use a step motor to control flow. The Sanhua EBV is versatile in that it can also replace the pressure regulating valve, electronic expansion valve, and solenoid valve at the same time, as well as be used as a safety valve to immediately cut off a system circuit in A2L refrigerant equipment. Another highly coveted set of products serving this segment is the Sanhua Braised Plate Heat Exchanger (BPHE) line. All Sanhua BPHE utilize an asymmetrical plate for higher heat efficiency, providing lower pressure drop on the water/glycol side and reducing pump power consumption.

Portuguese olive mill quadruples production capacity



With the installation of Alfa Laval's state-of-the-art Foodec Sigma decanter, Caminhos do Futuro has quadrupled its extra virgin olive oil processing capacity, increasing from 1,500 kg/hour to 6,000 kg/hour. As the last remaining mill in Montemor-o-Novo, the cooperative group recognized the urgent need to evolve in order to continue serving a growing community of farmers seeking to process olives from their groves. "We either modernized the process or lost competitiveness," states José Ferreira, the retired operator who dedicated over two decades to the olive oil mill. Alfa Laval, a trusted technology partner for decades, played a key role in the transformation. "Caminhos do Futuro has always had a vision focused on innovation, and Alfa Laval

has supported us every step of the way," says Nelson Fialho, current general manager. "The decision to invest in a brand-new first-extraction line followed months of careful evaluation and collaboration with their experts to identify the optimal solution for our needs." The mill already had an Alfa Laval olive oil decanter in operation since 1998, along with two high speed separators acquired in 1989 when the first line was installed—all of which remain mechanically efficient today. This reliability reinforced their decision to follow Alfa Laval's recommendation to repurpose the original line for secondary processing. Since 2024, the old decanter has been used to process pomace, making use of previously discarded material.

HRS brings chocolate's sweet spot to PACK EXPO Las Vegas



HRS Heat Exchangers will show visitors to PACK EXPO Las Vegas the benefits of tempering chocolate using the HRS R Series of

rotary scraped surface heat exchangers. It will also demonstrate a number of other highlights from its wide range of heat transfer equipment and systems for the food and beverage industry.

Tempering chocolate is necessary to produce consistently small crystals of cocoa butter when it is heated and cooled. Without this strict temperature control, the crystals formed are of different sizes and the resulting chocolate will 'bloom,' having a matt appearance and waxy texture.

Following a request from a key client who processes bulk chocolate from a number of suppliers, HRS worked with the client to develop

a chocolate tempering solution that could be mounted on a process skid.

The system comprised three HRS R Series rotary scraped surface heat exchangers mounted in series. It significantly sped up processing time and overcame the fact that tempered chocolate solidifies quickly as it cools, so it is important to maintain a working temperature until it has been moulded or poured into the final shape. Ultimately, the new heat exchangers increased the factory's production capacity.

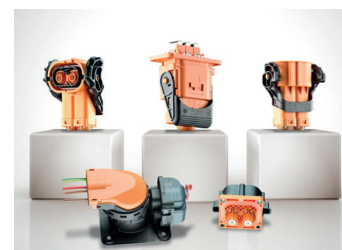
The HRS R Series also allows small solids, such as pieces of nuts or honeycomb, to be included in the molten chocolate without damaging them or the integrity of the product.

BASF's Ultramid T6000 polyamide

Materials giant BASF has developed several new polyamide products for electric and electronics (E&E) applications that require exceptional stiffness and strength. Customers can now choose from a tailored portfolio of PA66/6T compounds. Ultramid T6000 is a high-temperature polyamide that outperforms PA66 in mechanical and dielectric properties in humid and high-temperature

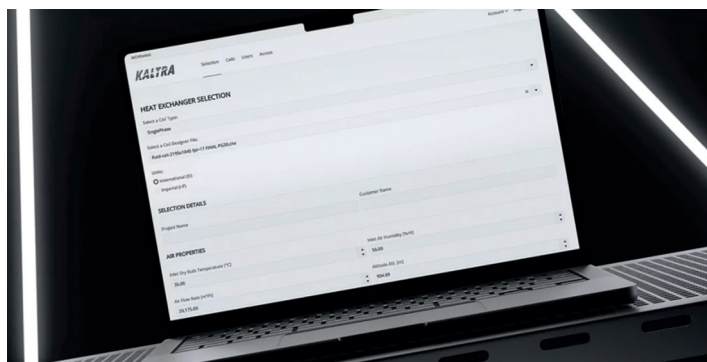
environments. Its lower moisture absorption ensures good dimensional stability. Ultramid T6000 allows for easy processing at low mold temperatures, similar to standard PA66. Due to its good colorability, compounds with different white shades can be manufactured, in addition to durable orange and grey. The flame-retardant grades are equipped with a non-halogenated flame retardant.

Ultramid T6000's good flowability makes it suitable for producing small and complex E&E components such as high-voltage connectors and miniature circuit breakers, as well as parts for electric powertrains and consumer electronics. For example, Ultramid T6340 G6 can be used in high-voltage connectors for EVs to provide a safe and reliable connection between the battery and inverter or between power



distribution and e-motor, even at elevated temperatures.

Kaltra announces AI-powered design mode



Kaltra is pleased to announce a groundbreaking development in its microchannel coil selection software: the integration of an AI-powered design mode, a feature set to launch by the end of 2025. This new "AI Mode" will transform how users approach coil design by providing intelligent, real-time guidance throughout the entire configuration process. Rather than relying solely on manual input and trial-and-error design iterations, users will now be assisted by an advanced algorithm trained to optimize coil parameters based on thermal performance, application type, refrigerant characteristics, physical constraints, and cost-efficiency. The upcoming AI Mode marks a major leap forward in usability and productivity. Designed with both experienced engineers and less-specialized users in mind, the system will: Analyze user input and application data,

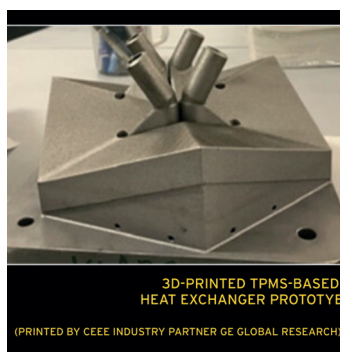
instantly recommending optimal configurations. Suggest design improvements based on best practices and Kaltra's extensive coil design database. Detect inconsistencies or inefficiencies in selections and offer corrective adjustments. Speed up the design process significantly—especially useful for large-scale OEM programs or urgent replacements. While revolutionary in functionality, the AI Mode will be seamlessly integrated into the existing interface of the MCHE selection software. Users can easily toggle between the classic manual approach and the new AI-assisted workflow, preserving flexibility for expert users who prefer fine-tuned control. The new version of the MCHE selection software is currently in the final stages of development, with beta testing scheduled for Q4 2025 and full rollout expected by the end of the year.

Identify Leaks Rapidly with G-Series Tube Testers from Curtiss-Wright



G-Series Tube & Joint Testers from Curtiss-wright enable rapid identification of leaking heat exchanger tubes, facilitating timely maintenance. Advanced features and user-friendly designs provide increased testing efficiency and accuracy. Test tubes from 0.28" to 2.5" (7.1mm to 63.5mm); Standard compressed air 40-125 PsiG (2.7- 8.5 BarG); ANSI N45.2, 10 CFR 50 App. B & 10 CFR 21 compliant; and Lightweight Aluminum construction.

UMD Team develops design optimization framework



In the issue of the International Journal of Heat and Mass Transfer, researchers from the UMD Center for Environmental Energy Engineering (CEE) present a comprehensive design optimization platform for a novel Triply Periodic Minimal Surface (TPMS)-based heat exchanger for high-temperature (900°C) and high-pressure (25 MPa) applications using air and supercritical CO₂ as the working fluids. The next generation heat

SPX FLOW and SIG expand collaboration



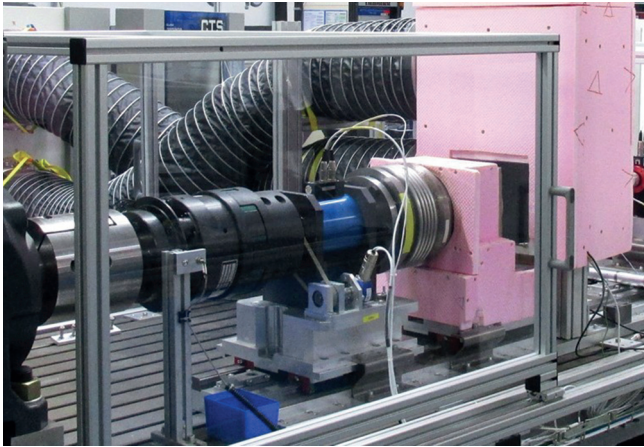
SPX FLOW is expanding its testing capabilities in the Middle East through its collaboration with SIG by enhancing its APV processing equipment housed at the SIG Test Filling Center—part of the SIG Customer Experience Hub in Dubai. This enhancement enables advanced trials, including fermentation, using APV technologies tailored to regional food and beverage needs. Launched in 2021, the current APV pilot line includes a FlexMix Instant vacuum mixer for preparing complex formulations, followed by a multi-UHT pilot system for thermal treatment. This enables the line to process up to 1,000 liters (L) of test product per hour. This first installation introduced SPX FLOW's APV thermal and mixing

technologies to the Middle East. The latest expansion includes: A two-line APV CIP station to enhance sanitary product testing; A new fermentation line that features a 1,000 L tank specifically designed for viscous products; and The line includes an APV plate heat exchanger cooler to support high-quality yogurt production from dairy or plant-based materials. With several successful trials already underway, the Center continues to serve as a strategic hub for SPX FLOW and SIG customers across the region, enabling end-to-end innovation from formulation to packaging. Full commissioning is expected to be complete by next month, further accelerating collaborative development.

exchangers, which showed a 10 times increase in volumetric power density compared to initial designs and are nearly three times smaller than conventional state-of-the-art printed circuit heat exchangers, are expected to push the boundary of efficient thermal management in high-temperature / high-pressure environments such as aviation and power generation. The new framework utilizes a multi-scale modeling approach, allowing for full heat exchanger simulations in seconds, which is significantly faster than the several days typically required to conduct full computational fluid dynamics (CFD) simulations of the same heat exchanger architecture. "The ability to quickly and accurately predict the thermal performance of full heat exchangers is critical for conducting optimization, where tens of thousands – or even more – full heat exchanger

designs are considered," says co-author and CEE Director Vikrant Aute, a research professor in the Department of Mechanical Engineering. The other authors are former CEE researcher Lalith Dharmalingam (M.S. '21), now with Bloom Energy; graduate research assistant Brian O'Malley; and postdoctoral researcher James Tancabel. The framework optimizes heat exchangers that are based on special shapes called Triply Periodic Minimal Surfaces (TPMS) – the most well-known of these structures is the gyroid. At first glance, the undulating shapes look like three-dimensional Spirograph designs, but TPMS aren't kiddie art projects: these complex geometries can pack a large amount of heat transfer area into a small envelope volume, resulting in highly compact heat exchangers.

Liebherr-Aerospace introduces an innovative lubricant



As part of a research and technology program, Liebherr-Aerospace Lindenberg GmbH (Germany) and dedicated lubricant manufacturers have, during the last four years, jointly developed a lubrication fluid that meets the challenging temperature conditions in aviation. One of the objectives was to achieve a constant friction ratio over a wide temperature range. This is required to ensure long term stability and performance of no-back brakes contained in actuators during the entire service life cycle of an aircraft.


In the automotive industry, so called "automatic transmission fluids" are used for a similar reason relating to friction. However, the products currently available on the market for this purpose are not suitable for the low temperatures required in aviation due to their high

viscosity. Therefore, the team developed a new formulation of these lubricants that provides the desired friction coefficient stability in a low-viscosity and therefore low-temperature compatible version. Synthetic hydraulic oils that are currently used as lubricants for aviation actuators and gearboxes change their viscosity depending on the fluid temperature. Compared to these lubricants, the new one not only demonstrated the desired friction coefficient consistency in an endurance test but also improved low-temperature efficiency and corrosion protection. It therefore represents a further building block in continuous product improvement of aviation products and demonstrates the relevance of lubricants to be considered as a "wet design element" as part of aircraft engineering and certification.

SunCoke Energy, Inc. completes Phoenix Global acquisition


SunCoke Energy, Inc. (SXC) (SunCoke) has completed its previously announced acquisition of Phoenix Global (Phoenix) for USD 325M. SunCoke has acquired all of the common units of Flame Aggregator, LLC, which, together with its subsidiaries, operates as Phoenix Global. The transaction was funded with cash on-hand and revolving credit facility borrowing. The acquisition of Phoenix adds electric arc furnace operations and international markets to SunCoke's portfolio. "We are thrilled to officially welcome Phoenix into the SunCoke family," said Katherine T. Gates, President and CEO of SunCoke. "This successful

acquisition is the result of SunCoke's disciplined pursuit of growth opportunities that will position us for long-term, sustainable earnings growth and increased shareholder value. We are excited by the opportunity to reach new customers and new markets with the addition of Phoenix's assets. We will leverage SunCoke's core strengths, including our advanced technology, operational discipline, and strong financials, to support and grow these new operations." Evercore Group L.L.C. served as the exclusive financial advisor to SunCoke, and Latham & Watkins LLP served as SunCoke's legal advisor.




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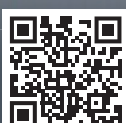
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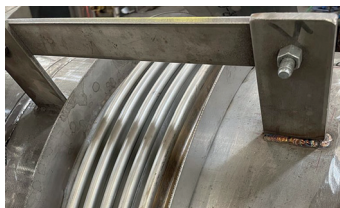
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Project News

Expansion joints in heat exchangers

In order to exchange heat, a heat exchanger always has a hot side and a cold side. The hotter fluid can be on either the shell or tube side, but the two sides are always at different temperatures. The temperature difference between the shell and tube materials causes them to expand and contract relative to each other. This thermal movement, known as differential thermal expansion, creates stress in any fixed-tubesheet heat exchanger. As part of the ASME code calculations, the shell, tubesheets, and tubes all must be checked to make sure they can handle these thermal stresses.



If the stress becomes too high for any component, a designer can add an expansion joint to the shell. This joint adds flexibility to the shell and reduces the thermal stresses. Expansion joints are crucial in maintaining the integrity and longevity of the heat exchanger by accommodating large thermal differences.

Caverion to deliver heating and cooling systems in Berlin

Caverion has won a project to provide heating and cooling systems for the new building of the German Federal Chancellery in Berlin.

The expansion will be built next to the existing Federal Chancellery in compliance with the Bund 40 (EGB 40) energy efficiency building standard. Caverion will deliver state-of-the-art heating and cooling systems to support the building's resource efficiency. The new building will have a gross floor area of around 57,000 m²,

including, among others, 400 office rooms spread over six floors, a canteen, a day care center, and an official residence. "The expansion is designed by Schultes Frank Architekten, whose plans were also used to build the existing Federal Chancellery. Caverion was involved in the construction of the existing building in the 1990s, and we are honoured to take part also in its expansion", says Manfred Simmet, CEO of Caverion Germany, EVP.

Valmet receives an order from Saica Group



Valmet has received an order from Saica Group (Sociedad Anonima Industrias Celulosa Aragonesa) to supply a biomass boiler and flue gas cleaning system for Saica Group's plant in El Burgo de Ebro, Zaragoza, Spain. The order is included in Valmet's orders received for the second quarter of 2025. The value of the order will not be disclosed. The boiler plant is scheduled to be handed over to Saica at the end of 2026.

The boiler to be supplied is a Valmet BFB boiler that utilizes bubbling fluidized bed (BFB) technology. It is engineered to produce steam with a capacity exceeding 700,000 tonnes annually. By utilizing biomass as fuel, the BFB boiler will significantly reduce fossil fuel consumption and CO₂ emissions, aligning with Saica's dedication to sustainability and circular economy principles.



Holcim, E.ON, and Orcan Energy launch joint large-scale project

E.ON Energy Infrastructure Solutions GmbH, leading cement manufacturer Holcim, and Orcan Energy are launching a joint large-scale waste heat recovery project at the Holcim cement

factory in Dotternhausen. The aim is to efficiently recover previously unused industrial waste heat and make it available for self-supply, local heating networks, and electricity generation. The

strategic partnership is a prime example of a forward-looking approach to greater energy efficiency and decarbonization in the energy-intensive cement industry.

In order to utilize the previously unused waste heat from the exhaust gases of the rotary kiln at the Holcim site in Dotternhausen, around 10 megawatts of thermal power is extracted at a height of around 70 meters via a heat exchanger. Then, it is fed into a high-temperature thermal oil cycle, which transports it to the various heat sinks.

Part of the energy is used for internal processes. In addition, the connection to potential district heating networks is planned. Besides the use in cement production and district heating

networks, power generation through Orcan Energy's highly efficient ORC (Organic Rankine Cycle) technology is a central element of the project. The new high-performance eP1000 system, which was developed specifically for large-scale industrial applications, is applied. The turbine at the heart of the plant remains highly efficient in both full-load and part-load operation, enabling it to respond flexibly to fluctuating heat quantities.

E.ON is responsible for the planning, construction, financing, operation, and maintenance of the plant as part of an Energy-as-a-Service model. For Holcim, this means no initial investment, but sustainable energy savings and CO₂ reductions over the entire term.



SLB awarded carbon storage contract for NEP project in the UK

Global energy technology company SLB has been awarded a technologies and services contract for carbon storage site development in the North Sea by the Northern Endurance Partnership (NEP), an incorporated joint venture between bp, Equinor, and TotalEnergies. NEP is developing onshore and offshore infrastructure needed to transport CO₂ from carbon capture projects across Teesside and the Humber — collectively known as the East Coast Cluster — to secure storage under the North Sea. SLB will deploy its Sequestri™ carbon storage solutions portfolio — which includes technologies specifically engineered and

qualified for the development of carbon storage sites — to construct six carbon storage wells. The project scope includes drilling, measurement, cementing, fluids, completions, wireline, and pumping services. The NEP infrastructure is crucial to achieving net zero in the UK's most carbon intensive industrial regions. NEP, via the Endurance saline aquifer and adjacent stores, has access to up to 1 billion metric tons of CO₂ storage capacity. The infrastructure will transport and permanently store up to an initial 4 million metric tons of CO₂ per year, with start-up expected in 2028.



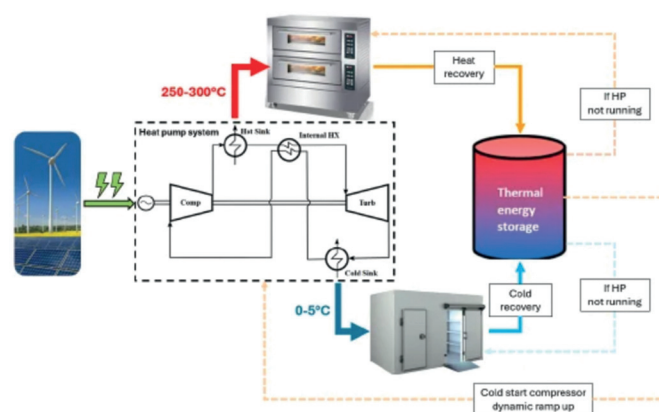
Casen heat transfer enables green methanol cooling at Tiaonan demo project



Shanghai Electric's landmark Tiaonan Wind-Power-Coupled Biomass Green Methanol Integrated Demonstration Project officially commenced commercial operation, marking China's first "zero-to-scale" breakthrough in green methanol production. The inaugural phase will produce 50,000 tonnes per year of renewable methanol, destined for use as marine fuel aboard CMA CGM container vessels, initiating the "Tiaonan Production – Land-Sea Intermodal – Shanghai Bunkering" international supply chain.

As the exclusive cooling-system supplier for the country's first large-scale green methanol plant, Casen Heat Transfer Technology Co., Ltd. provided end-to-end thermal management solutions, from design and fabrication through commissioning and ongoing lifecycle service. Leveraging industry-leading expertise, Casen's team ensured precise temperature control across key process units—hydrogen generation, vaporization, and synthesis—safeguarding stable operation and high-quality product output.

MG has been awarded a grant for the BREAD project



MG has been awarded a grant from the CET Partnership joint call 2024, consisting of 7 partners from Germany, Sweden, and Belgium. The overall aim of the project BREAD is the development of a sub-Megawatt (MW) scale heating and cooling system that will provide heat at temperatures above 250 °C and cooling around 0 °C and below. It will smartly integrate heat pump, heat exchanger, and heat storage technology. The project BREAD addresses the development of a sub-Megawatt (MW) scale heating and cooling system that will provide heat at temperatures above 250 °C (up to 400 °C) and cooling around 0 °C

and below. It will smartly integrate heat pump, heat exchanger, and heat storage technology. In the future, green electricity will play a significant role as a "primary" energy source for industries, and new innovations are needed to accomplish the transformation of industrial electrification. BREAD has the ambition to go beyond state-of-the-art in the following fields: Reversed Brayton Cycle Heat Pump for Sub-MW-range (from TRL3 to TRL5); Compressor/Expander (Turbomachine) (from TRL3 to TRL5); and High-Temperature and Low-Temperature Thermal Energy Storage (from TRL3 to TRL5).

McDermott awarded offshore contract by BRAVA Energia

McDermott has been awarded a sizeable offshore transportation and installation contract by BRAVA Energia, the most diversified independent oil and gas company in Brazil, for the Papa-Terra field in the Campos Basin and the Atlanta field in Block BS-4 within the Santos Basin, both offshore Brazil. Under the contract scope, McDermott will execute the transportation and installation of flexible pipelines, umbilicals, and

associated subsea equipment for two new wells at the Papa-Terra field and two new wells for the Atlanta Phase 2 development. The scope also includes pre-commissioning and onshore base support services. Operated by BRAVA Energia, the new wells at the Papa-Terra and Atlanta fields will support production ramp-up as part of the company's ongoing strategy to increase output and extend the



life of deepwater infrastructure. McDermott previously delivered the Papa-Terra tension leg wellhead platform — the first dry-tree

floating production system offshore Brazil and the first tension leg platform installed in South America at the time.

Al-Ittefaq Steel partners with Strataphy

Al-Ittefaq Steel Products Company (ISPC), the largest private steel producer in the Middle East, has joined forces with Strataphy to introduce geothermal-powered Cooling as a Service (CAS) for its facilities. This partnership marks the first time in the region that advanced geothermal cooling has been applied to a hard-to-abate sector such as steel manufacturing, significantly cutting carbon emissions while boosting energy efficiency. "Steelmaking is one of the most energy-intensive industries globally, and reducing its CO₂ footprint has long been a challenge," said Abdul Hadi A Al Yousef, Deputy COO of ISPC. "This partnership is a bold step toward transforming how we manage thermal loads in our operations.

By adopting Strataphy's cutting-edge geothermal technology, we are not only reducing costs but also demonstrating leadership in industrial sustainability." "I met with Strataphy's team and was truly impressed by their pioneering solutions tailored to the demanding cooling needs of steel production. Our plants require continuous, large-scale cooling, and Strataphy's Cooling as a Service model—powered by their proprietary subsurface technology—not only offers reliable and sustainable performance but also delivers significant energy, water, and chemical savings," said Ayaz Rizwan Khan, Senior Manager of Utility, Maintenance & Projects at Arab Steel Company (ISPC Group). "Their tech-driven approach is a



remarkable example of innovation that aligns perfectly with Saudi Arabia's Vision 2030 sustainability

goals. I wish them every success in introducing this revolutionary solution to our region."

Brenmiller Energy signs private placement agreement

Brenmiller Energy Ltd. (Brenmiller), a global provider of thermal energy storage (TES) solutions for industrial and utility customers, has entered into a securities purchase agreement with Alpha Capital Anstalt (Alpha). Pursuant to the terms of the Securities Purchase Agreement, the Company agreed to issue and sell to Alpha, subject to certain conditions, up to an aggregate of USD 25M in securities across multiple tranches, consisting of preferred shares, pre-funded warrants, and ordinary warrants. The proceeds from the financing will be used for general corporate purposes, working capital, and

the execution of Brenmiller's commercial TES projects across Europe, the U.S., and the Middle East. Under the terms of the Securities Purchase Agreement, subject to certain conditions and as long as any Preferred Shares or Additional Ordinary Warrants are outstanding, Alpha also has the right to purchase additional preferred shares and warrants from the Company up to an additional USD 20M (Subsequent Financing). The Securities Purchase Agreement also provides for certain additional funding by Alpha after the Equity Closing, which can come in the form of



warrant exercises, Subsequent Financing, or other financing arranged by Alpha (the Additional Funding), subject to certain conditions, up to USD 15M, over

a two year period beginning after the Equity Closing. Assuming full exercise of all warrants, the overall financing from Alpha may reach USD 50M.



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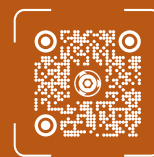
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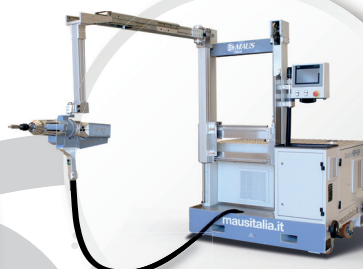
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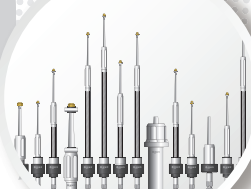
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