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CONTENTS ///

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Ceramics Expo has been joined at the Huntington Convention Center of Cleveland by two co-located events: Thermal Technologies Expo and High Performance Plastics Expo. This exciting new partnership gives Ceramics Expo visitors the opportunity to discover the very latest thermal management technologies and innovations, plus the latest high performance plastics and polymers solutions. Your free Ceramics Expo 2022 pass gives you access to both Thermal Technologies Expo 2022 and High Performance Plastics Expo 2022.

DEPARTMENTS ///

UPDATE ///

New Products, Trends, Services & Developments

Q&A ///

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ZIRCAR CERAMICS

RESOURCES ///

International Federation for Heat Treatment (IFHTSE)

The international association whose primary interest is heat treatment and surface engineering shares news of its activities to promote collaboration on issues affecting the industry. **16**

Industrial Heating Equipment Association (IHEA)

The national trade association representing the major segments of the industrial heat processing equipment industry shares news of it's activities, training, and key developments in the industry. **18**

METAL URGENCY ///

The chemical composition of Alloy 718 makes it suitable for manufacturing aerospace hardware via additive manufacturing. **20**

HOT SEAT ///

Two independent types of agitation used for measuring the cooling curve behavior of polymer quenchants show repeatable results within their bias and precision. **22**

QUALITY COUNTS ///

Managing quality control during heat treating is a crucial task that can speed up or slow down a system. **24**

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FROM THE EDITOR ///

Process control and pyrometry – a closer look

The March issue of *Thermal Processing* takes a deep dive into activities vital to the heat-treat industry, namely pyrometry and process control, and you'll find quite a few articles this month that deal comprehensively with those subjects.

Process control is an integral part of Epcon Industrial Systems, and Epcon's Tasha Jamaluddin shares her expertise on the use of sophisticated controls systems for optimal process operations and critical output quality.

On the subject of pyrometry, Ralph Felice with FARR Associates takes a look at the history of pyrometry and how it has evolved to tackle the problems of non-contact temperature measurement.

And don't miss out on what to expect from our monthly columnists:

›› D. Scott Mackenzie discusses the characterization of polymer quenchants.

›› In Quality Counts, Shaun Kim looks at how technology is the key to improving the efficiency of managing quality control.

›› And in Metal Urgency, I'm happy to welcome back Dr. Tri Shrestha with Metcut Research. He'll be sharing his insights several times in the coming year. In this issue, he looks at the microstructural effect of Alloy 718 on fatigue strength.

That's just a taste of what you'll find in this month's issue of *Thermal Processing*.

It's been more than a year since we debuted our Media Portal on our website, so I wanted to remind you that it can be an invaluable resource to direct you to the latest social media from heat-treaters from all across the map. It's one-stop shopping for social media, webinars, podcasts, blogs, and more. Head to our website and give it a go, and let me know what you think.

I also want to take the opportunity to say that if you're looking for a forum to share your expertise, please hit me up with suggestions at the email below so we can continue to make *Thermal Processing* the best heat-treat source it can be.

As always, thanks for reading!

KENNETH CARTER, EDITOR
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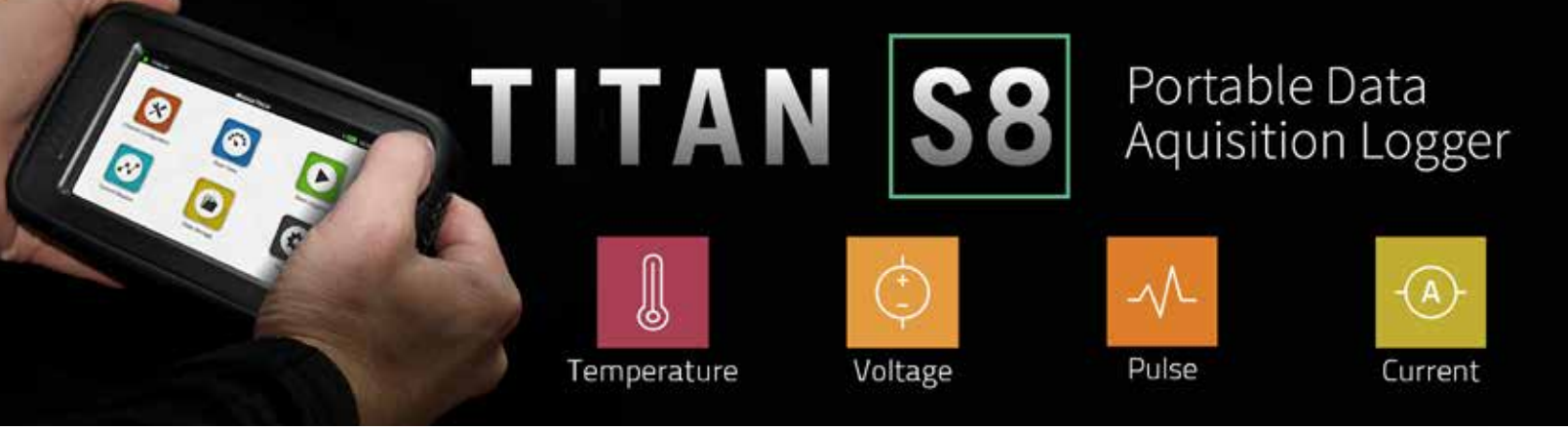

The **MadgeTech Titan S8** is a portable, multi-use data logger with eight input channels, one configurable alarm output and a user-friendly touchscreen interface. The Titan S8 is a complete, all-in-one solution that does not require a PC or any downloaded software for operation. This means the device is truly ready for use at a second's notice.

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Ipsen now offers in-the-field ultrasonic wall thickness testing for vacuum furnaces. (Courtesy: Ipsen)

Ipsen expands services with wall thickness testing

Ipsen has expanded its field service capabilities to include ultrasonic wall thickness testing for vacuum furnaces. The test helps customers verify the integrity of their chamber and determine its remaining lifespan.

"Having a better understanding of the furnace's condition will result in more accurate maintenance planning," said Ipsen chief service officer John Dykstra. "Customers can have peace of mind knowing their furnace is safe for operation, while also preparing for future repairs or replacement."

Vacuum chamber wall thickness testing is a service provided by Ipsen's field service engineers using an ultrasonic inspection instrument. This non-destructive method requires only the removal of a small amount of paint at each desired test point.

Ipsen's service team works with the engineering department to determine the appropriate thickness for each chamber wall, and whether it passes or fails to meet the ASME Pressure Vessel Code. When the test concludes, customers receive a detailed report charting the thickness of the chamber wall across a wide range of areas, as well as maintenance and repair recommendations.

MORE INFO www.ipsenusa.com

Celsa France chooses Tenova's NextGen® and iEAF®

Tenova Goodfellow Inc. has received an order from Celsa France for the supply of one iEAF® technology platform using the NextGen® System for their 150-ton scrap AC top charge furnace in Boucau, France.

Tenova Goodfellow Inc. is a subsidiary of Tenova. Celsa France is an EAF steel producer specialized in the production of steel billets from steel scrap. This order from Celsa France represents the third NextGen system to be installed in Europe, one of the more than 15 systems installed worldwide.

The scope of supply will include Tenova's state-of-the-art NextGen hardware for upstream off-gas measurement, which is the first critical step that enables all software solutions, including mass and energy balance that is needed for achieving net energy and melting-percent control with iEAF technology. Also included is optical temperature and velocity measurement, HMI for process data, and optimization support.

"We are pleased to continue our long-standing relationship with Tenova," said Nicolas Claveranne, production manager at Celsa France and project manager for this project. "The NextGen references — we are sure — will bring added value to the steelmaking operations of our plant."

"Since the beginning of this project the cooperation with Celsa France has been fruitful, and we have worked together to fulfill its targets. As per our heritage, our support will continue during the implementation and the execution of this project to reach the expected results," said Davide Masoero, area manager Europe Electric Arc & Ladle Furnace at Tenova.

Engineering, installation and commissioning of Tenova's digital platform technologies for Celsa France is scheduled for late spring 2022. (Courtesy: Tenova)

SEND US YOUR NEWS Companies wishing to submit materials for inclusion in Thermal Processing's Update section should contact the editor, Kenneth Carter, at editor@thermalprocessing.com. Releases accompanied by color images will be given first consideration.

It might seem that the tire industry does not use the solutions that are needed for metal heat treatment, but the tools and dies used in the production process are mostly treated in vacuum furnaces. (Courtesy: Seco/Warwick)

Engineering, installation and commissioning of Tenova's digital platform technologies is scheduled for late spring 2022.

MORE INFO www.tenova.com

Seco/Warwick to support Michelin tire manufacturing

Seco/Warwick will deliver to Michelin — the largest European tire manufacturer — a compact Vector® vacuum furnace with a 400x400x600mm heating chamber. It will be indispensable for the gas hardening process used in the manufacture of tools for premium tires.

"With a relatively low expenditure, the compact Vector vacuum furnace makes it possible to become independent from third parties. It also provides better control over the quality of heat-treated components and reduces the risk of delays which, as a result of lack of deliveries, slow down or obstruct manufacturing processes (tire manufacturing in this case). This is a very reasonable approach with a proven furnace design utilizing a round heating chamber, ergonomic pumping system, and a powerful cooling system based on a blower that ensures the maximum hardening pressure up to 15 bar abs," said Maciej Korecki, vice-president, vacuum furnace segment, Seco/Warwick Group.

At first sight, it might seem that the tire industry does not use the solutions that are needed for metal heat treatment. Few know that tire production requires specialized tools. The tools and dies used in the production process are mostly treated in vacuum furnaces. Most of tire manufacturers engage third-party hardening plants for that purpose. However, owning the device not only ensures market independence but also time and money savings.

The Vector vacuum furnace enables highly efficient hardening processes thanks to the use of high pressure and cooling gas. Vector vacuum furnaces can be used for the majority of standard hardening, tempering, annealing, solution heat treating, and brazing processes. However, a device can always be adapted to the specific requirements of the customer and thus to the particular industry. The device is available in several sizes, so its output perfectly fits the customer's needs. The Vector range is characterized by low consumption of energy and heating chamber performance as well as clean and quick processing. This flagship Seco/Warwick product is already in operation in more than 70 countries worldwide, working for industries such as aviation, automotive, and defense.

Michelin is the largest in Europe, and one of the largest global tire manufacturers. Its headquarters is located in Clermont-Ferrand (Puy-de-Dôme), France. The company manufactures tires mostly intended for passenger vehicles, trucks, agricultural machinery, and motorcycles as well as bicycle tubes and tires, and aircraft and space shuttle tires. Michelin has 56 production plants in 17 countries as well as three technology centers in France, Japan, and the United States. The Polish Michelin plant employs 4,126 people and is the largest Michelin plant around the world in terms of the number of employees, and ranks third in terms of production capacity.

MORE INFO www.secowarwick.com

Nitrex to deliver automated nitriding cell to manufacturer

Nitrex has secured additional business with one of the biggest automotive manufacturers in China. This is the third order from the customer, and in this phase of development, the company will install a second automated heat-treating cell for nitriding automotive parts.

As part of the company's third phase of growth, the new Nitrex automated cell, which will be placed adjacent to the first cell, aims to expand production capacity to meet increasing market demand. The investment in capital equipment will allow the customer to bring the production process in-house for greater control, flexibility, and enhanced effectiveness.

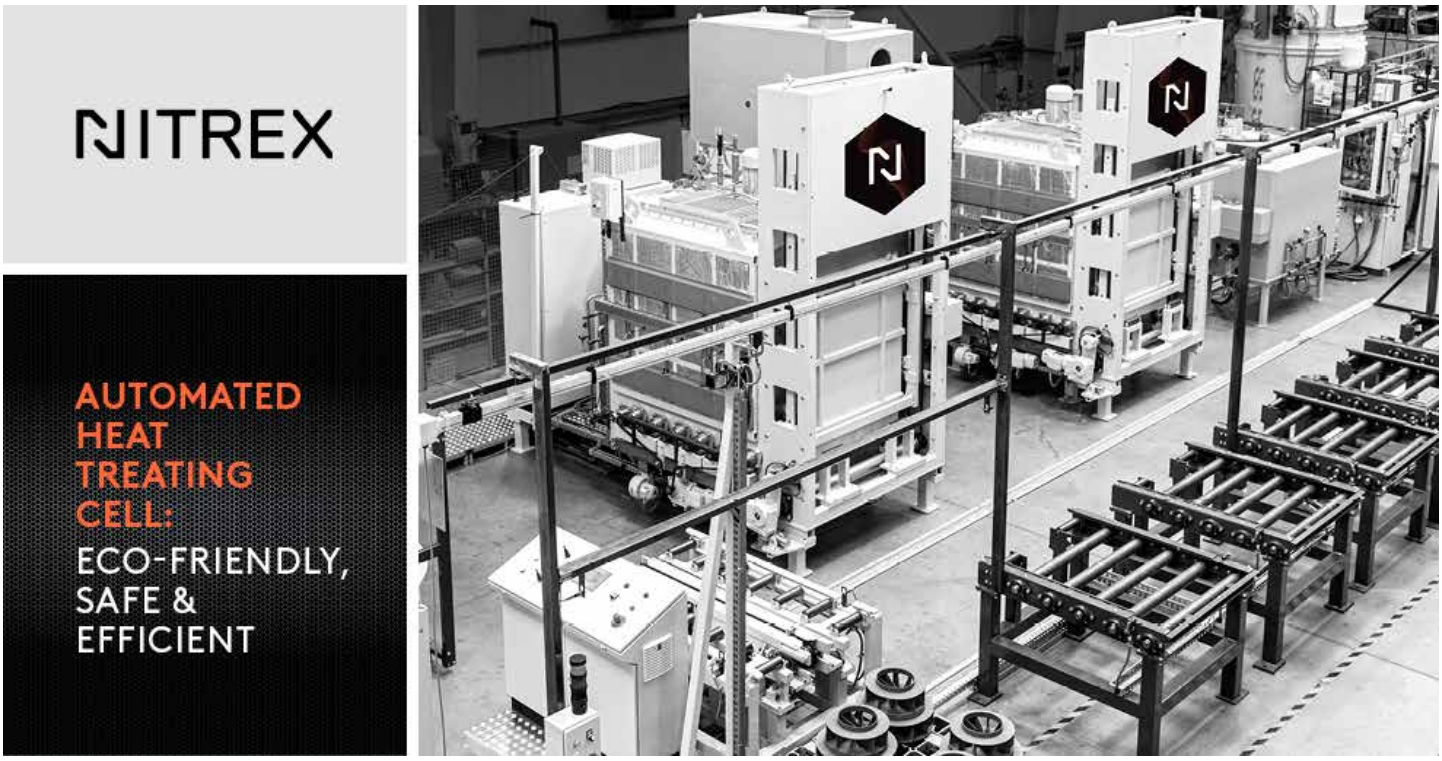
The decision to choose Nitrex as the single contractor for the full scope of the project was based on Nitrex's holistic approach and expertise in plant automation solutions and capabilities as well as the quality and dependability of previous system installations. Additionally, the Nitrex eco-friendly solution met the customer's requirements for green manufacturing and responsible growth now and into the future.

Nitrex will undertake almost all aspects of the cell for 24/7 lights-out manufacturing: furnaces, charge cars, loading/unloading and magazine tables, and auxiliary equipment (e.g., atmosphere neutralizer, water cooling stations, charge cooling station, etc.). All equipment will be connected to the Protherm 9800 automation platform for automatic handling and processing, which improves workflow efficiency, process reliability, furnace utilization, work order tracking, and real-time performance metrics.

For this latest order, six continuous flow-through nitriding systems, furnace model NXHL-910512, were ordered to create the fully automated cell. Delivery is planned for August 2022, and the cell should start operating in the fall.

Previously, during phase 1, three nitriding furnaces were delivered in August 2021 to create the first automated cell. Satisfied with the development and cooperation with Nitrex and the turnkey systems and Nitreg® technology, the customer ordered three more furnaces for phase 2 to complete the cell. These last three nitriding systems are currently under production and will be delivered in April 2022.

The complexity of this project is what



As part of an automotive company's third phase of growth, a new Nitrex automated cell will be placed adjacent to the first cell, aiming to expand production capacity to meet increasing market demand. (Courtesy: Nitrex)

makes it unique and interesting, as the automated cell is responsible for automatic loading/unloading, processing, and transport.

"A cell means that there is a dedicated area in the facility with entry and exit points," said Marcin Doroszko, engineering manager at Nitrex. "The cell controls the entire operation and smartly organizes the transport of charges between these points and the process stages in between. Upon entry, a trolley/charge car takes the charge to the washer, where the load is automatically cleaned. The charge is then moved to the furnace to be nitrided. With this stage complete, the load exits the cell and is transferred to the warehouse."

"This chain of events helps increase the plant's efficiency and productivity: The cell selects the furnaces in which it is possible to place consecutive batches or delivers the batches to several furnaces to process. Since charges are transferred to a cooling station outside the furnace, the furnace can continuously process batches without affecting the workflow and productivity," said Nikola Dzepina, international account executive. "This is a huge process simplification for the furnace operator and enables an automatic and autonomous operation of the area of the plant that controls surface treatment, allowing to increase productivity but also to maintain the repeatability of results. This deeply integrated and optimized approach is the future of heat treatment."

MORE INFO www.nitrex.com

L&L receives furnace order for precious metal recovery

L&L Special Furnace Co., Inc. received an order for 10 model GS1714 general-purpose, bench-top lab furnaces.

These furnaces will be used as part of a precious metals recovery system for a worldwide manufacturer of catalytic convertors, medical devices, and pollution environment controls. The assay division recycles many parts that were originally deployed as catalytic convertors for diesel motors, medical components, and electrical parts. The project is expected to be completed in the first quarter of 2022.

The precious metals are burned out of the existing product and placed in crucibles. The crucibles are heated in the L&L model GS1714 at temperatures between 1,800°F/982°C and 2,200°F/1,204°C. This allows any impurities in the metals to rise to the surface and be removed for further refinement.

The model GS1714 has an effective work zone of 10" high by 15" across by 13" deep. The furnace is designed to be placed on a bench top or with an optional furnace stand. It has a Honeywell DCP50 program control and overtemperature protection system. Solid-state relays drive the element circuit and Inconel sheathed thermocouples are included. There is a 3/4" alloy outlet on top of the furnace to remove any binder or contaminants that may exist within the product. Special anticorrosive paint helps in the harsh environment that the furnaces are required to operate. Part of the recovery process involves salt baths as well as other burnout processes in the same vicinity as the assay furnaces.

Also available is the larger GS2026 with all of the same options as the GS 1714 but featuring a work zone of 18" wide by 12" high by 24" deep.

The GS1714 bench-mounted box furnace. (Courtesy: L&L Furnace Co.)

The model GS1714 is typically in stock at L&L and available for immediate delivery. L&L can ship even special GS1714 furnaces in about two weeks after receiving the order.

MORE INFO www.llfurnace.com

Software companies team on pyrometry compliance

C3 Data's real-time pyrometry compliance status can directly inform Bluestreak™, a leading heat-treat manufacturing execution system (MES) and quality management system (QMS) whether parts about to be loaded into a specific furnace meet AMS2750 compliance.

This collaboration enables two informational platforms to work in unison, effectively eliminating human-error-prone (manual) processes associated with pyrometry compliance. Since Bluestreak™ is already being used by many heat treaters for quoting and sales, work order entry and management, scheduling of jobs, production control and real-time job-step tracking, quality management, and compliance assurance and documentation control, now operators will have the C3 pyrometry compliance connected to Bluestreak™ in real-time.

Both Bluestreak™ and C3 Data have built their solutions designed specifically for the heat-treat industry. Every heat-treat job has its own unique requirements, customer/part specifications, compliance requirements, preferred list of vendors, operational constraints, and audit management procedures to control, track, and document each individual job and work order.

"Our partnership with C3 Data is a logical one because we both excel in data integration and specification management. Bluestreak's integrated quality manage-

ment system ties quality control and quality assurance directly to production work centers, individual operator accountability, and equipment maintenance and management, including furnaces. Both companies help clients pass audits with ease and clarity, every time," said Todd Wenzel, president of Bluestreak.

Bluestreak's I MES I QMS™ suite of production control and quality management tools has been used successfully by heat treating, finishing, forging, powder coating, plating, etc., businesses since 2005. Bright AM™ is designed exclusively for the additive manufacturing environment, where the primary focus is quality processing and operations control. Bright AM can be customized to mirror AM's unique business workflows.

C3 Data provides a dynamic software platform built specifically for the thermal-processing industry to help ensure furnace compliance to any number of industry pyrometry requirements. C3 Data provides other services to heat treaters and calibration labs, including managing sensors, standards, technicians, scheduling, data collection, label printing, report generation, quality approval, audit preparation, training courses, and consulting.

MORE INFO www.go-bluestreak.com
www.c3data.com

CPMT appoints Pfingstler as new president

Thomas Pfingstler, Atlas Pressed Metals, DuBois, Pennsylvania, has been appointed president of the Center for Powder Metallurgy Technology (CPMT), succeeding Arthur (Bud) Jones, Symmco, Inc.

Thomas Pfingstler

Pfingstler, a longtime member of APMI International and the Metal Powder Industries (MPIF) Standards Committee, received the MPIF Distinguished Service to Powder Metallurgy Award in 2019. He has a well-rounded understanding of the PM technology and unique view of part design, production, and business management, honed during his nearly 40-year career that includes management positions in various production, quality, engineering, and purchasing areas. Pfingstler has a BS degree in management from Clarion University.

MORE INFO cpmtweb.org

Dri-Vault 253610 low-temperature infrared oven for laboratory and small-batch applications up to 230°F/110°C filters particulates, exhausts fumes. (Courtesy: Vastex Industrial)

Vastex adds low-temperature cabinet oven

Dri-Vault™ 253610 low-temperature infrared cabinet oven for heating, drying, curing, and conditioning of bonded or coated parts has been introduced by Vastex Industrial.

Intended for small scale production and laboratory applications, it features a double walled enclosure with positive-pressure filtered air flow to prevent particulates from entering the chamber, and a four-inch (10 cm) exhaust duct to remove moisture and fumes. Latched doors with gaskets maintain total darkness during operation.

The 177 CFM (5 CMM) blower draws filtered air over an industrial stainless-steel finned heater at 1,250 watts (120V) or 1,550 watts (240V). Digital temperature controls allow variable settings from air-only up to 230°F/110°C in one-degree increments.

Non-corrosive, coated steel racks measuring 25 inches (63.5 cm) wide x 36 inches (91.4 cm) deep are vertically adjustable to fit items up to 24 inches (61 cm) tall.

Warrantied for three years, the unit measures 39.5 inches (100 cm) deep x 34.75 inches (88 cm) wide. Height is 32 inches (81 cm) with optional casters, 29 inches (74 cm) without.

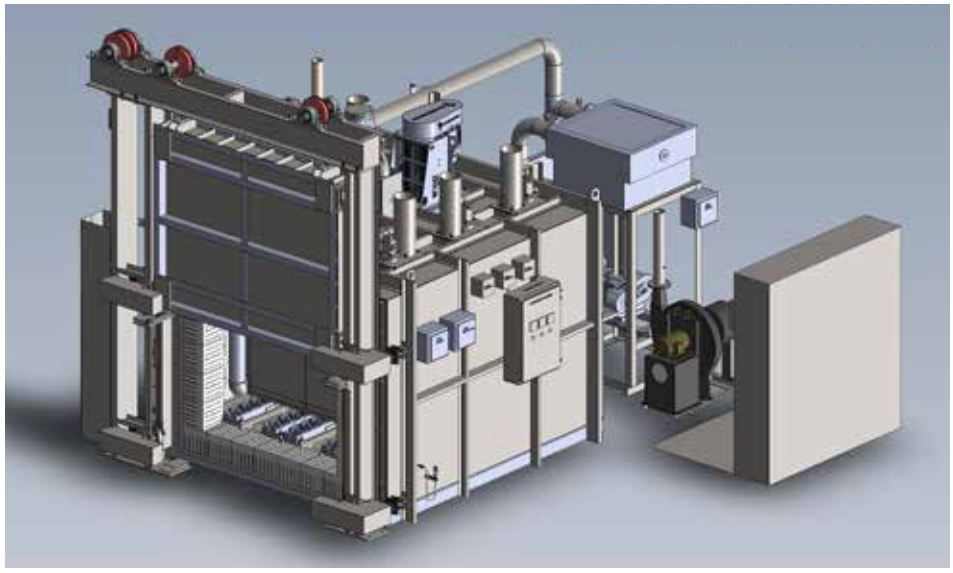
Vastex Industrial manufactures two larger models of cabinet ovens and 11 models of high-temperature tunnel ovens for pilot testing up to high capacity production.

MORE INFO www.vastexindustrial.com

Gasbarre TPS ships batch sintering furnace

Gasbarre Thermal Processing Systems shipped a 60" wide x 90" deep x 30" tall atmosphere box sintering furnace.

The batch sintering furnace will be installed at Mueller Brass Co., a major supplier of brass rod and forgings in the United States. The box furnace is designed with a maximum operating temperature of 1,650°F, a capacity of 14,000 pounds, and uses a nitrogen atmosphere. The system incorporates an Allen-Bradley PLC with SSi 9130 control and 12.1" HMI display. The indirect fired gas heating system incorporates parallel positioning control for efficiency and process flexibility. An integrated oxygen analyzer ensures proper furnace environment prior to heating. The accelerated gas cooling system improves floor-to-floor cycle time for the customer's production needs.



The Gasbarre Thermal Processing Systems batch sintering furnace will be installed at Mueller Brass Co., a major supplier of brass rod and forgings in the United States. (Courtesy: Gasbarre)

Gasbarre was selected as the equipment manufacturer based on their expertise in material processing, responsiveness to ser-

Aalberts Surface Technologies is a global company with more than 80 years of experience, operating in more than 70 countries. (Courtesy: Seco/Warwick)

vice the end user, and positive experiences with prior equipment purchases.

With locations in Livonia, Michigan; Cranston, Rhode Island; and St. Marys, Pennsylvania, Gasbarre Thermal Processing Systems has been designing, manufacturing, and servicing a full line of industrial thermal processing equipment for nearly 50 years. Gasbarre's equipment is designed for the customer's process by experienced engineers and metallurgists who understand the requirements.

MORE INFO www.gasbarre.com

Aalberts Surface Technologies continues expansion

Seco/Warwick equipment has been selected again by the international Aalberts Surface Technologies Group. The company already owns nine Seco/Warwick solutions, and this contract is the third one associated with the expansion of the machinery base in Dzierżoniów.

Aalberts Surface Technologies owns Seco/Warwick equipment working with both vacuum and atmosphere technology. This time, the Dzierżoniów hardening plant will receive an innovative AFT process line that is based on two-chamber atmosphere furnaces.

The delivery of new devices includes a third main furnace, tempering furnace, and an endothermic atmosphere generator as well as loading and unloading devices along with the auxiliary infrastructure.

"This contract covers a main AFT type atmosphere furnace, intended for carburizing, hardening, nitrocarburizing, and annealing processes," said Piotr Skarbiński, vice president, business segment atmosphere furnaces, Seco/Warwick Group. "The furnace is perfect for manufacturing processes for various transmission components, enabling the use of both conventional load arrangements with modular accessories (mesh, grids or 'cross-bars') as well as hardening baskets," Skarbiński said.

Customers who operate specialized hardening plants demand versatile solutions enabling them to carry out many different metal treatment processes. When deciding on the expansion of a hardening plant, one does not only take into account the equipment capacity, but also its versatility, reliability, and the necessary support. Commercial hardening plants do not allow for production outages; they should be ready 24/7 and their machinery should provide as many services as possible. Seco/Warwick has expanded the machinery base in many commercial hardening plants.

"Our earlier contract dating back to 2018 covered the first delivery of heat treatment furnaces for the new hall at Aalberts Surface Technologies in Dzierżoniów. But overall, this is our ninth contract with the group. The previous orders covered, for example, Vector vacuum furnaces or a three-chamber CaseMaster Evolution-T vacuum furnace. Last year, we delivered to the Netherlands a furnace operating under high vacuum which is not only the largest furnace with an all-metal heating chamber, but also the largest device of this kind to be operated in the Benelux. This customer has also purchased from us a universal BREW device for the tempering process. Apart from atmosphere

furnaces, commercial hardening plants use two flagship Seco/Warwick products, that is multi-chamber vacuum furnaces, the CaseMaster Evolution® (CMe®), and single chamber furnaces, the Vector®. The common denominator of both solutions is a flexible, versatile, and environmentally friendly vacuum heat treatment, which is our specialty," said Maciej Korecki, vice president, vacuum furnace segment, Seco/Warwick Group.

"We have been working with Aalberts Surface Technologies Group for many years. This is another time that we are involved in increasing the capacity of the Dzierżoniów hardening plant and in expanding its machinery base with reliable Seco/Warwick equipment. This cooperation is unique in the fact that we have already delivered our equipment not only to many branches of this partner, but also because they use a very wide range of our technologies. The fact that Aalberts Surface Technologies returns to us is a huge compliment as it means that our partner is satisfied both with the solutions we provide, and with the after-sales service. Partnership is an important value for us. If we work with a customer for many years, we see their huge development and are able to help them, this is invaluable. This is of particular importance when it comes to developing a partnership over many years, as it is in this case, delivering diverse technological solutions for many entities of a single corporation," said Sławomir Woźniak, CEO, Seco/Warwick.

Aalberts Surface Technologies is a global company with more than 80 years of experience, operating in more than 70 countries. The Dzieroniów plant was established in 2014 and is one of the most modern commercial hardening plants in the region. They are a supplier primarily for the automotive industry, but also for the wide machinery industry.

"We have decided to cooperate with Seco/Warwick because they provide us with the tailor-made solutions which always respond to our needs 100 percent. We share the passion and huge, constant drive for excellence which is inscribed in the DNA of Aalberts Surface Technologies. Cooperation with such an experienced company also brings professional consulting that helps us to optimally expand the Dzierżoniów hardening plant. The new line will significantly increase our capacity and will allow us to expand our business to other Eastern European countries," said Bartłomiej Olejnik, managing director, Aalberts Surface Technologies Heat Sp. z o.o.

"We have been cooperating with the Seco/Warwick Group for many years. They are our technology partner and with them, their solutions and support, together we can shape the heat treatment industry. What is important for this cooperation is the dialog, flexible approach, constant search for solutions for improvement, and the vast experience of our partner—combined, these allow us to implement our business and technological development with peace of mind," Olejnik said.

MORE INFO www.secowarwick.com

The Nitrex facility in Franklin, Indiana, received Nadcap accreditation for heat treating for multiple alloy families, stress relieving, carburizing, nitriding, vacuum heat treating, hardness, and metallography. (Courtesy: Nitrex Heat Treating Services)

Nitrex Indiana facility granted Nadcap reaccreditation

The Nitrex Heat Treating Services (HTS) facility in Franklin, Indiana, received the Nadcap (National Aerospace and Defense Contractors Accreditation Program) accreditation for the following processes: heat treating for multiple alloy families, stress relieving, carburizing, nitriding, vacuum heat treating, hardness, and metallography.

"This central U.S. location and the Nitrex expertise will be used to expand our aerospace focus and business in the U.S.," said Mark K. Hemsath, vice president of sales at Nitrex Heat Treating Services, Americas.

The Nadcap is known as the highest level of quality certification when it comes to heat treating. It is not only valuable in the aerospace sector, but it also shows a trusted level of expertise in the defense and precision industries.

"Nitrex is global leader in gas nitriding and this accreditation not only shows our commitment to offer the best quality to our customers, but also our expertise in alternative processes," Hemsath said.

Nadcap has approved the operations of the Nitrex HTS facilities in Franklin, Indiana, and in Queretaro, Mexico.

As the highest level of international aerospace approval, a Nadcap accreditation is considered to be the hardest one to obtain.

This industry-managed program has the most stringent requirements to ensure that those using special processes and heat-treating parts for the aerospace industry adhere to consistent, high-quality standards. Focusing on maintaining global quality standards not only helps ensure the safety of everyone using these products, but it also helps companies continually improve and refine heat-treatment processes to provide customers with the best product quality possible.

MORE INFO www.nitrex.com

Greetings from IFHTSE's new president

Dear members, colleagues, and friends:

I am Masahiro Okumiya, and I have been the new president of IFHTSE since January 2022. I work for the Toyota Technological Institute in Nagoya, Japan, and I specialize in metal surface hardening heat treatment and surface modification. I have presented many times at IFHTSE congresses and international conferences. Perhaps you have seen me, or we've had a conversation.

In the field of heat treatment, we are presently facing the enormous challenge of reducing carbon-dioxide emissions. I think that nearly everyone in research and development is working every day to solve this problem. All around the globe, heat-treatment companies strive to reduce carbon-dioxide emissions. At the IFHTSE Congress this September, there will be presentations on these issues, and we shall see valuable approaches and solutions.

The last IFHTSE Congress was in Vienna, Austria, in 2006. This time, it will be in Salzburg, which is famous for music, exquisite delicacies, and its most beautiful cityscape, so there could not be a better place to meet — the more so since IFHTSE was founded here 50 years ago. In 1972, when an international colloquium met in Salzburg, the first Governing Council Assembly approved the statutes and got the Federation started. I hope that in the 27th IFHTSE Congress, which is my first big task as president of the Federation, many people will participate and thus help make the event a success. Let us look forward to finally meeting in person after such a long time. See you in Salzburg.

Masahiro Okumiya

Masahiro Okumiya
IFHTSE president, 2022-2024

CONFERENCE UPDATE

European Conference on Heat Treatment/IFHTSE 27th Congress, September 5–8, 2022, Wyndham Grand Salzburg Conference Center, Salzburg, Austria.

Keynote speakers have been chosen for the ECHT/27th IFHTSE Congress. They include:

›› Prof. John G. Speer, director of the Advanced Steel Processing and Products Research Center (ASPPRC), Colorado School of Mines, Golden, Colorado, on "Recent developments and perspectives of Heat Treatment in Steel Processing." Prof. John Speer is the 2022 IFHTSE Medalist.

›› Prof. Jianfeng Gu, director of the Institute of Materials Modification and Modeling, Shanghai Jiao Tong University. "Modeling and Simulation in Heat Treatment and Surface Engineering." Prof. Jianfeng Gu is an IFHTSE Executive Committee Member.

›› Dr. Stefan Hock, IFHTSE Secretary General, "50 Years of IFHTSE — Past, Present and Future."

›› Prof. Massimo Pellizzari, Department of Industrial Engineering University of Trento, Italy, "Heat Treatment and Surface Engineering in Additive Manufacturing." Prof. Massimo Pellizzari is vice president IFHTSE, 2022-2024.

›› Dr. T. S. Sudarshan, president and CEO of Materials Modification Inc (MMI), Fairfax, Virginia, "Kaleidoscope of Surface Engineering."

Fluxtrol manufactures and supplies soft magnetic composites used in a wide range of induction-heating technology. (Courtesy: Fluxtrol)

SPOTLIGHT ON MEMBERS

IFHTSE is a federation of organizations, not individuals. There are three groups of members: scientific or technical societies and associations, universities and registered research institutes, and companies.

In this segment, we will highlight our members. This month we highlight:

Fluxtrol Manufacturing

Fluxtrol Manufacturing was founded in 1981 by Robert S. Ruffini, inventor, entrepreneur, and induction-heating enthusiast who specialized in the development and manufacture of soft magnetic composites for magnetic flux control in induction systems. In 1993, he founded the Centre for Induction Technology (CIT) for the purpose of education and promotion of induction technologies.

Fluxtrol has become a world leader in the manufacture and supply of soft magnetic composites. They provide a wide range of induction-heating technology engineering services to a multitude of global industries. They have brought forth many innovative solutions being used in thousands of applications ranging from automotive to aerospace, oil and gas, special metallurgy, biomedical, and food industry.

IFHTSE 2022 EVENTS

MARCH 27–30, 2022
ICRS 11 - 11th International Conference on Residual Stresses
Nancy, France | sf2m.fr/events/icrs-11

APRIL 25–27, 2022
12th Tooling Conference & Exhibition (Tooling 2022)
Örebro, Sweden | www.tooling2022.org

MAY 11–13, 2022
International Bosphorus Heat Treatment Symposium
Milan, Italy | www.sct-2020.com

JUNE 19–23, 2022
6th International Conference on Steels in Cars and Trucks
Salzburg, Austria | www.sct-2020.com

SEPTEMBER 5–8, 2022
27th IFHTSE Congress / European Conference on Heat Treatment
Salzburg, Austria | www.ifhtseecht2022.org

OCTOBER 10–14, 2022
Advances in Materials and Processing Technologies
Portorož, Slovenia | www.ampt2022.org

NOVEMBER 2–4, 2022
HTS – 14th International Exhibition and Conference on Heat treatment
Mumbai, India | www.htsindiaexpo.com

APRIL 21–24, 2023
5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies
Liangzhu Dream Town, Hangzhou, China

NOVEMBER 13-16, 2023
28th IFHTSE Congress
Yokohama, Japan

For details on IFHTSE events, go to www.ifhtse.org/events

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Prof. Kewei Xu | Xi'an University | China

ONLINE www.ifhtse.org | **EMAIL** info@ifhtse.org

Spotlight on IHEA member Bloom Engineering

Bloom Engineering began at a shop in Pittsburgh's North Side in 1934 and eventually moved to its current site in 1962. The company is named after founder Fred S. Bloom. Bloom, who had ties to the steel industry, began making burners because he saw an immediate need for safer, more efficient, and more reliable combustion equipment that could improve production capabilities.

Although Bloom focused on the steel industry during its early years, it now provided custom engineered solutions for heating processes in many industrial sectors. For example, its regenerative burner systems are now used throughout the world for secondary aluminum melting. Bloom has also provided equipment for industrial boilers, forges, thermal oxidizers, waste incinerators, air heaters, and iron-ore processing, to name a few.

Over time, Bloom has grown into a global company with manufacturing centers in Germany, Bloom Engineering (Europa) GMBH; China, Bloom Combustion Products (Shanghai) Co. Ltd.; and India, Bloom Combustion (India) Private Ltd. In addition, Bloom also owns HCT (Hotwork Combustion Technology Ltd.) and can provide spare parts for legacy HCT products along with select HCT designs, which are now offered under the Bloom name. Although Bloom has a manufacturing network throughout the world, its Pittsburgh office serves as the group headquarters. It is in the company's Pittsburgh-based combustion R&D lab and engineering departments where Bloom does most of its new product development and testing.

Manufacturing burners, fuel trains, control panels, and other combustion equipment is part of what Bloom Engineering does, but its focus is to develop proper engineering solutions to solve its customers' problems.

Since Bloom's beginning, the steel industry has been one of its key sectors. Today, Bloom provides equipment to steel mills for billet and slab reheating; ladle heating; strip processing including annealing, tempering, and galvanizing; stove burner ignition; and flares. Outside of steel, the secondary aluminum industry is where Bloom sees the most activity. Apart from being a world leader in regenerative systems for aluminum melting furnaces, Bloom also provides heating systems for holders and even rotary furnaces.

HIGH QUALITY PRODUCTS

Bloom is committed to providing high quality state-of-the-art products. However, because the company supplies custom equipment for highly demanding industrial processes, there are times when extra field tuning is needed before the equipment—or the overall process that the equipment is part of—perform optimally. It is at these times when clients get to see the full value that Bloom's experienced service staff and process experts provide. Walking away from a job before the client's equipment meets or exceeds expectations and all the production and environmental guarantees are met runs counter to both Bloom's legacy and its culture.

The ability to customize products allows Bloom to provide a great deal of value to its customers. A good example of this would be Bloom's 1610 burners, which are commonly bought to replace existing burners on steel reheating furnaces to reduce a furnace's overall NOx emission. For these types of retrofits, Bloom designs its burners to match as closely as possible the footprint of the burners being replaced, so that piping, mounting, and refractory changes are minimized, resulting in greatly reduced installation costs.

High temperature, high efficiency, ultra-low NOx, and multifuel applications are Bloom's specialty. There are many product lines that display these abilities but four really stand out: 1150/1650 regenerative burners, 1610 direct fired ultra-low NOx burners designed for

High temperature, high efficiency, ultra-low NOx, and multifuel applications are Bloom's specialty, such as the 1150/1650 regenerative burners.

With minor modifications, Bloom now knows that its products can be designed for use with hydrogen and continue to achieve ultra-low NOx emissions.

applications with preheated air and inputs above 4MMBtu/hr., the 1500-S line of direct-fired ultra-low NOx burners for capacities below 4 MMBtu/hr., and the 2370 high efficiency ultra-low NOx recuperative radiant tube burners.

Bloom is continuously innovating and has been granted more than 65 U.S. patents, the latest of which was published this year. Bloom also provides products with an incredible range of capacities. From 10,000 Btu/hr. pilot burners to 400 million Btu/hr. process heating burners, the company's product line covers about any heating need.

Above all else, Bloom is an engineering company. Manufacturing burners, fuel trains, control panels, and other combustion equipment is part of what the company does, but its focus is to develop proper engineering solutions to solve its customers' problems. Because Bloom custom engineers each product supplied, it can help its clients achieve optimal results from their heating equipment that might not have been possible using a standard "catalog" typed product. This approach can be summed up by the words of Bloom himself: "First, understand the customer's problem. Then define it in terms that allow a calculated, engineering solution. Apply properly designed equipment in the correct arrangement so that the furnace will produce the desired results in terms of capacity and quality. Last, but not least, go back to the installation and make sure that the furnace is living up to what the calculations indicated is should."

REDUCING CARBON FOOTPRINT

Throughout its 88-year history, Bloom has seen many changes in the industries it serves. Today another big change being considered by many is a switch from fossil fuels, which contain carbon and subsequently release large amounts of carbon dioxide into the Earth's atmosphere when burned, to fuels that contain little or no carbon such as hydrogen. Regardless of what the future holds, Bloom has gone ahead and tested most of its critical product lines on pure hydrogen. This includes its regenerative 1150/1650 burners, its 1610 series, and very recently, its 2370 radiant tube burners. With minor modifications, Bloom now knows that its products can be designed for use with hydrogen and continue to achieve ultra-low NOx emissions. Bloom is now ready to help design hydrogen-capable combustion systems. From the pipe trains delivering the hydrogen, to the burners that combust it, and combustion chambers that must be designed to work optimally with hydrogen's heat-release partners, Bloom plans to help its customers solve their combustion problems for many years to come.

Bloom has about 175 direct employees globally. Its U.S. staff numbers about 100 while the remaining direct employees work in either Europe or Asia. In addition to direct employees, Bloom has contracted with representatives in many additional countries and territories, including Mexico, Brazil, Australia, and South Korea.

Bloom Engineering Co. Inc. is in the south hills of Pittsburgh, Pennsylvania. Bloom's main phone number is 412-653-3500, but the company has sales staff throughout the world to service specific territories. For contact information for Bloom's sales representatives, go to: www.Bloomeng.com.

TRIRATNA SHRESTHA
MANAGER OF METALLOGRAPHIC LABORATORY AND CENTRAL COATINGS LABORATORY /// METCUT RESEARCH INC.

The chemical composition of this super alloy makes it suitable for manufacturing aerospace hardware via additive manufacturing.

Microstructural effect of Alloy 718 on fatigue strength

Gas turbine engines are widely used in aviation, power generation, and oil and gas industries. They are used in land, air, and marine. The origin of gas turbines goes back to aviation during World War II. Since then, there have been aeroderivatives of aviation gas turbine (jet) engines for use in land and marine. GE Aviation's Land and Marine LM2500 and LM6000 are aeroderivatives of its turbofan CF-6-80C2 aeroengines. At macrolevel, a jet engine is comprised of compressor, combustion, and turbine. A jet engine intakes air from outside and compresses it to increase pressure ratio (PR). A combination of low-pressure compressor, intermediate-pressure compressor, and high-pressure compressor compresses the air to step up overall PR. The compressors in turn are accompanied by respective turbines. Burning of fuel occurs in the combustor where nozzles spray fuel to combust with compressed air uniformly to generate maximum heat. This process sees maximum temperature rise in the system which puts limitation on material selection in terms of high temperature deformation, high temperature corrosion and fatigue.

(%)	Ni	Cr	Fe	Nb	Mo	Ti	Al	Co	C	Si	W	V
Min.	50	17		4.75	2.8	.650	.200	0.00	0.00	0.00		
Max.	55	21		5.5	3.3	1.15	.800	1.00	0.080	.35		
Avg.	53.4	17.17	18.88	5.10	3.01	9.36	.614	.331	0.057	.109	0.751	0.043

Table 1: Chemical composition of Alloy 718.

Nickel-based alloys have found use in many applications — aerospace, nuclear, power generation, metal processing, medical, material processing, and chemical and petrochemical industries — thanks to their excellent resistance to deformation and corrosion in wide-ranging temperatures and environments. In gas turbines, material experiences thermal fatigue, high cycle fatigue, high temperature oxidation, and creep. One of the widely used nickel-based superalloys in hot section of gas turbines is a precipitation-hardened Alloy 718. The alloy's superb weldability can ensure post weld cracking resistance, and better creep strength at up to 700oC, which makes the alloy suitable for manufacturing aerospace hardware via additive manufacturing. Presence of chromium gives the alloy ability to withstand sulfurizing, carburizing, and oxidizing conditions. Higher nickel maintains the face centered cubic (fcc) austenitic structure that provides enhanced high temperature fatigue strength, while presence of Nb, Ti, and Al promotes formation of precipitates that pin dislocations at elevated temperature. Chemical composition of Alloy 718 is shown in Table 1.

As-received microstructure having uniform, equiaxed ASTM grain size of 6.5 is shown in Figure 1. Presence of large grain size showing grain growth and twin is indicative of higher solutionizing temperature and slower cooling rate. The alloy forms a variety of phases, as shown in Figure 2, such as fcc γ' (Ni3(AlTi,Nb)), metastable body centered tetragonal (bct) γ'' (Ni3Nb), orthorhombic delta (δ) precipitates (Ni3Nb) and other fcc metallic carbonitride ((NbTi)(CN)). γ' and γ'' formed during post heat treatment are the primary precipitates that enhance high temperature strength by impeding dislocation flow. The gamma prime has coherent interface with the gamma phase due to low lattice parameter resulting in low interfacial energy. The size and distribution of the gamma prime play a crucial role in mechanical properties. Smaller precipitates in larger quantity in a grain are more effective in withstanding plastic deformation than the ones in grain boundaries. The γ' phase in as-received condition is spherical but the morphology changes during thermal processes and ageing from sphere to cube and dentritic. On the other hand, cooling of the

Nickel-based alloys have found use in many applications thanks to their excellent resistance to deformation and corrosion in wide-ranging temperatures and environments.

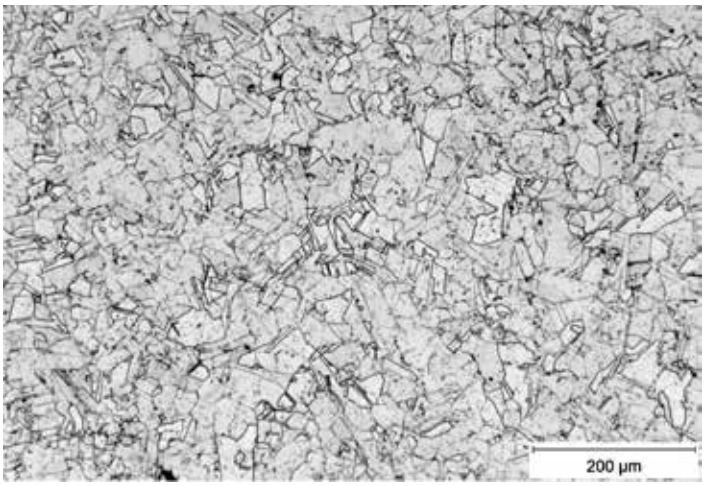

Figure 1: As-received microstructure of Alloy 718 having ASTM grain size of 6.5.

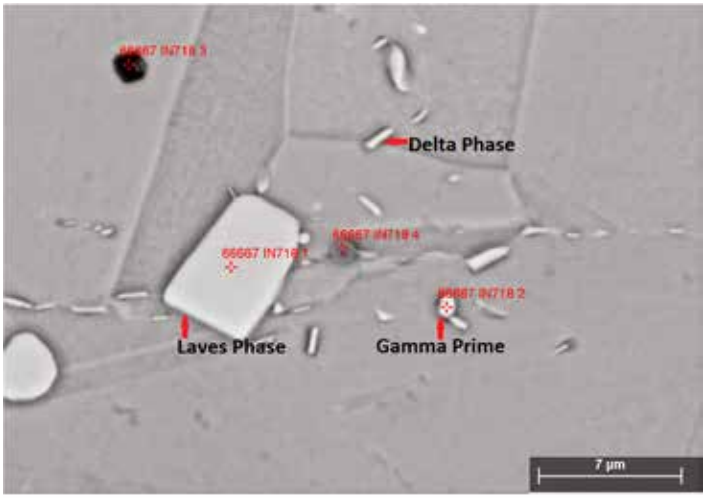

Figure 2: Showing precipitate distribution in as-received alloy.

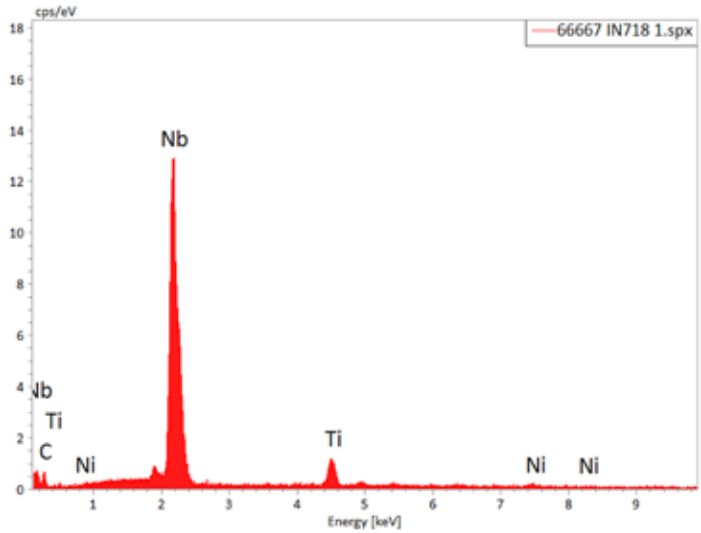

Figure 3: Energy dispersive spectroscopy spectrum of Nb-rich Laves phase shown in Figure 2.

alloy from solvus temperature also dictates the morphology, size distribution, and their volume fraction. Bimodal size distribution of the precipitate has better high temperature, high cycle fatigue properties [1]. Presence and distribution of δ phase and metallic carbonitride add to precipitation hardening mechanisms but are depending on materials processing. The needle-shaped δ phase is predominantly located at the grain boundaries and triple-points, as seen in Figure 2. Higher solutioning temperature helps dissolve δ phase. The alloy, when overaged at higher temperature, forms detrimental precipitates like hexagonal Laves phase ((NiFeCr)2NbMoTi), shown in Figure 3, which leaches NiFeCr away from the matrix; thus, weakening the solid solution and precipitates strengthening of the alloy.

Gopikrishna et al. [2] observed that high cycle fatigue life increased in finer grain sizes for both smooth and notch specimen tested at room temperature and 650oC. Delta phase, which was predominantly located at the grain boundaries, had no effect on high cycle fatigue life. Thus, the morphology of fractured surface appeared transgranular in nature. For heat treatment carried out above 1,085oC, slower cooling rate and stress intensity factor (ΔK) levels above 40 MPa , high fatigue crack propagation was observed. Slower cooling rate promotes formation of delta phase due to nucleation and growth. Prevalence of δ phase support void formation, coalescence, and accelerated crack growth [3]. Fatigue failure related to high volume fraction of delta phase has high crack growth rate (da/dN) and the fracture surface has intergranular morphology. Chang [4] conducted fatigue testing at temperature range of 400 to 660oC with various sinusoidal frequency of 0.33 Hz, 0.0055 Hz, and 0.33 Hz + 177 s hold time at each maximum load to evaluate cycle-dependent and time-dependent fatigue crack behavior. In fine grain samples fatigued at 0.33 Hz + 177s and temperature range of 400 – 593oC in air, da/dN increased by about 10X compared to 0.33Hz. Similar da/dN were observed for coarse grain as well. For ΔK of 23 MPa, 28 MPa and 33 MPa at above mentioned frequencies, increase in da/dN was observed for a coarse grain vs a fine grain microstructure. The increase was significantly higher in fast fatigue conditions of 28 MPa and 33 MPa ΔK. The coarse grain indicated lower volume fraction of γ' and γ'', and increased presence of δ and Laves phases, as shown in Figure 2, which lead to transgranular fracture morphology. Laves phase pulls Nb out of solid solution and leaves the matrix devoid of beneficial γ' and γ''; thus, weakening the precipitation strengthening mechanism. While prevalence of coarse δ phase on grain boundaries and triple-point promotes particle de-cohesion and are not effective in pinning dislocation, control of detrimental phases such as Laves and δ, and grain size are vital in maintaining the high temperature strength of the alloy.

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ABOUT THE AUTHOR

Triratna Shrestha is the manager of Materials Analysis and Central Coatings Laboratory at Metcut Research Inc. He has worked with coatings for aerospace, petrochemical, and power-generation applications and has expertise in materials testing and evaluation. He manages Central Coatings Laboratory for GE Aviation and is involved in failure analysis and continuous improvements. He received his B.S and Ph.D. in Materials Science and Engineering from the University of Idaho. He can be reached at tshrestha@metcut.com.

D. SCOTT MACKENZIE, PH.D., FASM
SENIOR RESEARCH SCIENTIST–METALLURGY /// QUAKER HOUGHTON INC.

Two independent types of agitation used for measuring the cooling curve behavior of polymer quenchants show repeatable results within their bias and precision.

Influence of agitation on polymer quenchants

Polymer quenchants are used extensively to quench a large variety of materials in a variety of processes. Polymer quenchants can be used for immersion quenching of steel, aluminum, and other alloys, including super alloys. Spray quenching is commonly used for induction hardening. There are predominantly four different types of polymer quenchants used in industry today.

To achieve consistent and uniform quenching, the quench rate must be controlled. The quench rate of a polymer is affected by concentration, temperature, and agitation. In this column, two typical methods of evaluating the agitation of polymer quenchants will be illustrated and compared.

LABORATORY DETERMINATION OF AGITATION EFFECTS

Traditionally, the quench severity of a quenchant was evaluated by quenching a heated probe into a bath of quenchant with no agitation [1]. In this test, a heated 12.5 x 60 mm cylindrical Inconel 600 probe is quenched into a 2.1 liter tall-form stainless steel beaker containing the quenchant.

However, this system is inadequate for an understanding of agitation effects. However, many test methods do not allow careful, reproducible study of agitation effects. Several small-scale laboratory agitation systems have been developed. In this column we are going to discuss the Drayton agitation unit (ASTM D 6549) [2] and the Tensi agitation unit (ASTM D 6482) [3].

DRAYTON UNIT (ASTM D 6549) [2]

The Drayton agitation system is shown in Figure 1. The agitation unit is a variable speed impeller pump, with a volumetric flow meter. Quenchant is pumped through a 25-mm diameter tube that is 150-mm in length. The tube is in the center of a 2-liter metal beaker that also serves as a reservoir. A fluid return line feeds the pump so that the quenchant can be in constant steady-state circulation.

Cooling curves are measured with the standard Inconel 600 quench probe (ASTM D 6200) [1].

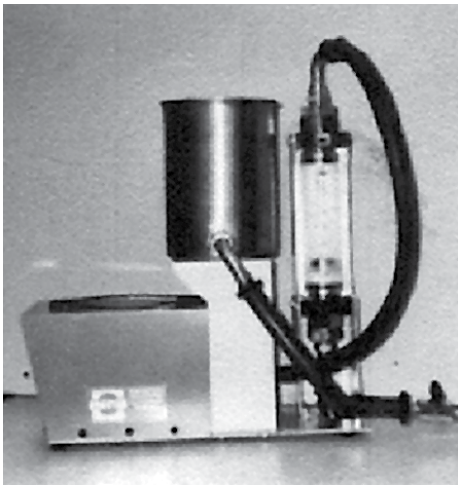

Figure 1: The Drayton unit with integral flow meter [4].

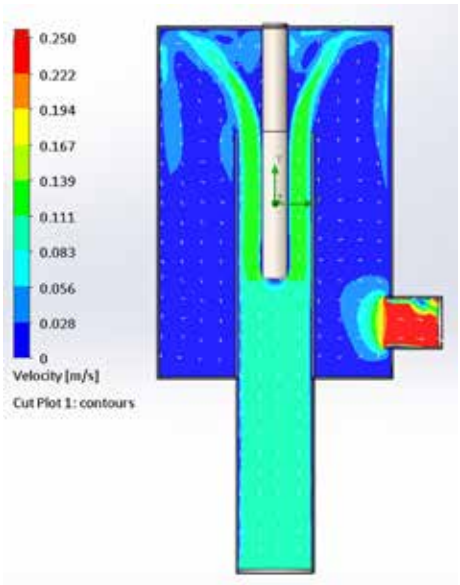

Figure 2: Flow profile through centerline section of the Drayton assembly (ASTM D6549). In the inlet tube, the flow is uniformly directed upwards.

Flow throughout the inlet tube is laminar and exhibits uniform flow velocities along the length of the tube (Figure 2). Cross sections of the flows below the probe insertion point and at the probe are very uniform (Figure 3). Some boundary layer effects are apparent.

The low velocity region near the bottom of the probe due to flow separation is evident in these plots. Somewhat higher velocities are seen further up as the flow reattaches to the probe surface, followed by a decline in the velocities due to boundary layer growth. The surface velocity patterns show a high degree of radial symmetry.

Guisbert and Moore [5] examined the effect of test conditions on the cooling curve behavior of two different PAG type polymer quenchants. The most important single factor for the test was the quench temperature. Increasing the quench temperature decreases the maximum cooling rate and decreases the temperature of maximum cooling. Further, decreasing the quenchant temperature increases the time to temperature to 600, 400, and 200°C. The quenchant temperature did not influence the cooling rate at 300°C.

Radial position was the second most dominant factor. It influenced the maximum cooling rate and the time to cool to 600 and 400°C at the lower concentration polymer. The general positive trend of an increase in the cooling time to 200°C is also shown in lower concentration polymer. Radial position did not influence the test results in the higher concentration polymer solution.

TENSI UNIT (ASTM D 6482) [3]

This agitation method, first described by Tensi and Stitzelberger-Jakob [6], is shown in Figure 4. Besides being inexpensive and easy to construct, it is reported to have little variation in flow velocity across the quench chamber. Another advantage is that it is possible to construct a linear flow velocity versus rev/min calibration curve, such as that shown in Figure 5 [6]. Thus, it is possible to relate the nature of the flow

surrounding the cooling metal that would be applicable in any size quench system with similar flow properties.

Commercially available units are manufactured from clear plexiglass. This allows observation of the flow and progression of the phases of quenching. Agitation is provided by a three-blade, 42-mm pitch and 50-mm diameter plastic propeller that is driven by a variable speed motor. Fluid flow is controlled by adjusting the speed of the motor, by controlling the RPM. The RPM can be calibrated using an optical tachometer.

Guisbert and Jarvis [7] performed a statistical analysis of the Tensi unit. They examined the effects of probe initial temperature, quenchant temperature, and quenchant flow rate on two similar PAG polymers at different concentrations. They found that the probe temperature and the quenchant temperature were the largest statistically significant factors. Quenchant flow rate, within the narrow range tested (950-1050 RPM), did not alter results.

In another study [8], the effect of probe insertion depth, motor RPM, and concentration on the cooling curve behavior of a PVP quenchant was examined. In virtually all cases the concentration of the polymer was the dominant factor. The effect of RPM or flow rate was small or non-existent for all cases except for the Temperature at Maximum Cooling Rate, T_{MCR}. From the published data showing flow rate as a function of RPM (Figure 5), the flow rate was varied from 0.2 m/s to 0.28 m/s. The recommended speed of 1000 RPM from ASTM 6482 yields a flow rate of approximately 0.24 m/s. This speed may not be adequate to reduce the variation on T_{MCR}.

At the low concentration of the polymer, the T_{MCR} was unaffected by RPM or impeller insertion depth. However, as the RPM was increased for the 20 percent concentration, there was a progressive increase in the T_{MCR}. However, the variation (standard deviation) of the test results was large and overlapped the results of the low concentration. These results were also observed with changes in the impeller insertion depth at the high concentration of the polymer, with the variation of the test results overlapping the observed variation of the impeller insertion depth on the lower concentration.

There is significant turbulence created by the impeller and sharp corners in the flow path of the Tensi unit [9]. The results of that work suggested that the higher turbulence in the Tensi unit results in an earlier and more consistent breakdown of the vapor film, leading to maximum cooling at higher temperatures.

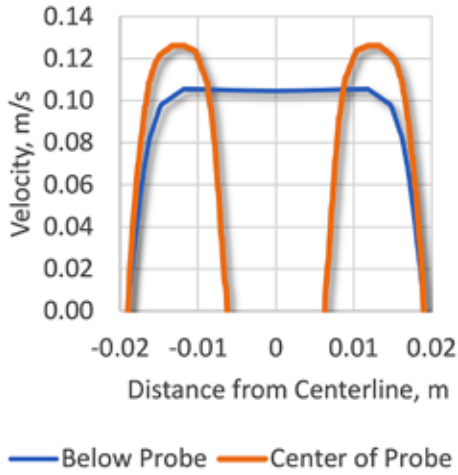

Figure 3: Cross-section of the flow profile below and at the insertion point of the probe.

Figure 4: Agitation system developed by Tensi.

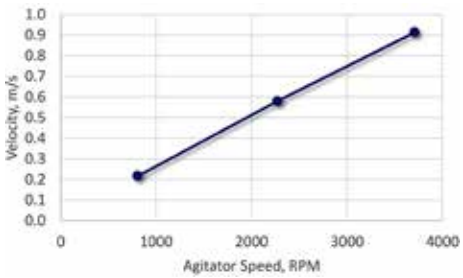

Figure 5: Linear flow velocity calibration as a function of agitation propeller speed for the Tensi Unit [3] for distilled water at 60°C.

CONCLUSIONS

In this column, a brief comparison of two different types of agitation used for measuring the cooling curve behavior of polymer quenchants was provided. Both types of agitation are covered by ASTM standards and show repeatable results within their bias and precision. The Tensi unit shows greater turbulence and is likely to be more reflective of actual quench tank behavior. It must be remembered that the two systems are independent of each other, and the curves generated by one method cannot be compared to the other agitation method.

As always, should you have any questions or comments regarding these articles or suggestions for other articles, please contact the editor or myself.

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SHAUN KIM
DIRECTOR OF QUALITY /// BYINGTON STEEL TREATING, INC.

Managing quality control during heat treating is a crucial, but potentially complicated, task that can speed up or slow down a system.

Technology is key to improving process efficiency

Efficiency. What is it, exactly?

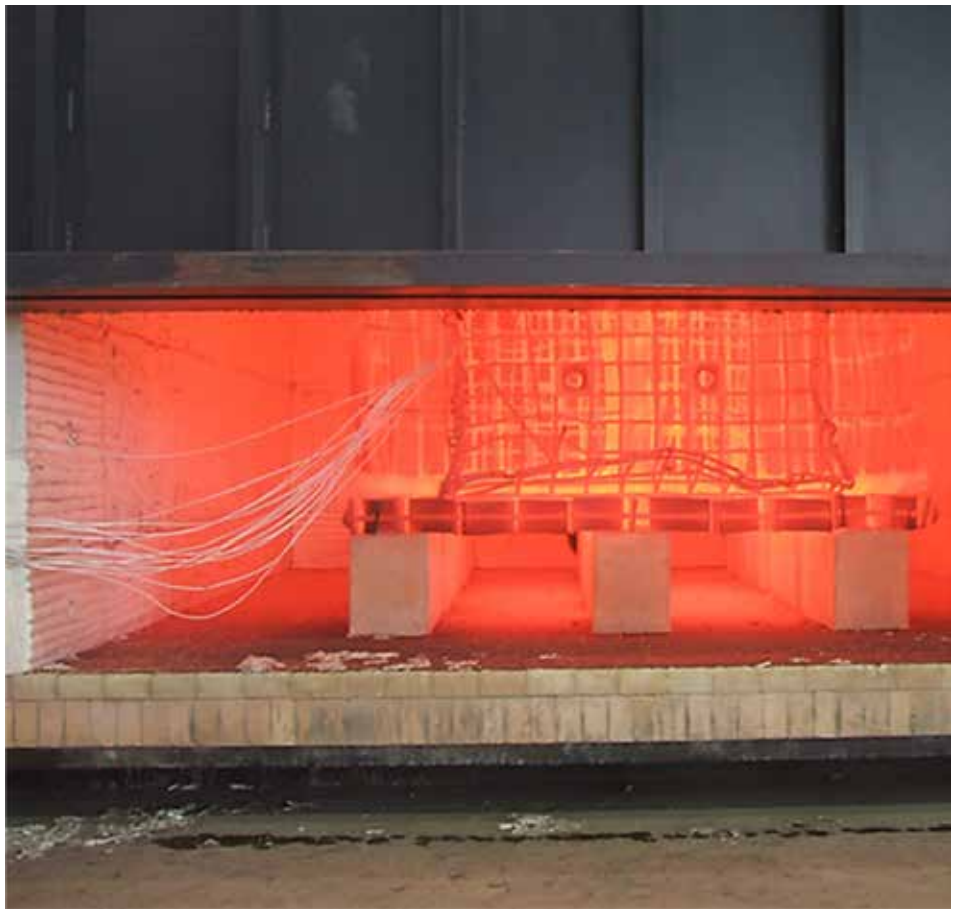
The term "efficiency" refers to the peak level of performance that uses the least amount of input to achieve the highest amount of output. From my perspective and the intent of this article, quality would be the output and the steps taken to improve the efficiency of quality would be the input.

This word, efficiency, is something that often swirls around in my head. I think about it so much that it feels like it owns real estate in my brain. It can be burdensome at times, but it's part of the job of being a quality director. I have a seemingly never-ending task to make the company's processes and procedures as efficient as possible.

Has efficiency been something you've thought about when it comes to your quality system? Do ideas on how to improve your system to meet the changing landscape of heat treating ever cross your mind? I hope the answer is yes. I would feel a little lonely if I was the only one guilty of having that thought process. I value providing solutions to inefficient processes regardless of complexity. Because of this, I'm constantly seeking ways to make our system function more efficiently. As I mentioned earlier, this can be a burden — but it gives me fulfillment to know I've made my system better while making my job easier.

Over the years in this industry, there have been numerous occasions when I saw the opportunity for efficiency improvement — specifically, in areas of procedures, processes, and traceability to name a few. I'd be lying if I said that all efficiency improvements made over the years were based on a proactive approach, because the fact is that sometimes a non-conformance or a customer complaint steers us in that direction. Regardless of the origins for these improvements, all quality representatives should place a high priority on improving efficiency. Whether it is a forced or proactive action, improving your quality system can come from the most likely and unlikely places. Improvements can originate in the form of critical thinking, or they can come from technological advancements that weren't used or readily available at the time the system was created. Although I could go on for pages on the topic of critical thinking and how to apply it, this article will focus on technology and ways to harness its power to serve your purpose and make your system more efficient.

It should go without saying, but quality has a crucial role in heat treating. From reviewing a standard for compliance to reviewing a heat-treat process for final certification, there are so many ways quality is involved. I'm not ignorant to the fact that some may already use the practices I'll mention, but some may not and this might be a great opportunity to clean up this part of their operation. I would be here for hours if I listed all the roles quality plays during the heat-treat process, so I will focus on a few key areas where I believe quality representatives can benefit from using technology. Calibration, temperature uniformity surveys (TUS), and system



Calibration, temperature uniformity surveys (TUS), and system accuracy tests (SATs) are common uses of technology to ensure quality control in heat treating.

accuracy tests (SATs) are common, so I'll focus on those.

I know that this is not the case, but let's assume for the purpose of this article that everyone reading this is a heat-treat supplier of AMS and Nadcap processes. We can start with calibration and TUS in accordance with all the requirements of AMS 2750F. How do you keep track of the scheduled initial or periodic TUS intervals that each furnace requires? I have found that using a Microsoft Excel worksheet can take care of my calibration and TUS scheduling. I am a novice when it comes to Excel, but luckily I have an engineer on my team who is well versed on the functions. After seeing my engineer in action, I was astonished by how powerful and useful it is. The worksheet we created lists all our equipment and has formulas for each depending on its furnace class. After the worksheet was complete, we added a dropdown box to select what month and year it was. Depending on the month and year chosen, the sheet automatically changes and lists each furnace needing calibration or TUS, as well as the required test temperatures for each furnace. It even lists whether the TUS is an initial or periodic. Further, if it was an initial it tells you how many consecutive tests you have performed up to that point. It made this part of my job so much easier. I can now open my Excel sheet, select a month and year, and have my required TUS/calibration schedule for that month — all in less than 10 seconds. That is efficient.

We made a similar sheet for our SATs. But this time our formulas are based on the SAT requirements of AMS 2750F. We include our thermocouple wire correction factors and field test instrument correction factors into our formulas. Of course, this changes every time you calibrate your test instrument or use new wire, so you must be on top of recording those when changed or the sheet will not be accurate. The pass/fail requirements of AMS 2750F are built in as well. This allows us to put the recorded temperature of the furnace and recorded temperature of the field test instrument into our sheet and it does the calculations for us automatically using data from our field test calibration in conjunction with the wire correction factors. After inputting that data, the cells associated with that furnace turn either green or red — green means a passing SAT and red is for a failing test. Simple. No calculations. No going back and forth between calibration certificates and wire certificates. Open your sheet, put the data in, and wait for green or red to show up. Before I took control of quality, this would take around 20 minutes to complete. After we made the sheet, it now takes less than five minutes to complete.

Technology is something ever-present in our daily lives, whether it's using the handheld minicomputer we call cellphones or using your computer to write a Word document as I am at this moment. We all use technology. I've only identified a few ways to use technology to make your quality system more efficient, but there are so many other ways to harness it to your advantage. It's up to you to determine how it can be helpful.

The takeaway: Technology is everywhere in our daily lives, and it would benefit you to use it often to better serve your quality needs. It will save time and hopefully provide you with peace of mind in certain areas as it has for me.

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SOPHISTICATED CONTROL SYSTEMS FOR OPTIMAL PROCESS OPERATIONS

Custom built control panel being tested prior to installation. Quality electrical engineering and controls design must be a priority in the preliminary design phase for successful integration. (Courtesy: Epcon Industrial Systems)

Whether installing new equipment or retrofitting an existing facility, make sure the industrial systems use the latest in controls technology and with the capacity to meet a range of variable operational demands while limiting operator oversight.

By TASHA JAMALUDDIN

A comprehensive control system, whether designing a new controls package or updating your existing system to a new controls scheme, is the most effective way to enhance any complex industrial manufacturing process — especially in more sensitive applications, such as coil coating or composite curing, where uniformity and precision are critical and when errors in operating controls are detrimental and extremely costly. The importance of controls is compounded when you have an integrated system where the process heating equipment is connected to an air pollution control system. These complex and expansive projects require sophisticated controls that regulate process speeds, temperature ranges, airflows, pressure, and VOC concentration levels, closely monitoring and adjusting hundreds of components simultaneously across and throughout various progressive stages of production.

The following six elements are the key parameters that must be accounted for in an industrial controls system that uses integrated process heating equipment, such as ovens and furnaces, and air pollution technology, such as thermal oxidizers:

- Temperature.
- VOC concentrations.
- Pressure levels.
- Oxygen ratios and air volumes.
- Combustion.
- Process flows.

In addition, it is critical that all these features are independently controlled and adjusted automatically in real time to ensure precise operating parameters are constantly maintained.

A well-designed control system ensures greater safety and hazard prevention and increases efficiencies and reliability, while also allowing for precise monitoring for strict operating parameters. The following case studies demonstrate how in two different applications, — a continuous coil coating line and a batch composite curing of aerospace parts — a sophisticated controls system plays a key function in not only optimizing overall system efficiency but also ensuring critical output quality.

CONTROLS CASE STUDY 1

Continuous metal coil coating line with oven and oxidizer system, heat recovery, and advanced air handling

A Brazilian pre-painted metal coil producer needed to replace its 20-plus-year-old coil coating line. The criteria for the system design included performance and coating uniformity, increased line capacity within the available process envelope, reduced energy consumption, compliance with environmental emissions regulations, and ease of operation.

The overall scope of the final design included a three-zone prime oven, a four-zone finish oven, integrated thermal oxidizer air pollution control and heat recovery system with primary and secondary heat exchangers, complete air handling ductwork, an advanced PLC control system with quality and performance monitoring sensors, and a user-friendly HMI interface. The advanced PLC controls monitor all operating parameters throughout the system to achieve targeted zone control set-points and monitor peak metal temperatures to ensure the process is meeting performance goals at all times.

Installed batch aerospace oven equipped with pneumatic guillotine doors and integrated air pollution control units. (Courtesy: Epcon Industrial Systems)

As an integrated system, the controls also need to simultaneously monitor the air pollution equipment. The thermal oxidizer not only needs to reach its setpoint temperature of 1,400°F but also maintain a residence time sufficient for complete VOCs combustion. To ensure this, the exhaust air volume flow is regulated by a damper opening as well as by a fan, so that the exhaust air's residence time in the oxidizer stays above one second.

The large quantity of fuel required to continuously operate a thermal oxidizer for VOC destruction can be exorbitant. To increase efficiency and minimize operating cost, heat exchangers can be used to recover and transfer thermal energy, which would otherwise be wasted. For this application, the engineering team decided on an integrated recuperative thermal oxidizer with primary and secondary heat recovery through a large diameter shell and tube heat exchanger.

The heat recovery maximizes efficiency as it extracts energy from the heat release from both the curing process and the final oxidization of VOCs. This approach provides most of the heat required to

run the ovens while concurrently meeting air emissions compliance regulations. However, temperature control modules and cooling and heating zones are essential, as the recycled hot air needs to be within the tight temperature range as it is supplied back to the oven.

Regulatory compliance requirements apply not only to process exhaust, but also the ambient air quality within the interior coating processes. Therefore, properly managing the air flow throughout the process is key as it affects VOC levels as well as both cure uniformity and energy consumption. To achieve this, a cascading air management strategy was designed, drawing air from the coater rooms and through the oven and oxidizer systems, which minimizes fresh air make-up, reducing overall system energy consumption. All the ductwork, from coater room exhausts through the ovens, oxidizer, and energy recovery, was specifically engineered for efficiency and proper air flow handling. Additionally, the exhaust air dampers are programmed to follow the hot inlet air dampers' opening percentage, enabling the air's continuous flow and ensuring the amount of air entering is slightly less than the amount of air leaving the oven, maintaining a constant negative pressure at all times to avoid fugitive emissions.

Uniformity of applied coating cure is key to product quality and requires a balance of temperature accuracy and airflow distribution. To achieve this, Epcon employed its proprietary integrated internal exhaust plenums within both prime and finish ovens, extending through the length of the oven.

Complementing the integrated internal exhaust plenums are temperature control modules. Each of these modules incorporates tandem recirculation fans and direct fired trim burners for each of the oven zones. Each of the recirculation fans are individually VFD controlled and tied to their own recirculation supply plenum at the top and bottom of each oven zone. Together with adjustable nozzles that allow the finely tuned oven balance to achieve exceptional and proven edge-to-edge temperature uniformity within ±3°F, which allows for a consistent cure coating.

The unique air handling configuration also provides higher velocity strip impingement, resulting in increased coefficient of heat transfer, which allows the ovens to be operated at lower zone temperature setpoints while still achieving targeted peak metal temperature. Lower zone temperatures translate to reduced energy costs as well as longer life expectancy of the system due to reduced thermal loads.

Automated coil coating line featuring a control panel for the precision of air flow management and temperature control modules. (Courtesy: Epcon Industrial Systems)

As operating safety and hazard prevention are always of ultimate concern, both the upper and lower pressure boundary values are defined as well as lower explosive limits (LEL). Sensors automatically adjusting the actuator openings of air dampers, and in case set pressure or LEL limits are breached, the whole system is shut down to prevent fires or flashback explosions.

The ultimate success of the line was the ability to achieve edge-to-edge temperature uniformities within such tight ±3°F margins. Equally as important, the oven's improved zone efficiency facilitates increased strip speeds, proven to be as much as 25 percent higher, allowing the manufacturer to meet its goal of increased throughput in the limited production space available.

Each component of the system was designed for optimal efficiency and performance for its individual tasks as well as its role in the overall system. Together, the design of the air managements system, PLC controls, remote sensors, and associated programming results in an integrated solution that delivers an easy-to-manage and control-balanced system.

CONTROLS CASE STUDY 2

Aerospace Batch Oven for the Uniform Composite Curing of Aerospace Parts

A composite material processing application for the aerospace industry needed an advanced system for batch ovens and integrated air pollution controls, equipped with high accuracy operating parameter requirements and controls.

Throughout the composite curing process, it is critical that temperatures and other operating parameters in the oven are controlled accurately in real-time with minimal delays. Composite materials and their bonding to the metal surface is a highly temperature-sensitive process, due to specific reaction kinetics and the atomic structure of the substrates. Reaching the peak temperature targets and the precision of timing is essential for manufacturing durable and high strength materials.

In addition, the curing process is highly demanding as it requires multiple sessions with different retention times and operating conditions. The issue with entering operating parameters manually is that it leaves a space for human error, but more importantly, it causes delays between sessions and variances in the process stages.

Since the curing process often represents the production bottleneck, there is a need for multiple ovens that will make up for excessive retention times and enable continuous production. Additionally, airplane parts need a highly controlled production environment to ensure the material's target tensile strength and durability are reached so the final material will remain stable at pressures and extremely low temperatures in the stratosphere.

The greatest challenge in industrial oven applications is maintaining the target temperature uniformly across all oven sections. The curing oven and its control system are custom designed to secure the constant quality production with monitoring where the user is notified by alarm if any of the parameters reached the critical boundary value.

The batch oven is designed for operating temperatures in the range of 300°F to 400°F. Therefore, using two electric 500 kW incoloy

Programmable and user-friendly touch pad controls are essential for operator success and can increase efficiency through variable pre-set parameters. (Courtesy: Epcon Industrial Systems)

heating element bundles in two chambers within the oven, the continuous heat supply is enabled by the electric heaters with a heat-up rate of 2°F to 5°F per minute using a three-phase electric power of 480V.

The distribution of heat throughout all oven sections and the achievement of a uniform temperature also requires air-flow control. Therefore, both chambers are supplied with two recirculation fans, posted at the opposite sides of the chamber with wall-mounted supply plenums installed on both sides that span the entire 62-foot length of the oven chamber. Pre-heated hot air is recycled through the return plenum installed on top of the curing chamber, creating a horizontal crossflow pattern from both sides, which enables their mixing and merging into one stream, flowing vertically through the working chamber. With two-chamber assembly and four recirculation fans, sufficient airflow through all oven sections is achieved, providing a highly efficient convection heat-transfer mechanism. The nozzle adjustment of the fans' plenums and programmed RPM of the fans' motors secure the flow regime of the air that additionally contributes to the airflow in every direction, covering all surfaces of the material. Each fan with an airflow also has a switch as an interlock; therefore, the alarm is sent if any of the fans fail. To maintain a proper curing atmosphere, four 1-inch vacuum ports are posted at each side of the chamber. These ports are piped to a single point connection to a transducer for monitoring via the control system.

During the heating session, the recirculation fans have a primary role in maintaining the uniform temperature across the oven, while exhaust fans work slower with a minor output. On the opposite side, the cooling session is more complex, as it requires control of the cold air flow by two parameters. Two exhaust fans posted at each chamber are responsible for cooling the oven at a rate of 10°F per minute, with an output of 12,000 CFM during cooling mode in contrary to heating mode when it is only 1,500 CFM. The exhaust fans work in conjunction with pneumatic modulating fresh air dampers. The high-accuracy pneumatic actuator adjusts the damper opening in real-time and regulates the fresh air intake. When the oven is required to be cooled, these dampers open, and exhaust fans speed up to draw fresh air inside the oven to efficiently cool the parts. The damper opening and the RPM of the exhaust fan motors are manipulative variables, and they are finely tuned based on the feedback loop to the master control panel.

The workspace temperature is monitored in the oven via multiple thermocouples that continuously monitor the temperature in all parts of the chamber. High sensitivity thermocouples monitor air temperature and humidity set points, which module the fan speeds and damping actuators according to a single thermocouple's response, making an energy-optimized system at all times.

Another addition in the oven was a device to rotate the material throughout the curing process, significantly contributing to equal exposure of all parts to the direct air stream, ensuring the highest quality of every millimeter of the product.

This custom control system was designed specifically to satisfy complex batch process operational requirements for the ovens, which included a PLC (programmable logic controller) that monitors and adjust all operating parameters, including fans speeds, vacuum manifolds, and electric heaters.

The success of the system is proof this type of control configuration is indeed the optimal solution for large batch curing ovens for the aerospace industry. Upon completion, Epcon's team tested the system with 50 thermocouples at different places within the large capacity oven. During the testing, all thermocouples registered temperatures within 4.5°F from the set temperature, showing the uniform temperature distribution in all the chambers' sections. The aerospace industry requires the highest quality products, which can only be achieved through extremely accurate control system for exact operating parameters and real-time.

CONCLUSION

Whether you are installing new equipment or retrofitting an existing facility, make sure your industrial systems use the latest in controls technology, from user friendly interfaces and remote monitoring capabilities, and with the capacity to meet a range of variable operational demands, while limiting operator oversight.

For a successful controls system overhaul, it is best practice to make sure the equipment manufacturer conducts a full controls test before shipment, adjusting and tuning based on required setpoint temperatures and predetermined process variable ranges and inlet values. In addition, once installed, thorough in-field testing should be performed to ensure all critical targets are still met.

Every industrial process application, across industries, has unique challenges and specific operating parameters. The best way to ensure the most efficient and safe operations of your production lines and thermal processing equipment is to invest in a robust quality controls system.

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Tasha Jamaluddin is managing director of Epcon Industrial Systems, LP, and is widely published with technical expertise across industrial applications. She is a graduate of Harvard Business School (OPM Class 51) with a Master's Degree from NYU, a certified LEED, AP with the US Green Building Council , and OSHA 30 Certified in General Industry Safety. She is currently serving her third charter for the Environmental Technology Trade Advisory Committee (ETTAC) to the U.S. Department of Commerce as Chair of the Climate Change Mitigation and Resilience Subcommittee.

WHAT PYROMETER USERS NEED TO KNOW

The evolution of pyrometry has gone from the single-color to the two-color to the multi-color pyrometer; recognizing that pyrometry can only measure solid and liquid targets, each developmental step has solved problems that were insoluble before.

By RALPH A. FELICE

Radiation thermometry, also known as infrared pyrometry, optical pyrometry, or simply pyrometry, is a non-contact temperature measurement technique that requires measurement of some portion of the thermal radiation given off by a hot object. The pyrometer, the measuring instrument, must look through some environment at the radiating target. There are several different types of pyrometer available; some make severe demands upon the operator, and some are less demanding. To make the proper pyrometer choice, the environment and target must be considered. Does the environment affect the radiation in some way, and if so, what correction is required? Does the target have the characteristics of an ideal radiator, and if not, what correction is required? These issues make non-contact temperature measurement difficult, but the rewards for success are substantial. For processing industries, the capability for fast, accurate, non-contact temperature measurement enables automatic process control, improves quality and productivity, and reduces energy usage. Fortunately, pyrometry has come a long way in a relatively short period and much of the uncertainty can be dispelled.

BASIS OF PYROMETRY

The vast majority of pyrometers are based on some aspect of Planck's Law, which says that the radiated spectrum of light from a hot object is governed only by its temperature. At the end of the 19th century, Max Planck was considering the problem of blackbody radiation, also known as cavity radiation. At the time, there was no theory that could describe the data from this source. In fact, physicists considered this problem to be one of the two cases left unsolved in their discipline. (They were a bit optimistic.) It was called the "Ultraviolet Catastrophe" because the equations that fit the data for longer wavelengths predicted infinite radiation at the shorter ultraviolet wavelengths. In reality, however, the radiation in these wavelengths decreased to zero, so a very substantial difference existed between theory and reality. Planck solved this conflict by a mathematical substitution: He replaced an integral with a series. This may sound esoteric, but the result was stunning. It implied the quantization of energy (lasers, tunneling diodes, nuclear bombs, etc.). Planck knew this (the quantization part, not the bomb part), and suppressed the data for a time since he didn't want to deal with the inevitable blowback.

For pyrometer users, one of the implications of Planck's mathematical substitution is the fact that pyrometry only works on solids and liquids. The continuum radiation of a thermal target only occurs when the radiating electrons are close together, as in solids and liquids. Solids or liquids suspended in a gas can be acceptable sources of thermal radiation, but the gas itself cannot.

A further implication is that no individual photon carries the temperature information, but that the information is contained in the wavelength distribution of light in the thermal spectrum. So, anything that changes that distribution along the way leads to error in the measurement.

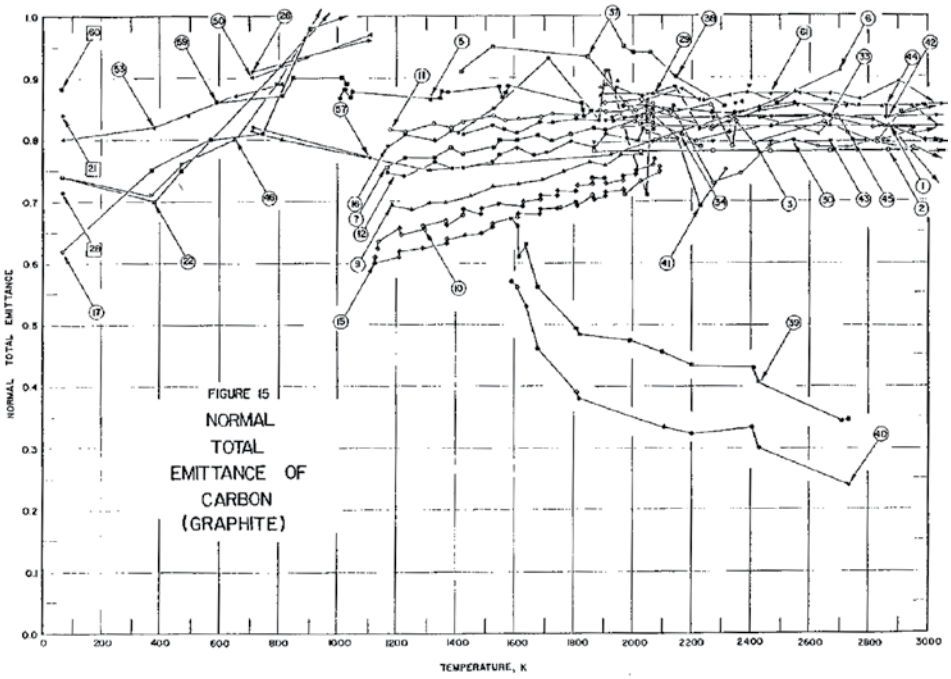

Figure 1: Emissivity of graphite from the thermophysical properties of matter. [1]

EMISSIVITY

In the ideal case, the radiated light from the thermal target depends only on the temperature. In reality, the emissivity (also known as the emittance) of the target material modifies the radiated spectrum as a multiplier of the mathematical statement of Planck's Law. The emissivity is nothing more than the efficiency of the radiator at each wavelength radiated. Emissivity ranges from zero to one; obviously, its effect can be very large.

To further confound the issue, emissivity is not a property of matter, but a property of the particular sample in question. Key parameters affecting the emissivity of a sample are the surface finish, the chemical composition, the degree of oxidation, the

phase, the wavelength at which the emissivity is desired, and the temperature itself. Graphite is one of the more common and better-known refractory materials. Figure 1 shows the reported emissivity of graphite as a function of temperature.

The number associated with each trace describes the conditions for that measurement. Clearly the values reported vary widely, from less than 0.3 to 0.99. Some show a temperature dependence, and some do not. And this is for a material, graphite, that is considered well behaved.

The problems of non-contact temperature measurement are associated with the material measured, the environment of the measurement, and the pyrometers themselves.

PYROMETERS AND THEIR EVOLUTION

The idea of emissivity and the development of pyrometers are intertwined. The first pyrometers, which appeared early in the last century, were merely light meters. They measured a quantity of light and that quantity was related to a temperature. This type of pyrometer is known as a single-color or brightness pyrometer. While the terminology "single-color" implies a single wavelength, all such devices actually use a waveband — some contiguous group of wavelengths. If the manufacturer reports an integral wavelength for the device, this is the effective wavelength, which means the mathematics work for this value. The waveband can be as wide or as narrow as desired. This raises the possibility that two pyrometers of different manufacture, both reported to use the same wavelength, might require a different value of emissivity to correctly report the temperature for the same target. The operator is required to know and enter the emissivity in this type of pyrometer.

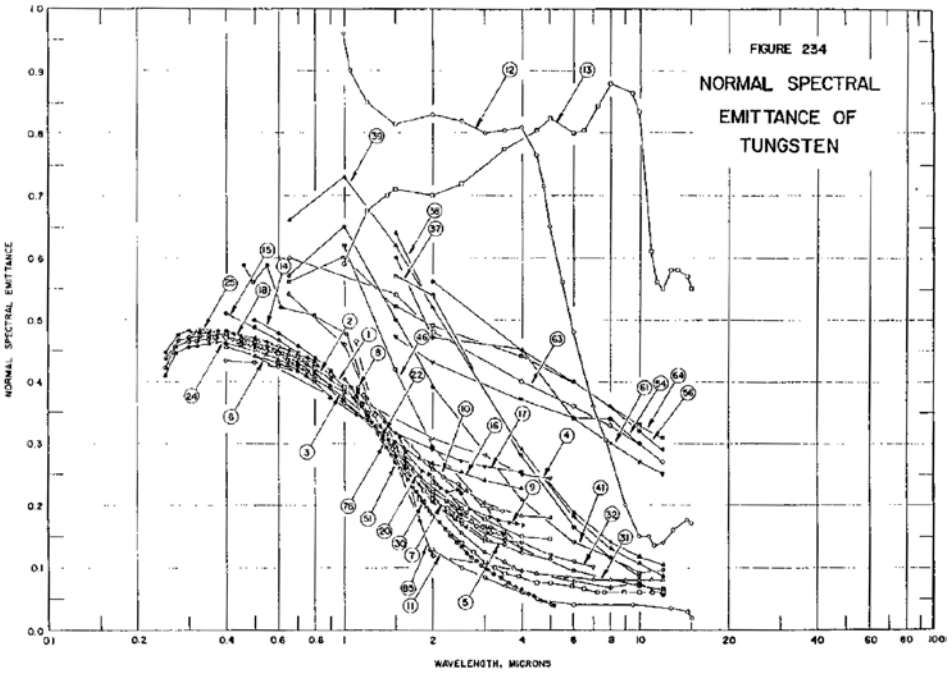

Figure 2: Spectral emissivity of tungsten. [2]

It is clear from Figure 1 that this is a daunting task. By the middle of the last century, a solution appeared. The two-color, or ratio, pyrometer was developed. This instrument took advantage of a mathematical manipulation of Planck's Law. If the intensity of the thermal radiation is measured at two wavelengths (also "colors," but actually wavebands, just as in the single-color pyrometer), the ratio of these intensities can be solved for temperature, and the expression for emissivity can be canceled out. This worked for graphite and other refractories, but did not work for an important class of materials: metals. For the emissivity to cancel out, it must be the same at both wavelengths; a target with emissivity constant with wavelength is described as semi-ideal, or "gray." But metals typically show a wavelength dependence of emissivity (i.e. non-gray), as seen in Figure 2 for tungsten. Again, each numbered

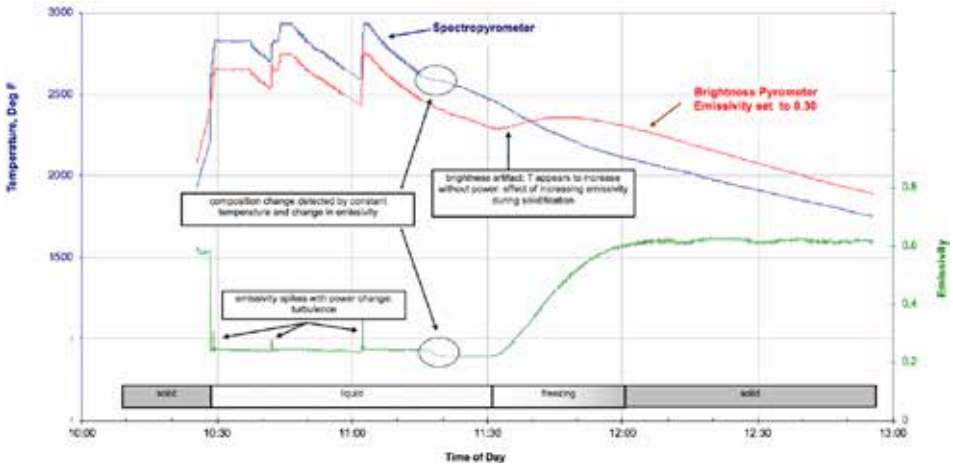

Figure 3: A nickel superalloy processed in an investment casting induction furnace; upper traces are temperature, plotted on left axis; lower trace is emissivity, plotted on right axis; horizontal bar shows phase of material for each time period.

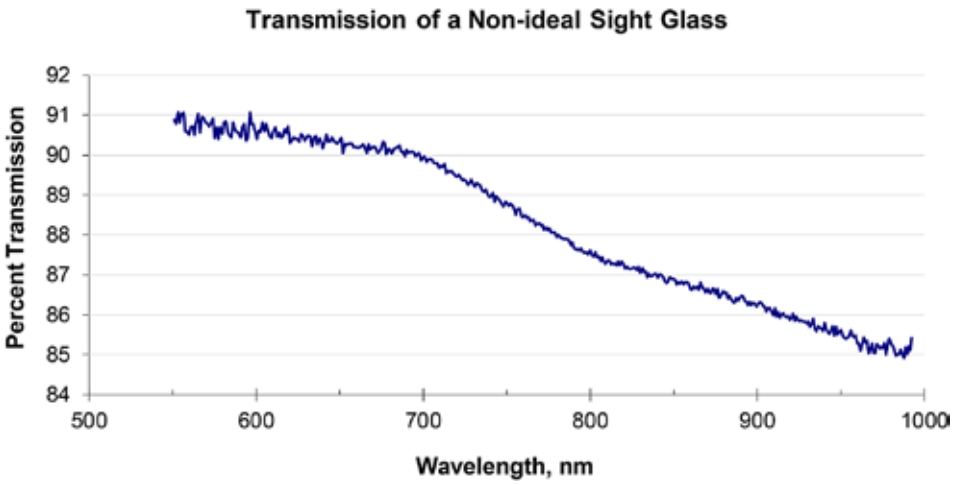

Figure 4: A window taken from an investment casting shop.

trace was measured under different conditions. Tungsten is a good example of a non-gray metal because it has been widely studied for its use in lighting applications, but it should be noted that every metal in the referenced volume shows similar spectral dependence of emissivity. For ratio pyrometers, the operator is required to either assume the ratio of the emissivities is one, or enter a "non-grayness" factor, an even more daunting task.

At the end of the last century, a further solution was developed that addressed the non-grayness (spectral variation of emissivity) of metals. Spectropyrometers, or multi-color (multi-wavelength) pyrometers measure very narrow wavebands over large spectral areas. The very large amount of data is then processed to determine the emissivity at the time of the measurement, thus eliminating the uncertainty of unknown emissivity. These instruments have been available now for about 25 years and have resolved some previously intractable issues. Figure 3 shows a nickel superalloy being processed in a vacuum induction furnace for investment casting, contrasting results from a single-color pyrometer and a spectropyrometer [3]. The operator rapidly melted the sample, changed power several times, and then left the melt to cool naturally just after 11:00. The spectropyrometer detected the emissivity changing with melting, freezing, and composition change; the solid phase emissivity before and after melting differed by 10 percent. The brightness pyrometer reports an impossibility, an increase of temperature without power being added. This is because its emissivity had been set by the operators to 0.3, but as the metal freezes, its emissivity actually increases from 0.2 to 0.6.

ENVIRONMENT: INTERFERENCE

It has been established that some section of the thermal spectrum must be measured accurately to determine the temperature of the radiating object. The environment can interfere in a number of ways. Material in the optical path can absorb some part of the radiation. Other materials, either in the path or nearby, might emit their own thermal radiation, which may enter the instrument's optics either directly or by reflection.

One common object in the sight path would be a window or sight glass into the furnace or process chamber. An ideal optical window, one that transmits all wavelengths equally, will block about 7 percent of the incident thermal radiation, simply from reflection from its two surfaces. For a single-color pyrometer, the operator must modify the emissivity setting to account for this; a two-color pyrometer or a spectropyrometer would show no effect. By way of contrast, the transmission of a non-ideal window is shown in Figure 4.

This window will affect all pyrometers in ways that are not immediately obvious. The solution for such windows is either replacement or calibration with the instrument of choice.

Other environmental interference could come from gaseous byproducts of the process or the method of heating. Gases may absorb radiation or emit radiation depending on their temperature. Material thrown up by the process can also absorb or emit. Figure 5 illustrates a rather extreme case, the tapping of a blast furnace. The yellow and red colors above the casting are sodium and potassium in the vapor state, radiating their respective primary wavelengths (lines) because of the high temperature of the process. Sparks of various yellow-gold colors can be seen throughout. The gas interference would affect a single-color pyrometer in a random fashion, as gas concentration is not constant. Two-color pyrometers would be

Figure 5: Offgas, sparks, and airborne liquid: blast furnace taphole at casting.

affected if the Na and K lines are within either of their wavebands. A spectropyrometer would not be affected by these gaseous lines, whether emission or absorption.

The sparks are another matter. The thermal radiation from the unwanted object, whether spark or furnace furniture or furnace wall, can enter directly by emission or indirectly through reflection. No instrument can remove thermal radiation of an undesired object from the thermal radiation of the desired object. Once the cream is in the coffee, it can't be removed. The solutions for this case are to measure only when sparks are not present, measure all the time and reject the data with sparks (spectropyrometers can do this), or design the measurement path to remove the unwanted radiation.

CONCLUSIONS

The problems of non-contact temperature measurement are associated with the material measured, the environment of the measurement, and the pyrometers themselves. The material issue is the emissivity, which varies with surface finish, composition, oxidation, phase, wavelength, and the temperature itself. Metals, which are mostly non-gray, can exhibit both gray and non-gray behavior as a result. This incessant variation is observed in many thermal processes, where the whole point of the operation is to change a feedstock to a finished product.

The environmental issue is interference. Thermal radiation from the target is absorbed by windows and gases. Stray thermal radiation from any heated source may enter the optics if a path is present. Reflections from these same heated sources and even the target itself can bounce around in the heating area and enter the optics, corrupting the measurement.

The evolution of pyrometry has gone from the single-color to the two-color to the multi-color pyrometer. Recognizing that pyrometry can only measure solid and liquid targets, each developmental step has solved problems that were insoluble before. The single-color made non-contact temperature measurement possible. The two-color made accurate temperature measurement of gray materials, but returned large errors when confronted with the non-grayness of metals. In the current stage of evolution, the multi-color pyrometer addresses both unknown and changing emissivity and the non-grayness of metals to return accurate temperatures.

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ABOUT THE AUTHOR

Ralph A. Felice is with FAR Associates. He started his direct involvement in pyrometry during a process study of a forging weld. The only variables were temperature and pressure, so temperature was important. Felice did what most would do at that time (pre-internet): He called in salespeople from the major pyrometer companies for a demonstration. None of the instruments agreed, and the problem was "left as an exercise for the student." For more information, go to www.pyrometry.com.

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Thermal processing

THE SCIENCE OF DIFFUSION BONDING

OR JOINING TOGETHER DISSIMILAR METALS

Combining the beneficial properties of different metals is the main reason to explore diffusion bonding. (Courtesy: PVA TePla America)

Working with an expert manufacturing partner can help to use the best properties of both similar and dissimilar metals.

By JEFF ELLIOTT

Metal diffusion bonding is an essential joining method for achieving a high-purity interface when two similar metals require superior structural integrity. The process involves applying high temperature, and pressure to metals mated together in a hot press causes the atoms on solid metallic surfaces to intersperse and bond.

There is probably no other commercially viable materials-joining process that can produce such consistent results today. The applied pressure induced by a hot-press tool, combined with software and loop-back sensors for precise control to within micrometer accuracy, can produce constant pressure over several square feet of area for a component assembly. As a result, this technology has attracted the interest of design engineers in the semiconductor, aerospace, and energy industries.

With such a high degree of process control, the diffusion bonding process is increasingly used to join dissimilar metals. Commercial processes of interest are titanium to iron-nickel alloys, titanium alloys to stainless steel, and even some aluminum to metal applications. The process also enables coupling between different alloys in the same material group, such as mild steel, tool steel, and metal-matrix composites.

To successfully use diffusion bonding, an understanding of the complexities of the interface and its effect on the chemical and thermo-mechanical properties of the bond is required. However, with the industry's traditional focus on welding and brazing, there has been minimal formal education on diffusion bonding, according to Thomas Palamides, Senior Product & Sales Manager — Industrial Furnaces, PVA TePla AG, a global manufacturer of industrial furnaces and PulsPlasma nitriding systems.

"Combining the beneficial properties of different metals is the main reason to explore diffusion bonding," he said. "However, when manufacturers reach out (to us about it), they often understand little about how the parts should be designed, prepared, or handled. They may have questions about process data and need guidance on issues such as heating, cooling, and pressing rates."

Consulting with an expert manufacturing partner is often the quickest way to consider the possible benefits of diffusion bonding. The approach can also help to tailor diffusion bonding to the manufacturer's process cost-effectively.

THE BENEFITS OF DIFFUSION BONDING

The importance of designing a dissimilar metal joint often lies in a desire to expose the correct metal surface to specific environmental conditions where a single alloy may not perform as well. Another reason is to introduce material systems that are lighter in weight or provide a level of corrosion resistance that can only be achieved by "packaging" dissimilar metals.

Diffusion bonding also has tremendous potential applications for conformal cooling. The concept is to bond layers of sheet metal that contain machined channel/microchannel structures. When combined, the channels can provide for cooling or heat dissipation. The layers can be bonded up to a stack height of 600 millimeters in the MOV diffusion bonding press, retaining the strength as the parent materials.

Another application related to conformal cooling is for plastic injection molds made in two-layer designs of low alloyed tool steel with stainless steel such as STAVAX.

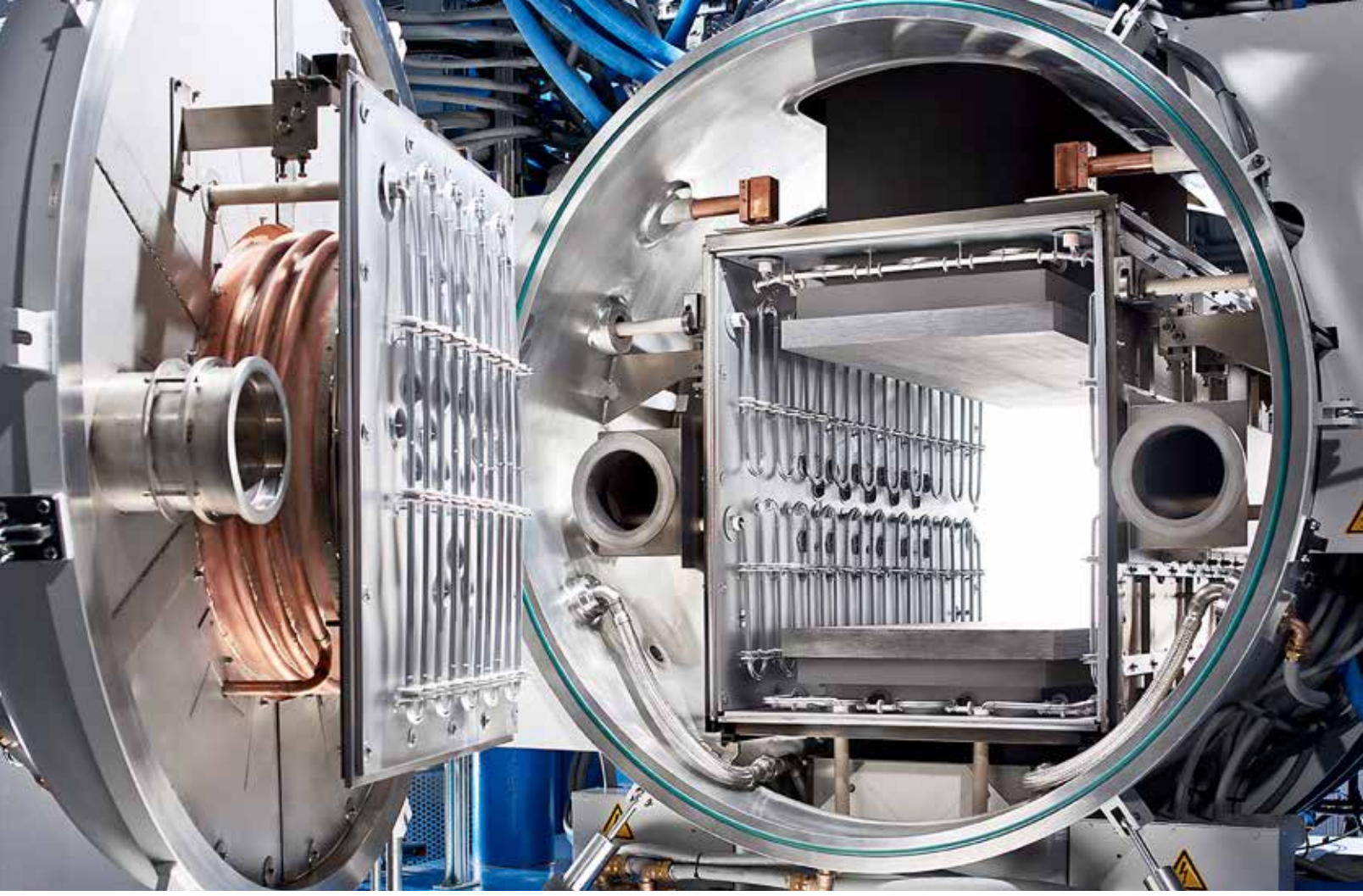
The concept is to bond layers of sheet metal that contain machined channel/microchannel structures. (Courtesy: PVA TePla America)

UNDERSTANDING DIFFUSION BONDING

Academia has researched dissimilar joining for decades, and much of the focus has been on high-performance materials such as titanium alloys. According to Palamides, expanding beyond commercially pure (CP) titanium, one often finds the existence of an intermetallic layer at the mating interface after processing.

"The influence of the solute elements, such Cu, Ni, and Ag are the major drivers for the intermetallic layer formation in titanium," he said.

The diffusion bonding process can occur as either a solid-state or a liquid-phase bonding process. Similar pure material bonding has



Advances in high vacuum hot presses now allow superior pressure control and rapid cooling systems to improve the bond, increase yields and significantly decrease cycle time. (Courtesy: PVA TePla America)

historically been as a solid-state operation. This method simplifies the process from an assembly standpoint, as faying surfaces can be easily matched before placing a charge into the furnace. Alignment pins and tack welding may be used for this process as well. Because no liquid phase is present in diffusion bonding, slight deformation occurs at the surface. This results from applied pressure used to flatten surface asperities and break up residual surface oxides before bonding.

In the liquid-phase diffusion bonding process, an interlayer typically melts at the faying surfaces. In this instance, lower pressure than solid-state diffusion bonding is used, and even less deformation occurs at the surface. Depending on the thermal cycle and composition of the interlayer materials combination and the interlayer selected, an inter-diffusion occurs between the interlayer and base materials on either side of the joint through the metallurgical processes known as a eutectic or peritectic phase change.

The thickness of the final intermetallic reaction layer is a result of first, from the liquid-phase diffusion and second, from the solid-state diffusion. Bond strength is a function of the intermetallic compounds formed, the thickness of the intermetallic zone, and anomalies, such as voids, at the interface.

EXPLORING DIFFUSION BONDING

There are several ways for manufacturers to investigate how diffusion bonding of dissimilar metals could benefit their process. Much scientific literature is readily available for specific material combinations and processing times and temperatures depending on the application. For example, Kavian O. Cooke and Anas M. Atieh conducted an exhaustive review published in 2020 titled *Current Trends in Dissimilar Diffusion Bonding of Titanium Alloys to Stainless Steels, Aluminum, and Magnesium Journal of Manufacturing and Materials Processing.*

While ample research exists on the subject, design engineers can still find it challenging to convert the information into real-world manufacturing of a specific part. When this is the case, it can be helpful to partner with experts with an extensive database of successful processing parameters from previous applications and access to industrial-scale equipment.

"In most cases, we start talking with the manufacturer about introducing new designs, and consult on possible materials, designs, and also conduct pre-bonding runs as needed," Palamides said.

PVA TePla provides support, including specific material combinations, processing times, and temperatures.

Palamides noted proper design will allow diffusion bonding of assemblies, whether an intimate interface or multiple interfaces that are planar parallel simultaneously. However, surfaces that are not perpendicular to the compressive force of the hydraulic ram will not bond properly.

The manufacturer begins by working with their mechanical, thermal, and modeling teams, according to Palamides. Once a design is complete, the next step is to fabricate trial samples that are truthful to the characteristics of the final interface.

"Locate a vendor who can perform contract service trial runs," he said. "Propose a test matrix to ensure your schedule is aligned with project goals."

ADVANCES IN DIFFUSION BONDING EQUIPMENT

Despite its benefits, the use of diffusion bonding has been limited by more practical considerations until recently. Specifically, the size limitation of the furnace chamber and limits to the amount and uniformity of the pressure applied across the entire surface area of the part. Run times are also long, often lasting an entire day.

Advances in high vacuum hot presses now allow superior pressure control and rapid cooling systems to improve the bond, increase yields, and significantly decrease cycle time.

In the case of the pressure applied, for example, integrated single cylinder hydraulic presses can apply a consistent, measurable amount of force. However, this provides very little control over large parts with more complex geometries. To improve force distribution, thick graphite pressing plates (10 to 15 inches in height) mate the metal layers together at a more consistent pressure. Unfortunately, this takes up furnace space while adding to the time to heat the surfaces of the metals.

Today, manufacturers such as PVA TePla offer multi-cylinder systems with large pressing plates that can accommodate various parts. The largest, the company's MOV 853 HP, can process substrates as large as 900mm (35.43") x 1,250mm (49.21"), which is quite large for diffusion bonding. The pressing force is 4,000 kN.

By controlling each cylinder independently, the integrated press provides remarkably consistent pressure across the entire surface. The MOV also comes with built-in pressure transducers along the bottom of the pressing plate. The individual hydraulic cylinders can be adjusted in the software to achieve uniformity even over large areas based on the sensor feedback.

PVA TePla has optimized a physical ink test method that identifies areas on the substrate where uneven pressure is applied.

"Today's equipment provides detailed measurements of the material properties during bonding," Palamides said. "This valuable feedback can show how the materials are compressing, if it is being crushed, and if a transient liquid layer is forming — and other KPIs of the procedure."

VERIFYING THE INTEGRITY OF THE BONDING INTERFACE

To ensure the quality of the interface, Palamides recommends analyzing samples through non-destructive inspection techniques, such as scanning acoustic microscopy (SAM), or more costly analysis performed using scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM-EDS). Subsequently, trial samples may be destructively analyzed and fabricated into standard mechanical test specimens to collect repeatable data.

While there is growing interest in diffusion bonding, all applications require thorough research to optimize the joining process. Only a few global firms can work with manufacturers through the process with the ability to advise on commercial system adoption. From the beginning, partnering with an expert in diffusion bonding will give manufacturers a competitive edge from part design through production ramp-up.

ABOUT THE AUTHOR

Jeff Elliott is a Torrance, California-based technical writer. He has researched and written about industrial technologies and issues for the past 20 years. For more information, contact PVA TePla America at www.pvateplaamerica.com.

COMPANY PROFILE ///

ROCKFORD COMBUSTION SYSTEMS

INDUSTRY LEADING COMBUSTION SOLUTIONS

Rockford's job is to ensure workers understand how to maintain the safety equipment as well as the functions of that safety equipment and what can happen if that safety equipment is circumvented. (Courtesy: Rockford Combustion Solutions)

Rockford Combustion Systems offers expertise and experience to improve NFPA compliance, worker safety, efficiency, and air quality, while reducing the risk of fires and explosions.

By KENNETH CARTER, Thermal Processing editor

For industrial furnaces and ovens to do their jobs involves a lot of potentially dangerous and hazardous machinery and materials. To run this equipment, workers need to be trained properly in order to avoid injuries — or worse.

Rockford Systems takes those demands seriously and has been working with safeguarding mechanical equipment and, by extension, the combustion market, for decades.

"The two really go hand-in-hand; we're big on safety; the basic philosophy of machine safeguarding — if you think about turrets and punch presses and other machines with pinch points or moving hazards — is the need to verify all conditions are individually proven correct before anything engages," said Robert Sanderson, director of Business Development with Rockford Combustion Systems. "That is the underlying pinning of our safety philosophy. In the combustion market space, the same philosophies are there. You prove all the conditions are safe before igniting. You've proven your fans are ready. You've proven all has been fully purged. You've proven the fuel system ready to go."

OSHA INSPIRED

Rockford Systems got its start in safeguarding mechanical equipment in the 1970s, shortly after the creation of OSHA.

"Back in the '70s, upwards of 18 to 20 percent of the industrial workforce was injured or maimed," Sanderson said. "A notable portion of those were deaths, actually. That was what really drove the creation of OSHA, to drive all that down and protect workers. Now, today, we are statistically much safer. OSHA is also a much larger entity. They look over a larger array of equipment and additional areas. The injury rates and statistics have really improved. So, the roots of Rockford Systems have been long established in safety."

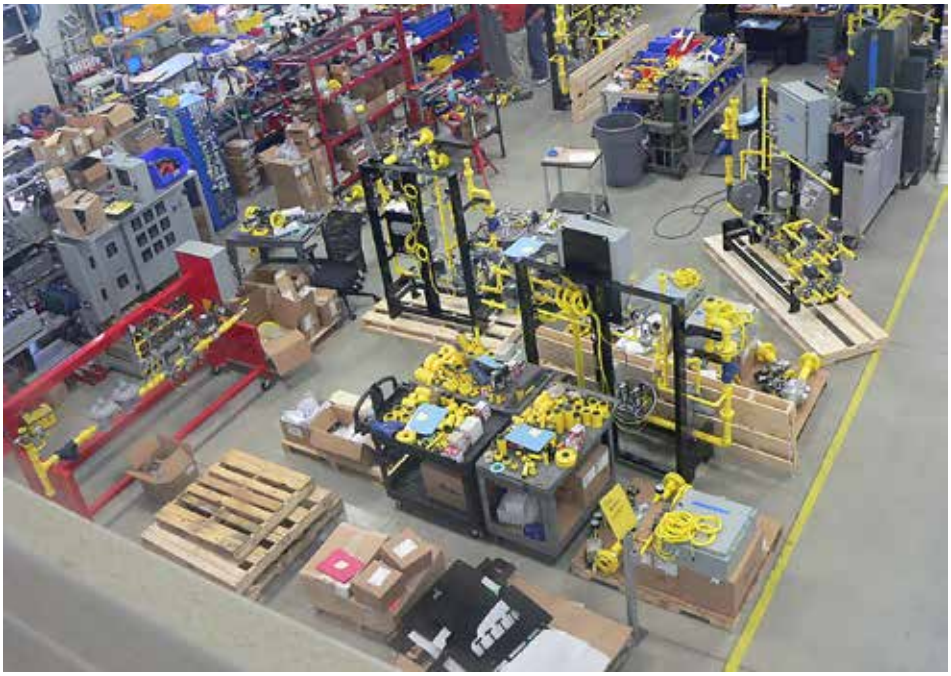
With an established record of protection devices and safety training for mechanical equipment, Rockford Systems expanded its safety offerings into the combustion market space, according to Sanderson. With that decision, Rockford Combustion Systems was created.

"The philosophies of mechanical and combustion safety — although you're looking at different parts — are really hand-in-glove the same; it is a good fit with our customers," he said. "Many of our customers need both sides of the business. It allows for holistic turnkey offerings, that we can go in and help them by improving safety to all areas of their manufacturing facilities, and not just to the OEMs, but to the end users."

CUSTOM SOLUTIONS

For the heat-treat industry, Rockford is a turnkey solutions provider, designing and delivering custom solutions as well as providing training, inspection, and annual reviews for its users so they can properly maintain, run, and operate their systems, according to Sanderson.

"Many people do not realize it, but the NFPA requires combustion systems be inspected at least annually and checked and tested, and that the operators review and are retrained annually as well," he said. "The operators are your first line of defense, if you will, to ensure that the equipment is maintained and running in a safe condition. One of the big things that we can do is provide that training at the facility or here, in-house. We can also help inspect the equipment or train the people on how to inspect it themselves."



For the heat-treat industry, Rockford is a turnkey solutions provider, designing and delivering custom solutions as well as providing training, inspection, and annual reviews for its users so they can properly maintain, run, and operate their systems. (Courtesy: Rockford Combustion Solutions)

VALVE SAFETY

Since much of the equipment in the heat-treat industry revolves around the use of different types of sometimes volatile gases, that equipment often relies on simple valves — valves to close, to provide

Rockford has a portable workshop that the company's experts can take with them directly into a customer's business. (Courtesy: Rockford Combustion Solutions)

safety, to provide throttling, and to provide control, according to Sanderson.

"Valves are mechanical devices," he said. "They wear out, and they leak. I like to say all valves all leak. It's just a question of how much, and is it an acceptable level? Is one drip a year out of a faucet acceptable, or are you willing to accept three drips a week or three drips a minute? All valves leak. So, when do you replace it? That is why you need to do annual inspections."

Rockford has a number of customers where they check and maintain the equipment, as well as provide an independent observation on how that equipment is running, according to Sanderson.

"One of the pieces of safety equipment used on fuel-fired equipment are pressure switches — high-pressure switches and low-pressure switches typically," he said. "The low-pressure switches basically are ensuring, at the front of the fuel piping, a minimum amount of gas pressure to safely operate is there. At the other end of the train is often a high-gas pressure switch to ensure that nothing between has failed, and you're not putting too much pressure, too much fuel, into the system — that you're not 'over-gassing' it. People have to check and maintain those devices. Some people have bad practices, however. They want to do what they can to keep things going and may not realize the consequences of their actions."

Those bad practices can result in damaged equipment or injuries when workers don't realize the hazard they are creating when they might be annoyed by an alarm and do something to bypass it, according to Sanderson.

"One of the key things we do is go through and make sure those switches are installed correctly; make sure that they are operating correctly; that they're arranged and set correctly; that the operators understand what those switches are for, and what to do if they're not working," he said. "Just because it's going off, doesn't mean that the switch is bad. It quite frequently is an indication that something else isn't right."

"We view our customers as partners; we want them to have positive experiences and relationships, and build upon that to grow and move forward with us."

PROPER TRAINING

Rockford's job is to ensure workers understand how to maintain the safety equipment as well as the functions of that safety equipment and what can happen if that safety equipment is circumvented, according to Sanderson.

In order to properly teach these combustion safety procedures, Rockford has a portable workshop that the company's experts can take with them directly into a customer's business.

"We have a hands-on workshop that we can take with us," Sanderson said. "We've built it. It's portable. It's kind of a valve train in a suitcase. We bring it. We set it up, and we give the workers

hands-on safety training."

During safety sessions, the portable workshop runs on compressed air to simulate how the system works when there is an actual fuel going through it, according to Sanderson.

"We can simulate faults and failures and show the workers exactly what's going on, so they can understand and appreciate it and see how it's supposed to work and what happens when it doesn't, in a completely safe classroom environment," he said.

COMBUSTION OPPORTUNITIES

Rockford was able to enter the heat-treating arena when a fuel burner and systems manufacturing company in Rockford, Illinois, went out of business, according to Sanderson.

"That was one of the ways that we were able to move into the market space," he said. "There was a lot of knowledge and talented, experienced workers that were in the area. So, we took advantage of that."

To that end, Sanderson said Rockford has matured with its customers, especially as COVID and other pandemic-related shortages and delays became a challenge.

"Being a fresh set of eyes, we bring a newer set of approaches to our offerings; we've developed a good number of partnerships with our suppliers," he said. "I like to refer to them as partners, not suppliers, because we really do have fantastic working relationships with them. We work with them, and they bend over backwards to support us."

And that includes finding alternate solutions for its customers as well, according to Sanderson.

"That's something we are not shy about doing, is to help our customers by finding creative, voluntary turnkey solutions," he said. "They may have always done it a particular way, but with COVID and other shortages — such as manpower — they may not necessarily be able to implement the same-old methods. We work with them to understand their processes and find other operations and other approaches with our turnkey offerings, to help get them out of painted corners."

CUSTOMERS AS PARTNERS

In essence, Rockford is in the business of wanting its customers to safely succeed, according to Sanderson.

"We view our customers as partners; we want them to have positive experiences and relationships, and build upon that to grow and move forward with us," he said. "We try to find creative, suggestive solutions for other ways to accomplish their tasks. We'll do it the way they want, but sometimes, there's another approach, because we see a lot of other ideas and applications in the industry. Some of our employees are from paint, from furnaces, from air heating, from food and beverage industries. We've got a lot of different skillsets. We work to cross train those experiences and bring those ideas from other market spaces to help find turnkey custom solutions."

Since starting the combustion part of its portfolio four years ago, Sanderson said Rockford has grown tremendously and is eager to tackle any challenges the future may hold.

"I see the industry transitioning toward alternate fuels and more alternate sources of heat," he said. "We will continue to be at the forefront of that, on the safety side, making sure people are properly addressing their fuels. Different fuels have different hazards. One can't just switch from natural gas to propane or hydrogen without addressing the unique hazards that those different chemical compounds introduce. Users need to understand how each behaves and their unique hazards. We will be there to assist them with those transitions, educating them and working to ensure the workers are safe."

Rockford is in the business of wanting its customers to safely succeed. (Courtesy: Rockford Combustion Solutions)

Sanderson said Rockford will continue to push those turnkey solutions in order to ensure the safety of both its customers' employees and their processes.

"That is the big driving factor for us — making sure everyone goes home safe every day," he said.

MORE INFO www.rockfordcombustionsolutions.com

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ADVERTISER INDEX ///

DAVID HAMLING /// VICE-PRESIDENT AND CO-OWNER /// ZIRCAR CERAMICS

"In addition to precision CNC-machined parts, we manufacture products we call heater modules (HTMOD) and furnace insulation modules (FIM)."

What's a typical week like for you at ZIRCAR Ceramics?

I drive the company's sales and marketing efforts and usually begin my day with a couple of hours of e-mail. We have some very important customers in Asia and Eastern Europe. I know that these customers and our reps that are working with them are eager to receive responses to their email. I am also the receiver of emails sent to sales@zircarceramics.com, and my policy is to respond to all inquiries with at least an initial technical response or with list pricing within eight business hours. It is so easy to shop the internet, and I believe that much of the success we have been having is due to the fact that a quick reply from us gets potential customers' attention and their business. When I finish with emails, I head to my office, or if I am traveling, to a customer meeting. I am very glad to see the COVID clamp loosening, and have been enjoying seeing customers again.

One of the roles I fill is the company's chief design engineer (CDE). My staff does a fantastic job of working with customers to ensure their drawings are properly interpreted and the jobs we send to our five CNC routers are going to result in manufacturing the custom cut parts correctly. In addition to precision CNC-machined parts, we manufacture products we call heater modules (HTMOD) and furnace insulation modules (FIM). HTMODs are engineered combinations of resistance wire heating elements and vacuum formed ceramic fiber insulation built into, usually, stainless steel enclosures. FIMs are engineered combinations of a number of our insulation materials built into a structural steel frame. I drive the design efforts for these products. It is important to note that, as we do not produce power supplies/control panels, we do not consider ourselves as furnace builders. In fact, the customers for our HTMOD and FIM products are usually OEMs that incorporate these products into the thermal-process systems they manufacture.

ZIRCAR has developed a coating for Alumina Textile Type AS-7M called Alumina Rigidizer Type AL-R/H. What is it and how can it help reduce fraying?

Actually, the Alumina Rigidizer/Hardener is a product my father, Bernie Hamling, developed in the early 1980s. This product is a colloidal alumina suspension of very, very fine aluminum oxide powders. It acts like a hairspray, if you will. As a surface treatment, it goes on very thin and acts as an adhesive coating between fibers in a textile or on the surface of a rigid fiber body. AL-R/H is the inorganic binder we use in the manufacture of our ALL-Alumina fiber products — making them useful in the reducing atmospheres employed in numerous thermal processes. and it acts as a binder, or an adhesive, between fibers in a textile. One of the things we hear from OEM furnace builders as well as heat treaters is: "Ceramic fiber dust in vacuum induction heat treating furnaces is a 'killer'" — meaning abrasive dust can damage working surfaces in vacuum pumps. Treatment with the Alumina Rigidizer/Hardener can work to significantly reduce particulate generation from low-density, low-mass materials.

Another interesting development from ZIRCAR is its RNKO-HD Alumina-Silica board. What makes it unique, and what is it designed for?

RNKO-HD is uniquely high in density for the type of material that it is — a low-density silica bonded ceramic fiber board. It has a bulk density of, nominally, 53 pounds per cubic foot, which imparts excellent machinability and high-compressive and flexural strength with exceptional creep resistance at temperature under load. We developed the material to make nozzles for continuous casting of aluminum sheet, but our customers have been successfully applying this material as firing setter plates, infrared reflectors, and hot-press insulation. Our next market development for this product is to work to have it adopted as backup insulation in large dense refractory-lined tundishes, crucibles, and torpedo cars used in primary metal industries.

ZIRCAR recently manufactured its largest fiber-insulated heater. For what type of jobs within the heat-treat industry would this accomplishment be ideal?

The largest heaters that I have made are used by a company that builds and operates molten salt baths for the heat treating of custom-machined turbine components they manufacture. In his July 2021 *Thermal Processing* article, Scott MacKenzie wrote, "For most general-purpose heat treating to 900°C, a 50/50 mix of sodium chloride and potassium chloride is the most common." This type of fiber-insulated heater is quite appropriate for this type of application.

MORE INFO www.zircarceramics.com

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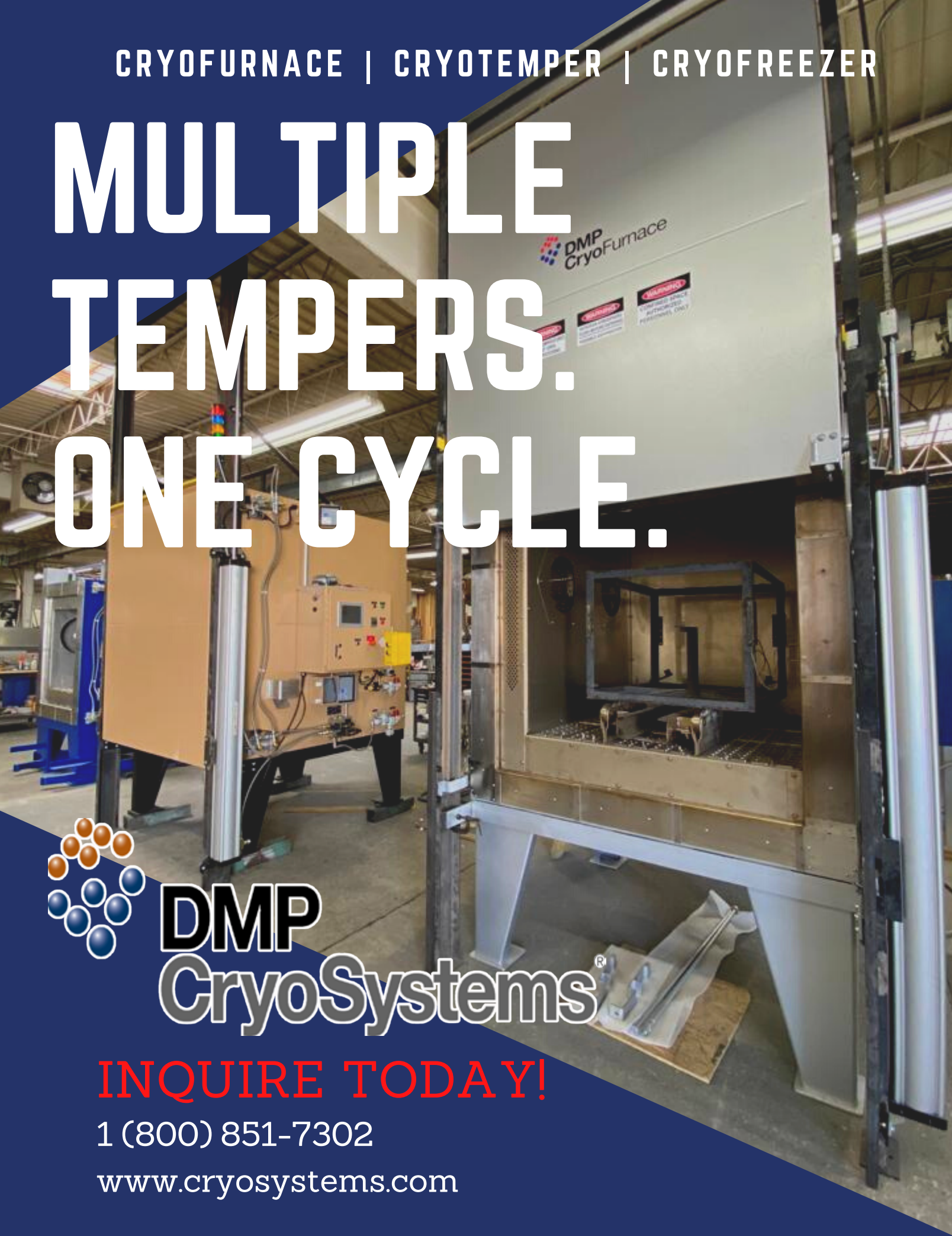

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