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Thermal processing

ISSUE FOCUS ///

COMPOSITES / FIXTURES

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HAVE SPECIALIZED CURING REQUIREMENTS

COMPANY PROFILE ///

I Squared R Element Co., Inc.

MAY 2019
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P/M Uni-DRAW® Batch Tempering Furnace

For Powder Metal Processing

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- Annealing
- Black Oxide
- Bluing
- Solution Treatments
- Stress Relieving
- T6 Heat Treatments
- Tempering

The Surface® Combustion P/M Uni-DRAW® Batch Tempering Furnace's patented round design provides a circular wind flow for excellent temperature uniformity. It has been designed specifically to temper or draw powder metal parts that have been oil quenched. Smoke generated in the processing is directed to the electrostatic precipitator, and its unique construction prevents smoke or oil contamination of the furnace insulation. This patented inside/out technology is also available in continuous designs to meet your high volume needs. The P/M Uni-DRAW® has been designed to be a companion to the Allcase® Batch Integral Quench Furnace or as a stand-alone unit.

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CONTENTS ///

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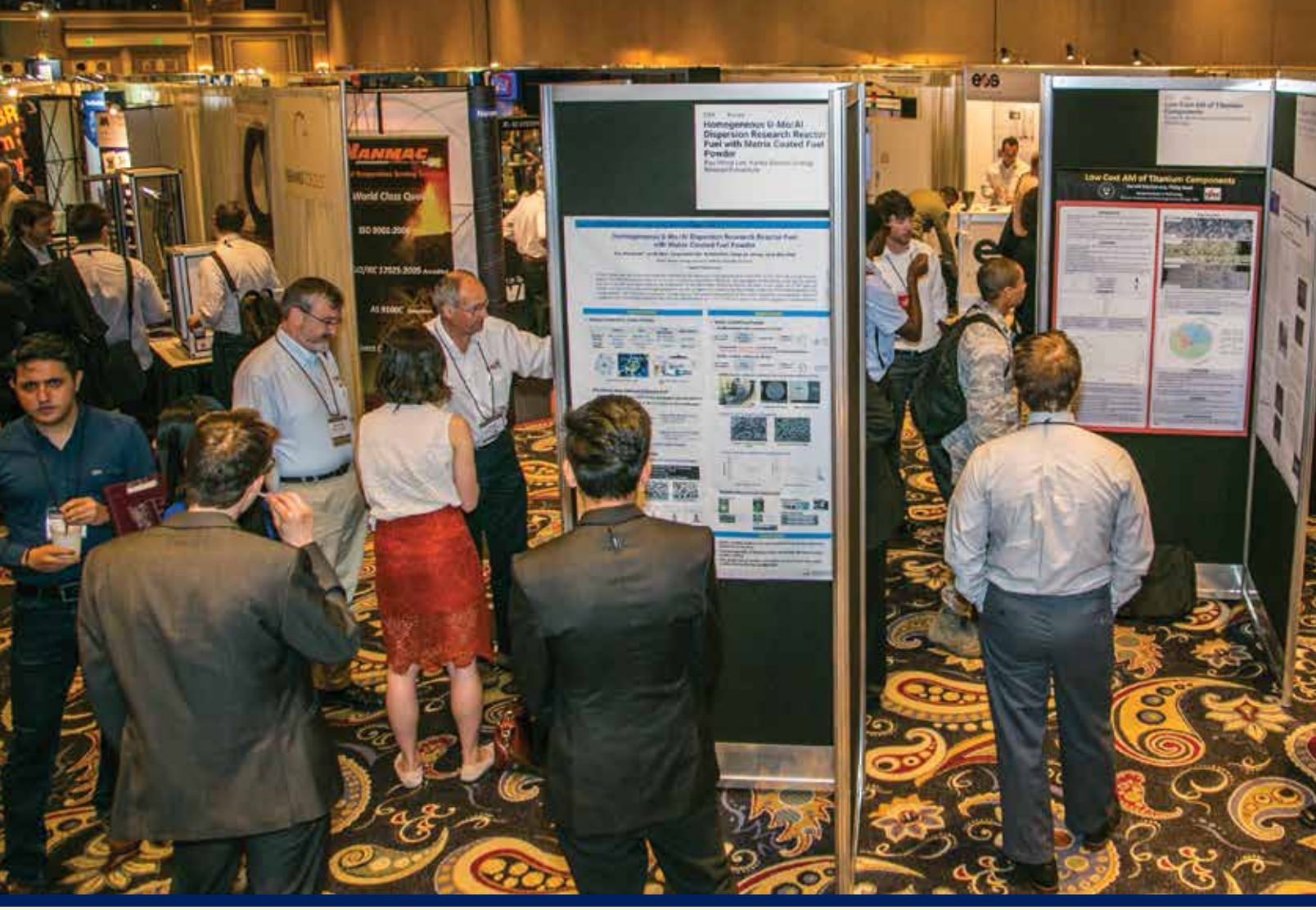


DEPARTMENTS ///

MAY 2019 VOLUME 8 / NUMBER 5

UPDATE ///

New Products, Trends, Services & Developments

- **Baker Furnace has AR platform for use on furnace lines.**
- **SCHWING's fluidized bed technology aids tool quality.**
- **eldec has customized energy source for induction heating.**

Q&A ///

ERIC FORD

VICE PRESIDENT OF SALES AND MARKETING /// GRAPHITE METALLIZING CORPORATION

RESOURCES ///

Industrial Heating Equipment Association (IHEA)

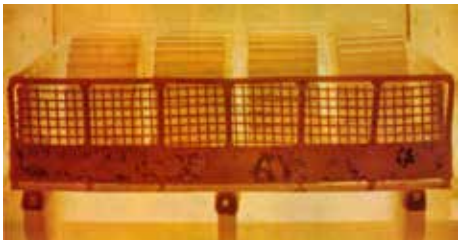
In this section, the national trade association representing the major segments of the industrial heat processing equipment industry shares news of the organization's activities, upcoming educational events, and key developments in the industry. **18**

METAL URGENCY ///

Understanding decarburization's fundamentals is vital to product performance. **20**

HOT SEAT ///

Carburizing, case hardening and the general history of thermal processing. **22**



QUALITY COUNTS ///

Challenge Accepted: This drafting technique provides suppliers with the organization necessary to show conformance to auditors and employees. **24**

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FROM THE EDITOR ///

Don't forget your composites and fixtures

Composites and fixtures are important, yet their importance can often be overlooked.

They're not splashy, like quenching. They're not flashy, like vacuum heating or induction heating.

But they are necessary elements of heat treating.

Thermal Processing thinks they are necessary, too. That's why this month's Focus takes an expert look at these two aspects of the heat-treat industry.

Starting with our cover story, Wisconsin Oven shares an article on the specialized curing requirements of filament-wound composites.

On the subject of fixtures, Semco Carbon takes a look at machining graphite components and goes into more detail about how various forms and fixtures used in vacuum furnaces and various sintering operations nearly all require graphite.

May's *Thermal Processing* also has a few other interesting features that you should definitely check out.

The company profile shines a spotlight on I Squared R Element Co. I had the pleasure of chatting with Christina Clowes, the company's vice president. The company has a unique history and offers some very special products that have helped to revolutionize the industry.

Speaking of revolutionary, in this month's Q&A, I spoke with Eric Ford, vice president of sales and marketing with Graphite Metallizing Corporation. Ford enthusiastically discussed his company's creation of Graphalloy, a graphite/metal alloy solution to anyone wanting to get rid of grease, since Graphalloy is self-lubricating and boasts a wide temperature range.

In addition to these features, be sure to check out our monthly columnists as they tackle a variety of subjects vital to heat treating.

I hope you enjoy this month's content, and if you'd like to contribute to a future issue, please don't hesitate to contact me. I'm always on the lookout for expert advice that furthers the advancement of the heat-treat industry.

As always, thanks for reading!

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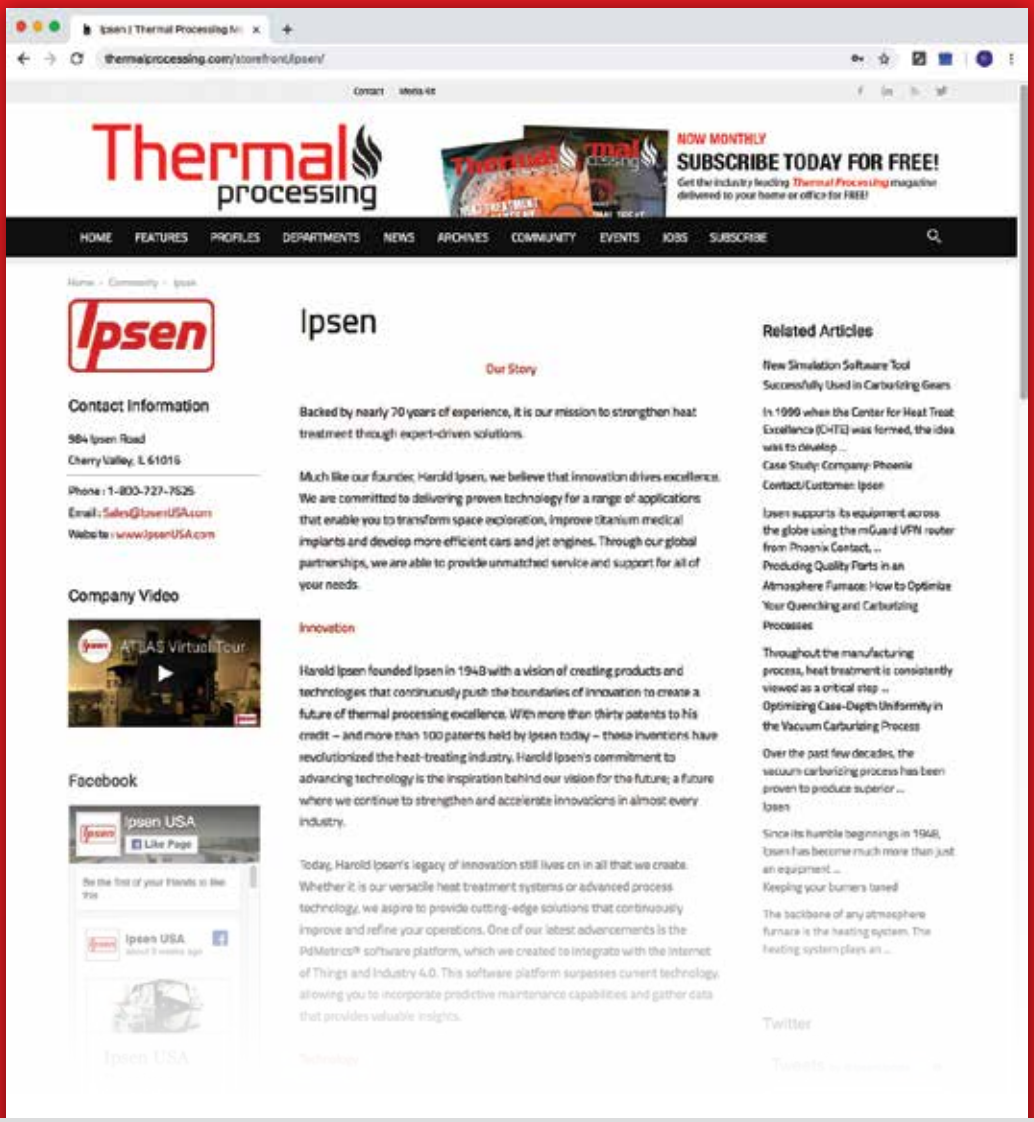

Connect your company to the heat treating industry with a storefront in the Thermal Processing Community.

Storefronts paint a portrait of your company with a 500-word description and include your logo, website link, phone number, email addresses, and videos. Your social media pages such as Twitter and Facebook are integrated with live updates, which may also be re-posted through our social media feeds.

With a community storefront, your company also receives a premium listing in the annual Buyer's Guide published each November. Premium listings feature graphic treatments to draw more attention to your company.

For information on how you can participate in the ThermalProcessing.com community storefront, contact

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Thermal processing

Augmented reality allows operators, maintenance personnel, and engineers to interact with the furnace through a tablet. (Courtesy: Thermal Product Solutions)

Baker Furnace has AR platform for use on furnace lines

Baker Furnace, a division of Thermal Product Solutions, presents the augmented reality (AR) platform to its furnace lines. Augmented reality allows operators, maintenance personnel, and engineers to interact with the furnace through a tablet. There are three levels available on the furnaces with a PLC: augmented operator, augmented maintenance, and augmented engineering.

The AR will have step-by-step procedures, component manuals, mechanical drawings, electrical drawings, and real, live data at the component level.

There is no longer a need to open electrical panels and put on ARC flash attire; with the tablet camera, all you have to do is point and click, giving you a view of the inside of the panel with all its components and live data.

"We are excited to be able to offer this augmented reality platform and give our customers advanced capabilities in their controls while greatly improving their user experience," said Sergio Luevano, general manager.

The augmented-operator level will provide systematic procedures on how to run the furnace. The system logs when the procedure starts and when the procedure ends. This will provide helpful data to your industrial engineers to do a timework study by providing data on typical loads. It will also increase productivity with training new operators and serve as a refresher for standard operating procedures. Operators will have the ability to pull up manuals or send messages to maintenance/engineering with issues or potential issues directly from their tablets.

The augmented-maintenance level will provide all electrical, mechanical drawings, component manuals, and step-by-step procedures on performing maintenance on critical components. By using the step-by-step procedures, it will provide a log when maintenance was performed and on what item. Maintenance personnel will have the ability to be on the machine and use the tablet to pull up manuals, troubleshooting tips, and have maintenance intervals for each component.

The augmented-engineering level will provide real, live data of components on the tablet. It is as simple as pointing the tablet camera toward the control panel. Clicking on the image of the panel will allow you to open up the panel on your screen. Both maintenance and engineering personnel will have the ability to be on the machine and use the tablet to pull up manuals, troubleshooting tips, maintenance intervals, and real-time data of components in the cabinet.

MORE INFO www.thermalproductsolutions.com

SCHWING's fluidized bed technology aids tool quality

Rolls, extruder screws, and broaching tools are all characterized by a wide variety of stress ranges with very specific mechanical properties. In order to set the desired individual characteristics, the corresponding areas must be tempered separately.

For example, the tool surfaces used for power transmission are exposed to greater torsional forces and highly dynamic stresses, so require special toughness. Due to intense wear, other work areas require more strength. A sophisticated technology is required to achieve the correct precise properties in a targeted, safe, and environmentally friendly manner.

"This is exactly what our fluidized bed systems offer," said heat-treatment expert

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.

Andreas Guderjahn from SCHWING Technologies. "High-temperature uniformity is their particular advantage. In addition, they offer the best heat transfer properties and are characterized by particularly homogeneous heat distribution."

Rolls, extruder screws, and broaching tools can easily be immersed in the fluidized bed with the tool end or shank to be tempered. SCHWING systems ensure consistent quality. Further advantages for customers are the short process times and the flexible loading options. In contrast to the induction process, for example, in which individual inductors must be used, parts of different shapes and dimensions can be processed in one single fluidized bed.

SCHWING systems guarantee the highest temperature accuracy across the workpiece and reproducibility of each individual process.

SSC Werkstofftechnik GmbH, based in Lüdenscheid, benefits from this. The company has been working with fluidized bed systems from SCHWING for several years. Dirk Pritschke is managing director of SSC and particularly appreciates the fact that he can partially temper his customers' rolls at the desired temperature within a very short time.

View into a SCHWING fluidized bed ready for operation at 800 degrees Celsius at SSC Werkstofftechnik GmbH. (Courtesy: SSC Werkstofftechnik GmbH)

Roll immediately after partial tempering: Heat treatment in a SCHWING fluidized bed at SSC Werkstofftechnik GmbH. (Courtesy: SSC Werkstofftechnik GmbH)

"It is important for us that the quality is right and that we as a service provider can work quickly and precisely and react flexibly," said Pritschke. "This is why we are convinced by SCHWING's fluidized bed technology."

The systems are indirectly heated by electric heaters and can be used over a wide temperature range, from room temperature to 1,050°C. Fine-grained aluminum oxide is

fluidized with compressed air or other gas in a process chamber resulting in a fluidized bed that is not only highly thermally conductive, but also has a special heat capacity due to its mass.

"The rolls can easily be immersed in the fluidized bed. We can then treat them very precisely at the desired temperature. The process can be carried out quickly and the results can be reproduced at any time," said Pritschke.

Further advantages are energy efficiency and environmental friendliness of the space-saving systems. In addition, they are safer than salt baths and don't pose health risks.

MORE INFO www.heat--treatment.com

eldec has customized energy source for induction heating

eldec CUSTOM LINE: the energy sources can be configured with single or multiple outputs and a wealth of power and frequency combinations. (Courtesy: eldec)

"Customized" is the key word when it comes to delivering a perfect production solution in plant and machinery manufacture. Each technology is to a large extent individually tailored to the customer's environment, guaranteeing a highly efficient, optimally configured process.

Induction heating, especially, is one technology that must be "customized," because the quality of the procedure depends on a range of specific details in the user's application. The generator, being the energy source, plays an important role in this, as the experts at EMAG subsidiary eldec, based in Dornstetten, Germany, know well. They have been developing a variety of generators for more than 30 years, including many customized models in their CUSTOM LINE. Their approach is to engineer all the resonant-circuit components in conjunction with the control architecture to form a customized product, which provides induction heating with high efficiency, controlled application of energy, and stable processes. In order to make this process successful, close collaboration with the customer is required throughout the entire development process of the generator.

There are many possible application areas for induction hardening technologies. This efficient technique is used in the manufacture of plant and machinery, in the automotive sector, in aerospace, and in tool-and-die making. In the latter case, it is used to harden precisely those features of the tool or die that carry the greatest load later in the punching or embossing machine. Another typical area of application is the heating of components for a subsequent joining process. The technology is also used in standardized applications such as induction brazing and soldering, especially in the energy sector. Its decisive advantage here is precise targeting: The electromagnetic field applied can be adjusted perfectly to the workpiece in terms of its frequency, output, and field characteristics, so only a very precisely defined area is actually heated. This precise application of energy also ensures speed, minimal workpiece distortion, and economical energy consumption.

In many respects, however, the result depends on the technology used. Apart from the inductor, it is the generator that attracts the special attention of the developers. The induction specialists at eldec therefore offer customers not only the standardized models of the PICO, MICO, and ECO series, but also the tailored products of the CUSTOM LINE. Harry Krötz, head of electrical engineering R&D at eldec, said, "We always adjust the resonant circuit, the inverter, and the inverter control to match the inductor, the required frequency, and the output. We do that even with our more standardized series, with which we can currently cover about 80 percent of applications. With our CUSTOM LINE, however, virtually all the components can be configured in a fully variable way — from general device control to the outputs and interfaces."

Just how far this approach goes can be seen by taking a look at the details of the configuration, such as the outputs, for example. The eldec engineers are not only able to equip their technology with single or multiple outputs, but also to distribute the output of the generator however they wish. For example, it can be made available in parallel for independent control, or it can be supplied in an "either-or" arrangement so it is only ever available at one of the outputs

at a time. What are the advantages of multiple outputs for the user?

"That depends on the heating task," Krötz said. "For example, you could use them to heat several locations on the part at the same time, speeding up the cycle time. You could also connect a variety of inductors to just one generator and operate them one after the other. This would allow you to reduce your purchasing costs for heating equipment if the cycle time was of secondary importance."

At the same time, eldec is always able to modify the power and frequency features of its devices in virtually unlimited ways to adapt the process to the customer's needs. The scope ranges from medium-frequency generators with 20 to 1,500 kW power output and a frequency range from 8 to 40 kHz up to high-frequency generators with 20 to 1,500 kW output and frequency ranges from 80 to 400 kHz. A multitude of combinations are possible. It is ultimately the part or the contours that need to be heated that determine the final design. This may even entail values greater than or less than the values quoted above.

"More and more often customers are asking for HF generators with very low frequencies, even below the 80 kHz mark," Krötz said. "Typically, we can even satisfy those requests. eldec also offers customized generators for outputs below 20 kW. For instance, we have built an MFG 5 with eight outputs several times for one customer. In fact, every second CUSTOM LINE generator constitutes a new system, one we have never before put together in that particular way before. We have a lot of experience now in expanding our technology toolkit." The same also applies to the "adjustment range," which refers to the ratio of the smallest inductor to the largest, or the range of frequencies which can be operated with a single generator.

To ensure the quality and stability of the technology, eldec uses a high degree of vertical integration, more than 90 percent. All the central components are designed in Dornstetten and assembled by hand. In addition, the whole sequence, from first customer contact to delivery of the product, is clearly defined.

All in all, eldec believes that its highly customizable generator range puts it in an ideal position in the marketplace.

"We have at our disposal a huge pool of knowledge gained from practical experience, we are continuously improving the technology, and we only supply components that are optimally configured and robust," Krötz said. "On top of that, our high level of vertical integration gives us the advantage of quick reaction times and high flexibility. That is a sought-after quality, especially for heating applications, which are often very specialized."

MORE INFO www.emag.com

Gasbarre announces engineering manager promotion

Gasbarre announces the promotion of Mike Harrison to engineering manager for Gasbarre Industrial Furnace Systems (formerly J.L. Becker), in Plymouth, Michigan.

Harrison started with Gasbarre in 2017 as a sales and metallurgical engineer. Since then, Harrison has demonstrated leadership and technical ability. In his earlier role, Harrison has shown a keen ability to develop and implement product and process standardization as well as technical solutions for the everyday challenges of customers. He holds a BS in materials science and engineering from the University of Michigan and an MBA from Walsh College.

Mike Harrison

"Our entire organization is excited for Mike and his new role," said Ben Gasbarre, president of Industrial Furnace Systems. "Mike's skill set, education, and experience within the heat-treating industry give him the tools necessary to not only help our organization, but our customers as well."

MORE INFO www.gasbarre.com

Swiss corporation Alu Menziken Extrusion AG chose a Nitrex nitrocarburizing system for its new state-of-the-art manufacturing facility in northwestern Romania. (Courtesy: Nitrex)

Swiss firm chooses Nitrex nitrocarburizing system for facility

Swiss corporation Alu Menziken Extrusion AG chose a Nitrex nitrocarburizing system for its new state-of-the-art manufacturing facility on a greenfield site in northwestern Romania.

Alu Menziken Extrusion AG is a manufacturer of aluminum profiles and complex extrusion press products. Nitrex Metal delivered and installed a turnkey NX-815 nitrocarburizing system that incorporates the Nitreg®-C technology for treating aluminum extrusion dies. The pit furnace has overall chamber dimensions of 31.5" diameter by 59" high (800 x 1,500 mm) with capacity optimized to nitrocarburize a 3,300-pound (1,500 kg) load. The process technology adapts to the application requirements to deliver improved performance of extrusion dies. Tailoring the application's surface properties has a positive influence on performance metrics like throughput per run and number of runs per die, which, as a consequence, mitigates the cost of tooling. Alu Menziken also chose the Nitreg®-C technology to reduce the possibility of potential failures such as premature washout and flaking that degrade the performance of dies.

"With a focus on the environment, Alu Menziken also sought to introduce eco-friendly technologies for all equipment at its greenfield facility. Not only is there a benefit of reduced process gas use with the Nitrex system, the integral high-efficiency neutralizer also helps comply with environmental regulations," said Marcin Stoklosa, Nitrex European project manager.

The modern factory situated in Mediesu Aurit, in Satu Mare, covers an area of 13 hectares and features the latest equipment for producing extrusions. Inaugurated this past November, the plant produces a range of profile products for aerospace and automotive companies, such as Audi, BMW, Bentley, and Daimler, looking for lightweight aluminum solutions.

Nitrex Metal is a worldwide partner offering modern nitriding/nitrocarburizing technologies, solutions, equipment, and services. Its Nitreg® potential-controlled gas nitriding and Nitreg®-C potential-controlled gas nitrocarburizing (ferritic nitrocarburizing-FNC) technologies are applied in the precision parts, automotive, aluminum extrusion, defense, gears, tool & die, plastics, machinery, and other industries.

MORE INFO www.nitrex.com

Ipsen USA enhances Midwest territory coverage

Ipsen USA announces the transition of Andrew Yazot from international sales manager to Midwest regional sales owner, effective immediately.

In this position, Yazot covers nine states in the Midwest, replacing former Midwest regional sales owner Matt Clinite, who was promoted to Ipsen customer service sales manager last month.

Andrew Yazot

"My mission is to continue the level of customer service Matt established with customers and prospects in the territory," said Yazot. "My technical background and attention to detail will allow me to do that."

Yazot joined the company in 2009 and has provided sales support in Eastern Europe, Russia, Germany, China, and parts of the United States. Yazot holds a degree in mechanical engineering and has worked in technical sales for more than two decades. Yazot will be based out of Ipsen's Cherry Valley facility.

"Andrew is a great asset to Ipsen with more than a decade of working experience in the industry," said Pete Kerbel, vice president of sales, Ipsen USA. "His breadth of domestic and international experience is what makes him a balanced problem-solver, and I have no doubt our Midwestern client base will succeed with Andrew as their representative."

Ipsen's sales team is made up of technical experts and engineers who devote themselves to being a partner in success. With more than 70 years of providing heat treatment solutions, Ipsen is committed to keeping its customer's furnaces operational and efficient.

MORE INFO www.ipsenusa.com

This Gruenberg walk-in oven has a maximum temperature rating of 138°C with work chamber dimensions of 31" W x 68" D x 72" H. (Courtesy: Thermal Product Solutions)

TPS ships Gruenberg explosion resistant truck-in oven

Thermal Product Solutions, a global manufacturer of thermal-processing equipment, announced the shipment of one Gruenberg explosion resistant truck-in oven to the defense security industry.

This Gruenberg walk-in oven has a maximum temperature rating of 138°C with work chamber dimensions of 31" W x 68" D x 72" H. The Gruenberg oven was constructed from a structural steel frame that supports the stainless-steel interior chamber liner and the exterior sheet metal. All interconnecting struts are non-continuous, which keeps the exterior cool.

The front-loaded explosion resistant oven used a horizontal airflow, which maximizes heating rates and temperature uniformity of the product load. Two circulation blowers are in a conditioning plenum chamber on the rear of the oven. The blowers direct air through perforated panels on one side of the chamber and flows horizontally across the product. The air exits the work chamber on the opposite wall back through the steam coil for reheating and recirculation.

"Gruenberg products are designed to meet the highest standards of safety specifications. This truck-in oven was designed to accommodate wet batches between 5-2,000 pounds of product and up to 1,000 pounds of water," said Denny Mendler, Gruenberg product manager.

Features of this Gruenberg walk-in oven include:

› Steam heat.

› Explosion resistant construction.

› Interior incorporates intrinsically safe design features.

› Special Teflon, Nylon and Gore tape to eliminate metal to metal contact.

› Fully welded 3304L stainless steel interior liner.
› Dye tested full penetration welds.
› Powered exhaust.
› Air exhaust HEPA filter.
› Intake air pre-filter.
› Intake air HEPA filter.
› Analog dial thermometer.
› Teflon truck spacers.
› Special loading trucks with non-metallic corner bumpers and shelf slides.

MORE INFO www.thermalproductsolutions

PhoenixTM achieves UKAS ISO/IEC 17025 accreditation for lab

Phoenix Temperature Measurement has recently obtained UKAS ISO/IEC 17025 accreditation for its calibration laboratory in the UK (Laboratory Number 10560). The new accreditation strengthens the quality of after-sales service and calibration provided by PhoenixTM to support the comprehensive range of temperature data loggers offered.

Such new in-house calibration facilities will provide customers with a quick, efficient UKAS data logger calibration option. This facility will be key in helping customers meet CQI-9 and AMS2750E standards for Heat Treatment and Temperature Uniformity Surveys (TUS). It is another quality step by PhoenixTM to help customers understand, control, improve, and certify their particular heat-treatment applications.

MORE INFO www.phoenixtm.com

L&L ships dual chamber box furnace for machine tooling

L&L Special Furnace Co., Inc., has shipped a dual chamber heat-treating furnace to a southeastern U.S. manufacturer of various items used in the production of heavy equipment and transportation devices.

The furnace will be used to heat-treat the tooling used to manufacture these items. Its top chamber is used to harden tool steels while its bottom chamber is used for tempering, stress relief, and pre-heating.

L&L Special Furnace Co., Inc., offers the QD Series box furnace for heat-treating and tempering. (Courtesy: L&L Special Furnace Co., Inc.)

The L&L model QD836 furnace's hardening chamber has an effective work zone of 16" wide by 16" high by 32" deep. The tempering chamber has an effective work zone of 14" wide by 14" high by 32" deep. The top chamber has a uniformity of ±20° above 1,200°F and the bottom chamber has a uniformity of ±10°F from 300°F to 1,250°F.

The furnace is controlled by Eurotherm temperature controls with overtemperature protection. Solid-state relays drive the electric heating elements and include heavy-duty, long-lasting 11 Ga. thermocouples.

All controls and fusing are in a side-mounted NEMA1 enclosure.

All of L&L's furnaces can be configured with various options and be specifically tailored to meet customers' thermal needs. L&L also offers furnaces equipped with pyrometry packages to meet ASM2750E and soon-to-be-certified MedAccred guidelines.

Options include a variety of control and recorder configurations. A three-day, all-inclusive startup service is available with each system within the continental United States and Canada. International startup and training service are available by factory quote.

MORE INFO www.llfurnace.com

AFC-Holcroft supplies Specialty Steel Treating

Commercial heat-treater Specialty Steel Treating in Fraser, Michigan, has invested in a new AFC-Holcroft UBQ (Universal Batch Quench) furnace and a UBT (Universal Batch Temper) annealing furnace as companion equipment, as part of a larger multi-year equipment standardization program intended to replace older equipment provided by another supplier. The UBQ and UBT are near duplicates to equipment recently provided by AFC-Holcroft as part of the same multi-year program.

Specialty Steel Treating has had a long relationship with AFC-Holcroft, and uses several types of AFC-Holcroft furnaces in its production facilities in Michigan and Connecticut, including multi-row pusher furnaces designed for high capacity output, as well as some large capacity UBQ batch equipment and accessories.

Tracy Dougherty, vice president of sales at AFC-Holcroft, said, "We're excited to be a part of the continued growth and expansion of Specialty Steel Treating. The customiza-

tion of these furnaces combined with state-of-the-art controls and IoT features (Remote Diagnostics™), enable both AFC-Holcroft and Specialty Steel Treating the ability to offer superior quality, performance, and continuous improvement to customers."

Delivery of the UBT is expected in the second quarter of 2019 to the Specialty Steel Treating site on Malyn Road in Fraser, with the UBQ to follow in the third quarter to the Commerce Road plant, also located in Fraser.

Founded in 1956, Specialty Steel Treating has been performing precision heat-treating for more than 60 years. SST is the only approved commercial heat-treat company in the country to heat-treat certain flight critical and flight safety configurations for prime aerospace and helicopter companies.

Founded in 1916, AFC-Holcroft, is one of the U.S. market leaders in the production of industrial furnace equipment for ferrous and non-ferrous metals. The company manufactures turn-key heat-treating systems for applications including commercial heat treating, bearings, automotive, aerospace, mining, aluminum heat treatment, gear manufacturing, fastener manufacturing, and alternative energy industries.

MORE INFO www.afc-holcroft.com

SXOil Lifter offers industrial parts washer detergent

SXOil Lifter LLC has developed SXOL, a high-efficiency industrial wash detergent designed to "lift" quench and cutting oils from metal parts. It resists emulsification to lift oil and provide effective skimming. No additions are necessary for the life of the bath (3-4 months, depending on thru-put volumes). It contains nontoxic, biodegradable formula that is safe for those with sensitive skin and skin allergies. No hazardous disposal is required.

SXOL is for use in all parts washers:

- Spray wash.
- Rotary washers.
- Spray dunk.
- Ultrasonic.

For use in heated industrial wash equipment:

- Lifts oil and lubricants from metal parts.
- Uses nano-invasive technology.
- Enables efficient skimming of removed contaminants.
- Allows user to recycle oil and lubricants.
- No hazardous disposal issues.
- Simple pH concentration test.

MORE INFO www.sxoillifter.com

Seco CAB furnace can help control cost, improve quality

Leading the way with another industry innovation, Seco/Warwick has delivered

Seco/Warwick has delivered and commissioned the first vacuum purging semi-continuous Active Only® CAB furnace for a North American automotive aftermarket manufacturer. (Courtesy: Seco/Warwick)

and commissioned the first vacuum purging semi-continuous Active Only® CAB furnace for a North American automotive aftermarket manufacturer. It is their first furnace of any type and simultaneously their largest capital equipment investment to date.

The new semi-continuous Active Only® CAB furnace, equipped with vacuum purging in the loading and unloading chamber, is one of its kind in the industry. It allows for reduction of nitrogen consumption and cost, and it provides extraordinary control of brazing atmosphere quality. This applies in particular to heat exchangers with joints brazed in a closed space. Vacuum purging allows for the perfect removal of oxygen from these spaces before brazing, which cannot be achieved by traditional purging.

Many business owners are starting to realize that not all services should be outsourced. One such industry group is automotive aftermarket manufacturers, who, with Seco/Warwick technology, gain an opportunity to rein in their costs by saving money on outsourcing as well as reduction of nitrogen expenses. The new furnace allows customers to braze their own heat exchangers, control their own quality, and manage their production schedules more reliably to improve deliveries to their customers.

Bringing previously outsourced services in-house is always a big undertaking. By offering world-class technologies and support, Seco/Warwick helps companies successfully go through such projects, to grow and gain more confidence in their capabilities.

MORE INFO www.secowarwick.com

Seco/Warwick nominated for best innovations award

Seco/Warwick is an award-winning company that has been interested in unconventional and innovative solutions since its inception. The company has developed many intelligent tools to support production processes using artificial intelligence, the Internet of Things (IoT), and the latest concept of Industry 4.0. Due to these innovations, the company has been nominated for the Intelligent Development Award in the category of Innovations in Industry 4.0. The Intelligent Development Award is a distinction appreciating the most innovative projects.

Observing the global market trends related to Industry 4.0, Seco/Warwick created a comprehensive management system for predicting maintenance issues for both metal heat treatment and vacuum metallurgy systems, equipped with a unique failure detection system. The effect of this project is the Seco/Predictive system for monitoring furnaces for heat treatment.

Seco/Predictive is an intelligent device control system that can detect potential failures before they occur. Unplanned downtime at work costs the global industry billions of dollars of lost revenue. The purpose of Seco/Predictive is predicting failures which previously seemed unpredictable.

Based on predictive analytics, Seco/Predictive, together with the Seco/Lens® leveraging augmented reality technology, are the latest group's solutions supporting production and service processes. Awareness of the need to implement advanced and intelligent solutions often called "the brains" of an entire production line, is constantly growing. Seco/Warwick, as a production company, perfectly understands these needs, offering innovations that increase the resilience of companies and their business performance.

The Awards Gala will take place at the IV Intelligent Development Forum in November. This is the fourth edition of the economic event for new technologies, innovations, inventors and innovative investments.

MORE INFO www.secowarwick.com

Lindberg/MPH ships aluminum melting and holding furnace

Lindberg/MPH announced the shipment of an aluminum melting and holding furnace. The melting and holding furnace was designed with an aluminum melt rate of 3,000 pounds per hour and the capacity to hold up to 40,000 pounds of aluminum.

The aluminum melting and holding furnace will be loaded with aluminum across a preheat hearth before being pushed into the molten aluminum bath. An exterior discharge well and working tap are included with the furnace as a means of aluminum removal. The equipment also features a circulation well for improved temperature and alloy uniformity.

This custom melting and holding furnace will be in the production of aluminum powder. Temperature of the metal is controlled through digital temperature controllers. Flue gases are controlled with a mechanical flue damper, reducing flue losses during low-fire operation. A totalizing gas meter was also included to accurately measure gas usage.

"The Lindberg/MPH engineering team worked closely with the customer on a custom design that met their application requirements. A factory trained technician supervised the installation of this custom furnace and performed the initial start-up to

ensure that everything went smoothly," said Andrew Paul, sales representative.

Features of this Lindberg/MPH aluminum melting and holding furnace include:

› Rugged fully welded steel plate furnace construction.

› High alumina castable lining for long refractory life backed with high efficiency insulating materials.

› One charge door and one side access door for easy access during charging and cleaning.

› Flue damper for energy savings during low-fire operation.

› Work and drain taps.

› Jib crane for molten metal pump insertion and removal.

› Laser metal level sensor.

› Stand-alone control panel.

› Programmable logic controller controls furnace functions and records status history.

› Temperature controllers with automatic preheat and dry out functions.

› Three-point laser metal level sensor with light tree level indication.

› Totalizing gas meter.

› Start-up and installation service.

MORE INFO www.lindbergmph.com

Grieve offers cooling chamber for steel parts

The No. 807 is a cooling chamber from Grieve used for cooling oven trucks of steel parts at the customer's facility. Workspace dimensions of this cooling chamber measure 84" W x 96" D x 72" H.

Features include:

› 7,000 CFM, 7 1/2 HP remote mounted exhaust blower to pull room air through load and exhaust.

› Aluminized steel construction.

› 1/4" plate floor.

› sectioned to pass through 72" wide doorway.

› Twelve 24" x 24" x 6" thick HEPA filters installed at top of workspace to filter exhausted air.

Grieve No. 807 cooling chamber. (Courtesy: Grieve Corporation)

MORE INFO www.grievecorp.com

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

Remembering where we came from

IHEA's 1959 board of directors and officers.

In this fast-paced world, it gets harder and harder to remember the past. It seems like the only thing that matters is this quarter. But without occasionally taking the time to stop and reflect on the past and where we came from, we tend to lose perspective.

It was January 19, 1929, when a group of furnace manufacturers met in Pittsburgh, Pennsylvania, to form an organization. It was initially called the Industrial Furnace Manufacturer's Association (IFMA), and there were seven founding members of the association:

- Chapman Stein Company.
- Costello Engineering Co.
- George J. Hagan Company.
- Holcroft & Company.
- Rust Engineering Company.
- Surface Combustion Co.
- William Swindell & Bros.

F.W. Manker of Surface Combustion was the association's first

IHEA members celebrate at an annual meeting in the 1950s.

president. Total receipts of the association in 1929 were $800. Expenses for 1929 were $75.75. 1929 was a really tough time to start anything, yet these companies had the vision to work together and form an association that would serve the industrial heating marketplace in the U.S.

In 1933, a meeting was held to study and discuss a proposed code under the National Recovery Act of 1933. In 1934, there was a hearing on the proposed code that was approved by the industry. The purpose of the code was to promote cooperative action among businesses to achieve fair competition and provide for national planning and a second section establishing a national public works program, which was ultimately signed by President Franklin D. Roosevelt on June 16, 1933.

At that point, 52 companies were reporting sales data to the IFMA Code Authority. However, between 1933 and 1936, membership and activities were at a low when Stewart Clarkson donated his time to rejuvenate IFMA.

In the ensuing years, IFMA served as a mediator for potential patent suits among members, and the Army Ordnance specifications for furnaces were reviewed by IFMA committee members. When World War II began, IFMA represented the industry in Washington, and membership doubled during that time. They also compiled a list of labor contract clauses that could be used by member companies.

By the late '40s, the association was promoting articles to appear in the trade press, getting 105 articles published in one year between 1947 and 1948. This was also the time frame that the association permitted Associate memberships.

In November of 1954, an official name change was made to the Industrial Heating Equipment Association. In the years since, IHEA has served the industry by providing a wide variety of educational opportunities, being an unbiased industry representative to NFPA codes, and influencing governmental agencies on behalf of the IHEA membership. 2019 also marks the 50th IHEA Annual Combustion Seminar, which has led the industry in combustion education since 1970.

Times have certainly changed in the 90 years since IHEA was founded. Communication is now instantaneous; responses are expected almost as quickly. Mobile devices are now almost an appendage for most people, and many individuals find it difficult to disconnect. As we looked back through 90 years of IFMA/IHEA history, we were reminded of letters that were typed with carbon paper and snail-mailed that could take days or weeks to reach their recipients. Everything happened at a much slower pace; 90 years of history, meetings, minutes, photos, committees, and people have gone into making IHEA the resource for the thermal processing industry that it is today.

As IHEA celebrates these milestone anniversaries, we hope that we aren't too busy to stop and reflect on where we came from and allow that to guide us to where we want to go as an industry. IHEA believes, by bringing together key executives that share our sense of responsibility, we will improve our industry and enjoy ourselves while doing it. We hope everyone will celebrate with IHEA as we turn 90 and work with us to further the mission of the industry started by our founding members on that long-ago January day.

IHEA 2019 CALENDAR OF EVENTS

MAY 14

NFPA 86 Updates Seminar

This new 1-day seminar which will highlight the recent changes to NFPA 86. If you already have a good knowledge of NFPA 86, then this seminar will be a great overview of the recent changes to the standard and how they affect you.

› Fabricators & Manufacturers Association (FMA) | Elgin, Illinois

AUGUST 28–29

The Powder Coating & Curing Processes Seminar

The day and a half Introduction to Powder Coating & Curing Processes Seminar will include classroom instruction and hands-on lab demonstrations.

› Alabama Power Technology Center | Calera, Alabama

SEPTEMBER 24–25

IHEA 2019 Safety Standards & Codes Seminar

This seminar is intended to help the attendee become better acquainted with the newly updated NFPA 86 – Standard for Ovens & Furnaces.

› InterContinental Hotel Cleveland | Cleveland, Ohio

For details on IHEA events, go to www.ihea.org/events

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

P.O. Box 679 | Independence, KY 41051

859-356-1575 | www.ihea.org

LEE ROTHLEUTNER
PRINCIPAL DEVELOPMENT ENGINEER /// THE TIMKEN COMPANY

Understanding decarburization's fundamentals is vital to product performance.

How to keep decarburization in check

The performance of heat-treated steel components is largely dependent on the condition of their surface. Wear and fatigue resistance are examples of design criteria primarily controlled by surface microstructure and mechanical properties. As a result, surface modifying heat treatments such as carburizing, nitriding, and induction hardening are often specified when a component's design requires a specific set of mechanical properties near the surface. Additionally, post-heat treatment processing such as grinding and hard turning demands consistent near-surface mechanical properties to ensure an optimized process can be achieved. Decarburization is one phenomenon that can occur in improperly controlled heat treatment processes that negatively alters the surface and near-surface mechanical properties of a component. Understanding the fundamentals of decarburization in controlled atmosphere heat treating is imperative to achieving the desired process and product performance.

FUNDAMENTALS

Decarburization is the process in which carbon is removed from a material. With respect to heat treatment, this process describes a chemical reaction that occurs on the surface and results in carbon leaving the steel in a gaseous state [1]. If the chemical equilibrium between the carbon in the steel and the carbon in the furnace gases cannot be maintained, decarburization can result. Although decarburization can be used in the manufacturing of materials such as electrical steels, it is generally considered the consequence of an improperly controlled heat-treatment process. The following chemical reactions are involved in maintaining furnace atmosphere equilibrium:

$$C_{Fe} + CO_{2(g)} \leftrightarrow 2CO_{(g)} \qquad \text{Equation 1}$$
$$C_{Fe} + H_2O_{(g)} \leftrightarrow CO_{(g)} + H_{2(g)} \qquad \text{Equation 2}$$
$$C_{Fe} + 2H_{2(g)} \leftarrow CH_{4(g)} \qquad \text{Equation 3}$$

It is important to note that it is generally accepted that Equations 1 and 2 are reversible reactions while Equation 3 is not [1]. Equation 1 represents the equilibrium between carbon in the steel (C_{Fe}), carbon dioxide gas ($CO_{2(g)}$), and carbon monoxide gas ($CO_{(g)}$). Equation 2 represents the equilibrium between carbon in the steel (C_{Fe}), water vapor ($H_2O_{(g)}$), carbon monoxide gas ($CO_{(g)}$), and hydrogen gas ($H_{2(g)}$). Equation 3 is the disassociation of methane gas ($CH_{4(g)}$) into hydrogen gas, and nascent carbon that can diffuse into the steel under the correct conditions. Causing the equations to proceed from left to right results in decarburizing while the opposite results in carburization. Changing conditions such as furnace temperature, gas flow rate or composition will shift the equilibrium of all three equations.

The extent of decarburization possible in a steel heat treatment process can be estimated by calculating the carbon diffusion distance using the following two equations.

$$D = D_0 \cdot e^{(-Q/RT)} \qquad \text{Equation 4}$$
$$t = d^2/6D \qquad \text{Equation 5}$$

Equation 4 is the diffusivity (D), which is calculated using the pre-exponential constant (D_0, 0.20 x 10^{-4} m/s^2 for carbon in austenite [2]), the activation energy (Q, 138.2 kJ/mol for carbon in austenite [2]), gas constant (R, 8.314 J/mol·K), and temperature (T) in Kelvin. Equation 5 is an approximation of the diffusion time (t) in seconds for a single carbon atom to travel a specific distance (d) in micrometers [3].

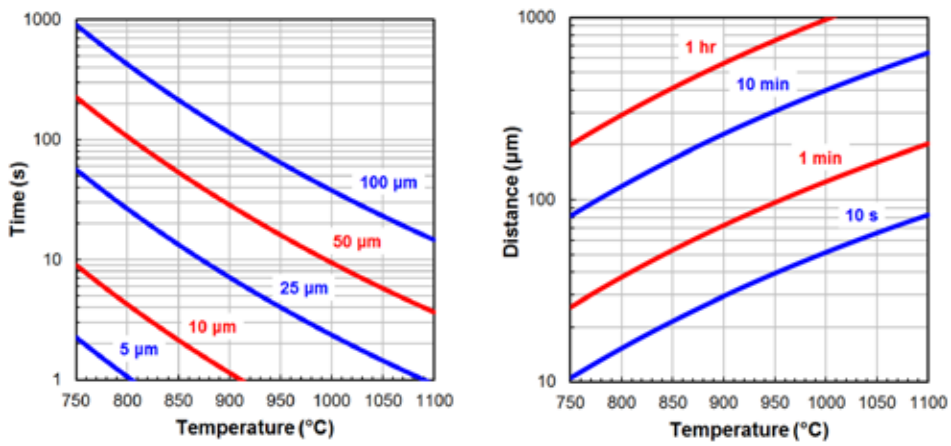

Figure 1: Calculations using Equations 4 and 5 to approximate the distance carbon can diffuse in austenite as a function of time at temperature [2, 3].

Figure 1 shows Equations 4 and 5 solved for carbon in austenite over a broad range of temperatures, times, and diffusion distances using consistent units. It is important to emphasize the two plots are approximations that do not account for the statistical nature of diffusion as well as common phenomena such as grain boundary and pipe diffusion. In addition, the presence of alloying elements such as chromium (Cr), molybdenum (Mo), vanadium (V), and tungsten (W) have been shown to significantly decrease decarburization rates [4]. However, this approach allows a process engineer to quickly determine what is feasible and what is not.

CHARACTERIZATION AND CLASSIFICATION

Decarburization is typically characterized using the terms: complete, partial and effective decarburization. Complete decarburization is also known as "free ferrite" because a ferrite layer transforms at the

surface in the absence of carbon. In medium- and high-carbon steels, this layer is readily identifiable due to its white-etching response. In low-carbon steels, this is more difficult to identify due to the high fraction of ferrite that can exist in the microstructure as a result of the cooling rate (e.g., low-carbon pearlitic steels). Partial decarburization is essentially the entire region containing a measurable carbon gradient that is not exhibiting "free ferrite." This region is often difficult to identify metallographically because microstructure changes occur much more gradually. Effective decarburization is the depth at which any measurable decarburization occurs that results in mechanical properties below the requirements specified for the component. If the mechanical properties of a material are correlated to hardness then the microhardness profile can be used to define the effective decarburization depth.

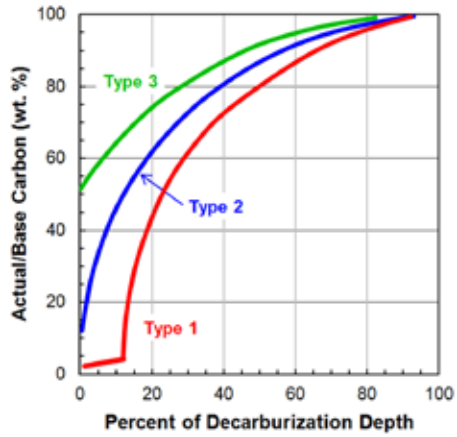

Figure 2: Three general types of decarburization in steel characterized by the degree of carbon loss from the material [5].

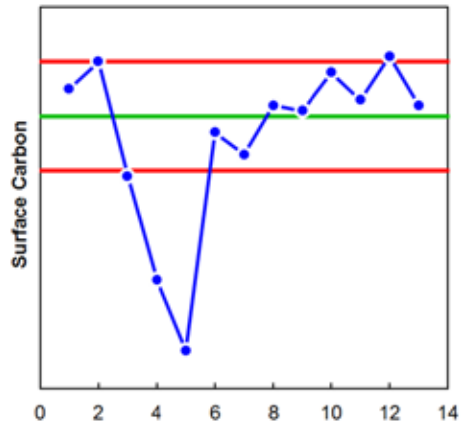

Figure 4: Surface carbon data from proxy samples used as a long-term method to monitor a furnace atmosphere.

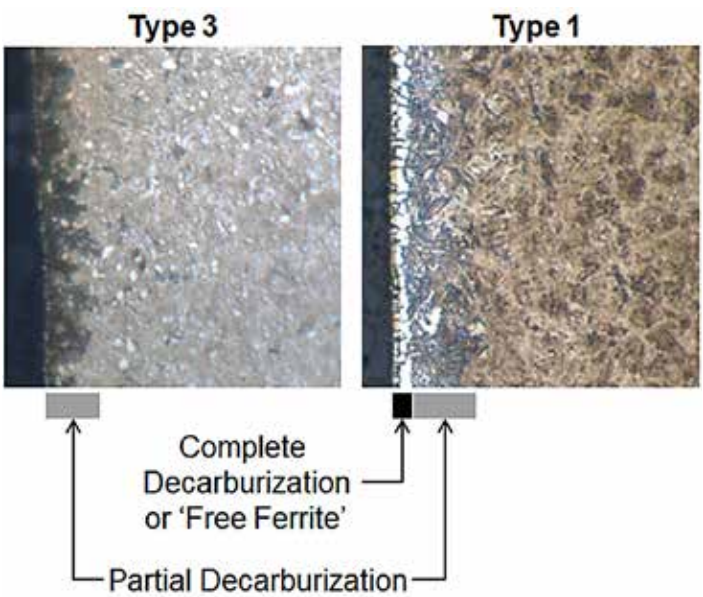

Figure 3: Example optical micrographs of quenched and tempered steel containing approximately 1 wt.% carbon exhibiting Type 1 and Type 3 decarburization.

Figure 2 shows three different carbon gradients that can be used to classify decarburization into types. These classifications can be used to select a process necessary to meet a product specification. Type 3 decarburization is defined by the surface carbon content of the steel not dropping below 50 percent of the base steel's carbon content. Type 2 decarburization is defined by the surface carbon content of the steel dropping below 50 percent of the base steel's carbon content but not low enough to completely remove all carbon from the surface causing carbon free ferrite to form. Type 1 decarburization is defined by the surface carbon content being low enough for an adequate depth to result in carbon free ferrite to form.

Figure 3 shows an example of optical micrographs of high-carbon steel exhibiting both Type 3 (left) and Type 1 (right) decarburization. The complete decarburization or "free ferrite" region is identified as the white-etching layer at the surface. Partial decarburization is identified as the dark-etching region that is likely upper bainite in these specific conditions. Although the partial decarburization layer may extend deeper into the steel than only the dark etching layer, microhardness traverses would be required to quantify it with any level of precision. In some instances, quantification of decarburization is not required and only a semi-quantitative check is necessary to validate that furnace atmosphere control is being maintained. Figure 4 is an example where a simple surface carbon check using optical emission spectroscopy (OES) was used to verify the process was being maintained. The green line indicates the target process, meanwhile the red lines indicate the acceptable surface carbon range. The drop in surface carbon observed during tests 3, 4, and 5 was verified to be real via metallography.

SUMMARY

Decarburization is typically the result of inadequate process control. In the case of atmosphere-controlled heat-treatment, the primary contributors to decarburization are carbon dioxide, water vapor, oxygen, and hydrogen. The extent of decarburization possible in a heat-treatment process can be approximated by calculating the diffusion distance of carbon in austenite for the duration and temperatures of interest. In extreme circumstances the surface can be completely decarburized resulting in free ferrite formation. In some instances, a relatively simple surface carbon check via OES can be done to ensure decarburization is being kept in check.

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[2] B.C. De Cooman and J.G. Speer, Fundamentals of Steel Product Metallurgy, Association for Iron and Steel Technology, 2011, p.40.

[3] J.D. Verhoeven, Steel Metallurgy for the Non-Metallurgist, ASM International, Materials Park, OH, 2007.

[4] ASM Handbook Vol. 4B: Steel Heat Treating Technologies, ASM International, Materials Park, OH, 2014.

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ABOUT THE AUTHOR

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JACK TITUS
DIRECTOR OF PROCESS AND DEVELOPMENT ENGINEER /// AFC-HOLCROFT

Carburizing, case hardening, and the general history of thermal processing.

How did we get where we are today?

Having worked in the heat-treating industry for 58 years, I agreed in January 2011 to write a monthly column about all things heat-treating for *Gear Solutions* magazine. A few years later, sibling *Thermal Processing* began focusing exclusively on heat treating and I moved to that publication. I accepted the task for two reasons: I wanted to give back in a sense — to share my experience, and perhaps entice a new generation of participation in the industry.

But I also felt that to achieve those objectives, I needed to provide a very brief narrative on how the industry, primarily carburizing and case hardening, got to where we are today.

Following the above philosophy, a question recently came up at lunch that prompted the following discourse:

As most interested parties know, vacuum carburizing (VC) has been around for decades. But what may not be so apparent is why it became a viable process in the first place. Metals Handbook Volume 2 (copyright 1964) doesn't even mention VC — only that vacuum has application for brazing and other processes that must be free from oxygen contamination. But how did it get its start? It likely was an experiment in a bell jar gone wrong somewhere in Europe. That isn't really the point. What is important is that once those experiments continued through the years, progress really began in the late '60s when it was discovered that carbon using propane in a vacuum partial pressure could be added to steel and the case depth increased more so than with endothermic gas — which was the only mainstream commercial carburizing process at the time.

What has proceeded ever since is how to control and predict the surface carbon and case depth that infrared, dew point, and now the oxygen probe could do for endo carburizing. Since to date no one has developed a similar device such as the oxygen probe for VC, we've no alternative but to rely on one of two methods to provide a starting point for predictive modeling software: the iron-carbon equilibrium diagram, or running an actual sample and analyzing its diffusion profile. There have been attempts by any number of entities to develop an oxygen probe or shim-test like device but to my knowledge none have so far been successful.

As the search continues for that elusive device, an even better method for predicting and controlling endo carburizing is still occupying the minds of the heat-treating community.

As the pursuit for control perfection continues, and once we know how to predict the outcome with unmatched precision, the carbon must still be able to enter the steel being carburized via LPC or endo or whatever means evolves.

That brings me to the next conundrum, namely carburizing temperature.

Two conflicting viewpoints seem to be the barrier or wall that

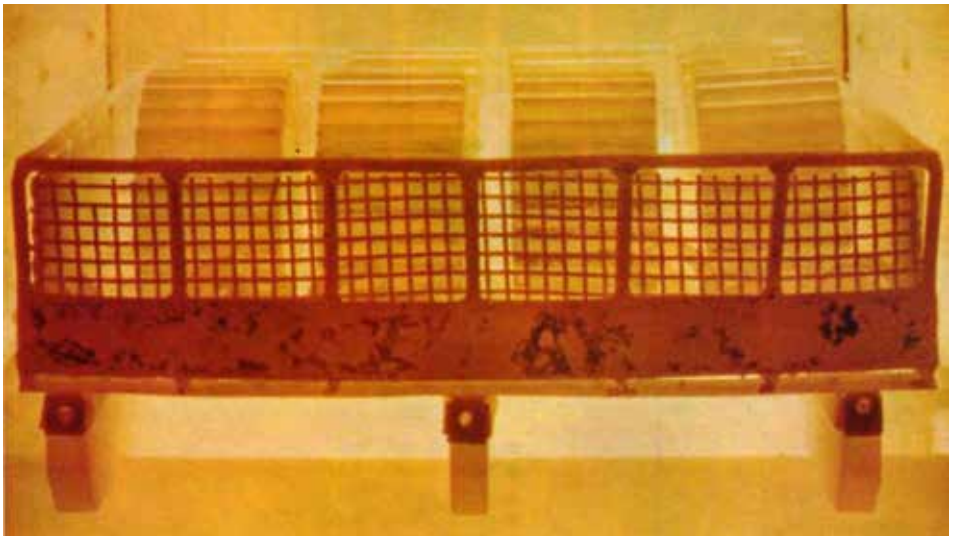

Figure 1. Tray of gears with test samples entering oil quench.

AUSTENITIZING TREATMENTS FOR 8620H SAMPLES

TEST	AUSTENITIZING TEMPERATURE, TIME	COOLING CYCLE	QUENCH
1	1150 C (2100 F), 0.5 h	Cool to 925 C (1700 F)	Gas quench from 925 C (1700 F)
2	1095 C (2000 F), 1.0 h	Cool to 925 C (1700 F)	Gas quench from 925 C (1700 F)
3	1140 C (1900 F), 1.0 h	Cool to 925 C (1700 F)	Gas quench from 925 C (1700 F)
4	925 C (1700 F), 4.0 h	–	Gas quench
5	925 C (1700 F), 6.0 h	Cool to 845 C (1550 F)	Oil quench
6	1140 C (1900 F), 1.75 h	Cool to 845 C (1550 F) Soak 0.5 h, Reheat to 845 C (1550 F) Soak 0.5 h	Oil quench
7	1140 C (1900 F), 1.75 h	Cool to 845 C (1550 F)	Oil quench

Table 1

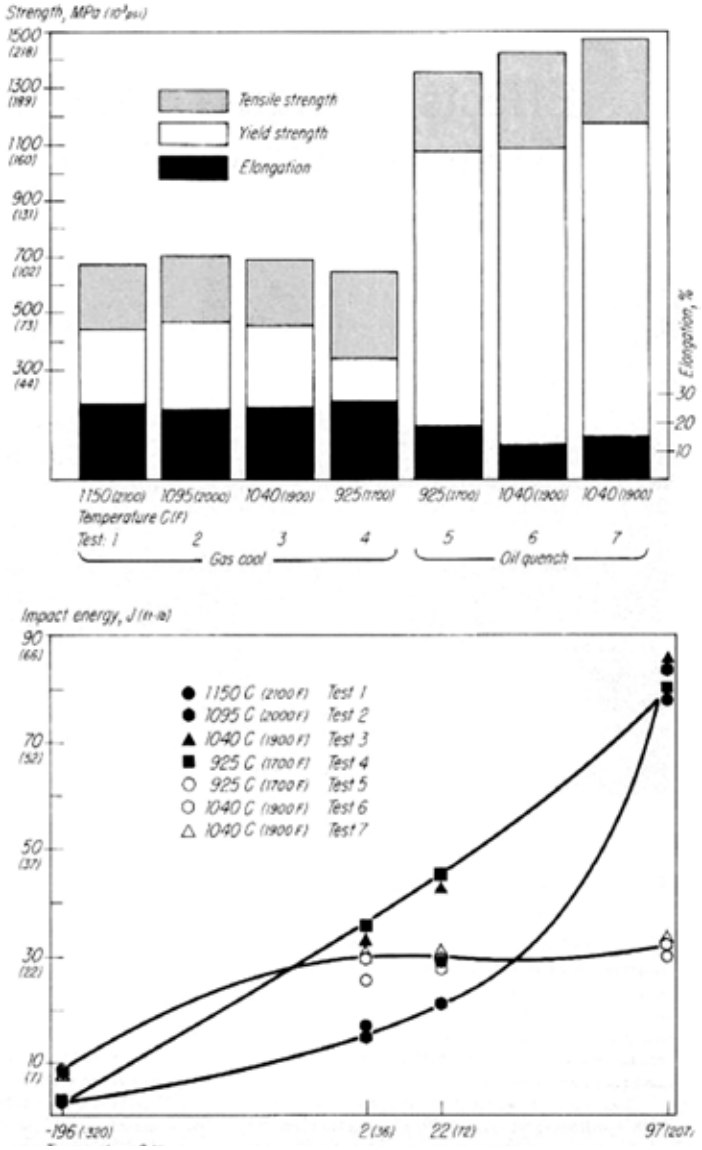

Figure 2. Table of tensile, yield, and Charpy impact results.

separates the pro high-temp energy savers vs. those on the con high-temp side who fear the reduction of mechanical properties. Many of those on the con side are comprised of the aerospace industry and producers of high strength components such as fasteners like bolts. On the aerospace side, both LPC and endo carburizing are used depending on the application. There remains, I believe, a subtle fear of LPC in extremely critical parts, notably very large components, especially gears that are press quenched where LPC is not applicable. Endo carburizing is so well understood and predictable, and the equipment so robust that you'll find seemingly antique furnaces, but well maintained, successfully producing extremely high-quality aerospace components. LPC equipment by design requires frequent and specialized maintenance where endo furnaces do not.

Most of the LPC and endo carburizing is conducted between 1,650°F and 1,700°F (899°C and 926°C). Vacuum furnaces can only perform LPC because they're vacuum furnaces designed with fragile graphite and molybdenum and operate up to 2,400°F (1,315°C) so it's in their best interest to promote high-temperature carburizing primarily above 1,850°F (1010°C). Likewise, endo gas atmosphere furnaces are also capable of carburizing at higher temperatures, however they have limitations due to the use of metallic or iron-based heat resistant nickel, chromium, cobalt alloys that are capable of

Two conflicting viewpoints seem to be the barrier or wall that separates the pro high-temp energy savers vs. those on the con high-temp side who fear the reduction of mechanical properties.

operating at 1,900°F or 1,950°F (1,038°C or 1,065°C).

The temperature dilemma relates to grain size and its effect on cracking from fatigue and tensile stress. It's well known that if the carburizing temperature is too high for the material austenitic grain growth can weaken the component. It's not too difficult to understand, but I like to make the analogy to the concrete overpasses we encounter every day on the highway. The overpass is continuously subjected to fatigue from traffic and wind forces. To counter those forces, designers added rebar, steel bars intertwined and crisscrossed throughout the concrete structure, to stiffen and strengthen the entire structure. Without rebar or with fewer numbers of steel rods, large unreinforced sections of concrete would begin to form small fatigue cracks — and without rebar, the cracks can continue uninterrupted.

In steel, a similar process takes place. The finer the grain size, the greater resistance to fatigue. Like rebar, the individual grains that are formed in the hot swaging of steel bar or hot rolling of plate, mechanically reduce the size and increase the number and orient the grains in the direction or rolling. If each post heat-treat process such as annealing, normalizing, and carburizing is completed within accepted limits, that original small grain size will be retained. However, if overheating such in carburizing in order to save time is conducted, mechanical properties can be sacrificed. The question becomes what is overheating? There's no complete definitive answer because it depends on the alloy additions the mill adds to help resist grain growth; that's why 1,750°F (954°C) is today the practical limit to avoid the risk.

Now I'm going to be my own devil's advocate:

There are ways to carburize at higher temperatures without sacrificing properties. I'm referencing an article published in *Metal Progress*, a publication of The American Society for Metals, called "Effects of High-Temperature Austenitizing on AISI 8620H," written by James G. Conybear and Wallace (Jack) Titus (November 1977 Vol. 112, No. 6). Jim was the primary author with yours truly conducting the tests on the two-chamber oil quench vacuum furnace, Figure 1, and performing the Charpy impact and tensile tests, Figure 2. The article set out to investigate if the time corresponding to specific carburized case depths at elevated temperatures for 8620H steel had any detrimental effects on mechanical properties. We didn't carburize the material but held it at various temperatures to affect the core properties (Table 1). I won't present the entire text but summarize the results with these three figures. Bottom line, at least for this 8620H study, processing at elevated temperature had no negative effect on the properties evaluated. For those interested, the entire article can be accessed at tinyurl.com/yxvftfbc.

Finally, since major steel producers are developing new micro alloyed carburizing grade steels that can retain critical room temperature properties, several furnace manufacturers including AFCH have and are developing hot zones to take advantage of the new materials.

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JASON SCHULZE
METALLURGICAL ENGINEER /// CONRAD KACSIK

Challenge Accepted: This drafting technique provides suppliers with the organization necessary to show conformance to auditors and employees.

Method means comparing checklists vs. procedure

Whether commercial heat-treating or captive, procedures are essential to the production of conforming product and its repeatability. Procedures can be challenging to write at times as, if we are too close to the process, we may feel that some items in procedures are obvious. Still, it is also difficult to assign authorship to an employee who is not as familiar with the process as, say, a process engineer.

In this article, we will examine a technique to writing heat-treat procedures that not only accounts for the specific requirements as they apply to a facility but up to the Nadcap level.

APPLICABILITY

Let's first establish customer and specification applicability. As an example, if processing to internally developed parameters that have no specification flow-down, but are Nadcap-approved, you would need to include both Nadcap checklist items as well as requirements as they apply to your own internally developed (and, possibly, customer-approved) process in the procedure. On the other hand, if processing to an AMS/SAE specification that is flowed down to via customer PO/Print and is Nadcap-approved incorporation of internal process requirements, AMS/SAE requirements as well as Nadcap checklist items would need to take place.

These items are typically identified during the contract review process. It is important to have a clear line-of-sight to your specific requirements as they apply to all hardware processed. This can enable suppliers to establish general higher-level procedures in place of low-level requirement-specific procedures (i.e. one procedure for, say, Rolls Royce parts and another for GEAE parts in heat treat).

I will use an example of a common scenario to begin this description. Let's assume Company X heat treats 410 stainless steel in accordance with the customer PO/Print which flows down AMS2759/3. With AMS2759/3, Company X is also required to maintain Nadcap-approved in heat treat.

GENERAL REQUIREMENT ACCOUNTABILITY

A simple start to this would be to funnel the requirements into three general procedures; a general heat-treat procedure, a general pyrometry procedure, and a general hardness testing procedure. This will allow all the requirements of each process to be in a single location when future changes are necessary.

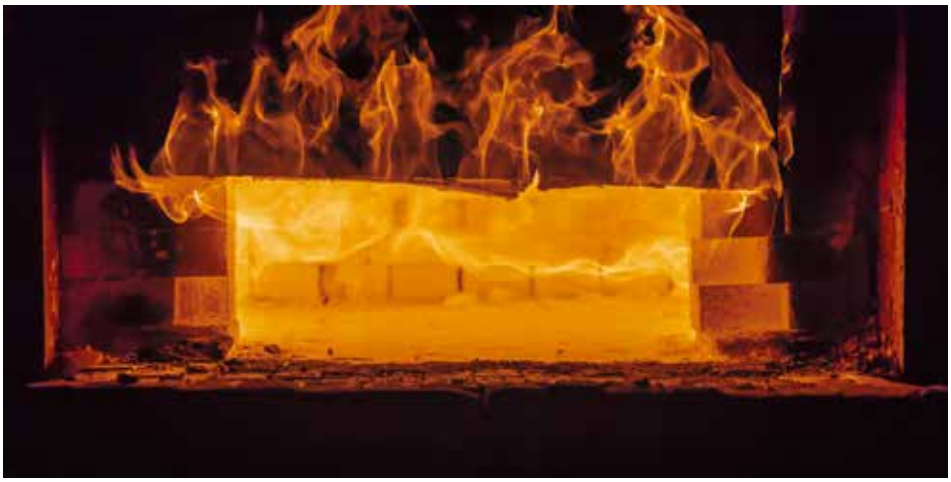
The general heat-treat procedure should include the heat-treat process requirements flowed down in AMS2759/3 (and, in this case, AM2759) as well as AC7102. The pyrometry procedure would include applicable requirements from AMS2759/3 (AMS2759) as well as AMS2750. The hardness testing procedure would include the requirements of ASTME-18.

The key is the structure of the procedures. During my years con-

3.1	Document Control			
3.1.1	Are the applicable revisions of the appropriate documents available at the appropriate workstation?	YES	NO	
3.2	Contract Review			
3.2.1	Are contracts and incoming purchase orders reviewed to ensure that: (U22)			
3.2.1.1	The quality and technical requirements, including any unique customer requirements, are adequately defined and documented?	YES	NO	
3.2.1.2	Adequate capability, customer approvals and resources by the processor to meet the requirements?	YES	NO	
3.2.1.3	Any deviations from the proposal/contract are resolved in writing by authorized personnel/Customer/Auditee?	YES	NO	
3.2.1.4	Adequate definition of the work statement to identify the specific process(es) to be performed including specification number(s), applicable Type(s), Class(es), Grade(s), etc.?	YES	NO	
3.2.1.5	Identification of the prime aerospace customer that has design authority?	YES	NO	
3.2.1.6	Identification of the aircraft model or hardware that the part numbers represent where applicable. (e.g. Boeing 777, Airbus A320, etc.)?	YES	NO	NA
3.2.1.7	Does the Auditee flow down contractual requirements internally and to sub-tier Suppliers?	YES	NO	
3.3	Control of Nonconforming Product			
3.3.1	Is the nonconforming material controlled, and the customer notified of each instance of nonconforming product in accordance with the contractual requirements?	YES	NO	
3.3.2	When reheat treatment is performed: is it allowed by specification, properly documented, retested, and in compliance with customer requirements? (U22)	YES	NO	NA
3.4	Corrective Action			
3.4.1	Are all corrective actions from the previous Nadcap audit still implemented (check the last full audit)?	YES	NO	NA

Figure 1

An approach to writing procedures may be to start, say, the AC7102 Nadcap checklist. This would go into the general heat-treat procedure. The flow could mimic the flow of the checklists to ensure a supplier has captured all the requirements within AC7102.



21. Document Control

21.1. Documents applicable to heat treat shall be retrieved per ***XYZ Procedure***.

21.2. Part and/or material specific controlled work instructions shall be retrieved each time a heat treatment is processed. Previously printed instructions shall not be used.

22. Contract Review

22.1. Contract review for product to be heat treated shall include the following items:

22.1.1. All quality and technical requirements, including any unique customer requirements, are defined and documented.

22.1.2. RSTW shall ensure the furnace is capable and certified to meet the requirements (i.e. temperature tolerance, testing frequency etc.).

22.1.3. Any deviations to a proposed contract shall be resolved with the customer in writing prior to processing parts.

22.1.4. The flow down shall include the definition of work statement which includes any material class or other specific requirements.

22.1.5. The identification of the prime aerospace company which has design authority shall be documented when available.

22.1.6. When applicable, the identification of the applicable engine model that the part numbers represent.

22.1.7. All specification and customer requirements shall be flowed down to sub-tier suppliers where applicable.

23. Control of Nonconforming Product

23.1. Nonconforming material shall be segregated from conforming material ***XYZ Procedure [insert nonconforming material procedure]***.

23.2. Disposition of nonconforming heat treatments must be obtained from the PO holder as ***Company X*** does not have design authority over commercially heat-treated product. Any product which ***Company X*** does have design authority over shall be dispositioned by ***Company X*** QA/Engineering for further action.

Figure 2

sulting with companies, I've seen procedures that appear to have had requirements inserted due to audit findings and/or specification changes with no real organization or flow. I've also seen procedures that essentially plagiarize the parent specification/checklist. Of course, I would strongly recommend against this approach, as it does not show an auditor how a supplier has accounted for specific requirements within the specification.

An approach to writing procedures may be to start, say, the AC7102 Nadcap checklist. As stated before, this would go into the general heat-treat procedure. The flow could mimic the flow of the checklists to ensure a supplier has captured all the requirements within AC7102. (See example in Figures 1 and 2).

COMPARISON OF CHECKLISTS VS. PROCEDURE

Each major topic within the checklist has its own paragraph within the procedure describing how that specific supplier addresses the checklist requirement.

This same approach can be used for specification requirements (i.e. prime, SAE/AMS, etc.). This may include tables showing temperature requirements for specific materials as well as specific process requirements as they are described within the applicable specification.

SUMMARY

Drafting internal procedures in this way gives suppliers the organization needed to clearly show conformance to both auditors as well as employees who need to conform to the procedures. This system also allows for insertion of new requirements as both checklists and specification revisions are released.

ABOUT THE AUTHOR

Jason Schulze is the director of technical services at Conrad Kacsik Instrument Systems, Inc. As a metallurgical engineer with 20-plus years in aerospace, he assists potential and existing Nadcap suppliers in conformance as well as metallurgical consulting. He is contracted by eQualearn to teach multiple PRI courses, including pyrometry, RCCA, and Checklists Review for heat treat. Contact him at jschulze@kacsik.com. More info: www.kacsik.com.

FILAMENT-WOUND COMPOSITES

HAVE SPECIALIZED CURING REQUIREMENTS

In order to properly produce filament-wound composites, several unique methods can be used to ensure this manufacturing process produces the correct end result.

By MIKE GRANDE

Filament winding is a manufacturing method for making tubular and cylindrical shapes of extreme strength and light weight. The technology involves wrapping a mandrel — which is a reusable steel core with resin-impregnated carbon fiber, Kevlar, or Fiberglas fiber — and then curing it in an oven. The mandrel is rotated while the fiber is kept taut during the wrapping process, and the fibers are pulled through a bath of liquid resin (epoxy, polyester, vinylester, or phenolic) before being wound onto the mandrel (Figure 1).

This process is used to produce water tanks, pressure tanks, pipes, missile housings, bicycle parts, golf clubs, aircraft components, power-transmission poles, filter housings, and many other parts used in industry, recreation, and the military. First used in 1968 for making Fiberglas reinforced pipe, the technology has been developed to manufacture tubular shapes with diameters from 10 to 158 inches.

After winding, the tubular shapes must be cured in an oven at 200° F to 400° F to harden the resin. The mandrels have to be kept rotating while being cured to nullify the effect of gravity on the resin and ensure a round profile. There are interesting ways this is done, and several oven configurations are used.

Figure 1: Filament winding machine (courtesy Roth Composite Machinery).

LOAD CART WITH ROTATOR

In this method of curing wound mandrels, the mandrels are loaded onto a cart that carries them into a batch oven. The ends of the mandrels are left bare (no filaments wound on them) for handling purposes, and the load cart has rollers that support the mandrels in these areas at both ends (Figure 2).

One of the rollers is powered to rotate the mandrels resting on them. They rotate slowly, just enough to keep the resin from migrating downward due to gravity. The rotation is achieved using a gear drive. In order to protect the drive system from heat damage, it is located outside the oven with a drive shaft (or shafts) protruding into the heating chamber through a seal. This is accomplished two ways: either with the drive system located on the cart, protected from the heat by an insulated plug; or with the drive located at the oven rear, outside the oven.

This system can handle mandrels up to 6,000 pounds, 5 feet in diameter, and 12 feet long, or even larger if required. The load cart design allows the wound mandrels to be loaded via overhead hoist. It is not unusual for an oven to cure multiple mandrels at one time and therefore have multiple rotators. There are two ways the cart drive rotates the mandrel without being exposed to the heat: the cart-mounted drive and the rear-mounted drive.

In the cart-mounted rotator drive design, the load cart has an insulated plug (essentially a heat barrier) that sits between the gear drive and the heating chamber. The plug is mounted to the cart (Figure 3), and travels with it as the cart moves. It is located at the rear of the cart, so that when the cart is in position inside the oven, the plug closes off the oven opening, serving as the oven door. When the cart is outside the oven, the plug is out of the way, permitting loading/unloading of the mandrels.

Figure 2: Cart-mounted support rollers on both ends.

As the weight of the cart loaded with mandrels is typically too large to move manually, the entire cart is driven in and out of the oven mechanically. This requires a second drive to rotate the cart wheels (at

least two of them), which moves the cart in and out of the oven. This drive is also located on the cart on the cold side of the plug. To bring power to the drives, a cord reel or power track is used. The advantage of the cart-mounted drive design is that the mandrels can be kept rotating while outside the oven, which is sometimes necessary.

The other style of rotator design is the rear-mounted drive arrangement. In this design, the gear drive that rotates the mandrels is located at the oven rear on the outside of the back wall of the oven (Figure 4), protected from the heat.

The gear drive rotates a shaft that penetrates through the oven rear wall. The end of the shaft inside the oven has a coupler mounted to it that engages a mating coupler on the rear of the cart and drives one of the mandrel support rollers on the cart. A key aspect of this design is that the coupler pair must be engineered so that, as the cart enters the oven, the two halves of the coupler automatically engage while the cart moves into place inside the oven, no matter what their rotational position.

Another key feature of the design is the heat seal where the drive shaft penetrates through the oven wall. The seal must allow rotation of the shaft without binding or excess friction, while preventing heat from escaping and damaging the gear drive. The rear mounted mandrel drive is less expensive than mounting the drive on the traveling load cart, but the disadvantage is that the mandrels cannot be rotating while the cart is outside the oven, since the drive is disengaged at that time. This is as opposed to the cart-mounted drive, which normally continues to rotate the mandrels even while the cart is outside the oven. It is sometimes necessary to keep the mandrels rotating at all times, even outside the oven, for example when there are multiple mandrels being carried on the cart at the same time. It may take 15 minutes or more to load multiple uncured mandrels onto the cart, which is long enough for gravity to affect the uncured resin if they are stationary.

AIRFLOW PATTERN

Cure ovens for fiber-wound composites can be electric or gas heated. The heat is often generated in a separate heater house, where the fan is located, then delivered to the heating chamber through supply ducts. The ducts have adjustable louvers to fine-tune the volume of air being delivered to different areas of the oven. As with many types of convection thermal processing, a higher volume of recirculated airflow provides the best temperature uniformity and oven performance.

It is also important the supply ducts that deliver the air are located such that they thoroughly and evenly deliver the heated air to the mandrel. The air supply ducts are normally located on both sidewalls, near the floor of the oven (Figure 5), and extend all the way from the front to the rear of the heating chamber to evenly deliver the air. This arrangement is referred to as combination airflow, since the air travels both horizontally and vertically through the workspace. The exact volume of recirculated air required is calculated, and the blower that moves the air is sized accordingly. It is critical the oven be specifically engineered for curing wound mandrels. A general-use industrial oven may not provide good results in curing fiber-wound mandrels.

POST CURE OF FILAMENT-WOUND MANDRELS

Depending on the resin formulation and other details, the wound, cured mandrels sometimes undergo a secondary (a k a final) cure. They don't need to be kept rotating during the final cure and can sometimes be heated while upright.

TOP-LOAD OVEN DESIGN

Another popular oven design for curing filament-would mandrels is the top-load oven, sometimes referred to as a coffin oven (Figure 6).

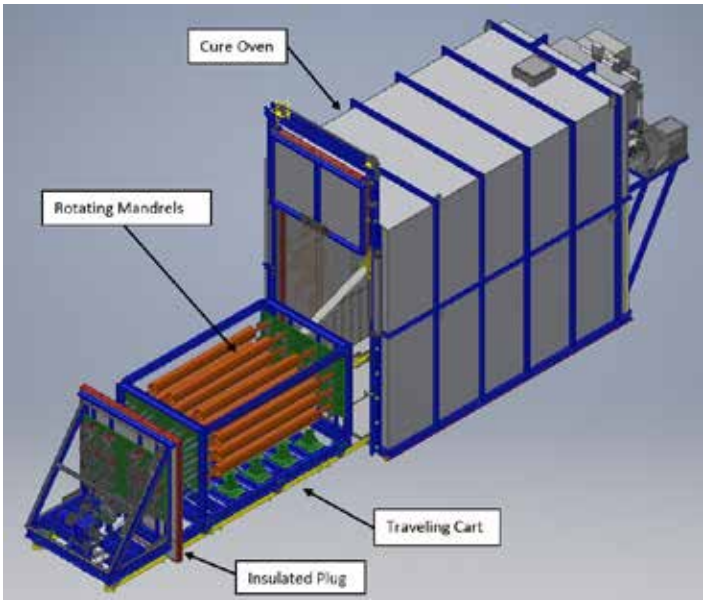


Figure 3: Cure oven with the cart outside the oven, showing 16 rotating mandrels.

Figure 4: Rotator mechanism, painted yellow, located on rear oven wall.

In this design, the oven door is located on the top, and the wound mandrels are loaded into the oven via overhead hoist. The oven door is commonly opened using a chain-lift system, powered either electromechanically or pneumatically, mounted to the side of the oven. The door can also be manually operated in some cases. A counterweight can be used to reduce the lifting force required. Further, the door can be split into multiple sections, each of which are easier to lift than the entire door would be. As with the load-cart style oven mentioned earlier, there are roller-style supports inside the oven at both ends of the heating chamber. The ends of the mandrels rest on the rollers, which are rotated using a powered drive located outside the oven. The drive is coupled to a shaft penetrating the oven end.

The primary advantage of the top-load design is that it requires less floor space than a cart-style oven. The oven footprint only needs to accommodate the width and length of the part. This is in comparison to the cart style oven, the footprint of which must not only accommodate the oven, but also the cart while outside the oven. The top-load oven footprint is, therefore, roughly half of the cart-style oven. The supply ducts that deliver the heated air are most often located on both

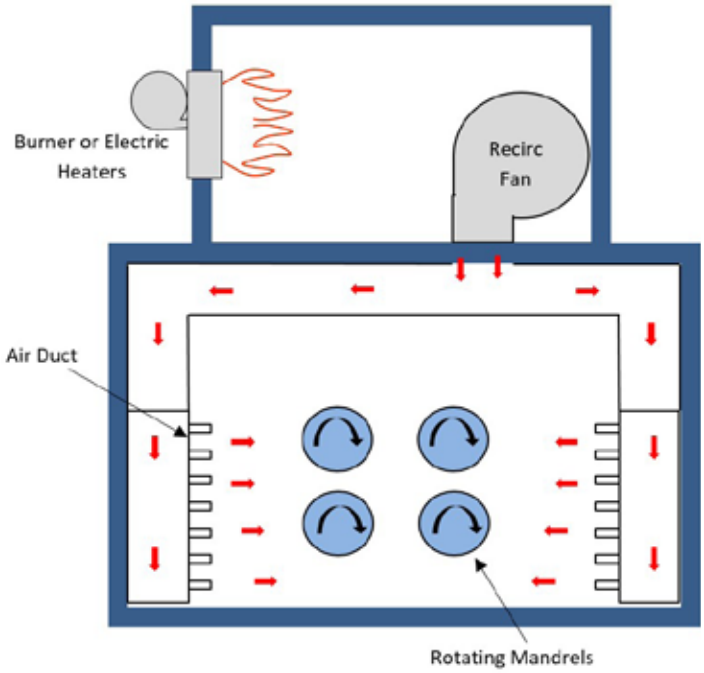


Figure 5: Section view of an oven for curing four fiber-wound mandrels, showing the heated air being delivered from supply ducts.

Figure 6: Top load oven design.

side walls, the same as in the cart style ovens, but can also be located at one end and direct the air axially down the length of the heating chamber, which is referred to as "end flow."

FIND THE RIGHT PARTNER

If you need to purchase or specify an oven for curing filament-wound composites, find a reputable oven manufacturer that can demonstrate experience and knowledge of both the curing process and effective handling and rotating of the wound mandrels. Look for a supplier that offers a 3-year or 5-year warranty at no additional charge. This shows they stand behind their product. A solid partnership with a good oven supplier will ensure your project is a success.

ABOUT THE AUTHOR

Mike Grande is vice president of sales at Wisconsin Oven Corporation. For more information, go to www.wisoven.com.

MACHINING GRAPHITE COMPONENTS

Addressing two of the most common challenges presented when graphite components are created.

By FILIP CUJBA

The various forms and fixtures used in vacuum furnaces and various sintering operations nearly all require graphite. Machining some of these graphite components can present challenges. Two of the most common challenges are:

› **Furnace components:** Heating elements and measuring electrical resistivity.

› **Sintering process:** Eutectic melting issues.

First, let's discuss vacuum furnaces and the purpose of graphite components and graphite tooling.

A vacuum furnace is a type of furnace that can heat materials to very high temperatures. The controlled heating function is designed to carry out metallurgical processes such as heat treatment, sintering, or brazing.

The area where the process heat is produced is called the hot zone. Since the early development of the vacuum furnace, engineers and thermal experts have tried to improve the insulating characteristics and the performance of the components inside the hot zone. Many of the early designs of vacuum furnaces used an all-metal design (Figure 1). The entire hot zone is manufactured completely out of metal components.

As vacuum furnaces became an important production tool, engineers have tried, with varying levels of success, to incorporate alternate materials into designs for vacuum furnaces.

One of the most common types of hot zones manufactured today uses graphitic materials in the form of sheets, felt, or board for insulating purposes. These hot zones also use synthetic graphite components such as heating elements, connectors, and furnace bases. In addition, various tooling used to support or locate material inside the furnace is composed of synthetic graphite. The multitude of acceptable graphite grades that is available, along with many available graphitic insulating components, offers the end user a wide selection of advanced materials options to choose from. Synthetic graphite also allows for complex machining, allowing for intricate designs to be produced relatively fast, and cost effective (Figure 2).

CHOOSING THE CORRECT MATERIAL

It is very important that with each particular application, the appropriate material is used. Choosing the correct materials characteristics and purity levels will ensure that vacuum furnaces, some of which are capable of running at uniform temperatures up to 5,250°F, can control and maintain an atmosphere with low contamination and minimal power losses.

As graphite has emerged over the past few decades as a highly engineered material, its use in manufacturing hot zone components increased. Vacuum furnace manufacturers, using graphite, were able to change the shapes, and reduce the size and weight of the hot-zone components to increase efficiency. They also incorporated graphite hot-zone components to facilitate intricate part designs that can be manufactured quickly and reliably. Modern purification processes allow for very high purity levels to be achieved with graphite. Synthetic graphite typically has a purity level of 300-500 ppm, but

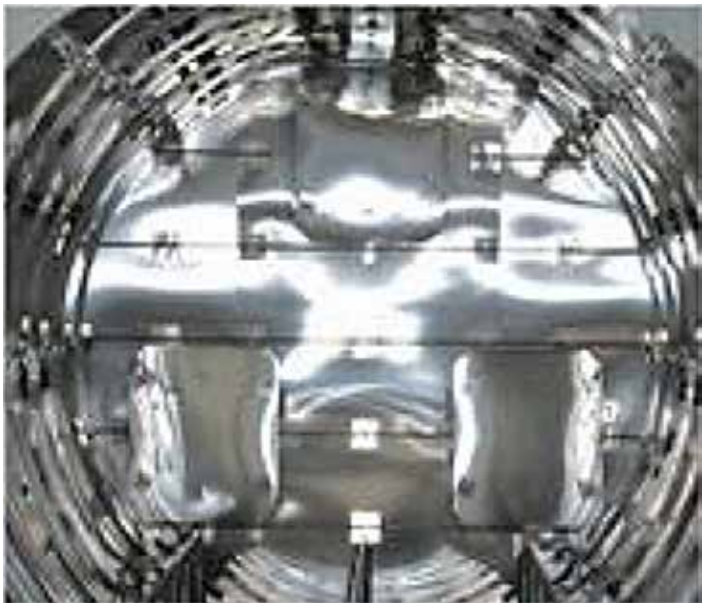


Figure 1: All-metal design hot-zone.

Figure 2: Graphite fixtures, hot-zone components.

with additional post-production purification, it is possible to reach levels of 0.05 ppm or less. (Furnace fixture engineered with reduced mass to obtain reduced ramp rates and quench rates.)

MEASURING ELECTRICAL RESISTANCE

The heating element is a critical component in graphite hot zones. One challenge that has arisen in the production of graphite heating elements is the proper measurement of electrical resistance. The graphite heating element's purpose is to get hot, reliably and consistently, from element to element.

When designing the manufacturing process for heating elements, one has to think about electrical resistance. In the case of most other graphite components, a print and a material spec sheet would suffice in order to produce the components. That is not sufficient when designing and machining heating elements. Clearly defining the electrical resistance, along with clear designation on how and where the resistance is to be measured, is critical for the efficiency of the hot zone. It is important to understand, though, that electrical resistance can vary between blocks of the same grade of graphite as well as within a single block of graphite. Using highly engineered synthetic graphite from world-class manufacturers does help with reducing variability in electrical resistance, but it doesn't transform this quality into a constant. Proper measuring and resistance testing of each arc element is the only way to ensure the vacuum furnace hot zone will produce constant temperatures and run efficiently.

The availability of multiple quality graphite grades is a benefit, but it can also pose a challenge as every grade has a different electrical resistance. It is important to note that an arc element's basic dimensions do affect its final electrical resistance, so setting the final electrical resistance as the mandatory requirement and allowing the part geometry to vary is good practice.

Thinner components have an increased resistivity compared to thicker ones. And then there is the consideration of the best location to measure resistance. Measure in one location and the values are totally different than if the measurement is taken in a different location. Measuring electrical resistance, it turns out, is quite complicated, and the sum of all these variables can pose a challenge for the uninitiated. Graphite component manufacturers need to have a good understanding of all these factors. They must choose the right materials and understand how resistance changes as dimensions change.

It is important for both the customer and vendor to clearly define how and where the target resistance is measured. Defining these parameters is critical to producing an element that will work properly. The burden is on the vendor to not only provide a quality product, but also to educate customers so they can make informed decisions.

This video shows resistance testing of a graphite arc element at various locations and the corresponding change in measured electrical resistivity: tinyurl.com/semco-carbon.

EUTECTIC MELTING

Another common issue encountered in heat treating metal components is eutectic melting and the role of graphite fixtures in the sintering process. Eutectic melting is the process in which an alloy of two or more metals, when heated, completely changes from solid to liquid at the same temperature. There are processes, such as brazing, where eutectic melting is a desired result. In fact, there are thousands of eutectic compositions used in brazing applications. They play a major role when heating a brazing filler metal up to the brazing temperature, as well as when cooling after brazing. During heat-up and melting, the eutectic composition will be the first to melt, and because of its narrow melting range (solids and liquids are at the same temperature), the eutectic composition will flow into the braze joint.

Figure 3: Eutectic bonding between stainless steel rings after processing in a belt-sintering furnace.

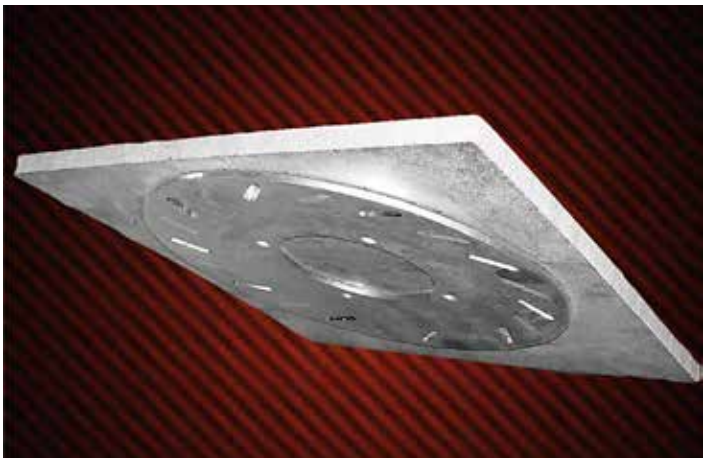


Figure 4: A part bonded to the graphite carrier due to carbon migration from graphite carrier to the stainless steel finished component.

While eutectic melting is sometimes preferred, there are also industrial processes where the eutectic melt is not a desired effect and can actually cause major issues within the process. A bonding effect can occur between various graphite fixtures and the processed materials. Heat-treat processes using graphite fixtures are susceptible to eutectic bonding. The cause of this susceptibility is the interaction between certain elements through solid-state diffusion. When graphite fixtures are present, carbon atoms can transfer from the graphite fixtures to the metal to be treated. This transfer can change the melting point of the metal and create fusion between the working surfaces or even the complete melting of the metal. The near-perfect surfaces on both the metal (especially oxide-free metal surfaces) and

The availability of multiple quality graphite grades is a benefit, but it can also pose a challenge as every grade has a different electrical resistance.

the graphite fixtures can contribute to this diffusion (Figure 3).

Eutectic bonding can occur in sintering as well as in vacuum processing with adverse results. In these processes, major consideration should be given to selecting the graphite fixture material and designing the synthetic graphite fixturing that best reduces surface contact.

Solid state diffusion of certain elements can cause the formation of an undesirable lower melting point alloy (eutectic). For example, solid-state diffusion between carbon and nickel can begin to occur at temperatures as low as 1,165°C (2,130°F) and cause local melting and bonding. Under the proper conditions, molybdenum will also combine with other elements to cause eutectic bonding. However, the molybdenum reactions with common elements in steel tend to occur at temperatures well above the normal heat-treating range.

The process of selecting the proper graphite fixture material is not to be underestimated. Severe eutectic bonding reactions can cause extensive damage to workloads. The cost to repair this kind of damage can reach into the tens of thousands of dollars. In the worst cases, entire hot zones need to be rebuilt. In Figure 4, an entire set of graphite fixtures, and the associated stainless-steel parts to be heat-treated, ended up being scrapped. The bonding process was so severe that the graphite plates and stainless-steel parts warped, making them unusable.

Sometimes the easiest solution is the best. Modifying the treat temperature by as little at 5 to 10 degrees F up or down can inhibit the eutectic ally from binding, or from being created altogether, if that is not the purpose of the treat. If the process does not allow modifying the treat temperatures, alternate solutions consist of creating barriers between the potentially reactive materials with non-reactive materials (insulators). These insulators are often available in the form of papers, graphite foils, or other solid shapes upon which the work pieces can be placed. Additionally, coatings of high-purity ceramic materials such as aluminum oxide can be used. These are available in the form of paints and sprays to be applied to the surfaces in contact.

To avoid any undesired effects of the heat-treat processes, consider all these scenarios and be sure to take the precautions recommended.

ABOUT THE AUTHOR

Filip Cujba is key account manager with Semco Carbon. Semco Carbon is a graphite component production facility in Lorain, Ohio. At its facilities, the company has crafted custom thermal-processing carbon and graphite items for almost 50 years by using its machining capabilities, CAD, and application engineering solutions to suit a client's budget, goals, and expectations. As a custom manufacturer, Semco Carbon produces a wide variety of graphite components for industries from paper and food processing to the military and aerospace. That being said, the company's mainstay has been, and will continue to be, the advanced heat-treat industries.

COMPANY PROFILE ///

I SQUARED R ELEMENT CO., INC.

THE POWER BEHIND QUALITY HEATING ELEMENTS

An LMA curing furnaces for up to 20-foot-long elements. (Photos courtesy I Squared R Element)

I Squared R Element is known for its high-quality heating elements and positive customer satisfaction, offering a fast turnaround on its products.

By KENNETH CARTER, Thermal Processing editor

When you name your company after the electrical formula for power, you better make sure you know what you're doing.

I Squared R Element Co. Inc. has been making electrical resistant heating elements for more than half a century, so it's safe to say that the company does, indeed, know its business.

"We have, fundamentally, two product lines that are used in industrial furnaces," said Christina Clowes, vice president at I Squared R Element Co. Inc. "One is a silicon-carbide heating element under the trade name, Starbar®, and molybdenum disilicide heating elements that are sold as Moly-D®. We have five different grades and five different sizes of heating elements that serve really anything from a piece of laboratory analytical equipment up to large industrial furnaces used in steel or ceramic processing or glass processing, and heat treatment."

The Starbar heating element has a maximum-use temperature of 3,100°F (1,700°C). The Moly-D element can operate up to an element temperature of 3,362°F (1,850°C).

SERVING MULTIPLE INDUSTRIES

Those major product lines are used in a myriad of different industries, according to Clowes.

"You name it, and we probably are there," she said. "Nonferrous alloy processing, so melting, holding, refining, those kinds of things. To a large extent, aluminum alloys, but magnesium and copper-based alloys as well, but aluminum dwarfs the rest, I would say. A lot of automotive making cylinder heads, car wheels, or any vehicle wheel for that matter. There's a lot of automotive use, for sure."

Some of that automotive-type applications include heat-treatment furnaces for automotive, metallurgical heat-treatment, carburizing, hardening, and case hardening, steal heat treatment where billets are heated prior to rolling or hot forging, ceramic processing, which could involve either tableware-type ceramics or technical ceramics that involve packaging and substrates for electronic applications, according to Clowes.

"We're heavy into the sintering of powder-metal components, whether it's traditional press and sinter parts or additive manufacturing type technology," she said. "That's been growing rapidly for us over the last few years."

Additive manufacturing is one of several technologies competing for a place at the table, but for the time being, it is still in its infancy, according to Clowes.

"We're working with quite a number of folks in that arena, and it's opened up new opportunities for us," she said.

SERVICE ORIENTED

Clowes said I Squared R Element prides itself in being a service-oriented business that focuses on the customer.

"That starts from the moment a customer tries to get in touch with us," she said. "We don't have voicemail, purposely, so if anybody calls our company, they never reach anything other than a live human being. There are no endless mailboxes full of messages that nobody ever responds to. And we offer fast delivery. It goes without saying, but maybe it doesn't, but quality is expected and the performance of high-quality, reliable products. But we deliver faster than anybody else, and that's really something that we focus on very heavily."

A Moly-D element being welded.

I Squared R has a 122,000-square-foot manufacturing facility in Akron, New York, with a large number of furnaces that enables the company to get its products out quickly, according to Clowes.

"Anything from a day up to two weeks is quite typical of our delivery time," she said. "I would say that four to five weeks would be quite a long delivery time for us, so we offer a rapid turnaround. Our focus is on providing the customer with the service when they need it."

Even with that quick turnaround, the company still is able to offer strong technical and customer support, according to Clowes.

"We provide free design engineering assistance to either OEMs or

A Moly-D automatic welding machine set up with close-up video for perfect alignment of the parts to be fused.

end users," she said. "I think we're well known for that, and that's a key strength for us as well to either troubleshoot or look at a project to upgrade an existing furnace and kind of re-engineer things from the ground up."

SOLVING PROBLEMS

That engineering support becomes immediately advantageous to solving customers' problems, whatever that problem turns out to be.

"It depends on what the challenge is, of course, but we'll assess that challenge, and if it's something that we do every day, because that is the business that we're in, then we have computer modeling programs to do the, let's say, repetitive calculations, so we don't have to do it all longhand every time," she said. "It's based on a lot of long experience and a lot of the people that we have working here in engineering and technical support and product development have been here a long time."

In that vein, I Squared R's employee experience runs deep. Clowes has been in the industry for 34 years; the owner, Jack Davis, has 57 years under his belt. Many of the company's other employees have 20 to 40 years of experience each, according to Clowes.

"There's a lot of knowledge and experience, and we are trying to pay attention to the next generation and how to pass that forward as well," she said. "That's a challenge unto itself, of course."

A FOCUSED WORKFORCE

Despite all those years of experience, I Squared R Element likes to keep its workforce on the small size, according to Clowes.

"We're a small company; we're about a hundred people," she said. "We intentionally keep ourselves lean so that we're not trying to do everything. We focus on some core activities, some core products, some core things that we want to do well, rather than trying to be all things to all people, if you will. So, I think focusing on our core business activity has been something that has actually helped steer what we do."

That doesn't mean, however, I Squared R is content with the status quo.

"We have been busy developing new products to meet challenges of our existing customers and new applications," Clowes said. "For example, the 3D metal printing area, that poses some challenges that we've had to overcome to really introduce a product that worked well with that particular technology. It's working beautifully, and we're growing quite quickly in that area."

SOLVING PROBLEMS

That philosophy has also allowed I Squared R Element to tackle other challenges head on. The end result is pushing the company past its initial comfort zone and into the future.

"One of our largest customers came to us a couple of years ago and

said, 'OK, we love your products; we love your company; we've been using them in this application, and we need to take things to the next level. We're looking to extend our operating campaign, which is X today, and we want it to be X times 2 tomorrow. What can you do to help us get to that point?'" she said. "Initially, the reaction was, 'Well, that's probably an impossible thing to do.' But we took the request as it was, and we set out to look at ways that we could perhaps change things to arrive at what they were looking for. We reformulated some things, developed an entirely new SiC body, and developed new protective infusion coating technology, and the result is that we exceeded what they were actually asking us to deliver."

Clowes said that initial challenge actually opened up new opportunities for the company in other applications.

"I always think that when customers come along, and they challenge you, and they want better and better and better, the initial reaction might be to think 'Oh, yes, these people are asking for something crazy,' but, in fact, it helps us to keep moving forward if we get those challenges, and I welcome that," she said. "That's a good thing for all of us actually."

Finding new ways to meet customers' needs is paramount in a manufacturing world with increasing competition from international manufacturers, particularly from China, according to Clowes.

"They're no longer the garage workshops they perhaps were in the past," she said. "They've got good technology, good people, good know-how, and they're improving. So, our job is to provide the best service and develop the best products and basically stay at least a few steps ahead of the best alternatives."

LOOKING TO THE FUTURE

Clowes expects I Squared R Element to stay quite busy as they continue to grow and develop new business in new applications. Working very closely with technology innovators on the engineering and design side at the outset is really important. Understanding their challenges and needs in a clear way is key to developing the best performing solutions for new and emerging technologies.

"I think it will continue to be increasingly challenging," she said. "Especially from competition and technology as it changes. I mean, nobody really knows what will happen tomorrow. Using the example of additive manufacturing-type technology, in the past, looking at raw products or forge products or machine products to get to a final form and the powder technology and its capability in producing complex shapes, lightweight geometries, honeycomb-type structures, those types of things, it really does open the doors to reimagine pretty much anything you can think of and the way it's produced. With a component of a certain size, the weight-savings alone that can be gained from a totally different structure that was not possible to form by any other technology, it's going to completely change things. For engineers of the future, it's a bit like comparing the thinking of the past when setting out to produce an engineering drawing on a drafting table with pencils and tools to form different shapes, compared with designing a component or assembly in 3D modeling software like SolidWorks — it's a totally different way of thinking."

Also, the increasing expansion of 3D printing is changing the face of manufacturing as the technology moves from plastics to metal, and eventually even more to ceramics and other materials, according to Clowes.

"Knowing what the future holds, you know crystal-ball gazing is quite difficult, but I think making sure that we stay on track and we keep in touch with people that are generating and developing future generation technology, that's something we try to do, hopefully effectively," she said.

AMERICAN MADE

I Squared R does all that while keeping the company and its products squarely — no pun intended — located in the U.S.

I Squared R Element was founded in 1964 by Davis and Stan Matys. Using their experiences in sales and research, the company soon became the largest manufacturer of silicon carbide heating elements in the United States. In 1993, the company added the molybdenum disilicide heating element line. I Squared R is today the only U.S. manufacturer of silicon carbide heating elements and high-quality molybdenum disilicide heating elements, according to Clowes.

The loading side of a production furnace for making Starbar elements.

"We are an American company; we fly the American flag; we only buy American products wherever we can, and we encourage our customers to do the same," she said. "We have one manufacturing operation here. We don't have operations in Asia or elsewhere in the Americas. We focus on what we do. We pay a decent living wage, and we're kind of a classic example of supporting and keeping the American middle-class alive."

MORE INFO www.isquaredrelement.com

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ERIC FORD /// VICE PRESIDENT OF SALES AND MARKETING /// GRAPHITE METALLIZING CORPORATION

"Our No. 1 achievement is the engineering, manufacturing, quality, sales, and customer service team we've put together to solve our customers' problems on a daily basis"

What does Graphite Metallizing Corporation do for the heat-treat industry?

Graphite Metallizing Corporation makes a product called Graphalloy. It's basically a graphite/metal alloy, that we provide in the form of a bushing. We started out in 1913 with some entrepreneurial engineers that figured out how to put graphite and metal together to make electrical contacts for elevators. Over the years, we've developed the product for applications in the harshest environments, such as the heat-treat industry.

The main thing that Graphalloy provides to the heat-treat industry is solutions to save maintenance time and money. Graphalloy is self-lubricating, so you don't need any grease or oil. We have a wide temperature range of grades that go up to 1,000°F in an oxygen environment, and nearly twice that in an inert environment. What that does for people in the heat-treat industry is it provides them with a self-lubricating, high-temperature product, which reduces their need to spend time replacing bushings, bearings, or repairing equipment.

What's a typical day like for you at Graphite Metallizing?

Graphite Metallizing is based in Yonkers, New York, where we have our foundry, shop, engineering, and support teams. What we do on a daily basis is work with our customers' engineering and maintenance personnel to develop solutions for their unique problems. It could be a solution for heat-treat ovens, furnaces, furnace tap gates, etc. For example, we provide industry standard cam followers with Graphalloy in place of the needle bearings. It could be diverter pillow blocks, cooling beds, conveyors, louvers, dampers, pot roll bearings, oven cart wheels. Anywhere you have grease and you want to get rid of it, Graphalloy can be a good solution.

How do you work with a customer when they come to you with a challenge?

Our engineers work one-on-one with their engineers or maintenance staff. The first thing we do is make sure they understand what Graphalloy is and what it can do. It is a unique material, and some people have assumptions about how you use it. We help them understand how they can use Graphalloy to save themselves time and money. We make Graphalloy in custom dimensions for the customer when they give us specific information about their application. For new or challenging applications, we often suggest that they test some Graphalloy parts in their specific application.

What has changed the most in the heat-treat world and how have you adapted?

The things that have changed the most and continue to change — and actually I see it in a positive way — are there are many more consolidations in the industry. You also see many of the older mills that were idle reopening, and you see companies providing more investment into those mills for refurbishing and increasing their capacity. All of those activities are positive for Graphalloy, because as they expand and modernize, many times they want to reduce maintenance costs by doing away with grease or they need a high temperature material for their cooling beds, conveyors, quench tanks, or other equipment.

One other thing I can say about Graphalloy is it works well when submerged in liquids. It doesn't swell, so we have a lot of these types of applications, such as in quench tanks. We have one customer where Graphalloy was in their quench tank for 25 years before they replaced it. Graphalloy is a long-lasting product, and that's why we are very careful to make sure we understand the customer's application completely before recommending a certain grade.

What do you consider some of your proudest achievements?

I think the No. 1 achievement is the engineering, manufacturing, quality, sales, and customer service team we've put together to solve our customers' problems on a daily basis. Our stated goal is "a satisfied customer who receives a defect-free product on time, every time," and we all work together to make that happen. One example of this teamwork is we had an automotive engine plant that came to us at a trade show and mentioned that they were looking to replace their greased bearings because every time the furnace door would open, it would fry the grease in the bearings, and they would often have to stop the line to replace them.

Over a period of two years, our team worked with them from testing in one furnace to completely replacing all their furnace bearings with Graphalloy.

The maintenance manager said that this saved them well over $100,000 a year just in maintenance and repair costs. Now, when the furnace doors open, the Graphalloy bushings keep everything working, since there's no grease to cook. The initial "test" furnace has been working for over five years now, without the bearings needing to be replaced.

MORE INFO www.graphalloy.com

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