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Thermal processing

ISSUE FOCUS ///

COOLING TOWERS / CERTIFICATIONS

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COMPANY PROFILE ///

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Thermal processing

FROM THE EDITOR ///

Certifications: An important part of heat-treating

At the risk of preaching to the choir, certifications, with their strict guidelines to ensure conformity, are a necessary function of any industrial process in general, and heat-treat process, specifically.

Nadcap certifications, in particular, have become a vital part of making sure a final product meets the highest standards. They not only improve standards, but they have the added benefit of lowering costs. It also lets a company's customers know that what's being offered has passed the most stringent of testing.

In this month's *Thermal Processing*, we take a look at Nadcap certifications, as well as cooling towers.

In an article from the Performance Review Institute, Jerry Aston, program manager for Heat Treating and Metallic Materials Manufacturing, shares his insights on how to improve performance and prepare for a successful Nadcap audit.

Cooling towers can be a quintessential piece of equipment when working with heat-treatment applications. In that vein, the designs behind cooling-tower technology are constantly being updated.

An article from Scott Maurer, sales manager at SPX Cooling Technologies, looks at how advancements in modular designs can provide up to 50 percent more cooling capacity, greater energy, installation savings, and more.

In addition to these informative stories, the August issue also includes some interesting pieces from some of our regular contributors.

And in our company profile, we take a look at Semco Carbon and how that company, with almost 50 years of experience with graphite and carbon composites, can supply just about anything a heat-treat customer may require.

In our Q&A, I had the pleasure of chatting with Nel Hydrogen's David Wolff and how that company is revolutionizing how hydrogen is supplied, making it safer, and sometimes even more economical, than conventional storage and production methods.

As you can see, we've tried to pack this issue with a lot of fascinating articles. I hope you enjoy them as much as I did.

Fall is just around the corner, so stay cool, and, as always, thanks for reading!

KENNETH CARTER, EDITOR
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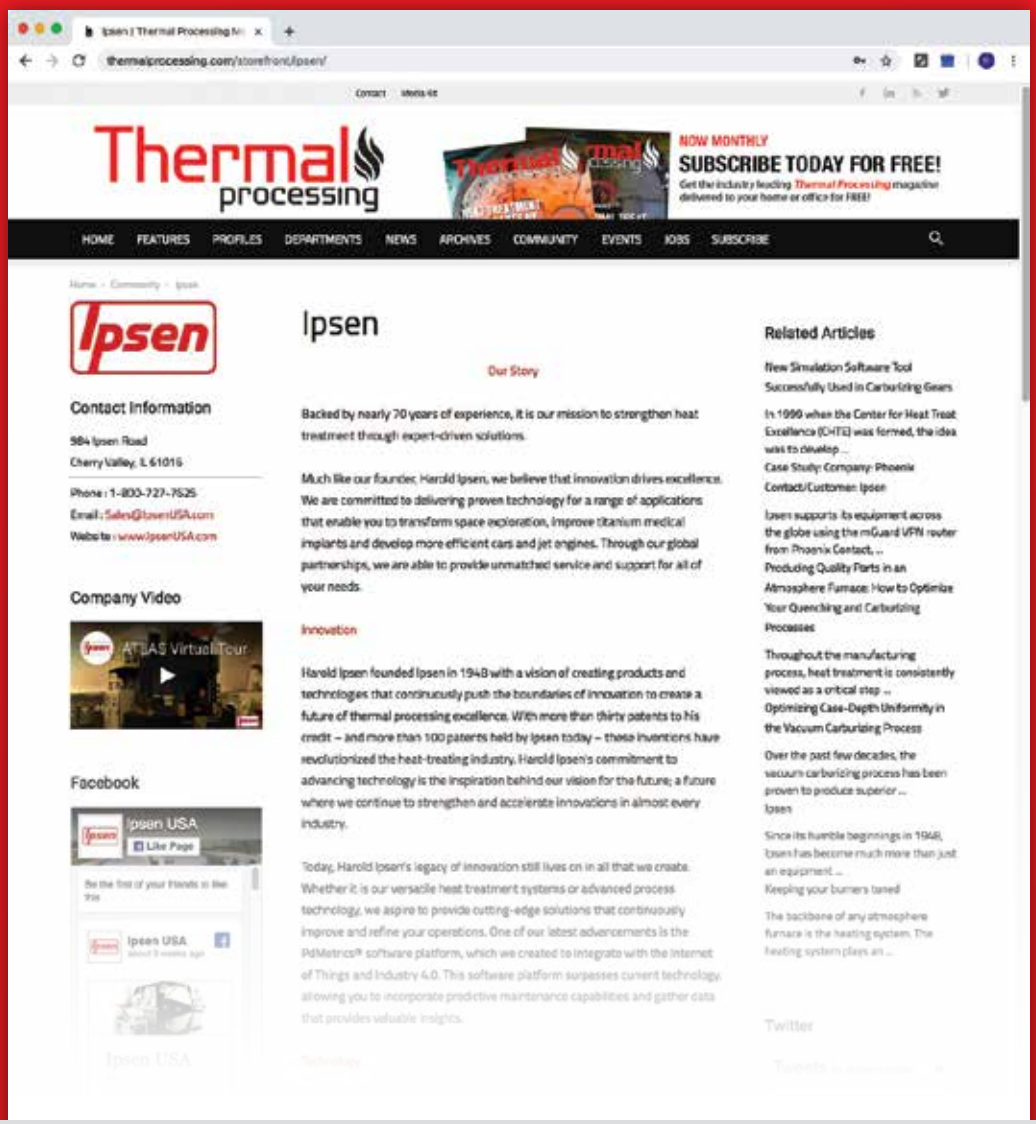

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Thermal processing

Tenova sells HTC Group to Ningbo Qijing

Tenova, a Techint Group company, has concluded the sale of the HTC Group, which includes four companies — IVA Schmetz (Germany), Mahler (Germany), Fours Industriels B.M.I. (France), and IVA Schmetz Industrial Furnaces (China). The four companies specialize in advanced technologies for heat-treatment processes for components.

The purchasers are Qizhi GmbH and Shanghai Qizhi Information Technologies Co., Ltd. both members of Ningbo Qijing Holding Co., Ltd. Ningbo Qijing is also the parent company of Qijing Machinery Co. Ltd., a company specializing in the research, development, manufacturing, and assembly of mechanic systems and precision parts mainly in the home electric appliance field and industrial application field.

"As an experienced company in supplying precision parts for different industries, we recognize in the heat-treatment one of the most critical processes for precision machined parts. We believe that HTC group, with its expertise and product range, has the potential to gain space and relevance in growing sectors, especially in the Chinese market," said Wang Yongqi, chairman of Ningbo Qijing Holding.

The demand for heat-treatment technologies is booming in the aerospace industry, while in two other business sectors such as medical and metals powders, this equipment will face a rapid expansion in the near future.

"Qijing group represents a solid industrial partner in search of an excellent European technological player to expand its business. While we as Tenova are focused more and more on the 'green' technologies for large steel and aluminum plants, I am convinced that Qijing is the right purchaser to boost the development of the HTC companies, that will enhance them and develop their full potential in other sectors," said Andrea Lovato, Tenova CEO.

The successful outcome of the purchasing process was possible also thanks to Seta Capital and UniCredit, which have acted as financial advisors to Tenova in the context of the transaction.

MORE INFO www.tenova.com

Sandvik opens coiled tubing line in China to cut delivery times

Sandvik has opened a state-of-the-art coiled tubing line for premium grades of seamless stainless-steel products in smaller dimensions at its Zhenjiang tube mill near Shanghai, China. The commitment to produce longer lengths of weld-free coiled tubing locally will allow customers in the Asia Pacific region to receive deliveries within 28 days, instead of waiting four to six months for longer-length reels to arrive from abroad.

Sandvik's coiled tube is supplied as level-wound on plastic-wrapped wooden reels in standard (55-260 m) or longer lengths (135 – 611 m), or as bulk coil, strapped into boxes.

"The new coiled tube offering is a further step in our commitment to boost the competitiveness of customers in China and throughout the Asia Pacific region," said Satish Sharath, business unit president Sandvik Tube APAC. "We've seen a rising demand on projects within chemical processing, oil and gas, alternative energy, and other industries for urgent local supplies of coiled tubing. The compact reels, ease of transport, and ability to precisely cut lengths in challenging situations allow customers to work fast and efficiently, with fewer connectors and zero risk of system leakage."

Initially, the focus will be on Sandvik 3R60™ (ASTM TP 316/316L) tubing – an austenitic chromium-nickel steel with a minimum of 2.6 percent molybdenum and low carbon content – in outer diameters from 6.0 to 14 mm. The coiled tube is supplied as level-wound on plastic-wrapped wooden reels in standard (55-260 m) or longer lengths (135 – 611 m), or as bulk coil, strapped into boxes. The new range complements Sandvik's current offering of six-meter straight lengths of hydraulic and instrumentation tubing, which are already available in the widest range of sizes and grades on the market.

"At first glance, most tubing looks pretty much the same," said Glenn Darley, regional sales and marketing director in China. "But numerous tests show that Sandvik truly sets a standard within the various product and grade standards, consistently delivering at the highest levels on key performance criteria such as ovality, corrosion resistance, surface smoothness, and tight tolerances. This – and our deep materials expertise – matters a great deal to end users who often discover the hard way that inferior local grades can lead to system leakage,

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.

unplanned maintenance or – even worse – a plant shutdown."

According to Darley, the 28-day delivery promise means, in effect, that Sandvik coiled tubing is now "closer than you think." In addition to Sandvik 3R60™ (ASTM TP 316/316L), the company will supply other grades of high-alloy and duplex tube products in a wide range of dimensions, however, they will be handled on a case-by-case basis, by country, and may be subject to slightly different delivery times than the 28-day guarantee now being offered for standard grades.

"Our aim is to better serve customers in the Asia-Pacific region," said Paul Tsai, production unit general manager at the Zhenjiang Mill. "The new offering combines advanced production technology and unique manufacturing know-how with extensive technical support." The mill he oversees, located 250 kilometers northwest of Shanghai, produces straight and U-bent tube for heat exchangers and hydraulic and instrumentation tubing in austenitic and duplex stainless steels as well as high-alloy austenitic stainless steels and nickel alloys.

MORE INFO www.materials.sandvik

MPIF presents Distinguished Service awards at expos

The Metal Powder Industries Federation's (MPIF) honored recipients of the 2019 MPIF Distinguished Service to Powder Metallurgy (PM) Award at its Industry Luncheon during Powdermet2019 and AMPM2019. The award recognizes individuals who have actively served the North American PM industry for at least 25 years and, in the minds of their peers, deserve special recognition.

2019 Award Recipients

Company name in parentheses indicates employer at time of retirement.

› **Denis Christopherson,** PMT, Federal-Mogul Powertrain.

› **Zhigang (Zak) Fang,** FAPMI, University of Utah.

› **Robert M. Gasior,** Arconic Technical Center.

› **Ryuichiro Goto,** Engineered Sintered Components.

› **William A. Heath,** PMT, MPP.

› **Stephen J. Lanzel,** Catalus Corporation.

› **Deepak Madan,** Luxfer Magtech.

› **David Milligan,** North American Höganäs Co.

› **Thomas Pfingstler,** Atlas Pressed Metals.

› **Daniel P. Reardon,** Abbott Furnace Company.

› **Christopher T. Schade,** Hoeganaes Corporation.

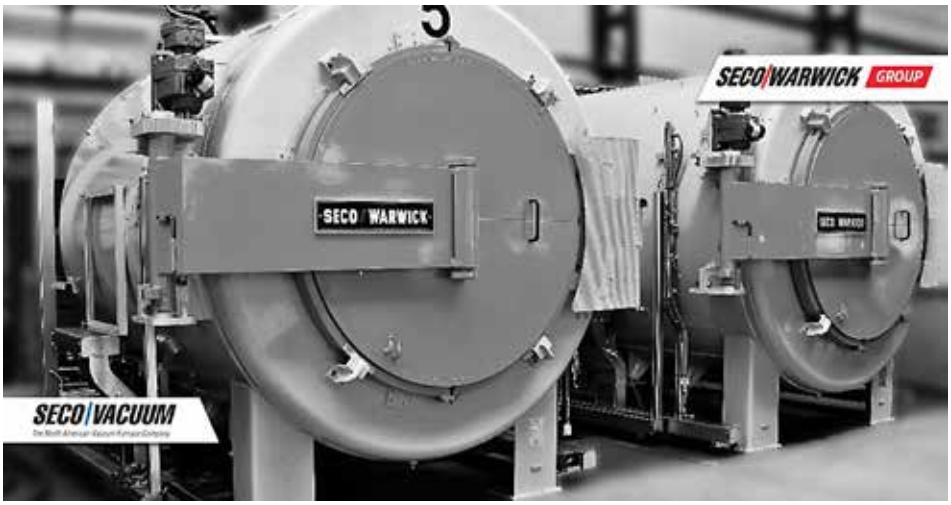
› **Michael Stucky,** Norwood Injection Technologies, LLC.

› **C. James Trombino,** (Metal Powder Industries Federation).

MORE INFO www.mpif.org

Automotive supplier orders furnace from Seco/Warwick

Seco/Vacuum, a Seco/Warwick Group company, signed an order for a high-volume nitrocarburizing line serving a major car maker via a tier one supplier. The horizontal retort furnace is known for its precision nitriding capability and productivity. The furnaces will allow the customer to produce, in North America, a significant number of parts used by automotive suppliers, and will be integral to a larger investment in the firm's compo-



Batch processing (FNC, nitriding, carburizing) offers end users processing of a large number of parts with a variety of furnace size options. (Courtesy: Seco/Warwick)

nent manufacturing operations. In addition to ferritic nitrocarburizing, the furnaces can also provide clean, stress relief processing.

Lower operating costs, attractive return-on-investment (ROI), precise control of case depth, and high-volume processing are trademarks of Seco/Warwick Group furnaces and automated handling systems.

"Ferritic nitrocarburizing (FNC) is a form of gas nitriding and Seco/Vacuum offers many standard sizes and options suitable for both small commercial heat-treaters as well as large automotive suppliers," said Piotr Zawistowski, managing director of Seco/Vacuum Technologies.

FNC is gaining popularity due to the resulting wear and anti-corrosion properties offered, including coupling with post-process high-temperature oxidation.

In the production of atmosphere heat-treatment solutions, Seco/Warwick Group uses its extended experience and state-of-the-art technology to simplify installations, reduce investment costs, and reduce process utilities consumption.

These benefits were the reason why another American producer of various transportation components chose to buy a new precision gas nitriding furnace with ZeroFlow® from Seco/Warwick Group. The furnace allows the company to offer engineered steel surfaces that exceed, in many cases, its competitors' product performance, giving it a heat-treating edge that is hard to replicate.

MORE INFO www.secowarwick.com

Oelheld introduces forging lubricants at Forge Fair 2019

Oelheld announced a line of forging lubricants at Forge Fair 2019. The company is also a new member of the Forging Industry Association.

The forging lubricants include:

› **AirForge OH 40009:** Combines cleanliness with the added lubricity of graphite in oelheld's synthetic die lubricant.

› **AirForge OH 40009:** A synthetic high-performance die lubricant for steel, titanium and nickel-based alloys. The product contains some graphite to add lubricity for deeper draw parts. AirForge OH 40009 is cleaner to work with than a true graphite lube. The maximum die temperature is 300°C and the maximum work piece temperature is 1,200°C.

› **AirForge OH 40028:** Semi-synthetic die lubricant guarantees unblemished surface finish on aluminum.

› **AirForge OH 40028:** A semi-synthetic die lubricant for warm forging aluminum up to 650°C. It is formulated for excellent lubrication and release properties. The product promotes superior material flow and guarantees unblemished surface finish.

› **AirForge 4028:** Transparent synthetic die lubricant for the optimum die and workpiece cleanliness.

AirForge 4028 is a synthetic, graphite-free, high-performance die lubricant for steel alloys with excellent lubricating properties. AirForge 4028 can be used at temperatures from 900 to 1,200°C. The excellent lubrication properties ensure no residue in the die and clean gravures.

The company will be at the Motion + Power Technology Expo in Detroit, Michigan, October 15-17, Booth #3803.

MORE INFO www.oelheld.com

Gasbarre announces new team member for field service

Gasbarre has hired Tom Spicer as a field service technician for Gasbarre Industrial Furnace Systems (OEM of J.L. Becker brand equipment), located in Plymouth, Michigan.

Spicer brings more than 20 years of industry experience to Gasbarre, having previously worked with OEMs assembling and servicing equipment and in maintenance at a commercial heat-treat facility. During his time in commercial heat-treating, Spicer gained extensive knowledge in processing and maintaining equipment for nitriding and ferritic nitrocarburizing applications.

Tom Spicer

Ben Gasbarre, president of Industrial Furnace Systems, said, "With the addition of Tom, we gain yet another team member with many years of industry experience. Tom's work as an equipment manufacturer and commercial heat treater gives him a perspective that will create more value for our customers. We are excited to have him on board."

Gasbarre is a full-service international OEM offering industry best equipment and services for powder compaction, thermal processing, and design and manufacturing technologies.

Gasbarre Thermal Processing Systems provides top-quality industrial heat-treating equipment, engineering, and service to customers around the world. Gasbarre's product offering, which includes the product lines of

Selective Laser Melting Machine SLM®280 of Rosswag. (Courtesy: SLM Solutions)

Sinterite, C.I. Hayes, and Industrial Furnace Systems, offers batch, continuous, atmosphere, and vacuum furnace systems, as well as a wide range of auxiliary equipment.

MORE INFO www.gasparre.com

Rosswag Engineering adds third SLM®280 melting machine

Rosswag Engineering has announced the acquisition of its third selective laser melting system from SLM Solutions. The third SLM®280 machine delivered to its facility in Pfinztal, Germany, expands production and development capabilities with the metal additive manufacturing technology.

A division of Rosswag GmbH, one of the world's leading providers of open die-forged products with nearly 120 years of experience in the manufacturing of 400 different metal alloys, the company has built decades of know-how in material science and combines its production expertise on SLM® machines with a complete in-house process chain from metal powder production, design, process simulation, and printing to CNC post-processing and heat treatment as well as metallurgical testing and quality control.

As a strategic partner of SLM Solutions in the advancement of the selective laser melting technology, Rosswag Engineering also qualifies new alloy powders and parameters by combining the capabilities of its simulation software package, powder atomizer, and three SLM®280 machines. With the ability to quickly produce special metal powders, simulate build results, print tests using SLM's material development module, then post-process and inspect builds in-house, the time to market cycle for new materials is reduced from months to weeks.

Using the Material Development Module from SLM Solutions, Rosswag duplicates part positioning and uses rule-based parameter variation for an automated and systematic analysis of parameter sets. After completing the qualification process, comprehensive data for production, including metal powder characteristics, process parameters, mechanical values, and chemical and metallurgical material properties are available.

"At Rosswag Engineering, our goal isn't only to provide our customers with quality products built on metal additive manufacturing machines, rather to help the technology gain acceptance and expand," said Gregor Graf, Head of Engineering at Rosswag. "By adding a third selective laser-melting system we are able to increase our production capacities and gain more flexibility for demanding material and part qualification processes."

Hendrik Schonefeld, head of sales EMEA at SLM Solutions, said, "Our partnership with Rosswag allows us to help customers develop small-batch and exotic alloys to meet their unique needs. SLM Solutions is focused on production applications, and our machines reflect this, however many customers need quick parameter development to prove their process before they get to that step, and the experts at Rosswag allow us to meet their needs as well, creating a full-service selective laser melting partnership for all types of customers."

So successful is the process developed by the experts at Rosswag that the company was recently the first company certified as metal powder manufacturer by TÜV SÜD Industrie Service GmbH through their audit based on the AD 2000 Code for pressure equipment and the European Pressure Equipment Directive (PED).

MORE INFO www.slm-solutions.com

Slovakian company places major order with Tenova

The Slovakian company U.S. Steel Košice, one of the largest integrated steel producers in Central Europe, placed a major order for the supply of an annealing and coating line (ACL) for dynamo steel strips to Tenova LOI Thermprocess, a worldwide leader in heat-treatment lines and furnaces located in Essen, Germany.

The plant bears the internal name Dynamo-Line no. 4 and will meet the highest requirements for the production of non-grain oriented electrical steel. The contract scope includes the engineering, to a large extent the turnkey delivery of all equipment, as well as the supervision of the assembly and commissioning including training.

The entire line is designed and delivered by Tenova, a company of the Techint Group and leader in innovative solutions for the metals and mining industries. Tenova, with its companies Tenova LOI Thermprocess and Tenova Italimpianti, supplies the complete annealing and coating line, including heat-treatment section (furnace) of the plant, the

U.S. Steel Košice placed a major order for the supply of an annealing and coating line for dynamo steel strips to Tenova LOI Thermprocess. (Courtesy: Tenova)

entire strip handling and chemical processing with drying oven following the coil coating, the associated electrical, instrumentation, and control technology including automation system.

The customer chose Tenova LOI Thermprocess and the advanced Tenova technology as its partner for several reasons. The multiplicity of references for comparable facilities, the short realization time, and the mathematical model were of crucial importance.

U.S. Steel Košice is a wholly owned subsidiary of U. S. Steel Group headquartered in the United States. It is a fully integrated metallurgical plant and one of the largest industrial companies in the Slovak Republic. In addition to the production of thin sheet, ultra-fine sheet and galvanized strip, non-grain-oriented electrical steel sheets have been produced for more than 30 years. The company is realizing extensive modernization measures to improve product quality. One of the measures is the dismantling of two outdated annealing and coating lines and at the same time the construction of the new modern annealing and coating plant.

During 2000-2019, Tenova received a total of 60 orders for heat-treatment systems for electrical steel, of which 34 plants are completely new installations.

MORE INFO www.tenova.com

Thermal Product Solutions names Jennings president

Thermal Product Solutions, LLC (TPS), a global manufacturer of thermal-processing equipment, has appointed Greg Jennings to the position of president and CEO.

Jennings has experience in Fortune 500 and private companies. He has held the position of Chief Financial Officer (CFO) at TPS since 2013. During his time as CFO, he was instrumental during the acquisition of Wisconsin Oven Corporation and Baker Furnace. Before TPS, Jennings held a number of domestic and international positions within SPX Corporation, a supplier of highly engineered solutions.

Jennings has an extensive educational background to support his experience in the industry. He has a BBA in finance from the University of Tennessee, MBA from Arizona State University, Masters in corporate innovation and entrepreneurship from Penn State University, and several professional certifications from accredited universities such as Cornell University and the New York Institute of Finance.

Greg Jennings

"I'm honored to lead the Thermal Product Solutions (TPS) organization, a company that has a long-standing history with each of its brands and customers. This business has

done a tremendous job of serving the most innovative companies in the world, and we will continue to stretch ourselves to understand each and every customer's need. I look forward to working with all of our incredibly dedicated TPS employees and partners to ensure that we challenge ourselves in pursuit of exceeding these customer needs through innovation, comprehensive customer service, and unparalleled quality," Jennings said.

Jennings will be at the Wisconsin Oven facility in East Troy, Wisconsin, and intends to maintain an active presence in the community through his role as a board member of the United Way of Walworth County.

MORE INFO www.thermalproductsolutions.com

Powder Metallurgy design excellence winners named

The winners in the 2019 Powder Metallurgy (PM) Design Excellence Awards competition, sponsored by the Metal Powder Industries Federation (MPIF), demonstrate outstanding examples of PM's diversity. These component fabricators use PM's flexibility to push forward new concepts and process controls, and demonstrate the inexhaustible well of capabilities PM can marshal in the service of component design. Designers continue to choose PM for critical applications such as auto engines and transmissions, medical devices, consumer products, hardware, and more.

Nine Grand Prizes and seven Awards of Distinction have been given in this year's competition.

Grand prize awards

› A Grand Prize in the Automotive–Engine Category for Conventional PM components was awarded to Capstan for a compact brushless dc actuator gear designed to optimize engine performance and reduce nitrogen oxide emissions for on- and off-road commercial diesel-engine vehicles. Made from SS-316L all gear dimensions meet AGMA level 7 requirements. This stainless-steel precision gear required unique carbide tooling for compaction.

› In the Automotive–Engine Category for MIM components, a Grand Prize was awarded to Indo-MIM Pvt. Ltd., India, for a turbo charger vane. The part complexity includes a thin-walled, curved profile with a thick lug on top. A two-drop, hot runner tool is used to produce 12 parts per shot without any slide involvement.

› A Grand Prize was awarded to Stackpole International, Canada, in the Automotive—Transmission Category for Conventional PM components for a clutch backing plate and pressure-apply piston used in the General Motors 9T50/65 Hydra-Matic transmission. The parts form a combined sub-assembly within the transmission together with a central hub and two roller-bearing races.

Compaction of the parts involves the use of multiple-element tooling, and a complex die design is needed to form the near-net-shape geometry.

› In the Automotive–Chassis Category for MIM components, a Grand Prize was awarded to Indo-MIM Pvt. Ltd., India, for a MIM-17-4 PH latching plate used in a collapsible roof assembly for passenger cars. A solid-film lubricant coating is applied to the part to reduce friction during operation of the collapsible roof. Molding was a challenge as the part has two thin features joined by a thicker slotted section.

› ASCO Sintering Co. was awarded a Grand Prize in the Lawn & Garden/Off Highway Category for Conventional PM components for a miniature planetary gear carrier set used in a commercial rotary irrigation system. The parts are made from SS-316N1,N2 compacted to a green density of 6.6 g/cm^3.

› A Grand Prize in the Hand Tools/Recreation Category for MIM components was awarded to Indo-MIM Pvt. Ltd., India, for right- and left-hand bindings in ski shoes. The parts are made from MIM-4605 that is zinc-blue passivated for corrosion resistance. Previously the parts were cast and required many secondary operations to meet the desired configuration and dimensional tolerances.

› In the Industrial Motors/Controls & Hydraulics Category for Conventional PM components, a Grand Prize was awarded to ASCO Sintering Co. for the spring seat of a hydraulic valve actuator mechanism. The part is made from SS-316H-20 and is compacted to a green density of 6.5 g/cm^3 prior to sintering. The five blades of the component are long and too thin to be compacted to net shape directly, so extra material is added in the region of the blades. A low-cost turning operation is needed to achieve the final part geometry.

› A Grand Prize was awarded to Indo-MIM Pvt. Ltd., India, in the Hardware/Appliances Category for MIM components for two MIM-17-4 PH parts, a keeper and a ramp used in a door-hinge assembly. The keeper has a thick but slotted, curved profile that extends 79 mm (~3 inch). By using three slides, two to form the hole running along the length, and another to form the slot at the center, two parts are produced per shot. Previously, the parts were cast and

2019 Grand Prize Winners
Foreground: Surgical camera K-mounts and miniature planetary gear set; second row: hydraulic valve actuators, ski boot bindings, turbo charger vane, and compact brushless DC actuator gear; back row: latching plate, clutch backing plate & pressure apply piston, and door hinge keeper/ramp. (Courtesy: MPIF)

2019 Award of Distinction Winners
Foreground: Ratcheting lock and valve poppet; second row: Camshaft & water pump sprocket, park range sensor control bracket and access hole cover; back row: fan clutch assembly and rotor vane. (Courtesy: MPIF)

required considerable machining to achieve the desired dimensions.

› In the Medical/Dental Category for MIM components, a Grand Prize was awarded to Indo-MIM Pvt. Ltd., India, for a MIM-17-4 PH K-mount main part used in a digital surgical camera. The challenge in molding was to develop a slide mechanism robust enough to form the y-section with ease and with precise matching to avoid flash. Previously, the part was made as two separate pieces that were subsequently welded. This tended to create sharp edges that damaged the cable during use.

Awards of distinction

› In the Automotive—Engine Category for Conventional PM components, an Award of Distinction was awarded to Catalus Corporation for an access-hole cover used to transfer collected oil from the crankcase ventilation system at the top of the engine into the engine block. It had to use an existing bolt pattern and have a low profile to permit clearance to the nearby engine control module. The PM part replaced an assembly of multiple stamped, machined, and drawn components and resulted in a 27 percent weight saving.

› Another Award of Distinction in the Automotive—Engine Category for Conventional PM components was won by Nichols Portland LLC for a rotor vane used in an engine lubrication oil-pump system. The part is sized, face ground, deburred, and cleaned. The product application requires high accuracy of rotor radial dimensions, ID spline and vane-slot features to reduce internal pump leakage and achieve the required system mechanical efficiency.

› An Award of Distinction in the Automotive—Engine Category for MIM components was made to Indo- MIM Pvt. Ltd., India, for a valve poppet used in the fuel-injection system of a diesel engine for heavy trucks. The extremely small part has a tight tolerance on its outside diameter and the perpendicularity of the three legs. Part-specific forms were used during sintering to maintain part quality.

› In the Automotive—Transmission Category for Conventional PM components, an Award of Distinction was won by GKN Powder Metallurgy and Ford Motor Company for a transmission park-range-sensor control bracket that acts as a stop to prevent over travel of a transmission rod in the parking system. While mechanical properties are not a major concern, the positional tolerance of the part once bolted in place is critical.

› An Award of Distinction was won by FMS Corporation in the Automotive—Chassis Category, for Conventional PM components for fan clutch assembly components made for their customer Kit Masters Incorporated and used in cooling systems for semi-tractors and other large, diesel-engine vehicles. The six PM parts included a bushing-tensioner retainer and an index coupler. All six parts are made from FC- 0208-50. The PM parts replaced machined components and offered a 60 percent cost saving.

› An Award of Distinction was won by FMS Corporation in the Hand Tools/Recreation Conventional PM components Category for camshaft and water-pump sprockets made for their customer Polaris Industries Inc. The parts are used in the Polaris Slingshot, 3-wheel, side-by-side "moto roadster." The water-pump sprocket was especially challenging, as the customer desired a one-piece shaft/sprocket design. The PM components represent a 40 percent cost saving compared with machining.

› In the Hardware/Appliances Category for Conventional PM components, an Award of Distinction was won by Webster-Hoff Corporation, and their customer Humanscale, for a ratcheting lock; part of the locking mechanism in an adjustable office chair arm. Unique fixturing is needed during sintering so that the part can meet the tolerances required for the post-sintering, drilling, and tapping operation.

The awards were presented during the 2019 International Conference on Powder Metallurgy & Particulate Materials (Powdermet2019) and co-located conference Additive Manufacturing with Powder Metallurgy (AMPM2019).

MORE INFO www.mpif.org

High-temperature cabinet oven from Grieve

Grieve oven No. 965 is a 1,350ºF (~733ºC) electrically-heated cabinet oven from Grieve currently used in heat treating titanium at the customer's facility. Workspace of this unit measures 24"W x 24"D x 24"H. 30KW are installed in nickel chrome wire coils, supported by a stainless-steel frame, to heat the oven, while a 1,300CFM, 1-1/2HP alloy recirculating blower provides horizontal airflow to the workload.

This Grieve cabinet oven features 11"-thick insulated walls, comprising 2" of 1,900ºF (~1,038ºC) block and 9" of 10 lb/cf density rockwool insulation, as well as an aluminized steel exterior, Type 304 2B finish stainless steel interior, plus inner and outer door gaskets, with the inner gasket sealing directly against the door plug and the outer gasket sealing directly against the face of the oven for optimum seal integrity.

Grieve oven No. 965 is a 1,350ºF (~733ºC) electrically-heated cabinet oven from Grieve. (Courtesy: Grieve)

Oven controls on No. 965 include a digital indicating temperature controller, manual reset excess temperature controller with separate contactors, recirculating blower airflow safety switch, 10" diameter circular chart temperature recorder, and an SCR power controller and fused disconnect switch.

MORE INFO www.grievecorp.com

TPS ships Gruenberg cleanroom ovens to medical industry

Thermal Product Solutions, a global manufacturer of thermal-processing equipment, announced the shipment of six Gruenberg cleanroom ovens to the medical industry.

These Gruenberg unitized ovens have a maximum temperature rating of 149°C with work chamber dimensions of 26" W x 26" D x 34" H. The Gruenberg cleanroom ovens were constructed from a structural steel frame that supported the 304L stainless steel interior chamber liners and the 304 #4 polished stainless-steel exterior. All interconnecting struts are non-continuous, which keeps the exterior cool.

The front-loaded cleanroom ovens used horizontal airflow, which maximizes heating rates and temperature uniformity of the product load, and a circulation blower in a conditioning plenum chamber on the bottom of the oven. The blower directs air through a semi-pierced panel 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 plenum for reheating and recirculation.

"Gruenberg products are designed to meet the highest standards of safety specifications. These cleanroom ovens were designed to accommodate the customer's existing robot and loading trays for the drying of very sensitive medical devices," said Denny Mendler, Gruenberg product manager.

Features of these Gruenberg truck-in ovens include:

› Electric heat.

› Fully welded 304L stainless steel interior liner.

› Powered vertical door.

› Nitrogen atmosphere.

› CDA purge system.

› Mass flow control system.

Six Gruenberg cleanroom ovens were recently shipped to dry medical devices. (Courtesy: Thermal Product Solutions)

› Graphite shaft seal.
› Internal cooling coil.
› Oxygen analyzer.
› Remote NEMA 12/IP54 control enclosure.
› Interconnecting wire harnesses.
› AB PLC.
› 2711 Panelview 1500 HMI.
› High limit thermostat.
› Circuit breaker disconnect switch.
› E-stop.
› Light tower with alarm.
› SCR power controller.

MORE INFO www.thermalproductsolutions.com

Advanced Heat Treat announces building expansions in Iowa

Advanced Heat Treat Corp. (AHT), a recognized leader in heat-treat services and metallurgical solutions, recently announced building expansions at its Monroe, Michigan, and Waterloo, Iowa, locations. The extra space will allow AHT to add more equipment and services.

The Michigan AHT location is expanding its pit where nitriding vessels are housed. The space will allow for two additional large nitriders.

AHT Burton, referred to by the street name as there are two locations in Waterloo, Iowa, is adding additional square footage onto its building. The expansion will allow for additional equipment and services to be added. The expansion is expected to be complete mid-summer.

While the expansions are the first for the Michigan and Burton facilities since 2006 and 2007, respectively, AHT recently doubled the shop floor at its corporate headquarters in Waterloo, Iowa, this past February.

AHT President Mike Woods said, "We're very excited about the growth AHT has seen over the past few years. Because of this, we felt it was necessary to expand our facilities and invest in additional equipment to better serve our customers and capture more of the market."

Last month, AHT also added two new induction units at the Burton Ave location, providing even better turnaround times and expanding capacity for large parts.

Advanced Heat Treat Corp. in Iowa invested in two additional induction units. (Courtesy: Advanced Heat Treat Corp.)

AHT has four locations: two in Waterloo, Iowa; one in Monroe, Michigan; and a fourth in Cullman, Alabama. Among the four locations, it offers more than 20 surface treatments including gas and ion nitriding, induction hardening, carburizing, carbonitriding, and more.

"This past year has been exciting. We thank everyone involved and look forward to another great year," Woods said.

MORE INFO www.ahtcorp.com

Baker Furnace installs quench tank for supplier

Baker Furnace, a division of Thermal Product Solutions, announced the installation of a quench tank for a supplier in the heat-treatment industry as part of its aftermarket services. The customer had two quench tanks and three drop bottom furnaces and needed the third quench tank in order to optimize quench loads per day.

The quench tank has three impellers capable of 27,000 GM on a 15,000-gallon tank. This style of agitation allows for thick, large castings to dissipate heat faster. The system runs on VFDs, which allows for cost savings and the ability to adjust as needed when less agitation is required.

"The customer had two existing quench tanks: one hot water and one cold water. Having only two tanks hindered quenching on all three drop bottoms, being that it takes six hours to heat or cool the tank. Adding the third, dedicated cool water tank, allows the customer to run two more loads per day, which is critical for a commercial heater," said Sergio Luevano, general manager.

Baker Furnace took on all parts of the project, including the civil engineering, city permitting, and installation. During the installation, three crane rail tracks were extended. To do so, Baker Furnace had to break the concrete, reinforce the concrete to accept the crane rail, and reinstall the crane rail. There was limited space in the facility for the third quench tank; the hoist required a 24' height and the building was 24'3". With limited space and a low-profile quench tank design, the system was able to be installed.

Features of this hoist tank include:
› Impellers.
› VFD on each impeller.
› Wireless remote to operate crane and quench tank.

MORE INFO www.bakerfurnace.com

Grieve offers 350°F bench oven with eight drawers

No. 1047 is a 350°F (177°C) bench oven from Grieve currently used for curing plugs on the ends of cords at the customer's facility. This bench oven has eight drawers with dimensions of 6" W x 13" D x 6" H with removable insert to close around cord. 2 KW are installed in Incoloy sheathed tubular heating elements, while a 300 CFM, 1/3-HP recirculating blower provides horizontal airflow to the workload.

This Grieve bench oven features 2" insulated walls, Type 304, 2B finish stainless steel interior and stainless-steel exterior with #4 brushed finish. Features include eight digital batch timers with common alarm; one timer positioned above each drawer to individually time process in each drawer. Additional features include an integral leg stand.

Controls on the No. 1047 include a digital indicating temperature controller, manual reset excess temperature interlock with separate contactors, and recirculating blower airflow safety switch. Additional controls include a circuit breaker disconnect switch and SCR power controller.

MORE INFO www.grievecorp.com

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

IHEA shines a spotlight on its recent member, Weishaupt Corporation

An aerial view of Weishaupt's main works in Schwendi, Germany.

Weishaupt Corporation recently joined the Industrial Heating Equipment Association and is proud to be part of a select group of organizations. IHEA strives to provide knowledge, training, and resources to its members and is the authoritative voice for industrial process heating professionals. Weishaupt will collaborate with all IHEA members toward a successful future.

Weishaupt has a lot to offer the heat-treat industry, so IHEA presents this brief profile so its members can get better acquainted with Weishaupt and what the company brings to the table:

The Weishaupt name is a byword for reliability, premium quality, and outstanding service. As a medium-sized, family-owned, and managed organization, it is large enough for its energy technologies to be a global success, but small enough to act independently, flexibly, and consistently. About 100 highly specialized technicians, designers, and engineers work on the development of products at the Weishaupt Research and Development Centre, taking them from the drawing board to the production line. The R&D Centre has been the foundation of reliable Weishaupt technology since 1962.

Weishaupt insists on the utmost quality and precision. Weishaupt releases only well-engineered equipment and accessories to the market to ensure they are reliable. Weishaupt recently has invested $13 million in a new burner housing production facility at its main plant in Schwendi. This will allow the company to meet the growing global demand of customers over the coming years for efficient large burners with low emissions. Weishaupt burners are used on a wide variety of heat exchangers and industrial plants, and their sound construction, high efficiency, and reliability have helped to support Weishaupt's reputation for outstanding quality.

Weishaupt is also setting the standard in Canada. A new headquarters facility for its North American subsidiary is under construction and will be launched in this year. The investment of approximately $18 million for the new 43,000-square-foot building has allowed the addition of administration, sales and parts provision, and a training room with three new boilers for the technical development of its customers and partners.

› For more information on Weishaupt Corporation, visit: www.weishaupt-corp.com.

› For more information on the Industrial Heating Equipment Association visit: www.ihea.org.

Practical training on operational burners.

The WM-G20 monarch®-series gas burner. Digital control, modular construction, and the latest technologies make the monarch®-series an all-around good investment.

Burner training room.

IHEA 2019 CALENDAR OF EVENTS

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

SEPTEMBER 24–25

IHEA 2019 Combustion Seminar

The industry premier seminar for industrial process heating professionals, this two-day event offers attendees the chance to learn the latest in combustion technology and visit with industry suppliers. The IHEA Combustion Seminar is designed for persons responsible for the operation, design, selection and/or maintenance of fuel-fired industrial process furnaces and ovens.

› InterContinental Hotel Cleveland | Cleveland, Ohio

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

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

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

Creep deformation of metals at elevated temperatures is of great concern for prolonged service life.

Creep deformation mechanisms in 9CrMo steel

The Generation-IV reactors in nuclear power plants are expected to address the growing energy demand by producing electricity and, at the same time, mitigating greenhouse gas emissions. Various reactor types, such as a Gas-Cooled Fast Reactor (GFR), Lead Cooled Reactor (LFR), Molten Salt Reactor (MSR), Sodium-Cooled Fast Reactor (SFR), Supercritical Water-Cooled Reactor (SCWR), and Very High Temperature Reactor (VHTR) are being considered.

The VHTR is a Gen-IV reactor system at the heart of the so-called Next Generation Nuclear Plant (NGNP). VHTRs are designed to operate at temperatures much higher than those of currently operating reactors. Moreover, they are designed for longer service periods (60 years or more) compared to the current operating reactors [1]. Depending on the VHTR design, Prismatic Modular Reactor or Pebble Bed Modular Reactor, the operating temperature of the reactor pressure vessel (RPV) can vary between 300°C and 650°C. Furthermore, the RPV in the VHTR will be more than twice the size of a typical RPV in a Light Water Reactor (LWR) [2], as shown in Figure 1.

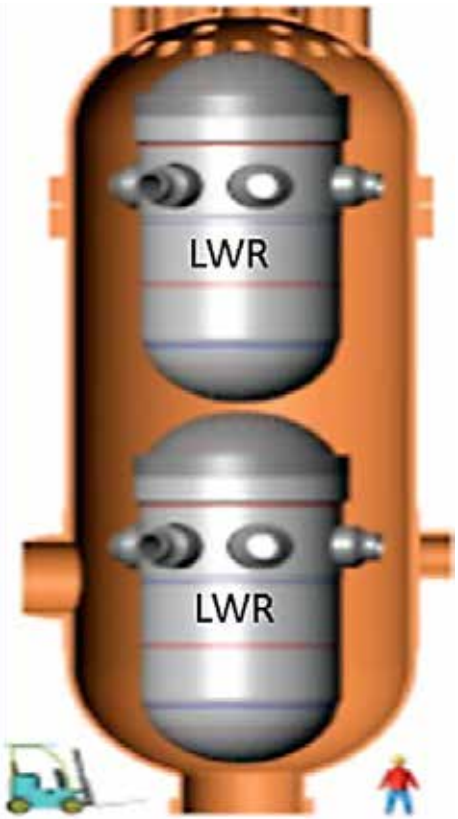

Figure 1: VHTR pressure vessel. [2]

When a material deforms in an elastic region, the material regains its original state after the load is removed. The elastic deformation is a linear relationship in which stress is directly proportional to strain according to Hooke's law. Materials cannot retrieve their original state when it is deformed in the plastic region. Despite the material being deformed plastically at ambient temperature, work hardening increases the strength of the material. During work hardening, prior dislocations obstruct the passage of any new dislocations, thus increasing the strength of the material. But at elevated homologous temperatures due to thermal energy, the dislocations annihilate and the work hardening is weakened. Creep deformation and rupture of metals is of great concern for prolonged service life at elevated temperatures. For an engineering structure operating in ambient temperature, creep is not considered as a significant deformation mechanism. In a high-temperature application, parameters like the duration of test, the grain size, subgrain size, precipitate size and their distribution, and effective stress all have a role in dictating the strength of a material.

A conventional creep curve consists of three distinct stages: primary, secondary, and tertiary, as shown in Figure 2. In primary creep, the strain rate (or creep rate) decreases with time as work hardening takes the center stage. The secondary stage, also known as steady-state creep, is of vital importance as it sheds light on the creep deformation mechanism. In the secondary creep stage, the material is deformed plastically while there is a higher degree of strain hardening and increased dislocation density, resulting in a constant creep rate. Strain rate increases as time increases in tertiary creep. Increased creep rate results in necking, crack, and void formation. Tertiary creep stage is very rapid so the materials in engineering structures are designed not to enter this stage.

The operational life of a material can be predicted from the knowledge of creep deformation mechanism. Norton's and Bird-Mukherjee-Dorn (BMD) relations are used to describe creep mechanisms. Norton's equation is:

$$\dot{\varepsilon}_s = k\sigma^n \qquad \textbf{Equation 1}$$

where $\dot{\varepsilon}_s$ is the steady-state creep rate, σ the stress, k a constant based on material property and test condition, and n the stress exponent — a constant for a mechanism. Diffusional controlled processes dominate the high-temperature mechanical properties of metals, especially above homologous temperatures of $0.4T_m$. The Bird-Mukherjee-Dorn (BMD) equation best describes the creep mechanism in this regime. BMD considers a wide range of parameters in determining the prevalent creep mechanism:

$$\frac{\dot{\varepsilon}kT}{DEb} = A\left(\frac{\sigma}{E}\right)^n\left(\frac{b}{d}\right)^p \qquad \textbf{Equation 2}$$

where $\dot{\varepsilon}$ is the steady state creep rate, A the microstructural mechanical constant, E the elastic modulus, b the burger vector, k the Boltzmann constant, T the absolute temperature, σ the applied stress, d the grain diameter, n the stress exponent, p the inverse grain size exponent, D the diffusivity. D is described by the following relation:

$$D = D_o exp\left(\frac{-Q}{RT}\right) \qquad \textbf{Equation 3}$$

where D_o is the frequency factor, Q the activation energy for creep, and R the universal gas constant.

The stress exponent can be obtained by plotting creep rate (s^{-1}) against stress (MPa). For high temperature diffusion-controlled

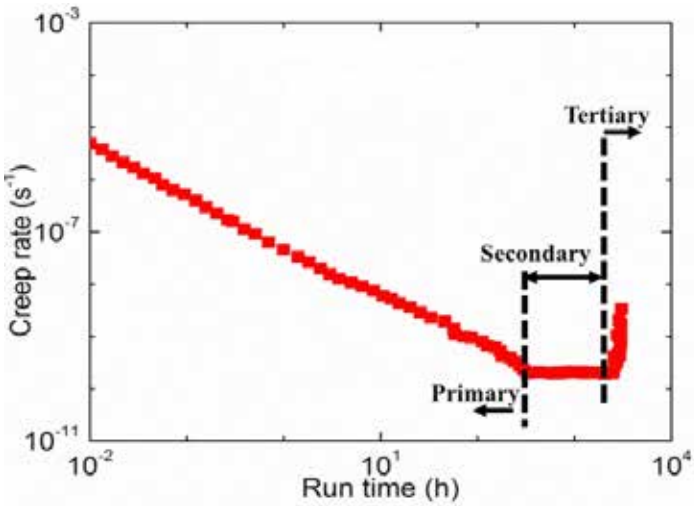

Figure 2: Creep rate vs. time showing three distinct stages.

creep, the stress exponent ranges from 1-7, which helps identify the rate-controlling creep deformation mechanism. Charit et al. [3] have identified various diffusion mechanisms and their parametric dependencies. A stress exponent of 1 is observed in Harper-Dorn, Nabarro-Herring and Coble creep also known as Newtonian viscous creep mechanisms. These are non-dislocation-based mechanisms that occur at very low stresses and high temperatures. Stress exponents of 2 and 3 are observed in superplastic materials and solute solution strengthened alloy, respectively. Dislocation climb is associated with a stress exponent of ≥5. Extremely high 'n' associated with high stress conditions indicates a breakdown of power-law creep. In precipitation-strengthened alloys, such as 9CrMo steels and oxide dispersion strengthened (ODS) alloys and intermetallics, such as Ni3Al, TiAl, a stress exponent above 7 has been associated with physically impossible high apparent activation energy [4,5]. Threshold stress has been incorporated to calculate effective stress, true stress exponent, true activation energy, and in identification of creep deformation mechanisms.

Creep studies carried out in 9CrMo steel at the temperature range of 600°C to 750°C and under stress of 35 to 350 MPa yielded two distinct creep deformation mechanisms. Newtonian viscous creep was observed in the low stress regime with stress exponent of n~1. The creep mechanism transitioned from the Newtonian viscous creep (n~1) to a power-law creep with high apparent stress exponents in the high stress regime. The high stress exponent was rationalized by incorporating threshold stress approach in the Bird-Mukherjee-Dorn equation, which helped identify rate-controlling mechanism as edge dislocation climb.

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ABOUT THE AUTHOR

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JASON SCHULZE
METALLURGICAL ENGINEER /// CONRAD KACSIK

Successful quality-control personnel need a thorough understanding of technical aspects of any thermal process to better ensure conformance.

Aluminum heat-treating has unique challenges

From a metallurgical and quality perspective, aluminum heat-treating presents unique challenges when compared to carbon-based steels. This article will examine the aspects of aluminum heat-treating that make it unique, and specific ways a quality team can account for the variables to ensure conformance throughout the thermal process. I will not be covering each specific aspect of the process, so excuse me if I leave out fine details.

A BRIEF HISTORY

In 1807, a British chemist, Humphrey Davy (1778-1829) discovered five new metals. One was aluminum. Due to aluminum's strong attraction to oxygen, he was unable to isolate the aluminum using an electric arc. With the introduction of bauxite into the process by Henri Sainte-Clair Deville in the 1860s, Karl Bayer (1847-1904) was able to design a process that could isolate the aluminum. Fast-forward to the modern day — the standard aluminum foundry uses the Hall-Heroult process, which has been modified over decades to produce an efficient process called electrolysis.

The aluminum oxide is melted and electrolyzed (Figure 1). The anode is made of graphite, a form of carbon. Oxygen ions move to the anode where they're converted to oxygen. The anodes are gradually worn away by oxidation. The cathode is also made of graphite. Molten aluminum is produced there. The process requires a lot of electrical energy, which is one reason aluminum is more expensive than steel.

ALUMINUM CLASSIFICATION

In general, aluminum is classified as two types:

- Heat treatable (precipitation-hardenable).
- Non-heat treatable.

Furthermore, aluminum will have a designated temper (i.e. F, O, T3, T4, T6, etc.).

HEAT TREATMENT OF ALUMINUM

Heat-treatable aluminum alloys can be strengthened by a suitable thermal process. The solubility of the alloy elements is directly related to temperature making wt% of each alloy element a critical factor.

Let's use A356.0 Al alloy as an example. This alloy is made up of aluminum (primary) - 6.5-7.5% silicon – 0.25-0.45% magnesium – 0.20% copper – 0.20% iron – 0.20% titanium – 0.10% zinc. The addition of magnesium is key. Magnesium (Mg) – Al-Si- alloys that contain no magnesium are considered non-heat treatable. The addition of Mg provides solid solution strengthening without decreasing ductility. Mg additions offer strength and corrosion resistance.

In general, solution heat-treating takes advantage of the precipitation hardening reaction. The objective is to take into solid solution the maximum practical amount of the soluble hardening elements in the alloy. This process also consists of soaking the alloy at a temperature sufficiently high and for a long enough time to achieve a nearly homogeneous solid solution.

aluminum oxide → aluminum + oxygen

Higher tier only

Cryolite is used to lower the melting point of the aluminum oxide.

The aluminum ions are reduced at the cathode (they gain electrons):

$$Al^{3+} + 3e^{+} \rightarrow Al$$

While the oxygen ions at the anode are oxidized (they lose electrons):

$$2O^{2-} \rightarrow O_2 + 4e^{+}$$

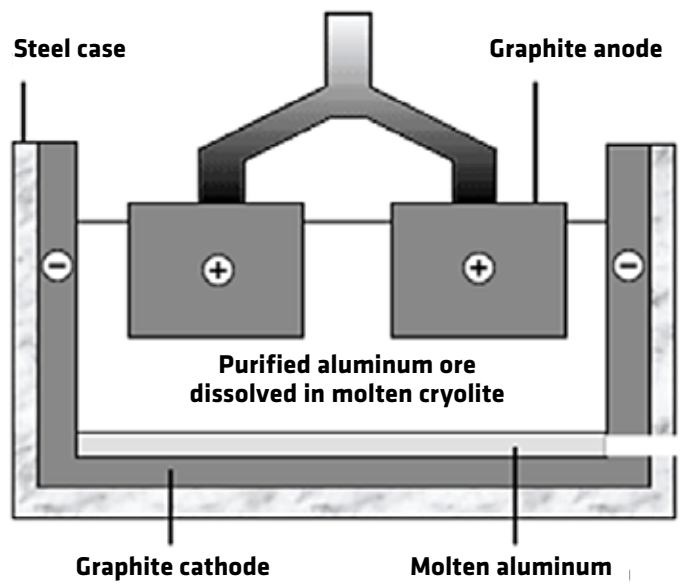

Figure 1

We will stick with A356.0 as we continue. Solution heat-treating of A356 produces the following effects:

- Dissolves Mg_2Si.
- Homogenizes the aluminum.
- Changes in morphology of eutectic silicon.

From a quality perspective, let's look at only the first one. To obtain the maximum concentration of magnesium and silicon, the solution temperature must be as close as possible to the eutectic temperature; ideally 10-15°F below the eutectic temperature. Control of temperature is critical. If the melting point is exceeded, incipient melting (localized melting at the grain boundary) may occur, and mechanical properties may suffer. This condition is only detectable by metallographic examination and is irreversible.

After quench, the aluminum may be aged. The process of aging causes the decomposition of various phases as the atoms dissolve in the aluminum matrix.

In other words, Mg_2Si precipitates out of solution (which was dissolved during solution heat treatment) in order to obtain hardening characteristics (hardness and conductivity). Figure 2 is a time-temperature plot for A356.0. Line A represents the time at which Mg_2Si precipitation begins. Line B represents the point at which maximum strength and hardness are achieved. An 18°F change in aging temperature changes the aging time by a factor of two.

HOW THIS TECHNICAL DESCRIPTION AFFECTS QUALITY CHARACTERISTICS

In relation to the previous information, a critical take-away should be the verification of raw material certifications. Quality personnel should design a system that will ensure all raw material received conforms to the purchase order requirements. This should include verification of each alloy element wt% as stated on the certification.

Another take-away should be solution temperature is typically 10°F-15°F below the eutectic temperature of the material. Therefore, aluminum solution heat-treating is required to take place in a furnace that has a uniformity of ±10°F (CL2 – AMS2750). When quality control is reviewing furnace charts to ensure conformance, the temperature achieved during processing is critical.

SUMMARY

It can be difficult at times for quality-control personnel to both ensure quality requirements are met and have a thorough understanding of the process itself. Understanding the technical aspects of any thermal process will better enable the quality representatives to ensure conformance.

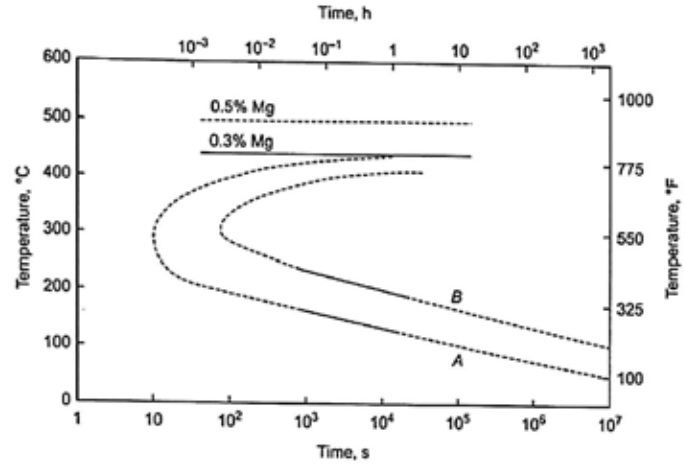

Figure 2: *D.Apelian, S. Shivkumar, and G.K. Sigworth, Fundametal Aspects of Heat Treatment of Cast Al-Si-Mg, AFS Trans., Vol 96, 1989, p 727-742.

ABOUT THE AUTHOR

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NEW COOLING TOWER TECHNOLOGY

AUGMENTS HVAC AND INDUSTRIAL PROCESSES

New advancements in modular designs provide up to 50 percent more cooling capacity, greater energy, and installation savings, fewer components, and easier maintenance.*

By SCOTT MAURER

Recent developments in factory-assembled cooling-tower technology are increasing the applications for so-called "package" towers supporting HVAC and industrial processes. Although field-erected towers have been preferred for power plants and industrial processes, today, well-designed modular products suit a broader range of applications to simplify processes and positively make an impact on their bottom line.

For example, an advanced design factory-assembled cooling tower can be delivered with 60 percent shorter lead time and installed up to 80 percent faster than what is typically estimated for building a traditional field-erected cooling tower. With no costly concrete basin construction required, simplified piping and electrical wiring, and flexible site placement, industrial processers more frequently consider the cost benefits of advanced factory-assembled towers.

REDUCING ENERGY AND INSTALLATION COSTS FOR HVAC APPLICATIONS

For HVAC end users who increasingly focus on reducing energy consumption, today's new cooling tower designs specifically address energy efficiency. Using larger box sizes and low horsepower motors to meet these needs, advanced factory-assembled crossflow towers can offer up to 50 percent more cooling capacity per cell and use up to 35 percent less fan power per ton of cooling.*

In addition to lower energy costs, these newer designs can also significantly reduce HVAC system installation costs. The increased cooling capacity per cell means customers require fewer cells, less piping, and fewer electrical connections, minimizing labor and material requirements. Safety hazards associated with long and complicated installation are minimized.

Table 1 compares installation and operating costs for a conventional factory-assembled cooling tower with that of a newer modular design in an HVAC project application. As shown, a typical cooling tower requires 1,125 horsepower to meet the project's cooling requirements. With three fewer cells, the newer tower requires only 750 horsepower to meet the same requirements, and customers reap significant cost savings.

REDUCING FIELD-ERECTION COSTS FOR PROCESS COOLING APPLICATIONS

Cooling-tower construction, cost, and time management continue to be major concerns for those overseeing large process cooling projects. It can take 20 weeks or more for components on a typical field-erected project to arrive on site, involving large labor forces and expansive staging areas. Construction costs can easily mount and exceed estimates, and contractors often anticipate delays. The longer an installation project stretches, the more likely weather issues will affect completion. Complex industrial projects also heighten site safety concerns.

Table 1 – Cooling Tower Installation and Operation Cost Comparison

	Conventional factory-assembled cooling tower	*Newer modular cooling tower*
Number of cells required	9	6
Horsepower	1125	750
Piping and wiring costs	$265,000	$185,000
3-year operating costs	$420,000	$280,000

Construction of a field-erected tower is a complex process that can take 20 weeks or more to complete. (Courtesy: SPX Cooling Technologies)

Industrial processors seeking alternative solutions are turning to pre-assembled cooling-tower modules built in a controlled factory environment and shipped to the site in six to eight weeks. The installation process is carefully staged and managed, with up to 80 percent time savings compared to field-erected projects. The shorter delivery and construction times of pre-assembled towers offer industrial processing customers a distinct advantage because meeting capacity requirements and managing downtime and outages are critical to their operations. Additionally, their modular design and the field assembly process reduce onsite labor, work duration, and lay-down area requirements, which contribute to the potential of a safer work environment.

Weighing the pros and cons of conducting a field-erected versus factory-assembled project, a customer recently received a construction estimate to replace a field-erected cooling tower, which called for 4,500 hours and seven weeks of field labor. When a modular pre-assembled tower was specified, the construction team could reduce the installation duration to less than two weeks — an enormous

savings in time and a boost to the plant's operational efficiency. The modular tower also eliminated the plant's additional costs for temporary cooling during the construction process.

Building a field-erected cooling tower requires constructing a foundation in the form of a concrete cold water basin. The cost of this basin alone typically adds 40 percent to the tower construction costs. However, a factory-assembled tower includes an integral basin and eliminates the additional construction cost in field-erected projects. The accepted practice is to assemble and leak-test these integral basins in the factory.

Field-erected towers often require onsite testing to verify they meet the specified cooling capacity. Conducted by independent third-party agencies, the tests typically cost about $25,000. Factory-assembled towers eliminate these additional expenses because they are certified by the Cooling Technology Institute to meet thermal performance as specified.

Field-erected towers often require onsite testing to verify they meet the specified cooling capacity. Factory-assembled towers eliminate these additional expenses.

The next generation of factory-assembled cooling towers can be delivered up to 60 percent faster than field-erected towers and installed 80 percent faster. (Courtesy: SPX Cooling Technologies)

DESIGN ADVANTAGES OF NEW, PRE-ASSEMBLED COOLING TOWERS

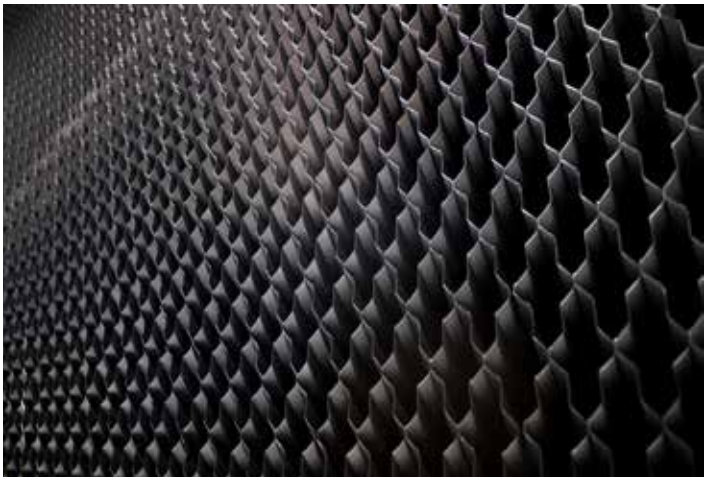
Cooling towers with advanced, modular design are often constructed of heavy mill-galvanized or stainless steel and engineered to withstand the demands of both HVAC and heavy industrial applications. If equipped with the latest in drift eliminating technology, these towers can achieve the lowest measurable drift rate, down to 0.0005 percent of circulating water flow, so less water escapes the tower.*

In addition, the broader market has demanded more features for convenience and easy maintenance. The newest designs make inspections and maintenance safer and easier. Some of today's towers even include up to seven-foot-high access doors and an expansive interior with service decks.

Cooling towers are typically designed to meet summer cooling demand. However, crossflow designs of modern, factory-assembled cooling towers permit "variable flow" operation, which reduces water-flow rate and energy consumption during cooler months. This ensures energy is only expended for cooling when the plant truly needs it, maximizing efficiency. By contrast, the counterflow design of many field-erected towers does not naturally allow changes in flow rate and uses the same amount of energy year-round, regardless of need.

Crossflow designs also shield cold water basins from sun exposure, thwarting algae growth that can compromise tower performance and call for more frequent maintenance. Additionally, in cold weather, a crossflow design helps prevent high winds from causing water escape, which can lead to icing and safety concerns.

Whether designing a cutting-edge cooling system or replacing a traditional cooling tower, carefully consider the latest technology and the best options for your application. Crossflow factory-assembled cooling-tower designs are more frequently being tapped as the more efficient and cost-effective choice, especially as an alternative to more expensive and time-intensive field-erected construction projects, for an array of HVAC, process cooling, and heavy industrial cooling applications.



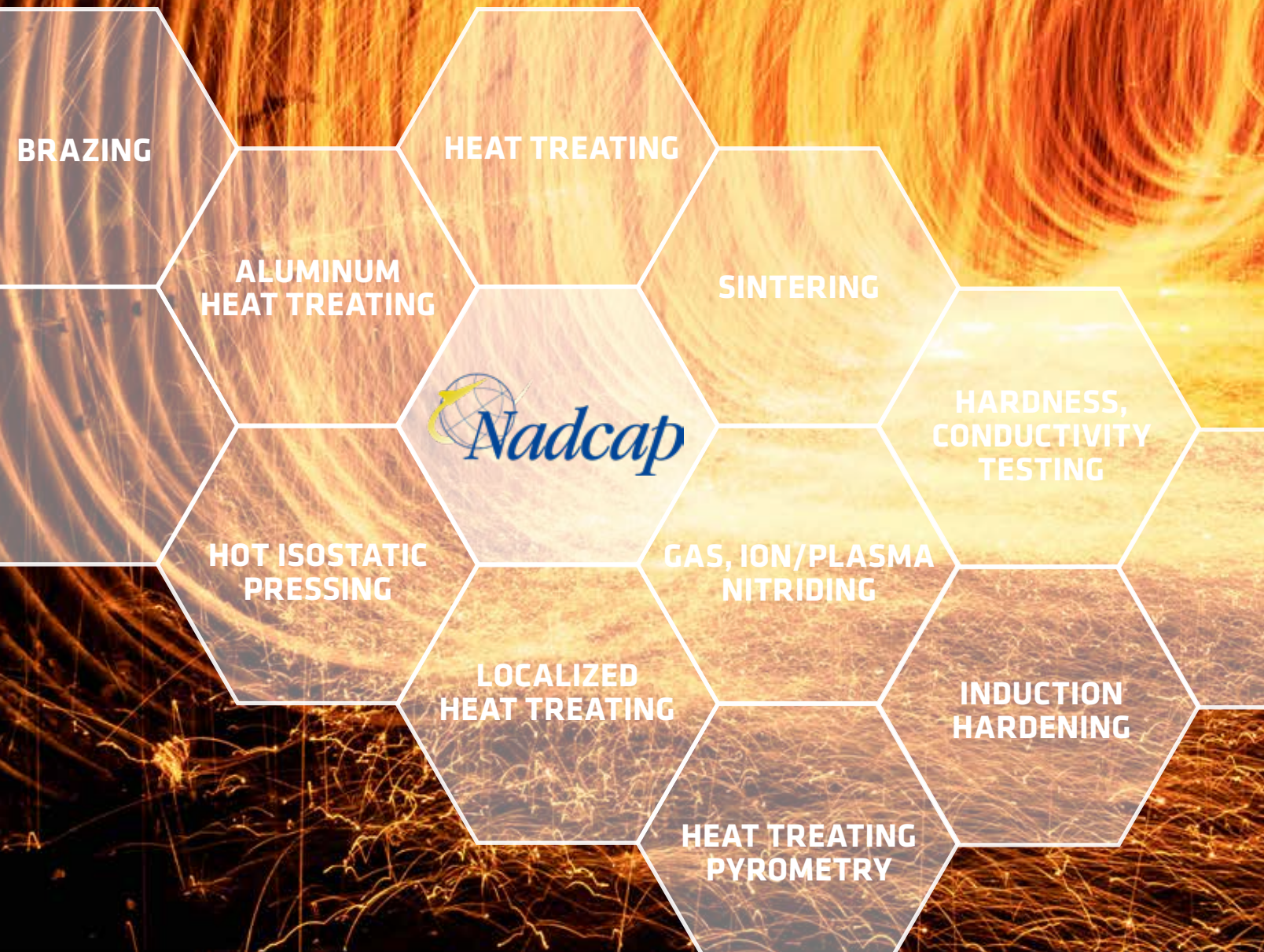
Today's advanced drift eliminator designs can achieve the lowest measurable drift rate, down to 0.0005 percent of circulating water flow, so less water escapes the tower.* (Courtesy: SPX Cooling Technologies)

**Compared to other factory-assembled single-cell cooling towers.*

ABOUT THE AUTHOR

Scott Maurer is a sales manager at SPX Cooling Technologies, based in Overland Park, Kansas. He holds a design patent and recently was a member of the development team for the new Marley® NC Everest® and MD Everest Cooling Towers. For more information, go to spxcooling.com.

IMPROVING AUDIT PERFORMANCE



The Heat Treatment Task Group offers its top tips in order to prepare for a successful Nadcap audit.

By JERRY ASTON

To add value to the aerospace suppliers who participate in Nadcap, there is an ongoing effort to do more to assist them in successfully passing Nadcap audits efficiently.

The Nadcap Heat Treatment Task Group, led by Cyril Vernault of Safran Group, has been active in this area, developing tools and holding technical workshops for companies who are considering having a Nadcap audit or wanting to improve their audit performance. Publishing detailed Nadcap audit preparation guidance is just one of the ways the Heat Treatment Task Group offers assistance. A selection of their top tips for Nadcap heat treatment audit success is described below.

PERFORM A SELF-AUDIT PRIOR TO NADCAP AUDIT

A recommended timeframe for pre-audit activity is provided. Central to that activity is downloading the Nadcap checklists and using them to perform a self-audit. Register on eAuditNet (www.eAuditNet.com) and contact PRI or your company eAuditNet administrator for access to the Nadcap checklists to assist in your preparation.

The Heat Treating Task Group conducts audits to the following audit criteria:

- **AC7102:** Heat Treating.
- **AC7102/1:** Brazing.
- **AC7102/2:** Aluminum Heat Treating.
- **AC7102/3:** Carburizing.
- **AC7102/4:** Gas and/or Ion/Plasma Nitriding.
- **AC7102/5:** Hardness and/or Conductivity Testing for Heat Treating.
- **AC7102/6:** Hot Isostatic Pressing (HIP).
- **AC7102/7:** Induction Hardening.
- **AC7102/8:** Heat Treating Pyrometry.
- **AC7102/9:** Sintering.
- **AC7102/10:** Localized Heat Treating.

Use the applicable checklists to conduct a pre-audit and address all non-conformances found using your documented corrective action system.

It is required that the self-audit is sent to the auditor at least 30 days prior to the audit to comply with AC7102, which requires that the supplier shall record each procedure, paragraph, and page number for each checklist question.

As part of your pre-audit activity, prepare and provide the following to the Nadcap auditor to facilitate his/her preparation for the site visit (also per AC7102):

- List of equipment.
- List of purchased services.
- List of quality personnel and approved heat-treating personnel on each shift.
- List of prime customers and specifications.
- List of heat treat specifications that supplier is working to.
- Copy of internal general procedures for heat-treat processing, pyrometry, and testing/inspection of heat-treated product.
- Organization chart.
- Personnel training.

PERSONNEL TRAINING

Ensure that you have a documented personnel training program that refers to everyone with heat-treating related responsibilities. An inadequate personnel training program creates uncertainty about the proficiency of the personnel processing the parts. Non-conformances may be written where a program does not include detailed reference to the following elements:

- Documented training to an established outline.
- Knowledge and experience.
- Initial and periodic evaluation of the competency.
- Exam, observation, interview, audit.
- Cleaning.

CLEANING

Cleaning prior to the heat treatment of parts is critical to process integrity, so during the audit, make sure all surfaces are clean and the parts are racked to allow access to all surfaces. The post-cleaning activity is just as important. Train your operators not to touch the parts after cleaning and that they know how to transport them. Finger marks can destroy properties, so they must use clean gloves and take all necessary steps to protect the parts from factory dust and grit.

PROCESS CONTROL

You must be able to demonstrate that you have reviewed the process control requirements for each of your customers and that you have an internal procedure and "system" that documents compliance. Identify other testing and controls required by specifications such as:

- Pyrometric Testing.
- Lotly or Periodic Tensile Testing.
- Periodic Metallurgical Testing (e.g. IGO/IGA Testing, Eutectic Melting, Cladding Diffusion, High Temperature Oxidation, etc.).
- Decarburization/Surface Contamination Testing.
- Leak Up Rate Testing.
- Hydrogen Pick Up Testing.
- First Lot Forging Qualification Testing.

If your audit scope includes hardness, complete the AC7102/5 checklist as part of your pre-audit, unless your company already holds Nadcap accreditation for AC7101/5: Hardness Testing (Macro) as part of a Nadcap Materials Testing accreditation.

Other testing that may apply are specified in AC7101/3: Mechanical Testing (RT Tensile) and AC7101/4: Metallography and Micro-indentation hardness:

- Metallography / Microhardness.
- Surface Contamination of Steels (IGA/IGO, decarburization).
- Titanium Testing (Alpha case and Hydrogen pickup).

REFRIGERATION OF STEELS

The AC7102 checklist asks whether procedures cover sub-ambient/sub-zero cooling according to the customer requirements, or in absence of customer requirements, whether the supplier has a default procedure.

To ensure compliance to the requirement, companies must have procedures that specify timings, temperatures, and tolerances and include requirements for sub-ambient (PH steels requiring 30°C or 20°C)

There must also be records to evidence time from quench (if required) and time and temperature achieved.

SAMPLING PLANS

It is expected that all heat-treating sampling plans contain a method for the inspector to determine the quantity of product to check in the lot and a specified frequency and method of sampling. This reduces the opportunity for individual interpretation and improves control through consistency.

You must be able to demonstrate that you have reviewed the process control requirements for each of your customers and that you have an internal procedure and "system" that documents compliance. Identify other testing and controls required by specifications.

FURNACE CONTROL AND MAINTENANCE

Per AC7102, the internal procedure is expected to specify the method for determining heat-up rate, start of soaking time, end of soaking time, and cooling rate.

Relevant procedures and instructions must be available at the work place and include methods or definitions of heat-up and cooling rates, start and end of soak, as well as atmosphere, quench delay, and quench residence times.

START OF SOAK

There are many different definitions of start of soak. The Nadcap auditor will be looking for your company to have rules regarding start of soak and for your rules to conform to the specifications, so make sure that you are familiar with them.

QUENCH

The quench system is the subject of many questions in the Nadcap heat-treating audit. There are three main liquid quenchants:

- Water.
- Water polymer mixes.
- Oil.

However, liquid nitrogen has also been used and witnessed during Nadcap audits. Forced air or gas may also be used as quenchants, although the system in place is typically an immersion system, but spray systems are also an option. Most specifications define the acceptable quench temperature range, with the maximum temperature typically expected to be ≤32°C/90°F at the beginning of the quench process.

The AC7102 checklist asks whether the quench mechanisms are operational and capable of meeting the maximum quench delay provisions of the specifications.

To avoid non-conformances that are commonly written against this question, make sure the quench tank will be ready before you load the furnace, as this prevents avoidable delays and their potential repercussions. it is also important that the bath temperature is recorded before the material touches the liquid and, normally, the maximum temperature during the quench process.

Quenchant maintenance is also key, with the checklist clarifying whether the quenchant agitation and/or agitation of the product during quenching conforms to the applicable specifications.

RACKS, FIXTURES, AND BASKETS

AC7102 asks whether the internal procedure require that the racks/fixtures/baskets are examined for integrity and repaired or scrapped as necessary.

The location in the furnace of the racks/fixtures/baskets is integral to this. There are many ways to define this. Using jigs and location guides such as track guides on the floor, stops inside the furnace, standard racks, etc. is one approach; another is to use marks on the furnace itself to show the maximum extent of any load.

PLATING

If your company carries out plating, as far as the Nadcap heat treating audit is concerned, plating is limited to the plating operations for successful heat treatment or brazing.

Any reference to plating in your Nadcap heat-treatment audit is not intended to replace plating for finishing purposes, as controlled by the Nadcap Chemical Processing Task Group. If your company already has a Nadcap chemical processing accreditation that includes both plating and stripping, responses to the applicable questions should be considered as "yes" unless otherwise noted as part of a finding during the Nadcap heat treatment audit.

PYROMETRY

There is a whole section in the Nadcap heat-treatment checklist dedicated solely to pyrometry testing. AMS 2750 is the source for much of the material and is considered the leading industry specification in this area.

To ensure the general requirement is satisfied, the Nadcap auditor will ask whether you have an internal procedure for pyrometry, addressing all the aspects of AMS 2750E and other customer specifications as applicable to your operations.

But the questions go into much more detail on all aspects of pyrometry, including:

- Thermocouples.
- Testing instrumentation types.
- Calibration.
- Process recorders/electronic data collection.
- Furnace classes.
- System accuracy tests (SAT).
- Temperature uniformity surveys (TUS).
- Load conditions.
- Offsetting Thermocouple Example.

To illustrate the depth the Nadcap audit goes into, take thermocouples as an example. Addressed in the AC7102 checklist, there are questions such as:

- Are the thermocouples being calibrated throughout the range in which they are to be used?
- Are procedures in place to ensure that the base metal thermocouples are only recalibrated when allowed by the AMS 2750E?
- Are procedures in place to ensure that the base metal thermocouples are only reused when allowed by the AMS 2750E?

Note how the questions are very specific, and bear this in mind during your audit preparation.

For clarity, base metal thermocouples are defined as those thermocouple sensors other than noble metal types B, R, and S. It does, however, include types E, J, K, N, and T.

To further highlight the depth of the audit, the Nadcap auditor will also want to know whether you are in compliance with AMS 2750E paragraphs 3.1.5.2 and 3.1.5.3, or more stringent customer requirements, for the life usage of expendable and nonexpendable base metal load thermocouples.

He/she will also want to ensure there are procedures in place governing the requirement that thermocouples made from rolls of thermocouple wire are not used when the difference in end-to-end (front-to-back) correction factors at any test temperature exceed AMS 2750E or more stringent customer requirements (1°F or 0.6°C for primary and secondary standards; 2°F or 1.1°C for all other uses including TUS).

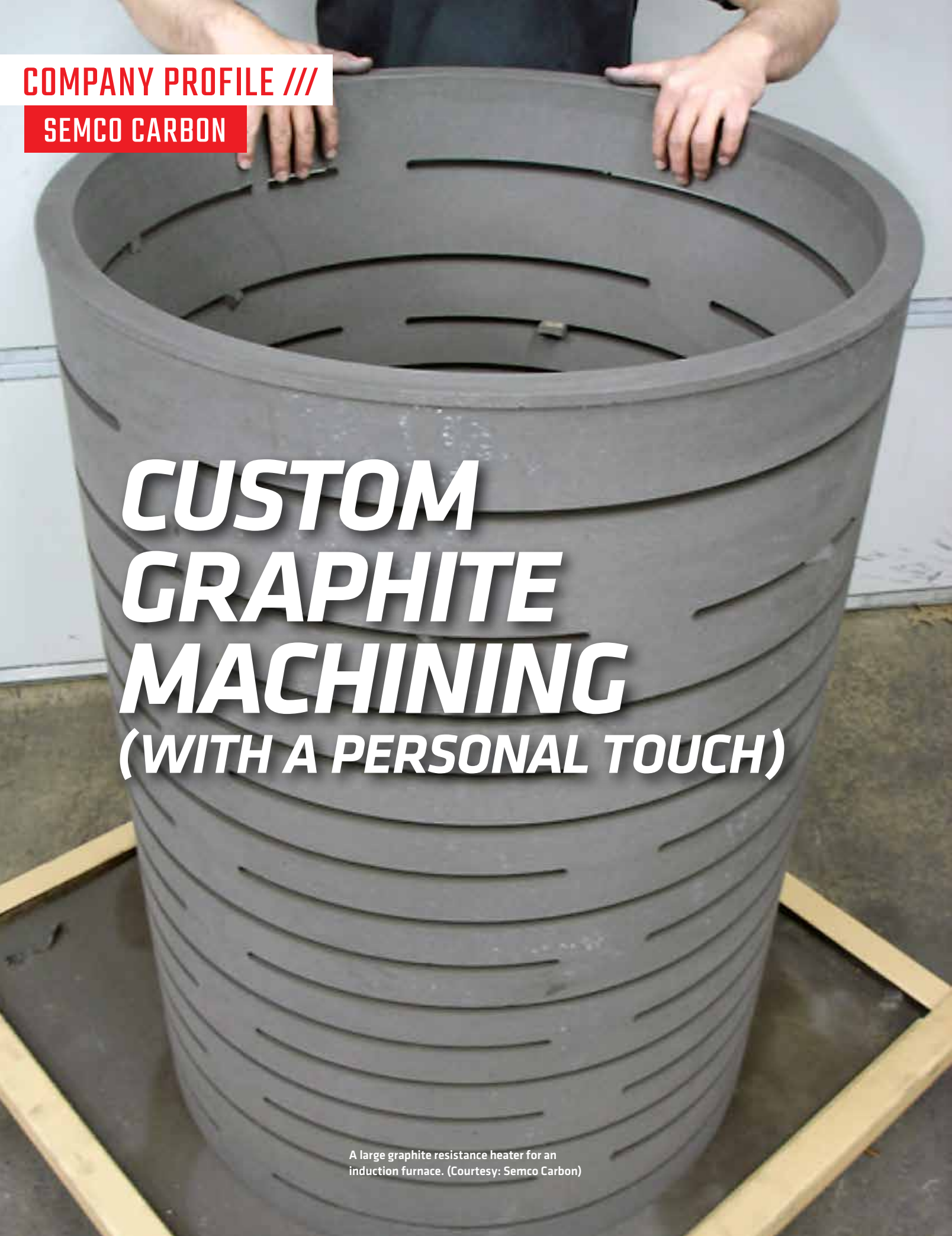
ABOUT THE AUTHOR

Jerry Aston joined the Performance Review Institute in 2003 as heat-treat staff engineer following 20 years at Roll-Royce plc. Aston joined Rolls-Royce plc when he left the University of Surrey, after reading for a Bachelors of Science degree in Metallurgy. In 2005, Aston was promoted to technical lead for the Heat Treat Special Process Group and later to technical and managerial lead of the Heat Treat Special Process Group. He is now the program manager for Heat Treating and Metallic Materials Manufacturing. If you have any questions, please do not hesitate to contact any member of the Nadcap heat treat department via heattreating@p-r-i.org

COMPANY PROFILE ///

SEMCO CARBON

CUSTOM GRAPHITE MACHINING (WITH A PERSONAL TOUCH)



A large graphite resistance heater for an induction furnace. (Courtesy: Semco Carbon)

Approaching five decades of experience with graphite and carbon composites, Semco Carbon can supply just about anything a heat-treat customer may need.

By KENNETH CARTER, Thermal Processing editor

In many industries, particularly in the heat-treating industry, the need for graphite and carbon composites is a must. The challenge lies in making sure those needs are met with speed, accuracy, and — most of all — quality.

The experts at Semco Carbon have been meeting those challenges head on for almost 50 years.

"We work closely with our customers to generate a product that will work for them and allow them to achieve their desired results for their customers at a cost-effective manner," said Matt Thompson, who is co-owner and co-president of Semco Carbon along with his brother, Vince. "Because we don't succeed unless our customers get the job and get the continuing business and then we succeed with them."

WORKING WITH ITS CUSTOMERS

One of Semco's core functions is educating its customers about how to achieve their goals in the most economical way, according to Matt Thompson.

"Generally, that involves a lot of hand holding and also a lot of intense re-engineering," he said. "It's working closely with a customer to get the product they actually need."

Semco machines almost all parts needed for the inside of vacuum furnaces — anything from heating elements, rails, posts, nuts and bolts, and felt and boards, according to Filip Cujba, key account manager with Semco.

"We can pretty much produce anything and everything that the heat-treat industry needs," he said.

It's very common within the heat-treat industry for organizations to buy a furnace then retrofit it, according to Vince Thompson.

"We supply some of the OEMs that are out there, but at the same time, we supply the end user," he said. "They'll make modification changes, and so the fixtures, the insulation packages, the specific heating elements — whether they be a curved, a plate, a ring, a serpentine — we redesign. We work closely with the customers to redesign their equipment."

EXPERT CAD SERVICE

That retrofitting often requires extensive CAD work, according to Matt Thompson, and that comes back to making sure the customer knows the initial cost of what they want done.

"It's not uncommon for our customers to be unaware of what nominal sizes of graphite blocks or grades are out there," he said.

"It's amazing how many times we get something that's designed by a customer's CAD guy, and he's asking for a graphite material that doesn't exist," Vince Thompson said.

Along those lines, Semco has the expertise to transform a customer's ideas into reality, according to Cujba.

Matt Thompson agreed.

"Quite often, we get a call from a customer who's in a quandary, and they've got a napkin sketch," he said. "It really calls for us to

A 140-inch graphite beam. (Courtesy: Semco Carbon)

Large heating element for a crystal growth furnace heat zone. (Courtesy: Semco Carbon)

jump in, have some real heart-to-heart conversations with them about what they're trying to do, how they're trying to go about it, what are the true needs versus the wants, and then we can work with them to build a solution."

MATERIALS READILY AVAILABLE

A large part of Semco's success — in addition to its engineering abilities — is its raw materials stocking facility, according to Matt Thompson.

"There are very few shops out there that can handle the number of different grades and the volumes of material that we have on our floor for immediate consumption," he said. "It really enables us to cut the lead times down. Especially since nobody calls you until they have a problem. They either have a furnace that isn't working, or they just purchased a new furnace, and they are doing a retrofit. We are kind of like the dentist; we get called whenever they've got a problem. We stock millions of dollars of raw materials on hand."

And that massive inventory has enabled Semco to thrive in a time where there is a shortage of graphite, according to Vince Thompson.

"It's been a relatively high shortage of raw graphite materials worldwide," Cujba said. "Beginning in 2018 and ongoing toward the end of 2019, prior to that year we had over 300 tons of graphite on our shelves."

Semco's stocking program allowed the company to pick up significant volume of the market share over the last 24 months during the shortage, according to Matt Thompson.

"Our phones were ringing off the hook," he said. "And we had a lot of happy customers because we were the first organization they called that didn't say no."

CONTINUED GROWTH

And Semco continues to add more capability, according to Cujba.

"As our expertise and as our capabilities have grown, we were able to satisfy and tackle larger and more sophisticated clients," Matt Thompson said.

Vince Thompson mirrored his brother's sentiment.

"We have a consistent emphasis on innovation and reinvestment in the company," he said.

Semco deals in what Matt Thompson calls "one-offs" of very large components for the heat-treat industry that can include metal trad-

A 120-inch OD high temperature furnace graphite load plate. (Courtesy: Semco Carbon)

ers, dealers, and vapor deposition, but then the company also can work with companies that do highly advanced heat treatments with alternate materials such as crystals.

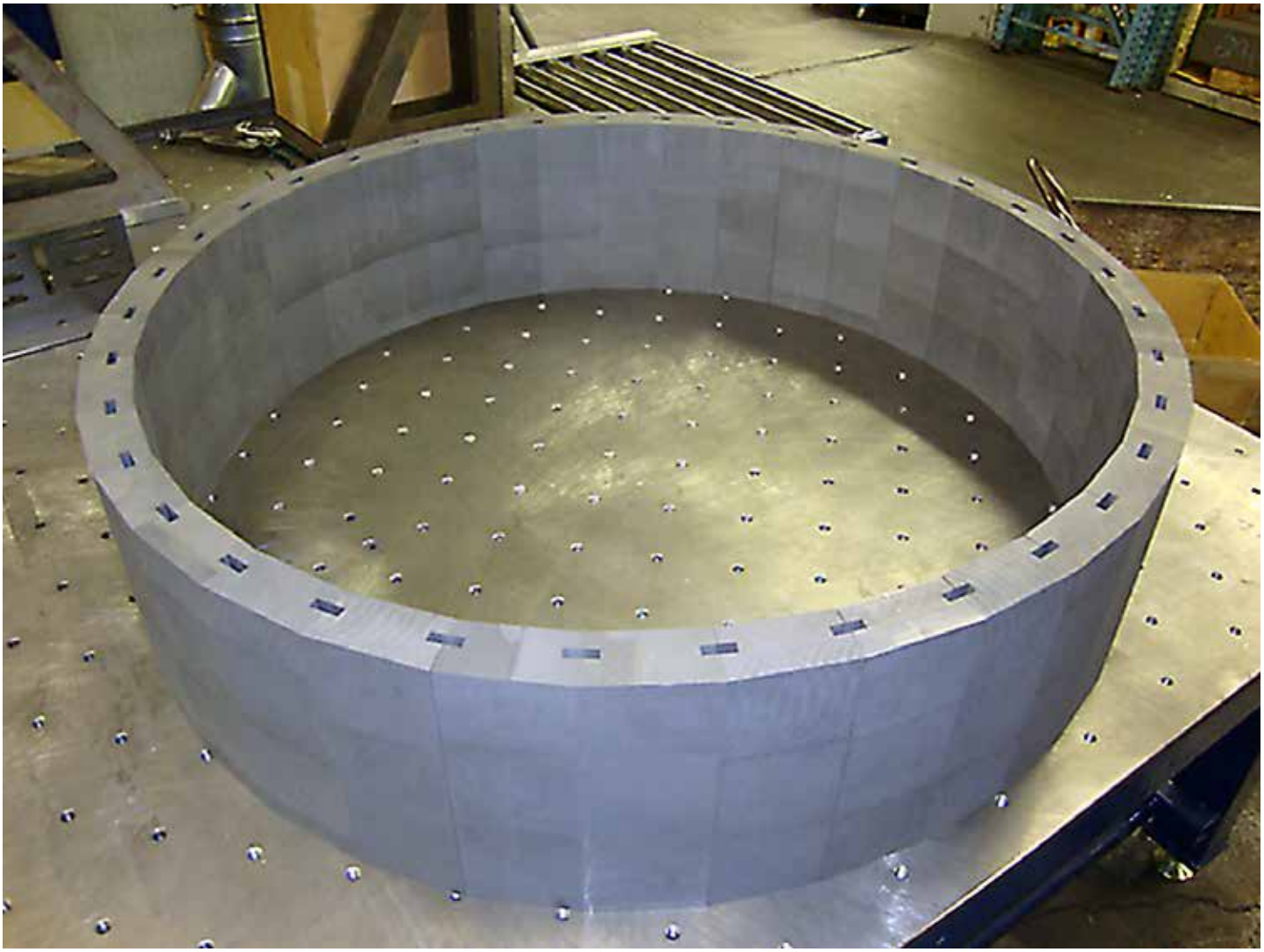
Semco's core business is graphite, but the company is working with machining and partnering with producers of carbon-fiber materials, according to Vince Thompson.

"It's a dynamic industry," he said. "With advances in material and technologies, there's always a smarter or more productive way to accomplish the same or better. And we just work really hard to convince customers and clients to give us a chance to demonstrate that to them. That's part of our core philosophy: to keep up with the advancements in technology on all aspects of production and customer needs."

CUSTOM HELP

It is not uncommon for Semco's customers to buy an off-the-shelf furnace or some other component and then need it to be reworked for an application unique to them because no general solution is available, according to Vince Thompson.

"It just doesn't exist," he said. "They're doing such ultra-high tem-



A susceptor assembly with a 54-inch diameter. (Courtesy: Semco Carbon)

perature heat treatment. A lot of the furnaces we deal with are home made."

It's what Matt Thompson jokingly refers to as a "Franken-furnace."

And many customers end up with variables they hadn't thought about, which is where Semco's experts pick up the ball.

"Those issues really become apparent." Matt Thompson said. "A good portion of our customer base operates furnaces where the upper service temperatures are well in excess of 3,100 to 3,200 degrees C, so getting it right at those temperatures is critical. Your margin of error in that temperature zone is very narrow."

MAJOR EXPANSION

A large part of what continues to make Semco successful is a recent expansion it implemented about 10 years ago, which involved a new facility, new equipment, new technology, and a huge employee training program, according to Vince Thompson. That training also meant making sure that training was added to the company's database of knowledge.

"We wanted it to be not individual knowledge; we wanted it to be tribal knowledge," he said.

That massive expansion paid off for a recent customer wanting to expand its product line, according to Matt Thompson.

"They were trying to gain some efficiencies with their business model that would make sense for them to justify the expansion," he said. "So, we worked with them. They had been running traditional induction furnaces. We did a tool and redesign for them, which ended up saving them 43 percent on material alone and over 80 percent in installation and service calls."

MORE GROWTH IN THE FUTURE

As far as the future is concerned for Semco Carbon, both Thompsons say they see a major growth and expansion in heat-treat made of alternative materials, as well as raw materials for alternative energies.

"With manufacturing sectors here rebounding under the current administration, we've seen a lot of reinvestment in those industries," Vince Thompson said. "I think that those are going to continue to grow." Semco has had its finger on the pulse of the industry for many years, which is what has, in large part made the company so successful.

"It's just moving along with the advancements that we see within the industry," Vince Thompson said.

Innovation and reinvestment have kept Semco ahead of the game, but it's a much simpler philosophy that the company's owners maintain is the key to Semco's many achievements:

"When our customers succeed, we succeed," Matt Thompson said.

MORE INFO www.semcocarbon.com

70-inch OD x 24-inch' long graphite round on a large saw. (Courtesy: Semco Carbon)

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"What's important to users is the hydrogen generator makes hydrogen at the same rate that they're using it, eliminating hydrogen storage."

What's a typical day like for you at Nel Hydrogen?
I'm in field sales and work with customers to make sure their process needs that involve hydrogen for atmospheres are met.

Why is hydrogen important to some heat-treat processes?
Hydrogen is a reducing gas, which means that it prevents, and to some degree, reverses oxidation. Hydrogen cleans up the part surface, which is particularly important for sintering applications because it enables parts to be successfully sintered to achieve desired density.

What are some of the challenges when using hydrogen?
Hydrogen is a flammable gas, so it's got all of the challenges associated with all other flammable gases, and hydrogen also has a few characteristics that make it trickier to work with. One, hydrogen (like helium) is one of the smallest molecules. As such, hydrogen and helium are both used as leak detection agents, and what that means is that hydrogen will leak through the smallest possible opening.

Therefore, it is extremely important for users of hydrogen to constantly maintain their piping system to make sure they don't have any leaks. In fact, unlike natural gas, you can't send hydrogen through plastic tubing, because it'll go right through.

Another consideration is, unlike natural gas, hydrogen cannot be odorized, because the odorant would interfere with the chemical uses of hydrogen—such as atmospheres. So, hydrogen is odorless, and so you must use detectors to determine if you have a hydrogen leak.

A third challenge with hydrogen is that it has a very wide flammability range. For example, we think of gasoline as being highly flammable, but gasoline has a fairly narrow mixture in air that will actually burn—if the blend is too rich or too lean, the gasoline simply won't ignite. Hydrogen has the widest flammability range of any gas, so it's flammable from 4 percent to 75 percent in air, which means that if you have a leak of hydrogen, it'll almost surely burn.

Finally, hydrogen has an enormous amount of chemical energy. A cylinder of hydrogen, which holds about 250 cubic feet, has the chemical energy of 35 pounds of TNT. So, you want to be very careful about having hydrogen leak and collect.

How do Nel's on-site generators create hydrogen?
We create hydrogen by electrolyzing water. We run an electrical charge through water, and we collect the hydrogen and provide it to the customer as a pressurized, pure, dry hydrogen stream.

One of the advantages of Nel's PEM electrolysis technology is that the hydrogen is very pure, and purity is not dependent on elaborate secondary purification steps. The only processing we do to that hydrogen once it's created is we dry it. No additional purification is necessary to provide 99.9995-plus percent pure, dry, pressurized hydrogen. What's important to users is the hydrogen generator makes hydrogen at the exact same rate that they're using it.

What are the advantages of the on-site hydrogen generator?
One advantage is the ease of permitting. Because hydrogen is so flammable and has such high-energy content, local fire departments are always very leery and very prescriptive about customers' storing hydrogen. When customers use hydrogen generation, it eliminates hydrogen storage, so many customers find that it is far easier to permit a facility using hydrogen generation than it is to permit a facility using liquid or gaseous stored hydrogen.

A second advantage is that we make very pure hydrogen at the same cost as industrial-grade hydrogen. Hydrogen comes in different grades, and certain processes benefit by additional hydrogen purity. If your process benefits from increased purity, you'll save by getting near semi-grade hydrogen for the cost of industrial grade hydrogen.

Because of the characteristics of hydrogen, if your setting requires you to keep your hydrogen indoors, then you need to build a gas room, which can be very expensive. Hydrogen generation makes it unnecessary to use a gas room, because our equipment is UL-compliant and therefore can go into a normal (unclassified) space.

We generally save people money on the overall cost of supply. If they look at their facility and compliance costs, the cost of hydrogen, and the cost of rental of cylinders or tanks, then they'll save money on the total cost of ownership.

Many people doing thermal processing in metallurgy don't store hydrogen. Instead, they use dissociated ammonia. When they dissociate ammonia, they make an atmosphere, which consists of hydrogen and nitrogen. Dissociated ammonia has been a very popular atmosphere because it's inexpensive to generate. And ammonia, unlike hydrogen, generally doesn't explode, but ammonia has its own challenges to deal with because it's toxic, and it has a very distinctive and powerful odor. Ammonia is a highly regulated hazardous material. A significant part of our business is helping people replace stored ammonia used with a dissociator with generated, zero-inventory hydrogen blended with stored or generated nitrogen.

MORE INFO www.nelhydrogen.com

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