Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

BURNERS & COMBUSTION / INSULATING MATERIALS

HIGH-EFFICIENCY GAS BURNERS

MAKE GOOD ECONOMIC SENSE

COMPANY PROFILE ///

Paulo

FEBRUARY 2019
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FROM THE EDITOR ///

Is it February already?

It looks like 2019 is moving at a brisk pace to match the brisk weather.

For *Thermal Processing*, February marks a bit of a milestone for us. After going to 12 issues a year, the month marks our first solo February issue.

And that's good news for you, because this month's issue is packed with expert advice as well as insider knowledge and know-how from some of the best the heat-treating world has to offer.

In our Focus section, we take a deep dive with articles discussing burners and combustion as well as a look at new and exciting insulating materials being developed.

Specifically, Steven R. Mickey, Martin G. Schönfelder, and Joachim G. Wünning share their expertise on how high-efficiency gas burners make good common sense.

An article from Mike Grande, vice president of sales with Wisconsin Oven, discusses how to select the correct industrial ovens for finishing applications.

And on the topic of insulating materials, Morgan Advanced Materials' Gary Jubb discusses the future of kiln lining fibers.

In our company profile, I talk with Phil Harris with Paulo, and how the company has provided cutting-edge heat treating for 75 years.

In addition to all of that information, I certainly would be remiss in reminding you about the amazing information you'll find in our monthly columns:

› **Hot Seat:** Predicting the outcome for today's various carburizing processes requires different procedures and processes.

› **Metal Urgency:** Impact on Case Depth Reporting in Steel.

› **Quality Counts:** Compliance via Internal Procedures.

With all that in mind (not to mention, in hand), enjoy the first official February issue of *Thermal Processing*. We're still very excited to bring you monthly coverage of the heat-treat industry.

Please let me know what's working for you, and let this serve as a gentle reminder that I'm always looking for fresh, informative articles to share with our readers. Hit me up if you're interested in having your work published.

And, as always, thanks for reading!

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Advanced Heat Treat Corp. received one new gas nitride unit in the fall, and two more in January.

Advanced Heat Treat Corp. adds three gas nitride units

Advanced Heat Treat Corp. (AHT), a recognized leader in heat-treat services and metallurgical solutions, recently announced the arrival of three new gas nitride units at its corporate headquarters in Waterloo, Iowa. The investment doubles its gas nitriding capacity at this location and allows the company to expand its UltraGlow® gas nitriding and UltraOx® surface treatment solutions.

The three new gas nitride units vary in size, allowing for the accommodation of various industries and applications including, but not limited to, agriculture, automotive, construction, aerospace, firearms and oil, and energy.

One nitride unit was to be operational in January, and the additional two running in February. AHT also has plans to design and build an additional unit later in 2019.

AHT President Mikel Woods said, "I'm excited on many accounts. One, we're adding capacity/back-up to an already growing agriculture/construction market. Two, we have plans to add a new Nadcap process in order to expand further into the aerospace market and meet our customer requirements/requests. And three, we're gearing up to go even bigger in 2019 with additional equipment."

The new units will house AHT's UltraGlow Gas Nitriding and UltraOx services, commonly used in manufacturing to prevent corrosion and improve wear resistance.

"UltraOx is rapidly replacing processes like QPQ/salt bath, chrome plating, and nickel plating; therefore, it was pivotal for us to invest in more equipment so that we can accommodate the growing demand and continue to provide our customers with the quality and service they have come to expect from AHT," Woods said.

AHT is Nadcap-accredited for ion nitriding at its corporate location, but with the additional capacity, AHT plans to gain accreditation in gas nitriding by this summer as well. The additional Nadcap accreditation will help AHT to accommodate additional aerospace needs and grow its UltraGlow gas nitriding service.

MORE INFO www.ahtcorp.com

Solar Atmospheres files patent application

Solar Atmospheres, Inc. filed a patent application with the United States Patent Office, application number 15/999,873, for a high-pressure, rapid gas quenching vacuum furnace using an isolation transformer in the blower motor power system. The gas quench with a 600 HP motor operates at 460 volts in argon gas, using a double wound, Magnetic Specialties, Inc. electrical isolation transformer, primary winding 1:1 to the secondary winding, with a variable speed drive and solid-state electrical spike protection for motor arc suppression.

MORE INFO www.solaratm.com

Baker Furnace ships custom waste incineration system

Baker Furnace announced the shipment of a custom waste incineration system to a pollution control company. These incinerators will be used to burn off waste after a 12-hour process. The system is designed with three gasification chambers that can burn 10 tons of waste a day per chamber. The waste incinerator is being installed in the Republic of the Marshall Islands in the Pacific Ocean.

The maximum temperature rating of the

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.

waste incineration system is 1,900°F. The proximity to the ocean causes an issue to salt contamination. The system is designed to withstand the harsh salt environment by using a special epoxy paint on the exterior. The harsh environment had to be considered on the selection of all components including but not limited to diesel firing burners, hydraulics, and conduit runs.

"Pollution control equipment has become very popular in recent years," said Sergio Luevano, general manager. "The islands of the Pacific have limited space to store waste and must find ways to dispose of it in a way that is safe for the environment."

Features of this waste incineration system include:

- Diesel fired burners.
- Two layer castable.
- High-temperature blast gate.
- Max temperature 1,900° F, Normal operating 1,800° F.

Baker Furnace, Inc. has been designing, engineering, and manufacturing industrial ovens, pollution control equipment, and other heating equipment since 1980. It is owned by Thermal Product Solutions (TPS), a leading American manufacturer of custom industrial ovens used for heat-treating, finishing, drying, curing, manufacturing automation, and process control. TPS is a global leader in thermal processing products and test solutions with brands including Blue M, Gruenberg, Tenney, Lindberg, MPH, and Wisconsin Oven.

MORE INFO www.bakerfurnace.com

Grieve has 2,200° F electric inert atmosphere furnace

No. 854 is a special high-temperature, 2,200° F electrically-heated, inert atmosphere floor furnace from Grieve, currently used for various heat-treating applications at a customer's facility.

Workspace dimensions measure 24″ wide x 48″ deep x 24″ high. 53KW installed in heavy-gauge, high-temperature Kanthal AF alloy wire, rod overbend design heaters provides maximum operating temperatures to 2,200° F.

This Grieve furnace features 9″ insulated walls, consisting of 4″ thick 2,600° F firebrick, 2″ thick 2,300° F firebrick and 2″ thick block insulation. A firebrick plate hearth is supported on firebrick piers. An electrically-operated vertical lift door is provided, with

No. 854 is a special high-temperature, 2,200° F electrically-heated, inert atmosphere floor furnace from Grieve. (Courtesy: Grieve)

remote foot pedal control.

Special inert atmosphere construction on No. 854 includes a continuously welded outer shell, high-temperature door gasket, sealed heater terminal boxes, inert atmosphere inlet, outlet, and flowmeter.

Safety and control equipment on-board this Grieve furnace include a digital indicating temperature controller, manual reset excess temperature controller with separate contactors and a four-channel strip chart recorder.

MORE INFO www.grievecorp.com

Roger A. Jones, FASM, honored as CEO Emeritus

Solar Atmospheres recently awarded the title of CEO Emeritus to Roger A. Jones, FASM. The honorary title was conferred by the company, and announces his semi-retirement as Solar Atmospheres' CEO, the culmination of 45 years of leadership and service to the vacuum heat-treating industry.

Roger A. Jones

A 1974 graduate of Hocking Technical College in Nelsonville, Ohio, Roger began his professional career in the heat-treating industry at ABAR Corporation. Jones left ABAR in 1978 to join the newly formed Vacuum Furnace Systems Corporation (VFS), working with his father and VFS founder, William R. Jones FASM. In 1983, Roger assisted the founding of Solar Atmospheres, Inc., serving as vice president until 1993. Jones was promoted to president in 2001, and eventually to CEO in June 2017, overseeing operations of all four heat-treating facilities.

As a member of several professional societies, Jones has provided leadership and has received numerous industry awards, primarily from the American Society of Materials (ASM) and the Metal Treating Institute (MTI). Jones has been recognized time and again for his outstanding commitment and service to the vacuum heat-treating industry.

MORE INFO www.solaratm.com

Super Systems upgrades American Heat Treating projects

Super Systems, Inc. recently completed two upgrade projects at American Heat Treating in Dayton, Ohio. Controls were upgraded on a Beavermatic integral quench furnace that included a Series 9205 with a 12.1" HMI for atmosphere and temperature control and datalogging, a Series 804 for oil quench temperature control (heating and cooling), and other ancillary items. A second project included a controls retrofit of a Lindberg 3000 SCFH endothermic generator with an SSi AutoGen control system.

Van Hatcher, instrument technician and project leader at American Heat Treating said, "Our long-range plan was to upgrade the controls on the Beavermatic, but when the old controller failed without notice, Super Systems jumped into action and did the complete upgrade project quickly. Our endothermic generator has been operating with the new SSi AutoGen controls with no issues since commissioning. We look forward to the operating cost savings that come with the automated turndown features."

Super Systems Inc., based in Cincinnati, Ohio, has been developing and manufacturing products for the thermal processing industry since 1995. SSi's products include probes, analyzers, flow meters, controllers, software solutions, and engineered systems. With more than 100 years of combined experience, SSi continues to satisfy industry demands with innovative technology, enabling customers to be more efficient and to produce higher quality products.

American Heat Treating in Dayton, Ohio, is a full-service commercial heat-treating company with atmosphere, vacuum, flame hardening, cryogenics, straightening, and sand/shot blasting. ISO 9001:2015 certified.

MORE INFO www.supersystems.com or www.ahtdayton.com

Wisconsin Oven ships thermal clean oven

Wisconsin Oven Corporation shipped an LP gas-fired heavy duty car bottom oven with fume incinerator to a leader in the oil and gas industry, to be used for prebaking drill pipe joints. (Courtesy: Wisconsin Oven Corp.)

Wisconsin Oven Corporation recently announced the shipment of an LP gas-fired heavy-duty car bottom oven with fume incinerator to a leader in the oil and gas industry. This car bottom oven will be used for pre-baking drill pipe joints.

The thermal clean oven has a maximum operating temperature of 800° F and work chamber dimensions of 8'6" wide x 50'0" long x 8'6" high. Guaranteed temperature uniformity of ±30° F at 750° F was verified through a 20-point profile test conducted in an empty oven chamber under static operating conditions.

The industrial oven has sufficient capability to heat 70,000 pounds of steel from a cold start to 750° F within 75 minutes. The load car is designed for a maximum loading of 172,000 pounds.

The fume incinerator is designed to incinerate the exhaust fumes from the oven and has sufficient capacity to handle 5,000 CFM of exhaust.

"This oven features the E-Pack™ upgrade with design features for more efficient energy usage. This is the second thermal clean oven featuring the E-Pack upgrade that this valued customer has purchased, and we look forward to their continued business," said Tom Trueman, senior application engineer.

Features of this car bottom oven include:

› Guaranteed temperature uniformity of ±30° F at 750° F.

› Exhaust fume incinerator.

› Digital recorder with Ethernet communication capabilities.

› 20,000 CFM quick-cool fan.

› Honeywell flame relay with integral purge timer.

› Load capacity of 172,000 pounds.

› Two CFM recirculation blowers.

This heat-treating oven was fully factory tested and adjusted before shipment from our facility. All safety interlocks are checked for proper operation and the equipment is operated at the normal and maximum operating temperatures. An extensive quality assurance check list was completed to ensure the equipment met all Wisconsin Oven quality standards.

MORE INFO www.wisoven.com

TMS 2019 annual meeting set for March in Texas

The TMS Annual Meeting & Exhibition, March 10-14, 2019, in San Antonio, Texas, brings together more than 4,000 engineers, scientists, business leaders, and other professionals in the minerals, metals, and materials fields for a comprehensive, cross-disciplinary exchange of technical knowledge.

More than 3,500 presentations are planned for TMS2019, but the conference is more than technical talks. Here is a sample of what's scheduled:

Keynote sessions take a closer look at these hot-topic issues:

› Materials and Manufacturing Innovation Keynote Session: Featuring four leaders in the emerging topic of Autonomous Materials Research.

› Additive Manufacturing Keynote Session: Tying together the seven additive symposia planned at TMS2019.

› Light Metals Keynote Sessions: Invited keynote sessions planned on timely topics in the aluminum and magnesium industries.

Special topic sessions include diversity in STEM and best practices to improve it. Experts from the front lines of the professional community share strategies, experiences, and insights into developing a more inclusive work and educational environment. "Science Policy Within the Materials Research Community" involves program managers, administrators, academic researchers, industry professionals, and former Congressional Fellows offering their first-hand experiences working in science policy.

Additionally, TMS will release two new reports at TMS2019: A Technology Study to Initiate the Third Wave of Digital Manufacturing — Metamorphic Manufacturing and Verification & Validation of Computational Models Associated with the Mechanics of Materials.

There will be special programming for young professionals, graduate students, and students, including poster competitions, mentoring sessions, networking events, and, new this year, a workshop on creating application packages for laboratory, university, or industry positions.

MORE INFO www.tms.org/TMS2019

Book on MPIF Standard Test Methods published

A Collection of Powder Characterization Standards for Metal Additive Manufacturing contains nine existing MPIF Standard Test Methods that can be applicable for the characterization of powders used in metal additive manufacturing (AM) processes, with an explanation of each standard. These standards, intended to present and clarify PM technology as an aid in conducting business, relate to those activities that concern designers, manufacturers, and users of metal AM parts.

As a bonus, this publication includes details (QR codes and Internet links) on viewing educational video clip demonstrations of the working mechanics of the cited test methods.

Member discount: MPIF and APMI International Members receive discounted rates on publications, standards, and books. Log in via the MPIF Publications Portal on www.mpif.org to order and receive the discounted rate. Otherwise, proceed directly to the new publication via the MPIF Publications Portal.

Included standards:

› **MPIF Standard 01 –** Method for Sampling Metal Powders.

› **MPIF Standard 02 –** Method for Determination of Loss of Mass in a Reducing Atmosphere for Metal Powders (Hydrogen Loss).

› **MPIF Standard 03 –** Method for Determination of Flow Rate of Free-Flowing Metal Powders Using the Hall Apparatus.

› **MPIF Standard 04 –** Method for Determination of Apparent Density of Free-Flowing Metal Powders Using the Hall Apparatus.

› **MPIF Standard 05 –** Method for Determination of Sieve Analysis of Metal Powders.

› **MPIF Standard 28 –** Method for Determination of Apparent Density of Non-Free-Flowing Metal Powders Using the Carney Apparatus.

› **MPIF Standard 46 –** Method for Determination of Tap Density of Metal Powders.

› **MPIF Standard 48 –** Method for Determination of Apparent Density of Metal Powders Using the Arnold Apparatus.

› **MPIF Standard 53 –** Method for Measuring the Volume of the Apparent Density Cup Used with the Hall and Carney Apparatus (Standards 04 and 28).

Metal Powder Industries Federation is the North American trade association formed by the powder metallurgy industry to advance the interests of the metal powder producing and consuming industries and provides a single point of reference for all MPIF member companies.

MORE INFO www.mpif.org

At your own pace, in your own space: IHEA offers Fundamentals of Industrial Process Heating Online course

Registration is open now for IHEA's Fundamentals of Industrial Process Heating Online Learning Course beginning April 15, 2019. The course is ideal for students who wish to further their studies at home or work in a flexible web-based distance-learning format. It's an affordable alternative to campus-based classes and allows students to go at their own pace. The program offers a vital tool to industrial process heating operators and users of all types of industrial heating equipment. Students learn safe, efficient operation of industrial heating equipment, how to reduce energy consumption, and ways to improve a company's bottom-line.

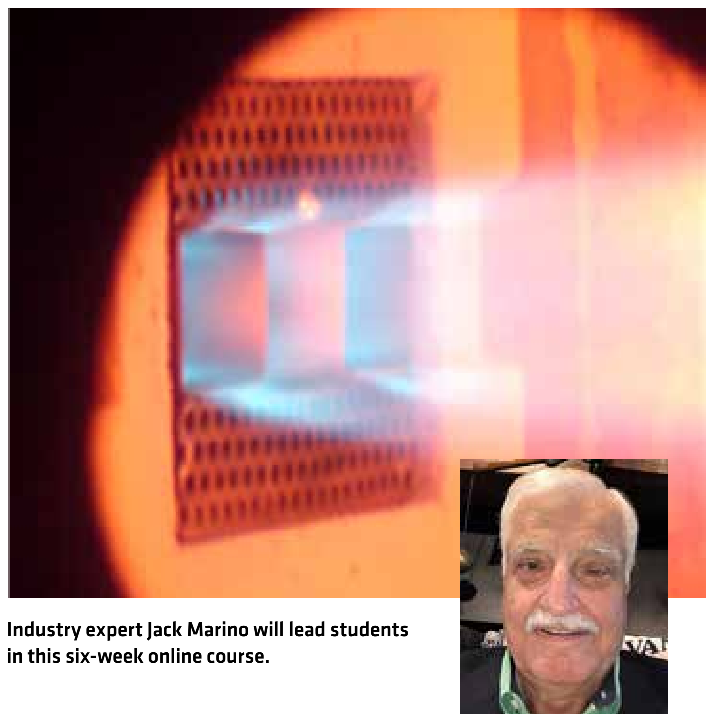
The fundamentals course provides an overview of heat transfer, fuels and combustion, energy use, furnace design, refractories, automatic control, and atmospheres as applied to industrial process heating. For a complete listing of the topics covered, visit www.ihea.org, click the Training and Events tab, and scroll to Online Course.

Industry expert Jack Marino will lead students in this six-week online course. Marino is a registered professional engineer with more than 40 years of experience in the heat-processing business. He is a graduate of Rensselaer Polytechnic Institute with a bachelor's degree in Aeronautical Engineering and has a master's degree in Engineering Science from Penn State. Marino began his career as a project engineer and worked his way to vice president of Engineering. He eventually became the owner and president of Denton Refractory Services Corporation, a refractory contracting and furnace construction company. He also started Hauck Manufacturing's Chinese company and served as president of Hauck Combustion (Nanjing). Marino holds six patents in combustion technology and is the author of numerous technical papers. His knowledge and experience are invaluable resources that online students can access throughout the course.

"The instructor has excellent knowledge of the course and quick response," said a former online student.

Upon completion, students will have general knowledge of instrumentation and control for efficient operation of furnaces and ovens in process heating. The use of vacuum heat processing, recuperators, regenerators, gas atmospheres, and quenching will also be presented. Particular attention is spent on efficient operation of process heating equipment and methods to achieve cost savings. Students will also receive a certificate of completion and Professional Development Hours for completing the course.

IHEA's online course is a terrific value for IHEA members and non-



Industry expert Jack Marino will lead students in this six-week online course.

members, considering no travel expenses are involved, and there is no time out of the office. Take advantage of the online tools provided and benefit from the ability to learn almost anywhere.

"Because of balancing an extremely busy workload and family life, I am not able to be on a regular schedule or take time in the evening to travel to a class," said a former online student. "The advantage for me is that I can check in when time permits and still stay up to date on all activities. The course information is directly related to my work and I found it to be very beneficial."

Registration for the Fundamentals course is open through April 12 at www.ihea.org/event/FundamentalsSpring19. Cost for IHEA members is $750 for two-member vouchers, and non-members is $925, which includes electronic course handbook, course instruction, quizzes and projects, class forums, and the opportunity to contact the instructor. There is also a registration discount available for two or more from the same company. Printed materials are available for an additional fee.

Executive officers recognize value of IHEA

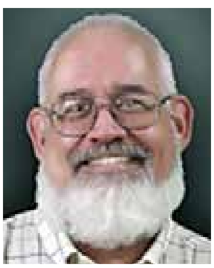
The Industrial Heating Equipment Association is one of the leading associations that represents major segments of the industrial heat processing equipment industry. Established to meet the need for effective group action in promoting the interest of industrial furnace manufacturers, the organization includes designers, manufacturers, corporate end users, professional service, and consulting members within the industrial heat processing industry.

IHEA is thankful to have the leadership of dedicated members. IHEA's executive officers share the importance of the association's work and its value to the thermal processing industry:

MICHAEL STOWE, P.E., C.E.M., ADVANCED ENERGY

IHEA President

Stowe is an energy consultant at Advanced Energy. He is the IHEA Board of Directors president and has been involved with IHEA for more than a decade. He has been an invaluable member of IHEA's education committee and served as the chairman of the Infrared Division and the Induction Division. Stowe has presented at countless workshops and seminars to promote infrared and induction technologies along with the benefit of being involved with IHEA.



In your time on the IHEA board, what do you think is IHEA's most significant accomplishment?
Providing exceptional technical, economic, and leadership information -— as well as wonderful social networking opportunities — to our members, year after year.

What is your vision for IHEA moving forward?
I see IHEA as the central clearinghouse for all things about industrial heating. IHEA should be the leader in communicating heating technology development, sharing the state of the heating industry, ensuring the safety of heating equipment, and providing conferences and events for networking and education.

What advice would you give non-members about joining IHEA?
IHEA is all about heating. Whether it is a vacuum carburizing oven or an infrared powder coating curing oven, IHEA covers the spectrum of heating in manufacturing processes. IHEA members are oven and furnace equipment OEMs, electrical utilities, combustion burner manufacturers, various heating magazine publishers, and even energy consultants. The widely varied membership provides an excellent opportunity for networking and keeping up with the latest and greatest heating technology developments. IHEA membership provides access to exceptional training opportunities, heating-related national standards updates, up-to-date economic news, and thought leaders across the heating industry. I have made so many professional and personal contacts and new friends during my time with IHEA.

B.J. BERNARD, SURFACE COMBUSTION

IHEA Vice President

B.J. Bernard is the president of Surface Combustion, Inc., and the vice president of IHEA. As testimony of his dedication, he has made his way through the officer rotation twice and continues to provide significant support to the association in countless ways. His guidance in the board room carries through to the overall industry.

In your time on the IHEA board, what do you think is IHEA's most significant accomplishment?
One of the core values of IHEA is education. We provide high quality training from industry experts at our Combustion, Induction and Safety Standards and Codes Seminars. We've also completely updated IHEA's online course, Fundamentals of Process Heating.

What is your vision for IHEA moving forward?
I would like IHEA to continue to be a place where the industry gathers to push the industry forward by jointly improving technology and safety and providing training opportunities to our stakeholders.

What advice would you give non-members about joining IHEA?
For non-members, the relationships forged at IHEA will serve you well. Knowing and having a relationship with vendors, competitors, and customers gives you a broader view of the industry and gives insight into key issues that affect us all.

Don't let another year pass without becoming an IHEA member. Join now and get a multitude of benefits right from the start. For more information, go to: www.ihea.org.

IHEA 2019 CALENDAR OF EVENTS

MARCH 5–6
Powder Coating and Curing Processes Seminar
Georgia Power Customer Resource Center (CRC) I Atlanta, Georgia

APRIL 15
Fundamentals of Industrial Process Heating I On-Line Distance Learning Course (six weeks)

APRIL 29–MAY 1
IHEA 2019 Annual Meeting
The Industrial Heating Equipment Association (IHEA) will celebrate its 90th anniversary at the 2019 Annual Meeting. Complete meeting details and registration information can be found at www.ihea.org.
Lido Beach Resort I Sarasota, Florida

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

ELIZABETH P. COOKE
SENIOR MATERIALS ENGINEERING SPECIALIST /// THE TIMKEN COMPANY

Efforts to reduce hardness testing to a universal, fundamental physical test have not been successful. Furthermore, conversion between different methods is not mathematically exact.

Hardness scale conversion

The use of hardness testing as a quality control method to check the outcome of a thermal treatment process is a common application of this measurement technique. The process wherein heat-treatment practitioners measure hardness by one method and convert the results to a different scale is generally known and a common practice. However, hardness data conversions from one scale to another may not always yield the expected results. The variation in conversion results from different hardness scales can make the difference between accepting and rejecting a production batch of components.

This discussion delves into the practical implications of hardness conversion. In this article, we explore the impact of converting from micro- to macro-indentation hardness methods — i.e., Vickers (HV) and Knoop (HK) to Rockwell C (HRC) — in case-hardened steels.

Methods of measuring hardness have been documented and in use for more than two centuries [1,2]. There are many hardness test methods that are performed by an array of techniques, from comparative references to scratch testing and indentation methods [1,3]. While hardness numbers have repeatable correlation to material strength, efforts to reduce hardness testing to a universal, fundamental physical test have not been successful. Furthermore, conversion between different methods is not mathematically exact [3,4].

Numerical hardness values are unique to each hardness scale and method. For an indentation hardness method, the reported hardness numbers are based on the load on the indenter, the geometry of the indenter tip, and the measurements of the permanent plastically deformed impression in the sample. Hardness numbers may be calculated as a function of either a projected area or as the contact surface area of the indentation depending on the scale used. Conversion of hardness numbers from one scale to another is generally accomplished by reviewing the tables and equations available in externally published standards, such as ASTM E140 or ISO 18265 [1,3]. However, the guidance in the ASTM E140 standard regarding conversion from one scale to another, states the following:

"Conversion of hardness values should be used only when it is impossible to test the material under the conditions specified, and when conversion is made it should be done with discretion and under controlled conditions." [1].

Furthermore, ASTM E384 confirms that there is no generally accepted method for precise conversion to other hardness scales [7]. While the conversion from one scale to another is straightforward, the converted hardness values need to be considered in the context of expected results from the thermal treatment process. The hardness conversion tables and equations in the standards generally correlate empirically derived numerical scales for specific materials and are not direct conversions of physical property relationships.

Micro-indentation hardness methods such as HV and HK are essential for certain situations because of the need to take multiple measurements within a small volume of material. In a surface-hardened steel, whether carburized or nitrided, the hardness gradient from the surface to the core must be evaluated. Assessment of this region requires a collection of discrete hardness values from small volumes of material [8]. The micro-hardness methods evaluate only the region of interest without being rendered inconclusive by overlapping with other adjacent areas within the microstructure. Hardness number conversions are also subject to variation in sensitivity at different hardness levels. Figure 1 illustrates typical cross-sectional views of surface-hardened steels with micro-hardness indentations. As the hardness decreases, the indentation size increases.

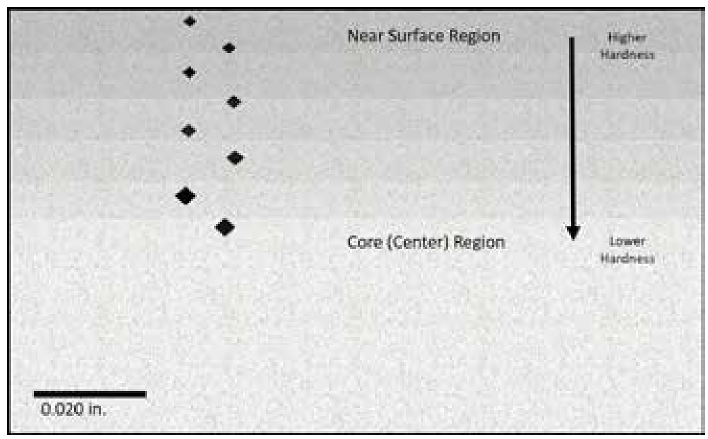


Figure 1: Schematic of micro-hardness indentation trace to measure case depth in a surface-hardened steel.

EXPERIMENTAL EXAMPLE

To illustrate the potential discrepancies created by hardness conversion, two case-hardened steels were examined and hardness numbers were converted from Vickers (HV) and Knoop (HK) to Rockwell C (HRC). In Figure 2, the hardness gradients for two case-carburized steel ring samples are shown as converted HRC values as a function of depth from the surface. Figures 2a and 2c show HRC versus depth for the gradient until it begins to transition to the core hardness, and Figures 2b and 2d are zoomed-in regions from the same data sets to illustrate the potential for reporting different case depths depending on which original measurement method was used. The hardness test equipment used for the study was calibrated and used routinely for production and development assessments as a referee location.

For the two steels, the hardness was measured both by HK and HV micro-indentation methods on the same samples from cut, mounted, and polished cross-sections of rings that had been carburized, hardened, quenched, and tempered to production heat treating specifications. The hardness data were also collected at two different HV and HK loads (500g and 1000g). All measurements were repeated twice

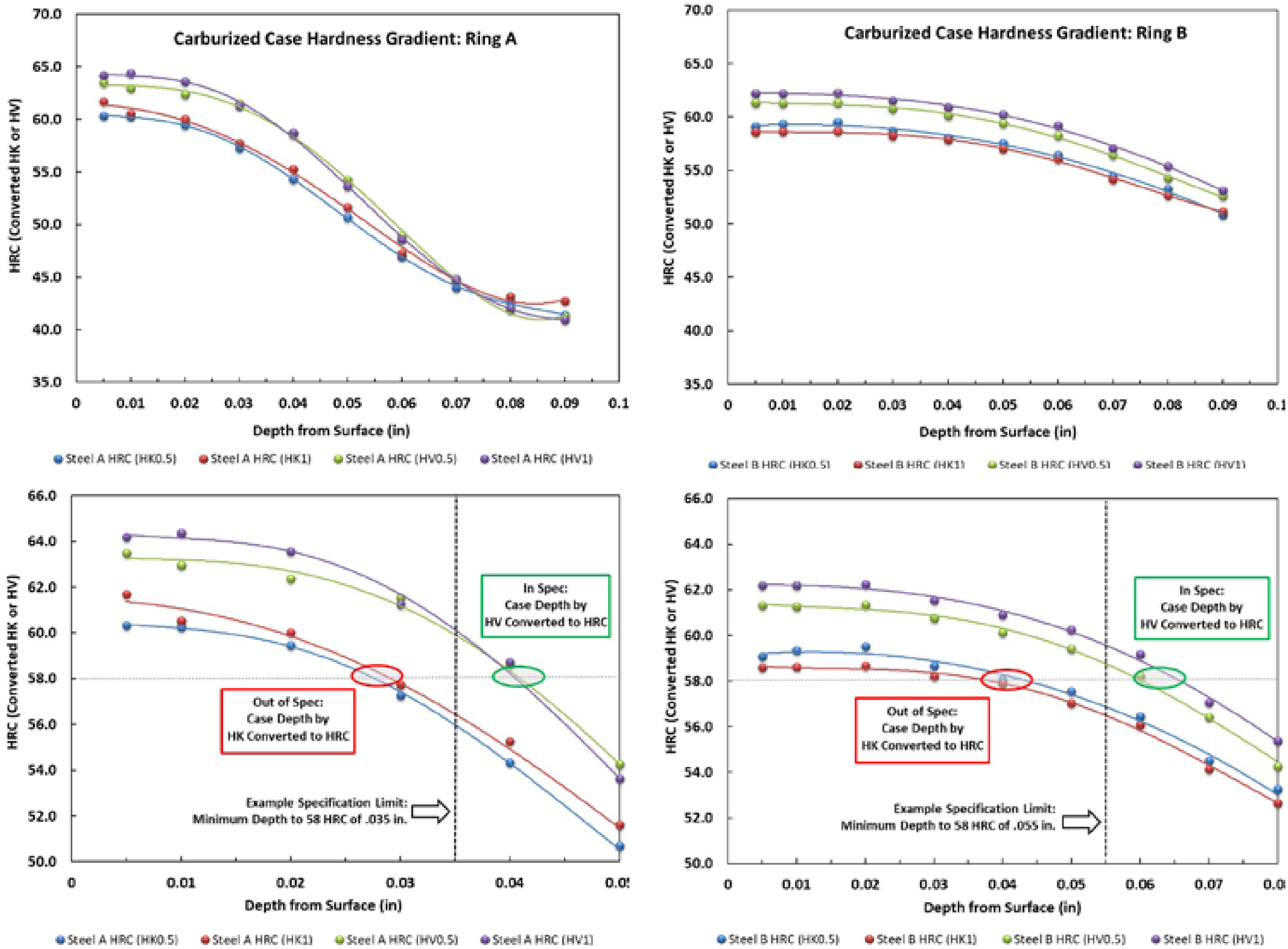


Figure 2: HRC hardness of carburized steels as a function of depth converted from HK and HV at two loads for: a) and b) alloy steel A; c) and d) tool steel B [9].

for a total of three data points per reported average converted HRC value. Data were initially recorded as output from the software in the automated micro-indentation system, followed by verification using the conversion guideline equations in ASTM E140 and visual assessment of the indentations.

In the next section, the implications of these variations are discussed. Both HK and HV conversions at the two test loads, 500g and 1000g, yielded consistent results within a particular method; therefore, discussions will be limited to one scale versus another.

DISCUSSION

Engineered products such as bearings or gears may undergo diffusional thermal treatments (including carburizing or nitriding) to harden just the near-surface region of the material. These products require validation that the depth of the surface hardening is adequate to meet the product design intent. These types of products are highly reliable and, in some markets, safety is also a critical requirement. When these products are surface-hardened, it is still a common practice to state the hardness requirements in terms of the Rockwell C hardness scale (HRC) on drawings or in specifications, in particular in the United States [3]. However, it is necessary to use micro-hardness techniques such as HK and HV for direct measurement. The hardness test method selection is constrained by the thickness of the hardened zone as well as the part geometry.

In Figures 2a and 2c it can be seen that for both the alloy steel and the tool steel, over a range of depths and hardnesses, the HK to HRC conversion yields different results than the HV to HRC conversion. Even though the thermal treatment processes, incoming material, and measurement system equipment may all be controlled, calibrated, and identical, the HRC hardness values converted from HK are lower than those converted from HV measurements. Overlap between the two methods occurs below approximately 45 HRC. This difference is large enough that on a practical front, simply making the conversion from one hardness scale to another to communicate results could determine whether the product is accepted or rejected. The differences in results from converted hardness numbers may also be greater from scale to scale than the accepted or known variation within any single hardness scale.

Examining the results over a narrower range of hardness and depths — as in Figures 2b and 2d, which are magnified views from the same samples that produced Figures 2a and 2c — puts the results in the context of specification limits. For both steels, as this example shows, the HRC results converted from HV would be accepted and the HRC results converted from HK might be rejected. While these limits were chosen for demonstrative purposes, they are consistent with actual requirements for these types of steels. At the 58 HRC level in Figure 2b, the difference in reported case depth for the HK conversion is approximately 0.015 lower than the HV conversion value. In Figure 2d, for steel B, the HK converted value is 0.025 less than the depth based on the HV conversion.

Conversion from one hardness scale to another introduces a bias that may be significant in some circumstances. This prevents ready interchangeability between test scales when working to a common requirement.

In a production setting when the difference between the conversions becomes evident, one initial response may be to assume there is a problem with the measurement itself, with the conversion calculation, or even with the treatment process. However, Figure 2 clearly demonstrates the inherent difference between the empirically derived conversions in ASTM E140 from HK and HV to HRC over this hardness range — further supporting the blunt guidance in the ASTM E140 standard to convert "only if impossible" to measure directly [5]. Therefore, practical solutions are needed in order to have the appropriate standard work in place.

When such differences do arise, or as practitioners establish by experience that the results for hardness conversions are not consistent from one scale to another, options for addressing them include:*

1. Accept/reject the product based on the converted values for the scale used.

2. Develop localized hardness scale conversions for the specific process, material, and product.

3. Change the specification requirements to reflect the most practical or preferred test scale in order to avoid conversion.

***Note:** All these discussions presume that the hardness test equipment is calibrated correctly and the thermal process is under control, has appropriate monitoring, and was initially validated as acceptable.

The selection of an option warrants discussion among practitioners, since there are pros and cons to each choice.

The first option benefits from a robust set of standard work, a consistent method, and preferably the use of only a single micro-hardness test method to avoid the anomalies that can arise if a choice of method is permitted. But this option — making a decision based solely on the converted results as presented — may mean the rejection of a good product as well as acceptance of a borderline product. While a practical specification typically has a range of hardnesses to define a "case depth," clearly the large differences between the converted results from the HK and HV scales in Figure 2 for each material will occasionally cause discrepancies. In that case, depending on the tolerance for risk and the application of the part, the decision to accept product based on as-is results may vary.

The second option — developing local conversion tables and correlation equations — takes into account the specific thermal processes, materials, and acceptable outcomes, and formalizes them to establish more uniform decision-making. Legacy experience may identify that the conversions sometimes produce different results, but by documenting the expectations using standardized samples and a robust data set, the variation inherent in the standard conversion curves is reduced. Additional consideration for documentation of expected outcomes may be warranted in the case where automated micro-indentation is used, since there may be conversions built into such systems. As with any measurement or data conversion for production, agreement among customers and suppliers should be part of this method's finalization.

Finally, the third option — starting with a micro-hardness requirement rather than HRC, and/or changing the existing specifications — is the most permanent solution. This approach requires starting with or converting to a specification that calls out an appropriate hardness method, such as a particular micro-hardness scale. While this is a permanent solution, the initial selection of the hardness scale and limits of the specification often rests upon decades of legacy experience, design practice, design systems, and successful product performance in the field, rather than an intentional selection of the best method to interrogate the surface hardening process.

Although the permanent fix is to change the requirements in a specification for measuring the surface hardening to a measurable scale, this is only possible with agreement among all parties, and may be unrealistic in some cases due to long-standing legacy requirements, specifications, and design systems based solely on Rockwell hardness. A solution for overcoming that is simply to be consistent within standard work, operating procedures, and data, so that the local conversion becomes a viable option.

Perhaps the most important consideration to remember is that the hardness conversions in external standards are guidelines. Conversion from one hardness scale to another introduces a bias that may be significant in some circumstances. This prevents ready interchangeability between test scales when working to a common requirement. Conversion tables should be considered a starting point, but likely will need additional boundaries and understanding to ensure that the converted result interpretation provides an adequate basis for decision making and quality control.

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NAF
KUKA

JACK TITUS
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Outcomes of the processes of atmospheric pressure and partial pressure on carburizing can be predicted using a number of viable techniques.

Carburizing today: The secrets to predicting success

Predicting the outcome for today's various carburizing processes requires different procedures and processes.

Carburizing today is performed by two primary processes, at or above atmospheric pressure and partial (vacuum) pressure. Below are some acknowledged practices plus procedures and techniques to evaluate their success.

Atmosphere carburizing consists of the following:

› Generated endothermic gas consisting of 20 percent CO, 39 percent H_2 and 40 percent N_2 plus fractions of CO_2 and water vapor requires approximately a ratio of 2.4 to 1 natural gas to air in a retort at temperature of 1,950 degrees F (1,066 degrees C) with a nickel catalyst. To produce 1,000 CFH of the endo mix requires 526 CFH of natural gas plus 219 CFH air. The gas-air reaction actually creates more gas than that used to produce, resulting in the output of 1.37 times the input gas volume.

› Nitrogen/methanol can produce the endo gas equivalent by dissociating methanol and adding nitrogen. For example: To produce 1,000 CFH requires 2.5 gallons of methanol and 400 CFH of nitrogen in a hot zone operating at a minimum of 1,550 degrees F (843 degrees C). Below 1,550 degrees F (843 degrees C), methanol cracking becomes less effective, creating higher concentrations of methane (CH_4), CO_2, and water vapor.

Partial pressure vacuum made its initial entrance into the carburizing scene by employing propane with its high value carbon level of C_3H_8 used at approximately 50 torr (67 millibar). This was followed by natural gas at about 400 torr (533 millibar) and finally LPC (low pressure carburizing) between 5 and 15 millibar.

A brief comparison follows:

› Propane worked but created significant quantities of soot, causing maintenance problems with electrical shorting and nonuniform case depth from bottom to top of tall loads.

› Recirculated natural gas (CH_4) at 400 torr (533 millibar) also worked, but hydrocarbon reactions with some local enriched natural gases created condensed tar at the higher pressure.

› Finally, acetone (C_2H_2) with its very high carbon content allowing lower pressure, has become the standard resulting in LPC.

› Plasma carburizing has a place of its own in the partial pressure genre and made its debut on the coattails of plasma nitriding. It found a niche primarily for case-hardening fuel injection nozzles for its ability to carburize into the extremely tiny holes of the injector. It also found some applications in the auto after-market for a few drivetrain components where the case depth uniformity was not as critical as that for similar OEM parts. The process was somewhat difficult to master, much like plasma nitriding, in that the higher concentration of energy added heat to the already hot parts, requiring the hot zone temperature control to try and compensate to prevent overheating of the load; not easy to achieve. It also operated at higher pressures than LPC or plasma nitriding.

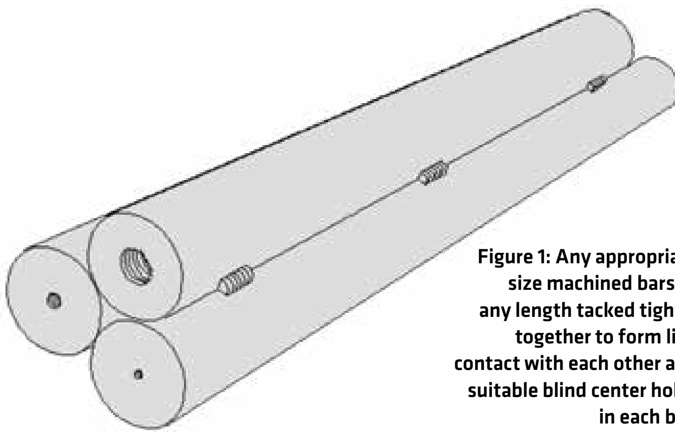

Figure 1: Any appropriate size machined bars of any length tacked tightly together to form line contact with each other and suitable blind center holes in each bar.

LPC or partial pressure vacuum carburizing has become popular because it eliminates IGO (intergranular oxidation) and it's true that improves the fatigue strength of steel.

Endo gas generated in a retort is the standard by which all carburizing methods are compared for surface, case depth uniformity, and CP (carbon potential) control.

No process is perfect, so the primary metric for comparison is consistency load-to-load and part-to-part. One of the measures I've employed over the years is the ability to carburize between closely placed parts and into blind holes, Figure 1.

Although LPC does a commendable job of carburizing into some blind holes, depending on the process, pressure-pulsed or gas-pulsed, (more on that later) all LPC parts must be racked in fixtures to assure uniform case and surface carbon; they cannot be shovel loaded, for example, like universal joint crosses or ball joints, as is routinely done in endo carburizing. Carburizing at 400 torr in recirculated natural gas also could do a good job of penetrating blind holes. Although the higher pressure didn't create the popularity of LPC, a good portion of the early fatigue improvement test results by vacuum carburizing at 400 torr was performed in the late 1970s.

Finding the best practice and procedure is a moving target, literally.

Endo gas carburizing is the benchmark for case hardening because the progress of carbon diffusion is determined as it occurs by the following two methods:

› Measuring the oxygen content of the atmosphere with the oxygen probe is today the primary method for controlling the CP (carbon potential). The millivolt output of the probe is cross-referenced

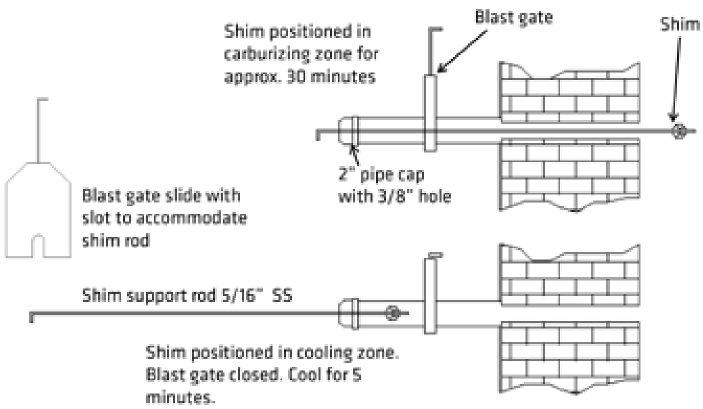

Figure 2: Shim test.

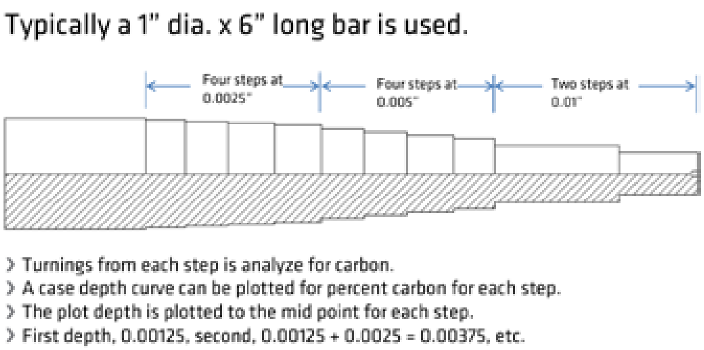

Figure 3: Carbon step bar analysis.

to the temperature and CO content of the atmosphere. The millivolts produced are an inverse function of the difference between atmospheric oxygen 20.9 percent to that of the endo atmosphere, i.e. the greater the difference, the higher the millivolt output. Existing carbon diffusion algorithms can predict the case depth when the surface carbon or the CP of the atmosphere is known. Oxygen probes out of the box are calibrated for 20 percent CO. If the CO content of the atmosphere is less or more, the probe process or furnace factor must be adjusted to the shim test result, Figure 2.

› The shim test is the failsafe procedure to calibrate oxygen probes. It consists of inserting a low-carbon, very thin 1008 steel shim typically 4 inches by one inch by 0.004 inches thick into the atmosphere via a special port. The shim's carbon content can be determined by weight gain or actual chemical analysis. If weight gain is used, the weight gain is divided by the original weight in grams times 100 plus the measured base carbon content of the shim steel. It's meant also as a quick reference during a long process to confirm the probe's accuracy. Finally, to determine the post-process surface carbon and case depth carbon, step bars can be included in the load, Figure 3. After quenching the load, the step bar is annealed to reduce its hardness so it can be turned in a lathe to remove in incremental steps the turnings for carbon analysis.

Today, carbon and case-depth-predicting software models are commonly used to estimate the time and CP required for achieving a specific target. But as popular as they are, they are only as accurate as the actual carbon penetrating the surface of the parts, and that's the function of the shim tests. However, the shim test does not work for vacuum carburizing.

The shim test works for endo carburizing because the controlling factor is based on the equilibrium of the atmosphere to the parts and shim material; the CP of the atmosphere will — when under control — not exceed the CP. If the CP is 0.80 percent, the surface carbon of the parts and shim will be at or very close to 0.80. The size or surface area of the load has little influence on the outcome as long as the rule of thumb of five volume changes per hour of endo gas flow to hot zone volume is maintained. However, partial pressure carburizing such as LPC has no such equilibrium or constant flow component. LPC, regardless of the gas used, relies on the assumed surface carbon if the acetylene flow is matched to the estimated surface area of the load; too much acetylene results in excess iron carbide, too little and the case depth will be shallow and nonuniform. Carbon diffusion models, as mentioned, exist to predict the desired result but part spacing and surface area are variables that can affect expected outcomes. However, pressure control must be taken into account. There is no hard and fast rule. Empirical tests have tried to estimate the quantity of acetylene used for a particular surface area but it's only an estimate from similar loads. Evaluating shim tests at 400 torr in natural gas results in carbon pick up of more than 2.5 percent; I'd expect LPC to be similar.

LPC or partial pressure vacuum carburizing has become popular because it eliminates IGO (intergranular oxidation), and it's true that improves the fatigue strength of steel. However, in my view, that's not its most beneficial property, primarily because shot peening has successfully improved the fatigue resistance of endo carburized steel by imparting compressive stress to the component's surface and has been used for several decades. It's the integration of HPGQ (high pressure gas quench) that has propelled LPC, due to its ability to reduce distortion during quenching.

Vacuum carburizing, due to its non-equilibrium relationship to the steel surface, has an extremely high carbon flux that results in an increase in carbon diffusion per unit of time compared to endo carburizing. Witnessing the evolution of HPGQ, the addition of acetylene and the desire to reduce distortion and reduce carburizing time, in my opinion, is the driving factor for LPC. There is also a perception that iron carbide, Fe_3C, is to be avoided at all costs. However, finely dispersed carbide provides improved wear resistance such as the common bearing steel 52100, which has a carbon content of 0.98 to 1.1 percent. Carbon in excess of 0.8 percent at room temperature exists as iron carbide.

Most LPC prediction models are designed employing the boost-diffuse method, meaning that as the assumed surface carbon concentration approaches 0.8 percent, the carburizing pulse stops to allow the surface to diffuse to some lower value, such as 0.65 to 0.75 percent before the next boost or pulse begins. As this process proceeds, the boost time shortens and the diffusion time increases until the model believes the target case profile has been achieved. Unfortunately, there is no as-it-occurs method of verifying the potential of the atmosphere for LPC.

Finally, for those anticipating the use of LPC, two control methodologies can be used: gas pulse and pressure pulse. The pressure pulse, in my view, is the more effective. In the gas pulse process, the acetylene pulse is replaced with nitrogen during the diffusion segment and assumes that the unreacted acetylene and H_2 (hydrogen) is scrubbed from blind holes and closely packed parts. Pressure pulse, as the term suggests, lowers the pressure for the diffusion segment, removing acetylene from holes, etc. This is a variation of a process employed by some furnace manufacturers early on, with propane at higher pressures and ineffective flow distribution methods that created soot problems.

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Once you're familiar with the specifications, learn to recognize the requirements.

Compliance via internal procedures

Verification of compliance is two-fold; witnessing operations being performed in accordance with internal procedures. As long as procedures are followed, the challenge in conformance is ensuring the internal procedures clearly account for all requirements set forth. In this article we will explore ways to ensure you are able to not only capture all of the requirements, but state them clearly and unambiguously within your procedures.

CAPTURING REQUIREMENTS

Of course, industry and prime specifications comprehension is imperative. It would be a daunting task to attempt to capture specification requirements if you're not able to comprehend the specification itself. There are many training programs out there. Some may be designed by individuals (such as my own courses I present), and others are designed by industry organizations such as eQuaLearn, ASM International and AMS/SAE.

The next step is capturing the requirements within specifications. If this is done a specific way, you will enable yourself to not only capture the requirements but also have somewhat of an audit document for future use and reference.

Once you are familiar with the specifications, your next step is to recognize and capture the specific requirements. It's important to recognize that, at times, you may have several requirements within a single paragraph, even within a single sentence. As an example, AWS C3.6M/C3.6:2016, para 5.2.1 states

"All brazing furnaces shall have automatic temperature control and recording devices in good working order capable of controlling the temperature profile of the furnace to the requirements of this specification. Furnaces shall have adequate capacity to accomplish uniform heating of the load at the rate required to prevent both

4	Unless specifically noted, requirements apply to all temperature sensor materials.	3.1.1.1	ACKNOWLEDGED	N/A	N/A	N/A

Figure 1

SPECIFICATION CHARACTERISTIC ACCOUNTABILITY

SPECIFICATION: AMS2658 Revision: D

Char. #	Requirement	Zone	Where Accounted For	Meets Req't Y/N	If NO, CA steps taken.	Meets Req't after CA Y/N
1	Purpose: This specification establishes hardness and electrical conductivity acceptance criteria of finished or semi-finished parts of wrought aluminum alloys.	1.1				
2	This specification has been used typically for nondestructive testing of wrought aluminum alloy parts to aid in determining correctness of alloy, temper, and/or heat treatment, but usage is not limited to such applications.	1.2				
3	APPLICABLE DOCUMENTS: The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein.	2.0				
4	The supplier may work to a subsequent revision of a document unless a specific document issue is specified.	2.0				
5	When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.	2.0				
6	TECHNICAL REQUIREMENTS: Equipment: The equipment used for hardness and electrical conductivity testing shall meet the requirements of ASTM E10…	3.1				
7	…ASTM E18…	3.1				
8	…ASTM E1004…	3.1				
9	…or MIL-STD-1537, as applicable.	3.1				
10	Calibration: Periodic calibration of electrical conductivity testing equipment and instrument conductivity standards shall be performed in accordance with the requirements of MIL-STD-1537.	3.1.1				

Figure 2

unacceptable thermal distortion of the assemblies and liquation of the brazing filler metal. The furnace and associated equipment shall be properly maintained in good working order."

When each requirement stated within this paragraph is broken out, it should be as follows:

1. All brazing furnaces shall have automatic temperature control…

2. … and recording devices in good working order …

3. … capable of controlling the temperature profile of the furnace to the requirements of this specification.

4. Furnaces shall have adequate capacity to accomplish uniform heating of the load …

5. …. at the rate required …

6. … to prevent both unacceptable thermal distortion of the assemblies…

7. … and liquation of the brazing filler metal.

8. The furnace and associated equipment shall be properly maintained in good working order.

Using this type of method, you can separate each requirement from a paragraph to stand alone and, when the time comes, account for it by stating what procedure and paragraph it is located in.

When separating requirements from the paragraphs it may be, at first, difficult to differentiate. As time goes on you will get familiar with how and when to separate the requirements. During this part of the process you will also gain a better understanding of the requirements within the specification.

INCLUDING REQUIREMENTS WITHIN A PROCEDURE

Once the requirements have been separated and documented on a characteristic accountability form you will then need to slowly go through each requirement and determine, first, which items are not necessarily requirements but items that merely need to be acknowledged in some way. As an example, AMS2750E paragraph 3.1.1.1 states "Unless specifically noted, requirements apply to all temperature sensor materials." This is not necessarily a straight requirement that you can show evidence of conformance against. Although, even though it is not a requirement, it is not omitted from the characteristic accountability form, as nothing should be left out. Figure 1 shows how this may look on a characteristic accountability form.

The characteristic accountability form should be arranged in such a way that you are able to identify responses to each requirement and, if it is found to be non-conforming, you're able to show what was done to account for it. Figure 2 is an example of this.

With this type of format, the characteristic accountability form may be used as an auditing tool as well. It can also be used to account for specification revisions when they occur.

SUMMARY

Developing characteristic accountability forms for each specification is time-consuming. But, in the end, it is worth the time as you gain a valuable tool to ensure conformance.

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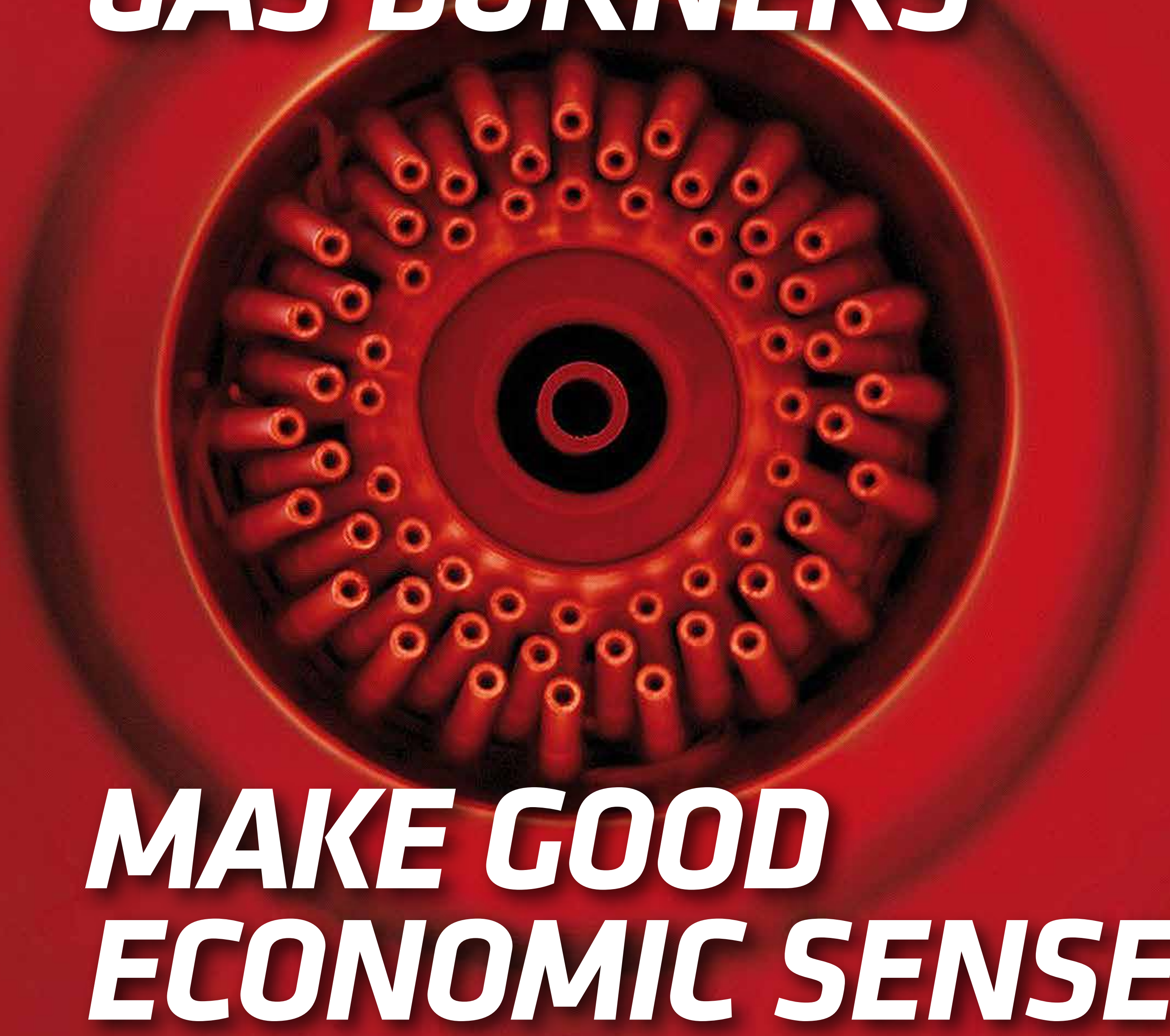
HIGH-EFFICIENCY GAS BURNERS MAKE GOOD ECONOMIC SENSE



One combustion technology offers the best of both worlds in efficiency and emissions.

By STEVEN R. MICKEY, MARTIN G. SCHÖNFELDER, and JOACHIM G. WÜNNING

Even though the price of natural gas is currently low, the investment in high-efficiency gas burners makes sense economically. This article discusses different types of high-efficiency gas burners and radiant tubes now on the market. It will also explain the tradeoff between efficiency and NO_x emissions and highlight a combustion technology which makes it possible to have the best of both worlds. Finally, the article will discuss a correction factor which can be used to adjust NO_x emissions limitations based on combustion efficiency.

GAS BURNER TECHNOLOGY

The graph depicted in Figure 1 shows combustion efficiency (based on the lower heating value) as a function of exhaust gas temperature prior to the heat exchanger (if one exists for a particular burner type). In the case of a direct-fired burner, this is equal to the temperature of the furnace. In the case of a radiant tube burner, this temperature is higher than the furnace temperature by an amount which is related to the heat flux density across the radiant tube (cf. e.g. [1]).

The curve labeled ε = 0 represents a cold air burner (i.e. no combustion air preheat). At a temperature of 1,832 degrees F (1,000 degrees C), the best possible efficiency for this type of burner is approximately 50 percent. Many older cold air burners have an efficiency that is even lower than the theoretical maximum due to a variety of factors such as burner design, lack of maintenance, and improper tuning.

The curve labeled ε = 0.4 represents a burner equipped with either a plug-in recuperator or a central heat exchanger. In this case, the combustion air is pre-heated to approximately 40 percent of the exhaust gas inlet temperature. At the reference temperature of 1,832 degrees F (1,000 degrees C), this burner type has an efficiency in the range of 60 to 65 percent.

The curve labeled ε = 0.6 represents a self-recuperative burner. With this burner type, the heat exchanger is an integral part of the burner, and it sits directly inside the wall of the furnace. This arrangement helps to minimize heat losses to the ambient and thereby provides increased efficiency. In this case, the combustion air is preheated to approximately 60 to 65 percent of the exhaust gas inlet temperature. At the same reference temperature of 1,832 degrees F (1,000 degrees C), this burner type achieves an efficiency in the range of 70 to 75 percent. Self-recuperative burners are available with either a metallic or ceramic heat exchanger. The metallic type can operate at temperatures up to approximately 2,050 degrees F (1,120 degrees C), whereas the ceramic type can typically operate at temperatures up to approximately 2,372 degrees F (1,300 degrees C). Figure 2 shows a cross-section of a self-recuperative burner.

There is a new generation of self-recuperative burners which does not fall within the typical range depicted in Figure 1. This burner type is known as "gap flow." With this design, the burner is equipped with many tiny tubes that serve as heat exchangers. This configuration effectively triples the heat transfer surface area, thereby increasing combustion air preheat to 75 to 80 percent of the exhaust gas inlet temperature. At the reference temperature of 1,832 degrees F (1,000 degrees C), this burner type has an efficiency in the range of 80 to 85 percent. It is available with either a metallic heat exchanger or a combination of a ceramic and a metallic heat exchanger. The metallic type can operate at temperatures up to approximately 1,832

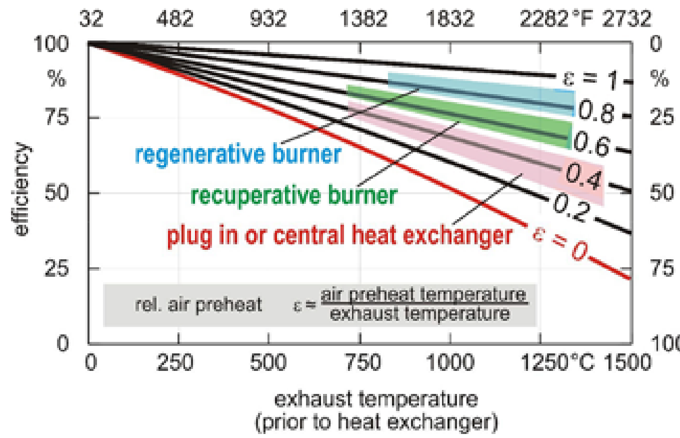


Figure 1: Efficiency vs. Exhaust Gas Inlet Temperature [2]

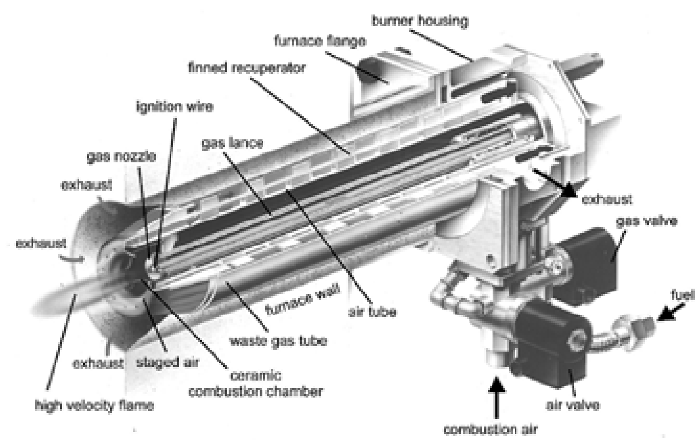


Figure 2: Self-Recuperative Burner [2]

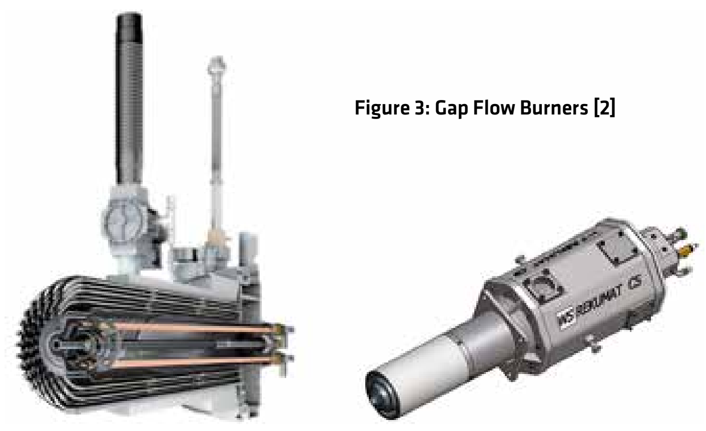


Figure 3: Gap Flow Burners [2]

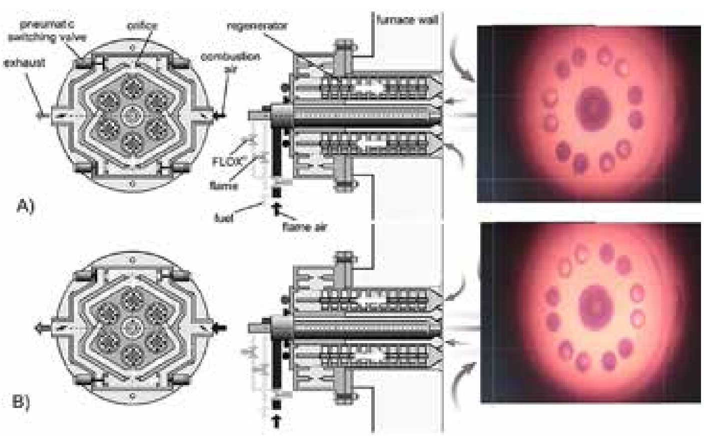


Figure 4: Self-Regenerative Burner [2]

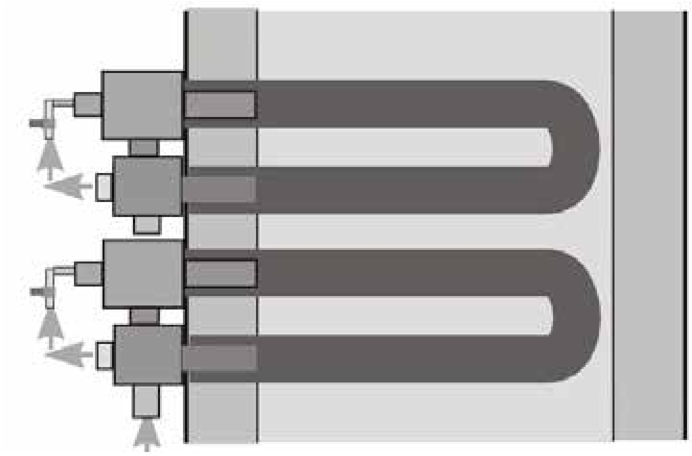


Figure 5: U-tube

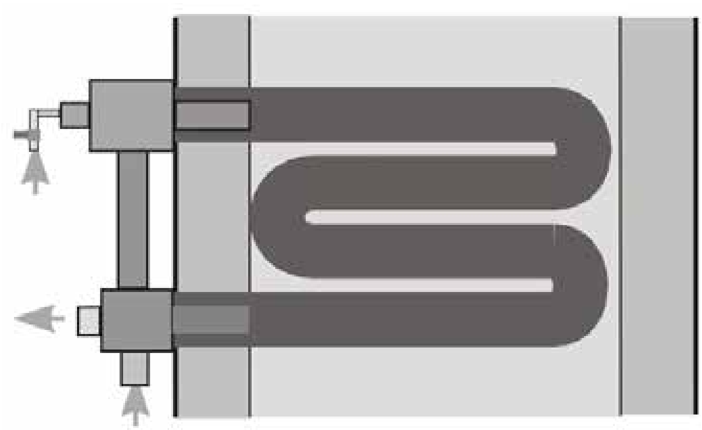


Figure 6: W-tube

degrees F (1,000 degrees C), whereas the ceramic/metallic type can operate at temperatures up to approximately 2,300 degrees F (1,260 degrees C). Figure 3 shows typical metallic and ceramic/metallic gap flow burners.

The curve labeled $\varepsilon = 0.8$ on the graph represents a regenerative burner. This burner type is equipped with heat storage media such as ceramic balls, discs, etc. Heat storage media is therefore in direct contact with either hot exhaust gas or cold combustion air depending on the point in the regeneration cycle. In the first half of the cycle, the hot exhaust gas heats the storage media to a very high temperature. Then switching valves are activated, and the flow path is reversed so that cold combustion air now flows over the heat storage media. With this arrangement, the combustion air is pre-heated to approximately 80 to 85 percent of the exhaust gas inlet temperature. At the reference temperature of 1,832 degrees F (1,000 degrees C), this burner type has an efficiency in the range of 85 to 90 percent. Traditional regenerative burners fire in pairs – one burner fires while the other exhausts and vice versa. A newer type known as the self-regenerative burner integrates all the regenerators and switching valves into one self-contained unit. Each burner contains six passageways, and each passageway contains a row of ceramic honeycomb discs that serves as the heat storage media. At any point in the cycle, three passageways are exhausting, and the other three passageways are admitting combustion air. After about 10 seconds, the switching valves cycle, and the flow path is reversed. Regenerative burners are also available in either metallic or ceramic varieties. The metallic type can operate at temperatures up to approximately 1,832 degrees F (1,000 degrees C), whereas the ceramic type can operate at temperatures up to approximately 2,372 degrees F (1,300 degrees C). Figure 4 shows a cross-section of a self-regenerative burner.

RADIANT TUBES FOR INDIRECT HEATING

In many cases, gas burners fire directly into the furnace chamber. In a number of cases, however, the process requires that work load not be exposed to the products of combustion. For example, some processes require a protective atmosphere, such as nitrogen, to prevent oxidation on the surface of the parts. In these cases, indirect heating is used. One method of indirect heating is to fire the burners into radiant tubes which, in turn, transfer heat to the furnace and work load by virtue of a temperature differential.

Cold air burners, or those that use either plug-in recuperators or a central heat exchanger, are paired with traditional, non-recirculating type radiant tubes. With this tube type, the burner fires into one end of the tube and exhausts out the other. Examples of this tube type are the U-tube and the W-tube (see Figures 5 and 6).

Self-recuperative and self-regenerative burners are paired with recirculating type radiant tubes. These tubes each provide some sort of path for internal recirculation, and the burner fires into and exhausts out of the same end of the tube, leading to improved temperature uniformity over non-recirculating tubes.

In the case of a single-ended radiant tube (see Figure 7), exhaust gases flow through an inner tube and then back toward the exhaust through the annulus between the inner and outer tubes. There is a critical space between the tip of the burner and the beginning of the inner tube assembly. The exhaust gases reach this point, and the high velocity burner jet creates a Venturi effect to draw a portion of the exhaust gases back into the inner tube. In this way, the exhaust gases are recirculated several times before they finally pass over the heat exchanger and out of a port on the burner.

A P-tube (see Figure 8) is similar to a U-tube, except that it has a cross-connecting piece to promote internal recirculation. The burner fires into one leg of the tube, and exhaust gases flow back through the other leg and into the cross-connecting piece. The high velocity burner jet creates the same Venturi effect to draw a portion of the exhaust gases back into the firing leg. Likewise, the exhaust gases are recirculated several times before they finally pass over the heat exchanger and out of a port on the burner.

A Double P-tube (see Figure 9) is like a P-tube, but it has two return legs. In this arrangement, the burner fires into the center leg and the exhaust gases flow back through the side legs. This tube type provides a larger surface area and is therefore used with higher input burners.

NO_x REDUCTION TECHNIQUES FOR HIGH EFFICIENCY BURNERS

Traditionally, there has been a tradeoff between combustion efficiency and NO_x emissions. In order to achieve high efficiency, it is necessary to preheat the combustion air to high temperatures. These high combustion air preheat temperatures lead to high peak flame temperatures, which are the primary driver in NO_x formation. NO_x emissions are an exponential function of peak flame temperature, so they tend to increase rapidly with increasing furnace temperature and increasing combustion air preheat temperature. There are a number of techniques available to help combat this problem.

One such technique is known as air staging. With this technique, a portion of the combustion air is mixed with all of the fuel to generate a partial reaction and release some heat. Then, the rest of the combustion air is introduced a bit further downstream to complete the reaction and release some more heat. In this way, the reaction is spread out rather than concentrated at one point. This serves to reduce peak flame temperature and thereby decreases NO_x emissions.

High velocity combustion also serves as an NO_x reduction technique. Mixing exhaust gases thoroughly inside the furnace or radiant tube has a temperature averaging effect. Therefore, peak flame temperatures are reduced, and NO_x emissions are decreased accordingly.

Likewise, flue gas recirculation can also serve as an NO_x reduction technique. Exhaust gases are very hot, but not as hot as a flame. So pulling a portion of the inert exhaust gases back into the flame front actually produces a cooling effect. This effect serves to lower peak flame temperatures and hence NO_x emissions.

All of these techniques are quite effective under normal conditions. However, when combustion air preheat temperatures reach very high levels, as in the case where self-recuperative or (self-) regenerative burners are used, the techniques are frequently not enough to reduce NO_x emissions to acceptable levels. Fortunately, a revolutionary combustion technology has been developed to resolve this problem. This technology is known as FLOX combustion, or FLameless Oxidation (cf. e.g. [1] or [3] for more information). With this special technique, fuel and air are mixed with recirculated exhaust gases and a spontaneous combustion reaction that produces no visible flame takes place. By eliminating the flame from the combustion reaction, peak temperatures are reduced dramatically, and this suppresses NO_x emissions to a fraction of the level achievable with traditional NO_x reduction techniques. This process only occurs above the auto-ignition temperature, and some safety factor is required; so the FLOX transition temperature is typically set at 1,550 degrees F (850 degrees C). Below this temperature, the burner operates in a normal mode of combustion with a flame. Once the FLOX transition temperature is reached, the gas is injected in a fashion which produces a more favorable mixing/recirculation pattern and prevents flame formation and attachment. If the temperature drops below 1,550 degrees F (850 degrees C), the burner automatically reverts to “Flame” mode.

CORRECTION FACTOR FOR NO_x LIMITATIONS

NO_x emissions are limited by law or code in many locations throughout North America. While this is beneficial for the environment and society, the method used to define the limit can significantly alter the outcome if it does not account for the full extent of influencing factors. In particular, this is the case for combustion efficiency in industrial furnaces. A one-dimensional emissions limitation standard can lead to adverse effects, preventing a well-intended initiative from achieving its goals or even leading to the exact opposite. A very simple correction factor can be applied to properly reflect combustion efficiency and therefore achieve the intended goals.

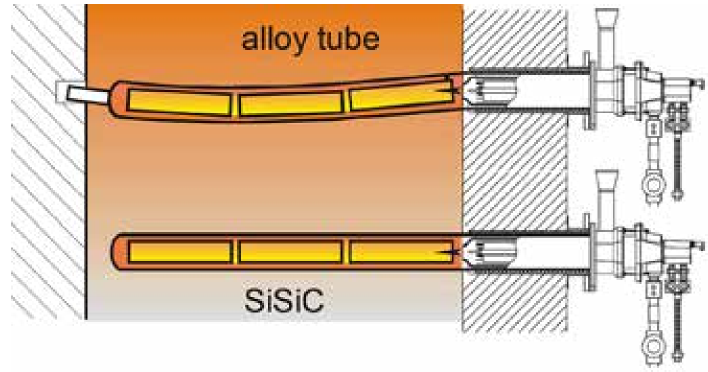


Figure 7: Single Ended Radiant Tube [2]

Figure 8: P-tube [2]

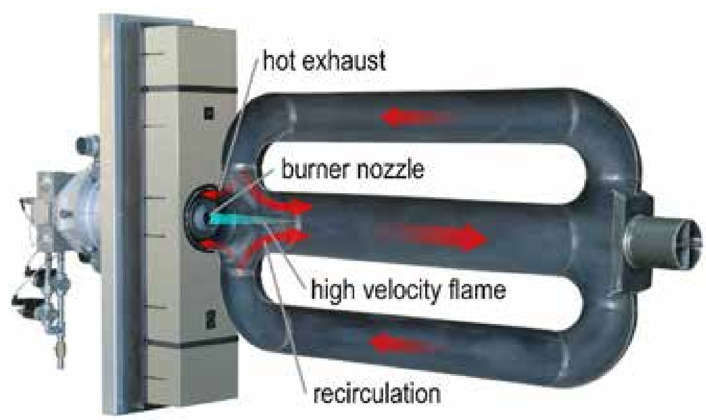


Figure 9: Double P-tube [2]

In general, there are two possible methods to better define the emissions limitation in order to achieve the intended objective:

› **1.** The overall absolute emissions of a pollutant can be limited (e.g. the limit could be expressed in pounds per year).

› **2.** The limitation of an emissions concentration in the exhaust gases can be corrected with an efficiency factor.

While Option 1 seems straightforward at first, it can be difficult to verify compliance in real-world applications, since there is typically no emissions monitoring device permanently installed to prove the true absolute amounts of a pollutant emitted per year. Option 2 could be used in a way very similar to today’s standard approach. Currently, the limitation of the concentration of a pollutant in the exhaust gases is spot-checked over the course of a typical operational cycle. In the case of NO_x emissions, an exhaust gas analyzer probe is inserted into the exhaust system, and several

NO_x readings are taken over a certain period of time. These values are then averaged to compare them to the limit previously set for the audited furnace.At the same time, the exhaust gas analyzer typically also determines the efficiency of the combustion system based on the CO_2 content and the temperature of the exhaust. These efficiency readings (or the published/guaranteed efficiency from the manufacturer) could then be used to adjust the emissions limitation.

Assume that the reference system (ref) is defined as the most efficient combustion technology that still achieves the emissions concentration limit (E_B) as defined by the authorities.

If the reference technology is able to achieve lower specific emissions, E_B should be set according to this lower value. Furthermore, assume that there is a more fuel-efficient technology (eff) available that does not meet the limitation for specific emissions.

The corrected emissions concentration limit (E_N) shall serve as the new limit for the high-efficiency technology, because it represents the value at which the total absolute emissions of the more efficient system are equal to those of the less efficient system.

The formula is as follows:

$$E_N = \frac{\eta_{eff}}{\eta_{ref}} * E_B$$

As an example, assume that a forge furnace operates at 2,280 degrees F with cold air burners.

The emissions concentration of the cold air burners (E_B) = 0.06 lb/MMBtu (50 ppm).

The efficiency of the cold air burners (η_{ref}) = 37 percent.

The company is planning to replace the cold air burners with regenerative burners.

The efficiency of the regenerative burners (η_{eff}) = 78 percent.

For this example, the corrected specific emissions limit (E_N) for NO_x computes to:

$$E_N = \frac{78\%}{37\%} * 0.06 \frac{lb}{MMBtu} @3\% \, O_2 = 0.13 \frac{lb}{MMBtu} @3\% \, O_2$$

Although the regenerative burner system emits 0.08 lb/MMBtu (70 ppm) @ 3 percent O_2, it stays well below the corrected limit (E_N) of approximately 0.13 lb/MMBtu (105 ppm) @ 3 percent O_2, thus saving 33 percent NO_x emissions per year compared to the cold air burners.

CONCLUSION

There are a variety of burner types available with varying levels of complexity and efficiency.

Most high-efficiency gas burners preheat the combustion air to increase the combustion efficiency. Traditionally, there is a tradeoff between efficiency and NO_x emissions; however, FLOX combustion makes it possible to have the best of both worlds.

Finally, if combustion efficiency is not considered when establishing a limitation for NO_x emissions, this can lead to the selection of equipment which actually produces higher absolute emissions.

However, a very simple correction factor can be applied to adjust NO_x emissions limitations to properly reflect combustion efficiency.

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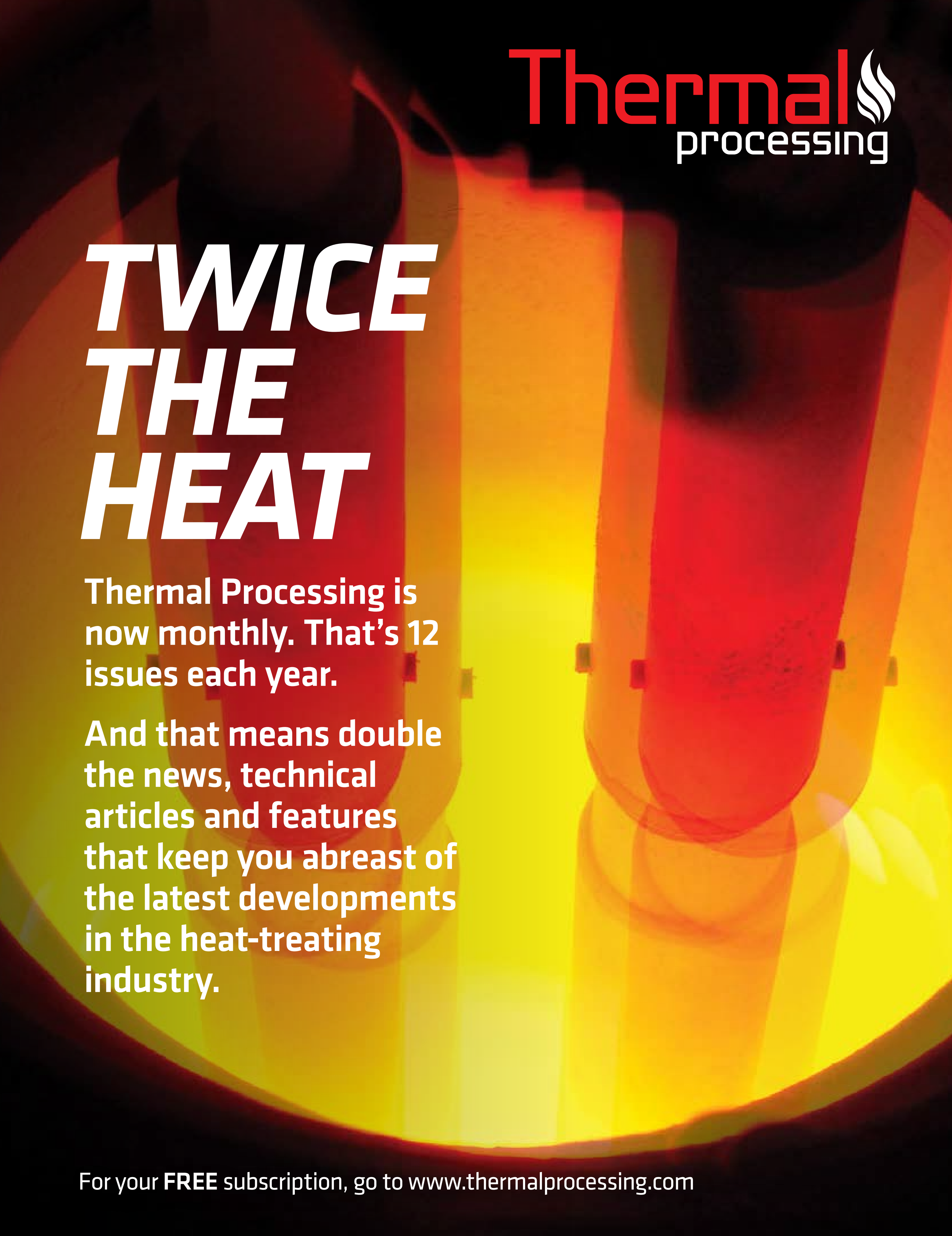
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SELECTING THE CORRECT INDUSTRIAL OVENS FOR FINISHING APPLICATIONS

A powder coating cell with the powder booth on the right and curing oven on the left. (Courtesy: Wisconsin Oven Corporation)

By doing a little homework and asking the right questions, you can select the best oven for your finishing needs.

By MIKE GRANDE

Finishing is defined as "completing the manufacture or decoration of a material or product by giving it an attractive surface appearance." In industrial applications, this most often means applying paint or powder to the surface, and curing it in an oven. A wide variety of products in every industry has a finish coat applied. When selecting a paint or powder, many formulations are available, and durability, cost, and coverage must be considered. Just as importantly, the correct oven must be selected for providing the finish cure. Industrial ovens are not all created equal, and there are ovens specifically designed for curing applications.

To select a curing oven, it is first necessary to determine the time and temperature your coating requires in the oven. Most industrial ovens designed for curing are rated at a maximum of about 500 degrees Fahrenheit (260 degrees Celsius). This is sufficient for most paint and powder applications, although there are a few coatings (Teflon for example) that require a higher temperature. Ask your paint/powder supplier what cure time and temperature are required for your coating. This will be necessary in order to set up your line or finishing cell, and to select the proper oven. Also ask what temperature uniformity is required. A common uniformity for curing ovens is plus or minus 10 degrees Fahrenheit, (5.5 degrees Celsius). This means that the temperature is not greater than 10 degrees Fahrenheit above the setpoint, nor less than 10 degrees Fahrenheit below the setpoint, anywhere in the usable work chamber; an example of a typical temperature uniformity specification would be 350 degrees, ±10 degrees Fahrenheit (177 degrees, ±5.5 degrees Celsius.)

PROPERLY DESIGNED RECIRCULATION SYSTEM IS CRITICAL

The heart of every industrial oven is its air recirculation system. It consists of the recirculation fan that forces the heated air to circulate throughout the work chamber, the ductwork that distributes the air, and the louvers or nozzles that accelerate and direct the air toward the load inside the oven. The most common airflow orientation is combination flow. In this design the air is delivered from supply ducts located on both side walls, near the bottom of the work chamber (Figure 1). It passes through and around the load, uniformly heating it in the process. The air then is drawn up into the return duct at the top of the work chamber, where it returns to the heating/recirculation system to be heated again.

Avoid using top-down airflow in a batch oven (Figure 2). In this design, the air supply ducts are at the top of the work chamber, and direct the air vertically downward onto the load. It is often less expensive than combination airflow, but it can leave the bottom of the load insufficiently heated, which will lead to undercured paint or powder. This is because hot air rises, and after it leaves the supply duct it will tend to turn back upward to return to the heating/recirculation system on the roof. In addition, the air can have difficulty penetrating the load, leaving the bottom of the parts unheated. Some low-budget ovens do not have any ductwork to distribute the air at all, just a vent to deliver the air into the work chamber at one location, in the rear for example. This is inadequate for curing applications.

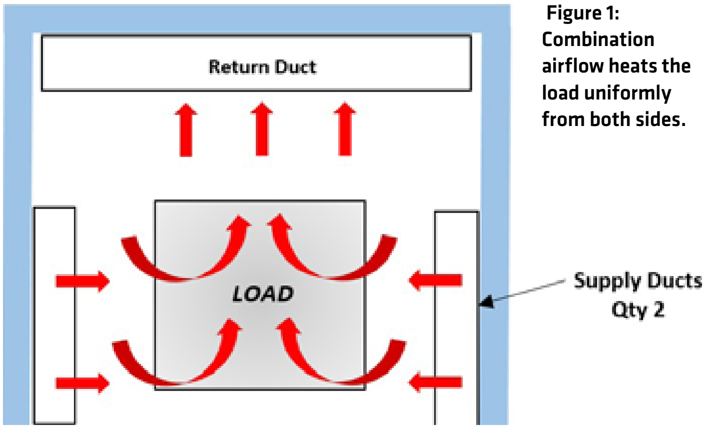


Figure 1: Combination airflow heats the load uniformly from both sides.

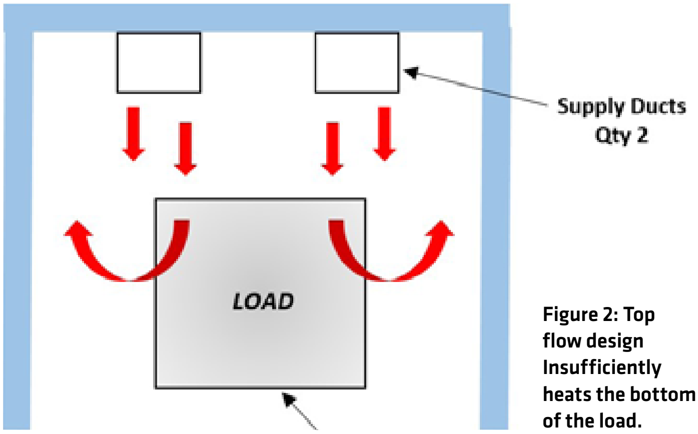


Figure 2: Top flow design Insufficiently heats the bottom of the load.

It is important the recirculation fan be sized correctly. If it is too small, it will not evenly heat the load. Too large, and it will blow the powder off the load and consume excess energy. Generally speaking, curing ovens should be designed with a minimum of six to eight air changes per minute. This refers to the recirculation airflow in cubic feet per minute (CFM), divided by the volume of the work chamber in cubic feet. A 5' W x 5' L x 5' H work chamber, for example, has a volume of 125 cubic feet (5 x 5 x 5). The minimum recommended recirculation fan should be sized for a minimum of 6 x 125, or 750 CFM.

Although a higher recirculation rate provides superior temperature uniformity and better heating performance, powder coating ovens must be designed for a reduced air velocity where the heated air leaves the supply ducts. If the velocity is too high, the air can blow the powder off the parts prior to gelling of the powder. This is done by adjustment of the supply louvers during testing, prior to shipment. The louvers should be adjustable to allow fine-tuning of the air distribution as necessary. One common way this is done is using bendable flaps stamped in an H-pattern (Figure 3). This offers a wide range of adjustability, and can't loosen and rattle as screwed louvers can.

Another alternative is to use a variable frequency drive on the recirculation fan to slow the blower down at the beginning of the cure cycle, then speed it up after the powder has gelled. This costs a little more, but provides the best of both worlds: superior heating and uniformity during the cure cycle, while avoiding blowoff of the powder at the beginning of the process.

HIGH-QUALITY COMPONENTS AND MATERIALS MAKE A BIG DIFFERENCE

When researching an oven purchase, you will find the features and components offered vary between different oven suppliers. Look for suppliers that manufacture ovens with high-quality, name-brand components, designed for ease of use and long life. A few examples are:

› **Door hinges:** Ball bearing hinges are preferred over friction style hinges. Unlike friction or strap hinges, they use ball bearings to support the doors. This prevents the doors from sagging, offers longer life and ease of opening and closing.

› **Door handles:** The door handles are the primary interface point between the operator and the oven. Better handles improve operator comfort and reduce fatigue. Look for large, high quality, ergonomic door handles that stay cool to the touch.

› **Control components:** Reputable oven suppliers use name-brand components mounted in a NEMA 12 enclosure, with EMT conduit on the oven itself, and 36-inch maximum flexible conduit runs.

› **Airflow switches** used on the recirculation and exhaust fans should include an indicator light to visually show when the switch is made.

› **The oven should be designed to meet the specifications set forth by NFPA (National Fire Protection Association) publication 86.** This document specifies the methods and devices required to meet industry-accepted standards of safety. The oven manufacturer's proposal should state the oven will comply with NFPA 86.

› **High-efficiency construction.** Different oven manufacturers have variations in the way they design and assemble the oven body. Although the basic construction uses a steel sheet exterior and an aluminized steel sheet interior with insulation sandwiched in between, some oven suppliers offer a high-efficiency design that uses reduced through metal between the interior and exterior. This is done using specially designed "rails" that maintain the spacing between the two, or with pinned construction that uses threaded rods instead of rails. A high-efficiency design will reduce energy use and provide a cooler oven exterior.

› **Direct drive fans.** The industry standard for high quality and longevity, direct drive recirculation and exhaust fans offer reduced energy use and maintenance. There are no drive belts in between the motor and the fan. Instead, the motor wheel is mounted directly to the motor shaft. Direct drive fans are available up to 10 HP, above which the fans must be belt-driven.

MAKE SURE YOUR OVEN IS FULLY ASSEMBLED BEFORE SHIPMENT

Reputable oven manufacturers fully assemble and test their ovens before shipment. This is in contrast to ovens that are shipped unassembled, sometimes referred to as knocked-down, then erected on the customer's factory floor. Since knock-down ovens are not assembled and tested before shipment, design problems or faulty components are not identified until after the equipment is fully installed. This causes delayed startup and lost production while a solution is being implemented. Heaters, blowers, and controls each typically have a lead time of four to six weeks, so it can be devastating to the installation schedule if any of these items are found to be defective. In addition, the price for a knockdown oven may not include the cost of assembly, and so may appear artificially low in comparison to an oven that is properly assembled and tested before shipment.

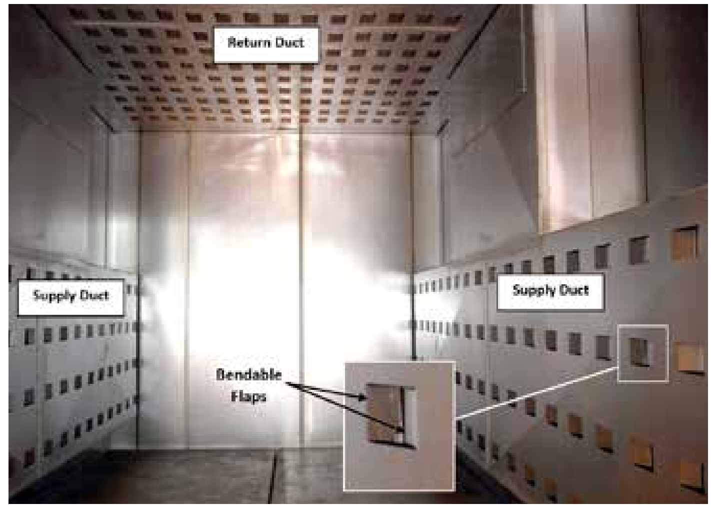


Figure 3: Adjustable H-pattern style supply louvers located in supply and return ducts.

Figure 4: The body of this batch oven is designed to be split into three sections for shipment.

For larger ovens that are too big to ship on a truck, or too large to fit through the doorway into your building, the oven body can be split into smaller sections (Figure 4). The sections are then bolted together at the jobsite for reassembly. The sections can be bulky, and an experienced rigger must be used to remove them from the trucks and set them in place. Well-established oven suppliers can perform the installation for you. This is a valuable service that ensures a trouble-free installation.

TESTING BEFORE SHIPMENT IS CRITICAL

Once you know the temperature uniformity required for your coating, the oven manufacturer will design your oven to achieve it, and then uniformity test the oven after it is built, to confirm the actual temperature uniformity has been attained. Correct uniformity is achieved by using sufficient recirculation airflow, the proper insulation, and the correct airflow pattern. Oven suppliers can do calculations as guidelines for these parameters, but it is necessary to test each oven prior to shipment to verify the uniformity has been achieved. Most often, a nine-point test is performed, but larger ovens may require 12 points, 15 points, or more. Make sure your chosen oven manufacturer performs this testing, and provides a document (Figure 5) certifying the oven has passed the required uniformity test.

Beware if the oven supplier merely states the oven is capable of achieving the required uniformity, but doesn't provide a certified

Customer: ABC Company
Job Number: 08867A
Date: 1/27/2016 (ACCEPTANCE TEST DURING CUSTOMER VISIT)
Technician: DG
Data Logger: Agilent
Test Parameters: AMS2750E (type A): (30) point test at 200°F (+/-5°F)
Calibrated Test Leads: Lot#14091-233
Calibration Correction(s): (-0.1) (Implemented Through Logger)
Calibration Range: Min: 195°F Max: 205°F
Controller Offset: None

	Locations								
Time	PT#1	PT#2	PT#3	PT#4	PT#5	PT#6	PT#7	PT#8	PT#9
1/27/16 9:29 AM	83.9	84.1	84.2	84.4	84.2	84.1	84.3	84.3	84.3
1/27/16 9:31 AM	85.7	86.0	86.2	86.2	86.2	86.1	86.3	86.3	86.2
1/27/16 9:33 AM	87.3	87.6	87.8	87.8	87.7	87.7	87.9	87.9	87.9
1/27/16 9:35 AM	93.8	94.4	96.4	96.4	95.2	94.7	95.0	95.4	95.8
1/27/16 9:37 AM	124.2	125.3	129.5	128.7	126.9	125.7	126.5	127.3	127.5
1/27/16 9:39 AM	149.1	150.4	155.0	153.8	151.9	150.3	151.8	152.2	152.5
1/27/16 9:41 AM	170.5	171.8	176.2	175.0	173.3	171.6	173.2	173.8	174.0
1/27/16 9:43 AM	187.9	188.9	192.5	191.8	190.1	188.4	189.8	190.5	190.7
1/27/16 9:45 AM	192.9	193.7	196.2	195.4	194.4	193.4	194.3	194.8	194.8
1/27/16 9:47 AM	194.9	195.5	197.3	197.0	196.1	195.1	196.1	196.2	196.4
1/27/16 9:49 AM	196.3	196.9	198.3	198.0	197.3	196.6	197.2	197.5	197.6
1/27/16 9:51 AM	196.7	197.1	198.4	198.1	197.5	196.9	197.5	197.8	197.8
1/27/16 9:53 AM	196.8	197.4	198.3	198.2	197.6	197.0	197.6	197.8	197.9
1/27/16 9:55 AM	196.9	197.4	198.1	198.0	197.5	197.1	197.5	197.7	197.8
1/27/16 9:57 AM	196.9	197.4	198.3	198.1	197.7	197.2	197.6	198.0	197.9
1/27/16 9:59 AM	196.9	197.2	198.0	198.0	197.4	197.0	197.5	197.6	197.7
1/27/16 10:01 AM	196.9	197.3	198.0	198.0	197.5	197.1	197.6	197.7	197.8
1/27/16 10:03 AM	197.1	197.5	198.2	198.1	197.7	197.3	197.7	197.8	197.9
1/27/16 10:05 AM	197.0	197.3	197.9	197.9	197.5	197.1	197.5	197.7	197.7
1/27/16 10:07 AM	197.0	197.3	197.9	197.9	197.4	197.2	197.6	197.7	197.7
1/27/16 10:09 AM	197.0	197.4	197.9	197.9	197.5	197.2	197.6	197.7	197.7
1/27/16 10:11 AM	196.9	197.2	197.8	197.8	197.4	197.2	197.5	197.7	197.7
1/27/16 10:13 AM	196.8	197.2	197.8	197.9	197.3	197.1	197.2	197.6	197.6
1/27/16 10:43 AM	197.0	197.2	197.7	197.7	197.4	197.2	197.4	197.6	197.6
Time	PT#1	PT#2	PT#3	PT#4	PT#5	PT#6	PT#7	PT#8	PT#9

Max:	198.4
Min:	196.3
Average Spread:	2.1
% OUTPUT AT SOAK:	0.0%

Figure 5: A temperature uniformity certification provided by an oven manufacturer.

test on your specific oven prior to shipment. This means proper adjustments have not been done to ensure the oven will meet the uniformity criteria specified by your coating supplier. After installation you may find your parts are not curing properly. Without a certified uniformity test, you won't know if the oven is the cause, or if some other variable is to blame, such as the paint formulation, the part cleanliness, or improper application, etc. This makes root cause analysis difficult, and causes unnecessary downtime and delays.

STRONG SUPPORT AFTER THE SALE

Look for an oven supplier that offers good support of your equipment after installation and startup are complete. They should have a team of factory-trained service technicians available to perform service work and PM on your equipment. Avoid companies that outsource their service work to third parties. These technicians aren't factory-trained, don't know the equipment as well, and aren't as responsive as a company's own technicians.

Take note of the warranty being offered. Some oven suppliers offer only a 30-day warranty, which is less than the industry norm, and should be a warning sign. Look for a company offering a three-year or five-year warranty. This tells you the components they choose and their manufacturing standards are such that they have confidence in the longevity of their equipment, and they are willing to stand behind it.

FIND THE RIGHT PARTNER

By doing a little homework and asking the right questions, you can select the best oven for your finishing application. It is important to find a reputable oven manufacturer you can rely on to offer the best equipment for your needs.

ABOUT THE AUTHOR

Mike Grande is vice president of Sales at Wisconsin Oven Corporation.

THE FUTURE OF KILN LINING FIBERS

A typical brick-fired heater in operation. (Courtesy: Morgan Advanced Materials)

Superwool® XTRA, a low-biopersistent fiber, meets stringent environmental requirements in addition to high-temperature tolerance and improved pollutant resistance.

By GARY JUBB

Lining iron and steel furnaces is critical to extend the life of the furnaces and to protect the purity of the metals being heat treated. Therefore, choosing the best material to meet these needs is crucial. For many years, the first-choice material for the industry has been refractory ceramic fiber (RCF), which can withstand the extreme temperatures within the furnace and has strong resistance to pollutants.

However, RCF has environmental, health, and safety (EHS) concerns. After numerous studies, RCF was classified as a category 1b carcinogen in Europe and is considered a substance of very high concern (SVHC) under REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals).

There's already pressure from European legislators to find safer alternatives, under the Carcinogens Directive, where technically possible, substitutes to RCF should be used. RCF is currently under consideration for further regulation in Europe, which will make the use of RCF more difficult with constraints and stringent controls likely to come into force.

This is compounded by the increasing commitment of major industrial companies and trade associations to improve green standards, placing the onus on the fiber industry to find alternatives that match the performance of RCF without adverse effects.

Backed by almost 10 years of research and development and more than 30 months in trials at customer furnaces, Morgan Advanced Materials' Thermal Ceramics business has launched Superwool® XTRA, a material that delivers the performance of RCF without the inherent EHS risks associated with it.

REINVENTING RCF

Since the 1990s, the Superwool brand has been a mark of quality in creating low bio-persistent (LBP) fibers that minimize health risk to furnace installers, operators, and other factory employees. Morgan Advanced Materials has achieved major advances in the performance of LBP fibers through Superwool HT™ and Superwool Plus™ grades. The evolution of the Superwool family of materials has been recognized with the Queen's Award for Enterprise: Innovation (2003), as insulating fiber experts have continued to innovate to meet — and anticipate — market demand.

This demand is now for a material that balances the performance of RCF with more stringent environmental safety. This is a significant challenge, because RCF has really strong characteristics that make it ideal for use in chemical processing, iron and steel processing, and ceramics factories. For example, RCF is very resistant to attack by alkali-based pollutants, something that needs to be considered when developing a viable alternative.

That's why, in recent years, the focus at Morgan Advanced Materials' Fibre Centre of Excellence in Bromborough, U.K., has been to challenge the assumptions in LBP chemistry. Rather than keep trying to make marginal gains in LBP performance, Morgan Advanced Materials flipped its approach and revisited the RCF itself. What the industry wants is an RCF equivalent that has low bio-persistence, so that's how development has been approached.

Lining iron and steel furnaces is critical to extend the life of the furnaces and to protect the purity of the metals being heat-treated. (Courtesy: Morgan Advanced Materials)

Superwool XTRA is an alkali metal silicate fiber especially combined to deliver the optimum combination of RCF and LBP properties.

A DIFFERENT FIBER

Superwool XTRA delivers the strength that industrial applications need, both in terms of its resistance to high temperatures and pollutants, but also its improved EHS credentials.

With a classification temperature of 1,450 degrees C, Superwool XTRA offers a performance equal — and in many cases superior — to RCF. The fiber is unusual in that it expands when heated to close shrinkage gaps at high temperatures. This is reversible, so when it cools, the shrinkage gaps return and are visible. Once heated again, it expands and closes the gaps again.

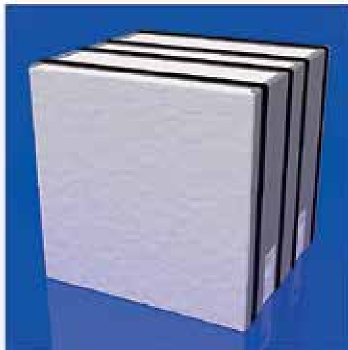
This means there is no reason to fill the shrinkage gaps with blanket — the normal practice for RCF. With a 2-percent shrinkage, open gaps with RCF normally require an installer to fill these gaps with thin blanket. This is not only time-consuming, but more material is required, adding to costs.

In terms of EHS qualities, Superwool XTRA is exonerated from any carcinogenic classification under nota Q of directive 97/69EC.

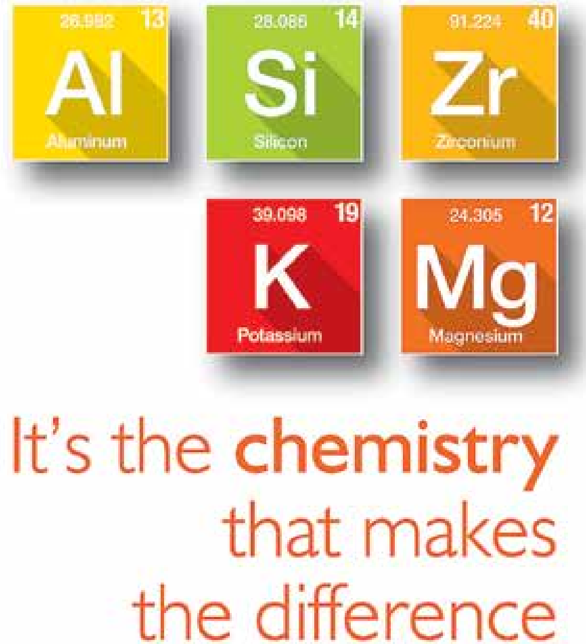
A key benefit is Superwool XTRA does not form crystalline silica, a common by-product when many refractories are heated to high temperatures. Having a fiber that produces no crystalline silica is a major breakthrough for the industry, which enhances EHS compliance.

The demand now is for a material that balances the performance of RCF with more stringent environmental safety. This is a significant challenge, because RCF has really strong characteristics that make it ideal for use in chemical processing, iron and steel processing, and ceramics factories.

Superwool XTRA Blanket



Superwool XTRA Pyro-Stack Modules



Superwool XTRA Paper

Superwool XTRA Unifelt

Superwool® XTRA™ Lining Materials in a variety of forms, from blanket, to Pyro-Stack modules, to paper and unifelt. (Courtesy: Morgan Advanced Materials)

A CLASS OF ITS OWN

Superwool XTRA has been extensively tested by Dillinger, at its mill for heavy plates in Germany. At the mill, as well as the pusher type furnaces used for slab reheating, there are three shuttle kilns for ingot reheating and for support of the pusher type furnaces on maintenance or heavy load. This environment was chosen for testing because of the high temperatures and high levels of impurities in their atmospheres, including sodium, potassium, iron, and chromium. Over time, these impurities weaken the lining, leading to high shrinkage and surface degradation. This, in turn, increases thermal conductivity and increases heat losses and often damage to the steel infrastructure of the furnace.

A small section of wall in shuttle kiln Number 2 was selected for an initial feasibility test, because the risk of any problems resulting in long downtime issues was considered to be low. Tested against the existing lining material used in this application, after six months of firing, Superwool XTRA showed 50 percent less shrinkage compared to RCF. Where the existing lining material was hard, full of cracks, and had discolored noticeably into a dark brown, the surface of Superwool XTRA remained softer, with no surface cracks, and there was little change in color. This proves that the material is outperforming existing RCF solutions in environments with high pollutant levels.

This success led the customer to reline half of the roof of shuttle kiln Number 3 for further testing, with similarly positive results. The customer has now decided to switch entirely to the new Superwool XTRA grade for the benefit of both the non-regulated status of this product and its superior chemical resistance and shrinkage performance, relative to RCF.

The refractory maintenance department has since presented Superwool XTRA to Dillinger's EHS Department as a working alternative to RCF. The key messages in its presentation are that Superwool XTRA will reduce risk for workers as well as reducing costs for installation, wrecking, and disposal. There are additional benefits in no or little maintenance for the filling of any shrinkage gaps, and no reduction in the insulating performance. As a result of this, Dillinger decided to set Superwool XTRA as their new standard, replacing the formerly used Cerachem® Fibre.

This example confirms the potential of Superwool XTRA. EHS concerns are an increasingly important driver in terms of meeting legislative compliance — and Superwool XTRA offers exceptional performance alongside low bio-persistence and no formation of crystalline silica.

From a commercial standpoint, the bigger benefit of this breakthrough in LBP is that it matches, and even exceeds, the established performance of RCF. Superwool XTRA is the future for applications requiring high temperature fibrous insulation.

ABOUT THE AUTHOR

Gary Jubb is Morgan Advanced Materials' Fibre Center of Excellence lead.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COMPANY PROFILE ///

PAULO

HELPING CUSTOMERS SUCCEED

A vacuum furnace at the Cleveland plant with an all-metal hot zone to support critical aerospace component processing. (Photos courtesy: Paulo)

For 75 years and counting, Paulo has made extensive investments in processes, people, and technology to ensure quality and consistency at every level of heat treating.

By KENNETH CARTER, Thermal Processing editor

The heat-treat industry is, ultimately, a service industry. And the experts at Paulo want to make sure its customers are as successful as possible.

"Our guiding words are to help our customers succeed," said Phil Harris, marketing manager with Paulo. "We're only successful if our customers are successful. We're helping people make the best parts that they can, helping them get the competitive advantage and if that's happening, they keep sending us work. That's the guts of it."

To that end, Paulo has been applying some of the most advanced heat-treat technology and processes to some of the world's most important manufacturers.

"We are experts in thermal processing and metal finishing," Harris said. "That includes heat treatment, brazing, plating, and now Hot Isostatic Pressing. And we do it with a wide spectrum of equipment types and processes."

WIDE RANGE OF HEAT-TREAT OPTIONS

Some of Paulo's myriad of heat-treating services include austempering, martempering, gas nitriding, vacuum heat-treating, annealing, solution treating, precipitation hardening, ferritic nitrocarburizing, case hardening, through hardening, induction heat treating, cryogenic and deep freezing, plug and press quench, and flattening and straightening.

"We operate a wide variety of furnaces," Harris said. "We have invested heavily in batch integral quench, continuous belt, and vacuum furnaces. And most recently, we've expanded into the hot isostatic pressing realm. We've bought a HIP furnace that will be up and running in the third quarter of this year."

One of the reasons Paulo can offer so much to its customers stems from the company's investment in people, according to Harris.

"We have a disproportionately large engineering staff compared to a lot of other heat-treaters," he said. "We've got the industry's largest staff of metallurgists who support our process design and conduct failure analyses. They also help us win new jobs while making current jobs better through continuous improvement. We've also got a skilled in-house engineering department that designs customized furnace controls, and equipment installation. We buy a lot of furnaces, but we never buy them off-the-shelf. We always add our own bells and whistles, custom controls that account for what we've learned over the years so that we provide the precision and repeatability that customers depend on."

Paulo's continuous belt furnaces have world-class control systems enabling repeatable quality processing at high volumes.

PROBLEM SOLVERS

And having a large base of engineering means that challenges are met with enthusiasm, not dread, according to Harris.

"We love problem solving. We like the hard jobs, and I think that comes down to the culture and having so much engineering support internally. We very rarely have to go to the outside," he said. "We will if we are met with a new challenge, but we're leaning on decades of knowledge and experience. We keep track of data obsessively, so we can always look back and find a similar problem that we've solved."

Paulo is able to do a deep dive into metallurgical evaluations where the company's experts aid customers in determining what success should look like for the parts that might be giving them trouble, according to Harris.

"We're looking at the whole supply chain. We've got our little part in it, but as you know, everything from material choices to how the parts are manufactured can contribute to an issue that doesn't crop up until heat treat," he said.

BEGAN IN 1943

It's that kind of continued growth and attention to problems — both large and small — that have contributed to Paulo's success that has spanned 75 years.

In 1943, Ben and Pauline Rassieur started Paulo Products, named after Pauline. The company offered heat-treating services using homemade salt baths and second-hand tempering furnaces.

Paulo has been family-owned and operated since the beginning,


Tool and Die heat treatment is a specialty of Paulo, where investments in high pressure quench vacuum furnaces are key to success.

A delivery truck from the 1950s at the first location in St. Louis, Missouri. Paulo has been heat treating since 1943.

according to Harris. The husband-and-wife founders worked for a mining company that still does business with Paulo.

"We still heat-treat for them," he said. "(Ben and Pauline) decided to strike out on their own doing some heat-treating — which they had done in a captive way at the mining company — and opened up a small shop in a rented space. It was wartime, so they couldn't really buy furnaces. They went to a junkyard and pieced together some salt pots themselves and started heat-treating."

The Rassieurs were planning to eventually make a product, which they did attempt a few different times, but it never took off, so they stuck with heat-treating, according to Harris.

But that original plant, based in St. Louis, Missouri, continued to grow organically for many years, and Paulo opened a plant in Kansas City in 1972.

"We heard from a steel supplier that there wasn't a good vacuum heat-treater in Kansas City, so we opened up a plant and grew that," Harris said. "Then through the '80s, we did a bunch of acquisitions."

MEXICO EXPANSION

At one point, Paulo had seven facilities across the Midwest and Southeast. By the early 2000s, a couple of those were consolidated, but Harris said Paulo is moving beyond the southern U.S. border into Mexico.

"Our most recent big expansion was down into Mexico," he said. "Just this last year, we opened a facility in Monterrey."

Part of that growth, while keeping a firm grasp of the company's roots, is something Harris considers one of Paulo's proudest achievements.

"I think growth can be tough. Sometimes companies lose their way as they grow from one shop to two and from two to five or more," he said. "Maintaining our culture and that family atmosphere even as we grow larger and larger is key. I think that's something to be proud of: knowing that when people send their parts to a Paulo plant, they can have faith that it's getting run correctly, whether it's St. Louis or Cleveland or whether it's now down in Mexico."

"Maintaining our culture and that family atmosphere even as we grow larger and larger is key. I think that's something to be proud of."

Crossing the border and being able to help and support a customer doing manufacturing in Mexico was a definite milestone for Paulo, according to Harris.

"That was a big deal for us," he said.

As Paulo eyes the next 75 years, Harris said he expects the company's heat-treat capabilities will continue to be an essential component of the manufacturing economy.

"We're not going anywhere," he said. "We continue to be family-owned and operated and the drive to support our customers through new processes, technology, and investment continues. We will be there to help our customers be successful with whatever changes come their way."

MORE INFO www.paulo.com

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Q&A /// INTERVIEW WITH AN INDUSTRY INSIDER

MIKE PAPONETTI /// SOUTHEAST SALES MANAGER /// SOLAR ATMOSPHERES

"I'm here to bring continued awareness of Solar's vacuum processing capabilities in the Southeast."

You were recently promoted to Southeast Sales Manager. How does this new position differ from your previous one?
In the last position, I was a regional sales manager. I worked more on growing sales in certain segmented markets, and I reported to a sales manager. Now, there are a lot of the same responsibilities, except I'm overseeing all of sales at our Greenville facility, and I report directly to the president of our Solar Atmospheres Greenville location, Steve Prout.

What's a typical day like for you at Solar Atmospheres?
The first week I actually spent a lot of time just reviewing everything that's been going on over the last couple of years since this facility opened. When I'm not traveling, we start our morning off with a meeting with the production team and go through daily workload, and then we start contacting people, and working on our follow-ups and quotes. There are a lot of opportunities in this growing area, so a lot of time is spent prospecting. That's definitely the main focus: getting the word out that we're here in the Southeast and turning over every rock, so to speak.

What states do you cover?
Our facility in Greenville covers Florida, North Carolina, South Carolina, Georgia, Louisiana, Alabama, Mississippi, Tennessee, and Arkansas.

What do you hope to bring to the heat-treat industry in your new position?
I'm here to bring continued awareness of Solar's vacuum processing capabilities in the Southeast. It is a challenge coming into a new market where there are established players. While we may be the new kid on the block in the Southeast, we are well-established innovators in the Northeast and the West Coast, rising to meet the many challenges of 21st century heat-treating.

How do you work with a customer when they come to you with a challenge?
We have a lot of resources at our fingertips at Solar with a research and development team at our corporate facility that includes a Ph.D. scientist and a metallurgist. We make it a team effort to provide solutions to a customer's problem. Solar excels at new processes, new challenges, doing something different that maybe the 'other guy' wouldn't want to deal with, because of the challenge it may represent, or it is too far out of their comfort zone.

In your 20 years of experience in the heat-treat field, what has changed the most and how have you adapted?
I started off with more traditional heat-treat and continuous furnace experience, and in the original company I was with, we slowly, but surely, incorporated vacuum. That is probably the biggest change I've seen: the need for vacuum heat-treating and seeing more and more people getting away from traditional heat-treat, moving toward vacuum. Not that traditional heat-treat doesn't have its place. But I've personally adapted by focusing more time and energy on higher-grade alloys that require vacuum processing. It used to be one or two heat-treaters might have a vacuum furnace in your region. Now, just about every heat-treater seems to have at least one or two vacuum furnaces, and there are more shops that are just vacuum heat-treating only, such as Solar.

What's caused that increase in need for vacuum furnaces?
It's just the way that the industries have changed. In my career I have witnessed the growth of medical and aerospace. As those industries have grown so has the increase in higher-value materials and components that lend themselves to vacuum processing. Manufacturing in the United States is just evolving, and with that, heat-treat has evolved.

Where do you see the heat-treat industry in the next five to 10 years and Solar Atmospheres' place in it?
The industry is still growing. We are seeing more and more need for technologies that used to be integral. Traditional carburizing is no longer always traditional. Now we're seeing more need for vacuum carburizing, because of the advantages from distortion, and some of the metallurgical properties. I see vacuum nitriding and vacuum carburizing continue to grow, and vacuum high-pressure quenching. It used to be very rare to see anybody with more than 2-bar quenching; now, there are furnaces with 20-bar quenching. Will that continue to grow and replace some traditional oil quench? I don't know, but I definitely see continued growth in vacuum.

Hopefully in five to 10 years, I'd like to see the Southeast facility with a couple expansions under its belt. I want to experience high growth as this area and region continue to grow.

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