INDUSTRIAL HEATING

The International Journal of Thermal Processing

OCTOBER 2018

FNA 2018 Show Issue #2

Maintain Your Refractories 32

INSIDE

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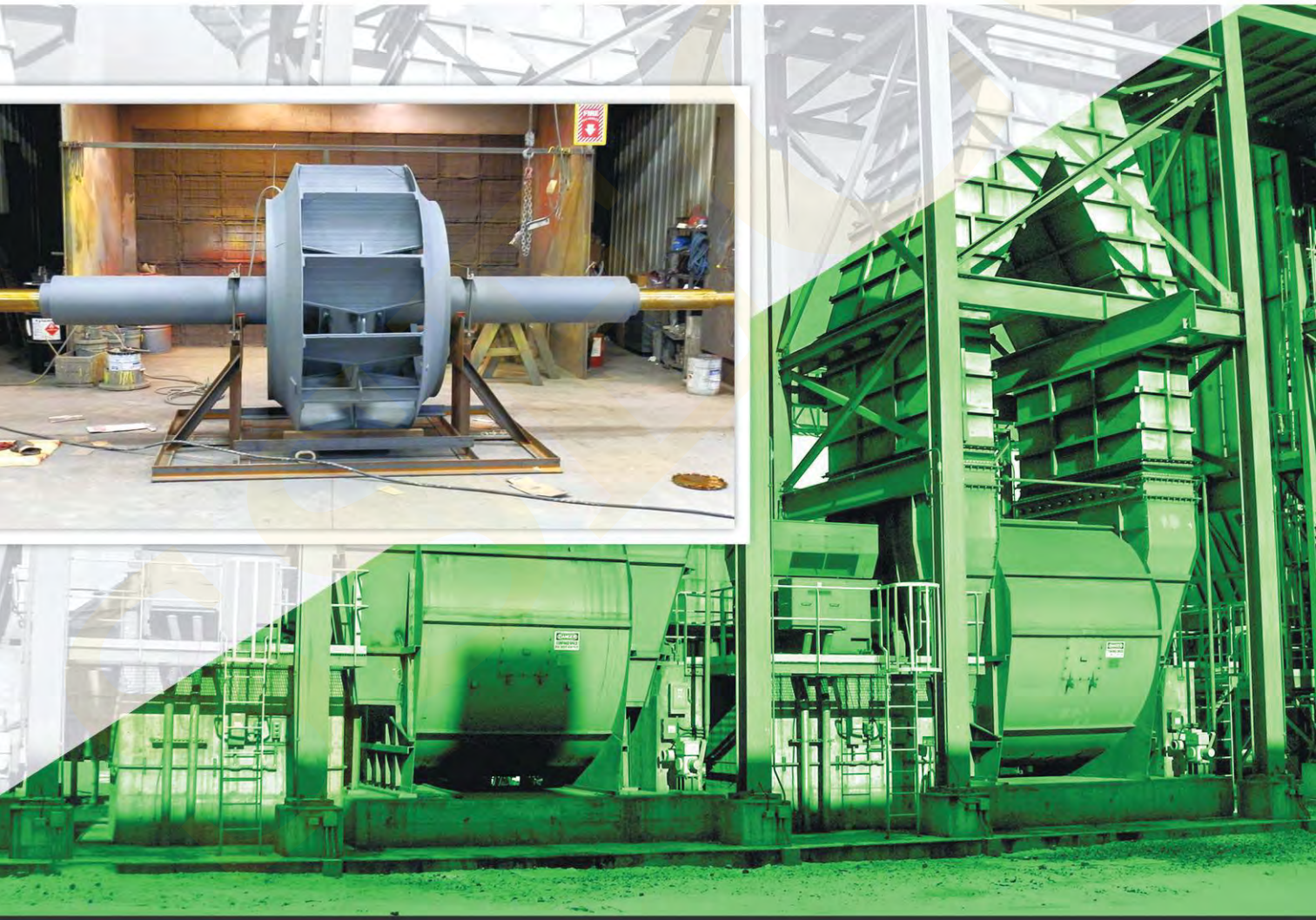

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SPECIAL SECTION

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Inspecting refractories to determine need for repair (p. 32).

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INDUSTRIAL HEATING (ISSN: Print 0019-8374 and Digital 2328-7403) is published 12 times annually, monthly, by BNP Media, Inc., 2401 W. Big Beaver Rd., Suite 700, Troy, MI 48084-3333. Telephone: (248) 362-3700, Fax: (248) 362-0317. No charge for subscriptions to qualified individuals. Annual rate for subscriptions to nonqualified individuals in the U.S.A.: $142.00 USD. Annual rate for subscriptions to nonqualified individuals in Canada: $177.00 USD (includes GST & postage); all other countries: $202.00 (int'l mail) payable in U.S. funds. Printed in the U.S.A.

Periodicals Postage Paid at Troy, MI and at additional mailing offices. For SINGLE COPY SALES OR BACK ISSUES ONLY: contact Ann Kalb at (248) 244-6499 or KalbR@bnpmedia.com. POSTMASTER: Send address changes to: **INDUSTRIAL HEATING,** P.O. Box 2146, Skokie, IL 60076. Canada Post: Publications Mail Agreement #40612608. GST account: 131263923. Send returns (Canada) to IMEX Global Solutions, P.O. Box 25542, London, ON, N6C 6B2. Change of address: Send old address label along with new address to **INDUSTRIAL HEATING,** P.O. Box 2146, Skokie, IL 60076. For subscription information or service, please contact Customer Service at: Phone: (800) 952-6643 Fax: (847)763-9538.

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2 Experts Speak Blog

Facts about the Elements

Keep up with Dan Herring's current blog series, "Facts about the Elements." He started this run in April 2017 and has covered elements from argon to zirconium … and plenty in between. ***www.industrialheating.com/Herring-expert***

3 Web Exclusive

Case Study: Part Failure Investigation and Resolution

A Chicago-area automotive parts supplier encountered frequent cracking of variable valve timing plates that were sent to a third party for heat treatment. After a thorough examination of the manufacture and heat treatment of the parts, metallurgists identified the cause of the cracking and recommended a custom solution to keep it from happening.

www.industrialheating.com/cstudy

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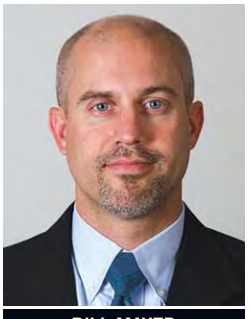
FNA 2018 is Here; Top-5 Articles



BILL MAYER
Managing Editor
412-306-4350
bill@industrialheating.com

2018 marks the 13th Furnaces North America (FNA) produced by the Metal Treating Institute and its media partner, *Industrial Heating*. Established in 1995, FNA has become synonymous with bringing top suppliers and heat treaters – both captive and commercial – from around the world to one location for technical education, networking and the latest developments in furnace equipment, accessories and services.

This year will be no different. Heat treaters and suppliers from nearly 40 states and 17 countries will converge in Indianapolis Oct. 8-10. This year's event offers 35 technical sessions, a featured keynote speaker, a two-day trade show with over 170 exhibitors and two high-energy networking sessions.

You can see the event's full schedule below, and for complete show information – including floor plan and exhibitor list – pick up a copy of our Show Directory at the venue. If you'd like to read more about the exhibiting companies, check out our Booth Descriptions on page 63.

Stop by *Industrial Heating's* booth (624) and say hello. See you in Indy!

Top Articles on our Website

If you haven't noticed, *Industrial Heating* has been running a series of best-of articles since late 2017. These articles have focused on a specific topic on our website and provided a ranking of the most-read features according to page views.

But what are the most-popular articles overall on www.industrialheating.com? We gathered the data – page views from the start of 2018 – and here are the top 5 on the list.

1. **How to Maximize Burner Efficiency**
   Because energy costs are a major factor for many industrial processes, it makes sense to carefully analyze how the natural gas is being used and whether the system is running at peak efficiency.
   www.industrialheating.com/maxburn
2. **Troubleshooting Thermocouple Failures in High-Temperature Applications**
   Just the fact that you have to shut down and replace a thermocouple means lost revenue. So, when you lose a temperature sensor – like a thermocouple – you need to know why it failed and how to prevent it in the future.
   www.industrialheating.com/tcfail
3. **Calculation of Heat-Treating Costs**
   Heat-treat costs are difficult to get a handle on. In this article, an accurate cost process is established. *www.industrialheating.com/costs*
4. **Comparing and Contrasting Carbonitriding and Nitrocarburizing**
   The terminology of heat treating is sometimes challenging. You have heard the terms carbonitriding and nitrocarburizing and know they are two different case-hardening processes, but what are the real differences between them?
   www.industrialheating.com/comcon
5. **Heat Treating 3D-Printed Metals**
   Metal 3D printing, or additive manufacturing (AM), is an advanced manufacturing method that opens up new possibilities for designing objects with optimized geometries and minimized weight using far less material and energy – important drivers for a future sustainable, energy-efficient industrial base.
   www.industrialheating.com/3Dadditive

Industrial Heating's website is a treasure trove of information. Please take advantage of our archives of feature articles. We're sure you'll find something interesting.

SCHEDULE

MONDAY, OCT. 8	
7:00 a.m.-6:00 p.m.	Registration and badge pickup
7:00 a.m.-6:00 p.m.	Exhibitor move-in
6:00-8:00 p.m.	Welcome reception
TUESDAY, OCT. 9	
7:00 a.m.-5:00 p.m.	Registration and badge pickup
8:00-11:15 a.m.	Technical sessions
11:15 a.m.-5:30 p.m.	FNA 2018 business expo
4:00-5:00 p.m.	Trade-show floor reception
WEDNESDAY, OCT. 10	
7:00 a.m.-1:30 p.m.	Registration and badge pickup
7:00-7:45 a.m.	MTI annual business meeting (MTI members only)
10:45 a.m.-2:30 p.m.	FNA 2018 business expo
2:30-10:00 p.m.	Exhibitor move-out
6:00-11:00 p.m.	MTI final night dinner (MTI members only)

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Is Natural Gas the Answer to our Energy Problems?

BARRY ASHBY
Washington Editor
202-255-0197
askbarry@industrialheating.com

Industrial Heating readers live and work in the most energy-consumptive manufacturing sector of the U.S. economy, so it is useful to examine the worlds of energy price and supply. But let us first look at natural gas and a business opportunity you may have missed.

The U.S. is now the world's largest producer of gas, and world demand is predicted to grow 1.8% a year to 2030. But America only has two LNG export facilities (Sabine Pass and Cove Point), which shipped 2 BCF/d total in 2017. More than 15 other LNG export facilities are awaiting building approvals as permitted by the Federal Energy Regulatory Commission (FERC), where approvals are taking five to six years to be granted.

There is an enormous market for U.S. gas exports because foreign consumers are paying four to six times U.S. production costs. Maybe you could help by calling your elected representatives and urge them to lean on federal bureaucrats to do their job – authorize LNG export terminal constructions. Then go help build LNG make-and-store facilities at new export terminals – U.S. exports are projected to be 8 BCF/d by 2020 and 12 BCF/d by 2025.

There is another driver for worldwide use of LNG – ship fuel. In 2020, maritime laws eliminate the use of high-sulfur liquid (bunker) fuels, which must contain less than 0.5% sulfur. Couple this with the fact that U.S. extraction costs for offshore oil and gas have dropped 50-70% since 2014, and we see an additional driver for those oceanside export terminals. Further, the net gas price for all U.S.-produced supplies is predicted to increase only $0.23 per thousand cubic feet until the end of this decade as strong gas demand grows through 2040 and is expected to sustain a 7.2% annual growth rate through 2030.

In the cost-of-energy equations, for comparison, world crude-oil prices have fluctuated significantly more than gas, ranging from $145/barrel in 2008 to $100/barrel in 2014, and are projected to be as high as $270/barrel by 2020. Know also that crude-oil demand, currently at 85 Mbpd and projected to grow to 106 Mbpd by 2030, is a reduction of 10 Mbpd due to this surge in gas supply at lowering costs. Understand that while $200 a barrel seems high by U.S. standards, people in European Union countries have been paying about $250/barrel for years due to high taxes. Now you can understand a driving reason for Brexit.

As a sidelight, while China has imposed retaliatory tariffs on over 500 U.S. products, LNG is not on the list. A general consensus is that, while China is the fastest-growing LNG market worldwide, it is not signing long-term delivery contracts with American suppliers in spite of its need to reduce coal use with gas replacements. So, China remains the third-largest U.S. gas export market behind Mexico and South Korea and is the world's second-largest LNG importer.

Major crude-oil producers are boosting their share of gas production to 40-45% of total energy output. The LNG share will rise to 40% of all producers' output by 2023, according to the International Energy Agency (IEA), and can meet any country's energy needs. U.S. gas prices have averaged $2.98 over the past year and $3.82 over the last 10 years. It should be $3.09 in November 2018; $2.70 in November 2019; and $2.96 in November 2020. Over the past 25 years, the average was $4.10, with the highest price of $13.42 in October 2005 and lowest of $1.44 in July 1995.

In spite of the blathering by many "enviromotionalists" about how use of renewable energy sources such as wind and solar could have a significant impact on Earth's climate, these are great ideas for very narrow applications and are not practical or affordable today compared to oil and, especially, natural gas. The IEA estimates that an additional $4.1 trillion of energy-efficient investments is needed over the next two decades to stabilize greenhouse-gas emissions at 550 ppm plus an added $2.7 trillion for energy-efficient equipment. This amounts to half the GDP of America.

With some common sense and efficient use of natural gas, our problems are greatly mitigated if not solved.

Endothermic Gas Generators

DANIEL H. HERRING
The HERRING GROUP, Inc.
630-834-3017
dherring@heat-treat-doctor.com

The father of the endothermic gas generator was a gentlemen by the name of Norbert K. Koebel, who was fond of saying to young engineers such as The Doctor, "Treat 'em right and they'll treat you right." He knew that the endothermic gas generator was the heart of any atmosphere heat-treat operation. True then, true now. Let's learn more.

Endothermic gas (aka RX® or endo gas) is primarily used for neutral hardening and as a carrier gas for gas carburizing and carbonitriding. Today, endo gas is typically supplied to the furnace so that the furnace atmosphere is essentially neutral to the surface of many steels and can be made chemically active by the addition of enrichment (hydrocarbon) gas, ammonia or air at the furnace proper.

Gas Chemistry

Endothermic gas is produced when a mixture of air and fuel is introduced into an externally heated retort at such a low air-to-gas ratio that it will normally not burn. The retort contains an active catalyst, which is needed for cracking the mixture. Leaving the retort, the gas must be cooled rapidly enough to avoid the so-called carbon reversal or carbon reformation reaction, where carbon monoxide breaks down into carbon dioxide and carbon (in the form of soot) before it reaches the furnace. The gas needs to be rapidly cooled in the temperature range of approximately 705°C (1300°F) to 480°C (900°F) or below to avoid this reaction.

The endothermic gas reaction (Equations 1-2) occurs in two steps and produces an atmosphere of nitrogen, hydrogen and carbon monoxide with varying percentages of carbon dioxide, water vapor and residual hydrocarbon as methane if natural gas is the feedstock.

$$CH_4 + \text{air}\ (2O_2 + 8N_2) \quad CO_2 + 2H_2O + 8N_2 \qquad (1)$$

$$2C_3H_8 + \text{air}\ (3O_2 + 11.4N_2) \quad 6CO + 8H_2 + 11.4N_2 \qquad (2)$$

The endothermic gas composition (Table 1), by volume, varies depending on the type of hydrocarbon gas feedstock. The use of a nickel-based catalyst (Fig. 1) accelerates the reaction. The nickel (Ni) attracts the hydrogen atoms of the methane, which attaches to the catalyst. The oxygen molecules approach and are attracted to the carbon atoms. The carbon atoms combine with the oxygen atoms to form carbon monoxide (CO). The hydrogen atoms combine to form H_2 and are released from the nickel attraction. The now-available nickel attracts new methane to continue the reaction (cracking) process. After the passage of the air-gas mixture over the catalyst, the reaction is "frozen" by chilling the gas rapidly to around 315°C (600°F) in either an air-cooled or water-cooled heat exchanger.

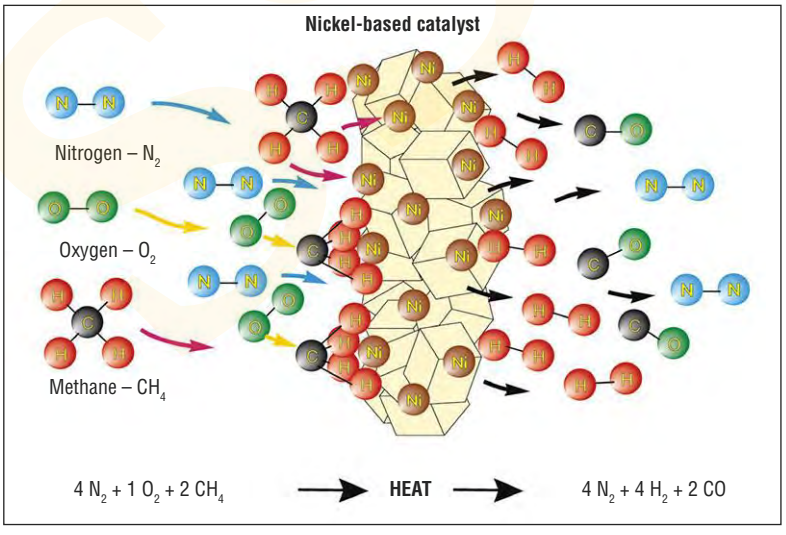

Fig. 1. Endothermic gas generator chemistry *(courtesy of Surface Combustion, Inc.)*

Equipment Overview

Endothermic gas generators consist of several basic components: a gas mixer, burner,

Table 1. Typical compositional ranges for endothermic gas

Gas constituent	Percentage (based on natural gas)	Percentage (based on propane)
N_2	40.9%	40.9%
CO	19.6%	23.3%
CO_2	0.4%	0.1%
H_2	38.9%	35.5%
CH_4	0.2%	0.2%
Dew point	+20/+50°F	-10/-15°F
(Air/gas) ratio	2.6:1	7.8:1

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TYPE	OPERATING COST	TEMPERATURE
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Chiller	$$$$	65°F

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Fig. 2. Single-retort endothermic gas generator *(courtesy of AFC-Holcroft)*

Fig. 3. Modular multi-retort endothermic gas (Rx®) generator *(courtesy of Surface Combustion, Inc.)*

combustion chamber and heat exchanger. They are available in single-retort (Fig. 2) and multiple-retort (Fig. 3) designs. The products of combustion of a fuel (e.g., natural gas) and air are combined at air/gas ratios typically between 2.5:1 and 3.5:1 to create the atmosphere. The reaction requires heat to proceed (hence the name endothermic), and, as such, these generators typically have heated combustion chambers.

Features

Endothermic gas generators are common equipment in the heat-treat shop. The main components of an endothermic generator (Fig. 4) are relatively simple and consist of:

- Heated reaction retort with catalyst
- Air-gas proportioning control components
- Pump to pass the air-gas mixture through the retort
- Cooler to "freeze" the reaction and prevent soot formation
- Fire check valve to prevent backfire in the fuel supply line
- Burnoff vent to combust excess gas produced
- Thermocouples (control, over-temperature, recording) and control instrumentation

Retort

The retort for an endothermic gas generator is typically a cast alloy – HU (38% Ni, 18% Cr) and HK (20% Ni, 25% Cr) are common. In some instances, retorts are fabricated from Inconel 600® (preferred alloy choice) or made of silicon carbide.

Retorts in most industrial generators are either thin and tall or thick and short. They vary in diameter from about 150 mm (6 inches) to 300 mm (12 inches). In larger-diameter designs, either the inlet pipe runs down through the center of the retort (to preheat the gas) or the space is occupied by a closed-ended pipe, typically 50-75 mm (2-3 inches) in diameter to avoid issues with a cold center in the catalyst bed.

Catalyst

For economic reasons only, manufacturers have gone away from supplying pure nickel shot as a catalyst and today utilize insulating firebrick catalyst cubes typically 25 mm (1 inch) in size coated with 3-7% nickel sulfate ($NiSO_4$). Smaller-sized cubes, 17.5 mm (11/16 inch) and spheres of 19 mm (3/4 inch) diameter, have also been used, but the pressure drop through the catalyst bed must be monitored due to increased packing density. The use of a refractory catalyst often suggests a smaller-diameter retort to assure both proper heat distribution throughout the catalyst bed and adequate dwell time at temperature for complete dissociation.

Summary

Endothermic gas generators have a long and proven track record of success. The gas produced is relatively stable and adequate for a broad spectrum of process applications. Maintenance is relatively simple, and problems with the equipment and technology are well understood and solvable on the shop floor.

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FNA 2018: The Future Will Meet You There

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Furnaces North America 2018 (FNA 2018), presented by the Metal Treating Institute in partnership with *Industrial Heating*, is the heat-treating industry's marquee event every other year. FNA 2018 will attract attendees from over 35 states and 20 countries, including Fortune 500 companies. For three days attendees will take part in networking events and educational sessions that will focus on emerging technologies, industry trends and advances in equipment.

Change is happening at such a rapid pace in today's economy, both commercial and captive heat-treat plants can't afford to miss FNA 2018. Demographic shifts, emerging technologies and consumer buying habits are driving what is manufactured.

The answers to the most pressing challenges in your heat-treat operation will be found at FNA 2018, either in technical sessions with suppliers you meet, at a booth with another heat treater that you connect with or at one of the social events.

FNA 2018 has three dynamic elements that will deliver the answers you and your team need in order to maximize your productivity, personnel resources and profits.

Element #1: Learning that LASTS

FNA 2018's technical conference, which is designed by a team of heat treaters and suppliers, has 35 key sessions focused on a wide array of technical issues in over 10 tracks. Session topics include:

- Productivity and data
- Processes
- Equipment
- Standards and pyrometry
- Controls and materials
- Maintenance
- Emerging technologies
- FNC/Nitriding
- Quenching and cooling
- Heat-treat business

Element #2: Business that CONNECTS

The most active part of any FNA experience is the trade show. With over 170 top suppliers in every facet of heat treating, this is where the daily needs of heat treaters are fulfilled. On the show floor, heat treaters and suppliers connect to learn about each other, what heat treaters are challenged with and how suppliers can solve those issues. FNA's Expo is a must for any owner, general manager, plant manager or maintenance/quality/production manager. FNA 2018 encourages companies to bring its key management team to help introduce them personally to the new trends and technologies shaping the future of heat treating.

Element #3: Networking is KING

At FNA, attendees experience a set of exciting social functions that allow heat treaters and supplier alike to connect with one another to discuss the ideas they learned during the conference and trade show. They also share their daily experiences in dealing with issues like energy, employee recruitment/retention, maintenance, audit compliance, plant safety and equipment purchases. FNA social events also help suppliers to get away from the trade-show booth and listen to the heat treater's needs in a more informal environment. This provides suppliers an opportunity to serve the heat treater better and develop products for their specific needs.

The Metal Treating Institute (MTI), the world's largest network of commercial heat treaters and suppliers, is the heat-treating industry's leading trade association for online training, financial benchmarking studies, research data, networking and industry information. Stop by MTI's booth (618-620-622) at the show to see what we have to offer.

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Wisconsin Oven Corp.

Industrial Ovens for Thermal Processing

MTI
Metal Treating Institute
904-249-0448
www.HeatTreat.net

Wisconsin Oven Corp. is celebrating its 45th anniversary in 2018. The East Troy, Wis.-based company has been designing, engineering and manufacturing industrial ovens and other heating equipment since 1973.

The MTI member's custom and standard industrial ovens (batch, conveyor and laboratory) are used for applications including heat treating, aluminum aging, powder coating, drying and composite curing. The largest oven the company has built was 300 feet long x 200 feet wide and about 75 feet tall. Wisconsin Oven also manufactures thermal incinerators for pollution control. This equipment is utilized by companies in a variety of industries, including aerospace, automotive, agriculture, construction, medical, military, mining and others.

Every oven manufactured is fully factory tested and adjusted prior to shipment from Wisconsin Oven's 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 is completed to ensure all equipment meets quality standards.

In the thermal-processing industry, there are only a few ways to differentiate your company from the competition. Wisconsin Oven is quick to credit one thing for creating that difference: its people. Approximately 150 employees allow this oven manufacturer to outperform its competition and provide outstanding customer service. The company's experienced design team is able to meet even the most stringent standards for customers' equipment.

Wisconsin Oven has developed a culture that recognizes workers for a job well done. The Work of Champions program is an initiative to reward the performance of employees who go above and beyond the call of duty. Whether they're working overtime to take care of a customer, saving the company money by producing quality work in remarkable time or making beneficial suggestions, those efforts will be recognized.

The company is also serious about being a leader in the community. Wisconsin Oven was named the United Way of Walworth County's largest contributor in 2017, with employee donations reaching $20,000, and president and CEO Dave Strand was named Honorary Campaign Chair for 2018. A heartfelt letter sent by Strand to members encouraging them to pay it forward resulted in $15,000 in donations to the United Way of Walworth County.

The future is bright at Wisconsin Oven. The company opened a new facility in East Troy just under a year ago in November 2017. The 130,000-square-foot plant was needed to accommodate the Blue M laboratory oven product line and provide additional manufacturing space for continued growth. According to Wisconsin Oven, that growth is expected to last for five to 10 years, especially in the areas of high-performance alloys and the energy industry.

Wisconsin Oven is owned by Thermal Product Solutions, a global leader in thermal-processing products and test solutions with brands including Baker Furnace, BlueM, Gruenberg, Lindberg/MPH, Lunaire and Tenney.

Visit www.wisoven.com for more information on Wisconsin Oven.


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Therma-Tron-X Inc./HTF LLC

IHEA
Industrial Heating Equipment Assoc.
859-356-1575
www.ihea.org

IHEA's newest member is quite a combination – of companies, that is.

Therma-Tron-X (TTX) was established in 1969 as an industrial oven manufacturer. The company built ovens for practically any operation, spanning several industries including food, finishing, metal treatment and packaging. Its product line expanded quickly, and TTX became a turnkey industrial finishing systems supplier by the early 1980s. The Sturgeon Bay, Wis.-based company's products included powder booths, pretreatment systems, material-handling systems, ovens and controls. By the late 1980s, TTX added water- and wastewater-treatment systems to its product line. Today, TTX serves as a custom finishing system supplier for industrial clients throughout North America.

HTF LLC, a recent acquisition of TTX, has been building heat-treat furnaces since 1998 in Sturgeon Bay, nearly next door to TTX. Brad Andreae (owner of TTX) and Dave Smith (former owner of HTF) often collaborated on projects and had a solid business relationship for nearly 25 years, making it a no-brainer to combine forces.

With approximately 260 employees, TTX/HTF serves the aerospace, agriculture, automotive and construction industries. The companies do not manufacture so-called cookie-cutter equipment. The business is based on innovatively engineered equipment that is conceived from the customer's needs. Because of this, TTX and HTF often test their products and processes in-house. In addition, all furnaces and ovens are tested, installed and commissioned by TTX teams. The company trains its customers on their equipment.

The industrial furnaces and ovens the company manufactures have a long list of capabilities and can be built to suit almost any application. HTF furnaces include atmosphere, batch, bell, box, car bottom, continuous, drop bottom, pit, roller hearth and tip-up. Their uses include annealing, carburizing, forging, neutral hardening, nitriding, normalizing, stress relief and tempering. TTX ovens, meanwhile, include batch, conveyor, convection, curing, dry-off and infrared. They can be used for aging, baking, curing, drawing and preheating.

HTF furnaces are designed meet the metallurgical process requirements for a particular product. Energy efficiency, uniformity and robust design are signature technologies. TTX is experienced at designing units that fit spatial needs and utility requirements. Its ovens can be incorporated into finishing systems or configured as standalone units. TTX has developed several proprietary technologies that are known throughout the industry, including the SST® (SlideRail Square Transfer) and the Econ-E Coat®.

TTX/HTF does more than manufacture equipment. The company has a full service and spare parts department that responds quickly to customers' needs. Technicians are available in person, over the phone or via internet at all hours so that repairs and upgrades can be done when customers are not in full production mode. TTX/HTF also offers VPN connection to all equipment, so troubleshooting can be done with ease.

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EQUIPMENT NEWS

Batch Furnace Lines

AFC-Holcroft received an order from Mincon Group for two separate, complete batch-style integral-quench heat-treatment lines. The equipment will be utilized for the heat treatment of components used in heavy industries like mining and drilling. Both batch furnace lines have features designed to reduce distortion of the products being processed. One line – consisting of an integral-quench batch furnace with an effective load size of 36 x 72 x 56 inches, tempering furnaces, washing and conveying equipment, controls system and accessory equipment – will be sent to a manufacturing facility in Benton, Ill. It has a gross load capacity of 6,000 pounds. The second line will be delivered to a facility in Perth, Australia.

www.afc-holcroft.com

Vacuum Furnace

TAV Vacuum Furnaces shipped a vacuum furnace that offers an advanced solution for aluminide coatings of aerospace engine and industrial gas turbine components. The furnace has dimensions of 39.5 inches (1,000 mm) in diameter x 39.5 inches (1,000 mm) high and a maximum operating temperature of 2102°F (1150°C). Parts are placed inside the loading fixture, which is positioned, with an overhead crane, on the base supports. A retort is then placed on the base, evacuated and then flushed with inert gas to obtain a clean, pollution-free environment. The retort is transferred inside the furnace, where it is heated up to the process temperature.

www.tav-vacuumfurnaces.com

Gas Nitriding Furnace

SECO/VACUUM Technologies supplied a precision gas nitriding vacuum furnace to a large North American heat treater. The horizontal, front-loading furnace is designed specifically for precision gas nitriding, ferritic nitrocarburizing and post-oxidation in a retort-style furnace with vacuum purge. The ZeroFlow furnace complements a prior SECO/WARWICK gas nitriding furnace already in production at the facility. The furnace extends the heat treater's capabilities by offering greater capacity to its growing nitriding customer base. The ZeroFlow gas nitriding method precisely controls the case depth and nitride layer formation (including white layer), achieving high surface hardness, improved wear resistance and longer fatigue life. www.secovacusa.com

Car-Bottom Oven

Lewco sold a custom car-bottom oven rated for a maximum temperature of 1300°F to an industrial manufacturer. The electrically heated oven, which will be used for annealing steel parts, has a workspace of 72 inches wide x 140 inches deep x 90 inches high. Manufactured and designed to NFPA 86 Class B standards, it is supplied with a rear-mounted heater box with 324 kW heat input and a 38,000-CFM high-efficiency circulation fan delivering dual airflow evenly throughout the workspace. A heavy-duty powered car serves as both the floor and door of the oven. The car-bottom design guarantees a tight overall seal, keeping the oven exterior cool and minimizing heat loss. www.lewcoinc.com

Electric Box Furnace

L&L Special Furnace Co. Inc. supplied an electric box furnace to a Midwestern engine manufacturer that produces parts for large industrial engines, motors and steam generators. The furnace, which has an effective work zone of 22 inches wide x 18 inches high x 22 inches deep, is used for hardening and annealing of a range of components employed in equipment manufacturing. The unit includes a complete digital control system, over-temperature protection and a counterbalanced vertical door for ease of loading. The furnace has an alloy fan that provides excellent uniformity (±10°F) from 300°F to 1800°F. www.llfurnace.com

Equipment & Business News

Hot Isostatic Press

The Center for Engineering and Industrial Development (CIDESI) in Querétaro, Mexico, purchased and installed an HIP system from **Quintus Technologies**. The HIP system performs hot isostatic pressing (HIP) of advanced materials for demanding applications, especially within the aerospace, automotive and energy industries. It has a work zone of 7.32 inches (186 mm) in diameter x 19.69 inches (500 mm) high, with an operating temperature of 2552°F (1400°C) and pressure of 207 MPa (30,000 psi).
www.quintustechnologies.com

BUSINESS NEWS

HarbisonWalker Opens Monolithic Refractories Plant in Ohio

HarbisonWalker International (HWI) celebrated the grand opening of its newly constructed monolithic refractories manufacturing plant in South Point, Ohio. HWI announced in February 2017 that it would invest $30 million to build a technologically advanced refractories plant.

Ground was broken for the facility on June 8, 2017, and the plant began shipping products in spring 2018. The plant features state-of-the-art processes and technology and utilizes lean-manufacturing techniques throughout its operations to maximize material flow efficiency and production.

Dowa Thermotech Opening Facility in North Carolina

Dowa Thermotech Co. Ltd., a global manufacturer of industrial furnaces and provider of heat-treatment services, will open a new facility in Lee County, N.C. The company will invest $22.5 million in Sanford with plans to serve clients in the automotive and industrial machinery markets. The investment will create 109

jobs. Dowa Thermotech, with headquarters in Nagoya, Japan, is a subsidiary of Dowa Holdings Co. Ltd., a global company operating in industry sectors including nonferrous metals, metal processing, environmental management and recycling.

Premier Thermal Solutions Increases Oil Q&T Capacity

Premier Thermal Solutions is increasing oil quench-and-temper capacity at its Atmosphere Annealing Mt. Hope facility in Lansing, Mich. Through the enhancement of an existing roller-hearth tray furnace, the facility will double its oil-quench capacity. The additional capacity is in response to increasing demand seen from many of the industries that Atmosphere Annealing serves, including automotive, energy, heavy equipment, heavy truck and rail. The furnace will be online in the first quarter of 2019. According to Premier Thermal Solutions the expansion will also provide additional back-up processing capabilities to further protect its customers' critical supply chain.

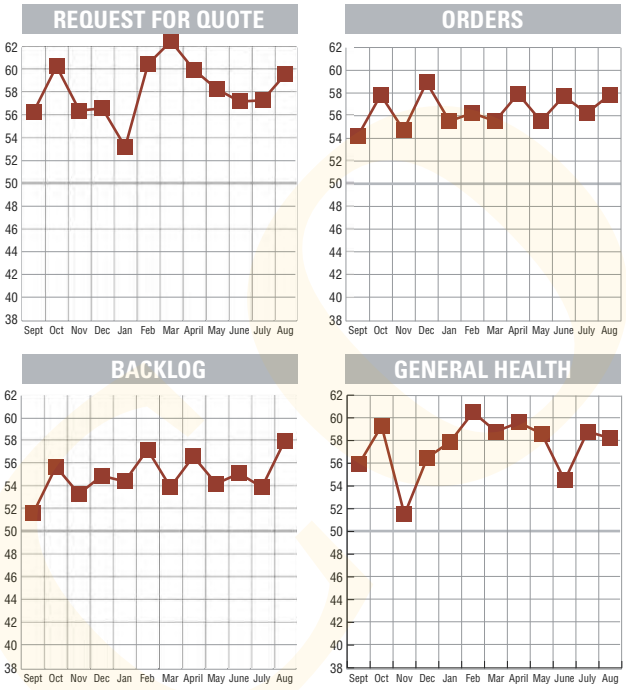
Andritz Acquires Asko Inc.

International technology group **Andritz** signed a contract for the acquisition of Asko Inc., a family-owned company headquartered in Homestead, Pa. Asko manufactures a wide range of shear knives, blades, liners, wear plates and accessories for the metals-producing, metals-processing and recycling industries. For Andritz, the acquisition further complements its service offerings for the metals industry. Founded in 1933, Asko has approximately 140 employees and delivers its products from four locations: Homestead, Pa.; Rock Hill, S.C.; South Holland, Ill.; and Amsterdam, Netherlands.

Metal-Powder Manufacturer to Expand Capacity

Tekna Plasma Systems Inc., a manufacturer of metal powder, will invest up to $128 million over five years to expand its global manufacturing output and boost its innovation capability. The project will help the Sherbrooke, Quebec-based company increase its capacity to over 1,000 tons per year and includes expanding manufacturing floor space, the purchase of production equipment and resources for product development efforts. The investment reflects Tekna's long-term commitment to the 3D-printing market. A first expansion phase in Canada and in France is scheduled to be running full scale by the third quarter of 2018 and will provide Tekna with an extra annual capacity of 250 tons.

ECONOMIC INDICATORS



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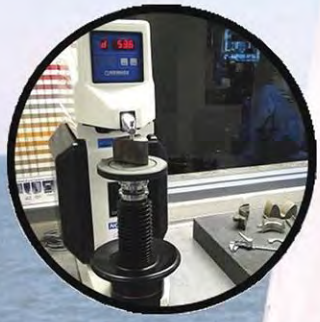

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LEARN MORE!

Avoid Costly Refractory Repairs with Proper Maintenance

Pamela Gaul – Plibrico Company, LLC; Northbrook, Ill.

As the old saying goes, "An ounce of prevention is worth a pound of cure." This is certainly true when it comes to your refractories.

Manufacturers around the world rely on refractories to safeguard their multi-million dollar industrial-grade boilers, incinerators and furnaces from thermal damage and corrosion brought on by operating temperatures that can reach 3000°F (1650°C).

Without refractories – the unsung hero of the manufacturing process – it would be impossible to process the raw materials that go into automobiles, chemicals, power-generation equipment, buildings, roads and much more. As such, it only makes good financial and business sense to provide basic refractory maintenance for your machinery. By protecting your critical heat-processing equipment, you can minimize costly downtime, reduce energy losses, prevent employee injuries and, more importantly, avert a catastrophic equipment failure.

Given refractories' importance to operations, it is important to remember that they are consumables and will wear out. This is significant because without proper maintenance your processing equipment may fail at the most inopportune time, and downtime for a furnace or dryer – even one day – can cost a company hundreds or thousands of dollars. The rewards of proper maintenance far outweigh the expense.

It is also important to remember that refractories are not commodities. Even within the general classification of refractories, there are significant variances in chemical compositions. As a result, refractories will have different maintenance schedules and repair practices.

Refractory maintenance has a cost. That is why maintenance needs must be factored in when evaluating which refractories to install in your application. For example, the upfront costs of engineered shapes may be 20-30% more than monolithic refractories. However, they require little to no dryout, are easy to install and in some cases last longer than some traditional castables. Also, if there are high-wear areas that may be difficult to reach due to their location or geometry, financially it is well worth going with the precast shapes to minimize future maintenance expense.

The Wear Factor

What causes refractories to wear? Time, temperature, corrosive gases, slag and operational practices will all take their toll, as will the overall engineering of the heat-processing equipment. Other culprits leading to the degradation of a refractory lining can be incorrect combustion controls, improper flame set-up, anchor failure or thermal shock resulting from severe temperature fluctuations. More times than not it is a combination of these or other factors that lead to refractory damage – not a single cause.

Not following the manufacturer's recommended curing and dryout schedule can also lead to degradation. If an end-user is looking to accelerate the process due to production demands, quick dryout products might be a good option.

Some manufacturers offer refractory materials that provide reductions in dryout time and may offer nearly the same properties as their traditional, non-fast dryout counterparts. The benefit to these quick-cure/dryout products are that dryout times are cut about in half, which can represent a time savings of up to 40-50 hours. While they offer an easy, time-saving solution, however, there are limitations to their material properties as well as cautions on dryout.

It is a good idea to use the dryout time to check items such as the vessel pressurization, exhaust system, temperature monitor, thermocouple position and moisture wicking.

How You Can Help with Refractory Longevity

The goal of periodic inspection, maintenance and repair is to ensure the longevity and performance of refractories (Fig. 1). During maintenance, worn parts and areas of excessive wear are repaired before turning into bigger issues.

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Fig. 1. During the inspection process, the refractory team will provide a comprehensive condition assessment to help determine the need for repair.

Depending on operational make-up, skills and budget, employing a permanent staff to perform these services might not make financial sense. Instead, working with an outside professional refractory contractor with extensive industry expertise who can provide maintenance services, emergency response and repair operations might be far more cost-efficient for the end-user.

Under either service structure, there are precautionary steps that can be taken in-house to extend refractory operation and increase longevity.

1. **Furnace heat up and cool down:** Follow procedures established by the furnace manufacturer. Proper heating creates positive pressure in a furnace, ensuring an equal distribution of temperature. Expansion or contraction control is vital to avoid damage to the refractory.
2. **Dust removal:** Keep the dust off the steel in roofs that have an exposed anchoring structure. This simple step keeps the stainless steel hardware from becoming too hot and fatiguing.
3. **"Good" cracks vs. "bad" cracks:** Understand the important differences between good cracks and bad cracks. Good cracks in the refractory are created and visible as part of the natural cool-down process. These should be left alone because they will disappear during the heat-up process. If the end-user fills "good" cracks, they will have problems down the road with shell bulge because the refractory will naturally expand during heat-up and production.

An Ounce of Prevention

Develop a relationship with a reliable, knowledgeable and nimble professional refractory expert who has your best interests at heart. During the inspection process, your expert and their refractory team should provide you with a comprehensive condition assessment to help determine the need for repair. Assessments allow the refractory contractor to analyze the state of the refractory and select the proper solution to ensure a durable repair.

Often, the first indication that there might be a problem with the refractory lining is the appearance of a "hot spot" on the shell. A hot spot is where an area of the shell is found to be operating at a higher temperature than the surrounding area. This can be due to cracking, spalling or other issues that result in deterioration of the refractory lining.

When hot spots are identified, the refractory professional will typically pack, grout, caulk or "stuff" the area if it is accessible from the outside. They may also "hot gun" from the inside.

The number and severity of hot spots, usually found using an infrared camera and heat-flow analysis, can help the refractory professional or engineer determine the integrity of the refractory lining. Depending on the results, the manager/engineer should perform a full cost-benefit analysis to help evaluate which is the best option – repair or complete lining replacement (Fig. 2).

When faced with any type of refractory repair, best practice will come down to scope and timetable. A quick repair may be addressed using a gunning (cold/hot) or shotcrete refractory

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Fig. 2. Depending on the inspection results, the plant manager should perform a full cost-benefit analysis to help evaluate which is the best option: repair or a complete lining replacement.

technique. Another possibility might be ramming plastic refractory just to fill a hole/spall or resurface the lining.

A more time-consuming and sometimes better option would be a full lining repair. These repairs are done to a more thorough degree, which allows for proper cure, dryout and anchoring.

A Pound of Cure – Premature Failure

Without proper refractory maintenance, you run the risk of premature failure of the refractory lining. The funny, or not so funny, thing about refractory failures is that you will usually not receive a notice on that day telling you that one of your critical systems will be failing. And once a failure occurs, it is all-hands-on-deck to address the issue and bring your operation back online as quickly as possible.

During the process, you or your refractory expert should collect samples of the existing refractory material to help identify the causes of failure. For example, glazing and excessive shrinking indicate exposure to excessive temperatures. Shearing away of the top refractory service can be evidence of thermal shock.

In addition, calculating a base-to-acid ratio will show if the type of refractory installed should have been selected in the first place. Refractory materials are manufactured to operate in different environments. A properly selected and installed refractory lasts longer, helps minimize shutdowns and leads to better fuel efficiency.

Lastly, fuel should be checked to determine if it is contributing to the degradation of the refractories. For instance, moisture content in fuel may be too high or contain chemicals that damage the lining.

Drama-Free Refractory Removal and Replacement

In some cases, the maintenance needed for heat-processing equipment is more than repairs can handle. This leaves a complete refractory lining replacement as the only option. This is highly specialized work requiring the skills of an experienced refractory installer.

To ensure drama-free refractory removal and replacement, follow these five key tips.

1. Enlist the support of a seasoned, knowledgeable and professional refractory contractor. Not all contractors are experts in refractory work. Make sure the contractor has quick access to refractory material.
2. Obtain a complete scope of work (SOW) and a solid plan. Some of the items that should appear in a good SOW include:
   - Amount of material needed and on hand

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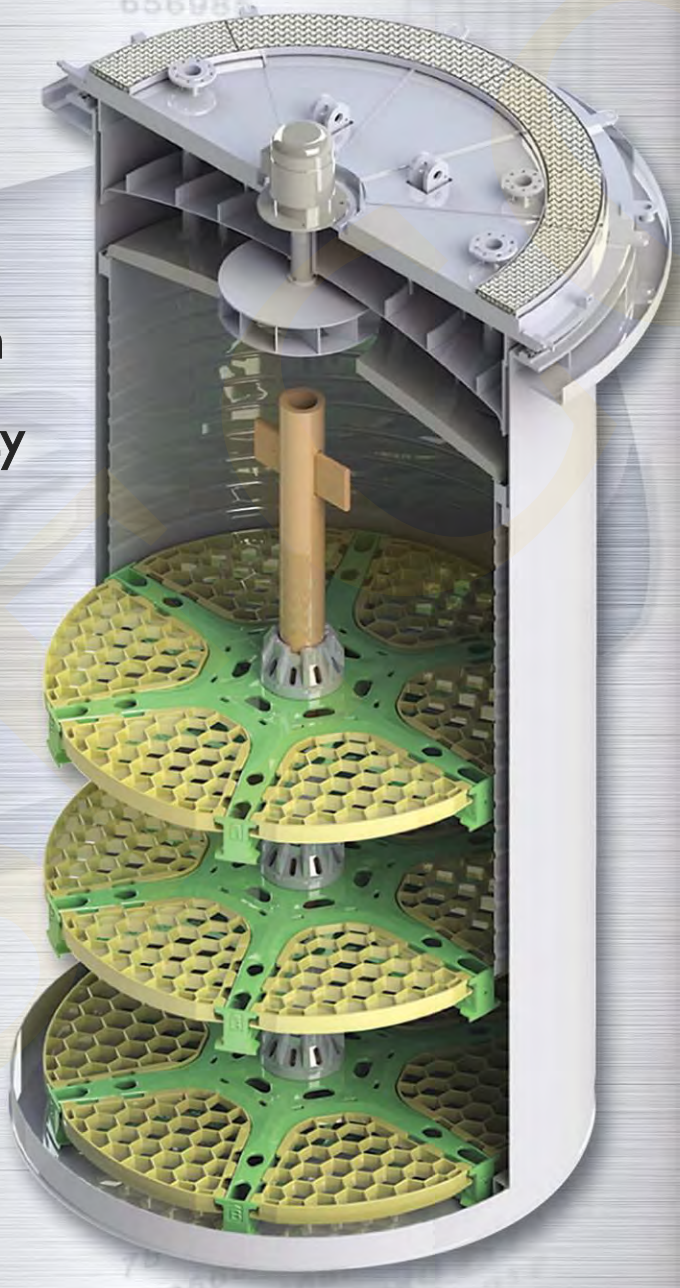

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- List of equipment supplied
- Schedule and details for the tear-out plan
- Proper curing/dryout plan

3. Prepare for the unforeseen. Often, problems do not reveal themselves until the unit has cooled and the tear-out begins. This reality necessitates contingency plans to be in place. Further, it underscores the importance of working with a fully stocked professional refractory contractor who has access to a refractory manufacturer that uses just-in-time manufacturing principles.
4. Where applicable, install and use precast shapes. These shapes are ready to install and require little to no dryout.
5. Discuss with your refractory expert if fast-dryout refractory material may be an option for you. Incorporating quick-dryout materials like Plibrico's FastTrack® can cut traditional dryout time in half.

When working with your refractory installer, it is important to focus on your specific application to drive refractory material requirements. It is easy to get caught up in flashy new refractory compositions and features. The application should determine the refractory material, not the other way around.

Good for Your Equipment, Good for Your Wallet

Proper refractory maintenance is not only good for your critical heat-processing equipment, it is good for your wallet. The reality is that the life of your refractory can be reduced by as much as 50% (or more) without proper maintenance. In fact, failing to provide basic refractory maintenance for an aluminum furnace, for example, can leave the end-user with an unbudgeted and unexpected bill for $150,000 or more to fully replace the roof. This is an expense that might have been put off many years with properly maintained refractory. It could then have been scheduled, budgeted and drama-free.

Worse yet, in the event of catastrophic refractory failure where the anchor tile system or full wall is snapped, the repair bill can easily top $200,000. Keep in mind these figures only address repairs. Add on the large cost of lost production and the total skyrockets quickly!

As Benjamin Franklin would agree, take care of your refractory – the unsung hero of the manufacturing process – and it will take care of you with a safe and efficient work environment, minimized downtime, reductions in energy losses and, more importantly, avoidance of catastrophic critical heat-processing equipment failure.

For more information: Contact Pamela Gaul, director of Marketing, Plibrico Company, LLC, 1935 Techny Road – Unit 16, Northbrook, IL 60062; tel: 312-981-2861; e-mail: pgaul@plibrico.com; web: www.plibrico.com.

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The Value of Scheduled Combustion-System Maintenance

Mike Shay – HEAT Combustion Solutions LLC; Cincinnati, Ohio

My colleagues and I have been in the combustion business for many years and have a wide range of experience with single-burner and multi-burner applications. What follows is some basic information concerning the maintenance and adjustment of combustion systems.

Experience has shown that regularly scheduled inspection and maintenance of combustion systems can provide heating processes with reliable and predictable results. We also see that in some cases lack or absence of regularly scheduled inspections and maintenance can cause poor performance, higher-than-required fuel usage, higher levels of emission, and unexpected component failures that lead to unnecessary and unwanted downtime.

Conversely, regularly scheduled combustion-system inspection and maintenance can provide longer equipment life, reduced downtime, improved product quality, energy savings and reduced emissions. Additionally, NFPA audits should be performed on an annual basis by a qualified company.

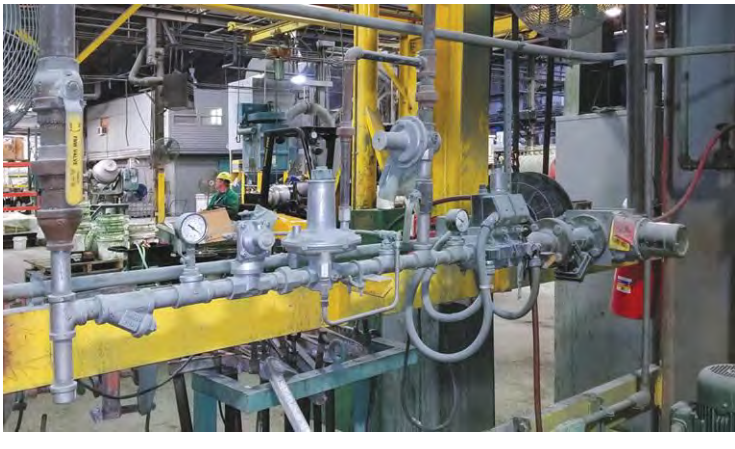
Annual NFPA Audits

Regulations change, and some of the changes may be applicable to your combustion system. The first audit purpose is to review the existing system and see how it stacks up against current NFPA 86 guidelines. This involves going through both the mechanical system (i.e., gas piping, air piping, control components and the control setup itself) as well as the electrical controls (i.e., flame safety, high-limit, temperature controls and sequence of operations – purge timing, light-off procedure, etc.). During the audit, you should document the system with a generic air and gas schematic, taking note of component part numbers and settings along the way. This information is then reviewed against the current NFPA 86 guidelines. Any deviances from the current guidelines should be addressed.

The second part of the audit is more of a safety check to make sure that the system components are functioning adequately. Technicians will go through the system and verify that every safety interlock is in safe working order by tripping the limit and verifying that the system shuts down safely. During this time, we are also verifying that the trip points are adequate for the application.

The burners and the burner controls should be inspected on an annual basis at a minimum. Here is a list of items that should be checked.

- Check fittings and piping for possible leaks.
- The inlet combustion air filters should be clean.
- Replace broken or worn auxiliary components such as pressure switches and gauges.
- Check the burner nozzle for dirt or carbon buildup.
- Sample the oil near the burner for a viscosity test if using heavy oil. This a simple sampling process. Viscosity meters will measure the viscosity of the oil. Refer to the burner manufacturer's technical data for recommended viscosity. Number 2 oil does not require heating in most applications.
- Clean the atomizer to ensure both oil and air passages are clear.
- Keep the indicators on the shut-off valves visible and clean.
- The main and blocking shut-off valves should have a proof-of-closure switch and must be wired to the burner control per NFPA.
- Check operation and setting of all switches: gas pressure, temperature, air flow, etc.



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- Check the furnace/firing chamber pressure. The furnace/system manufacturer will recommend the proper firing chamber pressure.

If the fuel and air received at the burner are not properly proportioned, you will not be getting the most economical working system. A deficiency of air will result in the incomplete combustion of the fuel and the subsequent release of pollutants to the atmosphere. If too much air is used (excess air), additional fuel will be required to heat this air. This will result in higher fuel usage.

Equipment Upgrades

Upgraded equipment such as burner components and fuel manifold components will utilize newer safety features that will automatically shut down systems if or when a safety limit is compromised. These safety features can protect plant personnel from injury and also protect the combustion equipment.

The use of orifice meters helps service technicians to accurately measure the flow of any gas. This, in turn, leads to a precise setting at each burner. A properly tuned burner generates peak efficiency. Orifice meters should be inspected and cleaned for optimal performance.

An LGV (limiting gas valve) is recommended for low-fire adjustment and fine tuning. Because pipe runs vary for different burners, a limiting gas valve can be used for fine tuning.

Pressure switches and shut-off valves perform safety functions in the gas lines. Keeping these components clean and functional are essential to reliable operation.

All the conditions of the safety-limit circuit must be made for the system to move on. Check each one physically and electrically to see if conditions are met.

Other system checks include:

- Output signal from fan
- Rotation and speed
- High/low fuel-pressure switches; verify with gauges or manometers
- Status of high-temperature-limit controller
- Temperature or reset controller if necessary
- System interlocks, such as door or material feed switches; verify physically and electrically

Flame Safety

Flame safety is essential to every combustion system. Flame supervision is typically achieved through a flame rod or UV scanner. These items need to periodically be pulled from the burner

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and cleaned. If the flame rod is found to be black with carbon buildup, it can be cleaned with emery cloth. Note that if excessive carbon buildup is found, it may also be a good idea to pull the burner and clean the surfaces within the burner body.

For a flame rod to work properly, it must ground from the flame rod to the burner body itself through the flame. If the flame rod is found to be drooping or sagging inside the burner, it is time for a replacement. Note that this is a sign that the flame rod is in excessive heat. If this is becoming a problem, investigate changing to a UV or IR scanner.

UV Scanner

Keep in mind that UV scanners come with some stipulations regarding adherence to NFPA 86. Be sure to check the latest NFPA 86 guidelines for proper implementation. UV scanners work by line-of-sight to the UV emitted from the flame. These can be pulled from the burner and cleaned with a shop rag or towel. Typically, only the bulb needs to be cleaned, but since they are line-of-sight, any lenses or windows will need to be cleaned as well. If the UV scanner bulb is becoming excessively dirty or overheating, investigate using cooling air and/or ceramic heat blocks to help alleviate the issue.

Again, it is very important to record and maintain the burner air and fuel settings for future reference. Once the combustion system is adjusted for desired operation, these setting records will be extremely helpful if or when the system performance has changed.

Summary

I have attempted to provide some basic information concerning the maintenance and adjustment of combustion systems. The applications of these combustion systems are numerous, and your system may have some special conditions to consider. For more information or on-site assistance, I would recommend contacting a reliable combustion equipment and service supplier. Help is only a phone call away.

For more information: Contact Mike Shay, director, Sales and Product Support, HEAT Combustion Solutions LLC, 4858 Provident Drive Unit C, Cincinnati, Ohio 45246; tel: 513-591-3000; e-mail: mshay@heatcombustionsolutions.com; web: www.heatcombustionsolutions.com. Assisting with this article were Brian Boehmer, sales engineer; Justin Powell, sales engineer; and Derek Seng, engineer.

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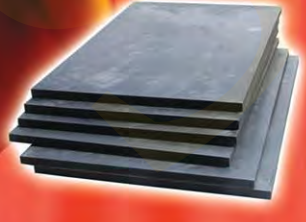

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Exploring Ferritic Nitrocarburizing and Different Post-Oxidation Treatments

Fig. 1. FNC control system and furnace
(courtesy of Kentucky Heat Treat)

Jim Oakes and Chuck Thomas –
Super Systems Inc. (SSi); Cincinnati, Ohio

Ferritic-nitrocarburizing (FNC) processing is becoming a more common alternative to coating processes that require improved mechanical properties and resistance to corrosion, often on plain-carbon and low-alloy steels.

The addition of nitrogen (N_2) and carbon into the steel structure improves corrosion resistance and mechanical properties of the steel component by forming nitrides, carbonitrides and even carbides with iron.[1] These compounds are stable at room temperature, preventing or delaying the formation of rust in corrosive environments.

Identified as a major contribution to enhanced corrosion resistance, post-oxidation of ferritic-nitrocarburized steel is used to improve corrosion in service. There are different methods of oxidizing the steel after this heat-treatment process. The additional corrosion resistance can be achieved through oxidation of any free iron at the surface that did not form one of the aforementioned nitrogen/carbon compounds.

Parts that are FNC processed have a typical metal appearance without much luster. Depending on how the FNC is performed, the process can also produce a matte finish, but generally the parts are gray/silver in color. The post-oxidation process produces a dark gray color that can appear black when coated with oil, which may be appealing for the part.

Many commercial heat-treat companies claim that a specific (usually trademarked) FNC process with post-oxidation is better than other processes with respect to enhanced property performance. Most commonly, this "advantage" refers specifically to corrosion resistance. The definition of corrosion resistance is typically associated with salt-spray testing. As a result, this is how corrosion resistance is usually defined in specifications and drawings.

As process controls and sensors improve and become more capable of selectively measuring and controlling parameters, guesswork can be removed from the process and allow for predictable and repeatable control.

Because many different processes are used for post-oxidation, there is specific interest in controlling the post-oxidation process using multiple oxidation methods and understanding if appearance and corrosion resistance is specific to one process over another. In order to fully understand this, it is necessary to control the oxygen potential. Of course, there are other factors that weigh in on the success of the FNC and post-oxidation process, which are also of interest when looking at these processes and controllable parameters.

The FNC process simultaneously introduces both nitrogen and carbon into the part while in the ferritic state (hence the name). Typical FNC processing temperatures vary between 1000°F and 1100°F (538-593°C). Process cycles can range from one hour up to 24 hours, depending on the application requirements. With this lower operating temperature and no requirement for quenching (the microstructure is developed prior to the FNC process), there is good dimensional control with FNC compared to other case-hardening processes.

The control parameters for nitrogen and carbon concentrations in gas FNC are nitriding potential (K_N), and carburizing potential (K_C), respectively. The ability to control these parameters offers process repeatability. Ammonia (NH_3) is the one gas used for delivering nitrogen to steel in gas FNC. The carbon-bearing gas can vary and usually depends on the gas availability, safety requirements, storage requirements and other similar factors. Common hydrocarbon gases used in FNC

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Fig. 2. FNC test part with post-oxidation in air

Fig. 3. FNC test part with post-oxidation in air with RPO

include endothermic gas, carbon dioxide (CO_2) and natural gas (i.e., methane, CH_4).

Ammonia dissociates on ferrous surfaces, and the nitriding potential is then defined as this partial pressure of gases shown:

$$K_N = \frac{p_{NH_3}}{p_{H_2}{}^{3/2}}$$

When a hydrocarbon is added, there is also an equilibrium established between gases. The most dominant reaction providing carbon to the steel is the heterogeneous water-gas reaction:[1]

$$CO + H_2 \rightarrow C_{ad} + H_2O$$

The carburizing potential for the heterogeneous water-gas reaction is then defined as the partial pressure of gases shown here:[1]

$$K_{CW} = \frac{p_{CO} \times p_{H_2}}{p_{H_2O}}$$

Other reactions that occur during FNC include the Boudouard reaction:[1]

$$2CO \rightarrow C_{ad} + CO_2$$

where

$$K_{CB} = \frac{p_{CO}^2}{p_{CO_2}}$$

and the methane reaction:[1]

$$CH_4 \rightarrow C_{ad} + 2H_2$$

where

$$K_{C-CH_4} = \frac{p_{CH_4}}{p_{H_2}^2}$$

The carburizing potential for the Boudouard reaction (K_{CB}) and methane reaction ($K_{C\text{-}CH_4}$) give a different value than the carburizing potential for the heterogeneous water-gas reaction. Therefore, the specific carburizing potential must be identified.

Control of the K_N is commonly through the use of an in-situ hydrogen analyzer and the precise measurements of the incoming gas flows. Although not always required for the calculation of K_N, the gas flows provide the ability to blend with gases that would dilute the H_2 since the K_N is calculated as a partial pressure of the amount of H_2 to NH_3 present.

The evaluation of the K_C parameter is accomplished by measuring the partial pressure of CO, CO_2 and CH_4 using a nondispersive infrared analyzer (NDIR). The partial pressure of H_2O can be calculated through the partial pressure of the H_2 and partial pressure of oxygen (O_2) using an in-situ oxygen probe. Similar to the K_N calculation, gas flows must be

Fig. 4. Two sets of FNC test parts run in a sealed pit furnace with an ammonia, nitrogen and CO_2 atmosphere.

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known and factored into the calculation so the dilution of the atmosphere is properly calculated.

There is significant variation in the flow ratios used for FNC processing.

- 95:5 to 50:50 NH_3:endo is typical when using endothermic gas as the hydrocarbon.
- 95:5 to 60:40 NH_3:CO_2 is typical when CO_2 is the only hydrocarbon.
- 95:5 to 70:30 NH_3:CH_4 is typical when natural gas is the hydrocarbon.

Gas-flow ratio is very common in the industry today. This type of control is still accepted in most applications, but the requirement of K_C control is starting to become more prevalent. Currently, the only industry standard defining recommended K_C values is AMS 2759/12.

Porosity

The compound layer (white layer) formed during the FNC process consists of nitrides, carbonitrides and carbides. The porosity of the white layer is a function of its nitrogen concentration and its proximity to the surface to produce thermodynamic instability. It is affected by K_N and K_C (i.e., the gas composition) during the process. As iron nitrides decompose back into iron and nascent nitrogen, the nitrogen bonds with itself to form diatomic nitrogen (N_2). N_2 is stable as a gas and will diffuse back into the furnace atmosphere, leaving porosity in the white layer.[3] Porosity can also be formed during cooling because the saturation limit of the white layer decreases with temperature.[1]

Porosity is thought to be both beneficial and detrimental to corrosion resistance. While porosity can trap oil and retain it in service to protect the part from a corrosive environment, a porous white layer is also more susceptible to cracking and/or breaking, leading to corrosion (which is why proper controls are required). Therefore, balance must be achieved for each application.

Post-Oxidation

Post-oxidation of a part that has been heat treated with a gas FNC process provides additional corrosion resistance and can improve wear properties by reducing the coefficient of friction.[1]

Post-oxidation after an FNC process is not necessary, but doing so delivers a finish and color that may be desirable. With post-oxidation, the goal is to achieve Fe_3O_4 (magnetite) – a form of iron-oxide that is stable and forms a dark gray/black color. Post-oxidation typically takes place at 850-1000°F (454-538°C), with that step of the process ranging up to 60 minutes. Some of the more common media for providing post-oxidation are air, H_2O, oxygen (O_2) and nitrous oxide (N_2O). Which media is used varies due to availability, safety and ease of control for the process. There are some claims that one type of media produces an oxide that performs better with respect to

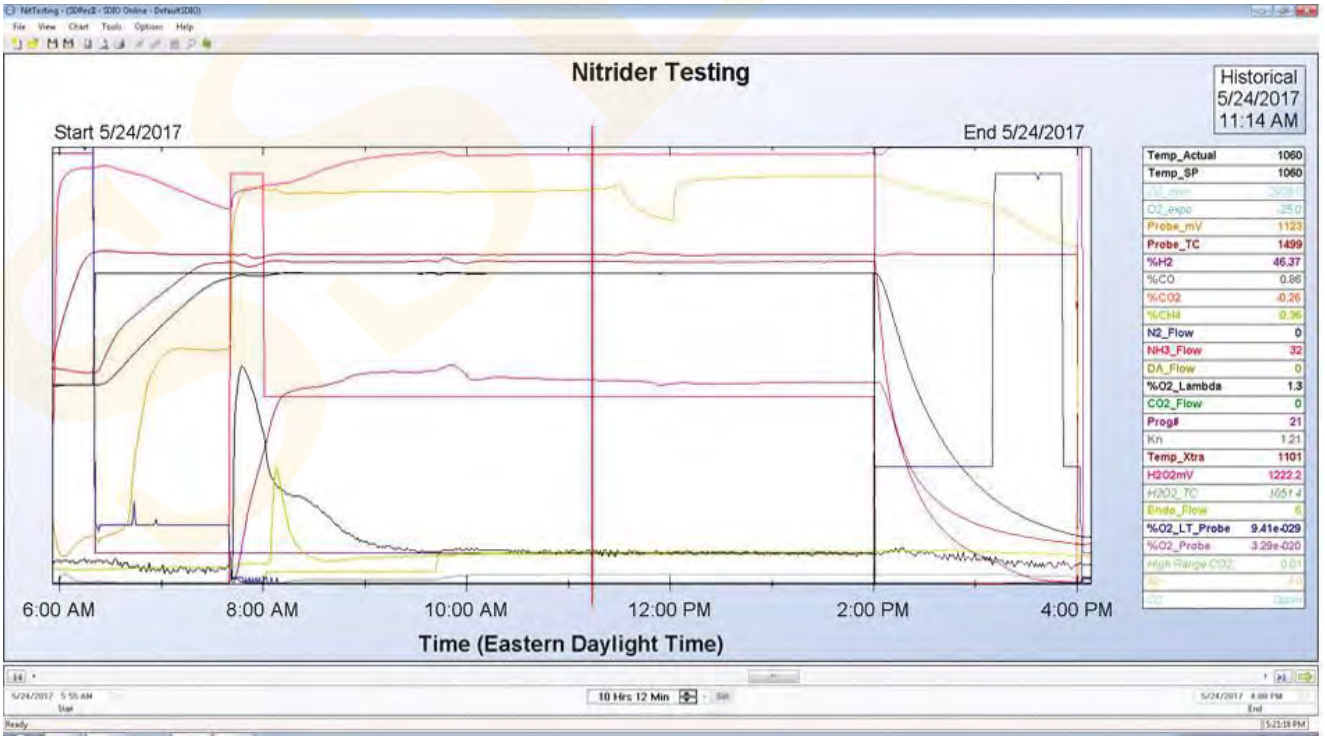

Fig. 5. FNC process chart. Control parameters include K_N, temperature, time, gas flows and K_C.

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corrosion resistance.

Lack of control in the post-oxidation process can lead to undesirable results. Not enough oxygen during the process can lead to gray parts, witness marks on parts and "shadowing," where the color of a part varies based on the racking configuration. If too much oxygen is available, hematite (Fe_2O_3) can form, affecting the color of the parts and possibly the corrosion resistance.

Case Study[2]

As mentioned previously, there is interest in the differences between the different types of post-oxidation processes and media used to perform the process. Part preparation, material type, FNC cycle and post-processes will all play a role in the evaluated performance of a part. Our case study used the same material processed under two FNC cycles, which was then divided out into groups for a secondary post-oxidation step. All parts were cleaned to remove dirt, debris, grease, oil and water. The purpose of running two FNC cycles was to generate variance in porosity with both tests having the same white-layer thickness. The targeted white layer was 15-20µm. Following the post-oxidation, the parts were cooled and stored to prevent any corrosion.

Five different oxidation processes were performed. Parts were heated up to 1000°F (538°C) in a N_2 atmosphere. Once the parts were stable, the oxidizing media was introduced into the furnace. An atmosphere of 10^{-25} percent O_2 was targeted. The parts were processed in this atmosphere for approximately one hour for each oxidation cycle. The oxidation media used for testing included air, oxygen (O_2), nitrous oxide (N_2O), water (H_2O) and quench into a water-oil mixture. Oxygen was measured using an in-situ oxygen probe. Upon completion of the process, parts were cooled to 150°F (66°C).

Half of the parts from each process group were coated with a solvent-based rust-preventive oil (RPO). The parts were submerged in the oil for several minutes and then removed and allowed to dry.

Two pieces of each test group were sent out for salt-spray testing, which was performed in accordance with ASTM B117. The samples were not cleaned prior to test and were tested at approximately 30 degrees from the vertical, parallel to the flow of the fog. When more than 10% corrosion was visible on the surface of the sample, the test was terminated for that sample. The test was terminated for the remaining samples after 408 hours.

Two samples of each experiment (12 experiment categories in all) were sent for salt-spray analysis. All of the dry samples failed after 72 hours of exposure to the salt, except for one of the samples oxidized in air. Most of the RPO samples lasted for the duration of the test with less than 10% corrosion or no corrosion at all.

Summary

No type of oxygen-bearing media appears to be more beneficial over another with respect to corrosion resistance. The oxygen potential can be controlled with an in-situ oxygen probe for consistency from load to load to create a specific oxide compound as well as help prevent appearance inconsistencies.

From the test results, we can draw the conclusion that the use of a rust-preventive treatment prior to corrosion testing will provide the best results as it relates to salt-spray testing. Our testing also shows that multiple oxidation processes can be used with a controllable process variable that will allow for equal corrosion resistance with a slight difference in appearance.

For more information: Contact Jim Oakes, VP business development, SuperSystems Inc., 7205 Edington Dr., Cincinnati, OH 45249; tel: 513-701-2122; fax: 513-772-9466; e-mail: joakes@supersystems.com; web: www.supersystems.com

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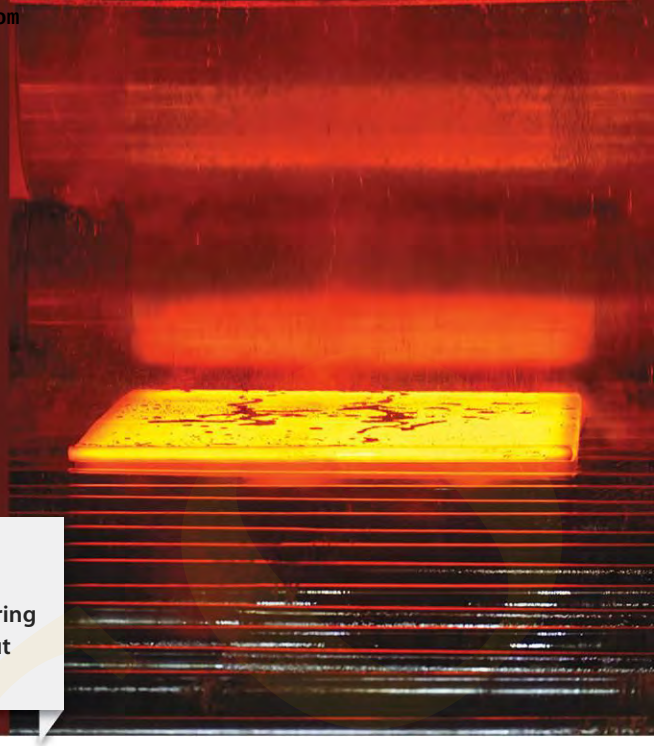


Frank Wallace and Katie Huller – Honeywell Combustion Safety; Brook Park, Ohio

In multiple-burner installations on industrial ovens and furnaces, pulse-firing techniques can improve temperature uniformity, reduce emissions and cut overall fuel costs. Is it right for your process?

Many industrial manufacturers are learning that pulsing burners – from high fire to low fire – is a quick way to reduce costs, improve safety and meet emission-level targets for industrial furnaces and ovens. Upgraded systems enhance efficiencies and production processes and help users gain the edge on the competition and generate greater revenue and profits.

Pulse-firing benefits include:

- Reduced emissions
- Temperature uniformity
- Improved process control
- Enhanced output
- Extended equipment life
- Improved product quality
- Increased safety
- Fuel savings

So, how does it work? Pulse firing is meant for multiple-burner combustion systems. In pulse firing, the heat input is controlled on each individual burner by modulating the frequency of the high and low firing ranges (Fig. 1). This results in specific control, flexibility and precision. In effect, the burners are fired at high fire for set periods of time and then cycled to low fire or turned off. This firing cycle is repeated throughout the course of the production period and is monitored by the process controller via the control algorithm within a programmable logic controller (PLC) or pulse-control module.

Unlike the typical linkage controls that modulate air valves – often found on combustion systems within the U.S. – pulse-firing technique requires an air solenoid valve at each burner as well as a ratio regulator on each burner's gas train for individual burner air/fuel adjustments. The burners are reliable and

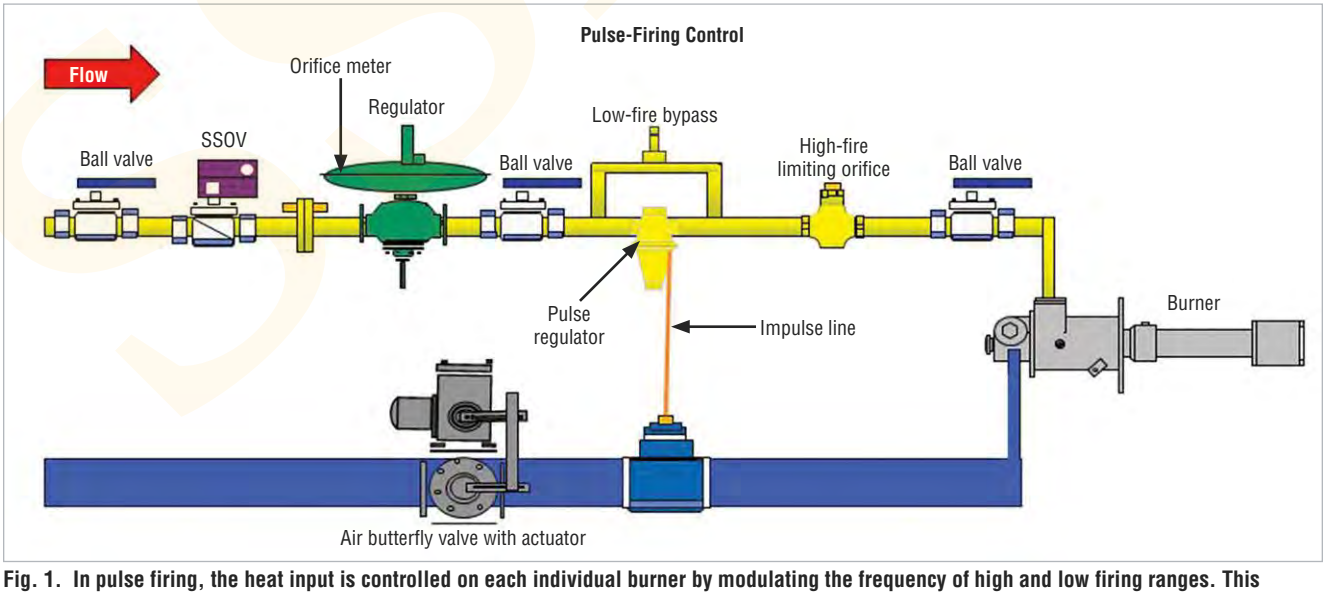


Fig. 1. In pulse firing, the heat input is controlled on each individual burner by modulating the frequency of high and low firing ranges. This results in good process control, flexibility and precision.

designed for high duty – more than 10,000 cycles.

Furnace chamber dimensions must also be analyzed. Sometimes burners are added or relocated to optimize turbulence and minimize cold spots. If the burner chamber is too large, the pulse-firing method would be ineffective, and the appropriate temperatures, mixing and uniformity may not be achieved.

Modifications to pulse-fired systems are completed electronically via the PLC or pulse-control module. The computer control ensures automated, safe and simplistic start-up. Complicated piping design becomes a non-factor, and commissioning time can be reduced for pulse-fired systems compared to cross-connected combustion systems.

Pulse-fired systems are efficient because they operate at high fire and on ratio. The highly turbulent chamber mixing shortens temperature ramp-up times and increases uniformity. This helps create the ideal conditions for higher product quality and production rates.

Equipment itself also may see extended useful life from intermittent operation at its peak firing rate. Specific burner types, like radiant-tube burners, encounter extended tube life from a more uniform tube temperature. Flat-flame burners maintain their intended flame shape from the high-velocity design of pulse firing, reducing the possibility of flame impingement or rogue flames that damage refractory.

Another attractive attribute of pulse-firing systems is the innate reduction of burner emissions. When there is low excess air and more gas being consumed, NOx levels are low, helping to meet regulatory emission targets.

The flexibility of being able to tune and control each burner is, by far, the most substantial benefit of pulse firing. Typically, the burners are tuned to one rate, high fire, which allows for straightforward maintenance and troubleshooting as well as sustained on-ratio air/fuel mixtures.

Pulse-firing systems can see up to 30% in fuel savings because they are not constantly firing or adjusting from low to high fire, which can reduce the accuracy of the air/fuel ratios over the firing ranges. Also, when the pulse-fired system is firing,

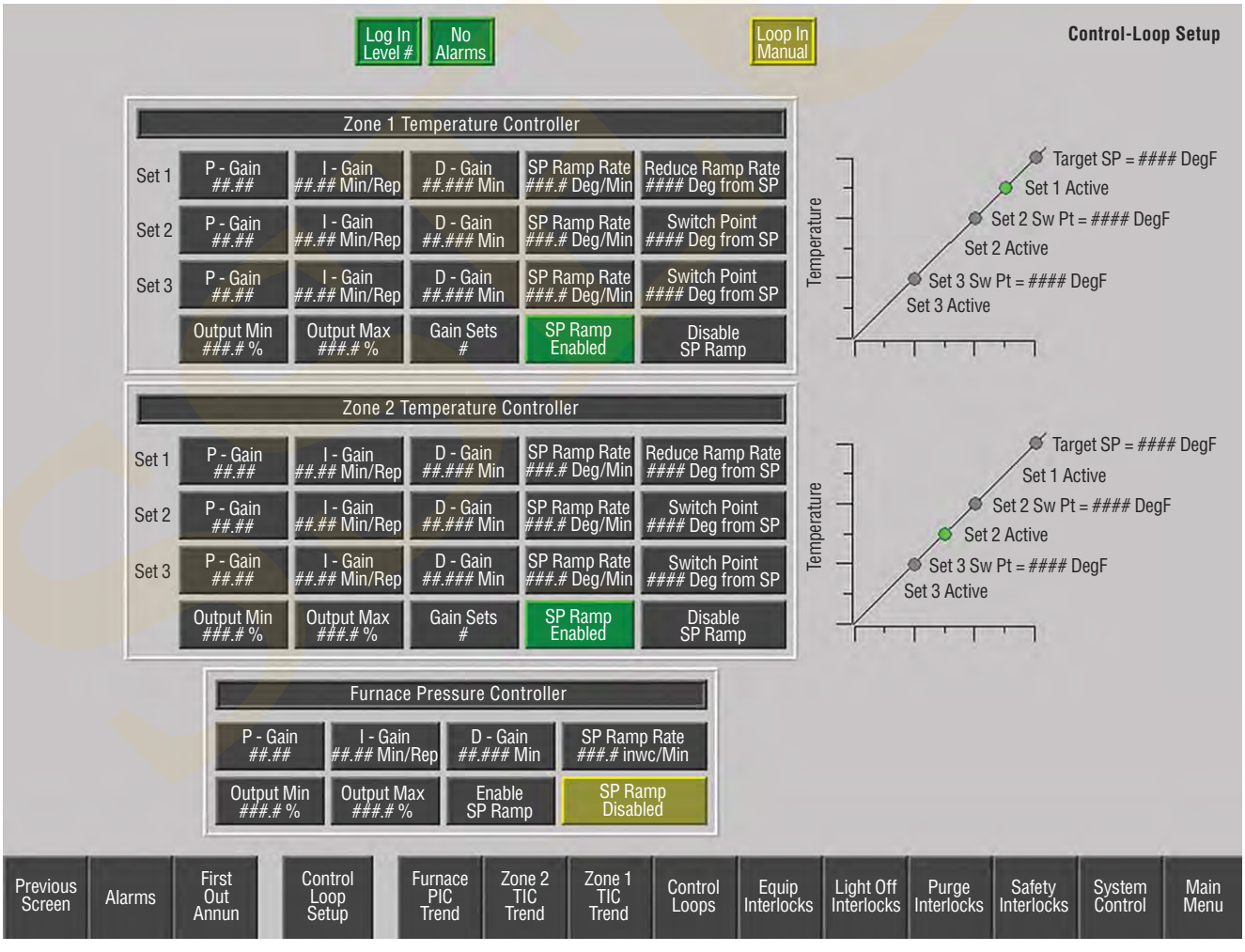


Fig. 2. The control-loop setup screen allows the operator to modify PID settings and provides a pictorial view of the current switch points.

the fuel used is benefitting production rather than being wasted by lingering in the combustion chamber and escaping through small leaks or cracks or accumulating to produce a potentially dangerous situation.

Case in Point: Stress-Relieving Furnace

A *Fortune* 500 metals corporation recently upgraded to a two-zone, pulse-fired control system on a car-bottom, stress-relieving furnace that was operating as a class 2 furnace at temperatures up to 1050°F (565°C). The previous control used an obsolete pulse-firing system that required an increasing amount of maintenance and could not achieve the desired, lower-temperature setpoints.

In the furnace, each zone on the system contained six direct-fired, medium-velocity burners, which were reused during the upgrade. The new on/off control system operates the burners only at their most efficient high-fire rate. Code-compliant burner safety-shutoff valves allow for individual burner shutdown. As heat demand increases or decreases, the control algorithm turns on or shuts off select burners, resulting in optimum fuel usage for those select burners.

Originally, the furnace was pulse fired with optional impulse-

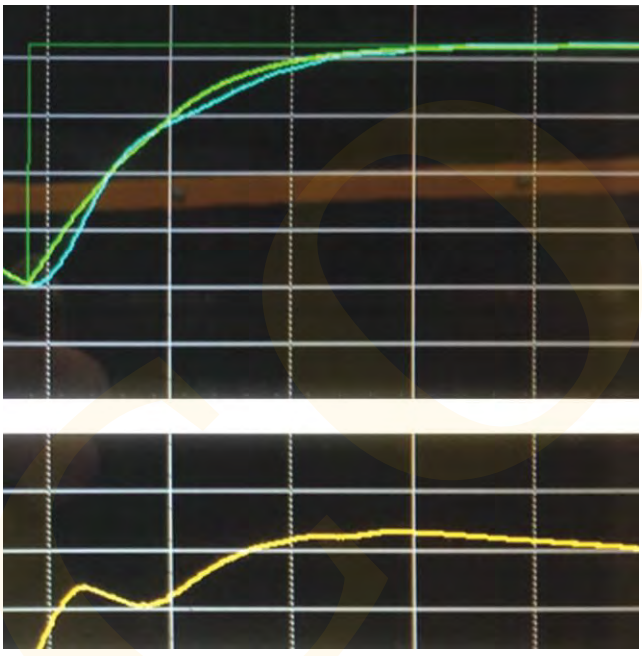
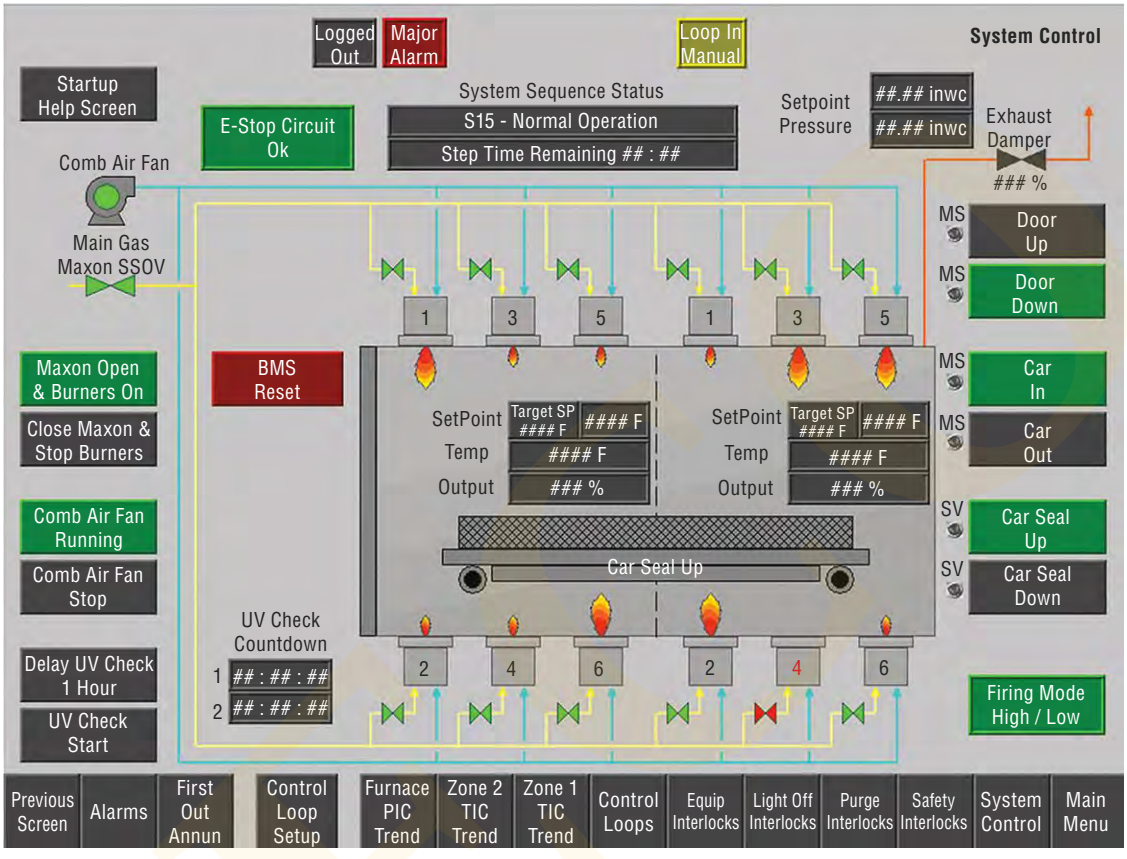


Fig. 3. The control-loop setup screen identifies which set of PID parameters is in use. The control-loop setup HMI screen and actual temperature trend are pictured.



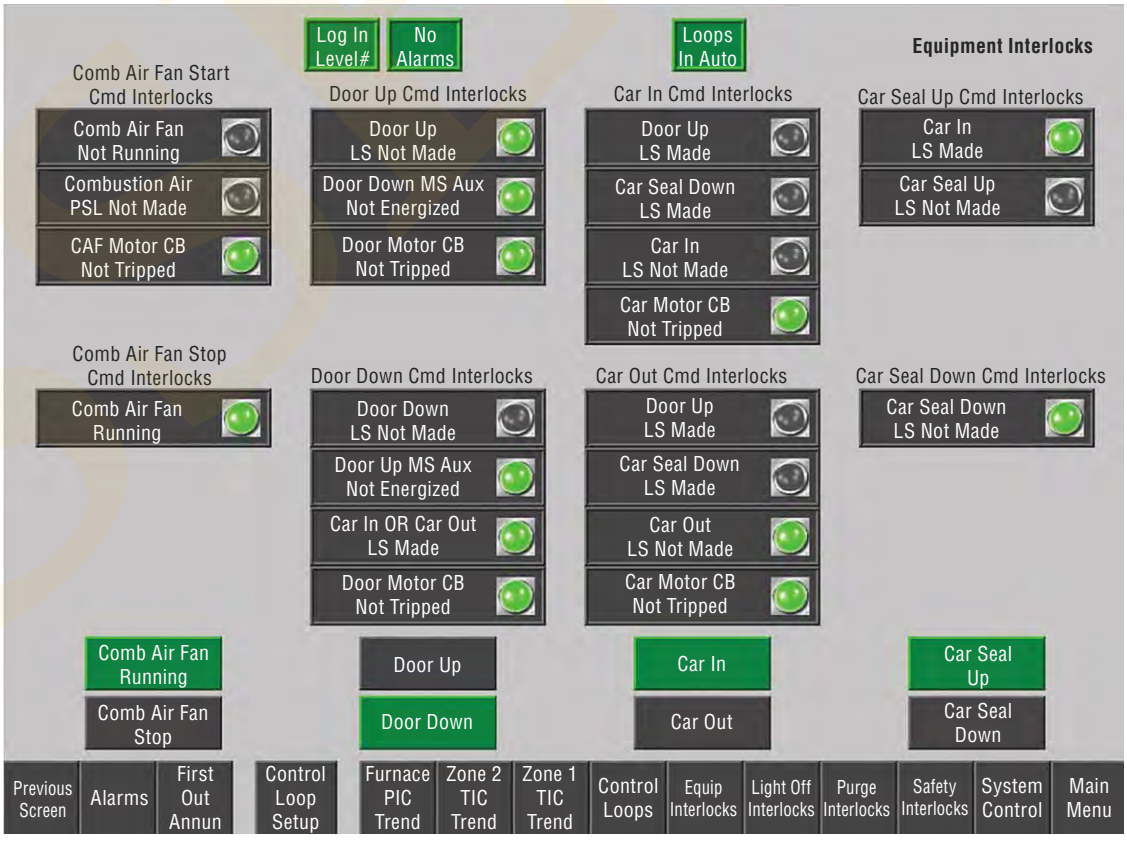


Fig. 4. The system control screen displays the control and status information required by the operator during normal operation. For example, the HMI screens show which burners are at high fire, low fire or off. If an equipment or control problem arises, permissive screens are available that will inform the operator of all inputs that the PLC code is expecting for a certain function. These tools point maintenance personnel to the exact location of a given problem and reduce the time it takes for troubleshooting.

bleed control for high excess-air operation. The pulse controller was an obsolete packaged unit that is no longer available, so it was removed. The existing PLC was replaced with a safety PLC compliant with the National Fire Protection Association (NFPA).

The PLC provides advanced, configurable safety logic; a human machine interface (HMI) touchscreen; and troubleshooting capabilities such as control overview and equipment-permissive screens. Modern pulse-firing controllers with rack-mounted burner-management system (BMS) units on the control-panel door and new gas valve-train components completed the install.

The temperature control-loop logic in the new PLC maintains up to three sets of proportional-integral-derivative (PID) constants. The PLC varies the active PID settings and setpoint ramp rates depending upon temperature difference (ΔT) from setpoint. This provides the ability to use more aggressive PID constants and ramp rates when further from the target setpoint and less aggressive settings when closer to setpoint to prevent overshooting.

The control-loop setup screen (Fig. 2) allows the operator to modify PID settings and provides a pictorial view of the current switch points. It also identifies which set of PID parameters is in use at the moment (Fig. 3).

The operator uses the system control screen to ascertain control and status during normal operation. For example, the HMI screens display which burners are at high fire, low fire or off. If an equipment or control problem arises, the control system alerts the operator of all inputs that the PLC code is expecting for a certain function. These tools point maintenance personnel to the exact location of a given problem and reduce the time it takes for troubleshooting (Fig. 4).

For the metals company, the result was a furnace that is operator-friendly, has Class 1 (±5°F) uniformity with accurate pressure control, excellent turndown via shorter pulse times and low-fire settings while high/low pulsing. With a flick of a switch, the system can be modified to pulse high/off if additional turndown is required.

The project took a total of four weeks (three weeks for installation and one week for commissioning). The initial investment is expected to be offset by reduced maintenance times, lower fuel usage, improved temperature uniformity and compliance with NFPA 86 requirements. The metals company experienced an immediate decrease in fuel usage of 5%.

Conclusion

The benefits of implementing better process control via upgraded combustion-control systems are vast and impactful. Depending upon the system's initial setup – from air/fuel ratio accuracy to equipment conditions and in-house maintenance abilities – savings on fuel and production efficiency can be well beyond the standard projections of 20-25%.

The transition to a pulse-fired system from current combustion designs can be a beneficial change for an organization. Pulse-firing techniques help secure enhanced product quality, extended equipment longevity and simplified burner maintenance and procedures.

These benefits can generate greater savings and, in turn, greater revenue for manufacturers. In the ever-changing manufacturing world with tighter environmental and safety restrictions, internal process enhancements can help ensure a sustainable future.

For more information: Contact Frank Wallace, project manager, Honeywell Combustion Safety, 2100 Apollo Drive, Brook Park, Ohio 44142; tel: 216-749-2992; fax: 216-398-8403; e-mail: info@combustionsafety.com; web: www.combustionsafety.com. Coauthor Katie Huller is the sales coordinator.

8 Great PM/Additive Manufacturing Articles

Reed Miller – Editor

The topic of "Sintering/Additive Manufacturing (AM)" garners much reader interest, particularly because of the dynamic nature of AM. Everyone wants to stay informed about this relatively new and developing technology. Check out these eight articles, which are the current reader favorites based on website activity, to stay informed.

Heat Treating 3D-Printed Metals

This September 2016 article is far and away the overall reader favorite in this category. It offers a great overview of 3D/AM. If you want to read a concise discussion of this topic, more than 1,000 online readers this year alone believe this is a great resource (www.industrialheating.com/3Dadditive).

Metal 3D printing, or additive manufacturing (AM), is an advanced manufacturing method that opens up new possibilities for designing objects with optimized geometries and minimized weight using far less material and energy – important drivers for a future sustainable, energy-efficient industrial base. New hot isostatic press (HIP) technologies are making it possible to accomplish heat treatments in the same vessel where HIP takes place, making for a faster, cheaper and more energy-efficient manufacturing process.

How Additive Manufacturing is Reshaping the Auto Industry

While additive manufacturing (AM) is a boon for specialized metal aerospace components, medical devices and custom implants, mass production of automotive components using 3D printing, or AM, may still seem a way off. Yet there are areas where the auto industry is already leveraging 3D-printing technology in its design and manufacturing strategies. What are those areas?

This article reviews the role of metal powders and industrial gases in several AM processes that involve laser metal fusion and laser metal deposition. It will also discuss how industrial gas technologies are helping to address the challenges ahead.

First seen in the May issue this year, you can find it at www.industrialheating.com/AMauto.

3D Printing Remakes the Strain Gauge

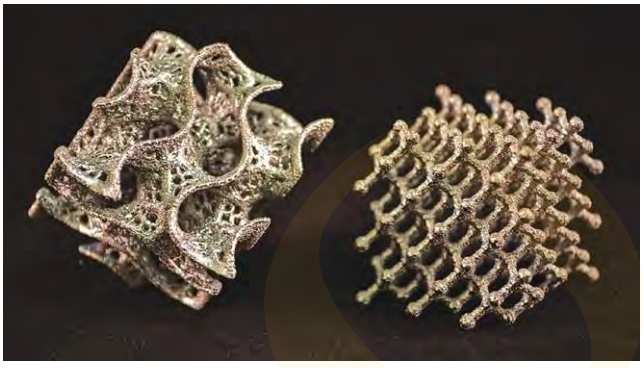
This article from Carnegie Mellon University (CMU) was seen in our February 3D Printing Report enewsletter.

A new 3D-printing technique for manufacturing strain gauges has been developed. This method significantly improves the sensitivity of strain gauges and increases their capabilities for use in high-temperature applications. You can learn more about it by going to www.industrialheating.com/3Dstrain.

Additive Manufacturing (3D Printing): Past, Present and Future

Some would say that 3D printing is a state-of-the-art manufacturing process. Perhaps it's more of a coming-of-age story. Just what is it all about? Why is it important to the high-temperature thermal-processing industry? We review the past, pres and future of this hot technology.

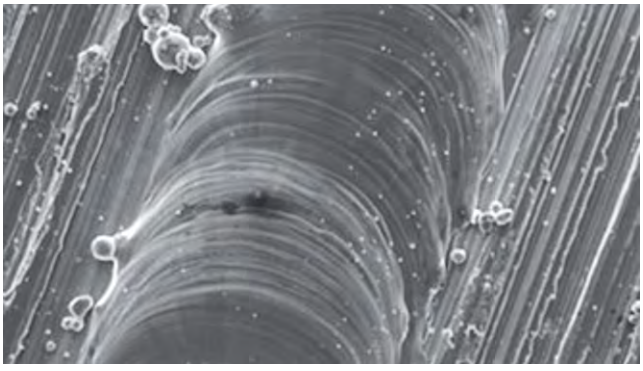
If you can read only one or two articles on this list, we suggest reading this May 2014 article (written by our editor) followed by the first one on this list. You can find this one at www.industrialheating.com/AM-3D.

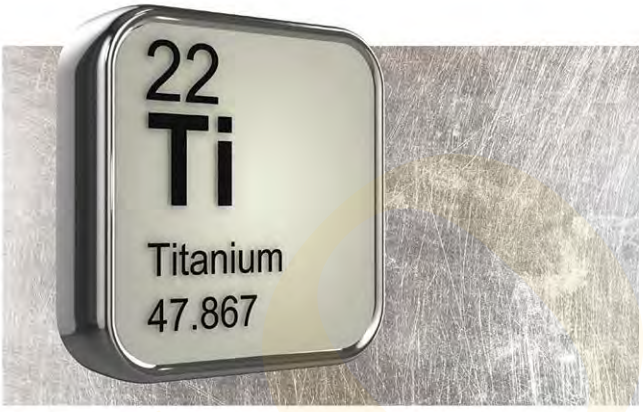


Designing a New Way to Train 3D-Printing Workers

A second article contributed by CMU was run in March as a website-exclusive about training workers in the 3D/AM field. Called ACADEMI, the training program is part of a long-term strategic alliance between America Makes, the national accelerator for 3D printing, and The Lanterman Group. The two are combining their efforts to develop ACADEMI as a nationally recognized training curriculum for additive manufacturing.

ACADEMI, which stands for Advanced Curriculum in Additive Design, Engineering and Manufacturing Innovation, is the first hands-on certification program in the U.S. focused on designing and producing products for 3D printing. Currently, other 3D-printing certification courses only teach participants the basics of 3D-printing software and equipment. But ACADEMI educates workers on how to apply the technology within their companies to drive competitiveness. You can learn more about it at www.industrialheating.com/Train3D.





Additive-Manufacturing Research Explores the Behavior of Metals, Alloys

Significant work is being done in the field of additive manufacturing, also known as 3D printing. This growing field allows manufacturers to create more-complicated, lighter parts with less wasted materials. Yet the industry continues to have questions about how materials that have been additively manufactured will behave in their environment. Will the materials be durable? Will corrosion be a problem? How will the part withstand stress?

You can get the answers to these questions by reading this December 2016 article, which was contributed by Worchester Polytechnic Institute (WPI), at www.industrialheating.com/amwpi.

Low-Cost Production of Titanium Alloys to Reduce Energy Consumption

This article from the U.S. Department of Energy (DOE) was first seen in February 2017. Advancements in nonferrous metals processing are of great interest to the DOE. Hydrogen

Sintering and Phase Transformations (HSPT) is a promising manufacturing technology that can be used to produce titanium-alloy components in a near-net-shape form.

Innovative options for titanium production are needed to allow the metal to be better utilized for its unique properties. Conventional processing results in titanium parts being more than 40 times more expensive than steel parts and 20 times more than parts made from aluminum. Read this article at www.industrialheating.com/Titanium.

Reimagining 3D Metal Printing

3D printing is quickly catching fire in the world of manufacturing. Although the aerospace and medical-device industries were the first players to adopt the process, all industries that work with metals, including automotive, are now beginning to realize the promise of 3D printing, also known as additive manufacturing (AM). AM has the potential to reduce waste, decrease time to market, increase product performance and promote product innovation.

Professor Jack Beuth from CMU, who has been researching AM for 20 years, believes that if a company has not begun to explore the technology, they should because when it comes to AM, the clock is ticking. Learn more by reading this May 2017 article here: www.industrialheating.com/3D-AM.

Looking at our reader-favorite list, we can see that web searchers are working to get their heads around this technology and are trying to figure out how they should be involved. For those already involved in AM/3D, learning how to process it is key.

INDUSTRIAL HEATING

We will continue to offer fresh content as this expanding technology continues to take shape. You can search additional content on our website by using this link: www.industrialheating.com/AMPM3D or using this QR code.

Furnaces North America 2018 • Oct. 8-10 • Indianapolis, Ind.

Exhibitor List and Booth Descriptions

Discover what the companies exhibiting at FNA 2018 are all about. Read the following booth descriptions to find out what they have to offer and/or what they'll be showcasing in Indianapolis. Advertisers in this issue are highlighted. Check out this month's Editor's Page on page 12 for a schedule of events and Heat Treat 5.0 on page 20 for a show preview.

Across USA Inc. 116
Across USA Inc. is an innovative manufacturer of CFC design carbon-carbon (C/C or carbon-fiber-reinforced carbon) composites, a highly engineered and lightweight, high-strength, heat-resistant composite material. Our products include many standard carbon-carbon shapes and sizes as well as custom-design C/C fixtures and furnace components, including heat-treat trays, racks, grids, plates, fans, rollers, fixtures, jigs, muffles, rails, fasteners, springs and insulation sheets. We design and provide material innovation by advanced carbon composite technology.

Advanced Energy 119-121
Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes. AE's power solutions enable customer innovation in complex semiconductor and industrial thin film plasma manufacturing processes, demanding high- and low-voltage applications, and temperature-critical thermal processes. AE builds collaborative partnerships to meet rapid technological developments, propel growth for its customers and power the future of technology.

Advanced Nitriding Solutions 642
We are a commercial nitriding company that provides plasma nitriding, ion nitriding, gas nitriding, S-phase nitriding, ferritic nitrocarburizing and black oxide. We are Nadcap ITAR and AS9100 certified and have an in-house metallurgical lab.

Aerospace Testing & Pyrometry ..215-217
We are an ISO/IEC 17025 company specializing in the calibration and testing of thermal-processing equipment. We offer temperature uniformity surveys, system accuracy testing, vacuum systems calibration, and consulting and training for Nadcap. We also offer customized pyrometry training to AMS 2750E, GE P10TF3, RPS-953, PWA-MCL-F40 and other prime aerospace pyrometry specifications. We have a full laboratory for the calibration of secondary standards and field test equipment in accordance with AMS 2750E.

AFC-Holcroft 314-316
See our ad on page 21
For over 100 years, AFC-Holcroft has offered atmosphere-based heat-treating equipment built to the highest standards for quality. Our extensive product range includes universal batch systems, mesh belt and cast-link belt furnaces, continuous pusher furnaces, roller-hearth and rotary-hearth furnaces, walking-beam furnaces, austempering systems, atmosphere generators, aluminum processing equipment and more. ISO 9001:2008 certified. Recently acquired by the AICHELIN Group, AFC-Holcroft is now part of the largest provider of atmosphere furnaces worldwide, with greater strength than ever before.
www.afc-holcroft.com

Ajax TOCCO Magnethermic.....133
See our ads on pages 28 and 65
Ajax TOCCO designs and manufactures custom induction heating systems for all metal industries, including: tooth-by-tooth gear scanners, vertical and horizontal scanners, lift and rotates, single-shot and unique applications. Other technologies include induction systems for melting, forging, bar and pipe processing, and unique applications for heating. Metallurgical, technical and product experts develop systems and processes for each customer and part. Hardened areas are precisely controlled in case depth, width, location and hardness. Distortion is reduced by precise heating and quenching.
www.ajaxtocco.com

ALD Thermal Treatment Inc. 636
See our ad on page 64
ALD Thermal Treatment is pleased to offer contract engineering services for its low-pressure vacuum carburizing process. As a leading supplier of vacuum systems and process technology, we serve the whole field of vacuum metallurgy and vacuum heat treatment with our products and services.
www.aldtt.net

ALD Vacuum Systems Inc.....104-106
ALD Vacuum Systems designs and manufactures vacuum furnace systems used in heat treating. We specialize in automated vacuum furnace systems, and our world renowned product line includes: ModulTherm, SyncroTherm, NitroTherm and DualTherm.

Allied Mineral Products Inc. 429-431
Allied Mineral Products Inc. supplies an entire line of monolithic refractories and precast refractory shapes for the metals and industrial markets. With three research and technology centers, 13 manufacturing locations and a global sales and technical support network, Allied prides itself on "being there" worldwide with refractory solutions. Allied offers a wide range of refractory products and engineering solutions for a variety of integrated steel applications.

Alloy Engineering Co. 329-331

AMETEK Land..... 444
AMETEK Land has been manufacturing precision measuring equipment since 1947. We are specialists in non-contact temperature measurement and combustion monitoring. AMETEK Land manufactures non-contact temperature solutions for flame hardening, laser hardening, laser welding, plasma nitriding and many other heat-treating and annealing operations. Learn how our SPOT family and Cyclops L family pyrometers will work for your process.

ANDRITZ METALS Inc. 602
See our ad on page 78
ANDRITZ METALS Group is a combination of leading suppliers that can offer equipment and services for all of your processing and finishing needs in stainless steel, carbon and nonferrous metals. In addition, the group supplies turnkey furnace systems, services and upgrades for the steel, copper and aluminum industries. Our service activities range from spare and wear parts, revamping, maintenance and automation upgrades, all provided by our experts in OEM quality. ANDRITZ METALS distinguishes between continuous and batch-operated furnaces.
www.andritz.com

APPI Energy..... 626
Founded in 1996, APPI Energy delivers apples-to-apples comparisons of supplier prices and contracts and negotiates supply solutions that reduce and manage energy costs on an ongoing basis for commercial and industrial customers. Unbiased and independent, APPI Energy has earned the endorsement of 158 trade associations and chambers of commerce, including MTI, to provide energy expertise to members.

Applied Ceramics Inc..... 638
Founded in 1967, Applied Ceramics Inc. (ACI) originally provided primarily alumina and zirconia kiln furniture and special refractory shapes. The company transformed from a kiln furniture supplier to a global enterprise with product lines stretching across various industries with multiple ventures.

Applied Test Systems 441
Applied Test Systems (ATS) has been a leading manufacturer of process heating and materials testing equipment since 1965. Our sales engineers are known for their ability to create custom testing solutions to meet a diverse range of customer specifications. Customers looking for a unique lab furnace or industrial oven can depend on over 50 years of experience and reliability, backed by our trained team of service technicians. We offer an extensive range of customizable options and accessories, including but not limited to: load train ports, thermocouples and connectors, viewports, liners, gas ports, mounting accessories and temperature control systems.

Ariane Group 244
For 40 years, Ariane Group has developed and manufactured a broad range of high-temperature composite materials. Sepcarb is our high-performance 3D carbon/carbon composite material. Sepcarb tooling is used for high-temperature processing (up to 2000°C) of aerospace and automotive components. The exceptional characteristics of Sepcarb carbon/carbon composite make it the ideal tooling material for brazing, annealing, carburizing and quenching of high-performance metals in vacuum or inert atmosphere furnaces.

ASM International 628
ASM International is a leading professional organization for materials scientists, engineers and technicians. It delivers professional development and improved materials performance for more than 25,000 members and 7,000 corporations served by members worldwide.

Avion Manufacturing Co..... 405-407
See our ad on page 58
Avion Manufacturing has been supplying stop-off coatings for over 40 years to the heat-treating industry. Ask us about our new stop-off for deep case carburizing. We are a supplier of boronizing agents and pastes. Tremendous advantages have been seen with boronizing of stainless steels. Coming soon is a reflective thermal barrier coating. **www.avionmfg.com**

AVS Inc..... 220-222
Since 1967 AVS Inc. has been the global pioneer in custom thermal-processing equipment, providing advanced technologies worldwide. AVS leads the industry in applications utilizing inert, reactive and oxidizing atmospheres; high temperatures and high pressures; and high-vacuum process parameters. From turnkey industrial production furnaces to servicing lab and university R&D units, no project is too big or small for an AVS solution.

Bloom Engineering Co. Inc.....503
Bloom Engineering has developed a reputation for quality industrial burners and combustion systems. Bloom's products can be used for a variety of applications and can be operated with

a wide array of fuels and capacity ranges. The industrial burners operate with low- to ultralow-NOx emissions. Bloom Engineering prides itself on having in-depth knowledge of the various heating applications in which its equipment is used. Bloom's customizable product line, extensive installation list, research and development capability, and on-site field service experience allow the company to provide the best possible solution for each situation

Bronkhorst USA 128
Bronkhorst USA Inc., based in Bethlehem, Pa., offers smart, low flow fluidics handling solutions that include the world's smallest and lowest flow Coriolis meters and controllers (mini CORI-FLOW); thermal mass flow meters and controllers (EL-FLOW and MASS-STREAM); pressure meters and controllers; vapor delivery modules; and associated electronics and software.

BTU International Inc.....419
BTU International specializes in precision-controlled, high-temperature belt furnaces for a wide range of custom applications, such as brazing, direct bond copper (DBC), diffusion and sintering. BTU's high-temperature belt furnaces have been manufactured in Massachusetts for over six decades and feature typical cross-belt thermal uniformity of +/- 2°C, as well as a variety of available process atmospheres (including air, nitrogen, hydrogen and forming gas).

Busch Vacuum Pumps and Systems.136
Busch Vacuum Pumps and Systems is a leading manufacturer and retailer of vacuum pumps, blowers, compressors and customized systems using vacuum technology. Busch offers a unique range of solutions, support services and technical expertise to meet the demand for diverse applications in every industry.

C3 Data.....541-543

Can-Eng Furnaces International Ltd. 111-113
See our ad on pages 4-5
Can-Eng Furnaces International Ltd. is a leading global designer and manufacturer of custom heat-treating equipment for both ferrous and nonferrous metals. Can-Eng's specialty is the design of unique high-volume industrial furnace systems for today's, and tomorrow's, demanding applications. Providing the latest improvements in energy-saving technology, material handling and automation, our advanced systems improve product flow and efficiencies of conventional systems. At the forefront of high-quality automotive fasteners and lightweighting technologies, Can-Eng builds engineering solutions to last.
www.can-eng.com

Carbon Composites Inc. 439

CC Jensen Inc.....339
C.C. Jensen Inc. supplies CJC Oil Filtration Filters and CJC Filter Inserts to maintain quenching and hydraulic oils and keep the oil clean and dry for optimum output. You get extended oil and component lifetime, cleaner parts, a stable quench curve, reduction of downtime and savings on maintenance budgets. We also provide equipment to reclaim oil from your waste oil stream.

Chemtool Incorporated 101-103
Tenaxol quenchants have been in the heat-treating industry more than 50 years. Tenaxol quenchants are a brand in Chemtool Incorporated's portfolio of products, as well as Dow UCON quenchants, which are sold and serviced exclusively by Chemtool Incorporated in North America. Chemtool Incorporated is the leader in the formulation and supply of various lubricants, cleaning agents, cutting fluids, adhesives and other solutions for diverse industrial applications

Cleveland Electric Laboratories 436-438
Cleveland Electric Laboratories (CEL) is a family-owned business that has been serving our customers since 1920 by proudly providing top-quality products, excellent customer service and exceptional attention to critical details. From our earliest days of servicing electric meters for the rail industry to our current complete line of thermocouple product offerings and advanced technologies, CEL always has placed the highest importance on serving the needs of customers while focusing on quality, efficiency and integrity.

CMI Industry Americas 304
See our ad on page 49
CMI Industry Americas offers heat-treating solutions for both new-investment projects and revamp projects worldwide. The products offered cover both ferrous and nonferrous markets. CMI has references in carbon steel, stainless steel, brass, titanium, silicon steel, copper and aluminum processes. Our engineering can provide expertise into processes, diagnostics, improvements and operation. **www.cmigroupe.com**

Conax Technologies 144
Conax is a manufacturer of TCs, RTDs and pressure and vacuum feedthroughs. For temperature monitoring, we provide calibration data in accordance with AMS 2750E. We manufacturer mineral-insulated metal sheath TCs for both base and precious metal TCs. Conax also provides high-temperature, high-purity ceramic and refractory metal sheath sensors.

Conrad Kacsik Instrument Systems . 333
For over 40 years Conrad Kacsik Instrument Systems has supported the thermal-processing industry. As a service company and system Integrator, we specialize in both process control systems and instrumentation. With offices nationwide, we service from coast to coast. Conrad Kacsik is ISO/IEC 17025 accredited by A2LA. Our team delivers: certified calibrations, temperature uniformity surveys, system accuracy tests, Nadcap compliance consulting services, supervisory control and data acquisition systems, and an in-house metrology lab.

Control Concepts Inc. 415
See our ad on page 71
Control Concepts Inc., founded in 1980, is a privately held company and the market leader in the design and manufacture of stock and custom SCR power controllers. Our single-phase, three-phase, zero-cross and phase-angle power controllers have voltage ratings ranging from 24 to 690 volts and current ratings ranging from 8 to 2000 amps. Our goal is to achieve continuous customer satisfaction by focusing on our key assets: power control application reliability, customer service and power control application assistance, and power control product delivery. **www.ccipower.com**

Cooley Wire Products 120
We provide heat-treating baskets, liners, fixtures and woven wire cloth.

Cornerstone Systems Inc. 416
Cornerstone Systems is the developer of Visual Shop, a comprehensive management software solution designed for the heat-treating industry. It includes quotations, certifications, process masters, order scheduling, shop-floor tracking, shipping, pricing, invoicing and much more. Analyze your business operations like never before with Deep Data Discovery.

Custom Electric Manufacturing, LLC .. 410
See our ad on page 9
Custom Electric offers customers more than 60 years of element manufacturing experience and 90 years of element design experience. Its original equipment and replacement elements are used in applications including heat treating, die casting, forging and gear manufacturing. Products include bayonet elements, immersion elements, rod overbend elements, helical coil elements and tubular elements. **www.custom-electric.com**

David Round and Ruger Industries..312
Founded in 1869, The David Round Company is one of the oldest and most experienced material-handling manufacturers in the world. David Round, with its Ruger Industries subsidiary, specializes in the production of both standard and custom-engineered hoists, jib cranes, lift tables, floor cranes, furnace loaders and more.

DeKalb Blower Inc. 600
We are engineers and manufacturers of high-temperature fans and blowers up to 2200˚F, including water-cooled and air-cooled designs. We also provide complete repair services and replacement parts

Diablo Furnaces 140
See our ad on page 23
Diablo Furnaces provides new standard and customized furnace equipment such as roller hearths, internal quench (IQ) furnaces, tempers, box, car bottoms, rotary, pit, mesh-belt and many others. Retrofits are handled at purchaser's plant or in-house at Diablo's manufacturing site. Diablo provides service, maintenance, parts, controls, installations and other services assisting large and small companies. Solutions range from turnkey furnace design and installation to a door modification. **www.diablofurnaces.com**

DixiTech CNC 539
DixiTech specializes in manufacturing new and remanufactured quench presses for the hardening and shaping of metal gears and bearing races. We also build heat exchangers for heating and cooling quench oil temperature/control.

Dry Coolers Inc. 204-206
See our ad on page 17
Dry Coolers Inc. is a leader in the heat-treat industry for the design and manufacture of fluid cooling systems. Skid-mounted solutions for vacuum furnaces, atmosphere furnaces, induction and salt baths are featured, along with the new global standard Solanus quench oil cooler. Engineers will be available to select the optimal equipment from a complete line of pumping stations, control panels, evaporative cooling towers, chillers and heat exchangers. Whether air-cooled, evaporative or chilled, Dry Coolers has the coolest solution! **www.drycoolers.com**

DuBois Chemicals/Heatbath 400
DuBois Chemicals/Heatbath is an innovative, leading supplier of advanced specialty chemicals. We offer the widest selection of oil quenchants, polymer quenchants and molten salts. Our objectives include achieving continuous improvement and complete customer satisfaction by: developing products to meet the customer's most demanding applications; manufacturing those products to the highest quality standards; and providing the customer with a full range of support.

Du-Co Ceramics Co. 338
We are an international manufacturer of technical ceramics using dry press, extrusion and roll compaction methods. Materials include steatite, alumina (standard and high purity), MgO (standard and high purity), mullite, forsterite and cordierite. Secondary machining operations and spray drying capabilities are also available.

Duraloy Technologies Inc. 524
Duraloy is a world leader in the production of specialty castings and assemblies. Exceptional patented and trademarked alloys developed by Duraloy, such as the MO-RE family of heat-resistant alloys, 22H and Super 22H, are still worldwide industry standards for heat-resistant alloys and the alloys of choice for many heat-resistant applications.

ECM USA Inc.....210-212
ECM USA Inc. is the leader in low-pressure vacuum carburizing furnaces. Our innovative solutions are designed for captive in-line or compact systems with specific requirements for low-pressure vacuum carburizing, neutral hardening, oil and gas quenching, carbonitriding, annealing and more. ECM's equipment has not only advanced the LPC process, but it has integrated vacuum oil quenching and the highest-powered 20-bar high-pressure gas-quenching system for production available.

Edwards Vacuum Ltd. 110
We are at the forefront of vacuum for all heat-treatment applications. We can provide you with high quality, reliable and cost-effective vacuum solutions with reduced environmental impact. Our experts can select the best option for your process, whether oil-sealed or dry-pumping technology.

Epcon Industrial Systems, LP.....516
Epcon Industrial Systems has been designing, engineering and manufacturing state-of-the art and leading-edge heat-processing equipment, including industrial ovens and furnaces for over 40 years. Epcon's ovens and furnaces are renowned for their quality and are built in compliance with OSHA and NFPA 86 standards.

Eurotherm by Schneider Electric 311-313
Eurotherm by Schneider Electric designs and manufactures products and systems to enable excellence in precision process control, secure data recording and advanced power control. More than 3,000 customers over the last 53 years have relied on our expertise in improving control and providing solutions for heat-treat standards (CQI9, AMS 2750E and Nadcap).

Fives North American Combustion...540
Fives North American Combustion offers an integrated array of products including; combustion products/controls and aluminum and steel processing furnaces. We offer life-cycle services from small repairs to rebuilds, refractory services and combustion system tuning.

Fluke Process Instruments 412-414
Three industry leaders – Raytek, Ircon and Datapaq – joined together to create Fluke Process Instruments, offering a broad portfolio of industrial temperature measurement solutions. Providing non-contact infrared temperature measurement and thermal profiling solutions is our business. With over 150 years of combined experience, we've pioneered a solution specifically for your needs.

Furnacare Inc. 238
See our ad on page 51
Furnacare is owned by TAV Vacuum Furnaces and TAV Engineering and has been established to serve its North American customers with technical support while growing its market share with its vacuum furnace product line. The product line serves the aerospace, automotive, industrial gas turbine, commercial heat treatment and research center markets. Furnacare/TAV partners and provides custom solutions to vacuum furnaces. **www.furna.care**

G-M Enterprises 315-317
See our ad on Back Cover
We are an innovative vacuum and atmosphere retort furnace manufacturer focused on high efficiency and performance. Our GMVAC-1 computerized, intuitive graphical furnace control system with process and equipment monitoring, diagnostics and easy troubleshooting capabilities makes problem resolution fast and easy, maximizing run time. The system uses seven separate bands of P.I.D. temperature control, allowing faster heating ramp rates without overshoot, yielding shorter cycles during temperature surveys. The system exceeds the AMS 2750E specification. **www.gmenterprises.com**

Gasbarre Furnace Group 401-403
See our ads on pages 42 and 60
Gasbarre Furnace Group (J.L. Becker, C.I. Hayes and Sinterite) designs, manufactures and services an extensive line of thermal-processing equipment to satisfy specific requirements for virtually any process including nitriding, sintering, brazing, hardening, nitrocarburizing, carburizing, carbonitriding, annealing, tempering, normalizing and stress relieving. Batch and continuous-type furnaces are available and include tip-up, vacuum, mesh belt, car bottom, pusher, box, pit, temper and roller hearth. We offer a full line of replacement parts and auxiliary equipment (washers and generators). Stop by our booth to find out how our extensive expertise can help your company thrive. **www.gasbarrefurnacegroup.com**

Gear Solutions and Thermal Processing 526

Gefran Inc. 129-131
Gefran Inc. is a wholly owned subsidiary of the Gefran Group, based in Italy. Operating directly in 16 countries, with nine manufacturing plants and with a network of over 70 authorized distributors all over the world, the company can boast a global presence. The group's activity is divided into three main areas of business: automation, sensors and motion control.

GeoCorp Inc. 326-328
We manufacture thermocouples, thermocouple wire and associated accessories. NIST-traceable calibration services are available with our ISO/IEC 17025:2005-accredited lab. Our custom-built thermocouples can ship in days. All of our material will meet AMS 2750E, BAC 5621L and all other quality specifications. Our tenured staff can offer assistance with finding the correct thermocouple or thermocouple wire to meet your requirements.

Graphite Machining Inc. 513
Graphite Machining Inc. has three machining locations with over 100 CNC and manual machines. More than 3 acres of graphite enables emergency shipments for graphite items needed. Elements, injection nozzles, connectors, feedthroughs, fasteners, hearth parts and furnace furniture are our specialty.

H.C. Starck Inc. 506
H.C. Starck is your one-stop refractory metals supplier for your high-temperature vacuum and atmosphere furnace processing needs. We supply fabricated products to OEMs, end-users and aftermarket furnace manufacturers from Mo, W and Ta, including MoLa, TZM, MoW and MHC alloys. Our products offer the best performance and operating efficiencies for high-temperature commercial, laboratory and production furnaces.

Halifax Fan USA 542
We are a U.K. custom industrial fan manufacturer with 60 years of experience. Our own factories are based in Ohio, U.K. and China. All our fans are available in metric or imperial, and we can manufacture to all international standards. We can supply fans up to 1700˚F.

Heat Treat Central 118
Heat Treat Central (HTC) is a U.S.-based business committed to helping heat treaters leverage globally sourced alloy for competitive advantage. HTC offers high-quality investment cast products for longer service life, less porosity, greater dimensional precision and reduced environmental impact.

Heat Treat Equipment.....507
Heat Treat Equipment supplies new and used furnaces and other heat-treating equipment. We will build new to your specifications. We have a large inventory of used and refurbished furnaces, generators, parts washers and other equipment offered at competitive prices. All our equipment can be purchased "as is, where is," or we can update and refurbish per your requirements. We also offer consulting services to help you with your business decisions.

Heat Treat Today.....505

Heat Treating Services Unlimited 501
Heat Treating Services Unlimited (HTSU) is a service company that provides refractory, maintenance, calibration, repair and testing services for process control systems and equipment within the thermal-processing industry. HTSU is proud to be doing business with some of the top end users and manufacturers within the industry.

HeatTek.....527
HeatTek is your global source for thermal system engineering and manufacturing. HeatTek manufactures custom industrial ovens, furnaces, parts washers and completely integrated thermal systems.

Honeywell Thermal Solutions ...100-102
Honeywell Thermal Solutions has united the industry's leading brands to provide the

continued on page 70

most extensive range of thermal solutions available. Our comprehensive portfolio offers the largest selection of burners, valves, sensors and controls for industrial and commercial heating applications globally. Our family of brands includes Honeywell Combustion Safety, Honeywell Combustion Service, Eclipse, Exothermics, Hauck, Kromschröder, Maxon and Honeywell Combustion Controls.

Houghton International.....305

I Squared R Element Co. Inc. 544
See our ad on page 69
For 50 years, I Squared R has been a leading manufacturer of high-quality silicon carbide heating elements that are used in industrial furnaces all over the world. SiC elements are a reliable and economical heat source for temperatures between 538-1538˚C. For furnace temperatures up to 1775˚C, we manufacture Moly-D elements. Processes that use these elements include metal melting, heat treating, brazing, sintering and die casting. Our staff is available to troubleshoot element problems.
www.isquaredrelement.com

Idemitsu Lubricants America Corp..... 443

Induction Tooling Inc. 327
See our ad on page 31
Now in our 42nd year, Induction Tooling Inc. is the world's premier source for selective hardening inductors. Our design team works closely with our customers to ensure that the end product produces a specification heat treatment to their parts. Our professionally staffed induction laboratory coupled with our ISO1725-certified metallurgical laboratory will heat treat customer's parts and confirm the results for a robust PPAP-ready process.
www.inductiontooling.com

Industrial Heating Equipment Association 616
The Industrial Heating Equipment Association (IHEA) is a voluntary international trade association representing the major segments of the industrial heat-processing equipment industry. Established in 1929 to meet the need for effective group action in promoting the interest of industrial furnace manufacturers, the organization has expanded and currently includes designers and manufacturers of all types of industrial heat-processing equipment.

Industrial Heating..... 624
Industrial Heating is the world's largest and most comprehensive integrated media resource focusing on high-temperature thermal-processing technology and practical applications.

INEX Incorporated 307
See our ad on page 72
INEX produces composite (silicon/silicon carbide) radiant tubes used in atmosphere-controlled heat-treat furnaces. These radiant tubes are capable of much higher heat flux rates, which in turn can reduce recovery times in batch furnaces or speed up continuous furnaces. This unique material does not creep, which is the principal cause of failure in nickel/chrome alloy tubes. Flanged, closed ends and finned tubes are available.
www.inexinc.net

ION-HEAT 518
Ion Heat is an innovative engineering company providing engineering and manufacturing services to industry around the world. From concept and engineering design to manufacturing, assembling and testing, we are the right partner for your product development team.

IPS Ceramics.....112

Ipsen 301-303
See our ads on pages 3 and 35
Ipsen designs and manufactures industrial vacuum and atmosphere heat-treating systems, supervisory controls systems and predictive maintenance software platforms for a wide variety of industries, including aerospace, automotive, commercial heat treating, energy and medical. With production locations in America, Europe and Asia, along with representation in 34 countries, Ipsen is committed to providing 360° support for customers worldwide.
www.ipsenusa.com

ITC - International Technical Ceramics, LLC.....538
ITC offers a full line of high-temperature, energy-efficient ceramic coatings used to reduce energy consumption, reduce refractory maintenance, improve temperature uniformity and increase refractory longevity. ITC coatings are also used to protect metal parts from oxidation due to prolonged used at elevated temperatures.

Jackson Transformer Company.....433
See our ad on page 73
Jackson Transformer Company is a leading designer and manufacturer of transformers, reactors, chokes and other magnetic products. We have been developing, designing and manufacturing magnetic products since 1955. We also provide repair and reconditioning services on transformers used in induction heating equipment, regardless of original manufacturer.
www.jacksontransformer.com

Jensen Oven div. of JB Autotech LLC.....345

JUMO Process Control Inc. 240
JUMO is a worldwide trademark for measurement and control technology. The company was established in 1948 by Moritz Kurt Juchheim in Fulda, Germany. In just a few decades, JUMO has grown from modest beginnings to an internationally successful company, with offices and representatives across the globe. JUMO began the United States subsidiary, JUMO Process Control Inc. in 1984.

Kanthal, Part of Sandvik Group 502-504
Kanthal is a world leading brand for products and services in the area of industrial heating technology and resistance materials.

Karl Dungs Inc. 143
See our ad on page 30
Karl Dungs Inc. is a global supplier of combustion controls for industrial process-heating applications. Our products include flame safety, scanners, safety shutoff valves, regulators, air and gas pressure switches, ignition transformers, actuators and fuel control valves as well as assembled custom-designed gas train systems. Our knowledge of global codes and standards allows us to support you on your combustion controls designs no matter where your equipment is to be located.
www.dungs.com

King Tester Corporation.....511

L&L Special Furnace Co. Inc. 216
See our ad on page 30
L&L Special Furnace Co. Inc. is the leader in high-uniformity batch furnaces, ovens, quench tanks and heat-treating systems. All manufacturing and engineering is done in-house from one location just south of Philadelphia, Pa. A major L&L commitment is to offer furnaces tailored to the special needs of each customer at a reasonable price by designing a wide selection of standardized options. A reputation for sophisticated engineering, quality workmanship and professional service has resulted in a large and growing base of satisfied customers. L&L sells and services worldwide.
www.llfurnace.com

Lectrodryer 125
Lectrodryer partners with customers to add value to the power generation, refinery, chemical, government, heat-treating and compressed-air markets.

Leybold USA..... 243-245
As a premier industrial vacuum equipment supplier, Leybold has a mission to help make furnace owners more profitable by raising productivity and reducing operating costs. We offer a wide range of vacuum components, standardized and fully customized vacuum solutions, complemented by vacuum technology accessories and instrumentation. Our core capabilities center on the development of applications and products that operate longer, faster, cleaner and more efficiently for you.

Lindberg/MPH 411
See our ad on page 29
Lindberg/MPH is a leading manufacturer of standard and custom industrial heat-treat furnaces. Their line of heat-treat furnaces includes pit, box, IQ and belt-type designs for the ferrous and nonferrous markets. In addition to heat-treat furnaces, Lindberg/MPH designs and manufactures a full line of melting and holding furnaces for nonferrous alloys. Lindberg/MPH customers cover a wide range of industries, including aerospace/military, automotive, commercial heat treating, energy/oil, electronics and forging.
www.lindbergmph.com

Material Interface Inc. 529
Material Interface introduces a new product, Minimox self-protective alloy treatment, to protect a variety of alloys in extreme conditions of elevated temperature and/or corrosive atmospheres. The product, which is applied in the field, can reduce oxidation of certain alloys, resulting in extended product life or reduced cost of production by minimizing secondary operations.

McDanel Advanced Ceramic Technologies 425-427
McDanel Advanced Ceramic Technologies is a leading manufacturer of high-quality industrial and advanced technical ceramics. Our experienced engineers specialize in developing custom prototypes to full-scale production of ceramic components utilizing a collection of ceramic bodies, including alumina, mullite, zirconia and sialon.

McLaughlin Services LLC.....421-423
McLaughlin Services has been building, rebuilding and servicing atmospheric furnaces and endothermic generators for over 10 years. Vacuum Engineering Services (VESCO) has been building hot zones, rebuilding vacuum pumps, modifying vacuum furnaces and servicing the vacuum processing industry for over 34 years. Both companies offer top-of-the-line field service, troubleshooting and consulting, preventive maintenance and a wide range of replacement parts.

Mersen USA Greenville-MI Corp.....341
Mersen is a premier manufacturer of graphite, Calcarb rigid insulation, Calcarb carbon and graphite soft felt, carbon/carbon and Papyex flexible graphite. We offer a wide range of sizes to meet all of your graphite and carbon requirements. Mersen also offers all high-temperature industries an innovative and wide range of smart, cost-effective graphite-based solutions.

Mercer Technologies Inc./ Midwest Vacuum Pumps 115

Metal Treating Institute 618-622
MTI, the world's largest network of commercial heat treaters and suppliers, is the heat-treating industry's leading trade association for online training, financial benchmarking studies, research data, networking and industry information.

Metallurgical High Vacuum Corp.... 306
With over 35 years of continuous business and service to customers in high-tech industries, MHV – with a proven quality management system, certified in compliance to the ISO 9001:2015 standard and controlled manufacturing methods – brings technical skill, experience and discipline to the business of industrial vacuum equipment.

Moltun International 515
Moltun International manufactures top-quality molybdenum, tungsten, titanium and related alloy products. Our products include basic nuts, sheets and consumables, moly billets and heads for glass or furnace melting operations to complex CAD-designed and drawn specialty alloys for the solar and energy industries.

MTI Corporation 242
MTI Corporation has been providing a total solution for materials research labs since 1995. MTI supplies ceramic, crystal and metallic substrates and nanopowder. MTI also provides laboratory R&D equipment.

Mycon Corporation 604

Nabertherm Inc. 330
Nabertherm has been developing and producing industrial furnaces for many different applications for 70 years. As a manufacturer, Nabertherm offers the widest and deepest range of furnaces worldwide.

Nanmac Corp. 510-512

Nel Hydrogen 139
See our ads on pages 44 and 77
Nel Hydrogen is a global hydrogen company delivering optimal solutions to produce, store and distribute hydrogen. Nel has a history of development and continual improvement of hydrogen plants. Our patented Alkaline and Proton PEM electrolysis systems coupled with uncompromising attention to excellence and quality enable us to provide solutions that meet global hydrogen requirements for thermal-processing applications including thermal spray, powder metallurgy, MIM and heat treating. **www.nelhydrogen.com**

Nitrex Metal Inc. 231
Nitrex Metal is a manufacturer and technology leader of modern nitriding and nitrocarburizing systems. Our turnkey systems can process a full range of steels, including 300 and 400 series of stainless steels, and our proprietary technologies like potential-controlled gas nitriding NITREG (AMS 2759/10A), potential-controlled gas nitrocarburizing NITREG-C and ONC (AMS 2759/12) guarantee the quality of the treatment.

Noble Industrial Furnace Co. Inc. 640
With more than 40 years of experience, Noble Industrial Furnace has developed a worldwide reputation for excellence in every area of industrial furnace design, construction, installation and maintenance. Each job, whether a small re-brick or the design and construction of a completely new system, is tailored to our clients' specific needs using the highest-quality components.

North American Cronite Inc. 105-107
See our ad on page 37
SAFE-Cronite is a world leader in the manufacture of cast alloy trays, fixtures and furnace parts for the heat-treatment, steel, automotive and aerospace industries. SAFE-Cronite is present throughout the world, with nine production, design and R&D facilities in the U.S., Mexico, France, England, Germany, Czech Republic, China and India.
www.safe-cronite.us

Nutec Bickley 514

Olstrad Engineering – NOXMAT 342-344
Olstrad Engineering offers combustion-system expertise based on experience in a wide variety of industries. We design, build and implement custom solutions tailored to the needs of our customers. Our control and automation solutions include expert programming and support and utilize the best available technology.

Onex Inc. 606
Onex provides refractory and combustion services for high-temperature processing equipment as well as being an original equipment manufacturer of high-temperature furnaces for the forge, heat-treat and aluminum industries.

Park Thermal International (1996) Corp. 500
We are a supplier of thermal-processing equipment and heat-treat salts, including catalyst, foil stop-off coatings, quenching oil, service and spare or replacement parts. Furnace and Oven are available new or used (refurbished) and in any size and configuration from small tool-room applications to large production furnaces with or without atmosphere and in electric or gas. Our "One Stop Heat Shop" concept adds value and convenience to our products and services.

Pfeiffer Vacuum Inc. 523
Pfeiffer Vacuum provides vacuum solutions for all vacuum furnace needs from a single source. We stand for reliable products and outstanding service. For over 125 years, Pfeiffer Vacuum has been setting milestones in industrial vacuum technology. Our comprehensive line of products ranges from individual components to complex vacuum systems. Our experienced engineering team also helps you select the most efficient solutions for your application.

PhoenixTM LLC.....525
See our ad on page 38
PhoenixTM designs and manufactures in-process temperature monitoring systems for furnace surveying and profiling. Protected by a thermal barrier (hot box), the data logger travels through the process monitoring the temperature at up to 20 critical points, eliminating the need for cumbersome trailing thermocouples. Industry-specific software provides process optimization tools and is able to generate AMS 2750E and CQI-9 compliant reports. PhoenixTM offers a comprehensive range of standard systems but also provides custom-built solutions to meet individual requirements. **www.phoenixtm.com**

Pietro Fiorentini 520-522
We manufacture gas regulators, slam shut valves and relief valves for burner systems.

PLANSEE USA LLC 237-239
Powerful products from strong metals! Plansee offers a comprehensive range of semifinished and standard molybdenum, tungsten and tantalum products as well as their alloys. The range covers sheets, ribbons, rods, wires, boats, furnace and spare parts.

Praxair Inc. 241
See our ad on page 61
Praxair Inc. is a leading industrial gas company in North and South America and one of the largest worldwide. They offer a full range of industrial gases and technologies. These gases include nitrogen, oxygen, argon and hydrogen. The proper application of these gases and technologies may enable substantial savings, increase your productivity and help meet your precise specifications. Contact Praxair to discuss protective furnace atmospheres, gas flow optimization, the integration of gas supply, the addition of flow controls into your process and more. **www.praxair.com**

Procedyne Corp.....214
Procedyne Corp. is a leading supplier of fluidized bed heat-treating equipment. Our systems provide excellent thermal uniformity and rapid heat-transfer rates, which compare to those found in salt baths. Procedyne manufactures furnaces in a wide range of standard and custom sizes with atmosphere and temperature capabilities.

Pro-Tech Company Inc. 430-432

Protection Controls Inc. 137
See our ad on page 62
Protection Controls Inc. is the only company whose primary product is combustion safeguards. We have made combustion safeguards for over 60 years. Our PROTECTOFIERS are available as single burner and multiburner controls both for manual (push-button start) and automatic operation. The basic combustion safeguard provides safe-start function then amplifies a flame signal of several millionths of one ampere to energize the gas valve train. Our PROTECTOFIERS allow sensing with flame rod (electrode) or ultraviolet scanners. **www.protectioncontrolsinc.com**

PVT Inc. 117
See our ad on page 25
PVT Inc., an Inductotherm Group Company, features its third generation of software controls specifically designed for aerospace applications on all of its new vacuum brazing systems. The state-of-the-industry controls provide enhanced recipe options, customization and input on a reliable, consistent and serviceable platform. This combined with five decades of furnace manufacturing experience results in a robust Class 1, Type 2 furnace that has the temperature uniformity, quick crossover and deepest vacuum for the most demanding aluminum heat exchanger and cold plate vacuum brazing applications.
www.pvt-vf.com

Pyradia.....336
For 45 years, Pyradia has been a major supplier of high-temperature industrial ovens and heat-treating equipment, from tabletop laboratory solutions to drop-bottom ovens for aluminum heat treating. We design and manufacture a broad range of standard and custom-built industrial ovens and furnaces for heat treatment at temperatures ranging from 800˚F to 3200˚F.

Qual-Fab, Inc. 532
See our ad on page 68
Qual-Fab, Inc. is a custom fabricator specializing in the fabrication of high-quality products utilizing high-nickel and stainless steel alloys. We offer a variety of products including fabricated muffles (flat and corrugated), inner covers, carburizing retorts and heater tubes and fans. Our fabrication facility and capabilities allow us to manufacture some of the industry's largest and longest products that are available.
www.qual-fab.net

Radyne Corporation..... 300-302
Radyne is the world-leading manufacturer and pioneer in the development of advanced induction and controlled-atmosphere heating equipment. From induction power supplies to full-turnkey induction heating machines and processing lines for almost every industry sector, we provide our customers with industry expertise, process engineering, inductor design and development, power supply and machine design, manufacturing, testing, and 24/7 service and support – under one roof from our Milwaukee headquarters.

Rock Valley Oil & Chemical Co. . 531-533
Rock Valley Oil & Chemical Co. is an employee-owned, independent lubricant company that manufactures, sells and distributes various types of industrial lubricants to over 39 countries globally. Rock Valley Oil specializes in quench oils, cleaners, coolants, cutting oils, stamping lubricants, rust preventatives and process oils.

Rohde GmbH.....130
Rohde is a German furnace builder based near Frankfurt. The products are planned, designed and manufactured in accordance with our philosophy: modernize and improve the proven and develop innovations. The company is a family business already in the second generation. Besides furnaces for processes such as ion nitriding, gas carburizing, carbonitriding, gas nitriding, nitrocarburizing, annealing and tempering, Rohde also offers salt recovery units.

Rolled Alloys 224
See our ad on page 70
Since 1953, Rolled Alloys has provided specialty alloys for thermal-processing applications. Our comprehensive inventory of heat-resistant alloys offers superior strength and oxidation resistance. Our value-added processing capabilities reduce labor cost, minimize scrap and streamline the process from order placement to shipment.
www.rolledalloys.com

RoMan Manufacturing Inc. 340
RoMan is a manufacturer of water-cooled transformers and power supplies used in the industrial heating market. Our transformers and power supplies are smaller and lighter, so they can be positioned closer to the heat source, reducing the need for costly transformer cabinets. Our transformers and power supplies are available in various voltages and frequencies.

RÜBIG Industrial Furnaces.....536
RÜBIG Industrial Furnaces has been producing customized heat-treatment plants since 1992. The know-how reflected in the construction of the furnaces has been gained in the in-house job shop. On this basis "SIR – Surface Improvement by RÜBIG" was developed – a concept that stands for the perfect surface. With new brand generations MICROPULS (plasma nitriding and/or coating) and GASCON (gas nitriding), RÜBIG has reached new heights in nitriding and coating.

Russells Technical Products Inc. 417
See our ad on page 76
Russells Technical Products is a global supplier of environmental test systems. We offer industrial mechanical refrigeration freezers to -120˚F (-85˚C) and industrial liquid nitrogen freezers (LN2) to -300˚F (-185˚C). Standard sizes are available from 15 to 60 cubic feet, or Russells can custom-design a freezer to meet your exact needs.
www.russells-tech.com

San Yung Electric Heat Machine Co..644

SBS Corporation.....332
SBS Corporation is a U.S.-based company in Sarasota, Fla., that has been providing the world with engineered products for fluid cooling, heating, filtering and controlling since 1974. Here at SBS, we pride ourselves on our ability to build a great product and provide excellent service. We believe our job begins when we receive an order and only ends when you, the customer, are happy.

SCC, Inc. 519-521
SCC Inc., a leader in the combustion controls industry, is a world-leading supplier of innovative products and complete solutions in the combustion control industry.

Schmidt + Clemens Group.....343
Schmidt + Clemens, established almost 140 years ago, is a privately owned German manufacturer of specialized alloys and components, supplying to the following industries: petrochemical, separation technology, power technology, industrial furnace construction.

Schunk Carbon Technology 233
Schunk Carbon Technology's premium carbon solutions are used in nearly every thermal application: heat treatment, medical and analysis technology, the glass industry and solar technology. Schunk Carbon Technology offers a broad spectrum of graphite, carbon fiber-reinforced carbon and ceramics, carbon and graphite felt materials, and components for these applications.

Schwartz GmbH 440

SECO/VACUUM Technologies LLC 404-406
See our ad on page 19
SECO/VACUUM Technologies, backed by the resources and reputation of SECO/WARWICK, is a leading vacuum furnace manufacturer in the North American heat-treating market with a lineup of furnaces designed to keep U.S. heat treaters pumping out quality parts.
www.secovacusa.com

SECO/WARWICK Corporation.. 426-428
See our ad on page 33
A leading supplier of continuous and batch heat-treating furnace systems, SECO/WARWICK Corporation is a global company backed by the R&D resources of a European parent company, SECO/WARWICK S.A. If you're looking for economical continuous heat-treating systems for your high-volume manufacturing processes, stop by booth 426-428 and see an innovative rotary retort system for the processing of small parts or a roller-hearth system for processing medium to large loads. Both of these systems offer peak productivity and low per-piece production costs. Ask us about our payback calculator.
www.secowarwick.com

Selas Heat Technology Company 630-632
Selas is an industrial burner and components manufacturer serving the industrial thermal-

processing industry with a comprehensive range of innovative and reliable gas burners, combustion systems and thermal components to support many different types and brands of ovens, furnaces and thermal-processing applications. Our proven approach to combustion blends rugged products with the best technologies to provide clean, safe and efficient heat.

Sentry Insurance 614

SGL Carbon 124
The "new" SGL Carbon is a technology-based company. Our high-quality materials and products made of specialty graphite and composites are used in future defining industries: automotive, aerospace, semiconductor, LED, solar and wind energy, and in the production of lithium-ion batteries. In addition, we develop solutions for chemical and industrial applications.

Siemens Industry Inc.....517
Siemens is a leading provider of continuous gas analyzer measurement products, training services, service repair and spare parts. In addition, we offer best-in-class after-sale product support such as 24-hour technical assistance, spare parts and quick ship inventory availability for urgent needs.

Signature Vacuum 114
Signature manufactures industrial vacuum furnaces, with standard products for various processes including brazing, sintering and heat treating, and custom-engineered products ranging from steam-heated ovens to high-temperature ceramic sintering furnaces.

Skyre Inc. 442
Skyre's solution to hydrogen supply lies within its revolutionary H2RENEW technology, which is capable of recycling and generating high-purity, high-pressure hydrogen using a solid-state process. Hydrogen normally exhausted and/or flared from an industrial process is captured, purified, compressed and stored for later use. Since hydrogen is recycled, no need for stored hydrogen or to generate quantities of gas.

Solar Manufacturing..... 211-213
See our ad on page 13
Solar Manufacturing designs and manufactures high-performance, technically advanced and energy-efficient vacuum heat-treat furnaces. Models range from compact R&D size furnaces to huge car-bottom vacuum furnaces for large, heavy workloads. Our furnaces feature improved graphite insulation materials, curved graphite heating elements, tapered gas nozzles, high-velocity gas-quench systems, and SolarVac interactive control systems. We design for vacuum heat-treat processes such as hardening, brazing, annealing, stress relieving, normalizing, tempering, sintering, low-pressure carburizing and vacuum gas nitriding. We will have our compact, economical Mentor furnace on display at FNA 2018. **www.solarmfg.com**

South Tek Systems.....545

Stand Energy Corporation 236
Stand Energy Corporation has been providing natural gas and electricity since 1984. Our expert energy management services are provided to commercial, industrial, institutional and government facilities. We help our customers control costs by offering customized supply and pricing options. Our years of experience and dedication to creating affordable energy solutions have fostered reliable deliveries behind the utilities in which we do business.

Struers Inc. 528-530
Struers Inc., the world leader in materialographic solutions, provides an entire range of equipment and consumables for materialographic specimen preparation –
continued on page 78

from manual machines to sophisticated preparation equipment. Complementing its materialographic products, Struers also sells an extensive line of hardness testers and Zeiss microscopes, providing a comprehensive range of lab solutions.

Super Systems Inc. 201-203
See our ad on page 27
Super Systems Inc. is a leading technology company serving the thermal-processing industry. We develop and manufacture products that improve the heat process, giving your company more accurate, consistent and dependable results. We offer carbon probes, programmable recipe controllers, atmosphere analyzers, flow meters and engineered systems along with advanced software solutions. Our state-of-the art production center is located in Cincinnati, Ohio, with international offices serving its clients here and around the world. SSi provides customer-oriented, on-site services with the industry's most experienced installation and start-up team.
www.supersystems.com

Surface Combustion Inc..... 200-202
See our ad on page 6
Surface Combustion has earned a trusted reputation over 100 years of providing rugged, reliable heat-treating solutions equipped with the latest technology and backed by strong technical support. Surface strives to build customer relationships that endure long after the initial equipment purchase. When you require a thermal-processing partner who can draw from a broad portfolio of proven designs, including pioneering atmosphere and vacuum products, let us show you the Value of Surface.
www.surfacecombustion.com

Taylor-Winfield Technologies Inc....141
See our ad on page 75
Taylor-Winfield Technologies is an original equipment manufacturer (OEM) of induction heating solutions. From a single power supply to a comprehensive automated parts production system, T-W will review your need or process and create a solution. Some of our process solutions begin in our research and development laboratory, where the "need" is evaluated on customer parts and the "proof of process" solution and concept is qualified for production use. Typical applications include heat treatment, brazing and soldering, hot forming and forging, melting, bonding and heat staking, wire stripping, solidification and process heating.
www.taylor-winfield.com

TE Wire & Cable LLC 127
TE Wire & Cable LLC, a Marmon Wire & Cable/ Berkshire Hathaway Company, is a premier thermocouple and specialty wire and cable manufacturer that was formed from the Wire and Cable Division of the Thermo Electric Corporation. Our operations for manufacturing of wire and cable have been in existence for more than 76 years, having been started to provide high-quality wire to the thermo-sensing and temperature measurement markets in 1941. TE Wire & Cable manufactures a full line of thermocouple wire and cable, from iron and nickel-based alloys, and copper instrument and control cable.

Televac.....612
For over 80 years, Televac has been a preferred supplier of high-performance vacuum gauging to the heat-treat and vacuum furnace industry. Televac also offers NIST-traceable calibration for all of our products, with fast lead times of 1-2 weeks. The Televac 7B Penning cold cathode is now available as the MX7B active gauge. The MX7B is contamination-resistant and easy to disassemble for quick cleaning and sensor replacement.

Tenova Inc. 126
Tenova Inc. designs and supplies advanced heat-treating furnaces for plate, pipe, wire, strip steel, forgings and specialty applications. We also provide a complete range of dedicated technical services, including equipment upgrades and revamps, studies, tune-ups, energy audits, automation system upgrades and spare parts.

Thermal Care Inc. 132-134
Thermal Care is the industry expert and value leader in industrial process-cooling solutions for the heat-treat industry. For nearly 50 years, Thermal Care has manufactured industrial process-cooling equipment and systems including portable and central chillers, evaporative cooling towers, adiabatic fluid coolers and pumping systems. Made in the U.S.A. and backed by an unmatched sales and support network, Thermal Care is the name that says it all

Thermcraft Inc. 122
Thermcraft is an international leading manufacturer of industrial furnaces and ovens, laboratory furnaces and high-temperature ceramic heating elements. Choose from standard designs or consult with our team of engineers to design a fully customized, engineered-to-order system. With over 45 years of thermal-processing knowledge, we can help you find the solution that best fits your application.

Thermo Transfer Inc. 138

Toyo Tanso USA 123

Trillium.....610
Trillium specializes in providing world-class vacuum pump repair, new and refurbished pumping systems, as well as accessories, spare parts and consumables in support of the vacuum metallurgy industry. Our entire organization is dedicated to learning about your particular business needs and challenges and working with you to ensure your success. With three nationwide locations, our Univac line of new rotary piston pumps and blowers, an in-house machine shop and ready-to-ship inventory, customers love our short lead times and competitive costs.

Ultra Electronics – Furnace Parts.....108

United Process Controls..... 226-228/227-229
United Process Controls provides advanced process control and automation products as well as solutions to OEM and end-user clients of heat-treatment and combustion applications. Our brands include Atmosphere Engineering, Furnace Control Corp., Marathon Monitors, Waukee Engineering and Process-Electronic. Together, they cover an extensive product range of probes, analyzers, process controllers, flow controllers, gas compressors, gas mixers/gas blending systems, flow control systems, as well as production software that improves process performance, efficacy and reliability while helping to comply with industry quality standards.

Upton Industries Inc..... 402
Upton technical personnel will be available to discuss our unique and diverse product line, including application designs for Ethernet-based automated salt bath furnace systems and continuous, batch atmosphere and specialty furnaces for Upton's engineered thermal solutions approach to material processing.

VAC AERO International Inc.....337
VAC AERO builds vacuum furnaces with the highest quality standards and lowest cost of ownership achieved through superior design and high-performance operation to fulfill any specialized processing needs. Constructed of the finest materials and craftsmanship, VAC AERO vacuum furnaces are operator friendly and designed for easy maintenance and minimal downtime to deliver outstanding quality and value to heat treaters. VAC AERO furnaces are ideal for a broad range of vacuum-processing applications of specialty alloys and engineered materials. VAC AERO furnaces operate worldwide in diverse applications in aerospace, power generation, medical, nuclear, tool & die, research and other high-tech industries.

Vacuum Pump Services Corp. 310
Vacuum Pump Services Corp. offers experience and expertise to all vacuum pump users providing intelligent vacuum pump repair, rebuild, recondition, direct replacement spare parts for most major manufacturers, new pumps, on-site preventive maintenance and troubleshooting on virtually any brand and type, including rotary pumps, blower pumps and oil vapor diffusion pumps. Every pump is tested and leak checked with a helium mass spectrometer for vacuum integrity prior to shipment. Our courteous staff of technicians is fully trained to provide our customers with superior service and quality workmanship.

Vacuum Research Corporation 537
We offer vacuum valves (gate, throttle and poppet style), ANSI, ISO, JIS and special flanges; and motor, air and manual actuators. We also provide rotary vane vacuum pumps and Pirani and diaphragm gauges.

W.H. Kay Co. 437
The W.H. Kay Company, located in Cleveland, Ohio, has served the industrial process-heating industry for over 80 years. We buy, sell and trade used industrial ovens and heat-treating furnaces and have over 200 units in stock ready for your inspection and shipment to your facility.

Williams Industrial Service Inc.230-232
Williams Industrial Service Inc. designs and builds high-performance heat-treating systems in standard and custom sizes. Count on us for superior performance with minimal maintenance. Ask about our optional heating systems as well as rugged and durable companion equipment.

Wirco Incorporated 205-207
Wirco Incorporated is a leading stainless steel foundry and fabricator of heat-resistant alloy tooling and furnace components. Wirco products include stainless steel furnace trays, fabricated and cast heat-treatment tooling, high-temperature furnace parts, cast radiant tubes and furnace rolls. With production facilities in Avilla, Ind., and Champaign, Ill., Wirco team members take pride in manufacturing American-made alloy products that help keep heat-treatment furnaces running worldwide.

Wisconsin Oven Corporation 413
Wisconsin Oven Corporation has been designing, engineering and manufacturing industrial ovens and other heating equipment since 1973. Their custom and standard industrial ovens are used for a multitude of applications, including heat treating, finishing, drying and curing. Many of the industries Wisconsin Oven serves require specific temperature uniformity and equipment performance documentation. Their experienced design team is able to meet even the most stringent standards for their customers' equipment.

WS Thermal Process Technology Inc. .. 218
See our ad on page 74
WS is a manufacturer of industrial burners with integrated heat exchangers. We offer both self-recuperative and self-regenerative burner types with either metallic or ceramic construction. These can be delivered as either direct-fired or radiant tube burners. Some of the advantages of this equipment are substantially improved temperature uniformity, longer life of burners and radiant tubes, reduced and simplified maintenance, high efficiency, and extremely low-NOx emissions. **www.flox.com**

Yangzhou Jinrun Mesh Belt Manufacturing Co. Ltd. 142
We are a China-based manufacturer of wire mesh belt.

York Wire and Cable Inc. 445
See our ad on page 66
York Wire & Cable Inc. is an industry-leading supplier of high-temperature lead wire, high-temperature control cable, thermocouple wire, thermocouple connectors and high-temperature alloys. **www.yorkwire.com**

ZIRCAR Refractory Composites Inc. 145
ZIRCAR Refractory Composites Inc. produces a comprehensive range of advanced high-performance ceramic composites and related products. Our materials are used around the world in demanding thermal, structural and electrical insulation applications at temperatures from 600˚C (1112˚F) through 1650˚C (3002˚F). For over 30 years, we have been a problem solver working with many industries to resolve their thermal melting, forging and heat-treating applications.

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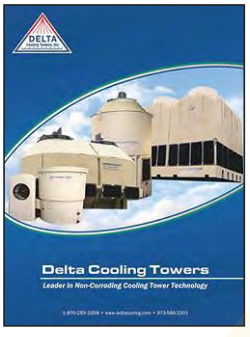

Cooling Towers

Delta Cooling Towers

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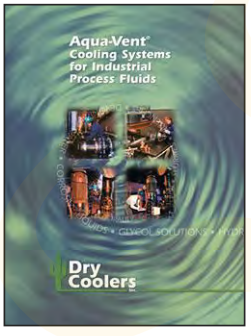

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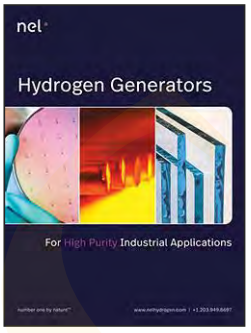

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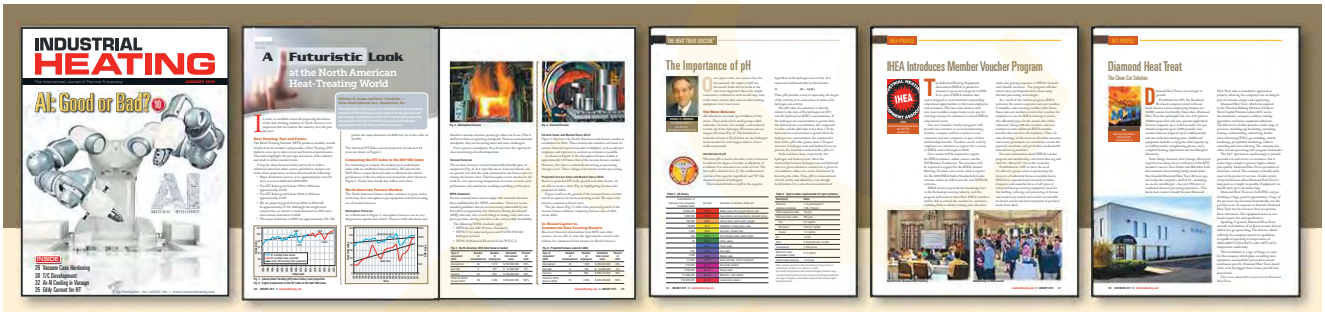

EMPLOYMENT OPPORTUNITY

SENIOR METALLURGIST

POSITION SUMMARY:

There is currently an opening for a senior metallurgist in the RBC Bearings New Product and Process Development Center, located within our Oxford CT headquarters. We are looking for a corporate level, technological leader in metallurgy and materials science who is a hands-on, team player. The person will be expected to act as consultant and metallurgical expert to all divisions of RBC, as necessary, responding to queries about materials, material acceptability, specifications, failure investigations, material performance improvements and material quality issues both internal and with our supplier base. The successful applicant will be expected to take a leadership role in material development as RBC expands its current product offering into new applications with structural and environmental challenges beyond our current knowledgebase and capability. The candidate is required to have excellent inter personal and communication skills, be a team player that is driven to succeed within in a fast paced, challenging, and demanding environment.

RESPONSIBILITIES:

- **New Product Development:** Research and Development of performance enhancing materials and material heat treatments.
- **Design:** Support RBC engineers on materials selection and evaluation, testing, fabrication, heat treatment, and plating.
- **Manufacturing:** Support the evaluation of material quality, obtain and maintain NADCAP heat treat accreditation where required, consult and assist with internal/external customer concerns regarding product quality, customer audits and approvals, materials and testing, failure analysis, destructive testing, procedures, evaluation of vendors for heat treating and plating
- **Metallurgical Analysis:** Improve existing metallurgical laboratory and maintain a list of vendors that can provide services outside of the labs capabilities.
- **Manage Corporate Metallurgy Function:** Conduct bi-weekly department update meetings, coordinate the projects of two Fellow level metallurgists with more than 80 years combined experience, and oversee a lab. Technician.
- **Oxford Heat Treat Department:** Technically oversee and support a newly implemented heat treat department within the Oxford, CT, manufacturing facilities.

REQUIREMENTS / QUALIFICATIONS:

- BS/MS/PhD in Metallurgy, or Metallurgical Engineering, or Materials Science
- 10 + years of related experience.
- Expertise in metallurgy, thermal processing, machining, chemical processing, plating, stress relieving, material standards, material processing and potential process changes affecting material performance.
- Keen knowledge of the causes of fatigue and failure of metals, especially – but not limited to – the field of bearings.
- Anticipate travel requirements to various customers, suppliers, and RBC facilities of approximately 25%.

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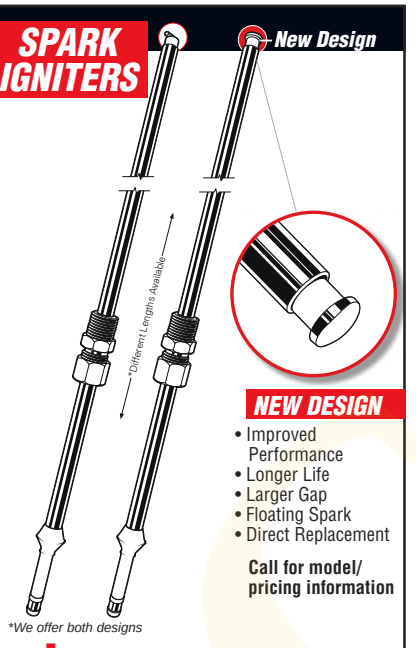

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Our auditors enjoy traveling domestically and/or internationally, a flexible schedule (some auditors perform 1 or 2 audits a month, while others desire to audit every week), competitive compensation that includes a daily rate plus travel expenses, meeting new people and keeping in touch with technology and the latest developments, networking with other industry professionals.

The ideal candidate will possess most of the following criteria:

- Bachelor's Degree in a technical field related to Heat Treating OR:
- High School Diploma and 5 years heat treating and/or brazing experience, preferably in the aerospace and / or medical device industries.
- Hands-on experience with some of the following heat treating processes: steels, aluminum, titanium, heat resisting alloys, brazing, carburizing and nitriding
- Familiarity with AMS 2750
- Familiarity with Industry Specifications
- Familiarity with Heat Treating equipment
- Familiarity in testing of heat treated material or product

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3000 CFH Ammonia Dissociator, Electric, Sargeant & Wilbur
3000 CFH Endo, Gas Fired, 2000°F, Lindberg, Air Cooled
3600 CFH Endo, Gas Fired, 1950°F, Surface Combustion,
3000 CFH Endo, Electric, 1950°F, Gasbarre, Water Cooled

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60"W x 60"H x 120"L, Electric, 1250°F, Wild Barfield, Carbottom
48"W x 36"H x 96"L, Electric, 1400°F, Lindberg
48"W x 36"H x 96"L, Electric, 2000°F, Lindberg
36"W x 36"H x 96"L, Gas Fired, 1000°F, Wisconsin, Double Ended
10'6"W x 6'H x 35'L, Gas Fired, 1650°F, Drever, Fiber Lined, Atmosphere
48"W x 48"H x 54"L, Electric, 1200°F, Sunbeam, Fiber Lined, 3 Zones
24"W x 18"H x 36"L, Electric, 2000°F, Lindberg, Atmosphere, Fiber Lined
108"W x 64"H x 96"L, Gas, 1250°F, Eisenmann

BELT FURNACES

1500 Pounds/Hour Mesh Belt Line, Gas Fired, Thermal Basic
12"W x 12"H x 12'L Heating x 12'L Cooling, Electric, 2050°F, C.I. Hayes
4000 Pounds/Hour Cast Link Belt Line, Rogers Eng. Excellent
72"W x 9"H x 24'L, Electric, 1600°F, Holcroft, Atmosphere/Cooling
16"W x 3"H x 20'L, Electric, 2400°F, H2 Atmosphere, Abbott
8"W x 4"H x 54"L, Electric, 2100°F, C.I Hayes, Atmosphere/Cooling
12"W x 3.75"H x 12'L pre-heat x 16'L high-heat, 2150°F, Abbott
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36" Diameter x 84" Deep, Electric, 1250°F, Lindberg Pit Nitrider

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36"W x 30"H x 48"L, Gas Fired, 1750°F, Surface Combustion
36"W x 30"H x 48"L, Gas Fired, 1750°F, Surface Combustion
30"W x 20"H x 48"L, Gas Fired, 1750°F, Surface Combustion
24"W x 24"H x 36"L, Gas Fired, 1950°F, Beavermatic, Complete Line
24"W x 24"H x 36"L, Electric, 1850°F, Sauder/Abar Ipsen Complete Line

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104"W x 24"H x 51'L, Gas Fired, 1600°F, Fiber Lined, Holcroft
60"W x 13"H x 40'L, Electric, 1600°F, Atmosphere, Wellman

ROLLER HEARTH FURNACES *(continued)*

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24"W x 24"H x 48"L, Electric, 2400°F, Advanced Vacuum Systems, 10^{-9} Torr Vacuum
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36"W x 5"H x 12'Long, Gas Fired, 500°F, I.H.E.I.
60"W x 10"H x 20'L x 10'L Cool, Gas, 500°F, Jensen
18'W x 6"H x 10'L x 4'L Cool, Gas, 500°F, Jensen

CABINET OVENS

48"W x 72"H x 48"L, Electric, 500°F, Despatch
48"W x 36"H x 24"L, Electric, 500°F, Inert Gas, Blue-M
36"W x 36"H x 48"L, Electric, 500°F, Grieve
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3,000CFH	Endothermic Lindberg (3) - Air	Gas
3,600CFH	Endothermic Surface (2)	Gas
5,600CFH	Endothermic Surface (2)	Gas
6,000CFH	Gas Atmos. Nitrogen Generator	Gas

BOX FURNACES

12" × 24" × 10"	Lindberg (Atmos.)	Elec 2000°F
12" × 24" × 10"	Lindberg (Atmos.)	Elec 2500°F
12" × 24" × 12"	Hevi Duty (2)	Elec 1950°F
12" × 32" × 12"	L&L (Retort)	Elec 2000°F
13" × 24" × 12"	Electra Up/Down	Elec 2000°F
17"×14.5"×12"	L&L (New)	Elec 2350°F
18" x 30" x 13"	Hevi-Duty	Elec 1850°F
18" x 36" x 18"	Hevi Duty	Elec 2000°F
18" x 36" x 18"	Lindberg (Fan)	Elec 1850°F
20" x 48" x 12"	Hoskins	Elec 2000°F
24" x 36"× 20"	L&L Up/Down	Elec 2000°F
24" ×48"× 20"	Lindberg	Elec 2200°F
36" × 72"× 42"	Eisenmann (Car Bottom)	Gas 3100°F
60"×216"×48"	IFSI (Car Bottom)	Gas 2400°F
60"×156"×60"	Lindberg Car Bottom	Gas 1850°F
126"×420"×72"	Drever "Lift-Off" (2) (Atmos.)	Gas 1450°F

PIT FURNACES

14" Dia × 60"D	Procedyne Fluid Bed	Elec 1850°F
28" Dia x 48"D	Lindberg	Elec 1250°F
28" Dia x 48"D	Lindberg	Elec 1250°F
Just Added 48" Dia x 60"D	L&N (2)	Elec 1400°F
72" Dia x 72"D	Flynn + Dreffein (2) (Atmos.)	Elec 1400°F
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VACUUM FURNACES

24" × 36" x 18"	Hayes (Oil Quench)	Elec 2400°F
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72" Dia x 96"H	Abar "Bottom Load"	Elec 2400°F

INTEGRAL QUENCH FURNACES

24" × 36" × 24"	AFC (Top-Cool-Line)	Elec 1850°F
30" × 48" × 20"	Surface (2)	Gas 1750°F
30" × 48" × 24"	Surface	Gas 1750°F
36" × 48" × 36"	Surface	Gas 1750°F

BELT FURNACES/OVENS

Just Added 10" × 6' x 7"	Abbott (Brazing)	Elec 2150°F
24" x 18'L	Thermal Basic Belt Line	Gas 1750°F
32" × 24' × 12"	OSI Slat Belt	Gas 450°F
36" × 24' × 8"	Surface Cast Belt (Line)	Gas 1750°F
60" × 40' × 14"	GE Roller Hearth (Atmos)	Elec 1650°F
60" × 40' × 14"	Wellman Roller Hearth (Atmos)	Elec 1650°F
72" × 25' × 12"	Wisconsin	Gas 500°F
Just Added 72" × 40' × 12"	EFCO Roller Hearth (Atmos)	Gas 1700°F

MISCELLANEOUS

Combustion Air Blowers (All sizes)

24" × 36"	Lindberg Charge Car (Manual)	
30" × 48"	Surface Charge Car (SE-ER)	

SBS Air/Oil Coolers (4)

24" × 36" × 24"	Salt Quench Tanks (2)	Elec 1000°F
30" × 48" × 30"	Surface Washer	Gas
30" × 48" × 36"	Surface Washer	Gas

(2) Bell & Gossett "Shell & Tube" Heat Exchangers

26" x 15' x 15"	Belt Washer/Dryoff	Gas
36" x 48"	AFC Charge Car (DE)	Elec

MISCELLANEOUS *(continued)*

24" Wide Table	Surface rotary Hearth	Gas 1750°F
30" x 30" x 30"	Subzero	-105 to 375°F Elec.

SBS Air/Oil Coolers (4)

AFC Pusher Line (Atmos.)		Gas 1750°F
36" Wide Table – Rotary Hearth (Atmos.)		Elec 1850°F
30" x 48"	Surface Roller Table	
36" x 48"	Holcroft Charge Car (DE)	
48" x 60" x 60"	Steel "Roll-in" Carts (3)	
54" Dia x 108" H	Ebner Bell (Atmos.)	Gas 1650°F

OVENS/BOX TEMPERING

8" × 18" × 8"	Lucifer	Elec 1250°F
12" × 16" × 18"	Lindberg (3)	Elec 1250°F
14" × 14" × 14"	Blue-M	Elec 1050°F
14" × 14" × 14"	Gruenberg	Elec 1200°F
14" × 14" × 14"	Blue-M	Elec 650°F
14" × 14" × 14"	Gruenberg (solvent)	Elec 450°F
15" × 24" × 12"	Sunbeam (N_2)	Elec 1200°F
20" × 18" × 20"	Blue-M	Elec 400°F
20" × 18" × 20"	Despatch	Elec 650°F
20" × 18" × 20"	Blue-M	Elec 650°F
20" × 18" × 20"	Blue-M (2)	Elec 800°F
Just Added 20" × 18" × 20"	Blue-M	Elec 1300°F
24" × 20" × 20"	Blue-M	Elec 1000°F
24" × 24" × 24"	Grieve	Elec 650°F
24" × 24" × 36"	New England	Elec 800°F
24" × 24" × 48"	Blue-M	Elec 600°F
24" × 36" × 24"	Grieve	Elec 500°F
24" × 36" × 24"	Demtec (N_2)	Elec 500°F
24" × 36" × 24"	AFC (N_2)	Elec 1250°F
24" × 36" × 24"	Trent	Elec 1400°F
25" × 20" × 20"	Blue-M	Elec 650°F
24" × 36" × 48"	Gruenberg	Elec 500°F
25" × 20" × 20"	Blue-M (Inert)	Elec 1100°F
26" × 26" × 38"	Grieve (2)	Elec 850°F
30" × 30" × 60"	Gruenberg	Elec 450°F
30" × 30" × 48"	Process Heat	Elec 650°F
30" × 38" × 48"	Gruenberg (Inert) (2)	Elec 450°F
30" × 48" × 30"	Surface (2)	Elec 1400°F
30" × 48" × 24"	Surface	Gas 1250°F
30" × 48" × 36"	Surface (Atmos)	Elec 1400°F
30" × 48" × 30"	Surface	Elec 1250°F
Just Added 36" × 36" × 36"	Grieve	Elec 350°F
Just Added 36" × 36" × 36"	Grieve	Elec 850°F
36" × 36" × 36"	Blue M Enviroment Chamber (-18°C to +93°C)	
36" × 42" × 72"	Gruenberg	Elec 450°F
36" × 48" × 36"	Pollution Control Burn Off	Gas 850°F
36" × 48" × 36"	Grieve	Elec 350°F
36" × 48" × 36"	Despatch (Horizontal Quench)	Elec 1200°F
36" × 48" × 36"	AFC	Gas 1250°F
36" × 36" × 60"	Despatch	Elec 500°F
36" × 48" × 36"	TPS (Environmental)	Elec -40°C to +200°C
36" × 60" × 36"	CEC (2)	Elec 650°F
36" × 84" × 36"	Lindberg (1996)	Gas 800°F
37" × 25" × 37"	Despatch	Elec 500°F
37" × 32" × 48"	Hotpack	Elec 750°F
38" × 20" × 26"	Grieve	Elec 500°F
42" × 72" × 36"	Despatch	Elec 1350°F
Just Added 48" × 24" × 36"	Blue-M (2)	Elec 600°F
48" × 48" × 20"	Lindberg (Hyd. Press)	Elec 1250°F
48" × 34" × 52"	Heat Mach. (2)	Elec 500°F
48" × 48" × 48"	TPS - Environmental	Elec 392°F
48" × 48" × 48"	Trent	Elec 1250°F
48" × 52" × 60"	Despatch	Elec 500°F
48" × 48" × 60"	Grieve	Elec 350°F
48" × 48" × 72"	Despatch	Elec 650°F
48" × 72" × 36"	Lindberg - Car Bottom	Elec 1600°F
55" × 30" × 60"	Precision Quincy	Elec 350°F
60" × 96" × 72"	OSI	Gas 500°F
68" × 72" × 72"	Gruenberg (3)	Elec 450°F
72" × 120" × 78"	Grieve	Gas 500°F
72" × 252" × 60"	Precision Quincy "Car Oven"	Gas 500°F
108" × 96" × 65"	Eisenmann (4)	Gas 1200°F

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U3644 BeaverMatic Batch Temper Furnace (36"W x 48"D x 36"H, 1500ºF, gas-fired)
U3651 JL Becker Batch Temper Furnace (36"W x 48"D x 36"H, 1350ºF, gas-fired)
V1010 Dow Batch Temper Furnace (30"W x 48"L x 20"H, 1250ºF, gas-fired)
V1024 PIFCO Batch Temper Furnace, Skid Hearth (36"W x 48"L x 30"H, 1200ºF, electric)
V1068 Surface Combustion Oil Quench Furnace (30"W x 30"D x 48"H, 1950°F, gas-fired)
V1081 Lindberg Batch Temper Furnace (20"W x 24"D x 18"H, 1250ºF, electric)
V1095 Surface Combustion Temper Furnace (30"W x 48"D x 30"H, 1250°F, gas-fired)
V1096 Surface Combustion Temper Furnace (30"W x 48"D x 30"H, 1400°F, gas-fired)
V1106 Dow Batch Normalizer Furnace (45"W x 84"D x 32"H, 1800°F, gas-fired)

Batch High-Temp Furnaces

U3556 Pacific Industrial Batch High-Temp Furnace (24"W x 36"L x 18"H, 2800ºF, electric)
U3637 Pacific Scientific Batch Temper (30"W x 48"D x 24"H, 1600ºF, gas-fired)
U3643 Surface Combustion Temper Furnace (30"W x 48"D x 42"H, 1400°F, electric, 81kw)
V1013 Thermolyne High-Temp Batch Furnace (10"W x 14"L x 9"H, 2000ºF, electric)
V1067 Seco Warwick Batch High-Temp Furnace (24"W x 36"D x 24"H, 2000°F, electric)
V1130 Onspec Slot Forge Furnace (72"W x 96"D x 48"H, 2000ºF, gas-fired)

Car Bottom Furnaces

V1140 Beavermatic Car Bottom Furnace (48"W x 72"D x 48"H, 1600°F, gas-fired)
V1141 Beavermatic Car Bottom Furnace (60"W x 144"D x 60"H, 1400°F, gas-fired)

Drop Bottom Furnaces

U3543 Despatch Drop Bottom Furnace (4'W x 6'L x 4'H, 1200ºF, electric)

Internal Quench Furnaces

U3569 Surface Combustion IQ Furnace (24"W x 36"D x 18"H, 1750ºF, gas-fired)
U3570 Surface Combustion IQ Furnace (24"W x 36"D x 18"H, 1750ºF, gas-fired)
U3606 Dow/AFC IQ Furnace (30"W x 48"L x 24"H, 1850°F, gas-fired)
V1046 Surface Combustion IQ Furnace (87"W x 87"L x 36"H, 1850°F, gas-fired)
V1082 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850ºF, gas-fired)
V1083 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850ºF, gas-fired)
V1092 Surface Combustion Allcase IQ Furnace (30"W x 48"L x 30"H, 1850ºF, gas-fired)
V1093 Surface Combustion Allcase IQ Furnace (30"W x 48"L x 30"H, 1850ºF, gas-fired)
V1111 Surface Combustion IQ Furnace (30"W x 48"D x 30"H, 1850ºF, gas-fired)

Mesh Belt Brazing Furnaces

U3529 CI Hayes Mesh Belt Brazing Furnace (18"W x 6"H x 8' heating, 2100ºF, electric)
U3592 JL Becker Mesh Belt Brazing Furnace (12"W x 6"H, 2100ºF, electric)
V1035 Seco Warwick Mesh Belt Brazing Furnace (18"W x 12"H, 2100ºF, electric)

Mesh Belt Tempering Furnaces

U3638 American Gas Furnace MB Temper Furnace (31"W x 5"H, 17' heated length, 1100ºF, gas-fired)

Pusher Furnaces

U3648 Ipsen P-12 Pusher Furnace (30"W x 30"L x 30"H, 1650°F,gas-fired)

Roller Hearth & Rotary Furnaces

U3550 PIFCO Powered Roller Hearth Temper Furnace (21"W x 12'L x 18"H, 1000°F, electric)
V1009 Ipsen Continuous Temper Roller Hearth Furnace (24"W x 10'L x 18"H, 1350ºF, electric)
V1091 Finn & Dreffein Rotary Hearth Furnace (13'3"ID x 5'3"ID x 4'W x 2'8"H, 2275ºF, electric)

Steam Tempering Furnace

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Vacuum Furnaces

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V1004 CI Hayes Vacuum Furnace, Oil Quench (18"W x 30"L x 12"H, 2400°F, electric)
V1128 Ipsen Vacuum Furnace (18"W x 32"D x 12"H, 2400°F, electric)
V1131 Abar Vacuum Furnace (34"W x 60"D, 2250ºF, electric)
V1135 Abar Vacuum Furnace 2 Bar (72"Dia x72"Deep, 2400ºF, electric)
V1136 Surface Combustion Vacuum Furnace, 2-Bar (26"W x 36"L x 22"H, 2400ºF, electric)
V1138 Ipsen Vacuum Furnace, 5-Bar (24"W x 36"L x 14"H, 2400ºF, electric)

Endothermic Gas Generators

U3594 AFC-Holcroft Gas Generator (3,000 CFH Endo, gas)
U3652 Surface Combustion Gas Generator (10,000 CFH Exo, gas)
U3647 Lindberg Gas Generator (3000 CFH Endo, 2050ºF, gas)
V1075 Lindberg Gas Generator (3,000 CFH Endo, gas)

Exothermic Gas Generators

V1036 Seco Warwick Gas Generator (3,000 CFH Exo, gas)

Ovens - Cabinet

U3625 Lindberg Atmosphere Oven (38"W x 38"D x 38"H, 850ºF, electric)
U3629 Cabinet Oven (30"W x 30"D x 36"H, 750ºF, electric)
U3642 Blue-M Cabinet Oven (36"W x 36"D x 36"H, 650°F, electric)

Charge Cars

U3621 Dow Charge Car, DEDP (66"W x 60"D x 54"H)
V1085 Holcroft Charge Car (DE/DP, 36"W x 48"D)
V1112 Surface Combustion Charge Car (SE, 30"W x 48"L)

Washers

V1084 Holcroft Spray/Dunk Washer (36"W x 48"D x 30"H, 190ºF, gas-fired)
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Beavermatic Gas Fired Car Bottom Furnace, 4' wide x 6' long x 4' high, 1,400°F max., 15,000 LB capacity, finer lined, powered car complete with ceramic piers, exhaust, blower and Honeywell controls.

BEAVERMATIC
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ABAR
ABAR HORIZONTAL VACUUM FURNACE, 2 BAR, 24"W X 18"H X 36"L, 2,400°F, 1,000 LBS, 150 KW complete with Nitrogen or Argon Atmosphere, Spencer Blower, Varian Diffusion Pump, Stokes Mechanical Pump, Roots Blower Moly Elements, controls, circular hot zone and loader.

ABAR
ABAR HORIZONTAL VACUUM FURNACE, 2 BAR, 24"W X 24"H X 36"L, 2,400°F, 1,000 LBS, 150 KW complete with Nitrogen or Argon Atmosphere, Spencer Blower, Varian Diffusion Pump, Stokes Mechanical Pump, Roots Blower Moly Elements, controls, circular hot zone and loader.

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SALT BATH TRANSFORMER
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Surface Combustion Gas Fired Mesh Belt Furnace, 42"W x 12"H x 36'-6"L (heated), 1,350°F, 2,000,000 BTUH, 2 zones, 3 fans and controls.

SURFACE COMBUSTION
Electric Batch/Oil Quench Furnace, 30" W x 30" H x 48"L, Max. Temp. 1,950°F, System 1 Rear Handler, 3500 Gal. Quench Tank, 2 Agitators & Controls.

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(2) INTEGRAL QUENCH FURNACES, 36"W x 30"H x 48"L, 1,800°F Max, Recuperated with Top Cool, Rear Handler, Oil Heaters (54kW), Re-Circ. Fan, Control System.

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