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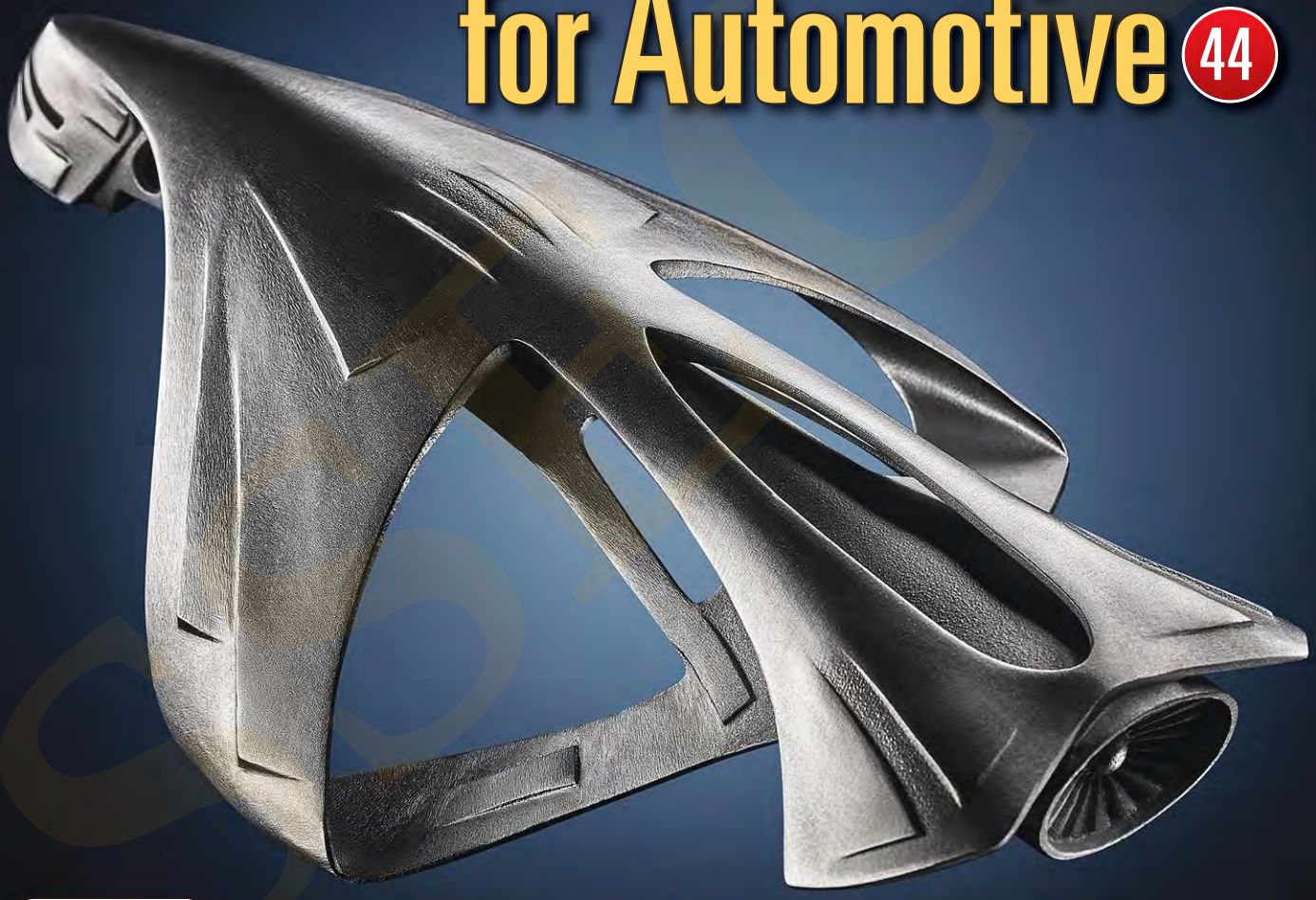

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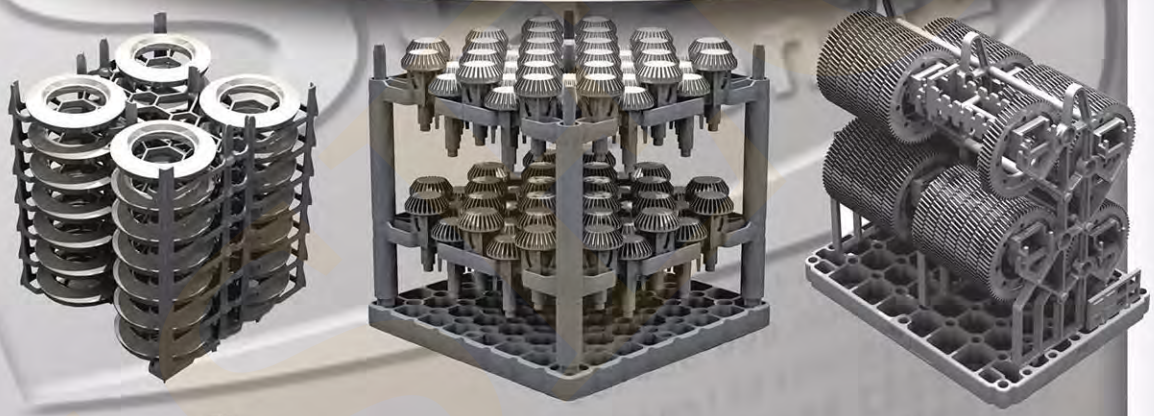

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SPECIAL SECTION

On the Cover:
The automotive industry can benefit from advances in additive manufacturing from sectors such as aerospace. This detailed starship concept was produced using a titanium alloy in a laser-fusion process with the printer chamber tightly monitored and controlled using Linde technology *(courtesy Linde, p. 44).*

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Motoring Musings

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Our automotive discussions this month center on recalls, technology and electrics.

Recalls

Poor heat treatment resulted in the recall of 5,400 model-year 2017 Civics for right driveshafts that can break in operation. Also, Tesla has voluntarily recalled 123,000 Model S vehicles (built before April 2016) with power-steering bolts exhibiting "excessive corrosion." This is Tesla's third and largest recall.

It may come as no surprise that a recent *Kiplinger* article indicated that five of the 10 biggest recalls in history have been automotive-related. Number 8 was the Toyota floor-mat recall in 2010, which totaled $3.2 billion. Number 6 was a General Motors ignition-switch recall in 2014, which was linked to 124 deaths and cost $4.1 billion. Number 4 goes back to 2000 for a cost of $5.6 billion. This was the Firestone-Ford tire recall that was linked to 271 deaths and more than 800 injuries in the U.S. alone.

The number-2-biggest recall in history was the 2015 Volkswagen "Diesel-gate" recall/scandal. VW recalled 11 million vehicles worldwide at a total cost of $18.3 billion. A *Reuters* video depicted the vast scope of this recall. Finally, the largest of all time is the ongoing Takata air-bag recall beginning in 2008 with costs in excess of $24 billion. Check out the full top-10 list and the *Reuters* video at www.industrialheating.com/recalls.

Technology

Automotive technology could almost be labeled "Tesla" because of their involvement in much of it. Hybrid-electric technology can now be found in virtually every vehicle category, with Tesla falling on the all-electric end of the spectrum. Tesla has apparently produced 9,766 Model 3s in the first quarter, which is well behind predictions of 2,500 per week. As a result, founder Elon Musk has taken charge of Model 3 production, saying it is his "most critical" job right now and indicating that he is "back to sleeping at the factory."

Autonomous vehicles certainly are high-tech. Recent news of two deaths associated with the technology may have set progress back a bit, but "semiautonomous" technology such as lane-departure, dynamic cruise control, radar-based collision avoidance and autopilot systems continue to move forward. Watch a company called Aurora Innovation, which is creating autonomous systems for use by Volkswagen and Hyundai – two of the largest automakers.

A newer consumer of autonomous technology is the commercial trucking industry. Needless to say, Tesla is participating by developing the Tesla Semi with prototypes expected in 2019. Watch for companies like Daimler, Volvo and Freightliner to be involved in addition to newcomers such as Starsky Robotics, TuSimple and Nikola Motors.

For my entire lifetime, flying cars have been a topic of conversation. Moving from conversation to production, Uber is building a flying taxi, and hovercraft-maker Kitty Hawk (backed by Alphabet CEO Larry Page) is working on consumer transports. Will Tesla be far behind?

Corvette Remake

All of this high-tech talk is important for us to be aware of because it could shape the future of our companies. We didn't want to leave out something that feels a bit more tangible and just as interesting. Were you aware that the Corvette C8 moves to a mid-engine V-8 in 2019? For many of its 65 years, a mid-engine Corvette has been discussed, but it's finally happening. Materials will play an important role in this newly designed Corvette, including a hydroformed aluminum space frame. Cast and forged aluminum components will be used in the chassis and powertrain, and die-cast magnesium will reinforce the dash. The bodywork will combine carbon fiber, fiberglass and injection-molded plastic, and fiberglass will be used for the leaf springs as well. Brake rotors will be manufactured from carbon-ceramic.

All this tech talk hasn't dissuaded me from my goal of waking my old-technology classic convertible from its winter nap. I, for one, am glad May is finally here.

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Entrepreneurship

BARRY ASHBY
Washington Editor
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Here's a happy subject this month: entrepreneurship.

Believe it or not, I know a lot about starting and running your own business. Beginning in 1963, four years after engineering school, I began manufacturing plastic parts for the aerospace industry. Then I filed a patent and, when it was issued in 1967, three others and I started a business to manufacture reinforced plastic grain storage silos that the rest of the world desperately needed. We immediately received a $25 million contract with financing from Argentina's government, but within a month their corrupt leadership changed and one partner "disappeared" and a second dropped dead on the streets of Perth. So, we stopped that venture.

A partner and I then made electronic signal jammers, selling them around the world, until we started making other high-tech facility security items and information-gathering things in three more firms that I started with others. They were all self-financed. All of this was before I started writing this column in 1972, and it was fun!

To be an entrepreneur requires self-realism, honesty in planning, ability to understand both defeat and success, and imagination. It is mandatory that you know yourself and your shortcomings. It is also essential that you are willing and content to work in an environment that is "different" from most jobs. It takes long soul-searching hours with commitment. Oh, and did I say imagination with realism?

This all leads us to a suggested entrepreneurship situation for readers of this journal. Maybe one or more companies could get together and bring the following ideas to reality – for world benefit and participants' profit.

Nearly 30 years ago a fellow named David Giles invented what he called FastShip. The patented method changed hull design so that, for example, a freighter 265 meters long x 40 meters wide with 10.5-meter draft and powered by five jet turbines driving water jets could complete a transatlantic crossing in 90 hours (compared to 160 hours with conventional container ships) and offload intermodal containers in under six hours (compared to the conventional 48 hours).

The hull design was quite different. For whatever reason(s) private shippers (e.g., Maersk) were hard against FastShip. Common sense says this new and different approach "horned in on their turf." This negativism also included the U.S. defense establishment, U.S. Navy and several support contractors on the Littoral Combat Ship project, which were sued by FastShip. Government and contractors totally lost the case for patent infringement. FastShip went bankrupt in 2012. It is still a good idea, the world needs it and it is essential to understand that FastShip is quite affordable.

Now let's add another dimension. Some fellows at MIT and Harvard have been studying sharks. They found that due to "denticles" in the skin structure, some of these creatures can swim 60 mph. Looking at denticles, we observe that they create a "cupped" surface that "increases lift without increasing drag." It is reported that lift can be increased by (as much as) over 300%. It works and has been tried. It is not a big deal for readers of this journal to put dimples (denticles) on the surface of vast areas of metal sheet used in ship hulls. Duh!

Now to skip ahead and sideways at the same time, let me introduce you to a friend of mine who knows all the folks involved with what is being described. I met John Bosma when he came to Washington, D.C. as part of the Reagan transition team at the White House in 1981. He is a prolific researcher and writer and knows all the folks mentioned that deal with both FastShip and denticle technology. He lives out near Seattle, but you can reach him at 410-446-8198 to discuss the issues mentioned here and to start building a team of entrepreneurs to make what seems like two good ideas into a reality. He has identified a team, including shipbuilders and system designers, but no one that can put denticles on metal for ship hulls.

Since none of this is set in stone, talking and learning is always the next step at a time and juncture like this. It will be fascinating to learn if these ideas go anywhere.

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Simulation Software (Part Three: Nitriding, Nitrocarburizing)

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Last but certainly not least, as the saying goes, is our discussion of gas nitriding and nitrocarburizing process simulators and how they are used to predict and control these case-hardening processes. Let's learn more.

Today, these simulators are available from several original equipment manufacturers and academic institutions for the purpose of determining the nitriding process parameters (i.e., cycle recipes) required to obtain a given case depth, to predict the compound-layer composition, and to anticipate both the final surface and core hardness as well as the hardness distribution throughout the case.

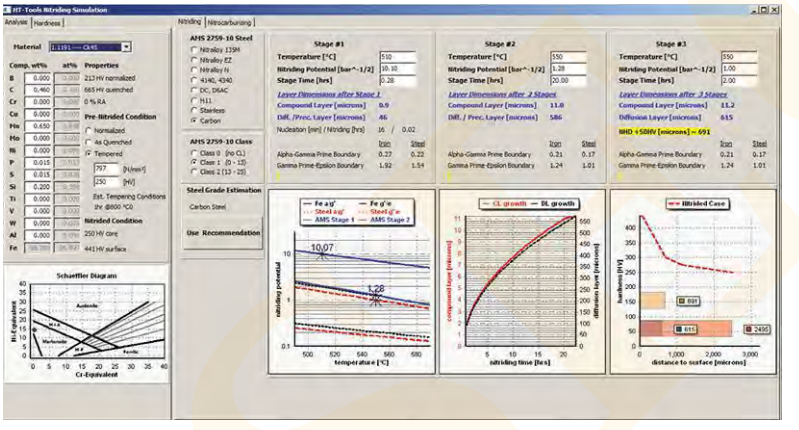

Fig. 1. Typical gas nitriding simulator output screen factoring in compound-layer composition and diffusion/precipitation-layer growth *(courtesy of United Process Controls)*

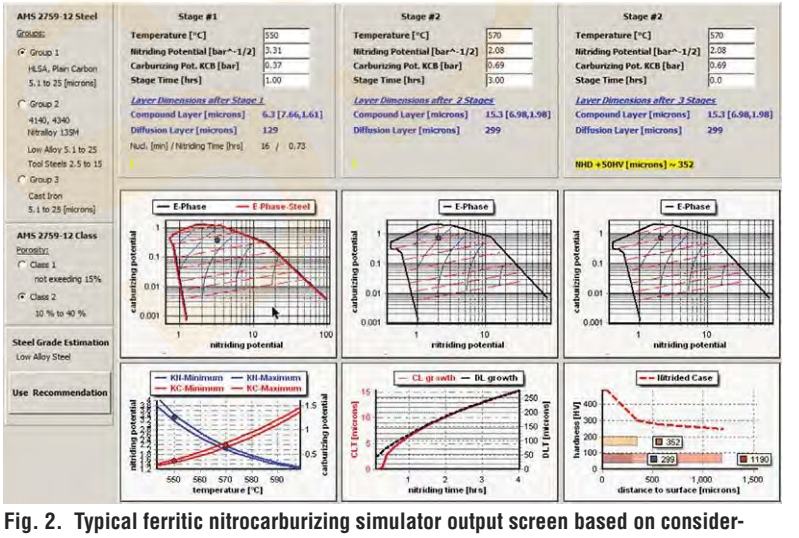

Fig. 2. Typical ferritic nitrocarburizing simulator output screen based on considerations of the iron-nitrogen-carbon phase diagram *(courtesy of United Process Controls)*

Key Challenges[2]

Nitriding simulations are strongly influenced by two preconditions: material composition (i.e., the effect of alloying elements on nitriding activity, solubility, phase boundaries and diffusion coefficients) and prior microstructure (i.e., core hardness and microstructure impacting the final surface-hardness increase, final core hardness and the final hardness distribution) produced by prior heat treatments such as annealing, normalizing, austenitizing and quenching, or quench-and-temper operations.

One of the reasons that the prior microstructure is so important is that simulators need to determine the amount of nitride formers not tied up as carbides. Nitriding processes are ideally performed on quenched-and-tempered steels. Tempering is performed at a temperature of at least 10°C (50°F) above nitriding temperature. Simulators (and most specifications) typically estimate hardness distribution and case depth. Case depth is defined as core hardness plus 50 HV.

Simulators also need to determine hardness changes during nitriding. This is done by assuming that the softening effects that occur with increasing temperature are similar to tempering effects. Other factors that influence the simulator models (and involve an in-depth understanding of kinetics and thermodynamics) are nucleation, compound-layer growth and composition, diffusion/precipitation-layer growth and final hardness distribution.

These factors are incorporated into the output of the various simulators (Fig. 1) based on work by such noted individuals as Sun and Bell (nucleation theory[4]), Hosseini, Ashrafizadeh and Kermanpur (compound-layer growth and composition[5]), Fick (diffusion modeling) and Kunze (precipitation layer growth[6]). While beyond the scope of this article, the reader is encouraged to review these papers to deepen their understanding of how these factors play a role in the inner workings of these simulators.

Ferritic Nitrocarburizing Simulators

Simulators for ferritic nitrocarburizing (Fig. 2) are typically adopted from their gas nitriding

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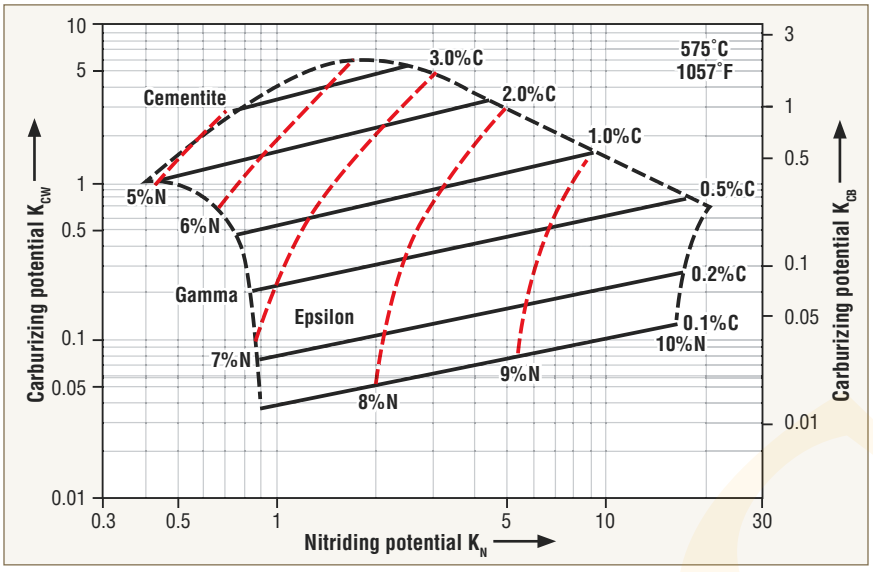

Fig. 3. Iron-nitrogen-carbon control diagram[12]

simulator cousins by looking at the iron-nitrogen-carbon diagram (Fig. 3) at a specific process temperature and adjusting the diagrams to match the steel in question by using appropriate activity coefficients.

Process Control

Control of a modern gas nitriding process (Eq. 1) is based on the modified Lehrer diagram[7] relating nitriding potential to the iron-nitrogen phase boundaries as a function of temperature.[11]

$$k_N = \frac{pNH_3}{p^{\frac{3}{2}}H_2} \quad (1)$$

Control of a modern nitrocarburizing process (Eq. 2) is based on the Fe-N-C control diagram, displaying $Fe_{2-3}NC$ epsilon ( ) phase depending on temperature, nitriding potential (K_N) and carburizing potential (K_C) as shown in Figure 3.

$$k_{CW} = \frac{pCO \cdot pH_2}{pH_2O} \quad k_{CB} = \frac{pCO_2}{p^2CO} \quad (2)$$

Open Architecture – One Man's Opinion

The individual companies and research institutions that have invested considerable time, money and effort into developing these simulators should be complimented, but commercially available software packages running on desktop or laptop computers are needed for their wider adoption and use.

Summary

In this series of recent articles, we have introduced the idea to the heat-treat community that process simulators not only exist but can be used for highly accurate prediction of process recipes and to anticipate the metallurgical structure (and ultimately the performance characteristics) of the parts being run. Nitriding and nitrocarburizing simulators are no less capable than their carburizing counterparts.

Surveys of the heat-treatment industry conducted by ASM International in the late 1990s and early 2000s outlined a series of eight key industry goals, one of which was outcome prediction based on heat-treat modeling. The accomplishment of that goal is closer than ever. As such, the heat treater needs to embrace and use these simulation tools in his/her daily work.

Acknowledgment

The writer – with great pride and humility – would like to acknowledge good friend Dr. Karl-Michael Winter for his contributions to this article; his unwavering commitment to advancing gas nitriding/nitrocarburizing technology throughout the heat-treatment industry; and his many lectures, papers and discussions over the years.

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Thermal Technologies

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

Thermal Technologies was founded in 1998 on a basic, yet complex, idea: providing a true alternative to customer concerns regarding quality and service when procuring heat-treatment processes.

The Chatsworth, Calif.-based company has accomplished this feat by adhering to its philosophy. "Combining our extensive heat-treating and metallurgical expertise with accurate processing will yield materials and services of the highest quality on time and at lower prices."

Today, with eight employees, Thermal Technologies services the aerospace, defense, medical, commercial, oil and drilling, tactical, food, automotive and entertainment markets. The company performs a wide variety of vacuum, atmosphere and open-fire thermal processes. These include:

- Vacuum – bright annealing, magnetic annealing, solution annealing, hardening, vacuum gas quenching, normalizing, stress relieving, tempering
- Atmosphere – carburizing, hardening, normalizing, oil quenching, stress relieving, tempering,
- Open fire – aging, annealing, hardening, stress relieving

Thermal Technologies, in keeping with its philosophy, offers more than heat-treatment processes. This MTI member also provides a wide range of support services, including metallurgical consultation, inspection, lab analysis, straightening, racking and sand blasting.

In fact, this range of services has helped set Thermal Technologies apart. Its vacuum processing features ultrahigh clean vacuum with leak rates ranging from 0-10 microns per hour, which exceeds most specifications. Meanwhile, its on-staff metallurgist is able to consult with customers on not only heat treating but also design needs. Perhaps most importantly, Thermal Technologies has proprietary methods that minimize and eliminate distortion issues throughout thermal processing.

Perhaps most vital to the company's success since its inception, however, has been digitization. Digital controls allow strict and total control of processing at the highest level. Digital records make Thermal Technologies' quality system accurate and precise, and it makes retrieving those same records hassle-free – a benefit to company and customer alike.

Committed to company growth and continual improvement, Thermal Technologies expanded operations into a 15,000-square-foot, state-of-the-art facility and became Nadcap-accredited in the past two years.

As for the future, Thermal Technologies will continue to strive to meet customer requirements by combining its heat treating knowledge and experience with accurate processing and to produce materials and services of the highest quality on time while remaining in full compliance with ISO 9001 and AS9100 quality standards. Furthermore, the company pledges to maintain a safe and environmentally friendly workplace in recognition of its responsibilities to employees, customers and community.

Visit www.thermaltechnologies.net for more information.

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Sneak Peek at ITPS Program

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ITPS – The International Thermprocess Summit – made its North America debut in the summer of 2016. The event returns July 30-Aug. 1 at the InterContinental Buckhead Atlanta. This time, however, it comes with the International Finishing & Coatings Summit (IFCS). The summits will bring together an impressive and diverse group of business leaders to help executives stay on top of the latest trends and innovations affecting their manufacturing operations.

Co-sponsored by the Industrial Heating Equipment Association and the Chemical Coaters Association International, summit organizer Anne Goyer said: "This combined event will provide a unique platform for industry intelligence and collaboration that drives manufacturing excellence. There is no other event like this in North America for executives in these manufacturing segments."

Here are a few program highlights (complete program details will be published in June's issue).

Factories of the Future/ What Does the Future Workforce Look Like?

Speaker: Dr. Irene Petrick, Market Innovation Director, Industrial Solutions Division/Internet of Things Group, Intel Corporation

An internationally recognized expert in strategic road mapping, Dr. Irene Petrick has worked with a wide variety of companies ranging from small businesses to Fortune 100 companies and the U.S. military. As director of business strategy for Intel's Industrial and Energy Solutions Division in the Internet of Things Group, she provides leadership in the integration of business and technology strategy to develop solutions. Her presentation will focus on the future of manufacturing and the manufacturing workforce.

Trends in Additive Manufacturing

Speaker: Todd Grimm, Founder and President, T.A. Grimm & Associates Inc.

An expert in additive manufacturing and rapid prototyping, Todd Grimm will present the latest technology trends and developments. Grimm effectively delivers highly technical aspects of this rising technology to both technical and non-technical audiences.

Congressional Priorities and Policies

Speaker: Omar Nashashibi, Founding Partner, The Franklin Partnership

President Trump has kept his campaign promise to shake up Washington, and it is anything but business as usual in the nation's capital. Omar Nashashibi lobbies Congress, the White House and federal agencies on behalf of manufacturing companies. This is your chance to hear directly from a Washington insider about the latest on trade, workforce training and regulations.

Driving Consistent Performance Excellence

Speaker: Dr. Amber Selking, Founder, Selking Performance Group

Delivering consistent performance excellence is critical to team success. Through her experiences working in manufacturing for SPX Corporation and as the mental performance consultant for the University of Notre Dame football team, Dr. Amber Selking will share insights from the field of human performance psychology that will help you deliver your best on a more consistent basis.

To review the complete program and register, visit www.itps-ifcs.com.

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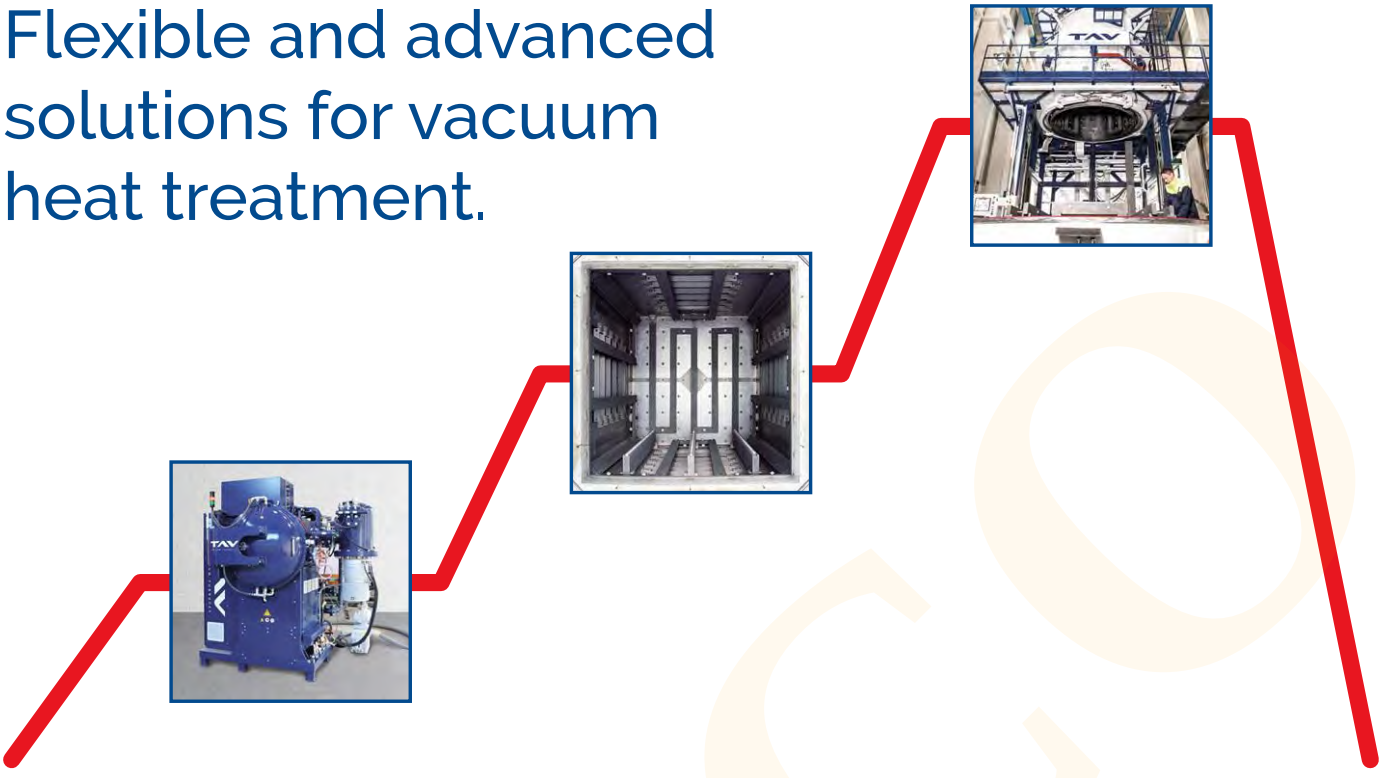

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EQUIPMENT NEWS

Box Furnace

L&L Special Furnace Co. Inc. delivered an intermediate-sized, front-loading box furnace to the Canadian government's forestry division. With a work zone measuring 16 inches wide x 16 inches high x 20 inches deep, the furnace is equipped with an atmosphere-sealed case for use with inert gas to displace oxygen and minimize surface decarb. It is purged with inert gas prior to loading, and the parts are then heated under a controlled atmosphere. Heating is supplied by Kanthal APM elements located on the sides, bottom, back and door. These elements are wire-wound coils with a heavy cross section that allows for higher soak temperatures for longer periods of time. The furnace's control system includes a Eurotherm EPC3004 multiple program control and over-temperature protection. www.llfurnace.com

Vacuum Furnace

Ipsen sold a vacuum furnace with 12-bar gas quenching to commercial heat treater Midwest Thermal-Vac (MTV) of Kenosha, Wis. The furnace includes a diffusion pump for high-vacuum levels and an all-metal hot zone to ensure part cleanliness, which is an important feature for processing parts that need to comply with Nadcap and medical-industry requirements such as MedAccred. This TITAN furnace has a hot zone measuring 18 x 24 x 18 inches with a 1,000-pound load capacity. It is capable of operating at temperatures ranging from 900°F to 2400°F (482°C to 1316°C) with ±10°F (±6°C) temperature uniformity. The shipment also includes Ipsen's PdMetrics software platform for predictive maintenance.

www.ipsenusa.com

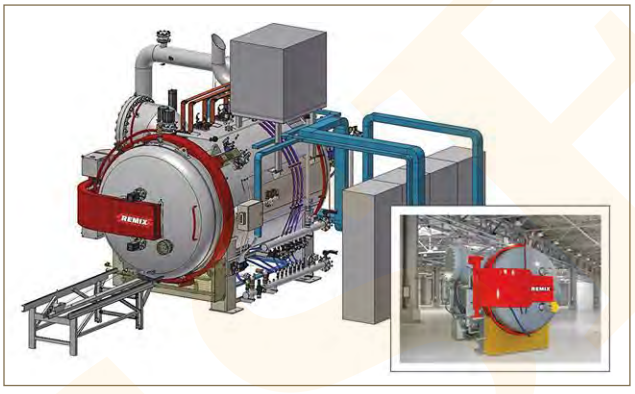
Heat-Treat System

Can-Eng Furnaces International Ltd. was awarded a contract from an India-based conglomerate to design, manufacture, install and commission an aluminum automotive casting heat-treatment system for its North American expansion in South Carolina. The solution-treatment, water-quench and artificial-aging system is arranged to provide T5, T6 and homogenizing processes. It will service three distinct aluminum product groups with unique treatment cycles. Can-Eng was chosen for this project largely due to the system's modular design concept, which offers efficient product, process and production flexibility for the company's new line of die-cast, lightweight aluminum automotive components.

www.can-eng.com

Vacuum Furnace

Poland's **Remix** delivered a horizontal high-pressure vacuum furnace to P&L Heat Treating Inc. of Youngstown, Ohio. The furnace will enhance P&L Heat Treating's production capabilities in the heat treatment of aluminum extrusion dies, forging dies used in the automotive industry, and parts for the aviation and



nuclear industries. The unit's internal size of 36 x 36 x 48 inches (910 x 910 x 1,220 mm) is ideal for various-sized dies, punches and forming rolls. The furnace's four-zone system of cooling nozzles facilitates precise control of cooling gases into the work zone. This allows optimized positive-pressure quenching of all load sizes by providing a directed gas stream directly where it is needed, which results in uniform hardening of metals and lower gas consumption.

www.remixsa.pl/eng

Pit Furnace

Lindberg/MPH shipped an electrically heated cyclone pit furnace to a steel heat treater. The furnace, which has a maximum temperature rating of 1250°F, will be used for a heat-treating process on aircraft components. The work chamber measures 38 inches in diameter x 48 inches deep and is constructed with

an alloy liner backed with 7 inches of block insulation. The top-load furnace features a thermocartridge recirculating fan and solid-wall baffle for uniform heat distribution. The furnace fan utilizes a centrifugal-blower-type alloy blade and a 5-HP motor with belt and pulley drive system.
www.lindbergmph.com

Homogenizing System

SECO/WARWICK supplied a traveling aluminum-log homogenizing furnace and cooler combination to Ohio Valley Aluminum Company (OVACO). The system will be installed at OVACO's facility in Shelbyville, Ky., and will be used to process aluminum billet and logs in a lean-manufacturing environment. It enables seamless processing without moving product until the process is complete, and it reduces cycle time by eliminating the need to transfer product to stationary coolers. The furnace utilizes SECO/WARWICK's patented reversing airflow design with upstream/downstream temperature control using an axial-flow fan wheel that reverses rotation on a timed basis, in turn reversing the direction of the horizontal airflow through the load. www.secowarwick.com

Endothermic-Gas Generator

United Process Controls (UPC) delivered an Atmosphere Engineering EndoFlex endothermic-gas generator to Jomarca, a fastener manufacturer in South America. The generator is intended for carburizing operations at the company's Brazilian plant, which includes 10 large continuous rotary-retort furnaces that process over 2,200 tons of fasteners a month. The high-capacity generator was integrated into the

plant's existing gas-distribution system in the first quarter of 2018 and is supplying endothermic gas to all carburizing furnaces. EndoFlex operates at a lower cost and mixes to more accurate ratios, which helps to maintain a constant furnace atmosphere and consistent gas quality at all times. The generator's intelligent control system automatically adjusts the production of endothermic gas to match the real-time demand of the furnaces. www.group-upc.com

BUSINESS NEWS

Bodycote Opens Facility in North Carolina

Bodycote opened a new facility for specialty stainless steel processes (S^3P) in Mooresville, N.C. S^3P processes increase mechanical and wear properties in stainless steel without adversely affecting corrosion resistance. The plant will support manufacturing supply chains in the southeast region. It will be accredited for both ISO 9001 and AS9100 to serve the customer base. Bodycote's S^3P technologies are dedicated to treating stainless steel, nickel-based and cobalt-chromium alloys (including martensitic and precipitation-hardened stainless steel materials) to improve resistance against surface wear such as galling, cavitation erosion and abrasive wear.

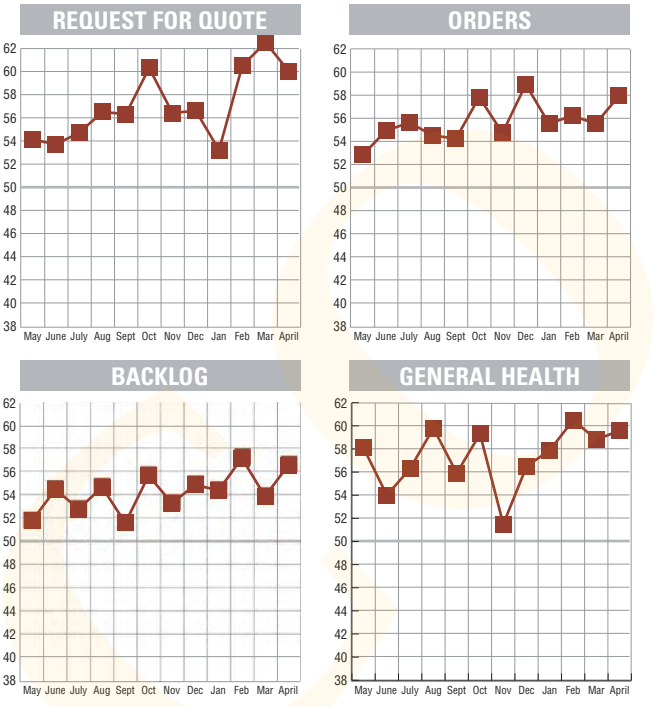
Carpenter Technology to Invest in New Hot-Rolling Mill

Carpenter Technology Corp. will invest $100 million in soft-magnetics capabilities and a new precision-strip hot-rolling mill at its Reading, Pa., facility to help meet increasing demand from aerospace, consumer-electronics and electric-vehicle manufacturing customers. The mill will increase overall capacity and offer greater flexibility in processing alloys for highly specialized soft-magnetics applications. Sophisticated equipment, special processes and highly controlled atmospheric conditions are required to produce soft-magnetic alloys to meet stringent specifications.

JSW USA to Invest $500 Million in Plate Mill

JSW USA plans to invest up to $500 million to install a technologically advanced, eco-friendly hot-end facility at its 700-acre campus in Baytown, Texas. The announcement marks the second and larger phase of a plate-mill modernization and expansion project that began in June 2017. The hot end's electric-arc furnace (EAF) is designed ...continued on p. 60

ECOMOMIC INDICATORS



Values above 50 indicate growth or increase. Values below 50 indicate contraction or decrease.
To participate in this survey, please contact Bill Mayer at bill@industrialheating.com

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Best of Induction

Reed Miller – Editor

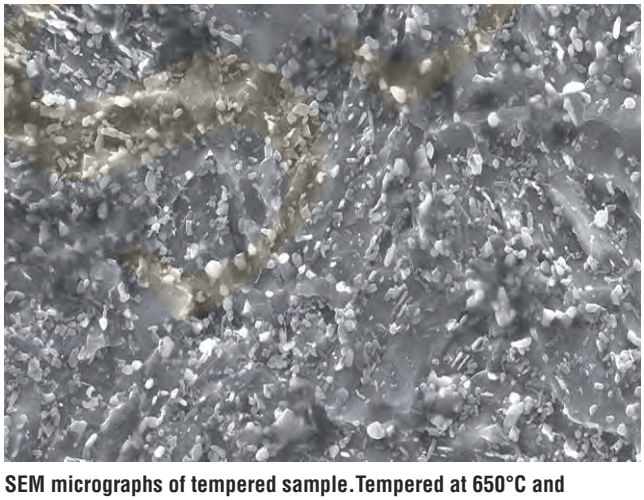
Have you been considering adding induction capabilities to your heat-treat or production facility? Our website is a great place to look for more information as well as comparisons of induction and other processes. Let our reader-favorite induction articles help you locate what you might need.

(Above left) Melting platinum in a ceramic crucible. (center) No caption in original feature. (right) Example of a vertical induction-hardening (scanning method) application *(courtesy of SMS Elotherm GmbH)*

Speaking of comparisons, three of the seven reader favorites compare induction with alternative processes. In fact, the most-read induction article was the third-most-popular article overall in 2017, and it compares induction and case hardening.

Comparing Induction Hardening, Case Hardening

Reducing fleet consumption in the automotive industry or service-free lifetime operation of components in offshore oil rigs all depends on the quality of the components used. The heat treatment – here the surface hardening – plays an important role for keeping geometrical dimensions as small as possible and boosting the component's resistance to ever-increasing loads at the same time.



SEM micrographs of tempered sample.Tempered at 650°C and held for 1 hour

This article, originally run in August 2015, discusses the advantages of induction heating and provides some specific examples to compare costs. Induction is well-suited to being incorporated into production lines due to the custom hardening configurations available. You can find this article at www.industrialheating.com/indvcase.

Comparative Analysis of Induction and Furnace Tempering

Another comparison article was originally run in December 2016. The Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute (WPI) in Massachusetts performed a one-of-a-kind research project aimed at better understanding the mechanical properties and microstructural features of steels that have been gas tempered and induction tempered. Ultimately, the findings from this induction and furnace tempering research project will help industry, especially heat treaters in the automotive industry, reduce cycle time and process costs while maintaining or improving product performance of toughness and strength.

For this study, AISI 4140 was used for its high hardenability and because it is widely used in engineering applications. Check out the findings, which compare microstructure and mechanical properties (hardness, tensile and impact toughness). You can find it at www.industrialheating.com/comparetemper.

Gear Materials and their Heat Treatment

The next-most popular "induction" article is not really an induction article. It is actually a third comparison article of heat treatments for gears. Gears play an essential role in the performance of many products that we rely on in our everyday lives. When we think about gears we generally separate them into two categories –

Announcing Two New eBooks

by Dan Herring, The Heat Treat Doctor™

Industrial Heating is pleased to announce two new eBooks by Dan Herring, The Heat Treat Doctor™, entitled "*A Comprehensive Guide to Heat Treatment*" Volume 1 (May 2018) and Volume 2 (December 2018). The eBooks will be free and available for download by heat treaters, metallurgists, designers, manufacturing engineers, supervisors, quality, safety and maintenance personnel, management and anyone interested in heat treating, manufacturing and academia worldwide.

Free Download at: IndustrialHeating.com/eBooks
Vol. 1 Coming in May 2018 & Vol. 2 Coming in December 2018

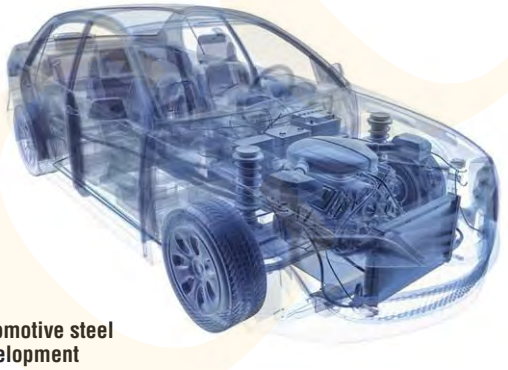
Typical commercial heat-treat load of gears for vacuum carburizing
(Photograph courtesy of Midwest Thermal-Vac)

motion-carrying and power-transmission. Motion-carrying gears are generally nonferrous or plastics, while load-bearing power-transmission gears are usually manufactured from ferrous alloys and are intended for heavy-duty service applications.

This article discusses gear materials and the properties necessary for demanding gear applications. Atmosphere, vacuum and induction processes are compared. For more, go to www.industrialheating.com/gearht.

Flash® Processing for High-Strength, Cold-Stampable Automotive Steel

Flash® processing of common steel is a promising manufacturing technology that can be used to produce high-strength, cold-stampable automotive steel for safer, lighter and more fuel-efficient vehicles. Flash processing is an extremely rapid heat treatment with a total process time of less than 10 seconds. Room-temperature or preheated steel is fed into



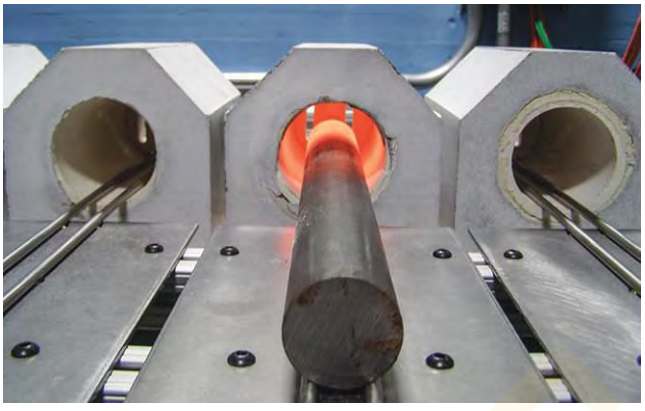
Automotive steel development

an induction heating unit that heats the material at a rate of approximately 400°C/s to temperatures above 1000°C (1832°F).

This interesting article was contributed by the U.S. Department of Energy in May 2017. You can find it at www.industrialheating.com/flash.

10 Considerations When Selecting an Induction Heating System

If you are in the process of considering induction for your facility, this article might be just what you need to read.



Induction heating bar end for fastener hot heading

Originally run in August 2016, this article steps through what to consider in your decision, which includes things like the materials to be processed as well as your part/coil shape and your plant logistics.

You will learn a general rule that the higher the frequency, the shallower the heating of the part. This may be more intuitive if you also consider that higher frequency also means lower power. Originally in the August 2016 print issue, this article can be read online at www.industrialheating.com/induction10.

Using Induction Brazing in Manufacturing Operations

This article was actually run in two parts in 2016, and both were very popular with readers. Induction is an excellent way to quickly heat up a localized area of a large assembly in order to permanently join them together. The induction-brazing process is examined to see what it is and how it can be effectively used by brazing shops to meet some of their production needs.

Induction brazing is a wonderful tool that many shops may wish to use for certain parts that need to be brazed quickly, are too large to fit inside a brazing furnace or perhaps have areas that cannot tolerate high heat since damage might result to those areas if heated to brazing temperature. It is safe, fast and very reliable when proper procedures are followed.

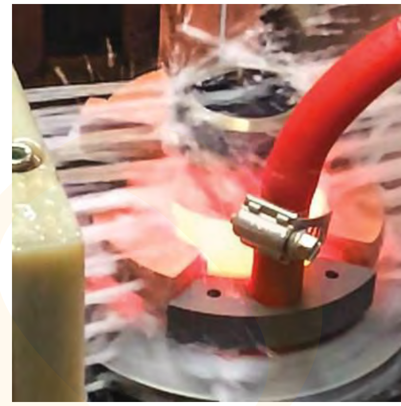

Induction coil used to heat a copper-alloy brazement *(courtesy of Ameritherm; Ambrell Induction Co.)*

Start with part 1 at www.industrialheating.com/kaybraze1 and then move to part 2 by navigating to www.industrialheating.com/kaybraze.

Design and Development of PPAP-Ready Wheel-Bearing Inductors

Did you know induction hardening requires a six-degree design equation to predict how a wheel bearing will respond in an induction field? Although great strides are being made to simulate induction patterns, most of today's inductor design and validation is still done through experience and experimentation. The objective of this article is to show how a wheel-bearing inductor is designed, fabricated and validated to be ready for Production Parts Approval Process (PPAP) and integration into robust manufacturing.

This reader-favorite induction article was originally run in May 2016, and you can find it at www.industrialheating.com/autoind.


Spindle hardening process development

We trust you will find these reader's-choice articles helpful as you learn more about induction and whether it is right for your operation. You can further mine the depths of induction on our website by going to www.industrialheating.com/induct or using the QR Code provided.

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Using EBSD for Improved Quality Process in Metallurgy

Chris Stephens and Keith Thompson – Thermo Fisher Scientific; Madison, Wis.

Materials development, methods development and quality assurance benefit from electron backscatter diffraction (EBSD).

EBSD microscope located in Carnegie Mellon University's Materials Characterization Facility
(courtesy Carnegie Mellon University College of Engineering)

Electron backscatter diffraction (EBSD) is a technique for determining the near-surface crystallographic and microstructural properties of a material. It is based on the automated capture and analysis of diffraction patterns formed when a sample is excited by an electron beam within a scanning electron microscope (SEM). This type of analysis is of particularly high value in metallurgy for new materials discovery, process development and quality control of existing processes.

While the roots of EBSD in a SEM go back 30 years, the advent of high-performance cameras, increased computational power and automated analysis routines have driven a recent boom in applications across materials science and quality control. Compared to other structural analysis techniques, EBSD has significant advantages. It is faster, less costly and has less onerous sample preparation than electron diffraction in a transmission electron microscope (TEM) and with a spatial resolution many hundreds of times greater than X-ray diffraction. Modern EBSD systems are now fast and versatile, yielding rich quantitative datasets in 2D and 3D with sub-micron resolution and with most analyses of metallurgical samples completed in less than 20 minutes.

There are three main operational modes of EBSD, each with differing requirements for sample preparation and analysis procedures.

1. **Orientational image mapping** (OIM) provides the crystallographic orientation and diffraction-pattern quality of a polycrystalline material across the sample with many tens to several hundreds of grains per map. The onus for mapping is therefore on speed of acquisition with exposure times of a few milliseconds. Once collected, these data sets are interrogated using grain reconstruction algorithms to assess the microstructure of the material.
2. **Phase identification** involves the determination of unknown phases through the

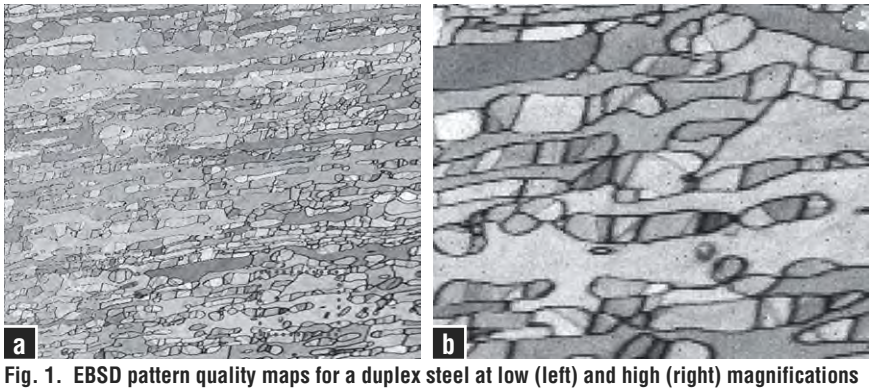

Fig. 1. EBSD pattern quality maps for a duplex steel at low (left) and high (right) magnifications

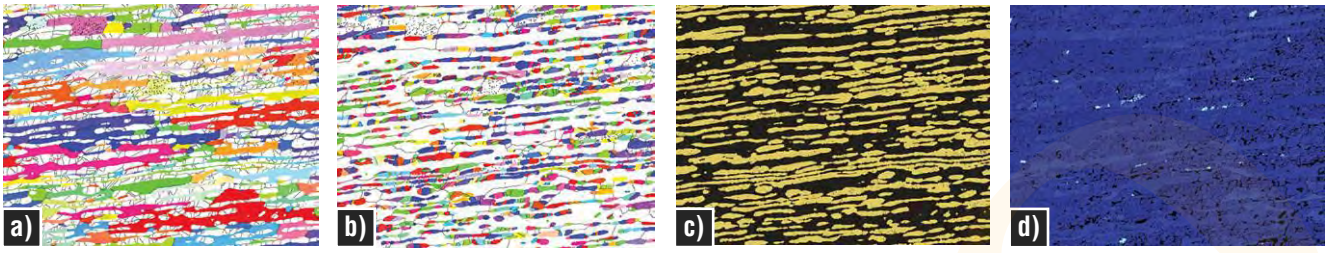

Fig. 2. EBSD analysis of a duplex steel: a) orientation distribution of ferrite, b) orientation distribution of austenite, c) phase distributions of ferrite (dark brown) and austenite (light brown) and d) strain analysis across the duplex

comparison of diffraction patterns against a database of many thousands of known phases. An example application would be in corrosion science, which investigates the transformation between the iron-oxide phases of hematite (Fe_2O_3) and magnetite (Fe_3O_4).

3. **Strain analysis** uses cross correlation of diffraction patterns to show changes and defects within the crystal lattice. This analysis method has the highest angular precision and is increasingly used in predictive failure analysis.

The increasingly faster speeds of analysis imply that EBSD-OIM may serve as an increasingly practical and valuable tool in metallurgical quality control with a focus on continuously monitoring the microscale. The basic nature of EBSD – electron beam on sample – inherently supports the simultaneous use of energy dispersive spectroscopy (EDS) for concurrent chemical analysis of the material.

Figure 1 shows an example of OIM and the information content available to the user. The case study involves the analysis of a duplex steel containing approximately equal amounts of ferrite (BCC) and austenite (FCC) grains. Of particular interest is the grain sizing, distribution and inter-orientation grain relationships between the ferritic and austenitic phases because this gives insight into the ductility and stress resistance within the material.

The samples were analyzed with an EDS detector and an EBSD camera. EDS phase mapping was performed using a principal component analysis technique, as developed by Paul Kotula at Sandia National laboratory[1,2] and employed in a phase mapping software package. Maps were acquired at 20 kV accelerating voltage with 1024 x 768 pixels and a 0.5 micrometer step size and exposure time of 1.5 ms, meaning the analysis time was approximately one hour.

Interpretation of the data begins with band contrast imaging, Fig. 1a, which gives a measure of the quality of the diffraction pattern at each pixel and is therefore related to the underlying crystallinity. Grain boundaries and defects typically yield low-quality diffraction patterns as represented by darker pixels, while the overall contrast of individual grains is related to the grain orientation. The enlarged image, Fig. 1b, shows the distribution of grains across the sample. There are distinct types of grains, one with large continuous features and another made up of smaller twin grains, signified by the straight-lined grain boundaries.

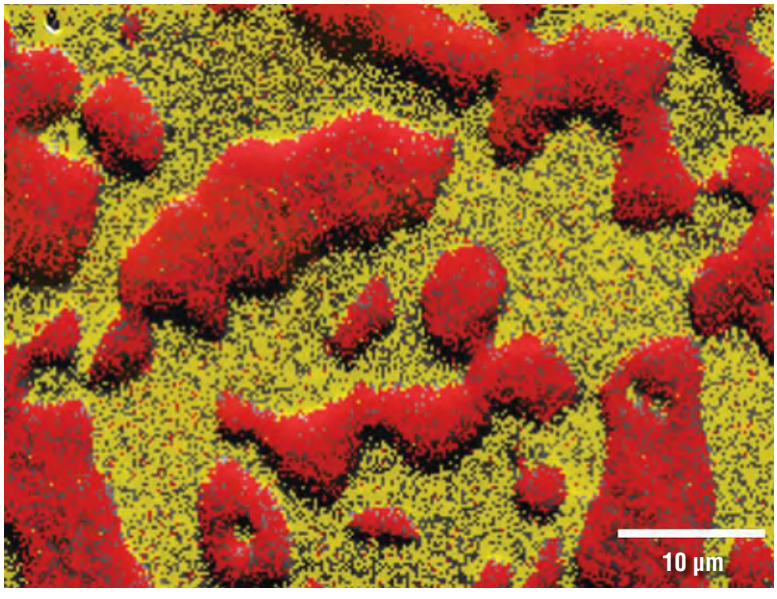

Fig. 3. High-magnification EDS phase maps for austenite (red) and ferrite (yellow) phases within the duplex steel

Table 1. Quantitative analysis of Figure 3

Element	Austenite weight, %	Ferrite weight, %
Cr	21.44	25.10
Mn	3.36	3.35
Fe	60.89	61.29
Ni	10.09	4.15
Mo	4.22	6.11
Total	**100.00**	**100.00**

Table 2. Corresponding quantitative results for Figure 4

Element	Phase 1	Phase 2
C	0.80%	0.80%
Si	0.70%	0.85%
P	0.04%	0.16%
S	0.05%	0.16%
Cr	19.18%	19.30%
Mn	1.19%	1.97%
Fe	70.36%	66.36%
Ni	7.68%	10.40%

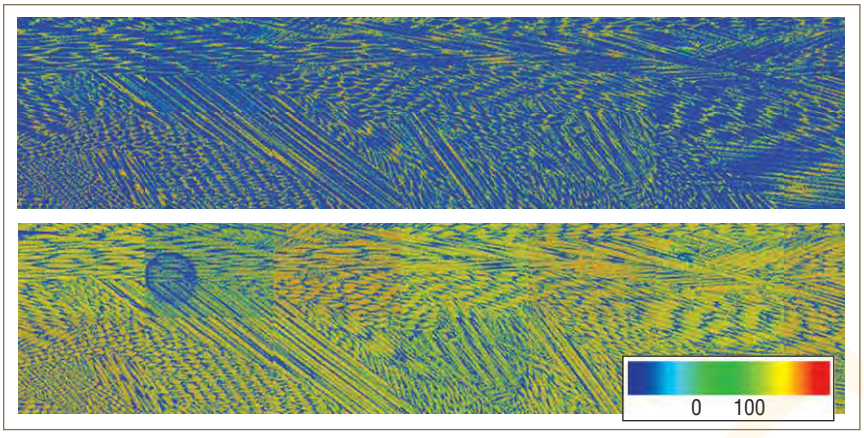

Fig. 4. COMPASS EDS phase maps: (top) phase 1, BCC; (bottom) phase 2, FCC

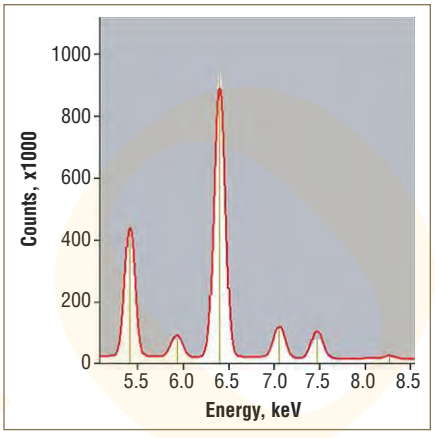

Fig. 5. EDS spectral of phase 1 and phase 2

Probing the data further, a phase plot, Fig. 2, reveals that the larger grains are ferrite and the smaller grains are austenite. The orientation maps for ferrite, Fig. 2a, reveal large, continuous grains without a preferred orientation. The distribution of austenite, Fig. 2b, shows a high number of twin boundaries within these grains. Overall, there was no relationship observed between the orientations of the austenite and ferrite phases. Figure 2c is a plot of the average orientation of each point in the grain relative to the average for the grain. Figure 2d shows the strain analysis across the material.

High-magnification EDS phase maps were generated as described earlier and displayed in Fig. 3. The red and yellow EDS phase maps correlate neatly with the austenite and ferrite phases identified with EBSD. Cr and Mo are ferritic stabilizing alloying elements. A quantitative analysis of the software phase maps indicates a 4% increase in Cr and 2% increase in Mo – at the expense of Ni – in the ferrite phase relative to the austenite phase. While subtle, this difference is sufficient to define the two unique crystal structures.

It is evident that the concurrent collection of EBSD and EDS data provides an additional level of information that is not available when employing only a single technique and that the combined data streams generate the statistical data required for process and quality control on the microscale. However, one may argue that both streams of information are not necessary in many analytical-use cases. When one technique has clear, practical use-case advantages over the other and if the information from one technique can be successfully correlated against the information from the other technique, it may be worthwhile to intentionally omit one of the two techniques.

In the case reviewed here, EDS has a shorter time to answers (5-10x faster), less-rigorous sample preparation requirements and a preferred analytical geometry (flat vs. tilted) relative to EBSD. It has just been demonstrated that both EDS and EBSD phase maps can be generated and correlated to each other. It is therefore reasonable to assert that EDS phase maps – at least as generated with the software algorithms described here – are sufficient to infer the crystal structure, sizing and distribution of grains within the metal that would otherwise have been obtained with EBSD. The detailed orientation information on the grains is lost without

the EBSD. However, this is balanced against the value that much larger sections of the material may be analyzed – such as for quality assurance and quality control purposes – and likely done so in a shorter amount of time.

This concept of large-area quantitative phase mapping is demonstrated on a sample of stainless steel 304 that underwent rapid heating and cooling during a welding operation. The weld was performed in the transverse direction (left to right) in Fig. 4. EBSD and EDS had previously been used to determine that the BCC ferrite phase had between 7.5-8.0% Ni. As the metal cooled, Ni was rejected from the ferrite, and FCC austenite with approximately 10-11% Ni formed in the boundaries between the ferrite grains.

An EDS-only acquisition was then performed over a large area of the sample, and phase maps of the elemental distribution were generated using the software's PCA algorithms. The region of steel studied was 5.5 mm long x 0.65 mm tall. This compares to the previous study that covered an area of 0.5 mm wide x 0.5 mm tall.

The resulting EDS software phase maps are shown in Fig. 4.
The two dominant components (i.e., chemical phases) are immediately apparent. The EDS spectra extracted from each phase and overlaid on each other are shown in Fig. 5 The two spectra are nearly identical with only small differences in the EDS peak intensity of Ni and Fe. The quantitative results (Table 2) demonstrate that phase 1, with 7.68% Ni, is BCC, while phase 2, with 10.4% Ni, is FCC.

Using this correlative approach, the FCC and BCC phases, including grain size and distribution, were effectively determined without the need to run concurrent EBSD. The details regarding the orientation of the BCC and FCC grains were not obtained. However, the ability to analyze a region roughly 15 times larger while maintaining sub-micron resolution provides both the fine detail of the material structure and the broader overview needed to both see the "bigger picture" of information in the sample and to sample a large enough number of grains for proper statistical analysis of the grain structure. For example, the grains identified in Figure 4 are long, thin and aligned with the direction of the weld.

Conclusion

Both EBSD and EDS are valuable tools for monitoring the microstructure of metallurgical samples. The decision on whether to utilize either one technique as stand-alone or both techniques simultaneously depends on the information type required (i.e., quantity vs. quality). Detailed grain orientation requires only EBSD. Correlation of crystal structure to materials chemistry requires both EBSD and EDS. General quality control of grain size and distribution via chemistry requires only EDS. Materials development, methods development and quality assurance/control benefit from both techniques as the use-case requires.

For more information: Contact Keith Thompson, product manager of microanalysis, Thermo Fisher Scientific, 5225 Verona Rd., Madison, WI 53711; tel: 608-276-5603; e:mail: keith.thompson@thermofisher.com; web: www.thermofisher.com/pathfinder. Dr. Chris Stephens is an applications scientist for the Thermo Scientific microanalysis product line.

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Additive Manufacturing for Energy Efficiency in Automotive Heat Treating

Tom Briselden – Saint-Gobain; Northeast, Pa.

Industrial heating continues to be challenged with processing new exotic materials for the automotive, aerospace and steel industries.

Fig. 6. Previous-generation ceramic heat-exchanger geometry for plug recuperators

New materials push the envelope of furnace temperature and environments that result in lower throughput and efficiency, higher emissions and more-frequent maintenance. Ceramic materials fill a critical gap in allowing furnace components to operate in these extreme environments. However, traditional ceramic materials are limited to simple tube, fin and nozzle designs. Thus, their wide-scale adoption and impact on sustainability are low.

Energy Consumption Trends

The ability to improve thermal efficiencies from 70-85%, operate at temperatures exceeding 1200°C (2192°F) and incorporate advanced low-emission burner designs requires the use of ceramic materials that can be formed with optimized geometries. These include twisted tapes, twisted channels and complex hole configurations impossible with current manufacturing platforms. The introduction of additive-manufactured (AM) advanced silicon carbide (SiC), including 3D-printed shapes, opens up a new window of opportunity for end-users, designers and manufacturers of high-temperature heating equipment.

The combined energy consumption of all manufacturing sectors in the U.S. is over 14 quads, generating over 500 million tons of CO_2 (U.S. DOE, Energetics-2010). This accounts for 18% of the world's energy and emissions. The manufacturing and assembly of a typical motor vehicle consumes between 25 and 30 GJ (23-28 MMBTUs) of energy and generates over 1 ton of CO_2 emissions (Argonne National Labs, September 2010).

Process heating is the single-largest source of waste energy generated from a typical manufacturing plant. With over 3,000,000 automobiles produced in the U.S. and 75 TBTUs of energy consumed each year, the reduction of waste heat and emissions due to process heating is critical to the long-term sustainability and reduction of environmental impact.

Counteracting Reduced Efficiency at Elevated Temperatures

Indirect-heated "atmosphere" furnaces account for a significant portion of high-temperature (>700°C, 1292°F) processes in the automobile manufacturing industry. Single-ended and U-type gas-fired radiant tubes are commonly used as the heating source with a thermal efficiency approaching 70%$_{LHV}$. With a typical atmosphere composition containing hydrogen, nitrogen, carbon and oxygen, the selection of radiant-tube material becomes a critical component in maintaining a gas-tight furnace.

When furnace temperatures approach 900-1000°C (1650-1830°F), efficiency is decreased and emissions are increased. As an example, one such process is hot stamping steel sheets coated with aluminum and silicon. The sheets are heated in the furnace to 900°C and are then hot pressed to shape. An Al-Si-Fe coating is formed on the surface of the part that provides strength and corrosion resistance. The higher temperatures required for this type of processing reduces combustion thermal efficiency and available heat to the furnace by more than 10%. Thus, throughput is reduced and energy consumption increased. The higher operating temperatures also have the potential to increase NOx generation and reduce component life.

An industry-standard single-ended radiant tube and U-tube combustion system (Figs. 1 and 2) consists of a radiant tube, burner, recuperator and flame-tube insert. The systems operate between 25-100 kW with efficiencies approaching 70%. Ni-Cr-based fabricated radiant tubes such as 330, 600, 601 and their typically cast counterparts HT and HX are often used for material working temperatures below 1100°C (2012°F).

Ceramic Opportunities for Radiant Tubes

Silicon-carbide radiant tubes (Fig. 3) are desired for working temperatures over 1200°C due to their greater heat release when

compared to traditional materials. An increase in heat release, measured as heat flux, permits a furnace to achieve greater temperatures with a given tube count, insulation configuration and production throughput.

These tubes must be gas-tight, have no porosity to minimize intergranular oxidation and be strong enough for both horizontal and vertical mounting. They must survive for at least three to five years in hydrogen-, nitrogen-, carbon- and oxygen-based atmospheres with contaminants such as aluminum, silicon and iron.

Significant progress has been made on manufacturing reaction-bonded SiC radiant tubes up to 300 mm (11.8 inches) in diameter and 3,000 mm (118 inches) in length. There has been limited acceptance of SiC U-tubes in the industry, however, due to the use of multicomponent designs with different coefficients of thermal expansion.

The use of a variety of joining and mounting techniques to accommodate the thermal expansion and strength issues is proven in a few applications. The ability to provide a functional, long-life ceramic U-tube continues to be a key challenge and key opportunity in high-temperature processes found in the automotive and steel industries.

Ceramic Opportunities for Flame Tubes

Flame tubes are often used to direct flame and exhaust gases and improve temperature uniformity. In both metal- and ceramic-based radiant tubes, these components must be able to operate in a low-oxygen combustion environment at temperatures exceeding 1100°C and accommodate changes in the radiant-tube dimensions over time (ovality and slumping). Utilization of a properly designed flame tube will help improve the temperature uniformity of the tube and decrease emissions generation of NOx. This is particularly helpful at increased operational temperatures where combustion efficiency may be reduced.

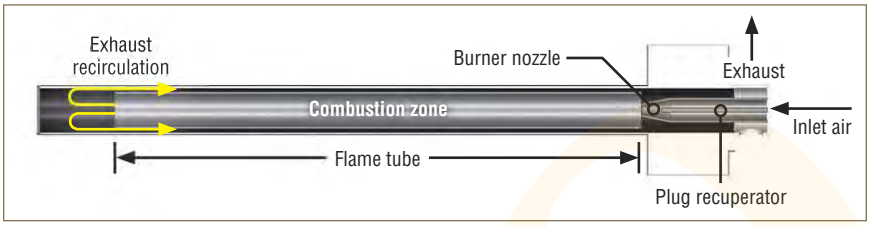

Fig. 1. Single-ended radiant-tube cross section with components

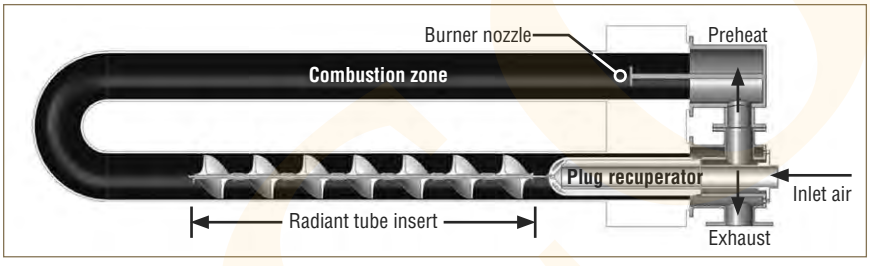

Fig. 2. Radiant U-tube cross section with components

Fig. 3. SiC radiant tube *(courtesy of Elster GmbH)*

Ceramic Opportunities for Radiant-Tube Inserts

Significant acceptance of radiant-tube inserts (Fig. 4) occurred over the last 10 years with the introduction of patented siliconized SiC twisted tapes such SpyroCor™. Current industry data indicates over 50,000 SpyroCor twisted-tape units have been installed worldwide and are saving, on an annual basis, over 2 trillion BTUs of energy. Radiant-tube inserts increase the efficiency of a radiant tube by 5-10% by enhancing the radiant heat transfer in the exhaust leg of the radiant tube. The improved efficiency increases the heat release from the tube to the material being heated.

To optimize the heat release in the exhaust leg of the radiant tube, the length, diameter and twist rate of the insert are customized for each installation using computational fluid dynamics (CFD) modeling. Typical results reported from industry are a 2-5% throughput improvement, 5-20% energy savings and NOx reduction, and improved temperature uniformity.

Ceramic Opportunities for Twisted-Channel Recuperators

The largest impact on a combustion system's efficiency can be realized in the design of the waste-heat recovery system. Traditional metallic-based, plug-type heat exchangers are inserted into the exhaust leg of the radiant tube. High-temperature waste heat is used to preheat combustion air entering the burner. Limitations in current material

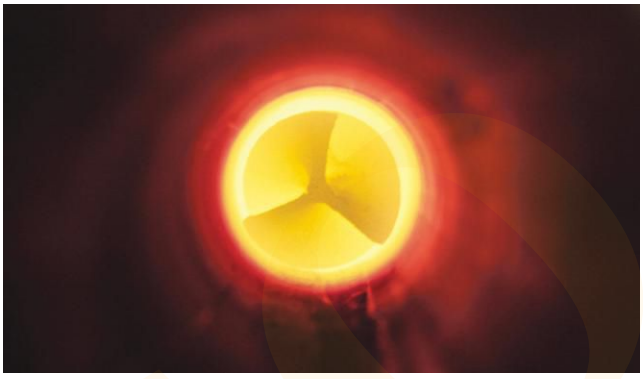
Fig. 4. Radiating tube insert

and burner designs limit the resulting preheat air temperatures to less than 425°C (800°F).

Some high-performance regenerative systems can have a significant impact on efficiency. However, these systems require two burners and two heat-exchange beds as compared to the traditional single-burner and recuperator configuration. While high-performance regenerative systems are more efficient than a metal-based plug recuperator, they are much more costly to design, install and maintain. Therefore, a technology gap (Fig. 5) exists for plug recuperators to generate over 500°C (932°F) preheat air temperature and achieve the efficiency of a regenerator. Both metallic and ceramic designs are limited to simple shapes, namely straight tubes with the option to enhance the surface with fins or dimples (Fig. 6). Typical efficiencies approaching 70% are realized.

The introduction of twisted-channel heat exchangers (Fig. 7) made from AM advanced SiC provides one means for bridging the technology gap and achieving efficiencies approaching 85-90%. The patented twisted-channel design increases the surface area of a heat exchanger by three to six times. The twisted flow path of inlet air and exhaust gas increase the heat-transfer coefficients within the channel by two times. Siliconized SiC allows for operating temperatures up to 1350°C (2460°F). By optimizing the twist rate, number of channels and length, preheat temperatures exceeding 1000°C are achieved.

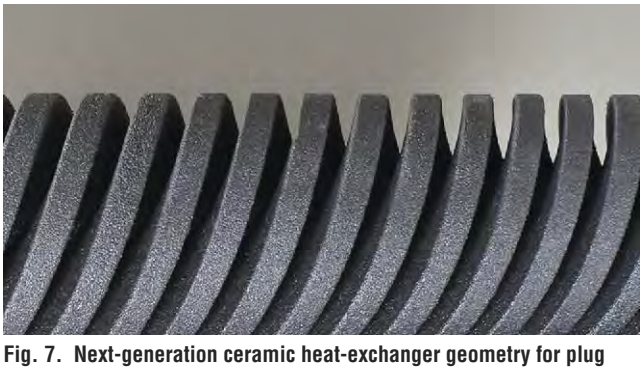
Fig. 7. Next-generation ceramic heat-exchanger geometry for plug recuperator

Energy: The Primary Resource

Energy is the primary resource used to extract value from all other resources. Energy is being consumed at a substantial rate and generating a corresponding increase in NOx and carbon emissions. The demand for lighter and stronger material in the automotive, aerospace and steel industries is challenging a plant operator's ability to maintain sustainable, cost-effective operations.

Current, industry-standard combustion systems are disadvantageous in the consumption of energy and the generation of emissions. The use of additive-manufactured SiC components is mature to a point where these high-temperature components can be integrated into a system to promote saving time, energy, emissions and maintenance costs in industrial heating processes.

The impact of these advanced components will reduce the net energy consumed in the production of each automobile. For automobile component suppliers, the impact is twofold.

- The increase in throughput will positively impact profitability.
- The cost savings from energy-efficiency improvements will help to offset the price pressure consistently applied to this market.

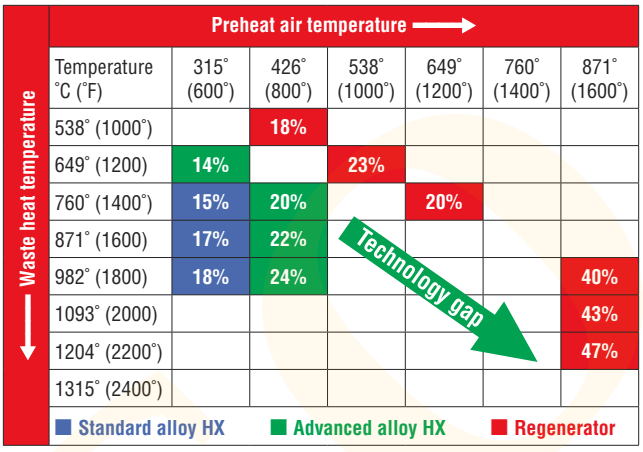

Fig. 5. Technology gap for high preheat air temperature with high-percentage efficiency

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How Additive Manufacturing is Reshaping the Auto Industry

Akin Malas – Linde Americas Hub and Grzegorz Moroz – Linde LLC; Bridgewater, N.J.

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.

This article will review those areas and 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.

The popularity of 3D printing with powder metals has risen rapidly over the past five years because it provides many benefits, including shorter lead times, fewer process steps, less labor and reduced waste. Most notably, however, it is AM's ability to produce new designs that are not possible with conventional metal fabrication methods such as casting and machining. With no need for this tooling, parts can be manufactured faster and on demand, reducing the need for extensive machine infrastructure and inventory. Quality advances in powder metal (PM) processes aided by industrial gas technology are helping to push AM and the automotive industry into fast forward.

There is a logical industry progression from prototyping to limited-scale production to mass production. Industrial gases such as nitrogen and argon and related control technology continue to help at every step. This includes improving the batch-to-batch quality of powder metals, the quality of metal 3D-printing processes and finishing operations.

Additive Manufacturing and Automotive

3D printing has been used in the automotive industry for prototyping for at least two decades. AM giant SLM Solutions announced in February that it is now producing limited quantities of spare parts for Audi's W12 engine using its selective laser melting process.[1] 3D printing is also now actively used in Formula 1 racing, allowing teams to test different concepts in just weeks. Last year, McLaren Racing even started producing 3D-printed spare parts on demand at trackside.[2] So how will the automotive industry move 3D printing into mass production?

There are already signs that automotive manufacturers and suppliers are buying multiple machines to increase 3D-printing production capacity with an aim to accelerate rapid prototyping, tooling and some pre-serial parts manufacturing. Using multiple machines responds to one major drawback of AM: speed. It may take 48 hours (or longer) to make a specialized metal part. But what if that part is needed for 10,000 cars a year?

Scaling from simple prototyping to mass production is formidable for an entire passenger car, but it is not a stretch for any single part. The simple answer is to 3D print 10,000 parts using 55-60 printers. Advances in AM technology, of course, can further improve 3D production rates. Also, when designing for manufacturing, a key goal is to reduce assembly. A single AM part can easily replace several parts, leading to further improvements in production rates and reductions in assembly costs.

3D printing an entire vehicle has, in fact, already been accomplished. In 2014, Local Motors of Phoenix, Ariz., produced a small electric two seater known as the Strati in

Fig. 1. 3D-printed wing from a powdered-metal titanium alloy. Freedom of design, lightweight construction, structural stability and surface detailing are primary advantages of additive manufacturing with powder metals *(courtesy of Linde)*.

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collaboration with Oak Ridge National Laboratory.[3] The company is focusing on low-volume manufacturing and now markets Olli, a co-created, self-driving shuttle.[4]

For major automakers to mass produce standard passenger cars by 3D methods, it will require multiple design cycles and an industry transition of a decade or more to overcome practical challenges. For example, producing multiple designs from the same machine does reduce capital investment, but changeouts can add undesired process variability … and any variability can add to manufacturing downtime.

Dedicated AM processes can address this with machine redundancy at scale, as mentioned previously, but will require a substantial investment in new AM tooling at each phase. There are faster approaches and shortcuts such as high repeatability, simplified design that reduces assembly and labor costs, or perfecting an end-to-end design and then mass manufacturing the entire car by duplicating dedicated factories.

Manufacturers are already pursuing these and other paths, and the economics for more 3D-printed automotive parts and assemblies appear to be falling into place.

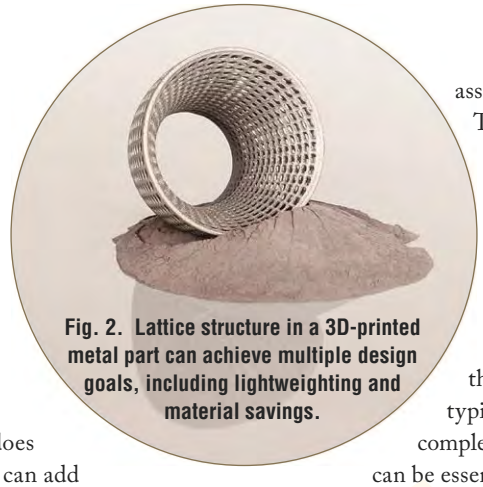

Fig. 2. Lattice structure in a 3D-printed metal part can achieve multiple design goals, including lightweighting and material savings.

The value of the automotive market for 3D printing was estimated at $600 million in 2016.[2] The global market for 3D-printing technology (all markets) is expected to reach $16.8 billion by 2022, according to Global Industry Analysts.[5]

It should be noted that this market estimate includes AM materials other than metals. Processes for powder metals typically require more energy and are more complex than for thermoplastics, but metal parts can be essential to meet structural requirements and to withstand high temperatures under the hood.

AM, of course, eliminates waste, which is important since the materials are more expensive than steel. The price of Ti-6-4, one of the most widely used grades of titanium due to its strength-to-weight ratio, stiffness and corrosion resistance, could be over $25/pound.[6] Even aluminum, the most widely used metal for lightweighting and alloying, has climbed from a low of about $0.65/pound in the U.S. in mid-2015 to about $1/pound in 2018.[7] The value of waste reduction climbs as AM quality improves. Zero defects would mean no rework, no recycling and no associated labor.

Technologies that Turn Powder into Repeatable Parts Quality

The ultimate goal for any 3D process is reproducibility, which drives down the cost of production and boosts reliability. In many cases, AM metal parts can exceed the performance of a cast metal part, for example, or replace multiple machined or brazed metal or plastic parts. The early targets for production in military and aerospace industries have been high-performance parts and applications that can meet multiple goals. For mass production, automotive designers must take into account the overall impact of AM processes on material and assembly costs as well as overall value, including potential for branding and customization.

PM press-and-sinter and metal injection molding (MIM) have already gained ground in the value chain of automotive component manufacturing. As mentioned, AM has already moved from rapid prototyping to an early mass-production method for special high-end car designs. AM technology has also found its way back to support the PM and MIM industries by providing easy and quick tooling and rapid prototyping to eliminate costly tool design failures. All these technologies still need to meet the demanding quality requirements of automotive manufacturers.

The PM value chain where industrial gases play a role encompasses: powder production, PM or MIM sintering, or AM followed by post heat treatment. All of these processes use industrial gases, which can be utilized for process control to achieve consistent, high-quality parts.

Like many of the components produced by PM or MIM sintering, 3D-printed parts also require some form of finishing process. The mechanical properties of parts produced by AM printers are highly dependent on an exacting manufacturing process and how the physical properties of the metal powder are impacted.

Even before the AM process, industrial gases and their enabling technologies play a fundamental role in the production and handling of the metal. A high-pressure stream of argon

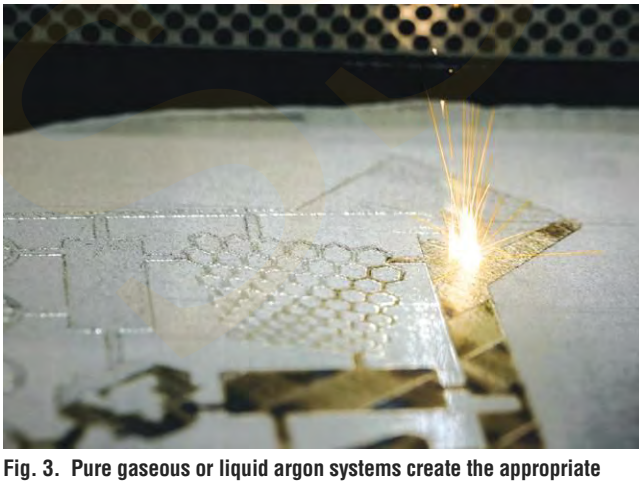

Fig. 3. Pure gaseous or liquid argon systems create the appropriate inert atmospheres for laser metal fusion (LMF), which is known by many as metal selective laser sintering, metal laser melting, direct-metal printing and direct-metal laser sintering *(courtesy of the MTC Catapult, U.K.).*

(Ar) or nitrogen (N_2) moving at Mach speeds atomizes molten highly alloyed metals into small, uniform spheres of powder particles. This creates the "raw" material from which finished parts will be formed.

Metal powders are susceptible to oxygen and moisture, which can impact their performance during printing. Powder storage cabinets are now available from Linde that not only control the temperature and humidity with an inert gas but will purge the atmosphere whenever a cabinet door is opened and closed to return it to normal levels.

Laser-Based Processes

Gases are also vital for the various laser-based layering processes to "bind" the powdered-metal alloys. One such method is laser metal fusion (LMF). A high-power laser beam scans over a bed of metal powder to form the required shape. After each layer is scanned by the laser, the bed is lowered a short distance and a new layer of powder is applied.

The process takes place in a sealed chamber with a controlled-gas atmosphere, using an inert gas such as Ar or N_2. Typical parts made by this method include combustor and fuel-injector prototype parts for aerospace, wheel suspension and drive-shaft fittings, and prototypes for medical devices. Active gas mixtures are currently being developed to fine-tune the properties of the manufactured part.

To further monitor and protect the metals in the printing chamber, Linde developed the ADDvance™ O_2 precision, a first-of-its-kind measuring and analysis technology developed in direct response to needs at Airbus Group Innovations. The portable unit can measure and more precisely control the level of oxygen and humidity within the printer chamber to help prevent unwanted reactions.[8]

Fig. 4. Aluminum- and titanium-alloy powders are highly sensitive to oxygen and humidity. ADDvanceTM O_2 precision from Linde precisely monitors and controls these levels during 3D printing for reproducible quality.

Another AM process is laser metal deposition (LMD). LMD uses a high-power laser beam connected to a robot or gantry system to form a melt pool on a metallic substrate fed layer-by-layer with powder. The metal powder is contained in a carrier

gas and directed to the substrate through a concentric nozzle around the laser.

This solution uses Ar, helium (He) and nitrogen gases in the design, provision and installation. An active gas supply can also be mixed to satisfy project demands. LMD is used for a range of applications, including cladding and repair as well as mold-to-surface application for high-value parts such as aerospace engine components and military equipment.

Finishing Treatments for Perfect Parts

Hot isostatic pressing (HIP) is an advanced material heat-treatment process that utilizes high-temperature and high-pressure conditions to eliminate internal porosity and voids within cast-metal materials and components. This helps ensure the integrity of manufactured parts by improving mechanical properties and fatigue performance. This process optimizes reliability and service life of critical high-performance products, including automotive engine parts, components for gas turbines, turbo charter wheels, aerospace structural parts, medical implants and prosthetics. High-purity argon is typically used to provide the inert atmosphere necessary to prevent chemical reactions that might adversely affect the materials being treated.

Once a component has been produced, it must go through a final step of cleaning to ensure it is ready for market. Parts that have been printed have some rough surfacing and flashing that require smoothing before they are ready for use, and technology to solve this is integral to the entire AM process.

CRYOCLEAN® Snow from Linde is a water-free cleaning technology specifically designed for industrial surface finishing. The technology produces dry-ice particles on demand for cleaning. By feeding liquid carbon dioxide (CO_2) into a specially designed snow chamber, solid dry-ice particles are created and shot onto the surface of the component using compressed air for an effective cleaning process to smooth out edges of a finished piece.

For 3D metal-printed parts, Linde now offers CRYOCLEAN AM, which adds abrasives to the high-pressure flow of CO_2 particles. The blasting process is ideal for removing surface oxides and unfused metal powders.

For more information: Contact Akin Malas, head of application technology, metals & glass; Linde, Americas Hub, 200 Somerset Corporate Blvd., Suite 7000, Bridgewater, NJ 08807; tel: 908-464-8100; e-mail: akin.malas@linde.com; web: www.lindeus.com. Grzegorz Moroz is program manager, metals and protective atmospheres, Linde LLC.

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2018 VIEW FROM THE TOP

This special section is dedicated to the advertising companies in this issue. Learn more about what they do, and find out what makes them successful. Stay in touch with the thermal-processing industry, and read VIEW FROM THE TOP.

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Projects big and small are welcome. In addition to offering outstanding lab equipment, we also provide sample testing for most product lines, including induction heaters. Our expert sales team can help match the right equipment for the job.

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For over 50 years, metals processors have come to rely on Air Products' high-purity industrial gases, gas handling equipment and technology, gas atmospheres and unmatched industry experience and technical know-how to help them improve product quality, reduce operating costs and increase production.

"Our expertise goes far beyond gas production and delivery," said Pedro Riveros, director-strategy, technology and sourcing for Industrial Gases Americas. "Our experienced team of application engineers and R&D specialists work closely with customers to fully understand their particular needs and develop and implement comprehensive, cost-effective solutions that optimize their production processes."

Air Products helps customers optimize their heat-treating processes by providing controlled atmosphere solutions, enabling equipment, as well as process optimization and troubleshooting. New application development and customer-support activities are carried out at Air Products' state-of-the-art heat-treating lab in Allentown, Pa., which includes furnaces capable of testing a wide variety of atmospheres, metallurgical and atmosphere analysis equipment, thermodynamic equilibrium and diffusional calculation capability, and computational fluid dynamics (CFD) modeling. By leveraging these capabilities, Air Products' engineers provide numerical and lab simulations of customer operations prior to actual field testing.

According to Riveros, the company also has developed atmosphere and process monitoring systems featuring Air Products Process Intelligence, enabled by the Industrial Internet of Things (IIoT). Its intelligent atmosphere analyzers and control systems help metals processors monitor and control composition parameters to ensure their furnaces are running with the desired gas atmosphere, as well as provide alerts for any needed maintenance or adjustments.

Pedro Riveros, director-strategy, technology and sourcing for Industrial Gases Americas

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ALD Thermal Treatment Inc.

Innovative Vacuum Technology

Since ALD Thermal Treatment Inc. opened in 2005 in Port Huron, Mich., it has provided a testimonial to the distortion minimization merits of vacuum carburizing (LPC) + high-pressure gas quenching (HPGQ) by means of its unique automatic equipment, which offers a premier source for heat-treatment services to the precision manufactured component segment.

Port Huron and its sister facilities in Mexico and Germany revolutionized the processing of gear components by providing superb metallurgical and dimensional characteristics. ALD continues expanding its processing benefits to fuel injection systems, bearings and other critical applications, such as aerospace components.

This year, ALD Thermal Treatment will start the operation of one additional automated line for engine components with cryogenic processing in a large scale. The company will also add equipment for nitriding and ferritic nitrocarburizing (FNC) processes. As a complement, our laboratory is now able to perform spectrometry analysis in addition to our dimensional and hardness inspection capabilities.

ALD is continuously looking for new business opportunities and is evaluating new facilities to support customers in growing markets. Recent expansions in processes and capabilities reflect our commitment to a solid future in the heat-treatment market.

ALD recently received, for the third year in a row, "Supplier of the Year" recognition from GM for both of our plants in the U.S. To be an award winner means having something no one else has, and it certainly provides motivation to continue striving to earn other customers' confidence.

Enrique Lopez, sales and marketing director-North America

The Solution

ALD Thermal Treatment Inc.
2656 24th St., Port Huron, MI 48060
Phone: 810-357-0685
www.aldtt.net

Busch

Vacuum Pumps and Systems

Busch has more than 50 years of vacuum technology experience and offers tailored vacuum solutions for all sectors of the materials heat-treatment industry.

Charles Kane, president, explained, "Busch offers a wide range of vacuum products suitable for low to high vacuum ranges. Our systems are designed to provide optimal solutions for heat-treatment processes. We supply large and small – from complete units with control systems to the replacement of existing plant components."

With its extensive network of 61 companies in 43 countries and agencies worldwide, Busch is present at every location in the world where steel and other materials are vacuum heat treated. Both manufacturers and users of heat-treatment equipment can benefit from Busch's know-how and experience as vacuum specialists.

Charles Kane, president

According to Kane, "Whatever the vacuum needs are, Busch offers the system best suited to our customers' technical and economic requirements. We also recommend a beneficial maintenance plan from our wide range of service options. The quality of our customers' products is our primary concern."

BUSCH
Vacuum Pumps and Systems

Busch LLC
516 Viking Drive
Virginia Beach, VA 23452
www.buschusa.com
info@buschusa.com
1-800-USA-PUMP

Control Concepts Inc.

Control Concepts is very bullish on the industrial heating marketplace for 2017 and 2018. We've been a market-leading designer and manufacturer of SCR power controllers since 1980. In fact, that's all we do 24/7/365.

Providing ultra-reliable power controllers designed to meet the needs of high-temperature thermal-processing customers, as well as short lead times, has been the hallmark of our organization since its inception. As our team develops new, state-of-the-art controllers, we consider not only the latest power control needs but also total installed cost.

Understanding the industries we serve has enabled us to design and bring products to market that exceed those needs. For example, when safety grew in importance and became an absolute necessity, we developed a touch-safe power controller with a 100,000A Short Circuit Current Rating (SCCR). Then when customers requested digital connectivity, we developed and introduced FUSION series controllers, which provide the ability to communicate over all standard bus networks. When it was necessary to reduce the cost of digital communications, we introduced a bus module that makes multiple-zone digital control more cost-effective. Additionally, realizing that plant floor space is highly valued, we developed MicroFUSION power controllers, which reduced the physical size of the power controllers by as much as 35%. Finally, understanding utility power penalties, we designed and developed a unique SCR firing mode that improves power factor and lowers plant power bills.

Cory Watkins, CEO

Control Concepts vows to continue being a leader in the thermal-processing industry by providing the most profitable long-term power control solutions for our customers. Watch for news from us in the near future. We are well on the way to introducing the next generation of power control for the industrial heating market.

CONTROL CONCEPTS
SCR Power Controllers

Control Concepts Inc.
18760 Lake Drive East
Chanhassen, MN 55317
www.ccipower.com

Diablo Furnaces

Diablo Furnaces is a successfully profitable heat-treat furnace OEM company that is comprised of individuals that have been in the industry from five to 40 years. Our objective is to manufacture atmosphere heat-treat equipment – including IQF's, car-bottoms, tempers, tip-ups, washers, power transfer carts and special furnaces – and provide replacement parts, rebuilds, installation, safety upgrades, training and service to not only its own brand of equipment but all heat-treat brand equipment.

Our high level of service begins with identifying the customer's voice when he/she calls to understanding the project's schedule. Service includes availability of replacement parts on-hand – such as fans, pushers and recuperative burners – for delivery within 24 hours or being able to deliver same day. Service also includes dispatching engineers to repair equipment on-site at the customer's facility within 24 to 48 hours if possible.

This level of service has been extended to our existing customers. As a result, much success has been gained.

Sue Harrod, chief operating officer

Mission Statement

To set "fire" to the industry by spreading our desire for excellence in all things, while raising the bar in our continuous pursuit of perfection at a cost savings to our customers.

Diablo Furnaces
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815-636-7855

Dry Coolers Inc.

Dry Coolers Inc. is a major supplier of industrial cooling systems and professional engineering services. Located in the heart of the automotive industry, Dry Coolers has experience working with large and small companies to design and manufacture energy-efficient industrial process cooling solutions, including air-cooled heat exchangers, pumping stations, chillers and cooling towers.

Our specialty is providing reliable cooling for high-temperature processes such as vacuum furnaces, induction equipment and quenches. We have been a leader and innovator for over 30 years in the heat-treating market and are active members in MTI and IHEA.

Using degreed, in-house engineering talent and the latest CAD design programs, Dry Coolers provides state-of-the-art assistance to make installation go smoothly. Our involvement in a project can be as simple as that of a supplier of individual system components or as complex as the complete design and installation of plant-wide cooling systems.

Dry Coolers can supply Internet-enabled, PLC-driven systems for automated operation. Each project is provided with professional documentation in the form of operation and maintenance manuals, engineering and installation drawings. Drawings are provided with 3-D views as well as conventional 2-D layouts for clarity of illustration. Control panels are designed and assembled in-house and certified UL 501a.

Dry Coolers is authorized to apply the American Society of Mechanical Engineer (ASME) certification mark to its products. Dry Coolers can now offer the ASME Section VIII, Division 1 certification mark to its Solanus quench oil coolers, Thermoflow plate-and-frame heat exchangers, CyClean centrifugal separators and other products.

Brian Russell, president

Dry Coolers also owns and operates DCI Thermal Equipment (Foshan) in China to service the East Asian market. We focus on product quality and customer satisfaction, and we are ISO 9001:2015 registered. Call us today with your cooling needs. We are ready to assist you.

Dry Coolers Inc.
575 S. Glaspie St., Oxford, MI 48371
www.drycoolers.com; sales@drycoolers.com
800-525-8173

ECM USA Inc.

These are very exciting times at ECM Technologies' and its subsidiaries, ECM USA, ECM India and ECM China, with equipment advancements in vacuum furnace technology. Not only are we the leader in low-pressure vacuum carburizing (LPC), but we have been expanding our offering with vacuum induction melting (VIM) products and other processes in the photovoltaic and semiconductor markets.

Our most innovative in-line LPC system, the NANO, is being showcased in our newly expanded SYNERGY CENTER in our Pleasant Prairie, Wis., location, which is capable of LPC, hardening, brazing and annealing along with the capability of 20-bar gas quenching in either nitrogen or helium. The SYNERGY CENTER is fully functional and capable of full distortion and metallurgical testing and analysis with complete results in just days, not months.

Another recently launched innovative new product is our DUO PITLESS oil quench low-pressure carburizing system. These three models can use your current atmosphere line without replacing your ancillary washing and tempering. Get high-quality carburizing results with tight metallurgical control along with shorter cycles that hundreds of our customers all over the world experience daily.

Dennis Beauchesne, general manager

Of course, the NANO and DUO PITLESS are only additions to our broad installed base of FLEX and JUMBO LPC systems using more than 1,100 heating cells on more than 230 systems that served industry for over 25 years.

Watch for our ECM USA Open House-20th Anniversary Seminar in September. We are ready to serve you and your furnace needs.

ECM USA Inc.
9505 72nd Ave., Suite 400
Pleasant Prairie, WI 53158
info@ecm-usa.com
www.ecm-usa.com
Phone: 262-605-4810

G-M Enterprises

California-based G-M Enterprises is a leading supplier of state-of-the-art vacuum furnaces to the aerospace, nuclear, metal injection molding and high-temperature sintering industries, as well as to commercial heat-treating companies. G-M Enterprises also provides equipment for VPA (vaporized aluminide coating) of aircraft engine blades and vanes to withstand extreme atmospheric/space conditions.

G-M Enterprises has pioneered vacuum furnaces for high-pressure quench up to 20 bar with unique external cooling blower and heat-exchanger construction to meet critical cooling requirements and produce the highest metallurgical results and properties. G-M holds many U.S. and European patents for its innovative and unique designs.

Suresh Jhawar, chief executive officer

Superior user-friendly design features, user-friendly computer control software, fast and dependable aftermarket quality service and a reputation of making furnaces that really work make G-M Enterprises the most qualified company in the marketplace to supply equipment and services to meet your heat-processing needs.

G-M Enterprises
525 Klug Circle
Corona, CA 92880
www.gmenterprises.com
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951-340-4646

Induction Tooling Inc.

Now in our 42nd year, Induction Tooling Inc. is the world's premiere source for selective hardening inductors. Through the years we have grown and continuously improved our business model. With customers in the automotive, heavy equipment, agriculture, aerospace and medical industries, we are able to supply production inductors that are PPAP ready.

Our design team works closely with our customers to ensure that the end product produces a specification heat treatment to their parts. To accomplish this, we build inductors that are induction-laboratory tested using our customers' parts. Our induction laboratory is capable of replicating the exact frequency, power and time that our customer might expect or has achieved in production. Characterization of the inductor is the process of homing in the closet midrange of the specification-hardened depth. To do this we must adjust the heating effect of the inductor geometry, including manipulation of the flux field, using products commonly called intensifiers. Once the midrange specification-hardened depth is achieved, the part is cut into pieces, mounted in Bakelite and examined by our metallurgical staff, which is headed by Sandra Midea, P.E.

Since our metallurgical laboratory is ISO 17025-certified as a commercial testing facility, we are able to examine our customers' parts when processed on their equipment often the same day before submitting a professional metallurgical report.

William Stuehr, president/CEO

The process of building quality selective hardening inductors requires precise flow from design to production. The details are addressed in between. It is imperative to have a full-service facility under one roof. Our design team, production personnel and laboratory staff work diligently to accomplish this.

Induction Tooling Inc.
12510 York-Delta Drive
North Royalton, Ohio 44133
www.inductiontooling.com
Phone: 440-237-0711
Fax: 440-237-7009

Ipsen

Ipsen's team of engineering experts continue to expand the possibilities of heat treatment by designing innovative, highly technical atmosphere and vacuum solutions for customers' unique challenges.

When it comes to advanced engineering, Ipsen works consultatively with the customer to understand their needs, as well as parts and process requirements. Then our team of over 20 engineers develops a design strategy and – using engineering simulation tools, such as finite element analysis (FEA) and computational fluid dynamics (CFD) – has the ability to test product designs early in the process to ensure we provide the best solution.

It's really impressive to see the magnitude and complexity of projects we've completed over the years. For example, Ipsen recently built a vertical, high-pressure quenching furnace complete with twin cooling systems designed to quench with 1,000 horsepower for a customer that specifically required a large furnace with a very aggressive cooling rate. In addition, we currently have a furnace occupying an entire section of our facility. it's the largest horizontal vacuum furnace we've ever manufactured and has a load capacity of 210,000 pounds.

Our commitment to delivering quality solutions extends to every project, regardless of scope – from developing proprietary software and controls to taking in-field measurements, designing upgrades and retrofits (including custom-engineered solutions for non-Ipsen equipment) and assisting with technical support inquiries.

Kevin Woerner, director of engineering and supply chain

As technology continues to advance, it is exciting to know that soon we could be engineering, testing and manufacturing highly technical furnace solutions for projects that have yet to be imagined. When a team with 300 years of engineering experience works together, anything is possible.

Ipsen USA
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Kanthal

Kanthal is Sandvik's brand for heating technology products and services and a world leader in its business segment. In order to further strengthen the brand in the marketplace, it's endorsed as "Part of Sandvik Group." Kanthal® is a leading manufacturer of resistance materials in the form of wire, strip, heating elements and complete systems for electrical heating.

An important part of the Kanthal portfolio is services, which means we provide a complete solution for your heating needs – from system design through to delivery, commissioning and installation. Once the system is installed, we will support you with preventive maintenance, repairs, replacements, service and refurbishment.

We are recognized for our world-leading research and metallurgical expertise, which we combine with knowledge of how they can best be deployed in our customers' applications. Our control of the entire value chain, from smelt to finished product, also serves as a guarantee of unparalleled quality. In other words, materials technology is embedded in our DNA.

We continuously drive the materials evolution process forward to meet current and future requirements in terms of advanced materials for critical parts in customer products. We have 150 years of experience in this field. Through our involvement in the creation of products that offer a longer service life, yield higher productivity and reduce energy consumption, we help make industrial operations across the globe safer, more efficient and sustainable. To highlight that many other companies share our values, we have established the annual Kanthal Award, which rewards innovative solutions that make a difference.

Nicklas Nilsson, president

Wherever you are located, we are not far away. Contact us – we can show you potential cost savings and energy-efficient solutions with electrical heating that may surprise you.

KANTHAL®

Part of Sandvik Group

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Pfeiffer Vacuum

Pfeiffer Vacuum is one of the world's leading providers of vacuum solutions for industrial applications. The product portfolio comprises a wide range of vacuum pumps, gauges, gas analyzers and leak detectors. Pfeiffer Vacuum has over 125 years of experience in building pumping stations.

What sets us apart?

Pfeiffer Vacuum's innovative magnetic coupling available on our Roots pumps eliminates the shaft seal to provide more reliable operation. Since the shaft seal is eliminated, there are no unexpected process interruptions due to oil leaks. This technology offers a safer environment – no oil on the floor. It also reduces downtime since there is no radial shaft seal to maintain.

Vacuum Pumping Stations

Pfeiffer Vacuum CombiLine™ pumping stations offer solutions in low, medium and high vacuum with a pressure range of up to $5\text{-}10^{-4}$ mbar. CombiLine pumping stations are a combination of individual vacuum pumps and components that are mounted on the same frame with interconnecting piping.

Standard and Gas-Cooled Roots Vacuum Pumps

Pfeiffer Vacuum OKTA G series Roots pumps with pumping speeds from 210-12,000 m^3/h offer solutions in the low and medium vacuum range. The air-cooled pumps provide high differential pressures with lower power consumption.

Mobile Helium/Hydrogen Leak Detectors

The ASM 310 helium/hydrogen leak detector is the lightest (just 46 pounds), smallest footprint (133 in^2), and fully configured helium mass spectrometer leak detector available.

A sintering furnace that utilizes Pfeiffer Vacuum rotary vane pumps, Roots blowers and leak detection equipment.

PFEIFFER VACUUM

Pfeiffer Vacuum
24 Trafalgar Square, Nashua, NH 03063
www.pfeiffer-vacuum.com; 800-248-8254

SAFE Cronite

SAFE Industry is the convergence of three distinct branches with shared methods contributing to a common cause to define our future.

SAFE Metal leads the world in the production of cast steel components. SAFE Metal parts are used in high-speed trains, semi-trailers, public-works vehicles and mining equipment. SAFE Demo, the "DEcoration and MOlding" specialists, are the number-one worldwide supplier of airbag covers and precision plastic trim parts for the automotive industry. SAFE Cronite is the global leader in the manufacture of fixtures and parts in refractory alloys for the heat-treatment, steel, incineration, power-generation, mining and aerospace industries. We are present throughout the world, with over 700 employees in seven production, design and R&D facilities in the U.S., Mexico, France, Great Britain, Germany, Czech Republic, China and India.

SAFE Cronite is known worldwide under the names Cronite, Klefisch and Mancelle, with more than 150 years of experience in the design and manufacture of nickel-based heat-resisting cast steel components. Our global foundries are equipped with numerous production processes: green sand for mass production, chemical sand for items over 2 tons, lost wax for very accurate parts, CFC composites for distortion-sensitive applications, machining, welding and fabrication.

SAFE Cronite is known for being "Better by Design." Our design offices are equipped with the latest 3D CAD systems to enable simulation of mechanical constraints at temperature with 3D printing of prototypes and rapid machining of patterns.

Jim Demarest, vice president of sales and marketing

SAFE Cronite has invested heavily in our North American foundry with the addition of centrifugal, chemical sand and QuickMold casting processes. We currently manage over 5,000 global standard fixture and furnace part patterns to keep you operating and improving.

North American Cronite
37162 Sugar Ridge Road; North Ridgeville, OH 44039
www.safe-cronite.us; Phone: 440-353-6594
Fax: 440-353-6599

SECO/WARWICK

With the recent policy developments and technology advances, SECO/WARWICK is seeing a significant increase in inquiry and quoting activity for both our aluminum furnaces and our continuous and batch steel-processing furnaces. With the obvious expected increase in demand for domestic steel, we're seeing many roller-hearth furnaces coming out of mothballs and/or undergoing significant refurbishments to increase the productivity of these most economical of all furnace types.

We're also seeing significant increased interest in rotary-retort furnaces, which fastener manufacturers are eyeing to replace their more expensive-to-operate mesh-belt furnaces. These rotary retorts are more compact and produce better metallurgical results than mesh-belt systems.

Coming off of a very healthy 2017, SECO/WARWICK is expecting a very strong 2018. In addition to developing inside systems so that we will more consistently deliver product on time, on spec and on budget, we are very optimistic about the return of manufacturing to the U.S. We believe the long-term reshoring of manufacturing will bode well for not only SECO/WARWICK, but for all of our customers and competitors. We're bullish on 2018.

Jonathan Markley, North American managing director

SECO/WARWICK Corp.
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814-332-8400

Solar Manufacturing

The Brightest Solutions Through Ingenuity

Solar Manufacturing stands out above our competition. As one of the nation's premier developers of innovative vacuum furnace designs, our trailblazing engineering offers heat treaters advances in energy efficiency and performance. Since 2002, heat treaters from a wide variety of industries have trusted in our ingenuity for their vacuum heat-treat processing.

Solar Manufacturing knows vacuum heat treating inside out. Our experienced engineers bring decades of expertise to the design side of the business, and our knowledgeable technicians provide world-class manufacturing to keep Solar in the forefront of vacuum furnace innovations. We offer unmatched expertise to solve our customers' most difficult heat-treating problems and advance the art and science of vacuum furnace technology. Our ingenuity has led the industry with innovative hot zone designs, advanced new insulation materials, high-performance gas quenching and state-of-the-art SolarVac® Polaris Controls, a new generation of PLC-based control systems developed to simplify the operation and expand the capabilities of our vacuum furnaces.

Like our engineered-to-order furnaces, our "standard" models are rich in features and versatility to suit our customers' specific and demanding requirements. Models range from compact R&D furnaces to large horizontal, front-loading production furnaces. In addition to vertical bottom-loading configurations, we also design unique, very large-capacity car-bottom furnaces in lengths up to 48 feet.

Jim Nagy, president

Solar Manufacturing has also developed a good name throughout the industry in aftermarket sales and support. Whether you need a durable, energy-efficient replacement hot zone, fast responsive spare parts, field service or a maintenance contract, we can assist you in keeping your vacuum furnace at its peak operating condition.

SOLAR MANUFACTURING

Solar Manufacturing
1983 Clearview Rd., Souderton, PA 18964
www.solarmfg.com; info@solarmfg.com
267-384-5040

Surface Combustion

Established in 1915, Surface® provides customers rugged, reliable thermal-processing equipment. Our strength lies in the breadth of our product portfolio, our unparalleled process knowledge and our commitment to customer service. From our standard atmosphere and vacuum furnace designs to custom-engineered thermal-process solutions to quick and responsive aftermarket support, Surface stands ready to serve you.

For over 60 years, the Allcase® batch integral-quench furnace has been the versatile workhorse of industry. Whether used for automotive, off-road, aerospace, mining, oil-field, wind power, tool and die or commercial heat-treating applications, it is well known for producing quality, repeatable results. Surface provides a full host of companion equipment and best-in-class controls and automation solutions to enhance the Allcase line.

In the same vein, our RX® endothermic atmosphere generators are unequalled. Customers consider our generators to be an on-site utility that run with minimal, infrequent adjustment.

Surface maintains customer relationships for decades. Our Rebuild/Retrofit business unit offers effective capacity, productivity and process upgrades. The Aftermarket Parts business unit can ship most replacement parts immediately from our multi-million-dollar inventory. Our field service engineers and technicians repair furnaces, solve equipment problems, perform preventive maintenance and train personnel on proper equipment operation.

B.J. Bernard, president

Innovation is a tradition at Surface. We remain highly dedicated to the pursuit of new technology through extensive research efforts and enhancing our current products.

Contact Surface Combustion for your heat-treat furnace needs, and we will provide the ideal solution.

Surface® Combustion

Surface Combustion
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www.surfacecombustion.com

TAV VACUUM FURNACES

Why should a safety PLC be installed on your vacuum furnace?

Safety systems are a key strength essential for TAV VACUUM FURNACES, and it is recognized by all its customers since vacuum furnace production must comply with the most stringent specifications and international norms.

Several years have already passed since EN ISO 13849-1 and IEC 62061 replaced the obsolete EN 954-1 as the technical standards concerning the safety-related functions of control systems. Meanwhile, safety PLCs are increasingly replacing common safety relays in many non-common applications. So, why should they be installed on vacuum furnaces?

- Emergency stop is not the only safety function.
- Safety PLCs can elaborate analog signals.
- Analog signals provide better diagnostic coverage.
- Safety PLCs can implement more complex logics (with a specific sequence of operations).
- Safety PLCs can significantly reduce tampering risks.

As manufacturers, we have the responsibility not only to use reliable components to minimize faults and provide ease of use to avoid the need to bypass any safety but also to prevent or detect that a safety function has been altered as far as technically possible.

With a safety PLC, all the safety logic is securely embedded inside the controller itself. To modify the logic in a safety PLC, you need not only specific software but also a password set by the manufacturer for the single machine. The security level can be further increased by combining the safety PLC with smart sensors.

Currently, TAV VACUUM FURNACES installs safety PLCs on specific vacuum furnaces. It is the responsibility of vacuum furnace manufacturers to keep consistent with the rapid changes in this field.

TAV VACUUM FURNACES

TAV VACUUM FURNACES
www.tav-vacuumfurnaces.com
info@tav-vacuumfurnaces.com

Thermocouple Technology

Thermocouple Technology (TTEC) is composed of an experienced group of professionals dedicated to providing precision temperature measurement and control devices for industry. Founded in 1985 by veteran temperature sensing specialists, TTEC has provided temperature sensing products/solutions to nearly every industry.

By leveraging their engineering and design resources, they ensure that key process temperatures are being measured in the most accurate, efficient and reliable way. TTEC's commitment to service through superior engineering, product quality and customer satisfaction has helped them maintain many loyal customers dating back to their establishment.

The 33-year-old company is continuously implementing new infrastructures to stay on the cutting edge. TTEC has committed significant capital to increase their inventory of critical high-temperature raw materials to ensure that time-critical orders are filled in days, not weeks. Their recent expansion of the calibration lab and newly streamlined manufacturing programs ensure efficient production of precision assemblies. Additionally, investments in machinery and skilled personnel have resulted in additional capabilities and process control. Expect new and improved product solutions in the months and years to come.

Michael McKinney, president

TTEC's enthusiasm for understanding the physical changes that occur in extreme industrial environments has resulted in advanced product developments. Next time you are presented with a temperature-related challenge, feel confident that you can reach out to TTEC's sales and engineering team for a custom solution.

TTEC THERMOCOUPLE TECHNOLOGY

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to generate the lowest emissions possible for steel production. According to the company, JSW USA will be the only entity of its kind (for the products it makes in North America) blending scrap with direct-reduced iron (DRI)/hot briquetted iron (HBI). Once the hot-end project launches, JSW USA is expected to create 500 new high-wage jobs before it becomes operational 18 to 24 months later.

ATI to Expand Isothermal Forging, Heat-Treating Capacities

Allegheny Technologies Inc. announced that its board of directors approved an investment to expand its isothermal forging and heat-treating capacities to satisfy growing demand from the aerospace market. This self-funded, multiyear expansion of approximately $95 million represents ATI's fourth isothermal press, which will be located at the company's forging center of excellence in Cudahy, Wis. The associated heat-treating expansion will also be in Cudahy. The expansion will take approximately three years to complete and fully qualify for aerospace-related production. According to ATI, the investment will increase capacity to produce technologically advanced powder-to-isothermally-forged jet-engine components.

Upstate Refractory Services Acquires Hanyan-Higgins

Upstate Refractory Services (URS) of Newark, N.Y., acquired the assets of Hanyan-Higgins Company Inc., a refractory sales and service business. URS specializes in engineered precast refractory shapes; stack-bonded ceramic-fiber panels used in furnace roofs, walls and doors; refractory relines and repairs; and distribution of refractory materials. Hanyan-Higgins has been a distributor of Plibrico refractory products for over 60 years, and URS will continue to offer Plibrico across upstate, central and western N.Y.

Aerospace Company Expansion Includes Vacuum Furnace

StandardAero Component Services announced a significant investment and expansion at three of its U.S. sites during 2018. The company will invest approximately $16 million to increase shop capacity by 260,000 square feet collectively at facilities in Cincinnati and Hillsboro, Ohio, and Miami, Fla. The Miami site will add 30,000 square feet of working space and install an additional vacuum furnace, a state-of-the-art clean line and add water-jet cleaning capabilities. As a result, the facility will be able to repair large engine cases.

INDUSTRY EVENTS

June 5-7

Thermal Processing in Motion – Including the 4th International Conference on Heat Treatment and Surface Engineering in Automotive Applications; Spartanburg, S.C.
www.asminternational.org

June 6-8

19th China International Heat Treatment & Industrial Furnace Exhibition; Guangzhou, China www.heattreatmentexpo.com

June 17-20

AMPM 2018 – Additive Manufacturing with Powder Metallurgy; San Antonio, Texas www.ampm2018.org

June 17-20

Powdermet 2018 – International Conference on Powder Metallurgy & Particulate Materials; San Antonio, Texas www.powdermet2018.org

July 30-Aug. 1

International Thermprocess Summit 2018; Atlanta, Ga.
www.ihea.org

Sept. 11-12

Forging Industry Technical Conference; Long Beach, Calif.
www.forging.org

Sept. 25-28

Heat Treat Mexico 2018 – Advanced Thermal Processing Technology Conference and Expo; Queretaro, Mexico www.asminternational.org

FNA 2018

Oct. 8-10

Furnaces North America 2018; Indianapolis, Ind.
www.furnacesnorthamerica.com

Oct. 14-18

Euro PM 2018 Congress & Exhibition; Bilbao, Spain
www.europm2018.com

Oct. 15-17

2018 Die Casting Congress & Exposition; Indianapolis, Ind.
www.diecasting.org

Nov. 13-15

EUROFORGE – 1st European Fair and Congress for the Forging Industry; Berlin, Germany
www.euroforge-confair.com

LITERATURE & WEBSITE SHOWCASE

Induction Heaters

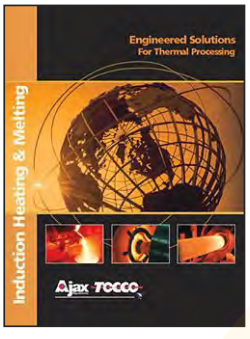
Across International

Founded and based in New Jersey, Across International supplies laboratory equipment in the areas of heat treatment and material processing for universities, research facilities and labs. We have more than 20 years of industrial manufacturing experience with induction heaters, drying ovens, ball mills, lab furnaces and pellet presses.
www.acrossinternational.com

Industrial Gases

Air Products

Air Products, a worldwide leading industrial gas supplier, brings significant experience in gas supply, applications development and safety to help you improve quality, reduce operating costs and increase production. We offer high-purity gases, gas-handling equipment and technical know-how from metals-processing-focused applications engineers to help you succeed.
www.airproducts.com/mp



Induction Heating Systems

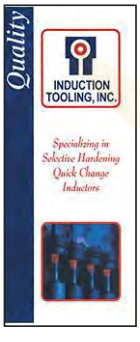
Ajax TOCCO Magnethermic Corporation

Ajax TOCCO Magnethermic Corporation is a world leader in the induction heating, melting and forging industries. Our proven applications include brazing, annealing, hardening, tempering, seam annealing, shrink fitting, curing, forging and melting.
www.ajaxtocco.com

SCR Power Controllers

Control Concepts, Inc.

Control Concepts, Inc. is known for reliable products, expert customer support and next-day shipping. Visit our website to find the ideal controller for your application, or contact us about modifications and custom OEM controllers. We also carry metering and signal conditioning cards and high-speed, branch-rated fuses and fuse blocks.
www.ccipower.com



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www.inductiontooling.com

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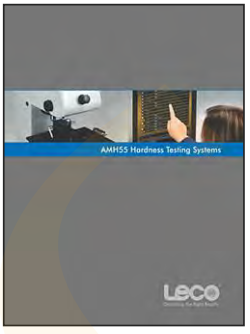

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www.tteconline.com

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www.tiniusolsen.com

Induction Heating Systems

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Ultraflex Power Technologies has been manufacturing induction heating equipment since 2008. We offer the most advanced and innovative digitally controlled technology in the industry. Our high-quality products, global technical support and cutting-edge simulation tools ensure Ultraflex customers get the most out of their induction systems.
www.ultraflexpower.com

Thermal Processing Products

Hand-held Induction Heating System

Radyne

The Voyager HHT portable hand-held induction heating system is designed for use in tight spaces. Suited for brazing, heating, drying and coating applications, it moves the assembly line directly to the finished assembly. Built with Radyne's proven VersaPower Xtreme power supply, the unit has the capability to store thousands

of recipes. The system includes real-time monitoring and tracking of parameters, and it can log, export and print data for product traceability. Voyager HHT has a convenient integrated trigger for ease of use, and it can run in manual and recipe operation modes.

www.radyne.com

Refractory Mixer/Pump

Blastcrete Equipment

The RMX-5000 mixer/pump is designed for refractory work. Its high pumping pressure allows users to pump material extreme distances, including 450 feet vertically. The user-friendly, rugged unit is available with a paddle mixer, which provides the torque necessary for demanding applications, including refractory, where materials are more difficult to mix. RMX-5000 features a 1,000-pound mixer capacity and a 1,200-pound hopper capacity.

www.blastcrete.com

Simulation Software

Simufact Engineering

Simufact Forming 15 allows users to simulate induction heating and case-hardening processes. For induction, users can identify errors, remove unwanted effects and make optimizations. For case hardening, the software allows users to calculate the adjusting carbon distribution that results during carburizing below the surface of the component. With the added parallelizable segment-to-segment calculation method, Simufact Forming 15 is able to simulate large models with deformable bodies quickly and efficiently.

www.simufact.com

Inert-Atmosphere Bench Furnace

Grieve

No. 1044 is a 2000°F (1093°C) inert-atmosphere bench furnace that can be used for heat-treating processes. Workspace dimensions measure 12 inches wide x 18 inches deep x 8 inches high, and 6 kW are installed in nickel-chrome wire coils supported by ceramic plates. The furnace features 5-inch-thick insulated walls comprised of 1 inch of 2600°F ceramic fiber , 1 inch of 2300°F ceramic fiber and 3 inches of 1900°F block insulation. Features include an inert-atmosphere flow meter, high-temperature door gasket and sealed heater terminal boxes. Controls include a digital programming temperature controller and manual reset excess temperature controller with separate contactors.

www.grievecorp.com

Thermal Mass Flow Meter

Fox Thermal Instruments

The Fox Model FT4X thermal mass flow meter is designed for industrial process applications and includes a data logger that records flow rate, totals and other events and alarms. Advanced features of the data logger include: 40 daily totals; settable contract time defines the contract day; time/date stamped alarm and event logs; power off totalizer; and display of density and gross heating value based on selected gas composition. Model FT4X can be used in applications monitoring pure gases, mixed gases and complex flare-gas compositions. A USB connection port comes standard on the new unit, which allows quick and easy access with a laptop.

www.foxthermalinstruments.com

X-Ray Diffractometer

Stresstech

The Xstress Mini is a lightweight X-ray diffraction analyzer that can be used for residual stress measurements for quality and process control. It is easily transportable, which makes it ideal for measurements on-site, at the factory or in the laboratory. The single-unit system includes an X-ray tube and high-voltage generator and can collect simultaneous data from two tilts in about 30 seconds. www.astresstech.com

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C0068 Despatch Box Furnace (60"W x 72"D x 66"H, 395°F, electric)
U3644 BeaverMatic Batch Temper Furnace (36"W x 48"D x 36"H, 1500°F, gas-fired)
V1010 Dow Batch Temper Furnace (30"W x 48"L x 20"H, 1250°F, gas-fired)
V1024 PIFCO Batch Temper Furnace, Skid Hearth (36"W x 48"L x 30"H, 1200°F, electric)
V1049 Surface Combustion Temper Furnace (87"W x 87"L x 36"H, 1350°F, gas-fired)
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, 1250°F, electric)
V1090 Lindberg Nitrogen Temper Furnace (24'W x 36"D x 18"H, 1350°F, gas-fired)
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, 2800°F, electric)
U3637 Pacific Scientific Batch Temper (30'W x 48"D x 24'H, 1600°F, 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, 2000°F, electric)
V1067 Seco Warwick Batch High-Temp Furnace (24"W x 24"H x 36"D, 1800°F, electric)
V1130 Onspec Slot Forge Furnace (72'W x 96"D x 48'H, 2000°F, gas-fired)

Batch Oil Quench Furnaces

C0086 Huber Car Bottom Furnace (10'4"W x 12'9"D x 8'H, 1800°F, 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

C0069 Enviro-Pak Drop Bottom Furnace (48'W x 48'D x 48'H, 1200°F, electric)
U3543 Despatch Drop Bottom Furnace (4'W x 6'L x 4'H, 1200°F, electric)

Internal Quench Furnaces

C0064 Lucifer IQ Furnace (18"W x 24"D x 18"H, 1900°F, electric)
U3569 Surface Combustion IQ Furnace (24"W x 18"H x 36"D, 1750°F, gas-fired)
U3570 Surface Combustion IQ Furnace (24"W x 36"D x 18"H, 1750°F, 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)
V1047 Surface Combustion IQ Furnace (62"W x 62"L x 36"H, 1850°F, gas-fired)
V1048 Surface Combustion IQ Furnace (62"W x 62"L x 36"H, 1850°F, gas-fired)
V1062 Surface Combustion Super IQ Furnace (36"W x 72"D x 36"H, 1950°F, gas-fired)
V1082 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850°F, gas-fired)
V1083 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850°F, gas-fired)
V1092 Surface Combustion Allcase IQ Furnace (30"W x 48"L x 30"H, 1850°F, gas-fired)
V1093 Surface Combustion Allcase IQ Furnace (30"W x 48"L x 30"H, 1850°F, gas-fired)
V1111 Surface Combustion IQ Furnace (30"W x 48"D x 30"H, 1850°F, gas-fired)

Mesh Belt Brazing Furnaces

C0102 JL Becker Mesh Belt Brazing Furnace (30"W x 24'5" heated L x 10"H, 2050°F, electric)
C0103 JL Becker MB Brazing Furnace w/Exo & Dryer (30"W x 24'5" heated L x 10"H, 2050°F, electric)
C0119 Grieve Mesh Belt Furnace (36"W x 15'Heated L x 15"H, 1100°F, gas-fired)
U3529 CI Hayes Mesh Belt Brazing Furnace (18"W x 6"H x 8' heating, 2100°F, electric)
U3592 JL Becker Mesh Belt Brazing Furnace (12"W x 6"H, 2100°F, electric)
V1035 Seco Warwick Mesh Belt Brazing Furnace (18"W x 12"H, 2100°F, electric)

Mesh Belt Tempering Furnaces

C0044 CGS Moore Mesh Belt Curing Oven (22"W x 20'L x 10"H, 500°F, gas-fired)
C0073 Heat Machine Mesh Belt Tempering Furnace (24"W x 10'L x 12"H, 1250°F, gas-fired, PT2501)
C0075 Industrial Heating Mesh Belt Tempering Furnace (24"W x 22'L x 12"H, 950°F, gas-fired, PT3630)
C0079 Internat'l Thermal Flat Wire Continuous Furnace (9'W x 10'H, 24' heating, 17' cooling, 650°F, gas-fired)
C0080 Surface Combustion Mesh Belt Temper Furnace (18"W x 11"H, 13' long, 1000°F, gas-fired)
C0081 Park Thermal Mesh Belt Temper Furnace (17.5"W x 7"H, 15'8" long, 900°F, gas-fired)
C0083 Eltropuls Plasma Furnace System (56"Dia x 80"D, 1022°F, electric)
C0090 Hengli Mesh Belt Sealing Furnace - Atmosphere (5.9"W x 3.5"H, 2100°F, electric)
U3638 American Gas Furnace MB Temper Furnace (31"W x 5'H, 17' heated length, 1100°F, gas-fired)
V1022 Surface Combustion Mesh Belt Tempering Furnace (42"W x 36'D x 12"H, 1350°F, gas-fired)

Pit Furnaces

V1088 Leeds & Northrup Pit Furnace (24" ID x 30" deep, 750°F, electric)

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, 1350°F, electric)
V1091 Finn & Dreffein Rotary Hearth Furnace (13'3"ID x 5'3"ID x 4'W x 2'8"H, 2275°F, electric)

Steam Tempering Furnace

U3616 Degussa Durferrit Steam Tempering Furnace (24"Dia x 48"D, 1200°F, electric)

Tip Up Furnaces

C0043 Industrial Furnace Tip-Up Furnace (8'W x 22'4"D x 6'H, 1800°F, gas-fired)

Vacuum Furnaces

C0013 CI Hayes Oil Quench Vacuum Furnace (24"W x 36"D x 18"H, electric)
C0027 Pacific Scientific Vacuum Temper Furnace (24"W x 36"D x 24"H, 1450°F, electric)
C0111 Lindberg Vacuum Furnace (15"W x 24'L x 12"H, 2400°F, electric)
U3612 AVS Vacuum Annealing Furnace 2-Bar (18"W x 24"D x 12"H, 2400°F, electric)
U3635 Lindberg Hydryzing Gas Generator (6000 CFH Endo, gas)
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, 2250°F, electric)
V1135 Abar Vacuum Furnace 2 Bar (72'Dia x72"Deep, 2400°F, electric)
V1136 Surface Combustion Vacuum Furnace, 2-Bar (26"W x 36"L x 22"H, 2400°F, electric)
V1138 Ipsen Vacuum Furnace, 5-Bar (24"W x 36"L x 14"H, 2400°F, electric)

Endothermic Gas Generators

C0093 JL Becker Modular Endo Gas Generator (3-4000/6-8000/9-12000 CFH)
U3594 AFC-Holcroft Gas Generator (3,000 CFH Endo, gas)
V1075 Lindberg Gas Generator (3000 CFH Endo)
V1105 Surface Combustion Gas Generator (5,600 CFH Endo, 1950°F, gas)
U3647 Lindberg Gas Generator (3000 CFH Endo, 2050°F, gas)
V3512 Surface Combustion Gas Generator - 5,600 CFH Endo

Exothermic Gas Generators

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

Material Handling - Conveyors

U3565 Conveyor - Roller (48"W x 20'L)

Ovens - Cabinet

U020 Blue-M Oven/Ref (20"W x 20"H x 18"D), (-4°F/400°F)
U3625 Lindberg Atmosphere Oven (38'W x 38'D x 38'H, 850°F, electric)
U3629 Cabinet Oven (30'W x 30'D x 36'H, 750°F, electric)
U3642 Blue-M Cabinet Oven (36"W x 36"D x 36"H, 650°F, electric)

Ovens - Walk-In

C0038 Despatch Walk-In Oven (54"W x 108"L x 72"H, 500°F, electric)
C0039 Gehnrich Walk-In Oven (72"W x 96"L x 72"H, 400°F, electric)
C0108 Park Thermal Walk-In Oven (90'W x 144'D x 72'H, 850°F, gas-fired)

Freezers

V1129 Webber Freezer (-120°F, electric)

Blowers

U018 Twin City Blower (20 HP, RBA-SW, Class 22)

Charge Cars

U3621 Dow Charge Car, DEDP (66"W x 60"D x 54"H)
V1051 Surface Combustion Charge Car (DEDPER, 87"W x 87"L)
V1085 Holcroft Charge Car (DE/DP, 36"W x 48"D)
V1112 Surface Combustion Charge Car, SE, 30"W x48"D

Scissors Lifts & Holding Stations

V1086 Holcroft Scissors Lift & (2) Holding Tables

Heat Exchanger Systems

U030 Graham Systems Heat Exchanger - Plate
V1104 SBS Heat Exchanger

Holding & Cooling Stations

V1113 Forced Cool Station (30"W x 48"D x 30"H)
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Water Cooling Systems

U3404 JL Becker Cooling Tower with Tank (Tower: 51"W x 36"L x 64"H, Tank: 72"W x 84"L x 66"H)
U3595 JL Becker 2-Tank Water Cooling System (tank: 72"L x 36"W x 37"H, 2 Dayton 1HP Motors)
U3646 HydroThrift, Duplex Pump Base, Water Cooling System
V1038 Bell & Gossett Shell & Tube Heat Exchanger with Tank

Washers

V1052 Surface Combustion BIQ Washer (87"W x 87"L x 36"H, 180°F, gas-fired)
V1084 Holcroft Spray/Dunk Washer (36"W x 48"D x 30"H, 190°F, gas-fired)
V1101 Surface Combustion Spray Washer (36"W x 48"D x 30"H, 180°F, electric, 58kw)

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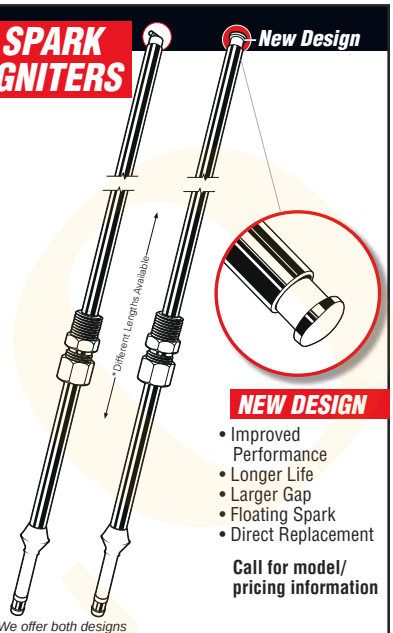

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17"×14.5"×12"	L&L (New)	Elec 2350°F
18" × 30" x 13"	Hevi-Duty	Elec 1850°F
18" x 36" x 18"	Lindberg (Fan)	Elec 1850°F
20" x 48" x 12"	Hoskins	Elec 2000°F
24" × 48"× 24"	Hevi-Duty	Elec 2350°F
36" × 48"× 36"	CEC (Atmos-N_2)	Elec 2000°F
36" × 72"× 42"	Eisenmann (Car Bottom)	Gas 3100°F
60"×216"×48"	IFSI (Car Bottom)	Gas 2400°F
60"×156"×60"	Lindberg Car Bottom	Gas 1850°F
64"×180"×68"	Swindell-Dress. Car Bottom	Gas 2350°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	L&L Nitrider	Elec 1200°F
72" Dia x 72"D	Flynn + Dreffein (2) (Atmos.)	Elec 1400°F
48" Dia x 60"H	"Bell" Nitrider (Retort)	Elec 1200°F
VACUUM FURNACES		
15" × 24" x 10"	Ipsen - VFC 224	Elec 2400°F
24" × 36" x 18"	Hayes (Oil Quench)	Elec 2400°F
Just Added 24" x 36" x 24"	TM - Temper	Elec 1400°F
48" x 48" x 24"	Surface (2-Bar)	Elec 2400°F
60" Dia x 96"H	Ipsen "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
BELT FURNACES/OVENS		
12" × 120" × 15"	Grieve (Solvent)	Elec 450°F
24" × 18"L	Thermal Basic Belt Line	Gas 1750°F
Just Added 24" × 40' × 18"	Despatch	Elec 500°F
32" × 24' × 12"	OSI Slat Belt	Gas 450°F
36" × 24' × 8"	Surface Cast Belt (Line)	Gas 1750°F
36" × 28' × 22"	Lewco (2)	Elec 350°F
60" × 40' × 14"	GE Roller Hearth (Atmos)	Elec 1650°F
60" × 40' × 14"	Wellman Roller Hearth (Atmos)	Elec 1650°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
Wilson Hardness Testers (Superficial)		
(2) Bell & Gossett "Shell & Tube" Heat Exchangers		
26" x 15' x 15"	Belt Washer/Dryoff	Gas
36" x 48"	AFC Charge Car (DE)	Elec
30" x 30" x 30"	Subzero	-105 to 375°F Elec.
MISCELLANEOUS *(continued)*		
Just Added 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
22" × 18" × 15"	Precision Quincy	Elec 1000°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 (3)	Elec 1400°F
30" × 48" × 36"	Surface (Atmos)	Elec 1400°F
30" × 48" × 30"	Surface	Elec 1250°F
36" × 36" × 36"	Grieve (Solvent)	Elec 500°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"	AFC	Gas 1250°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
38" × 20" × 26"	Grieve	Elec 500°F
42" × 72" × 36"	Despatch	Elec 1350°F
48" × 30" × 48"	Precision Quincy (2)	Elec 550°F
Just Added 48" × 48" × 20"	Lindberg	Elec 1250°F
48" × 34" × 52"	Heat Mach. (2)	Elec 500°F
48" x 48" x 48"	TPS - Environmental	Elec 392°F
48" x 52" x 60"	Despatch	Elec 500°F
48" × 52" × 68"	Despatch (Solvent)	Elec 500°F
48" x 48" x 48"	Lindberg (Argon Atmos)	Elec 1400°F
48" × 48" × 60"	Grieve	Elec 500°F
50" × 50" × 50"	Grieve	Elec 1250°F
55" × 30" × 60"	Precision Quincy (2)	Elec 350°F
68" × 72" × 72"	Gruenberg (4)	Elec 450°F
72" × 120" × 78"	Grieve	Gas 500°F
Just Added 72" × 120" × 72"	Grieve	Elec 650°F
72" × 180" × 72"	Precision Quincy	Elec 450°F
72" × 252" × 60"	Precision Quincy "Car Oven"	Gas 500°F
108" × 96" × 65"	Eisenmann (4)	Gas 1200°F

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