INDUSTRIAL HEATING

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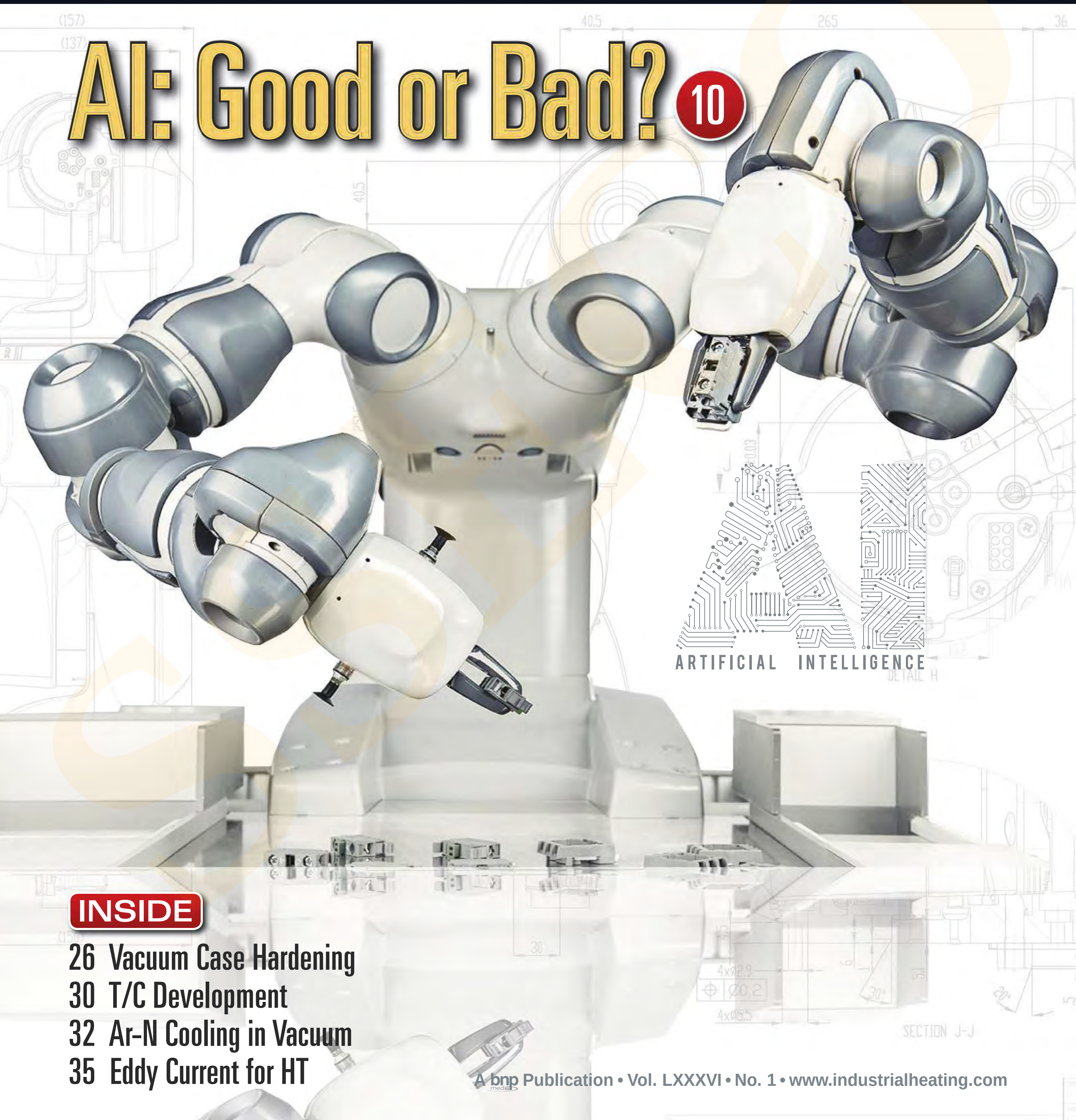
JANUARY 2018

AI: Good or Bad? 10



INSIDE

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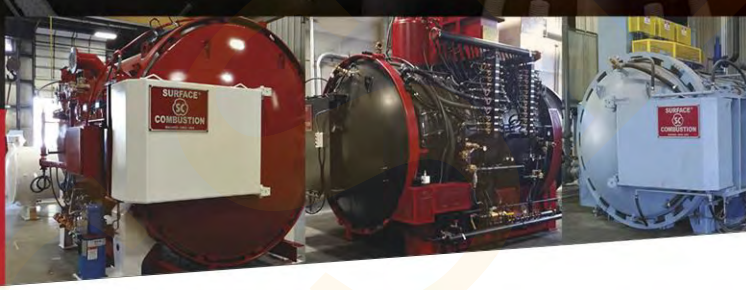

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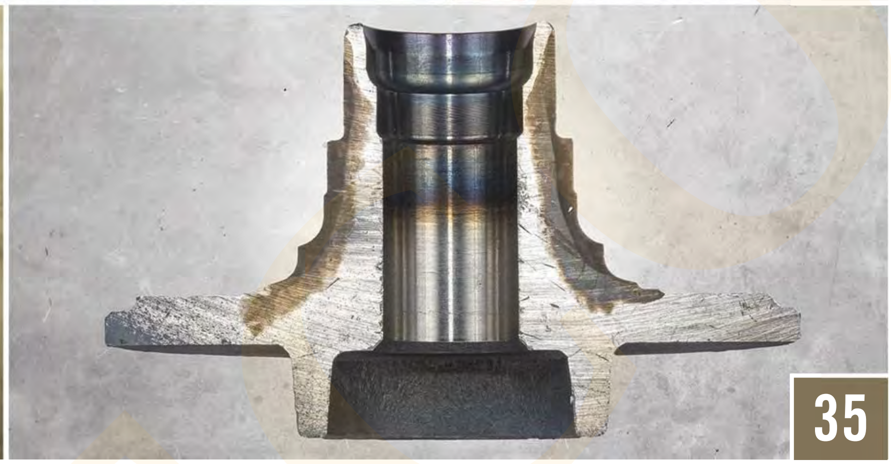

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Disruptive, Necessary New Technology

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What is your view of new technology? How do you think artificial intelligence (AI) will affect our thermal-processing businesses? We would like to primarily focus on AI in this column. Perhaps what we discuss will help you to think differently about the pros and cons of AI. As a starter, check out a recent *Industrial Heating* online exclusive article written by an industry outsider at www.industrialheating.com/AI.

Here's what I said about AI in my article titled "Technology Speeds Change of Thermal Processing" last year. "It is predicted that software will disrupt most traditional industries in the next 5-10 years, and our industry is certainly traditional. It is anticipated that computers will become more intelligent than humans by 2030. The Internet of Things (IoT) has developed with AI, and both are moving exponentially. Simply, the IoT is the network of connected devices. In time, nearly everything will be connected in such a way that we can access and control devices with our cell phones. In high-temperature thermal processing, AI and the IoT are impacting the way we do temperature surveys and perform maintenance."

As evidence that AI is really happening, FORTUNE magazine indicated that "last year venture capitalists invested $5 billion in 658 (AI) companies, a 61% increase from the prior year." This $5 billion in 2016 compares to just $589 million as recently as 2012. A graphic used by FORTUNE interestingly showed that most of this investment came from the U.S. in 14 different segments. These include automotive technology, core AI, Internet of Things (IoT) and robotics.

It appears that AI is here to stay. How can you use it to grow your business? McKinsey & Co. took a look at the various market sectors to predict which have the greatest growth potential. They believe that "manufacturing" has a 60% potential for automation to have a large impact. Manufacturing is second on their list, next to "accommodation, food services." McKinsey identified 12 technologies that could have a potential economic impact of $14-33 trillion in 2025. A sampling of these technologies includes IoT, advanced robotics, autonomous vehicles, energy storage, 3D printing and advanced materials. All of these technologies have a potential to disrupt our industry.

Is this disruption a bad thing? Specifically, is a robot/cobot friend or foe? In reality, the answer is yes, but it could be argued that this disruption is a good thing. In fact, AI such as robots might just be what will make American manufacturing competitive again. How? Well, a company might re-shore jobs if domestic technology results in fewer workers. For example, a company with 60-70 workers in China could move back to the U.S. with six or seven American jobs plus automation. Technology (AI) is the way the U.S. will see a greater share of global production and a net increase in factory jobs.

Another example involves a company in Michigan that added robots, which resulted in a revenue boost from $8 to $50 million. The workforce actually increased from 100 to 180, and only one-third of those jobs involve repetitive tasks.

Not only will repetitive tasks be reduced, robots can replace workers doing dangerous jobs. An example would be bridge inspection. AI options for this hazardous occupation include a battery-powered robot that uses ground-penetrating radar and sensors to locate deteriorating steel or concrete. Also, Carnegie Mellon University has developed a drone that can "create a high-resolution 3-D model of the bridge, which can then be safely analyzed by an inspector on the ground."

Another way we will see AI simplify our lives would be to use it to analyze all of the data generated by the IoT. Instead of engineers and technicians spending time combing through piles of data, AI can do it and alert engineers to problem areas that may need their attention.

AI is nothing more than a tool we can use or ignore at our peril. It's your choice, but choose wisely!

The Impact of Regulations on the Economy

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Although we previously dealt with this topic in May 2017, it's important enough to cover again. Government regulation (federal, state and local) is killing the American economy. Burdens on industry and businesses (there is a difference) often come from requirements for licenses and procedures of supervisory oversight.

Licensing costs over $203 billion nationwide to the economy. Common sense tells us that this is unnecessary. Examples include (per *The Wall Street Journal)*:

- To work in California as a door repairman, carpenter or landscaper requires 1,460 hours of supervised on-job training plus purchase of a $500 license.
- Arizona harassed a student cosmetologist who gave free haircuts to homeless people without having a license to do so.
- Several states and the Washington, D.C. government require six years of education with a final exam plus a $1,120-$1,485 license to be an interior designer.

In 2015 the Federal Register grew by 81,611 pages over the prior year, publishing 3,378 regulations with 600 having direct impact on small businesses. These federal requirements cost nine times the stated cost of compliance; to this must be added state and local regulations and their costs. An unacknowledged factor is that compliance with EPA regulations actually costs fourfold more per employee for small compared to large businesses.

A survey in 2012 by the National Federation of Independent Business found that 72% of all business owners have serious problems with regulations, 25% found the extra paperwork the greatest compliance problem, and 22% cited actual compliance and the real complexity of it as the most expensive part of operational problems. The volume and complexity of all regulations was cited by 60% of businesses as the "costly headache".

During the Obama presidency, 25,155 new regulations were issued, imposing a $727 billion cost on America's economy and requiring 460 million hours of new paperwork. Current federal regulatory compliance costs are $1.88 trillion, or 11% of national GDP. Environmental regulations, tax compliance, occupational health and safety, and homeland security top the list of expenditures.

And also realize that the number of small businesses is shrinking due to this overwhelming load, which does not account for existing state and local regulations. Experts summarize by saying that for every 10% increase in regulatory costs, the country experiences a 5-6% loss in businesses with fewer than 20 employees.

Is this burden, questionable in so many respects as needed or beneficial, worth it? For over 25 years, small businesses created approximately 64% of all new jobs in our country. But a practical remedy to this waste eludes the public. It is notable that the banking sector of the U.S. economy has a regulatory assessment process in place as required by the Economic Growth and Regulatory Paperwork Reduction Act of 1996 and implemented by the Federal Financial Institutions Examination Council.

Two appropriate questions are: "What can you do about all this?" and "Are you going to do it?" The Small Business Administration (SBA) issued a public request for information (Docket No. SBA-2017-0005) Aug. 4, 2017. Remember that President Trump signed Executive Orders (#31771 and #31777) that addressed regulatory costs and relief of burdens, and this SBA request seeks relevant information. Questions and comments were solicited from the public covering items such as:

- Are SBA regulations unnecessary or burdensome?
- Which SBA regulations are outdated and/or should be repealed?
- Cite regulations that are unnecessarily complicated.
- What regulations need modification?

While the intent was for submission of comments by Oct. 16, 2017, the SBA must listen to an informed and cooperating public – you, the affected party. You are urged to contact Holly Turner, SBA, at 202-205-6335 or IGA@sba.gov.

Why not get involved and give it a try? If you get a response that says you are too late or that your concern should be addressed by another agency, call your Congressman and both Senators. It is time for citizens to hold government accountable for how societal behavior is coerced.

Simulation Software (Part One: Atmosphere Carburizing)

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One of the Doctor's many New Year's resolutions is to convince every heat treater to purchase and use simulation software for recipe creation and to aid in process control and troubleshooting. The time has come – the technology is proven and robust. Today, we will talk about simulators and controls for atmosphere carburizing. In our March 2018 column (since February's focus is on nonferrous heat treatment), we will talk about low-pressure carburizing simulators. Then in a follow-up column, we will introduce you to nitriding/ferritic nitrocarburizing simulators. Let's learn more.

Why Simulators?

We all know how important precise furnace atmosphere control is to successful heat treating. Meeting or exceeding customer specifications and producing both predictable and repeatable metallurgical and mechanical property results are the goal of every heat-treat operation. Nowhere is this more critical than in carburizing and other case-hardening processes where we deliberately change the composition of the furnace atmosphere at various points in the cycle. In addition, changes to material composition, part loading and/or process parameters (time, temperature, carbon potential) influence the final results.

In gas carburizing, the addition of carbon at the part surface followed by diffusion allows us to achieve both the desired case depth and hardness.

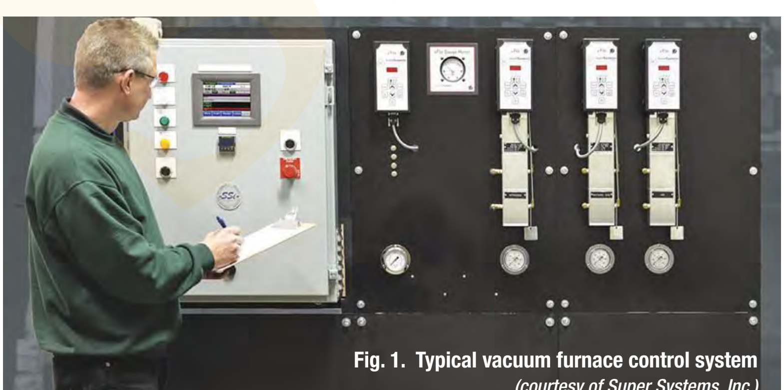

Fig. 1. Typical vacuum furnace control system
(courtesy of Super Systems, Inc.)

Measurement and control of furnace atmospheres are often performed continuously using in-situ (oxygen probe) devices or via extractive (dew point or infrared) methods. A combination of techniques is often used.

Simulation and modeling software allow us to predict and determine in real time the carbon profile. Taking this one step further, one can use this type of software to control the process by utilizing the atmosphere inputs and varying the time to achieve the desired case depth and carbon profile at any given temperature. Prediction of hardness profiles is just an algorithm away.

Historical Overview

Years ago, the only effective way of trying to control the carburizing process was to establish a relationship between the volume of enriching gas to that of the carrier gas. This led to rules of thumb such as adding natural gas at 10% of the endothermic gas flow for carburizing or adding ammonia additions at 3-5% of the endothermic gas flow when carbonitriding. This was followed by techniques involving measurement of the carbon potential using either dew point or periodic shim-stock measurements.

These methods were common up until the early 1970s, when the first oxygen (carbon) probes were introduced. Once the zirconia carbon-sensor technology was proven robust, the technology swept the industry. Over the years, this measurement method has been refined, first by introducing a sensor correction factor and then using three-gas (CO, CO_2 and CH_4) infrared analysis in conjunction with the oxygen probe to input a more accurate carbon setpoint. It then evolved further with the introduction of continuous, nondispersive infrared analyzers that measure continuously rather than periodically, allowing for automatic operation.

Today, coil tests are being used to simplify shim-stock verification methods. Finally, true representation of atmosphere was achieved using metallurgical evaluation of parts in combination

with the aforementioned methods. From all these results, proper correction to the carbon calculation can be determined, yielding more accuracy on the in-situ control parameter from the oxygen probe.

While modeling/simulation of the carburizing process began in earnest in the 1970s, it wasn't until the advent of more powerful, smaller computers and their industrialization that programs emerged to allow complex calculations in real time. However, these tools only became of interest to the heat-treat industry over the past two decades as demands for higher quality and tighter control became paramount.

One of the lessons learned was that calculating the carbon potential for gas carburizing requires assumptions with regard to material chemistry, base atmosphere composition, temperature and changes to the atmosphere over time. The composition of the base atmosphere and the way in which the gas is measured were found to have significant effects on the accuracy of the calculated carbon potential.

Today, many control methods are time-based with changes to carbon and temperature setpoints. Due to the variable nature of the process, however, this method does not provide the necessary accuracy of control or repeatability of results. In addition, it is common to be conservative ("err on the safe side") when providing a time for segments of the process. Simulators and their associated control systems (Fig. 1) optimize the carburizing process.

How to Optimize Results

The best way in which to utilize a predictive model in real-time control is to ensure that the variables accurately represent the conditions to which the parts are exposed; to build confidence by running data-logged values through the modeling software; and to compare those values to metallurgical results. Using this three-step process of building, verifying and controlling allows for accuracy in method and confidence in results. "What-if" analysis is another important aspect of these programs, allowing different inputs (e.g., time, temperature and boost-diffuse steps) to be explored.

Atmosphere Carburizing Simulator Example

One simulation program on the market is CarbCalcII (Super Systems Inc.). This control software package is capable of not only predicting the carbon profile developed during atmosphere carburizing, it can be used for real-time monitoring, real-time control, process replay modes and what-if simulation. It includes the capability to predict the carbon-transfer rate between the furnace atmosphere and steel during boost-diffuse carburizing or steady-state (constant carbon-potential) carburizing and during temperature drops and stabilization at hardening temperature. The ease of use, recipe development and ability to "tweak" the cycle are key advantages of the software.

Multiple screens and operating modes (Fig. 2) allow the user to input key process variables (including material chemistry and atmosphere composition), create multiple segment recipes, view the impact on results and view the carbon profile (actual versus desired). For example, the software comes with an alloy database that includes the most common steels used in heat treating. Within the standard materials is the ability to change an element's chemistry (e.g., the ability to input the actual heat carbon content). It also allows the user to create custom chemistries to support new or foreign alloys that are becoming more common today.

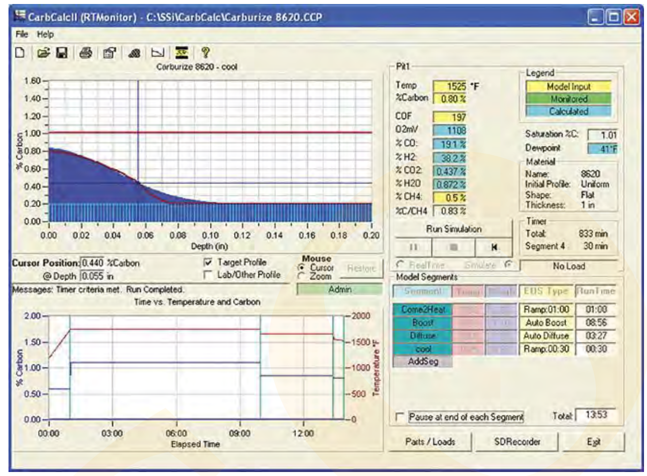

Fig. 2. CarbCalc II simulator screen shot *(courtesy of Super Systems, Inc.)*

In real-time and replay modes, the output allows users to display the carbon profile using data retrieved from the control instrumentation while process control runs in the background. Carbon profiles can be altered, and the program will modify the required time at temperature based on the actual carbon profile received from the control instrumentation. In addition, there is a load-tracking system to enable historical information on previously processed loads to be quickly retrieved and profiles re-created or modified.

Summary

Atmosphere carburizing simulators and similar predictive control tools help heat treaters do their jobs more efficiently, with better control, less operator intervention and at lower cost. In addition, they simplify record keeping and provide the type of documentation demanded by today's manufacturing community. If you or your heat treater atmosphere carburize, make a promise to yourself and your company to insist that simulators are part of the process. Simply stated, it will improve quality and keep our industry competitive.

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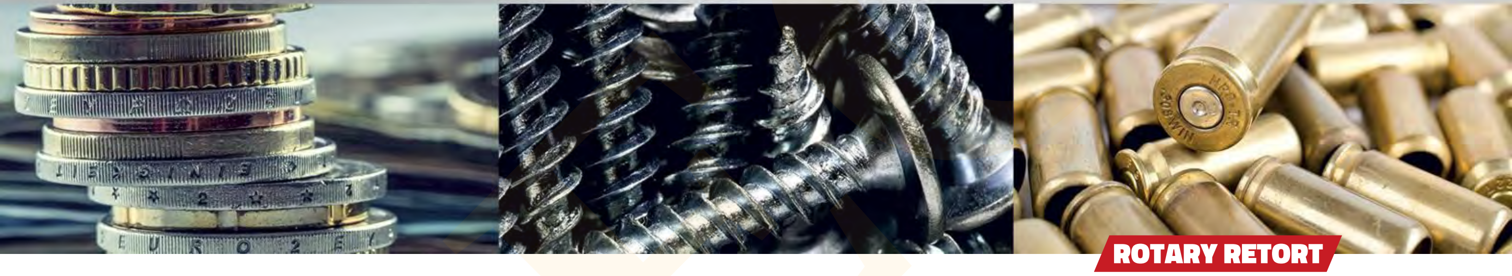

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Technology Fueling Growth in Next Two Decades

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"In my opinion, there will be **more change by 2020** than we have seen in the previous decade."

All I can say when it comes to emerging technologies is "Wow!" It used to take a decade for change to have a dramatic and lasting impact on business models. You could walk toward change, and take your time preparing for it. Think about the automobile. Henry Ford invented the car in 1903, but it wasn't until 1913 that it went into mass production. The horse-and-buggy industry had 10 years (plenty of time) to plan and change its business model to compete.

You no longer have the luxury of time. Today, the future is moving at us at a pace never before seen in history. In my opinion, there will be more change by 2020 than we have seen in the previous decade. The question for your heat-treat plant is: "Are you keeping up with the pace of change that will allow you to compete for the record growth that lies ahead in the 2020s and 2030s?" Look at how fast change is happening now.

- According to *Forbes*, the top 10 jobs in 2010 didn't even exist in 2004.
- It took the telephone 75 years to reach 50 million people. It took the game Angry Birds 35 days to reach 50 million people.

The world around the heat-treating industry is changing in ways in which you need to stay tuned. Processes are changing. Materials are changing. Every industry is looking to strip out costs and add processes like additive manufacturing to increase profits. You cannot wait. If you are going to capitalize on the growth coming your way, your company must look at how it needs to change to meet the driving demands in product, delivery and customer experience of the future.

If you are unsure about the "growth coming your way," let's take a look. Just as the 78 million baby boomers drove the 1980s and 1990s to be the most lucrative times in our economic history, the over 100 million millennials are going to do the same for the next two decades. Everything they buy is going to grow dramatically because of the overwhelming number of them that will be in the marketplace. You need to be in industries selling the products they buy.

When you look at your company, are your people, processes, safety procedures, technology strategy, operations and production ready to maximize your growth?

One of the driving elements preparing for fast-pace change is technology. Technology is key because it can do the following three things:

- **Remove** any friction, anxiety or stress in the business model, with regard to delivery, product, customer experience and operations.
- **Allow** for real-time analytics through smart technology and data management, making instant changes to maximize production, productivity and profits.
- **Connect** you with the entire supply chain in your industry, allowing for information sharing that enhances the intercompany communication channels.

If your company does not have a strategy to stay ahead of the technology curve, you will most likely be left behind in your ability to compete. New smart technologies are helping small, medium and large manufacturers maximize people, time and capacity while minimizing safety risks, error rates and downtime as well as enhancing the ability to perform predictive maintenance and production.

Through data analytics, companies are able to learn from their past data to make real-time, predictable decisions about the future. The following are 10 emerging technologies you need to explore that are changing the landscape of every industry and how products move through production.

- Self-driving technology
- 3D printing/additive manufacturing
- Sensors
- Drones
- Artificial intelligence
- Robotics
- Nanotechnologies
- Virtual reality
- Holograms
- Information sharing

Push, challenge and lead your company into the future, because the future is unforgiving to those not prepared or informed. Make sure that your company is researching any and all types of technology advances to maximize the efficiency of your heat-treat plant.

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Charles Wiberg was determined to operate a successful commercial heat-treat operation. He established Midland Metal Treating in the 1960s but was forced to sell the business in the recession of 1980. Instead of waving the white flag, however, Wiberg founded ThermTech just two years later. To put it mildly, his determination paid off.

Wiberg started ThermTech in Waukesha, Wis., with a 20-year-old- Ipsen IQ furnace and a ton of know-how when it came to refurbishing used equipment. He was also able to build some of his own furnaces, which came in handy when serving the foundry businesses that were plentiful in the region at the time.

Growth has been steady and constant at ThermTech. In 1990, the company built a new 35,000-square-foot facility. Ten years later, ThermTech constructed a 20,000-square-foot addition to that facility and moved back into the plant that it originally rented when the business started. In 2011, the company leased a 65,000-square-foot facility about 3 miles away to accommodate austempering and quench-and-temper equipment and its fabrication shop.

New furnaces were sparse in ThermTech's formative years. Instead, two used vacuum furnaces were purchased to accommodate its tool-steel business. During this time, the company was able to successfully grow with used, refurbished equipment and self-manufactured furnaces, including the CEW (Charles Edward Wiberg) line. It wasn't until 2001 that ThermTech bought its first new furnace, a 10-bar vacuum unit. Today, however, new equipment is not an issue. ThermTech has added five IQ furnaces, several large box furnaces and additional vacuum equipment since 2003.

All of this equipment is put to good use. The company serves the agriculture, construction, medical, military and mining industries. ThermTech also does work for the forging industry, specifically the oil and gas sector. This MTI member offers a wide range of services, including age hardening, annealing, carburizing, nitriding, normalizing, straightening, vacuum and more. With two staff metallurgists, the company is able to take on jobs that many other heat treaters pass up.

ThermTech is also one of the few heat treaters with a dedicated customer service department. There is no automated phone system here. Customers are on tight schedules and need instant answers, so that's what ThermTech provides. The company's customer portal is a prime example. Its computer system allows customers to check work in progress, download data and access invoices.

ThermTech was, and still is, a family affair. Wiberg's wife, Joan, and daughter Michelle all worked for the company and played vital roles in its early days. Today, ThermTech is operated by son, Steve Wiberg, and daughter Mary Wiberg Springer. Charles Wiberg built the foundation for the company, but his guidance and support since his retirement in 2002 have been instrumental in ThermTech's continued success.

In fact, Charles Wiberg's philosophy of always marching forward is not lost on his son and daughter. Over the next 5-10 years, ThermTech will focus on automating and improving efficiency throughout its operation. The company is looking to install manipulators/robotics wherever it makes sense, and it will continue to keep up with changes in the marketplace, especially with respect to new technologies.

IHEA Introduces Member Voucher Program

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

The Industrial Heating Equipment Association (IHEA) is pleased to announce a great new program in 2018. It is a part of IHEA member dues and is designed to assist members in providing educational opportunities to their own employees and customers. This has come about as each year more members request ways to pre-pay for meetings and pay for customers to attend IHEA's educational events.

Our new "member voucher program" will provide two vouchers to each manufacturing member company and four vouchers to our corporate end-user companies as part of their membership benefits. Vouchers can be used by employees or customers to register for a variety of IHEA events throughout 2018.

One voucher will be required to register for IHEA seminars, online courses and the Fall Business Conference. Two vouchers will be required to register for the IHEA Annual Meeting. Vouchers can even be used to register for the 2018 IHEA Safety Standards & Codes seminar, where we will review the new NFPA 86 revisions.

IHEA strives to provide the knowledge base to the thermal-processing industry, and this program will assist in that effort. IHEA members will be able to extend the vouchers to customers, enabling them to obtain training and education while also gaining exposure to IHEA's network and valuable resources. The program will also attract more participation from those using thermal-processing technologies.

As a result of the voucher program, IHEA welcomes the newest corporate end-user member, Caterpillar, and returning member John Deere. Since end-user members receive four vouchers for employees to use for IHEA training or events, this effectively pays for the annual dues when redeemed. Along with the vouchers, end-user members receive additional IHEA member benefits that extend to all employees. They can take advantage of discounts on all online resources and events, participate on committees, receive the quarterly newsletter and get further involved with manufacturing members.

For more information about IHEA's voucher program and membership, visit www.ihea.org and click the "About Us" tab on the menu bar.

Established in 1929 to meet the need for effective group action in promoting the interests of industrial furnace manufacturers, IHEA has expanded and currently includes designers and manufacturers of all types of industrial heat-processing equipment used for the melting, refining and processing of ferrous and nonferrous metals and certain nonmetallic materials and for the heat treatment of products made from them.

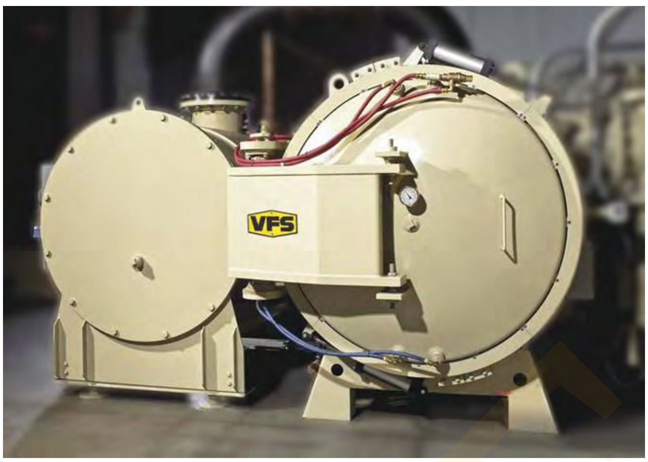
Benefit from valuable IHEA training


Networking at IHEA events

EQUIPMENT NEWS

Vacuum Furnaces

Ipsen shipped a total of 14 vacuum furnaces to seven states, as well as to Indonesia and Japan. The furnaces will be used in support of the additive-manufacturing, aerospace, automotive and commercial heat-treating industries. The shipments included: a vertical bottom-loading



MetalMaster vacuum furnace with an 84-inch-diameter work zone and 8,000-pound load capacity; and four standard TITAN vacuum furnaces. Other furnaces shipped include three HIQ (horizontal internal quench) and HEQ (horizontal external quench) furnaces from the VFS product line that will process parts for the aerospace and commercial heat-treating industries.
www.ipsenusa.com

Bright-Annealing Line

Ebner will supply a vertical bright-annealing line to Arinox, a member of Italy's Arvedi Group. Features of the line, which will be used in the production of ultra-thin precision steel strip, include: a gas-fired muffle furnace, processing temperatures up to 2100˚F (1150˚C), maximum strip width of 62 inches (1,575 mm) and throughput capacity of 7.8 tons/hour. The facility will start production at the beginning of 2019.
www.ebner.cc

Vacuum Systems

Retech, part of SECO/WARWICK Group, is the main supplier of advanced vacuum technology for a recycling and refining plant for titanium alloys in France. Retech designed and supplied three

metallurgical units for the facility: two vacuum arc remelting (VAR) furnaces for titanium melting and a plasma melting furnace. The first VAR furnace has been installed. Construction and delivery of the second is planned in the next stage. The plant, which recently opened in Saint-Georges-de-Mons, is the first in Europe to produce titanium ingots with scrap from major manufacturers of aircraft and their subcontractors. www.retechsystemsllc.com

Electric-Arc Furnaces

Tenova, over the last eight months, has been awarded contracts for six electric-arc furnaces (EAF) in China. In an effort to improve the reduction rate of CO_2 emissions promoted by China's government,

steelmakers are converting their facilities to EAF technology. Tenova's Consteel Evolution system continuously preheats and feeds metallic charge to the EAF while simultaneously controlling gaseous emissions. www.tenova.com

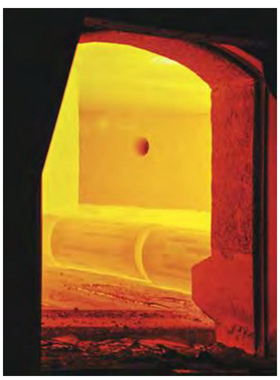
Tempering System

SECO/WARWICK partnered with a hand-tool manufacturer in North America to custom-design a unique pit-type tempering furnace system to increase production capacity. The system will

be utilized for heat treating power-tool components and was specifically designed to fit into a limited footprint within the existing facility layout. SECO/WARWICK's atmosphere heat-treating equipment is used both with and without protective atmospheres in a wide range of configurations for most heat treatments in use by tool manufacturers.
www.secowarwick.com

Walking-Beam Furnace

SMS group received an order from Spain's Forjas Iraeta Heavy Industry for the supply of a 30-ton-per-hour walking-beam furnace to be used upstream of its existing breakdown mill for flange production. The goal of the project is to install furnace technology for proper and optimal reheating of a wide range of products. The charge will include blooms from 200-500 mm (7.9-19.7 inches) square and round blooms from 300-700 mm (11.8-27.5 inches) in diameter, in lengths between 3-5 meters (9.8-16.4 feet). www.sms-group.com



BUSINESS NEWS

Arconic Expanding Capacity, Adding Heat-Treat Furnace

Arconic Inc. plans to install a new horizontal heat-treat furnace at its Davenport Works facility in Iowa. The furnace will enable the company to heat treat longer and thicker plate than ever before, including material for its recently installed Thick Plate Stretcher, which began commercial production this year and is the largest thick plate stretcher in the world. Construction on the project, which required a $137 million investment, is expected to begin late this year with commercial production expected to start in 2019.

TimkenSteel Brings Q&T Facility Online, Increases Heat-Treat Capacity

TimkenSteel brought its newest heat-treatment asset, an advanced quench-and-temper facility, online and has started processing customer orders. The addition of the $40 million facility, located at the company's Gambrinus Steel Plant in Canton, Ohio, increases TimkenSteel's existing quench-and-temper capacity by 50,000 tons, or 45%, and brings the company's total annual heat-treatment capacity to 500,000 process tons. According to TimkenSteel, it is the largest of its four heat-treatment facilities.

Saint-Gobain Acquires Spin-Works International

Saint-Gobain's High-Performance Refractories business acquired Spin-Works International Corp., a manufacturer of 3D-printed and extruded silicon-carbide ceramic components that improve energy efficiency, recover waste heat and reduce emissions for customers in a wide range of high-temperature industrial processes. The acquisition expands Saint-Gobain's capabilities in the ceramic industrial burner and heat-recovery markets, especially in the steel and automotive businesses. Spin-Works is based in North East, Pa., and has approximately 20 employees.

Aleris Opens Kentucky Automotive Production Facility

Aleris opened its aluminum automotive-body sheet production facility in Lewisport, Ky. The $400 million investment positions Aleris to meet significant growth in North American automotive demand. Announced in 2014, the project added heat-treatment and finishing capabilities, including two continuous annealing lines, a wide cold mill and an automotive innovation center. The company began shipping automotive products from Lewisport this month.

Equipment & Business News

Nucor to Build Merchant-Bar-Quality Mill in Illinois

Nucor Corp. will build a full-range merchant-bar-quality (MBQ) mill at its existing steel mill in Bourbonnais, Ill. The MBQ mill will have an annual capacity of 500,000 tons and is expected to cost $180 million. The project, which will take approximately two years to complete, will allow Nucor to fully utilize its existing bar mill by optimizing the melt capacity and infrastructure already in place. It will also take advantage of an abundant scrap supply in the region.

Nutec Bickley Acquires Olson Industries

Nutec Bickley of Monterrey, Mexico, a manufacturer of industrial furnaces, ovens, ceramic kilns and combustion systems, acquired **Olson Industries** of Burgettstown, Pa. The acquisition will see Nutec Bickley complement its existing product range to offer more complete packages for the steel, aluminum and alloy industries. Bringing Olson Industries' line of equipment onboard will enable the Metals Business Unit to consolidate its position in the North American market and secure access to larger projects. Olson has been supplying industrial furnaces and process heat-treating equipment since 1945.

ATI Forms Stainless Steel Joint Venture

Allegheny Technologies Inc. reached a definitive agreement to form a 50-50 joint venture (JV) with an affiliate company of **Tsingshan Group**. The JV, Allegheny & Tsingshan Stainless, will manufacture and sell 60-inch-wide stainless sheet in North America. First shipments are expected in early 2018. The JV is projected to add approximately 100 manufacturing jobs in western Pennsylvania.

Cast Iron Foundry Celebrates First Pour

Brembo had a successful first pour at its all-new cast iron foundry in Escobedo, Mexico. The 269,000-square-foot facility, which has a melting capacity of approximately 70,000 tons per year, will cast iron rotors for the company's nearby disc machining plant. The first pour is a preliminary test that ensures all systems are functioning properly and is the first step in testing the foundry's full production line in anticipation of production ramp-up. During this test, the foundry's furnaces were charged and the molten raw material from these furnaces was poured into a mold for the first time.

Arconic, Airbus to Produce 3D-Printed Metal Parts

Arconic announced a multi-year cooperative research agreement with **Airbus** to advance metal 3D printing for aircraft manufacturing. The companies will develop customized processes and parameters to produce and qualify large, structural 3D-printed components, such as pylon spars and rib structures, up to approximately 3 feet in length. The deal combines Arconic's expertise in metal additive manufacturing and metallurgy with Airbus' design and qualification capabilities. Under this agreement, Arconic will use electron-beam high-deposition-rate technology to 3D print parts.

INDUSTRY EVENTS

March 5-7
MIM 2018 – International Conference on Injection Molding of Metals, Ceramics and Carbides; Irvine, Calif.
www.mim2018.org

March 11-15
TMS 2018 Annual Meeting & Exhibition; Phoenix, Ariz.
www.tms.org/tms2018

April 16-20
Wire & Tube 2018; Düsseldorf, Germany
www.wire-tradefair.com / www.tube-tradefair.com

April 23-25
IHEA Annual Meeting/MTI Spring Meeting; Scottsdale, Ariz. www.ihea.org / www.heattreat.net

April 23-26
Rapid 2018; Fort Worth, Texas www.rapid3Devent.com

May 1-3
Ceramics Expo; Cleveland, Ohio www.ceramicsexpousa.com

May 7-10
AISTech 2018 – The Iron & Steel Technology Conference and Exposition; Philadelphia, Pa. www.aist.org

June 6-8
19th China International Heat Treatment & Industrial Furnace Exhibition; Guangzhou, China
www.heattreatmentexpo.com

June 17-20
Powdermet 2018 – International Conference on Powder Metallurgy & Particulate Materials; San Antonio, Texas
www.powdermet2018.org

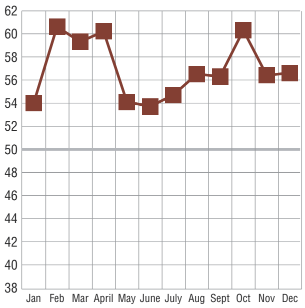
July 30-Aug. 1
International Thermprocess Summit 2018; Atlanta, Ga. www.ihea.org

Sept. 11-12
Forging Industry Technical Conference; Long Beach, Calif. www.forging.org

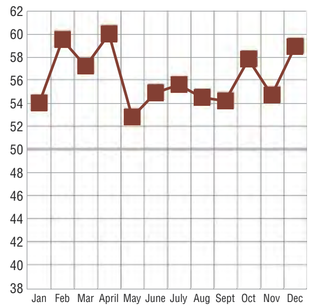
Oct. 8-10
Furnaces North America 2018; Indianapolis, Ind.
www.furnacesnorthamerica.com

ECOMOMIC INDICATORS

REQUEST FOR QUOTE



ORDERS



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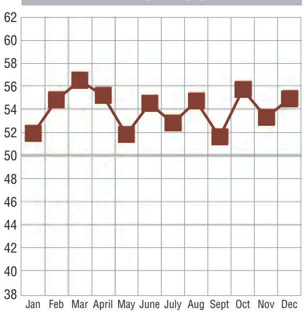
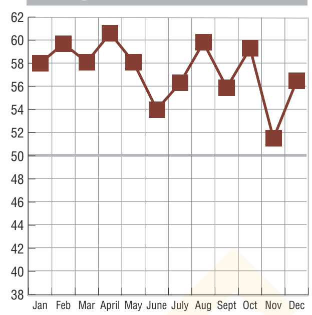


GENERAL HEALTH



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

Case Hardening Under Vacuum with Oil Quenching

Bill Warwick – SECO/VACUUM; Meadville, Pa.

Vacuum heat treating encompasses a wide variety of processes. Case hardening is just one of them. Examples include carbonitriding and carburizing.

Fig. 1. Load of low-pressure carburized (LPC) power-transmission components (SECO/Vacuum Technologies, LLC)

By diffusing carbon into the part surface, followed by quenching of the part, a hard and wear-resistant surface is formed while maintaining a ductile core. Transmission gears, pinions (Fig. 1) and shafts are excellent examples of carburized parts.

How Carburizing Takes Place

After pulling vacuum in the loaded furnace, heating begins as soon as the furnace reaches a preset vacuum level. A partial pressure such as nitrogen, hydrogen or ammonia can be introduced during the heat-up to reduce oxides or to introduce nitrogen into the steel surface to facilitate high-temperature carburizing (PreNit®).

Convection heating at the beginning of the cycle is also common to reduce cycle time. Once the entire part load has reached and is uniformly at temperature, a hydrocarbon gas source is added. Typical gas mixtures include 100% acetylene or acetylene mixtures with other gases such as ethylene, hydrogen and, in some cases, nitrogen. Diluting the acetylene can assist in process control by limiting the process reaction.

Introduction of the gas mixture directly into the hot zone initiates a catalytic decomposition of the acetylene gas on the surface of the parts to be processed according to reaction (1).

$$C_2H_2 \rightarrow 2C + H_2 \quad (1)$$

Once the reaction has taken place, the carbon adsorbed at the surface will start to diffuse into the material according to Fick's second law of diffusion. Because the nature of the carbon saturation is immediate and to control carbide formation in the steel, the gas is injected in short spurts of a few seconds to a few minutes, which is alternated with intervals of either vacuum or inert gas such as nitrogen or argon introduced into the hot zone. During these intervals, the carbon diffuses deeper into the part. This is called a "boost/diffuse" cycle, which is repeated until achieving the proper case depth and carbon profile.

When using acetylene in a low-pressure carburizing (LPC) process, a pressure of 3-10 Torr is typical, and vacuum pumps are used to remove the gaseous byproducts of the reaction from the system. Both the case uniformity and repeatability of the process can be assured through proper control of the carburizing process.

Efficiency of the Process

The availability of carbon in the furnace atmosphere drives the effectiveness of the process, as well as the adsorption of carbon at the part surface and the rate of carbon diffusion into the part.

An example using conventional endothermic-gas carburizing can be seen by looking at the carbon flux (carbon potential) generated from carbon monoxide (CO) and supplemental gases in endothermic atmospheres, usually methane or propane

Fig. 2. Load of hydraulic tool jaws ready for LPC (SECO/Vacuum Technologies, LLC)

(equation 2). Depending on the formation process used, the CO content is in the range of 20-30% of the atmosphere. Subsequently, the supplemental gases make up about 10% of the total flowrate. It must be noted that effective utilization of all of the carbon will not occur.

$$J = -\beta (C_o - C_s) \qquad (2)$$

In this example, J represents the carbon-flux portion of the endothermic atmosphere. It relates proportionally to the carbon transfer coefficient (β) and the difference between both the atmospheric carbon potential and the concentration difference at the surface carbon ($C_o - C_s$). Typically, the force driving this reaction is in the range of about 0.2-1.2%. Knowing this allows us to determine that an endothermic-gas carburizing process will provide up to about 3 g/m^3 of carbon into the process.

By comparison, LPC mixtures offer approximately 60-90% of the available carbon (mass). This promotes a higher potential adsorption force on the surface of the part and is almost 100 times higher than displayed by endothermic gas. Therefore, depending on the hydrocarbon mixture used in the LPC process, about 600-900 g/m^3 are available, giving an approximate 100-fold increase in process efficiency.

Influence of Time

An important process parameter is time at carburizing temperature for carbon to adsorb into the alloy, and it is somewhat dependent on the material being run. The case depth will be determined by the carbon diffusion process (equation 3). The rate of carbon diffusion (J, carbon flux) is dependent on the different carbon concentrations $C_1 - C_2$ (at the unit distance dx), with D being the diffusion coefficient. Limiting this difference between carbon concentrations is the solubility of the carbon into austenite and the carbide-formation limitation, normally to a maximum value of 1.73% C at 1900˚F (1040˚C).

$$J = D\,\frac{(C_1 - C_2)}{dx} \qquad (3)$$

Another process parameter is temperature, the controlling factor of diffusion coefficient (D), which is roughly 50% higher at 1740˚F (950˚C) than at 1700˚F (925˚C), 100% higher at 1800˚F (980˚C) and 200% higher at 1875˚F (1020˚C). Therefore, increasing the temperature of the process significantly reduces the time needed to reach the desired case depth.

Fig. 3. Lathe and machine-tool LPC components (SECO/Vacuum Technologies, LLC)

Fig. 4. LPC furnace running loads of parts (SECO/Vacuum Technologies, LLC)

Table 1. Low-pressure carburizing time as a function of case depth[a]

Effective case depth[b] mm (inches)	Carburizing time (hours:minutes)					
	925˚C (1700˚F)	950˚C (1740˚F)	980˚C (1800˚F)	1000˚C (1825˚F)	1020˚C (1875˚F)	1040˚C (1900ºF)
0.50 (0.020)	1:23	0:57	0:39	0:30	0:24	0:19
1.00 (0.040)	5:30	3:50	2:35	2:00	1:35	1:15
2 (0.060)	22:00	15:10	10:20	8:00	6:10	4:50

Notes: a. SAE 5120 (16MnCr5) steel; b. Effective case depth at 0.35% carbon

Table 2. Microhardness results

Sample No.	Row	Distance, mm (inches)	Hardness (HV1)	Hardness (HRC)	ECD, mm (inches)
80	1	0.1 (0.004)	719	59.5	0.492 (0.019)
		0.3 (0.012)	669	58.7	
		0.5 (0.020)	545	52.1	
		0.7 (0.028)	484	48.0	
		0.9 (0.035)	473	47.2	
81	2	0.1 (0.004)	706	60.4	0.481,(0.019)
		0.3 (0.012)	656	58.2	
		0.5 (0.020)	539	51.5	
		0.7 (0.028)	479	47.8	
		0.9 (0.035)	-	-	

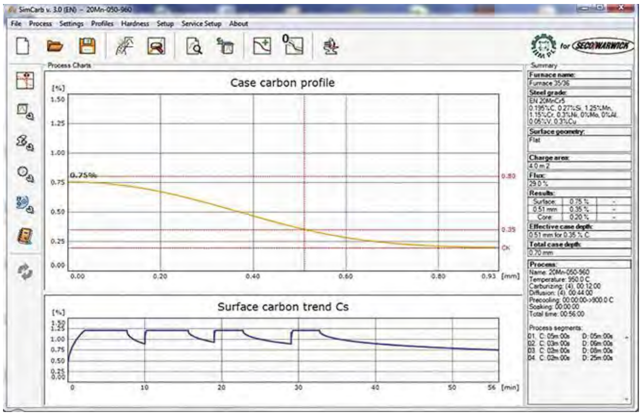


Fig. 5. SimVaC® LPC simulation (SECO/Vacuum Technologies, LLC)

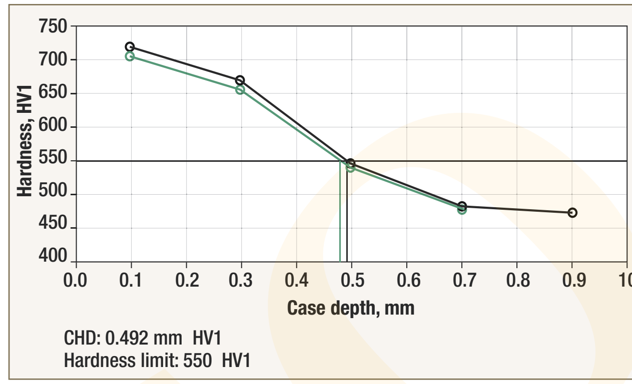


Fig. 6. Microhardness effective case-depth profile (SECO/Vacuum Technologies, LLC)

Running atmosphere furnaces at elevated temperatures will dramatically increase the maintenance needed to keep them operational. The same limitation cannot be said in regard to LPC equipment, whose materials of construction are typically designed for a 2400˚F (1315˚C) maximum operating temperature (well above the carburizing temperature). This is the reason that using the boost/diffuse method at temperatures over 1825˚F (1000˚C) can offer tremendous reductions in process time (Table 1) – up to four- to fivefold as compared to a carburizing processing temperature of 925˚C (1700˚F).

Uniformity of Carburizing

Typical case-depth uniformity for loads in LPC processes is in the order of ±0.0015 inch (±0.038 mm) to ±0.002 inch (±0.050 mm), which is dependent on both the desired case depth and carburizing temperature. To be successful, one must make certain that the parts, when limited by volume or weight (packed densely or lightly), are all uniformly at the process temperature at the beginning of the carburizing cycle. The ability of the hydrocarbon gas to penetrate (by varying pressure levels) and quickly change the carburizing atmosphere (through the use of boost/diffuse methods) will result in this tight case uniformity.

Alternatively, in atmosphere carburizing, case uniformities of ±0.005 inch (±0.127 mm) to ±0.010 inch (±0.254 mm) are typical. It is important to remember that uneven temperature distribution throughout the load will affect uniformity as well. One explanation for this is the effectiveness of the carburizing gases in LPC processing, as already mentioned. In endothermic-atmosphere furnaces, the internal fan circulates the atmosphere in the order of 2-3 m/s.

By contrast, LPC can replace the atmosphere much more frequently, up to once every five seconds (even though the demand for the carburizing mixture is lower). This results in a 100-fold increase (in volume) of gas at pressure of 7.5 Torr compared to atmospheric pressure of 760 Torr. Given the pressure difference in the furnace and the speed of gas particles entering at several hundred m/s (at the gas nozzle outlet), the hydrocarbon gas will fill the entire load within a fraction of a second.

A Metallurgical Advantage

Due to the absence of oxygen in the hydrocarbon gases used in LPC, one of the many metallurgical advantages is the avoidance of intergranular oxidation/intergranular attack. This offers improved mechanical properties (e.g., fatigue strength in gears) while also producing residual compressive stresses at the part surface.

Case Study – Low-Pressure Carburizing

Industrial machinery parts (Fig. 3) of 5120 (20MnCr5) steel are LP carburized (Fig. 4) to an effective case depth of 0.020 inch (0.5 mm) followed by oil quenching and tempering to obtain a surface hardness in the range of 58-62 HRC. The microstructure requested was tempered martensite with finely dispersed carbides, free of grain-boundary oxidation or carbides. Fatigue life was required to be 20,000 cycles.

The process parameters were determined using a LPC process simulator known as SimVaC® (Fig. 5), in which it was suggested that the load be carburized at 1740˚F (950˚C) for 60 minutes and quenched in oil from an austenitizing temperature of 1580˚F (860˚C). After quenching, parts were cleaned and tempered at 350˚F (180˚C).

Each load consisted of 196 parts weighing approximately 150 kg (330 pounds) and occupying 4 m^2 of surface area. The total processing time was five hours, during which the furnace used 260 kWh of electrical energy, 3 kg (6.6 pounds) of liquid nitrogen, 300 g (0.67 pounds) of hydrocarbon gas (acetylene and ethylene), 75 liters (2.6 $feet^3$) of hydrogen and an insignificant amount of compressed air. The furnace runs four cycles per day, or 1,000 cycles per year, producing 200,000 parts. Heat-treatment costs decreased by approximately 30% compared to outsourced heat treatment. Transportation and extra part handling were eliminated.

The process resulted in a microhardness profile (Fig. 6, Table 2) with the following parameters.

- Effective case depth (550 HV, 52.5 HRC): 0.50 mm ± 0.05 (0.020 inch ± 0.002)
- Surface hardness: 61 +/-0.5 HRC

Summary

Low-pressure carburizing is a proven and cost-effective technology whose advantages make it a clear choice to replace alternative technologies such as atmosphere or salt-bath carburizing.

For more information: Contact Bill Warwick, vice president – sales, SECO/VACUUM, 180 Mercer Street, Meadville, PA 16335; tel: 814-332-8561; fax: 814-724-1407; e-mail: Bill.Warwick@SecoVacUSA.com; web: http://www.SecoVacUSA.com

References

1. Korecki, Maciej and Michal Bazel, Emilia Wolowiec-Korecka and Slywester Paweta, "Case Hardening in Modern Vacuum Furnaces," white paper, 2014
2. Herring, Daniel, *Vacuum Heat Treatment Volume II*, BNP Media, 2016

Major Step Forward in Type K and N Thermocouple Performance

Trevor Ford – CCPI Europe Ltd.; Sheffield, UNITED KINGDOM

The base-metal mineral-insulated (MI) thermocouple is the most widely used temperature sensor for industrial temperature measurements and has been for over 80 years. The reasons why this has been and will continue to be the case is due to the fundamentals of the thermocouple itself; that is, it is a sensor that is simple, robust and low-cost with an easily measured output.

Fig. 2. Low-drift mineral-insulated design

The base-metal thermocouple (initially as type K, J, E or T sensors) has been used in the temperature range of -200 to 1000˚C (-328 to 1800˚F) in all aspects of industry from food production to metals processing. Initially in the form of insulated-wire constructions, by the 1940s it took the form of mineral-insulated (MI) thermocouple constructions, which had the effect of providing a more robust device as well as increasing the temperature range of the base-metal thermocouple (Fig. 1).

This was particularly the case for the type K combination for use above 1000˚C (1800˚F). In the 1960s, the development of the type N thermocouple combination pushed the operating temperature range of the base-metal thermocouple even higher, as it gradually became recognized as the base-metal thermocouple combination of choice for work in the region up to 1250˚C (2380˚F).

Thermocouples in the form of a type K or type N have remained the sensor of choice for industry in the temperature range up to 1250˚C due to their overall general performance. This has allowed them to become the most cost-effective sensors in this temperature range and the most widely used by industry.

Due to this long-term experience in industry, the limitations of the base-metal thermocouple are also widely understood. The major issue is that of drift or change in output when exposed to high temperature. The higher the temperature the greater the drift and, therefore, the greater the error when using these sensors for temperature measurements.

Industry has countered this limitation of type K and type N thermocouples by having specifications detailing in-process checking procedures and limiting the operational life of base-metal sensors. Specifications such as the heat-treatment specification published by SAE, AMS 2750, detail the maximum temperature and number of uses after exposure to these temperatures. This is how and why type K and N thermocouples have remained the most cost-effective temperature sensors for industrial applications.

New Development

Today, we can inform you of a major development in base-metal thermocouple technology that will further enhance and strengthen the position of type K and N thermocouples in industry while also increasing the possible temperature range of reliable operation for these industrial sensors. Due to groundbreaking fundamental scientific work conducted by researchers at the University of Cambridge, a new low-drift, high-temperature type K and type N mineral-insulated thermocouple sensor has been designed.

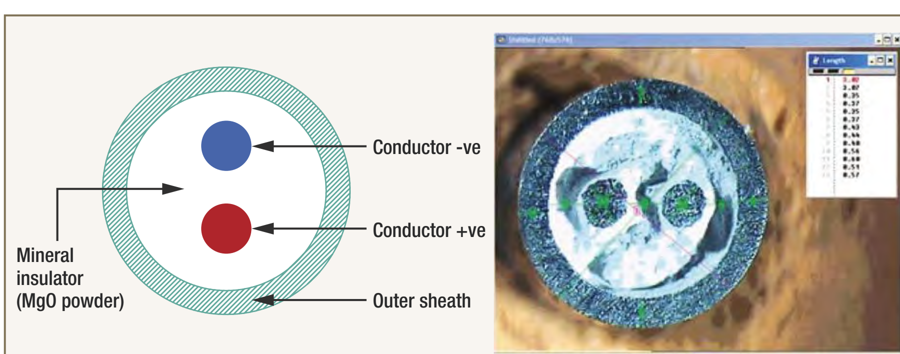


Fig. 1. Conventional mineral-insulated cable construction

The researchers have spent the last six years studying the reasons and mechanisms of drift in these sensors. Once the fundamentals of the actual reasons for the drift had been understood, they turned their attention to applying their extensive expertise to working out how to reduce or stop the main causes of the drift process. As with all the best developments, the concept they arrived at was a very simple one.

Once the concept of this new low-drift type K and type N thermocouples had been developed, the next step was to conduct tests to see how the theory and practice actually worked. Extensive testing was conducted by the laboratories at the University of Cambridge and further independent testing was conducted in parallel by an industrial IEC 17025-accredited calibration laboratory based in the U.K. The results of the testing confirmed beyond doubt how the newly designed type K or type N mineral-insulated thermocouples significantly reduced drift to a level that had not been seen before.

How does the new design work?

Technical publications and white papers written by the researcher responsible for this development, Dr. Michele Scervini, and the technical director of CCPI Europe Ltd., Trevor Ford, have been published. They provide details of the new low-drift MI cable design and the results of extensive testing that confirm the superior low-drift performance of these sensors to any base-metal thermocouple counterpart (Fig. 2).

Why is this new design unique?

Most developments in science, temperature measurement being no exception, are usually at the fundamentals of measurement, such as the development of the new pure-element thermocouple combinations (Palladium v Platinum or Gold v Platinum) that have applications for increasing accuracies in the high-temperature range. As tends to be the case, however, this development will be mainly for operation in the laboratory and not for direct use for industrial applications. This low-drift development in MI type K and N sensor technology not only gives a major leap forward in low-drift temperature-measurement performance but also provides a sensor that can increase the confidence directly in those everyday industrial temperature measurements.

This is one of the first times there has been a major increase in operation performance of an industrial contact temperature sensor that does not require the change of measurement equipment, wiring or procedural use by industrial users to get the dramatic increase. To the user both in appearance and in operation, the new low-drift MI type K and N thermocouple sensors will outwardly appear the same. In fact, the only differences the user will see is the remarkable reduction in drift and, therefore, increase in accuracy measurement performance.

How can this new technology be applied in industry?

As discussed, there are many specifications that have been developed to make sure when existing designs of type K and N MI thermocouples are used for accurate or critical temperature measurements. Drift limitations are minimized by stipulating operational times and temperatures. Unfortunately, these same specifications will result in the slow adoption of this new thermocouple design. Since the new low-drift thermocouple is still designated type K or type N, the specification limitations will still apply. This will result in the user not being able to take advantage of the lower-drift, higher-temperature, higher-stability properties of the sensor.

Summary

How do we make sure 20 years does not pass, as happened with type N thermocouple development, before industry can take advantage of this step forward in temperature-measurement technology? The best way would be for users to write to the relevant standards committee asking them to review current standards limitations on base-metal thermocouples with a view to adding this new design to the standard.

For more information: Contact Pat Durkin, VP sales & marketing, TE Wire & Cable LLC, Saddle Brook, N.J.; tel: 888-349-3662; e-mail: d.p.durkin@tewire.com; web: www.tewire.com

Comparing Argon and Nitrogen Cooling in Vacuum Furnaces

Alex Pohoata – F&B Mfg. LLC; Phoenix, Ariz.

This article provides actual data for testing performed to compare argon and nitrogen as cooling media in vacuum furnaces. The data includes five different highly alloyed materials.

Argon and nitrogen are the most utilized gases for cooling during thermal processing in vacuum furnaces. Nitrogen (AW = 14.0067) is approximately 2.9 times lighter than argon (AW = 39.948). Nitrogen has a faster cool rate (approximately four times faster than argon) and is much cheaper than argon (approximately eight times cheaper). However, nitrogen has a tendency to be slightly decarburizing for steels and to form nitrates at the surface of NiCo alloys at temperatures above 1450˚F.

Most of the aerospace OEMs would rather avoid the usage of nitrogen as cooling gas due to the reasons listed above.

In some specific applications, cooling in nitrogen may have a beneficial effect on mechanical properties of the processed alloys. A good example is related to the cold-forming industry. Some NiCo alloys, such as Inco 625 or Inco X-750, have a tendency of spring-back after the first forming. In order to bring the part to the desired shape, more than one cold-forming operation may be necessary. Typically, an in-process anneal is applied before two forming operations. A faster cooling rate during the annealing process may lower the hardness for some materials, such as Inco X-750.

The purpose of this analysis was to compare the effects of cooling various alloys in argon versus nitrogen on mechanical properties and surface morphology.

Sheet-metal samples were tested in Abar-Ipsen furnaces. The furnace used could cool in either nitrogen or argon at pressures less than 1 bar ("negative" pressure). All the tests concluded that using nitrogen instead of argon for thermal processing metal sheet (less than 0.500 inch think) does not affect mechanical properties of the material, does not create any particular surface contamination (as long as the vacuum chamber is maintained very clean) and, in cases such as annealing of Inco X-750, can reduce the hardness to a desired value.

Background

Five different materials were selected to be tested. Five samples 1 inch wide x 4 inches long x 0.072 inch thick were cut from the material received for each test.

Five samples of each material were processed using argon cool, and five samples of each material were processed using the same recipe but with nitrogen cool.

All the samples were processed one batch after another in the same vacuum furnace with no other parts on that load. The vacuum-chamber pressure was maintained at 0.5 µm (microns) during soak.

The samples were tested for hardness (10 readings, two on each sample). After that they were evaluated for the following mechanical properties: grain size, bend test and surface contamination (depth of intergranular attack and/or intergranular oxidation – IGA/IGO).

Test Results

Testing of Inco X-750 (AMS 5542)

The material was in-process annealed at 1800˚F for 50 minutes. Results for hardness and tensile testing can be found in Table 1.

Table 1. Hardness and tensile results for Inco X-750 and 321 stainless

		Inco X-750		321 CRES	
		Nitrogen	Argon	Nitrogen	Argon
Hardness (HRB)	Average standard deviation	103.2	104.9	70.1	69.1
		0.98	0.36	3.63	3.57
Tensile	Yield (KSI)	89.5	106	28.1	26
	UTS (KSI)	152	166	83.5	84.5
	Elong. (%)	34	30	57	60
	P value	0.000142 signif. diff.		0.561 not significant	

Fig. 1. Incolloy X-750 solution annealed and nitrogen quenched (500X)

Fig. 2. 321 CRES solution annealed and nitrogen quenched (500X)

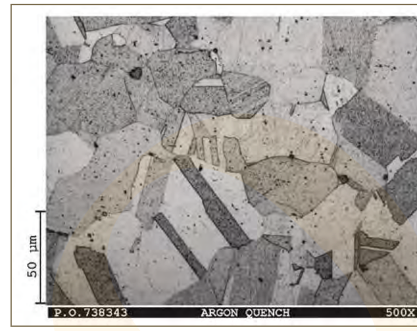


Fig. 3. 321 CRES solution annealed and argon quenched (500X)

Results for bend test – 180° bend over D=2T – are shown in Table 3. Grain size and surface contamination results are also shown in Table 3. The microstructure can be seen in Fig. 1.

Testing of 321 CRES (AMS 5510)

The material was in-process annealed at 1800°F for 30 minutes. Results for hardness and tensile testing can be found in Table 1. Results for bend test – 180° bend over D=T – are shown in Table 3 as well as grain size and surface contamination. The microstructure is shown in Figs. 2 and 3.

Testing of Inco 625 (AMS 5599)

The material was in-process annealed at 1800°F for 60 minutes. Results for hardness and tensile testing can be found in Table 2. Results for bend test – 180° bend over D=2T – are shown in Table 3. Grain size and surface contamination results are also shown in Table 3. The microstructure can be seen in Figs. 4 and 5.

Testing of Inco 718 (AMS 5596)

The material was in-process annealed at 1800°F for 30 minutes. Results for hardness and tensile testing can be found in Table 2. Results for bend test –

Table 2. Hardness and tensile results for Inco 625, Inco 718 and Hastelloy X

		Inco 625		Inco 718		Hastelloy X	
		Nitrogen	Argon	Nitrogen	Argon	Nitrogen	Argon
Hardness (HR15N)	Average	67.4	67.1	42.8	44.6	58.74	58.18
	standard deviation	0.7	0.65	0.43	0.2	0.43	0.048
Tensile	Yield (KSI)	66.5	71.5	189	182	39.9	39.9
	UTS (KSI)	135	136	220	213	104	104
	Elong. (%)	48	47	20	20	52	52
	P value	0.314 not significant		0.00001 signif. diff.		0.018 not significant	

Table 3. Bend test, grain size and surface contamination testing results

		Inco X-750	321 CRES	Inco 625	Inco 718	Hastelloy X
Bend test	Nitrogen	No cracks	No cracks	No cracks	No cracks	No cracks
	Argon	No cracks	No cracks	No cracks	No cracks	No cracks
Grain size	Nitrogen	6.5	9.5	6.5	8	2.5
	Argon	5.5	8.2	7	8	2
Surface contamination	Nitrogen	None	None	None	None	None
	Argon	None	None	None	None	None

Fig. 4. Inco 625 solution annealed and nitrogen quenched (500X)

Fig. 5. Inco 625 solution annealed and argon quenched (500X)

Fig. 6. Inco 718 solution annealed and nitrogen quenched (500X)

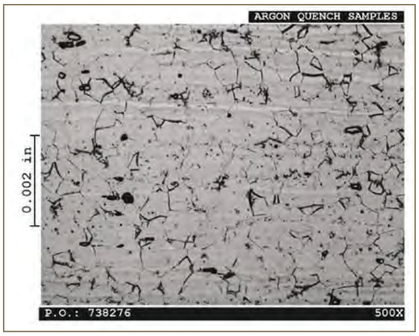


Fig. 7. Inco 718 solution annealed and argon quenched (500X)

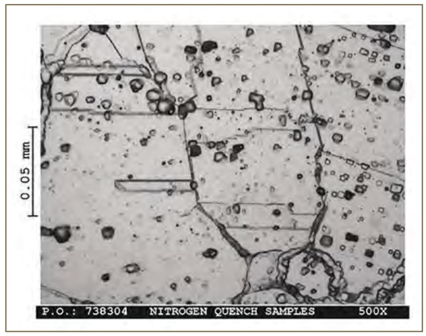


Fig. 8. Hasteloy X solution annealed and nitrogen quenched (500X)

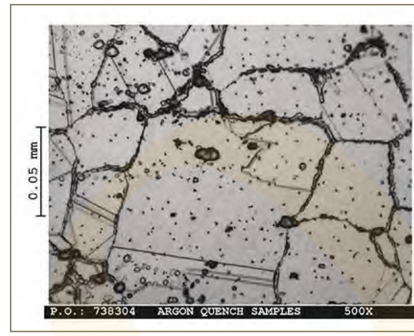


Fig. 9. Hasteloy X solution annealed and argon quenched (500X)

180˚ bend over D=2T – are shown in Table 3. Grain size and surface contamination results are also shown in Table 3. The microstructure is shown in Figs. 6 and 7.

Testing of Hastelloy X (AMS 5536)

The material was in-process annealed at 1975˚F for 15 minutes. Results for hardness and tensile testing can be found in Table 2. Results for bend test – 180˚ bend over D=1.5T – are shown in Table 3 along with grain size and surface contamination results. The microstructure is shown in Figs. 8 and 9.

Conclusions

Cooling Inco X-750 in nitrogen significantly reduced the average hardness as well as the yield and tensile strength. Ductility of the material was increased when compared with cooling in argon. There was no surface contamination and no change in microstructure, grain size and bending capability during cooling in either media.

Cooling CRES 321 in nitrogen showed no significant change when compared with cooling in argon, except a slight refining of the grain size. The surface morphology was not affected.

Cooling Inco 625 in either nitrogen or argon developed practically the same average of hardness, bending capabilities and overall mechanical properties. No surface contamination was identified after processing in nitrogen.

Cooling Inco 718 in nitrogen resulted in a significant decrease in hardness when compared with cooling in argon. No contamination was detected on the test coupon surface.

Cooling Hasteloy X in nitrogen slightly increased the hardness, but all other properties were the same when compared with cooling in argon.

In some specific applications, such as cold forming, when a faster gas cool is necessary during in-process anneal, nitrogen gas can be succesfully used to replace argon. Even though in some cases material properties remained the same, the reduction in the cost of cooling media can be very attractive for the processor.

During this analysis, no contamination and no change in surface morphology of the test coupons used was identified. IH

For more information: Contact Alex Pohoata, special process engineer, F&B Mfg. LLC, 4245 N. 40th Ave., Phoenix, AZ 85019; tel: 602-533-1107; e-mail: apohoata@fbmfg.com; web: www.fbmfg.com

Eddy Current Heat-Treat Validation for In-line Production

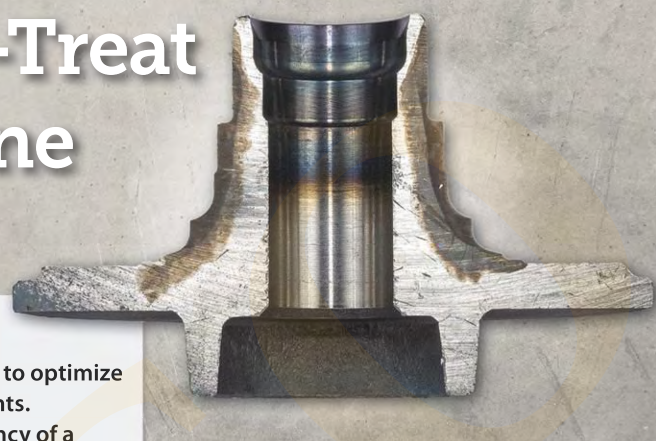


Fig. 1. Sectioned and heat-treated wheel bearing

Dan DeVries – Criterion NDT; Auburn, Wash.

Heat treatment is an invaluable process that allows manufacturers to optimize the mechanical and physical properties of their metallic components. This helps provide a desired level of performance and life expectancy of a product. The end results are tailored by parameters such as heating method, temperatures, cycle times, atmospheres, quench media and tempering.

Heat-treat results can vary due to variations or mistakes in manufacturing processes. Variations can occur from differing temperature zones in an oven, condensation dripping onto parts, bent induction coils and tooling misalignment.

Failure to quickly identify components with improper heat treatment can lead to an increase in both scrap and warranty costs. Here are five recent recalls related to heat-treatment anomalies.

- In September 2017, there was a recall of Hyundai Santa Fe vehicles due to crankshaft assemblies produced with insufficient heat treatment because of an improperly positioned heat-treatment coil.[1]
- In September 2017, SIG SAUER found that a limited number of rifles were built that may have had an improperly heat-treated hammer that could cause a significant safety hazard.[2]
- In June 2016, Meritor issued a recall for a small number of non-drive front steer axles because they may have not received the correct heat treatment. Improperly heat-treated axles could result in fracture and loss of vehicle control.[3]
- In 2015-2016, Dodge found Ram 1500 pickups built within a three-month period with parts of the rear axle shaft that may have been improperly heat treated, which could cause the axle to overheat, wear and fracture.[4]
- In 2014, GM announced a recall of certain model-year pickup trucks due to an improper heat treatment. This could cause the rear axle to fracture while the vehicle is being driven.[5]

Methods to Ensure Heat-Treatment Quality

There are three traditional ways to check heat-treatment quality:

1. Monitor heat-treatment manufacturing processes
2. Sample (batch) testing
3. Continuous (in-line) testing

Monitoring heat-treatment manufacturing involves monitoring the performance of heating and cooling processes. Variances in these processes can signal a potential heat-treatment process failure.

Sample (batch) testing can be accomplished using various methods. Impact (hardness) testing is most commonly used, as well as tensile testing for some critical parts. Rockwell or Brinell hardness testing and Knoop/Vickers microhardness testing are traditional impact-test standards.

In sample testing, microstructural measurements are often needed to obtain qualitative results.[6] Microstructure analysis can be subject to operator interpretation, and image analyzers are often used to improve result consistency.

Microstructure analysis usually involves cross-sectioning a component using a water-cooled metallurgical cut-off saw or water-jet cut-off. Local grinding burns must be minimized during the cutting process.[7]

The cut area is then etched to visually enhance the case pattern in order to obtain a depth measurement. For case-depth measurements, one commonly used etchant is Nital –

Fig. 2. Modern eddy current testing instrument with touch-screen display showing results of multi-frequency testing

a weak solution of nitric acid and alcohol. Figure 1 shows a cut and etched wheel bearing clearly displaying the heat-treatment patterns.

Continuous (in-line) testing involves checking components while on the production line. Integral testing stations are installed downstream of heat-treat and quench processes. Testing systems are integrated with sorting mechanisms to automatically reject out-of-tolerance components. Eddy current technology is one of the primary methods used for continuous in-line heat-treatment validation.

How Eddy Current Heat-Treatment Testing Works

Eddy current testing is based upon electromagnetic induction, which was discovered by Michael Faraday in 1831. It is a standardized testing technique that is widely used in aircraft and nuclear power-plant testing. It has also been used for the last several decades in the automotive, industrial and medical markets.

Eddy currents are used to detect variations in the structure of metallic components. These structural variations can be caused by differing material alloys, component geometry or because components received differing heat treatment.

Unlike the testing processes mentioned in the previous section, eddy current testing is a comparative test, not an absolute test. It doesn't yield a numeric hardness or case-depth value. It merely indicates that a component under test is different from a group of parts with known good parameters. For in-line production testing, this is adequate to identify components that fail defined quality standards.

Fig. 3. Gear passing through an eddy current coil

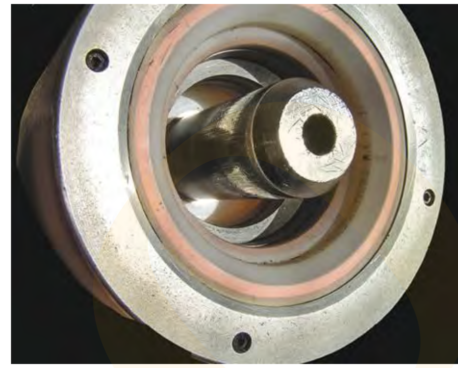


Fig. 4. Multi-coil probe for testing wheel bearings

Eddy current testing offers the advantage of testing every single part while on the production line. With batch testing, if a problem is discovered the entire manufacturing run or "lot" is then suspect and must be tested, reworked or scrapped.

Eddy Current Production Testing Systems

A typical eddy current production testing system consists of an eddy current instrument, test coils or probes, mechanical fixturing and a material-handling system. A typical eddy current instrument contains eddy current coil drivers, digital signal processing circuitry and computer processing to rapidly identify when material structure differences have been detected. The instruments also have communication interfaces to PLCs, which activate material-handling system sorters to remove noncompliant products.

Newer eddy current systems have easy-to-use touch-screen user interfaces (Fig. 2). Automated setups using multiple frequency selections help to ensure that multiple variations can be identified. Older eddy current systems were often difficult to set up and manage, which resulted in manufacturers not using systems to their full potentials.

Eddy current coils consist of copper magnet wire that is wound into a desired shape. This coil is energized by the eddy current instrument at multiple frequencies and generates eddy current flow within the component under test. Figure 3 depicts a gear passing through an eddy current coil.

Often, a second eddy current coil housing with a known "good" component is also

What makes eddy current technology unique?

- Testing is fast. Typical testing times are in the millisecond range, which makes it perfect for in-line testing. For small parts like pins or balls, testing can be integrated with a feeder or sorter mechanism that can test several parts per second. For larger parts, you are only limited by time for part handling.
- Testing is repeatable. Eddy current tests are consistent and don't require an operator to make a human judgment. Consistent mechanical positioning is required to ensure accurate and consistent results.
- Testing is easily integrated into production lines. Modern eddy current instruments are made to integrate right into production lines. They communicate with material-handling PLCs to work in conjunction with robotics and sorting devices. Instruments can be programmed to stop assembly lines when consecutive heat-treat anomalies are discovered.
- Testing is clean. There is no need to apply couplants for testing. It is not necessary to wash parts clear of oils or cutting fluids prior to testing.

Fig. 5. Small-parts sorting unit

Fig. 6. Epson robot and demo gear test station *(courtesy of Schneider & Co.)*

connected to the eddy current instrument. This reference part helps to increase test sensitivity of the eddy current system.

Eddy current probes can be configured with one or more windings that surround the part under test. Some smaller parts can be quickly passed through a coil for high-speed sorting. Complex components can be evaluated with a multi-coil probe (Fig. 4), providing results within fractions of a second.

Fixturing and Material Handling

Eddy current coils must also consistently align with every component under test. Stainless steel guides and rings are often used to provide positive locating on the part as well as prevent damage to the coils within the housing.

For small, simple components, a sorting mechanism (Fig. 5) is often an adequate solution. For larger or more complex parts, a dedicated material-handling system or robotic system is often implemented.

Figure 6 shows a SCARA-type robot made by Epson and a demonstration test station that has been set up for testing differential cam/side gears. The robot is programmed to pick up a part from the tray on the left and place it into the eddy current coil closest to the robot. The second eddy current coil holds a "reference master" that is used as part of the differential comparison test.

Valve Case Study

An engine valve manufacturer's process involved hardening the tips of the valve to ensure durability over the life of the automotive engine. Before using eddy current, valve-tip hardness testing was performed using statistical batch-testing methods. This involved gathering samples of the recently hardened parts and destructively examining them. Test methods included Rockwell testing as well as visual inspection (cut, polish and etch).

Several months after installing an eddy current test system, 300 valves in a row were suddenly rejected. The production line was stopped, and the valve tips were examined with a Rockwell test and found to be "soft." Upon cutting, polishing and chemically etching, the parts visually showed an incorrectly located heat treatment. The cause was found to be a mechanical misalignment on the induction hardening machine. A guide rail had loosened, resulting in a heat-treatment zone intended for the upper valve shaft and tip to be located further down the shaft than desired.

Conclusion

Eddy current testing is a good way to ensure that all components on a production line are validated for proper heat treatment. This technology also helps save time and money by reducing both scrap and warranty costs associated with improperly heat-treated components.

For more information: Contact Dan DeVries, director of marketing at Criterion NDT, 3702 W. Valley Hwy, Auburn, Wash.; tel: 425-891-5163; e-mail: dan.devries@criterionndt.com; web: www.criterionndt.com. USA-based Criterion NDT specializes in providing engineered eddy current solutions for hardness verification and flaw detection.

References available online

Across International

Founded and headquartered in New Jersey, Across International supplies laboratory equipment for heat treatment and material processing. Our equipment can be found in universities, research facilities, and laboratories all over the world. We have more than 25 years of industrial manufacturing experience, including induction heaters, drying ovens, ball mills, laboratory furnaces and pellet presses.

Customer satisfaction is always our top priority. We respond to all inquiries within the same business day. We offer lifelong technical support for all of our machines, in addition to our excellent customer support. Our knowledgeable sales team will help you select the perfect equipment for your project. We base our recommendations on your application's specific requirements so that you can be certain the job gets done properly every time.

Ajax TOCCO Magnethermic Corp.

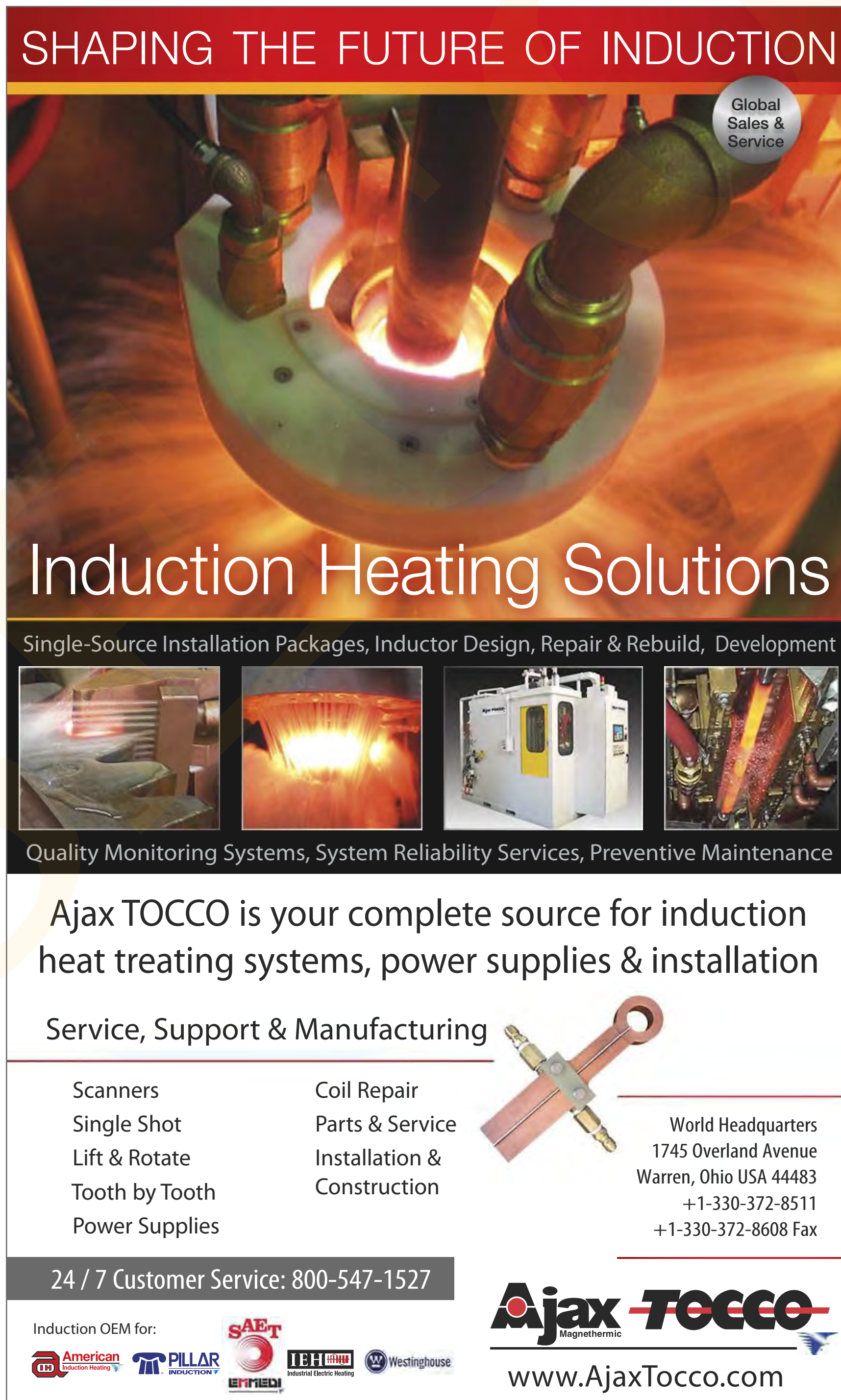
Ajax TOCCO induction heating systems are used throughout the world for hardening, annealing, stress relieving, tempering, brazing, bonding, shrink fitting and many other processes requiring fast, efficient, economical heating. These processes are being applied to virtually any metallic shaped parts, ranging in size from fractions of an inch to substantial lengths and diameters.

As pioneers in induction heat treating, Ajax TOCCO continues to shape the future of induction. Our group of companies will analyze customer requirements to provide the most reliable, efficient and cost-effective solutions to meet their needs.

Ajax TOCCO has over a century of combined, proven technical development and experience and specializes in a wide range of heat-treating applications, including:

- Axles
- Bars
- Bearings
- Camshafts/crankshafts
- C.V. joint components
- Cylinder liners
- Gears/sprockets
- Hand tools
- Mill rolls
- Pins
- Pistons
- Shafts/rods
- Tubes
- Valve seats
- Wheels, hubs/spindles

Ajax TOCCO Magnethermic®, a subsidiary of ParkOhio Holdings Corp.®, designs and manufactures world-class induction heating and melting equipment for various industries and applications throughout the world.



ALD Thermal Treatment

Improved Materials, Enhanced Fatigue Resistance for Gear Components

To answer the demand for fuel-efficient vehicles, modern gearboxes are built much lighter. Improving fatigue resistance is a key factor to allow for the design of thin components to be used in advanced vehicle transmissions. The choice of material and the applied heat-treat process are of key importance to enhance the fatigue resistance of gear components.

By applying the technology of low-pressure carburizing (LPC) and high-pressure gas quenching (HPGQ), the tooth root bending strength can be significantly enhanced compared to traditional heat treatment with atmospheric carburizing and oil quenching.

Besides heat treatment, significant progress has been made over the past years on the steels being used for gear components. The hardenability of case-hardening steels such as 5130H, 5120H, 20MnCr5, 27MnCr5 and 18CrNiMo7-6 has been increased in recent years. An important factor for fatigue resistance is the grain size after heat treatment. Therefore, grain size control is a key goal when developing new modifications of steel grades.

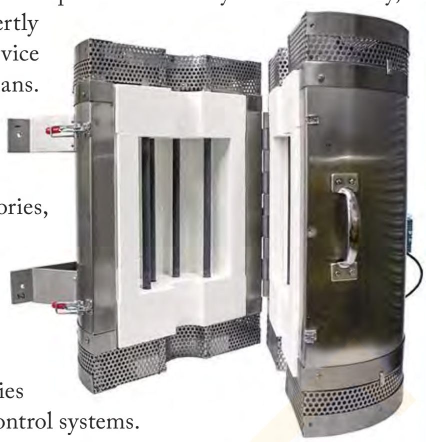
After enhancing grain size control, it was possible to increase the carburizing temperatures over the past years from 930°C to 980°C (1700°F to 1800°F), which resulted in shorter heat-treatment cycles and significant cost savings.

With the introduction of new microalloyed steels for grain size stability, carburizing temperatures can now be even further increased to temperatures of up to 1050°C (1920°F), leading to even more economic process cycles. By adding microelements such as niobium or titanium in the ppm-range, nitride and carbonitride-precipitates are formed. These precipitates effectively limit the grain growth during the heat-treatment process.

TECHNOLOGY SPOTLIGHT

Applied Test Systems

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



TECHNOLOGY SPOTLIGHT

Centorr Vacuum Industries

Centorr Vacuum Industries is a high-temperature vacuum/controlled atmosphere furnace manufacturer with an installed base of more than 6,500 units worldwide. Their furnace offering ranges from large commercial and production units with hot zones over 3 m x 3 m (9.8 feet x 9.8 feet) to smaller lab and research-and-development furnaces for use at temperatures over 3500°C (6332°F). They are located in Nashua, N.H., with a fully staffed Aftermarket Field Service group and an Applied Technology Center offering R&D support and toll production service.

Custom Electric Manufacturing Co.

The Value of Experience

Custom Electric Manufacturing Co. produces heating elements for electric thermal-processing equipment. Products include: bayonet heating elements, ribbon and strip heating elements, plug/rack heating elements, rod overbend elements and modules, helical coil heating elements, tubular and silicon-carbide elements, immersion heating elements, and elements for temperatures ranging from 200° to 2280°F.

The successful performance of these products in a broad range of applications reflects the experience Custom Electric brings to the marketplace.

Element Design Experience

Custom Electric's element design group has more than 70 years of electric thermal-processing experience. It has designed elements for most types of electric heating equipment and most industrial heating applications. Seventy years of problem-solving experience translates to quick solutions for issues related to equipment performance and element replacement downtime.

Element Alloy Experience

Custom Electric fabricates elements from most electric resistance alloys, including high-temperature Fe/Cr/Al alloys. Experience in how these materials perform in different environments enables engineers to recommend alternative alloys. The benefits of upgrading include longer element life and lower thermal-processing costs. A large inventory of wire, rod and strip ensures that alloys necessary to fill orders are in stock.

Element Manufacturing Experience

Custom Electric has 45 years of element manufacturing experience. Its methods of production are continuously refined to maximize efficiency and enhance quality. Manufacturing and scheduling experience mean emergency orders ship within 48 hours without delaying normal production.

Application Experience

Custom Electric heating elements support dozens of heating applications, including aluminum die casting, heat treating, drying and curing, and glass tempering. We know the types of equipment our customers use and the heating processes performed. We also visit customer plants to keep current with changing requirements. One result of such visits is expansion of the element repair program. In many instances, damaged elements are returned to service for half the cost of a new element.

Experience-Based Performance

The value of experience is superior heating-element performance. Take advantage of Custom Electric's experience. Talk to Bob Edwards, Vic Strauss or Bob Fouquette today.

Bob Edwards, president

Vic Strauss, VP, engineering

Bob Fouquette, chief engineer

Fe/Cr/Al immersion elements and silicon nitride tubes are designed for molten metal applications like aluminum die casting.

Custom Electric manufactures open coil heaters from Ni/Cr and Fe/Cr/Al alloys for service at temperatures up to 2280°F.

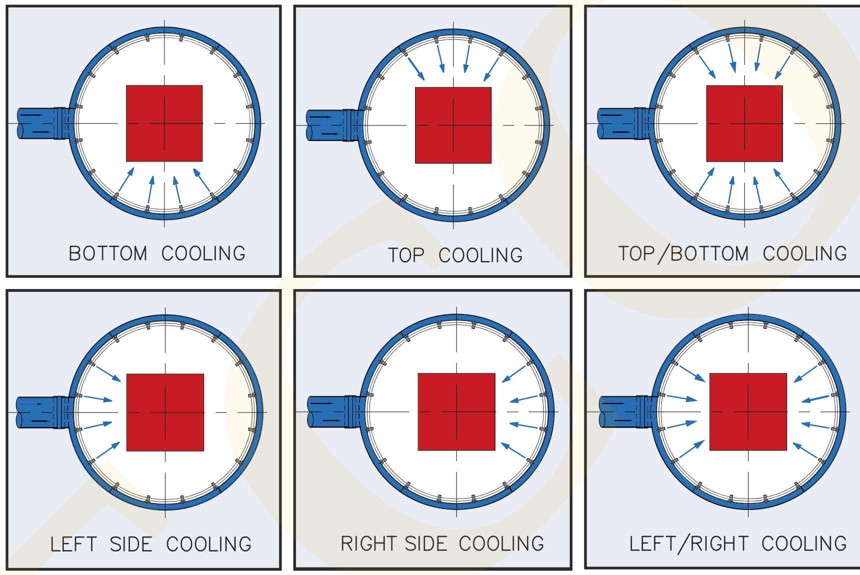
G-M Enterprises

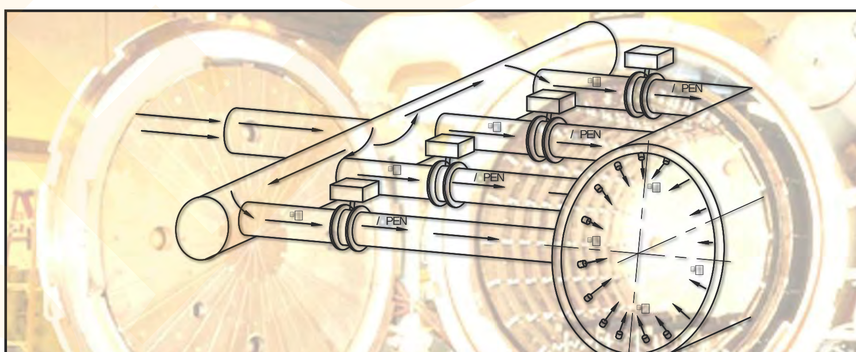
The technological advancement in controlled and directional flow of cooling gases in a vacuum furnace without internal moving parts provides unparalleled metallurgical and physical results.

The Quantum Quench™ – 4 Directional Gas Flow without internal moving parts is a breakthrough in controlled and uniform cooling while controlling distortion. Generally, gas flow direction affects how heat is extracted from the part.

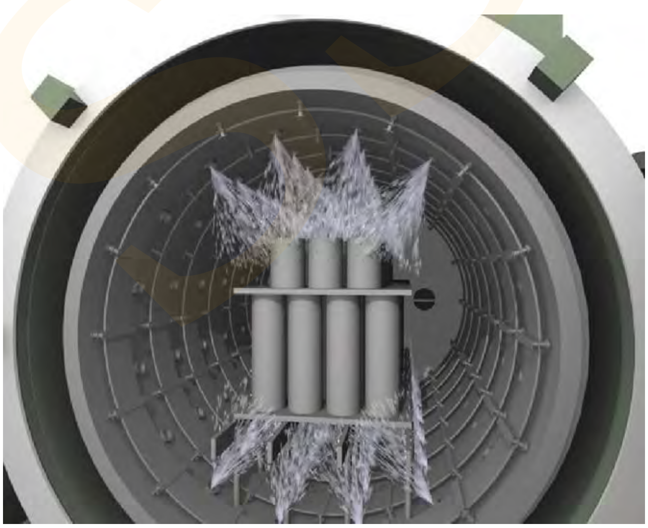
- A part exposed to top to bottom cooling gas flow will have a cooler top surface
- A part exposed to bottom to top cooling gas flow – the bottom surface is cooler
- A side-cooled part will be cooler on the gas-admission side

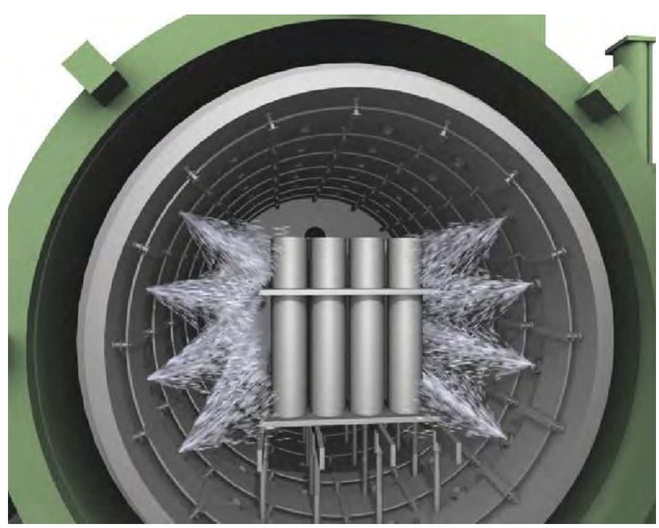
G-M Enterprises has the resources – developing new products, timely manufacturing and prompt service – to consistently meet its customer's heat-processing needs. G-M's experience, field-service maintenance, installation and aftermarket parts support helps add value to every system it designs and builds.





Quantum Quench™ – 4 Directional Gas Flow outline diagram





TECHNOLOGY SPOTLIGHT

Delta Cooling Towers

We are introducing our new anti-microbial (AM) cooling tower, which minimizes Legionella risk. According to test results from Special Pathogens Laboratory, The Legionella Experts, our tower displays the only anti-microbial activity against Legionella bacteria out of all the common cooling-tower materials. We begin manufacturing with anti-microbial resin, which is fully compounded into base cooling-tower casing and fill material. Our anti-microbial additives operate on the cellular level to continuously disrupt and prevent uncontrolled growth of the microorganisms and biofilm.

TECHNOLOGY SPOTLIGHT

Grieve Corp.

No. 954 is an electrically heated 2000˚F (1093˚C) inert-atmosphere, heavy-duty box furnace that can be used for heat treating titanium. To heat the load, 57 kW are installed in nickel chrome wire coils, supported by vacuum-formed ceramic fiber. Workspace dimensions measure 30 inches wide x 48 inches deep x 30 inches high. The oven's 7-inch-thick insulated walls comprise 5 inches of 2300˚F ceramic fiber and 2 inches of 1700˚F ceramic fiber, while the 6.5-inch floor insulation comprises 4.5 inches of 2300˚F firebrick and 2 inches of 1200˚F block insulation. Controls include a digital programming temperature controller, manual reset excess temperature controller with separate contactors and a strip chart recorder.

Ipsen

PdMetrics® Software Platform with Augmented Reality

"After installing PdMetrics, it notified us that a heating element on the diffusion pump – while not failing – was not performing properly. In the past, we might not have known something was wrong until it failed. This time, though, we were able to quickly replace the heating element without any lost production time."

Many of you have probably imagined a tool that allows you to anticipate disruption. Or a tool that gives you the power to optimize equipment performance and production efficiency. Well, much like this customer discovered, the PdMetrics software platform for predictive maintenance is that solution.

Unique in the thermal processing industry, PdMetrics notifies users when maintenance or further actions are required. For example, rather than replacing hot zone components based on how much time has passed, PdMetrics algorithms analyze a variety of data points to let users know at the earliest possible time that the hot zone has begun to show signs of deterioration.

Keeping companies ahead of the industry curve, the PdMetrics platform can augment and redefine your day-to-day operations, resulting in optimized furnace performance and minimized downtime. Developed as a way to create value from the wealth of data available on your equipment, it utilizes proprietary sensors and control algorithms to deliver comprehensive predictive maintenance for your equipment.

New developments to the PdMetrics platform, such as augmented reality (AR), will also transform the way operators experience their equipment and perform maintenance. Imagine sending out a service technician to repair a piece of equipment. With the addition of AR, he can see its past service history, an[illegible] other service technicians access step-by-step troubleshooting instructions and view a digital overlay of the equipment he will be repairing. Not only does he have all the necessary information to make an accurate diagnosis, but he also knows exactly what steps to take.

PdMetrics also connects factories globally in a way not possible before. This is accomplished with the platform's ability to integrate with multiple furnaces as well as smart connectivity that allows you to receive alerts via email and text message. This makes it increasingly simple to monitor not just multiple furnaces within one location, but also furnaces within different facilities around the world.

That's a solution you can rely on to optimize your business and maximize your success. Discover the power of predictive maintenance at go.IpsenUSA.com/Augmented-Reality.

TECHNOLOGY SPOTLIGHT

I Squared R Element Co.

Developed in response to customers' increasing needs for higher-performing SiC heating elements for use in more technically challenging applications, we are proud to introduce Starbar-type HDS and HDS-LMA.

Starbar HDS and HDS-LMA are high-density (2.65-2.7 g/cc), high-strength recrystallized silicon carbide rod-type heating elements that exhibit exceptional oxidation resistance, which leads to extremely slow aging in service and very long element life.

HDS-LMA is an HDS element infused with LMA glaze coating for even higher levels of protection for use in chemically aggressive furnace atmospheres containing water vapor, alkali metal species and flux vapors and in applications that utilize oxygen enrichment.

HDS-type elements have a very strong, robust crystal structure that has been developed for optimum performance.

TECHNOLOGY SPOTLIGHT

Protection Controls Inc.

Combustion Safeguards

Protection Controls Inc. offers this comprehensive Service Manual covering all PROTECTOFIER combustion safeguard units. It provides important and valuable information on installation, service guides, testing and troubleshooting, as well as specifications, features and application on Protection Controls' single and multi-burner units.

Protectofier provides continuous, automatic protection against buildup of combustible fuel mixtures due to flame failure or other faults in furnaces, ovens, boilers and other heating equipment. The system is used in any application where gas or oil burners are used. This includes heat-treating furnaces, paper and textile dryers, glass and brick kilns, dryers, air make-up heaters, thermal oxidizers and afterburners, crematories, and many more.

Solar Manufacturing

Solar Manufacturing stands out above our competition. Since 2002, our trail-blazing ingenuity has led the heat-treating industry with advances in energy-efficient hot zone designs, feature-rich SolarVac® interactive furnace controls and high-performance gas quenching systems. At Solar Manufacturing, we are constantly looking for ways to improve furnace performance.

Take our HFL-SSQ series, for example, with our high-pressure gas quenching system. We strive to make our hardening furnaces achieve better results utilizing higher quench pressures, direct-exit, sliding radiation baffles for an unrestricted gas flow path, higher gas velocity and available low-pressure gas carburizing.

The HFL-SSQ is a horizontal, front-loading vacuum heat-treating furnace with high-pressure gas quenching designed for high-production commercial and captive heat-treating shops. It is a high-temperature, high-vacuum, batch-type furnace with electrical resistance heating elements. The new and improved, high-performance internal gas quench system provides the highest efficiency gas flow in the industry for rapid cooling at pressures up to 135 psig/20 bar. An appropriately sized motor drives a high-speed radial fan to recirculate the quench gas straight through the water-to-gas heat exchanger and then into the hot zone at high velocity. The unique, tapered graphite gas nozzles are positioned to direct quench gas at the workload for optimum cooling. All aspects of form, fit and function are designed for easy maintenance and minimal downtime.

When you need a new furnace, we've got you covered with models in a wide range of sizes – from the compact Mentor™, our not-so-typical laboratory-size furnace loaded with standard production furnace features, to the very large HCB series of vacuum car-bottom furnaces uniquely designed to process large workloads of up to 150,000 pounds and 48 feet long. We also offer horizontal front-loading and vertical bottom-loading furnaces of various sizes.

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, responsive spare parts, field service or a maintenance contract, we are here to provide you with reliable support.

Our ability to create outstanding value is fueled by our experienced staff and our unique relationship with our affiliate company, Solar Atmospheres, a progressive commercial heat treater with four U.S. facilities and a vast number of operating vacuum furnaces. Our affiliation affords us an unparalleled testing ground for improving furnace design, operation, repair and maintenance. Together, we develop new solutions to vacuum processing applications and advance the art and science of vacuum furnace technology.

Some say it's thinking outside the box; we call it ingenuity.

TECHNOLOGY SPOTLIGHT

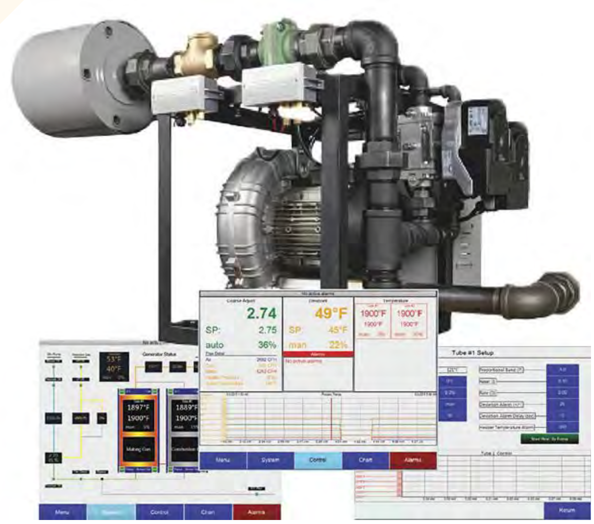
ADVERTORIAL

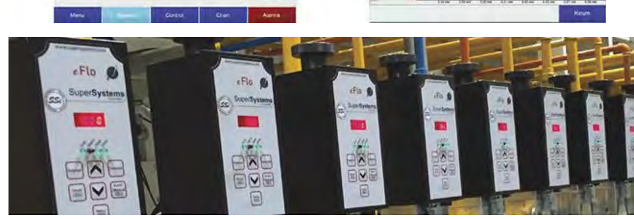
Super Systems Inc.

Super Systems Inc. provides a worldwide presence supporting thermal applications with offices around the globe. Stemming from our expertise in atmosphere control and engineering services, we have brought flow control and measurement to our suite of products. Covering applications such as atmosphere furnace control, nitrogen methanol mixing systems, endothermic generator demand systems and a plethora of standalone flow meters, we are now addressing control and monitoring gas and liquids used in heat treating worldwide.

*e*Flo 2.0 is SSi's newest electronic flow measurement instrument. *e*Flo 2.0 is designed for the harshest industrial environments, allowing for easy replacement of manual flow meters and seamless integration into existing control systems. *e*Flo 2.0 features Bluetooth connectivity, pressure and temperature compensation, inlet/outlet pressure display and more in a compact footprint.

For endothermic generator control, SSI's AutoGEN represents the latest technology in controls utilizing sophisticated flow loop algorithms to perform demand-based control. AutoGEN is designed to fully automate generator control including temperature, dew point, air/gas flow and automatic turndown. AutoGEN is easily configured for single or multi-tube generators and provides an easy-to-use interface with visibility of all configuration parameters, process variables, current/historical charts, alarms and inlet/outlet gas flows.





Surface Combustion Inc.

Surface Combustion has provided customers rugged, long-lasting equipment based on our technical and practical experience since 1915.

Innovation is a tradition at Surface. More than 675 patents and 75 registered trademarks support our technical accomplishments. Surface remains highly dedicated to the pursuit of new technology through extensive internal research efforts and partnering with leading consortia like the Center for Heat Treating Excellence (CHTE). Technologies that customers can use and that meet Surface standards of rugged reliability are important to our present-day development objectives.

Many of Surface's technological successes have manifested themselves in our diverse vacuum furnace line. For example, Surface manufactures vacuum furnaces incorporating patented low-pressure carburizing (LPC) and gas heating solutions. We are one of the first companies to bring ion (plasma) nitriding and carburizing to market. Surface also provides our own line of vacuum process controls and instrumentation that meets AMS 2750E requirements.

Power Convection® (PC) Single-Chamber Vacuum Hardening Furnaces

The PC is designed to be rugged and deliver workhorse performance. Its hearth holds up to "rough" handling by furnace operators and is designed for heavy loading (an industry-leading 4,000 pounds in the 36-48-36 model). Additionally, Surface provides ample clearance between the load and the elements/inner chamber to prevent unfortunate loading accidents.

Maintenance can be completed on the PC in hours. Inner chambers are designed to last 3-5 years and many exceed that life span. The inner chamber framework offers high resistance to wind erosion. The reliable heating design utilizes a rugged and trouble-free variable reactance transformer (VRT). The furnace casing water jacket spacing is large to reduce risk of blockage.

The PC temperature uniformity performance is tight (+/- 10˚F or better) over a wide range (1000-2400˚F). The space from the elements to the load not only provides ample clearance during loading, but uniform radiation view factor for uniform temperature. Arched heating elements provide greater heat release and encompass a larger work envelope than polygon-shaped heating elements. Surface engineers have minimized element supports and feed-throughs, thus reducing heat losses.

The cooling performance is enhanced as the PC is designed for maximum wind flow velocity through the workload for 2- or 6-bar cooling. Surface's direct internal wind flow velocity pattern provides the PC with faster cooling rates, even with a larger work area and a smaller, more efficient fan.

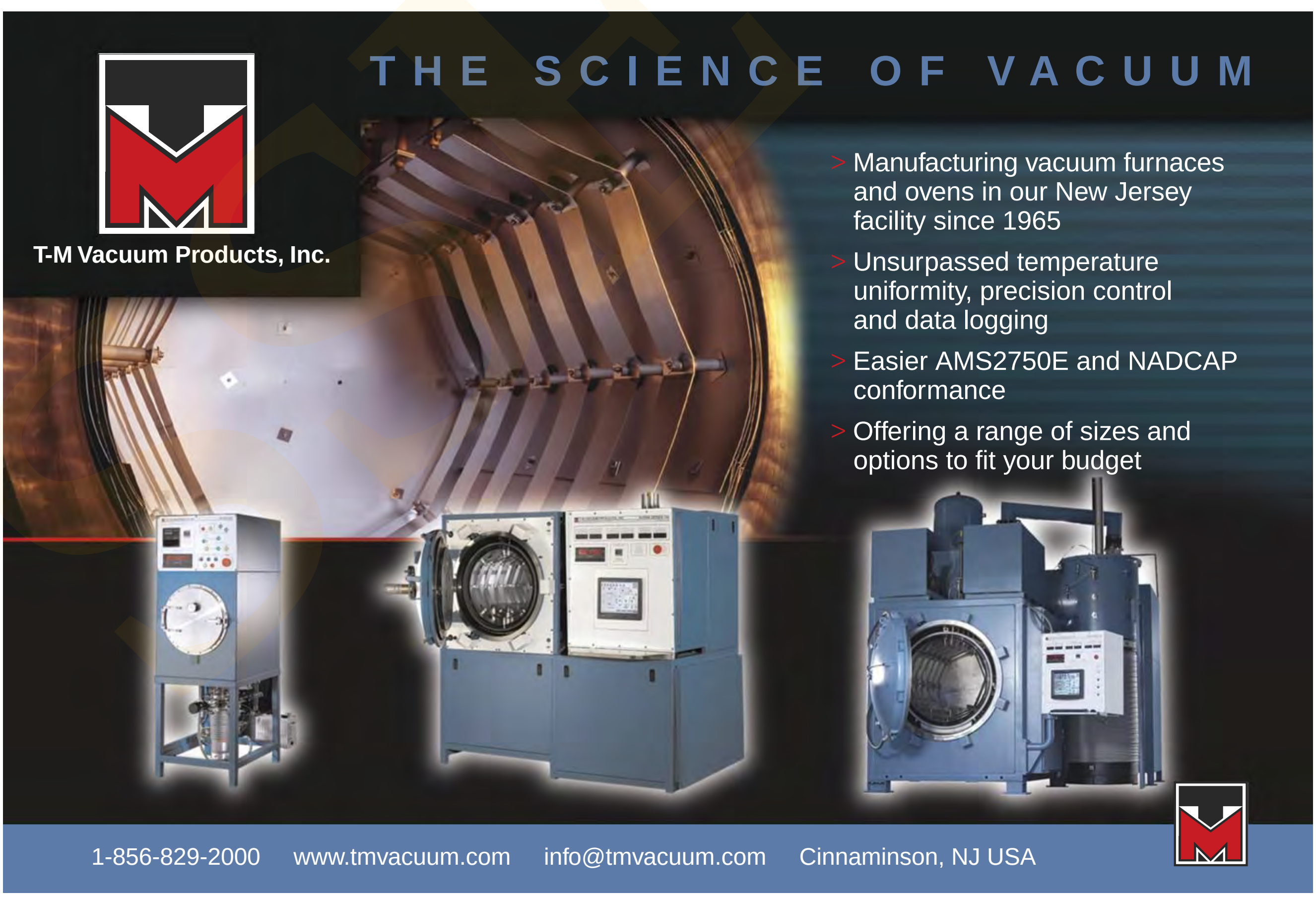
VacuDraw® Vacuum Tempering Furnaces

The VacuDraw is the right furnace for low-temperature vacuum processing. Tempering or aging parts in a vacuum furnace designed for high-temperature processing results in longer cycle times due to slower heating rates versus the higher convection heating of the VacuDraw. Furnaces designed to operate at high temperatures often have poor temperature uniformity at lower temperatures (<1200˚F). After installing a VacuDraw, one customer saw a reduction in tempering time from 18 hours to 8 hours, and the parts had tighter tolerances and more predictable test results due to better temperature uniformity. Surface has recently further improved the cooling performance of the VacuDraw with 2-bar cooling, thus improving floor-to-floor time.

T-M Vacuum Products

A pioneer in the high-vacuum heat-treating industry, T-M has been manufacturing high-vacuum furnaces and ovens since 1965 in our New Jersey facility. Our furnaces come in a work-zone sizes ranging from 2-36 cubic feet with operating temperatures from 200°C (392°F) up to 2000°C (3632°F) with ±3°C temperature uniformity available in most models. We offer vacuum/pressure levels to 10^{-8} torr/6 bar.

Our furnace systems come with full computer control and data logging, and our ovens come with PLC/color touch-screen interface control and data logging. We offer a wide range of sizes and options to fit your budget.



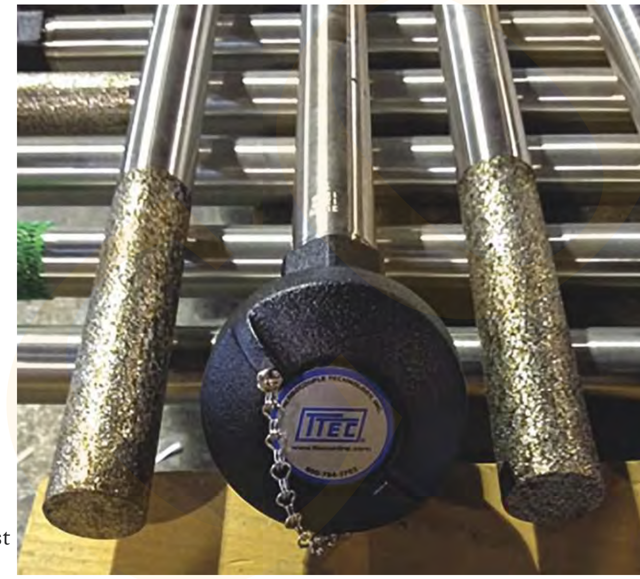
Thermocouple Technology

Thermocouple Technology offers a revolutionary MVD Tungsten Carbide Treatment for thermowells, protection tubes and other critical components.

The product is used to create a stronger, long-lasting product. The Tungsten Carbide is fused with the thermowell material and becomes an integral part of the mass of the well, resulting in a substantially harder and more durable product. The treatment is specially designed for highly abrasive/erosive environments with temperatures ranging from 0-2000°F in typical applications and as high as 2350°F when utilizing their highest performance alloys as the substrate.

The MVD Treatment increases the life of the elements by 2-4 times in most applications, with some applications lasting more than 10 times as long. MVD has been tremendously successful in extending the lifespan of protection tubes, thermowells and multipoint assemblies found in coal-fired power plants across the world.

Thermocouple Technology uses this superior product upon request and is capable of treating applications up to 50 feet in length.



ULVAC Technologies

ULVAC designs and manufactures vacuum pumps, leak detectors and instruments for heat treating and R&D that utilize vacuum technology. ULVAC also produces systems for vacuum brazing, precision metallurgy, automatic leak testing and vacuum processes that are used in many industrial markets.

Industrial Vacuum Pumps

The ULVAC VS650A/750A is a robust, install-anywhere industrial vacuum pump with speeds up to 750 m^3/h. Designed for low-vibration operation, these pumps feature air or water cooling for added convenience.

Fast Leak Detectors

The ULVAC Heliot 900 helium leak detector has the fastest pumping speed for helium so that you can find smaller leaks quickly. Fast response time, fast background cleanup and a tablet-style touchscreen makes the Heliot easy to use while improving productivity.

Wisconsin Oven
Horizontal Quench System

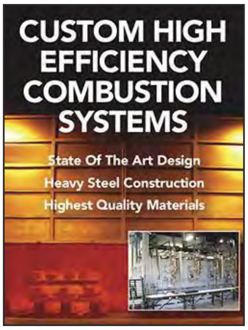
Wisconsin Oven Corp. designs and manufactures horizontal quench systems for heat-treating applications. These systems are a cost-effective alternative to a drop-bottom furnace for applications requiring a quench time of 7-15 seconds (depending on load size and customer requirements). It is available in 10 standard sizes, has maximum temperature ratings up to 1400°F and provides excellent temperature uniformity. The horizontal quench system has standard load capacities of up to 6,000 pounds. These features, combined with its range of quench times, make it ideal for a wide range of solution heat-treating applications.

A high-capacity recirculation blower, along with fully enclosed and pressurized supply ducts, delivers heated air with a combination airflow arrangement. This type of uniform airflow ensures even heat distribution throughout the work chamber and excellent temperature uniformity. Optional PLC control, data acquisition, trending and reporting are also available.

The standard operating procedure for a horizontal quench system is similar to that of a drop-bottom furnace. Parts are loaded on a work grid located on the rollers (quench platform). An electric pusher/extractor mechanism pulls the load into the furnace for heat treating. After the heating cycle is completed, the pneumatically operated vertical lift door is opened and the extractor mechanism pushes the load onto the quench platform. Then the load is quenched. An optional two-tier quench platform will allow one load to be charged into the furnace while another load is quenched. These systems can be designed for manual or automatic operation.

There are many benefits to a horizontal quench system compared to a drop-bottom furnace. Horizontal quench systems are easier to service and maintain due to the fact that most components are on or near floor level. They also cost, on average, 25-50% less when compared with a similar-sized drop-bottom furnace.

All units are fully factory tested at maximum temperature and adjusted as necessary to obtain the temperature uniformity required. A systematic evaluation utilizing a checklist with more than 150 points is utilized to ensure the equipment meets all of our quality standards and complies with the customer's scope of supply. This attention to detail results in reduced installation and start-up times, which lowers the overall cost of ownership.



Custom High-Efficiency Combustion Systems

Air & Energy Systems

We custom design our 300-2300°F systems to our customers' specifications and offer turnkey manufacturing and installation. We have been providing quality heat-processing equipment to the thermal-processing industry for more than 30 years.

www.AirAndEnergyInc.com

Combustion Safeguards

Protection Controls Inc.

This comprehensive Service Manual covers all PROTECTOFIER combustion safeguard units. It provides important and valuable information on installation, service guides, testing and troubleshooting as well as specifications, features and application on Protection Controls' single and multi-burner units. For a free copy, fax 847-674-7009.

www.protectioncontrolsinc.com

Materials Testing Equipment

Applied Test Systems

This brochure gives an overview of ATS' extensive line of affordable yet uncompromising materials testing equipment. ATS is large enough to offer an extensive line of standard products. However, it is and always will be flexible enough to custom-tailor any systems for a specific application.

www.atspa.com

Hardness Testing

Sun-Tec Corp.

Sun-Tec Corp. specializes in Rockwell-type, Brinell, Vickers and Knoop, Leeb, tensile/compression, ductility testing and sample preparation equipment. We also supply hardness standards, indenters and anvils. Clark Instrument, Detroit Testing Machine and Service Physical Testers are divisions of Sun-Tec, which is a 17025-accredited company.

www.sunteccorp.com

Vacuum and Controlled Atmosphere Furnaces

Centorr Vacuum Industries

The MIM-Vac M is specifically for the metal injection molding (MIM) market. It is designed primarily for second stage binder removal and sintering and has a number of design improvements specific for use with MIM feedstocks.

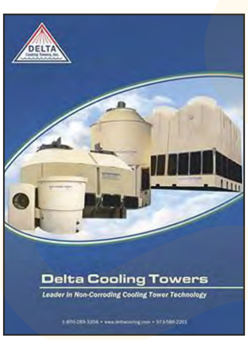
www.centorr.com

Carbon Atmosphere Analyzer

Super Systems Inc.

The CAT-100 atmospheric carbon potential analyzer provides a measurement of carbon potential in a furnace with a carbon-bearing atmosphere. The easy-to-use product provides a fast reading based on analysis of a metal coil soaked in the furnace for about 30 minutes. The CAT-100 has a color touch screen with features that include logging stored readings and furnace settings.

www.supersystems.com/CAT



Cooling Towers

Delta Cooling Towers

Delta Cooling Towers manufactures a complete line of corrosion-proof engineered-plastic cooling towers. The towers carry a 15-year warranty on the casing, which is molded into a unitary leak-proof structure of engineered plastic. All models are factory assembled and simple to install.

www.deltacooling.com

Temperature Measurement

Thermocouple Technology

Thermocouple Technology (TTEC) manufactures a full line of industrial temperature measurement products, including thermocouples, RTDs, thermowells, transmitters, thermocouple wire, indicators, controllers and accessories. TTEC's experienced engineers specialize in custom-built temperature sensors for applications exceeding 4000°F.

www.tteconline.com

Silicon-Carbide Heating Elements

I Squared R Element Co.

Starbar and Moly-D elements are made in the U.S. with a focus on providing the highest-quality heating elements and service to the global market. I Squared R Element has been providing high-quality service for over 40 years.

www.isquaredrelement.com

Industrial Vacuum Pumps

Ulvac Technologies

The ULVAC VS650A/750A is a robust, install-anywhere industrial vacuum pump with speeds up to 750 m³/h. Designed for low-vibration operation, these pumps feature air or water cooling for added convenience. The VS650A/750A is an all-in-one pumping powerhouse built for a wide variety of applications and is suitable for installation in any facility as-is.

www.ulvac.com

Thermal Processing Products

Refractory Technology

Stellar Materials LLC

Thermbond 7200 Series can substantially reduce the cost of most furnace repairs through its ability to provide consistent properties regardless of installation method. It provides excellent and consistent properties with all common installation methods – casting, pumping, gunning, ramming and shotcreting. Thermbond 7200 Series is mixed with water for casting or pumping, with 7200 Liquid for gunning or ramming, or with 7200 Accelerator for shotcreting. Only two different liquids are required for all five major installation methods, and the amount of liquid is roughly 5% by volume of the dry mix. Depending on the installation configuration, thickness, lining condition and geometry, Thermbond 7200 Series can be fired in at up to 200°C per hour with no holds. www.thermbond.com

Actuator for Pyrometer

Ametek Land

The SPOT actuator provides remotely controlled target alignment of a SPOT pyrometer for improved accuracy in temperature measurement for aluminum processing applications. The motorized unit is designed for use at the billet reheat furnace exit, die entrance and exit, and quench exit on aluminum extrusion presses. The actuator is capable of operating in automatic or operator-controlled modes to suit the needs of an individual aluminum plant. It enables extremely accurate alignment, as it takes 900 measurement points over 90 degrees and aligns on the optimum measurement position on the profile. www.landinst.com

Tungsten Carbide Treatment

Thermocouple Technology

An MVD tungsten carbide treatment increases the life of thermowells and protection tubes. The tungsten carbide is fused with the thermowell material and becomes an integral part of the mass of the well, resulting in a substantially harder and more durable application. The treatment is specially designed for applications in highly abrasive/erosive environments where the temperature range is ambient to 1800°F. It is capable of withstanding temperatures up to 2300°F. www.tteconline.com

Deep-Groove Ball Bearings

The Timken Company

A full range of metric deep-groove ball bearings is now available. The portfolio includes standard, thin-section, narrow, wide, miniature and extra-small deep-groove ball bearings from 3-400 mm bore sizes. Deep-groove ball bearings follow ISO standards and are qualified for electric motors to keep equipment operating smoothly. All bearings: feature super finishing on the raceways to reduce friction; use premium low torque/noise grease; and meet precise manufacturing standards, minimizing noise and vibration. www.timken.com

Helium Leak Detector

Leybold

Phoenix 4, a new family of helium leak detectors, is suited for research and development and industrial applications. With an ergonomic design and improved measuring characteristics, the versatile helium leak detector is available in three classes. It can be operated comfortably via a color touch display or wirelessly with any Internet-capable mobile device. The optimized display design allows users to intuitively navigate through the menu. www.leybold.com

Heat Exchanger Inspection Kit

Olympus

The NORTEC 600D heat exchanger inspection kit enables a single user to inspect ferrous, nonferrous, finned and un-finned tubing with a system that is easy to use and requires minimal training. It offers a convenient alternative to inspections that rely on larger, heavier equipment. Users can quickly detect corrosion, pitting, cracks, wear and erosion in various types of heat exchangers. With an intuitive, simple interface and presets for each application, users can easily adjust parameters to quickly obtain ready signals and do their jobs faster. www.olympus-ims.com

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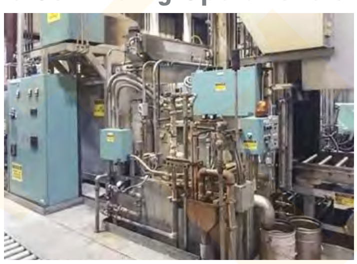
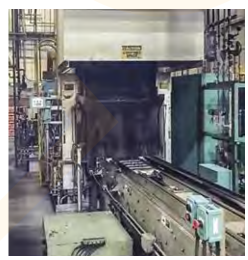




Complete State-of-the-Art Heat Treat Line
Dowa Thermotech 1800°F Carburizing, Wash, Temper Furnace Line (2010)

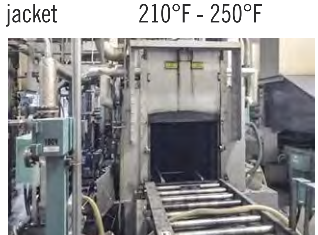
FURNACE:
Carburize and Quench Model: TFC-80-ERT. Carburizing,quenching, carbonitriding, bright quenching.
Furnace Load Dimensions: 26"W x 49"L x 24"H
Furnace Capacity: 1200 pounds (approx.)
Tray Dimensions: 48"W x 24"L x 2"D

QUENCH:
Quench Load Dimensions: 103"W x 71"L x 166"D
Quench Tank Capacity: 1800 gallons
Quench Temperature: 150°F
COOLING CHAMBER: Sealed with water-tight jacket

WASHER: Spray, Dunk, Wash, Dry
Model: TW2-264824-D
Type: Alkali cleaning with drying room
Load Dimensions: 26"W x 49"D x 24"H
Drying Temp: 210°F - 250°F

FURNACE:
Model: TFA-264824-L Low Temperature Temper Furnace
Load Dimensions: 26"W x 49"D x 24"H
Heated: Electric, 40 KW, 58 Amps, one (1) zone
Temperature: 400°F



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If your needs are not listed below, please let us know and we will locate a furnace/oven to suit your needs. We have all the ancillary equipment available for the above such as Tempering Furnaces, Washers, Charge Cars and Endo Generators.

INTEGRAL QUENCH FURNACES

SURFACE COMBUSTION

(2) INTEGRAL QUENCH FURNACES, 30"W x 30"H x 48"L, 1,750°F, 1,000,000 BTUH, Trident Tubes, Endo/Natural Gas/Ammonia, SSI Atmosphere Controllers, SSI Gold Probes, Oil Filters And SBS Coolers. System Comes Complete with a Gas Fired Temper, Washer and Charge Car.

AFC - HOLCROFT

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

SURFACE COMBUSTION

INTEGRAL QUENCH FURNACE, 5000 lb. Payload Each, 36"W x 36"H x 72"L, Recuperated Rear Handler And Controls.

SURFACE COMBUSTION

INTEGRAL QUENCH FURNACE, 10,000 lb. payload, 87" W x 87" L x 36" H, 1,850°F, 4,600,000 BTUH, 12,500 Gallons, 6 Agitators, Eclipse Burners, 3 Rear Handlers & Controls with PLC.

USED EQUIPMENT

ABAR

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

ABAR

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

USED EQUIPMENT *(continued)*

CGS MOORE

CGS Moore Gas Fired Mesh Belt Furnace, 22"W x 10"H x 20'L (Heated Zone), 800,000 BTUH, 500°F Max. c/w controls.

INDUSTRIAL HEATING EQUIPMENT

Industrial Heating Equipment Gas Fired Mesh Belt Furnace, 24"W x 10"H x 22'L, 500,000 BTUH, 950°F c/w controls.

HOLCROFT

Holcroft Gas Fired Mesh Belt Furnace, 24"W x 9"H x 14' 8"L, 400,000 BTUH, 750°F c/w controls.

PARK THERMAL

Park Thermal Gas Fired Mesh Belt Furnace, 17-1/2"W x 7"H x 15' 8"L, 375,000 BTUH, 900°F c/w controls.

HUBER

Huber Gas Fired Car Bottom Furnace, 10'-4"W x 8'H x 12'-8"L, 1,800°F, 5,200,000 BTUH and controls.

PARK THERMAL

Park Thermal Gas Fired Box Furnace, 3' W x 3' H x 4' L, 1,200°F, 500,000 BTUH, pneumatic vertical rising door, powered rollers and controls.

PARK THERMAL

Park Thermal Gas Fired Car Bottom Furnace, 36" W x 36" H x 96" L, 1,200°F, vertical lift door at both ends, powered car with cast hearth, re-circ. fan and controls.

SURFACE COMBUSTION

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

SECO/WARWICK

High Temperature Electric Furnace, 24" W x 24"H x 36" L, Max. Temp. 1,800°F, Powered Rollers, Load/Unload Table & Controls.

SURFACE COMBUSTION

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

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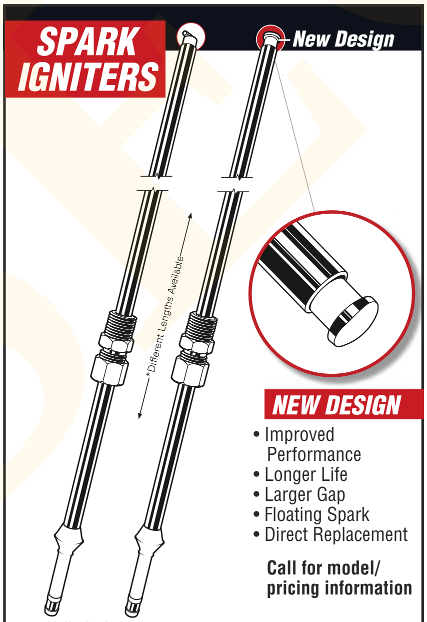

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Batch Temper Furnaces

C0049 Can-Eng Batch Temper Furnace (30"W x 48"L x 30"H, 1400°F, gas-fired)
C0052 Surface Combustion Batch Temper Furnace (30"W x 48"L x 30"H, 1200ºF, gas-fired)
C0068 Despatch Box Furnace (60'W x 72'D x 66"H, 395ºF, electric)
C0113 Lindberg Batch Temper Furnace (48'W x 48'L x 48'H, 1400°F, electric)
U3644 BeaverMatic Batch Temper Furnace (36'W x 48'D x 36'H, 1500ºF, gas-fired)
V1010 Dow Batch Temper Furnace (30"W x 48"L x 20"H, 1250ºF, gas-fired)
V1024 PIFCO Batch Temper Furnace, Skid Hearth (36"W x 48"L x 30"H, 1200ºF, electric)
V1049 Surface Combustion Temper Furnace (87'W x 87'L x 36"H, 1350ºF, 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, 1250ºF, electric)
V1090 Lindberg Nitrogen Temper Furnace (24'W x 36'D x 18"H, 1350ºF, gas-fired)
V1095 Surface Combustion Temper Furnace (30"W x 48"D x 30"H, 1250ºF, gas-fired)
V1096 Surface Combustion Temper Furnace (30'W x 48'D x 30'H, 1400ºF, gas-fired)
V1106 Dow Batch Normalizer Furnace (45'W x 84'D x 32'H, 1800ºF, gas-fired)

Batch High-Temp Furnaces

C0007 JL Becker Batch High-Temp Furnace with atmosphere (72"W x 72"H x 72"L, 1650ºF, gas-fired)
U3556 Pacific Industrial Batch High-Temp Furnace (24"W x 36"L x 18"H, 2800ºF, electric)
U3637 Pacific Scientific Batch Temper (30'W x 48'D x 24'H, 1600ºF, gas-fired)
U3643 Surface Combustion Temper Furnace (30'W x 48'D x 42'H, 1400ºF, electric, 81kw)
U3645 Surface Combustion Hi-Temp Furnace (42'W x 60'D x 24'H,1850ºF, gas-fired)
V1013 Thermolyne High-Temp Batch Furnace (10'W x 14'L x 9'H, 2000ºF, electric)
V1067 Seco Warwick Batch High-Temp Furnace (24"W x 24"H x 36"D, 1800ºF, electric)
V1130 Onspec Slot Forge Furnace (72'W x 96'D x 48'H, 2000ºF, gas-fired)

Batch Oil Quench Furnaces

C0086 Huber Car Bottom Furnace (10'4'W x 12'9'D x 8'H, 1800ºF, gas-fired)

Car Bottom Furnaces

C0071 Gas Mac Car Bottom Furnace (7'8'W x 12'6'D x 7'0'H, 1150ºF, gas-fired)

Drop Bottom Furnaces

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

Internal Quench Furnaces

C0064 Lucifer IQ Furnace (18"W x 24"D x 18"H, 1900ºF, electric)
U3569 Surface Combustion IQ Furnace (24"W x 18"H x 36"D, 1750ºF, gas-fired)
U3606 Dow/AFC IQ Furnace (30"W x 48"L x 24"H, 1850ºF, gas-fired)
V1046 Surface Combustion IQ Furnace (87'W x 87'L x 36'H, 1850ºF, gas-fired)
V1047 Surface Combustion IQ Furnace (62'W x 62'L x 36'H, 1850ºF, gas-fired)
V1062 Surface Combustion Super IQ Furnace (36"W x 72"D x 36"H, 1950ºF, gas-fired)
V1082 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850ºF, gas-fired)
V1092 Surface Combustion Allcase IQ Furnace (30'W x 48'L x 30'H, 1850ºF, gas-fired)

Mesh Belt Brazing Furnaces

C0102 JL Becker Mesh Belt Brazing Furnace (30'W x 24'5' heated L x 10'H, 2050ºF, electric)
C0103 JL Becker MB Brazing Furnace w/Exo & Dryer (30'W x 24'5' heated L x 10'H, 2050ºF, electric)
U3529 CI Hayes Mesh Belt Brazing Furnace (18'W x 6'H x 8' heating, 2100ºF, electric)
U3592 JL Becker Mesh Belt Brazing Furnace (12"W x 6"H, 2100ºF, electric)
V1035 Seco Warwick Mesh Belt Brazing Furnace (18"W x 12"H, 2100ºF, electric)

Mesh Belt Tempering Furnaces

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, 1250ºF, gas-fired, PT2501)
C0074 Holcroft Mesh Belt Tempering Furnace (24'W x 176'L x 12'H, 750ºF, gas-fired, PT3136)
C0075 Industrial Heating Mesh Belt Tempering Furnace (24'W x 22'L x 12'H, 950ºF, gas-fired, PT3630)
C0079 Internat'l Thermal Flat Wire Continuous Furnace (9'W x 10'H, 24' heating, 17' cooling, 650ºF, gas-fired)
C0080 Surface Combustion Mesh Belt Temper Furnace (18'W x 11"H, 13' long, 1000ºF, gas-fired)
C0081 Park Thermal Mesh Belt Temper Furnace (17.5'W x 7'H, 15'8" long, 900ºF, gas-fired)
C0083 Eltropuls Plasma Furnace System (56'Dia x 80'D, 1022ºF, 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, 1100ºF, gas-fired)
V1022 Surface Combustion Mesh Belt Tempering Furnace (42"W x 36'D x 12"H, 1350ºF, gas-fired)

Pit Furnaces

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

Roller Hearth & Rotary Furnaces

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

Steam Tempering Furnace

U3616 Degussa Durferrit Steam Tempering Furnace (24'Dia x 48'D, 1200ºF, electric)

Tip Up Furnaces

C0043 Industrial Furnace Tip-Up Furnace (8'W x 22'4"D x 6'H, 1800ºF, 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, 1450ºF, electric)
C0111 Lindberg Vacuum Furnace (15'W x 24'L x 12'H, 2400ºF, electric)
U3612 AVS Vacuum Annealing Furnace 2-Bar (18'W x 24'D x 12'H, 2400ºF, 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, 2400ºF, electric)
V1128 Ipsen Vacuum Furnace (18"W x 32"D x 12"H, 2400ºF, electric)
V1131 Abar Vacuum Furnace (34'W x 60'D, 2250ºF, electric)
V1135 Abar Vacuum Furnace 2 Bar (72'Dia x72'Deep, 2400ºF, electric)
V1136 Surface Combustion Vacuum Furnace, 2-Bar (26'W x 36'L x 22"H, 2400ºF, electric)
V1138 Ipsen Vacuum Furnace, 5-Bar (24'W x 36'L x 14'H, 2400ºF, electric)

Endothermic Gas Generators

C0093 JL Becker Modular Endo Gas Generator (3-4000/6-8000/9-12000 CFH)
U3594 AFC-Holcroft Gas Generator (3,000 CFH Endo, gas)
V1021 Surface Combustion Gas Generator (2,400 CFH Endo, gas)
V1075 Lindberg Gas Generator (3000 CFH Endo)
V1105 Surface Combustion Gas Generator (5,600 CFH Endo, 1950ºF, 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

C0037 Grieve Cabinet Oven (36"W x 36"L x 36"H, 650ºF, electric)
U020 Blue-M Oven/Ref (20"W x 20"H x 18"D), (-4°F/400ºF)
U3625 Lindberg Atmosphere Oven (38'W x 38'D x 38'H, 850ºF, electric)
U3629 Cabinet Oven (30'W x 30'D x 36'H, 750ºF, electric)
U3642 Blue-M Cabinet Oven (36"W x 36"D x 36"H, 650ºF, electric)

Ovens - Walk-In

C0035 Park Thermal Walk-In Oven (48'W x 48'D x 60'H, 500ºF, electric)
C0038 Despatch Walk-In Oven (54"W x 108"L x 72"H, 500ºF, electric)
C0039 Gehnrich Walk-In Oven (72"W x 96"L x 72"H, 400ºF, electric)
C0108 Park Thermal Walk-In Oven (90'W x 144'D x 72'H, 850ºF, gas-fired)

Freezers

V1129 Webber Freezer (-120ºF, 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

Compressors

U023 Spencer Turbo Compressor

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)
Many other holding stations - ask for details

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)
V1038 Bell & Gossett Shell & Tube Heat Exchanger with Tank

Washers

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

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Heat Treat Lines

V1137 T-6 Annealing & Aging Furnace Line
C0109 Dowa Thermotech Carburizing, Wash, Temper Furnace Line (26"W x 49"D x 24"H, 1800ºF)

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2,000CFH	Ammonia Dissoc. Drever (3)	Elec
3,000CFH	Endothermic Lindberg (3) - Air	Gas
3,600CFH	Endothermic Surface (2)	Gas
5,600CFH	Endothermic Surface (3)	Gas
6,000CFH	Gas Atmos. Nitrogen Generator	Gas

BOX FURNACES

12" × 24" × 10"	Lindberg (Atmos.)	Elec 2000°F
12" × 24" × 10"	Lindberg (Atmos.)	Elec 2500°F
12" × 24" × 12"	Hevi Duty (2)	Elec 1950°F
12" × 32" × 12"	L&L (Retort)	Elec 2000°F
13" × 24" × 12"	Electra Up/Down	Elec 2000°F
17"×14.5"×12"	L&L (New)	Elec 2350°F
18" x 30" x 13"	Hevi-Duty	Elec 1850°F
18" x 36" x 18"	Accutherm	Elec 2000°F
18" x 36" x 18"	Lindberg (Fan)	Elec 1850°F
20" x 48" x 12"	Hoskins	Elec 2000°F
24" x 48"x 24"	Hevi-Duty	Elec 2350°F
36" x 48"x 36"	CEC (Atmos-N_2)	Elec 2000°F
36" x 72"x 42"	Eisenmann (Car Bottom)	Gas 3100°F
60"x216"x48"	IFSI (Car Bottom)	Gas 2400°F
60"x156"x60"	Lindberg Car Bottom	Gas 1850°F
64"x180"x68"	Swindell-Dress. Car Bottom	Gas 2350°F
96"x360"x48"	Sauder "Autotilt"	Elec 1400°F
126"x420"x72"	Drever "Lift-Off" (2) (Atmos.)	Gas 1450°F

PIT FURNACES

14" Dia x 60"D	Procedyne Fluid Bed	Elec 1850°F
72" Dia x 72"D	Flynn+Dreffein (2) (Atmos.)	Elec 1400°F

VACUUM FURNACES

15" x 24" x 10"	Ipsen - VFC 224	Elec 2400°F
24" x 36" x 18"	Hayes (Oil Quench)	Elec 2400°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" x 36" x 24"	AFC (Top-Cool-Line)	Elec 1850°F	
30" x 48" x 20"	Surface (2)	Gas 1750°F	
30" x 48" x 30"	Surface	Gas 1750°F	Just Added
48" x 72" x 36"	Lindberg (Top Cool)	Gas 1850°F	

BELT FURNACES/OVENS

12" x 120" x 15"	Grieve (Solvent)	Elec 450°F	
24" x 18'L	Thermal Basic Belt Line	Gas 1750°F	Just Added
32" x 24' x 12"	OSI Slat Belt	Gas 450°F	
36" x 24' x 8"	Surface Cast Belt (Line)	Gas 1750°F	
36" x 28' x 22"	Lewco (2)	Elec 350°F	
42" x 15' x 18"	Infratrol (Like New)	Elec 500°F	
60" x 144" x 6"	Diamond Engr.	Elec 800°F	
60" x 40' x 14"	GE Roller Hearth (Atmos)	Elec 1650°F	
60" x 40' x 14"	Wellman Roller Hearth (Atmos)	Elec 1650°F	

MISCELLANEOUS

Combustion Air Blowers (All sizes)		
24" x 36"	Lindberg Charge Car (Manual)	
30" x 48"	Surface Charge Car (SE-ER)	
24" x 36" x 24"	Salt Quench Tanks (2)	Elec 1000°F
30" x 48" x 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)*

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" x 18" x 8"	Lucifer	Elec 1250°F	
12" x 16" x 18"	Lindberg (3)	Elec 1250°F	
14" x 14" x 14"	Blue-M	Elec 1050°F	
14" x 14" x 14"	Gruenberg	Elec 1200°F	
14" x 14" x 14"	Blue-M	Elec 650°F	
14" x 14" x 14"	Gruenberg (solvent)	Elec 450°F	
15" x 24" x 12"	Sunbeam (N_2)	Elec 1200°F	
20" x 18" x 20"	Blue-M	Elec 400°F	
20" x 18" x 20"	Despatch	Elec 650°F	
20" x 18" x 20"	Blue-M	Elec 650°F	
20" x 18" x 20"	Blue-M (2)	Elec 800°F	
20" x 20" x 20"	Grieve	Elec 1250°F	
22" x 18" x 15"	Precision Quincy	Elec 1000°F	Just Added
24" x 20" x 20"	Blue-M	Elec 1000°F	
24" x 26" x 24"	Grieve	Gas 500°F	
24" x 24" x 24"	Grieve	Elec 650°F	
24" x 24" x 36"	New England	Elec 800°F	
24" x 24" x 48"	Blue-M	Elec 600°F	
24" x 36" x 24"	Grieve	Elec 500°F	
24" x 36" x 24"	Demtec (N_2)	Elec 500°F	
24" x 36" x 24"	AFC (N_2)	Elec 1250°F	
24" x 36" x 24"	Trent	Elec 1400°F	
25" x 20" x 20"	Blue-M	Elec 650°F	
24" x 36" x 48"	Gruenberg	Elec 500°F	
25" x 20" x 20"	Blue-M (Inert)	Elec 1100°F	
26" x 26" x 38"	Grieve (2)	Elec 850°F	
30" x 30" x 60"	Gruenberg	Elec 450°F	
30" x 30" x 48"	Process Heat	Elec 650°F	
30" x 38" x 48"	Gruenberg (Inert) (2)	Elec 450°F	
30" x 48" x 30"	Surface	Elec 1400°F	
30" x 48" x 36"	Surface (Atmos)	Elec 1400°F	
30" x 48" x 30"	Surface	Elec 1250°F	
36" x 36" x 36"	Blue M Enviroment Chamber	(-18°C to +93°C)	
36" x 42" x 72"	Gruenberg	Elec 450°F	
36" x 48" x 24"	L&L (Inert)	Elec 1200°F	
36" x 48" x 36"	Grieve	Elec 350°F	Just Added
36" x 48" x 36"	AFC	Gas 1250°F	
36" x 60" x 36"	CEC (2)	Elec 650°F	
36" x 84" x 36"	Lindberg (1996)	Gas 800°F	
37" x 25" x 37"	Despatch	Elec 500°F	
38" x 20" x 26"	Grieve	Elec 500°F	Just Added
42" x 54" x 30"	L&L	Elec 1200°F	Just Added
42" x 72" x 36"	Lindberg	Elec 1250°F	Just Added
48" x 30" x 48"	Precision Quincy	Elec 550°F	
48" x 48" x 36"	JPW (New)	Elec 1250°F	
48" x 48" x 60"	Prec-Quincy	Elec 500°F	
48" x 34" x 52"	Heat Mach. (2)	Elec 500°F	
48" x 48" x 36"	JPW (New)	Elec 1250°F	Just Added
48" x 48" x 48"	TPS - Environmental	Elec 392°F	Just Added
48" x 52" x 60"	Despatch	Elec 500°F	Just Added
48" x 48" x 48"	Wisconsin (Like New)	Elec 650°F	
48" x 48" x 48"	Lindberg (Argon Atmos)	Elec 1400°F	
48" x 48" x 60"	Grieve	Elec 500°F	
50" x 50" x 50"	Grieve	Elec 1250°F	
55" x 30" x 60"	Precision Quincy	Elec 350°F	
72" x 120" x 72"	Grieve	Gas 500°F	Just Added
72" x 180" x 72"	Precision Quincy	Elec 450°F	Just Added
84" x 156" x 84"	Steelman (Solvent)	Gas 500°F	
108" x 96" x 65"	Eisenmann (4)	Gas 1200°F	
96" x 360" x 48"	Sauder "Autotilt"	Elec 1400°F	

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