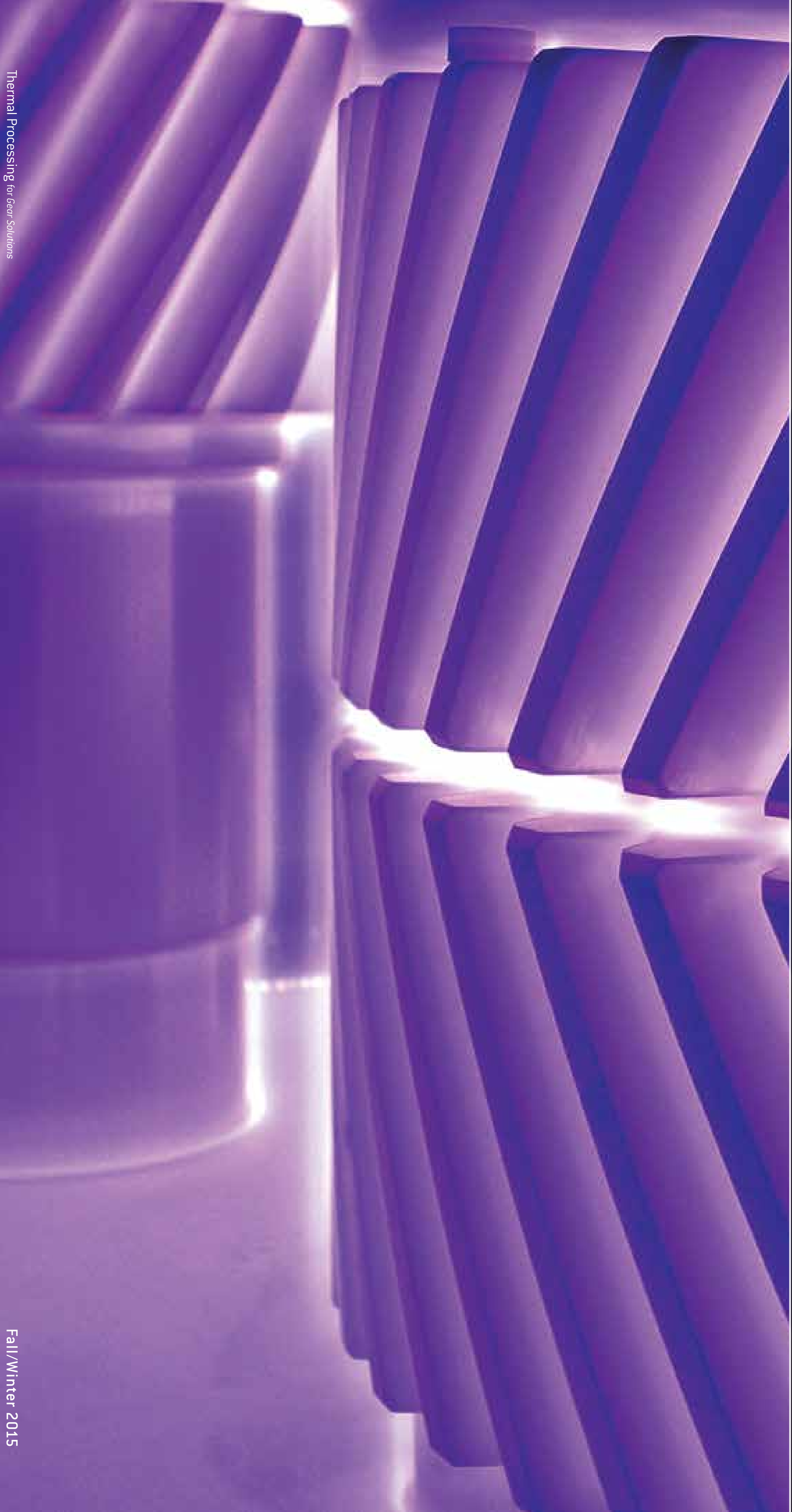

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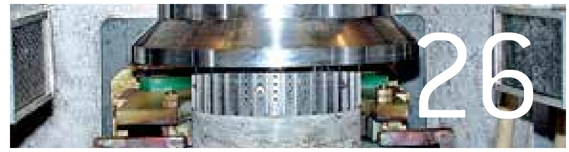

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RULE #1.
Choose the least expensive heat rejection technology

When choosing a cooling system consider your climate and the maximum operating temperature of your equipment for optimum efficiency. Lower fluid temperatures increase energy usage and operating costs.

TYPE	OPERATING COST	TEMPERATURE
Air Cooled	$	105°F
Evaporative	$$	85°F
Chiller	$$$$	65°F

Air cooled heat exchanger

Evaporative cooling tower with outdoor mechanical room

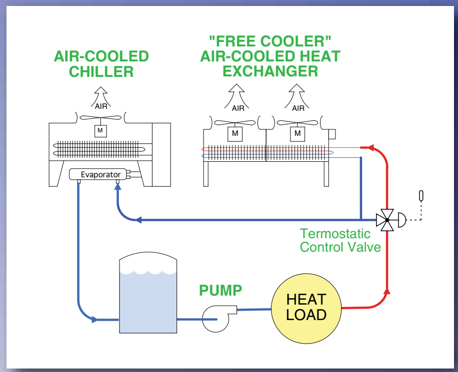
Chiller (mechanical refrigeration)

RULE #2.
Use hybrid systems to save energy

Combine different types of systems to achieve the best features of each with the greatest energy savings.

The "free cooler" shown at right eliminates the need for refrigeration compressors to run in a cold winter climate, saving energy and wear and tear on the chiller.

Another hybrid example is to "trim cool" an air cooled heat exchanger with an evaporative tower used in summer only. Substantial savings are realized in water, chemicals and electricity.



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DEPARTMENTS

Fall/Winter 2015
Volume 4 / Number 2

RESOURCES

Cover photo: Advanced Heat Treat Corp.

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LETTER FROM THE EDITOR

It's almost show time! Learn about some of the latest developments in heat treating processes currently being used to improve the quality and repeatability of gear heat treatment at ASM Heat Treat 2015. This issue of *Thermal Processing for Gear Solutions* will help you get ready for it.

The American Gear Manufacturers Association (AGMA) and the ASM Heat Treating Society are co-locating Gear Expo and the 28th ASM Heat Treating Society Conference and Exposition on October 20-22 at the Cobo Convention Center in Detroit, Michigan. The two events bring together an exciting mix of technical information, education, and networking, as well as a first-hand look at equipment, supplies, and services from exhibitors serving the heat treating and gear manufacturing industries. The conference will feature more than 130 presentations about some of the latest developments in heat treating technology including advances in heat treating, quenching and cooling, vacuum processes and technology, atmosphere development, and surface engineering.

In gear manufacturing, surface engineering is an especially important topic, as surface properties are critical to prevent failures due to wear, corrosion, and fatigue. Gears are used in a wide variety of applications including automotive, aerospace, power generation, agriculture, mining and construction, and many more. Gear materials selected will have the necessary strength and toughness in core properties but are given surface treatments such as carburizing, nitriding, carbonitriding, and cyaniding, as well as induction, flame, and laser hardening, to improve their fatigue and wear properties. These treatments produce a hard case, which is specified to a certain hardness and depth required for the specific application.

This issue of *Thermal Processing* magazine contains several articles to give you a flavor of some of the technologies used to produce case-hardened parts, including vacuum carburizing, ion nitriding, and nitrocarburizing, as well as a new inductive hardening and tempering process that combines the benefits of induction heating and hardening with the benefits of press hardening.

After parts are case hardened, they must be checked to verify that the treatment produced the required results. Some tests are used to verify the quality of heat treatment without damaging the part. Such test methods include ultrasonic testing and eddy current inspection (featured in this issue). Nondestructive eddy current inspection can test for conditions such as misplaced case, shallow case, short heat, short quench, and delayed quench. It provides a clean, fast, and repeatable process that can be performed in the production line to inspect all parts produced.

We hope you enjoy this issue of *Thermal Processing*, and we look forward to seeing you at ASM Heat Treat 2015. Be sure to visit us at Booth #517 at the Heat Treat Expo as well as our *Gear Solutions* Booth #2239 at AGMA's Gear Expo.

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OPERATIONS

EFD Induction Awarded Orders for Induction Scanners To Harden Sun Gears and Output Shafts

EFD Induction USA has recently won major orders from two American tier-one automotive suppliers. The orders involve EFD Induction HardLine-type induction scanning systems for the hardening of sun gears and output shafts. Each system comprises an induction scanner, a power source, and various optional features.

The first order comprises an EFD Induction Rotary Table (HardLine RT 550) hardening system for treating sun gears and a vertical scanner system (HardLine VM 1000) for hardening output shafts.

The second order is for two vertical scanner systems, a HardLine VS 300 for hardening sun gears and a HardLine VL 1000 for treating shafts.

All the systems are powered by EFD Induction Sinac power sources and feature CNC-based control systems. Each machine also features a closed-loop cooling system.

HardLine is EFD Induction's family of systems for surface and through-hardening with equipment available to handle everything from small gears with complex geometries up to the giant slewing rings used in modern wind turbines. The vertical scanners support a range of optional subsystems, including automated loading and unloading solutions, indexing tables with unlimited position control, double tailstocks and centers for the simultaneous hardening of two workpieces, and an HF/MF chuck connection for quick changeovers between high and medium frequencies. The hardening system can also be paired with an integrated or separate tempering station.

FOR MORE INFORMATION: WWW.EFD-INDUCTION.COM

Solar Atmospheres Launches New Mobile-Friendly Website

Over the past year, Solar Atmospheres has developed a brand-new website focused on better demonstrating its unique capabilities and services in vacuum heat treating, vacuum brazing, vacuum carburizing, gas nitriding, annealing, sintering, and many other areas.

With the changes in technology and the company expansion, Solar was proactive in improving the current website to a more mobile-friendly version while adding features to assist new and existing customers.

The vacuum heat treating pages highlight the wide range of expertise Solar Atmospheres offers companies and the customized approach it takes for every project. The company takes pride in finding solutions for its customers that not only fit their needs, but also surpasses their expectations.

The new website continues to offer a live-chat capability to allow a person to communicate quickly with Solar's customer service or technical support personnel. This enables the Solar staff to get to know its customers better and answer any questions. Solar Atmospheres is one of the only vacuum heat treating companies with this capability.

Another feature is its resource section where technical documents, industry articles, and news are available for viewing or downloading. Solar's staff has been published in many magazines, newspapers, and associated journals, and they continue to prove why Solar is one of the most experienced and innovative heat treating companies in the industry.

To learn more about Solar's quality and performance standards, visit its "Why Solar Atmospheres" section to peruse the quality programs, certifications, and policies that help make Solar Atmospheres a leader in the heat treating industry.

FOR MORE INFORMATION: WWW.SOLARATM.COM

Companies wishing to submit materials for inclusion in UPDATE should contact the editor, Molly J. Rogers, at editor@thermalprocessing.com. Releases accompanied by color images will be given first consideration.


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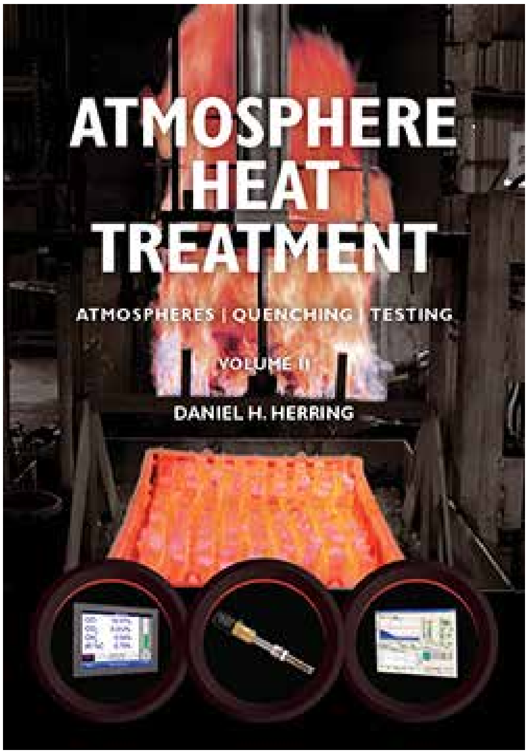
Heat Treat Doctor Publishes Second Volume on Atmosphere Heat Treatment



Dan Herring's latest book, *Atmosphere Heat Treatment, Volume II,* focuses on furnace atmospheres, quenching practices, testing, safety, conservation, maintenance, and specification compliance. Together with *Volume I* (2014) that emphasized fundamental principles, materials, metallurgy, applications, and equipment, these volumes serve as a comprehensive resource on the subject of atmosphere technology as conducted in furnaces and ovens. It affords insights into practices and procedures used throughout the heat treatment industry. Together with its companion work, *Vacuum Heat Treatment* (2012), Herring has provided a well-rounded introduction to this multi-faceted subject.

These works offer the heat treatment industry a unique perspective on atmosphere heat treatment. They are intended to provide the reader with practical advice, a diverse set of application examples, and a wide range of technical and engineering information necessary to make informed decisions about why and how to heat treat.

What makes these books unique is that they are written in such a way that engineers, metallurgists, heat-treat operators, supervisors, managers, quality and production engineers, or just about anyone interested in thermal processing or manufacturing can become skilled in the art and science of atmosphere heat treatment.

FOR MORE INFORMATION: WWW.HEAT-TREAT-DOCTOR.COM

Industry Veteran Appointed Senior Vice President of Houghton and President of Global Metals

Houghton International Inc., a global leader in metalworking fluids and services, announced the appointment of Marcello Boldrini as senior vice president of Houghton International and president of Global Metals. In this newly created position, he will assume the global leadership of Houghton specialty product lines for the major metal industries, including steel and aluminum. He will report directly to Mike Shannon, Houghton chief operating officer.

Boldrini brings decades of experience in the global chemical industry to Houghton where he will be responsible for leading all global commercial activities to drive growth in the company's metals businesses. He will be a member of the company's executive committee and will join the boards of Houghton Japan and Korea Houghton.

"Marcello brings valuable leadership and industry experience to Houghton," said CEO Paul DeVivo. "We are realigning our businesses to better serve our global customers, and I am confident that Marcello will lead our metals organization to expand Houghton's market leadership."

Boldrini joins Houghton from Momentive, a $7-billion global specialty chemical company where he held the position of executive vice president and chief marketing officer. He was previously the senior vice president and general manager for Momentive's global Phenolic Resins business. Prior to Momentive, Boldrini held several leadership roles at Ashland Inc., including managing director of Europe, based in Milan, Italy, and managing director of Asia, based in Singapore, for the electronic chemical division. He then held the roles of vice president of M&A and business development for Ashland, vice president and general manager for the global Specialty Polymers and Adhesive Division, and vice president of global product management, marketing and business development for the Performance Materials Group. Early in his career, he held commercial and business leadership roles in Europe at Quaker Chemical and Unichema. Boldrini holds an M.S. in chemistry from the University of Milano and an M.B.A. from Bocconi University in Milan, Italy.

FOR MORE INFORMATION: WWW.HOUGHTONINTL.COM

Today's control technology enables adjustments in the furnace atmosphere correlated to the percent carbon calculation.

by Jim Oakes

There are many demands for precision manufacturing of steel components. Heat treatment is a critical step in nearly all manufacturing processes to achieve required part performance properties, including strength and fatigue properties. Manufacturers also want to extend component service life, and heat treatment is a necessary process to reach that goal.

Technology is used to ensure that manufacturing processes allow for tight tolerances to meet design requirements. Tolerances are also being tightened for properties resulting from heat treatment, such as hardness variation, case depth range, and microstructural variation. Heat treatment systems and procedures are established to ensure metallurgical results are achieved to meet specification requirements for the parts produced. Heat treating processes present operating challenges with high furnace temperatures, critical atmospheres, and corrosive environments; equipment and controls are put to their test in these harsh applications.

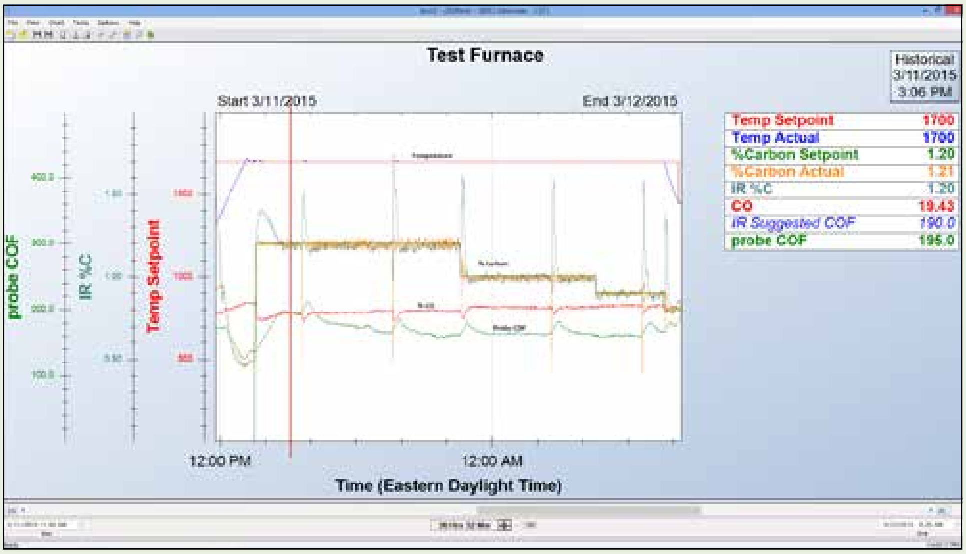


Figure 1: Deep case-carburizing cycle using in-situ probe with continuous NDIR three-gas analyzer to alter carbon calculation by periodically adjusting the COF in the control instrument. Variations in atmosphere allow for the analyzer to adjust in-situ control.

IMPORTANCE OF PROCESS CONTROL

To maximize quality, steps must be taken in all heat treating processes to ensure that time, temperature, and atmosphere are not compromised. A good example is carburizing in a gas atmosphere to provide an effective case hardness and depth. An oxygen probe is used for in-situ monitoring of the furnace atmosphere, measuring the "lack" of oxygen in the atmosphere. This calculation uses an EMF (in millivolts) generated by the probe, which is created by the partial pressures of oxygen, carbon monoxide (CO), and temperature to calculate the percent carbon available to the surface of the workpiece. For carburizing, the atmosphere must be rich in carbon and at a suitable temperature to allow carbon to be transferred to the surface and diffused into the part. Carbon activity at the surface and diffusion rate are calculated based on atmosphere, material type, and temperature.

CO present in the atmosphere is the most significant source of carbon to the part to develop the proper case hardness and depth. It is critical that the CO content of the furnace atmosphere is maintained and consistent for control instruments to make accurate calculations. Proper levels of CO and hydrogen (H_2) are maintained continuously using a fresh source of prepared atmosphere, enriching gas (usually natural gas), and air, providing a carbon-rich atmosphere that can be controlled to a specific carbon activity.

Prepared atmospheres having a composition of 40 percent H_2, 40 percent N_2, and 20 percent CO are commonly produced using endothermic generators and nitrogen-methanol mixing systems. With a consistently prepared atmosphere, CO remains stable and measurements of carbon potential are calculated based on values of carbon dioxide (CO_2) and oxygen (O_2). These are the common control process variables used today. Furnace oxygen probes are connected to a control instrument that calculates percent carbon assuming that one of the components of the atmosphere has a consistent source of CO. Therefore, maintaining a consistent prepared atmosphere is critical for successful operation of process controls.

Today, control technology enables adjusting the CO, generally known as the CO factor (COF) or process factor (PF), correlated to the percent carbon calculation. This correction factor (COF/PF) is set to ensure that the probe is accu-

Three-gas analyzer

rately calculating the carbon potential. There is debate regarding COF/PF adjustments in the heat treating industry. The most important factor regarding these settings is the precision, repeatability, and accuracy of the process to produce quality results.

Atmosphere composition — independent of the probe reading — is monitored and used to improve the accuracy of the carbon calculation using only the probe input. This is performed by adjusting the correction factor (COF/PF) configured in the atmosphere-control instrumentation. Historically, the adjustment process has been intermittent using atmosphere sampling methods, including dew point, nondispersive infrared (NDIR) three-gas analysis, shim stock, carbon bar, and coil resistance. More recently, manufacturers are requiring continuous atmosphere monitoring and adjustment. Continuously sampling the gas and making adjustments to the COF/PF is implemented using a dedicated gas-monitoring system. The focus is on three main gases — CO, CO_2, and CH_4 — which are the larger components of the furnace atmosphere and have the most significant impact on the carbon present. Using NDIR cell technology, major atmosphere components are monitored to provide an additional carbon potential reading, which is independent of the calculation provided by the in-situ probe. Data are used to provide real-time feedback to the control instrument. The COF/PF is adjusted based on the three-gas reading. The control feedback loop uses multiple technologies to create the most precise atmosphere control available today (as illustrated in Figure 1).

SUMMARY

An oxygen probe plus NDIR control creates an opportunity to maintain the most accurate carbon control levels by adjusting the controller calculation. When performed in real time with the carbon probe, variations are quickly accounted for, delivering precise control and leading to proper metallurgical results with reduced labor and furnace time.

ABOUT THE AUTHOR: Jim Oakes is the vice president of business development for Super Systems Inc. (SSi) where he is responsible for marketing and growth of various business segments and development of product-innovation strategies to meet customer needs. He has extensive experience in the heat treating and software/IT industries. Oakes can be contacted at joakes@supersystems.com or go to www.supersystems.com. Visit SSi at the Heat Treat Expo, Booth #727, on October 20-22 in Detroit, Michigan.

The new norm for tempering hardened steels is induction tempering that allows hardening and tempering in the same cell.

by Fred Specht

Image 1: Solid bar is heated progressively using a series of induction coils to austenitizing temperature prior to quenching and tempering.

Tempering hardened steels is one of the most important heat treating processes used in part manufacturing. Induction tempering produces hardness and mechanical properties similar to those produced using conventional oven tempering. The advancement of cell manufacturing led the way to combining induction hardening and tempering in the same manufacturing cell where other manufacturing operations are carried out, such as steel cutting, grinding, machining, and drilling. Thus, parts are completely manufactured including heat treating in the cell, one piece at a time. This lends itself to lean manufacturing. Hardening and tempering time cycles are of a much shorter duration than other processes in the cell. Optical pyrometers are often used to measure part surface temperatures achieved during hardening and tempering and are stored in a computer for use in statistical process control (SPC) calculations.

TEMPERING METHODS

There are five methods of induction tempering: single shot, continuous progressive, vertical scanning, conveyor, and slack quenching.

Single shot, or static heating, for tempering is best used for short parts or where a narrow zone must be tempered. This method uses separate power supplies and coils for both the hardening and tempering process. The workpiece must be allowed to completely cool to a temperature below 150°F before starting the tempering cycle.

Continuous progressive is used to process quenched and tempered bar and pipe (see Image 1). Parts 8 to 24 feet long are commonly processed end to end. These induction systems are common in large production shops. In the process, a bundle of unhardened bars, pipe, or tubes is indexed to a positive drive, and individual pieces pass through a series of induction coils at a controlled forward rate. The pieces are slightly rotated while moving through the coils until they reach the austenitizing temperature (approximately 1,700°F) and then pass through a series of quenching chambers for cooling. Following cooling, they pass through a series of lower power, lower frequency induction coils at the same forward motion rate. After heating for tempering, the workpieces are indexed to a slow cooling table and then to final bundling. Advanced computer controls combined with optical pyrometers enable a repeatable process, as all process recipes and control limits are stored in the computer for each material type and diameter.

Vertical scanning is commonly used to induction harden the workpiece in one pass. A second scan is then used for induction tempering after the workpiece temperature stabilizes below 150°F. The quench is not turned on during the temper cycle to allow heat to penetrate deeper than in the original hardening cycle. The second pass for tempering uses only about 30 percent of the power used for hardening and a slower (30-50 percent) scan speed than that for hardening.

Conveyor tempering uses a channel-type coil with very low power densities over an extended period of time (see Image 2). The coil uses a separate power supply and lower frequency than used for hardening. After the part is hardened and part temperature has equalized to the quench media temperature, the part enters onto a conveyor at a controlled rate of forward motion and is reheated to the required tempering temperature. Usually more than one part is being heated at the same time on the conveyor in a hairpin or channel coil with power left on continuously. The low power density enables the temperature to equalize throughout the workpiece via conduction.

Slack quenching (leaving residual heat from the hardening process in the workpiece) is used regularly in large-diameter single shot and with horizontal scanners. In single shot hardening on large parts, there is a significant amount of heat in the part. The spray quench volume and time is controlled to produce a completely transformed microstructure at which point quenching stops and allows subcase heat to migrate back to the hardened case to reduce stress and hardness.

For example, SAE 1045 carbon steel cylinder rods are induction hardened using a horizontal scanner. Typical case depths are 1.5 to 2.5 mm. The forward motion of the rod through the quench at up to 3 inches per second enables controlling the exit temperature of the bar in the 350°F range to reduce as-quenched hardness from 64 to 60 HRC. This method uses the residual heat and no further tempering is required. Tight control of quench temperature, quench pressure, and quench flow is managed through a computer and PLC. The larger the diameter, the easier it is to control the exit temperature. It is harder to control smaller diameter bars because they have less total residual heat and, therefore, a smaller process window.

Image 2: Channel coil uses a separate lower-frequency power supply to heat multiple parts at the same time while parts are moved forward on a conveyor.

ABOUT THE AUTHOR: Fred Specht is the vice president of sales for North America for Interpower Induction USA. To learn more about Interpower Induction USA's products and services, visit www.interpowerinduction.com or stop by the Interpower Induction Booth #243 at the Cobo Center in Detroit at the ASM Heat Treat Expo & Conference on October 20-22 to view and discuss the latest in induction heat treat technologies.

While LPC with electric heating and HPGQ have won over many auto OEMs, oil LPC, oil-marquenching, and heating with natural gas can offer an effective, lower cost alternative for neutral hardening and carburizing.

By Jack Titus

It's no secret that the heat treating industry is one of the major recipients of the impact when the U.S. Environmental Protection Agency (EPA) makes a regulatory statute. The quantity of natural gas for heating and generating electricity consumed by heat treating is very large. Thus, the movement to reduce NOx (oxides of nitrogen) and other so-called greenhouse gases is of concern for the industry. But what about CO_2? Natural gas (methane) is the cleanest burning fuel besides hydrogen, liberating only CO_2 and water vapor from its combustion.

NATURAL GAS

It is a myth that green plants and trees convert CO_2 into oxygen, but they do consume CO_2. In simple terms, oxygen is produced from green plants and trees as the result of the reaction of water vapor (H_2O) and daylight during photosynthesis. Also, CO_2 reacts to form sugars within the plants. So, both water vapor and CO_2 produced by the combustion of natural gas are not a detriment but are helpful to a healthy atmosphere. It has been said that if hydrogen today replaced all of the natural gas burned and totally eliminated all of the CO_2 entering the atmosphere, that CO_2 dissolved in the oceans and lakes would reenter the atmosphere to regain natural equilibrium.

Heat treating furnaces in the U.S. are heated primarily using natural gas and, in certain locations, using electricity. Table 1 shows the energy distribution for electricity generated by various sources in 2014 and 2015. In 2014, 66 percent of the U.S. electrical energy was produced by hydrocarbon and petroleum products, not counting the natural gas consumed for heating.

OIL QUENCHING

By its organic association, oil will continue to be a reliable quench media for years to come simply because it is applicable to the widest range of steel hardenability. But the discussion about distortion resulting from oil quenching after carburizing continues into the 21st century. The following example addresses that.

AFC-Holcroft's 36 in. x 48 in. x 36 in. UBQ gas-fired, integral-quench batch furnace with a 3,500-pound maximum payload has a connected natural gas capacity of 1,200 ft_3/h. Heating a 3,500-pound charge to 1,700°F requires 770,125 Btu. Non-recuperated radiant tube gas-fired furnaces typically have an efficiency of 50 percent, meaning that half of the gas burned in the radiant tube will leave the tube as exhaust gases. Thus, if 300 ft_3 of gas is burned, only 150 ft_3 is available to heat the load and overcome furnace wall heat losses. Recovering some of the heat exiting the exhaust by preheating the combustion air can save energy by improving the efficiency to about 63 percent.

Industrial burners are set up to produce 3 percent excess oxygen in the radiant tube exhaust to reduce the potential to create CO. Ideal, or stoichiometric (on ratio), combustion for 1,000 Btu natural gas is an air-to-gas ratio of 10:1. Because 78 percent of air is nitrogen plus 1 percent argon, neither of which contributes to combustion but are heated, 3,000 ft_3 of air is required to burn 300 ft_3 of natural gas. When the combustion air is preheated to approximately 800°F by passing the air through an exhaust heat exchanger (also called a recuperator), the air/gas combustion efficiency improves. More efficient burner systems are being developed continually.

	Coal	Natural Gas	Nuclear	Hydro-electric	All Renewable Except Wind	Wind	Misc. Petro
2014	39	27	19	6	2.6	4.4	2
2015	30	30					

Table 1: Distribution (%) of energy in U.S. by generating source. Source: U.S. Energy Information Administration

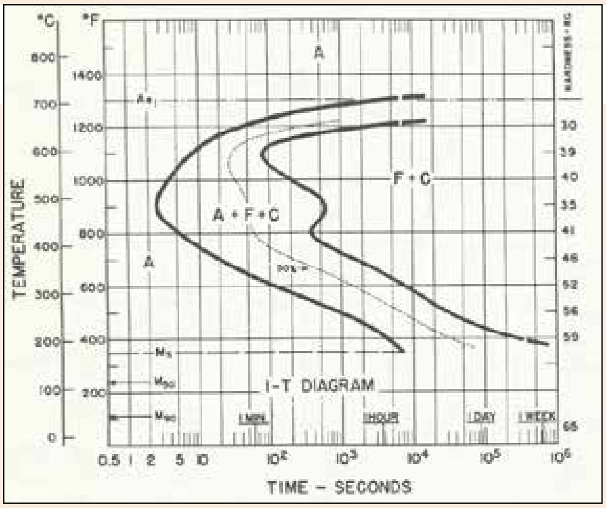


Figure 1: Isothermal transformation diagram for AISI 1321 manganese steel carburized to 0.8% C. Austenitized at 1,700°F. Ms = 350°F

WHY LPC AND HPGQ?

Three reasons why the automotive industry adopted low pressure carburizing (LPC) and high pressure gas quenching (HPGQ) include:

- LPC is cleaner than endo gas, it is not explosive, and there is no significant effluent
- It integrates fairly well for a heat-treat system into the manufacturing chain
- HPGQ reduces distortion in gears

However, disadvantages of the process include:

- Electric heating is expensive and still consumes coal
- HPGQ requires high hp motors
- Capital outlay is high
- Maintenance costs are high
- HPGQ with 20 bar helium under the best circumstances cannot match the core hardness achievable using high-speed quench oil

LPC evolved to where it is today primarily because of acetylene, and control technology has matured as well. For example, modeling programs predict the time, temperature, and acetylene flow to achieve a specific case/carbon profile. However, the *maximum* hardness of that profile can only be realized using high-speed quench oil.

Vacuum furnace design basically remains unchanged, incorporating graphite-based insulation, low-voltage, high-current graphite heating elements, and intricate element-isolation systems. It appears that all LPC systems offered today follow the design intended for high-temperature vacuum furnaces originally developed for processes such as brazing and hardening tool and die steels. Even at elevated temperatures, carburizing will not likely exceed 1,900°F in the foreseeable future.

LPC can be described as a vacuum purge followed by a pressure or flow pulse carburizing process. The hot zone does not need to look much different than a traditional endo-carburizing hot zone with accommodation for the low-pressure vacuum purge. All of the intricacies now associated with vacuum furnaces can be eliminated. Heating elements, electrical isolation, and related maintenance could be a thing of the past. Heating can be done using electric elements or natural-gas radiant tubes made of traditional materials. Insulation can be ceramic, so carbon can be burned out just as in today's endo-carburizing furnaces. As for quenching, the entire two-chamber system can be designed for vacuum pressures, but not the extremely low levels associated with traditional vacuum furnaces.

The development of the multichamber vacuum furnace could be tied to the decade between 1975 and 1985. Major vacuum furnace suppliers developed their own versions of two- and three-chamber furnaces. Most three-chamber systems consisted of a gas quench at one end and an oil quench at the other with a graphite-lined vacuum hot zone in the center. Some furnaces had an oil quench and loading vestibule in lieu of a gas quench and operated as a straight-through system. LPC, or vacuum carburizing, played a minor role in the process in early multichamber furnaces, as they were primarily used for air hardening and high-speed steels in the attempt to displace salt-bath heat treating. Hot zones were designed to operate as high as 2,400°F. In all cases, the oil quench chamber was evacuated to remove oxygen from the quench oil and purge the air prior to moving the load to the graphite hot zone, which was continuously kept hot. After 1985, multichamber vacuum furnaces began to lose their popularity due primarily to high cost and the beginning of the demand for six-bar HPGQ to accommodate new hotwork die steels.

Marquenching is the go-to process to control distortion in oil quenching. The process involves quenching into oil where the oil temperature is held at just above the Ms (martensite start point) of the alloy. Parts are held in the oil until their core reaches the oil temperature, after which martensite transforms uniformly during post wash and cooling. The oil has a maximum operating temperature, and with atmosphere furnaces, the major issue with oil quality is sludge caused by oil oxidation. This is not an issue with AFC-Holcroft's LPC/UBQ, because oxygen is precluded from being present above the oil. The advantage of marquenching is emphasized in Figures 1, 2, and 3, which show how surface carbon affects the Ms point for 1320 and 1321 manganese steels [1]. The Ms point decreases with increasing carbon potential.

As for LPC, when using a furnace that incorporates a ceramic-lined hot zone and has no cold spots (as found in existing vacuum furnaces), all of the acetylene is available for carburizing, which improves efficiency and reduces the need to account for the surface area of the workload.

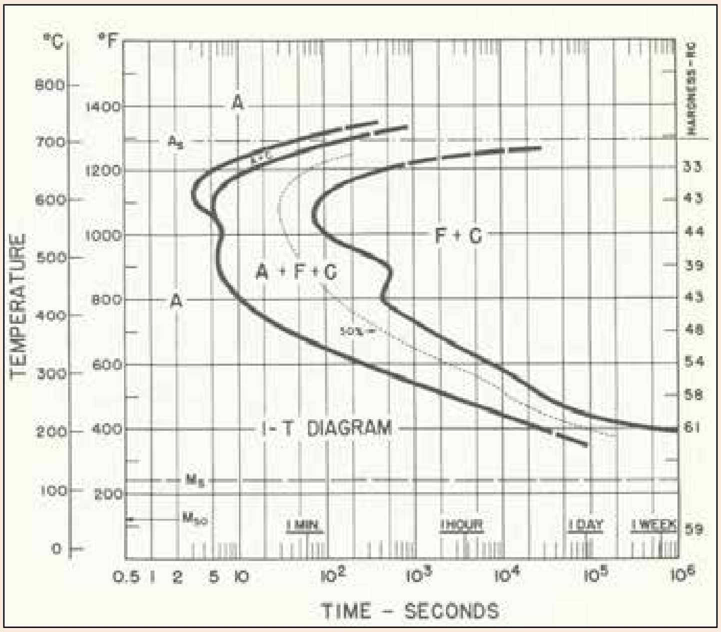


Figure 2: Isothermal transformation diagram for AISI 1320 manganese steel carburized to 1.0% C. Austenitized at 1,700°F. Ms = 240°F

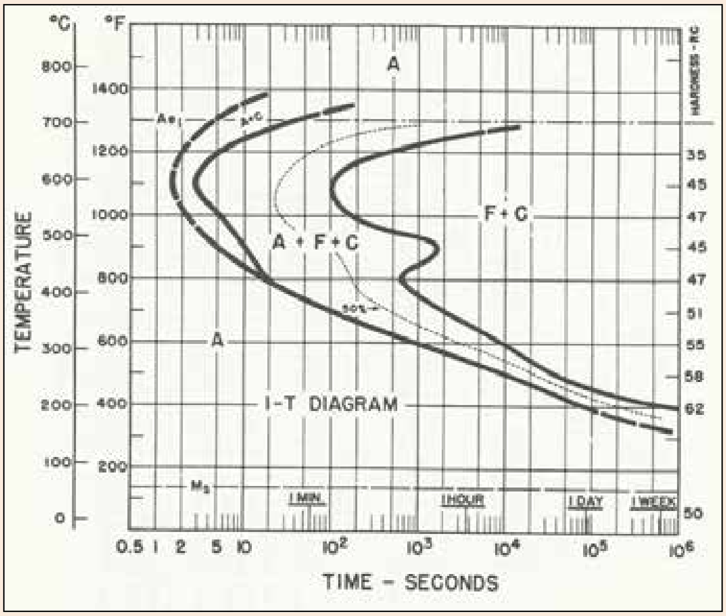


Figure 3: Isothermal transformation diagram for AISI 1321 manganese steel carburized to 1.2% C. Austenitized at 1,700°F. Ms = 130°F

CONCLUSION

Based on these observations, it makes sense for the next generation of carburizing systems to go back to integrating the advances of LPC and the wide application range of modern marquench oils.

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Specialty Steel Treating Inc.

Specialty Steel Treating Inc., a family business specializing in precision-controlled heat treating, provides its customers with exceptional service and is a leader in the industry with the highest heat-treated product quality and a vision for new opportunities and change.

By Ed Kubel

Specialty Steel Treating (SST) was founded by Donald Cox in 1956 in Warren, Michigan, and began operations in a 4,000-square-foot plant with one furnace. Today, it has six facilities — five located in Michigan and one in Connecticut. The company has grown to over 250,000 square feet of operating space in its 59-year history. Michigan facilities are located in Fraser (corporate headquarters) and Farmington Hills, and the Connecticut plant is in East Granby.

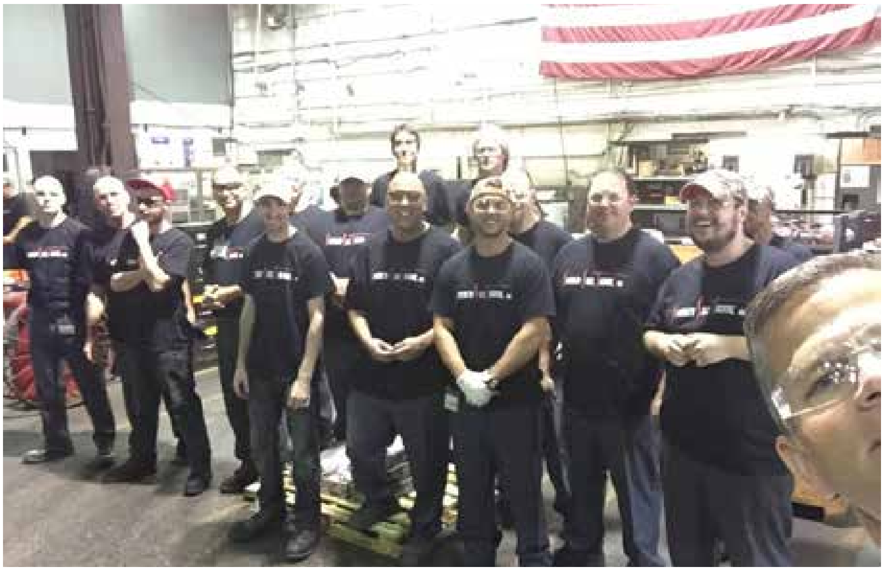
SST BUILT ON A DREAM

While working for a company before starting SST, Cox had many new ideas about improving furnace design and improvements in heat treating performance. He left the company to implement his ideas in his new start-up, Specialty Steel Treating. With capital from a mortgage on his house, he bought his first furnace and set up shop in a modest facility.

Working with the furnace equipment OEM during the construction of his first furnace, Cox debated with the furnace manufacturer on the design of this type of furnace and his concern about the muffle and atmosphere inlet for stainless steel heat treating and brazing using a hydrogen atmosphere. He finally accepted the recommended design by the OEM.

Upon installing the furnace and the initial start-up involving heating the furnace to operating temperature and introducing the atmosphere, an explosion occurred that severely damaged the furnace. Cox and the OEM spent many weeks during the holiday season in 1956 to repair and redesign the furnace to the specifications that he wanted. Due to the circumstances of the furnace failure, the OEM offered a generous grace period on paying off the furnace.

Many years later, Cox revealed to his staff that if it wasn't for the grace period to pay for the furnace, he may not have survived his first year of operation due to lack of work and revenue.



SST MISSION

The mission of SST is Performance, Integrity, and Improvement. Performance to exceed customer expectations with regard to quality, delivery, and cost. Integrity to maintain the highest level of integrity to its customers and the industry. Improvement to maximize productivity and efficiency of all business activities through a program of continuous improvement.

PRODUCTS AND SERVICES

SST is known in the aerospace industry as the premier heat treating source for precision-controlled heat treating services. For many years, SST has been the only source for certain flight-critical and flight-safety helicopter transmission parts with unique and challenging configurations. SST was a crucial source for the final "Return to Flight" program of the last Space Shuttle Program. The aerospace industry accounts for about 40 percent of SST work, 25 percent is industrial related, and automotive, heavy equipment, trucks, rail, and firearms markets account for the other 35 percent of business. SST is ISO 9002 and Nadcap certified and is an FAA Certified Repair Station.

Primary services offered include gas and vacuum carburizing, press and plug quenching, roller quenching shafts, vacuum heat treating with 6-bar pressure quench, normalizing, batch oil quenching, neutral hardening, carbonitriding, gas nitriding, and precipitation hardening.

COMPANY GROWTH

During its 59 years in business, the company has grown and expanded numerous times. From its beginning in Warren, Michigan, the first move was to a larger 12,000-square-foot facility in 1960 still in Warren. The next expansion was in 1967 to a 30,000-square-foot facility in Fraser. Due to the growing business, this building was expanded to the maximum size allowable by the property. In 1969, the plant in East Granby, Connecticut, was opened at the invitation of Sikorsky Aircraft seeking a quality heat treating source in the region. In 1979, SST opened the facility in Farmington Hills, Michigan, at the request of Ford Motor Company to process ring and pinion gears for the company. Between 2006 and 2011, SST opened three additional facilities in Fraser due to its process capabilities and position in the taper-bearing market.

SST entered the vacuum carburizing arena in 2003 and is now a crucial supplier to the aerospace industry for certain critical programs and challenging part configurations.

PEOPLE AND COMMUNITY

"People make a company," said SST's Vice President Mark Sosnowski. "We believe we have exceptional associates at Specialty Steel at every level. The dedication, service, and expertise our staff presents to the company and industry go from the president to each employee, and this is the main reason for SST's success throughout the years."

Employee job satisfaction is evident by the tenure of SST associates. While there are new team members being added to the company as growth continues, the average tenure of the team is over 15 years, and many associates have well over 25 and 30 years with the company.

SST is involved in the community and is a strong supporter of various programs through participation and donations including the Fraser DARE Program and the DEA Survivor's Benefit Fund every year. SST works closely with local firefighters and police annually to ensure proper training is performed on prevention and reaction to hazards within the heat treating industry.

PROMISING FUTURE

As a family business, SST has been successful for several generations. Today, the third generation is deeply involved in the operation and success of the company, and the fourth generation has begun their journey within the company to continue the level of growth and success that was started almost 60 years ago.

"The same philosophy will be ingrained into each generation to come: respect all those who work for the company, respect and serve its customers with exceptional service, and continue to be a leader in the industry with the highest quality, best service, and a vision for new opportunities and change," said Sosnowski.

FOR MORE INFORMATION, contact Mark Sosnowski at (586) 293-5355 or at mark@sst.net. To learn more about Specialty Steel Treating, visit www.sst.net.

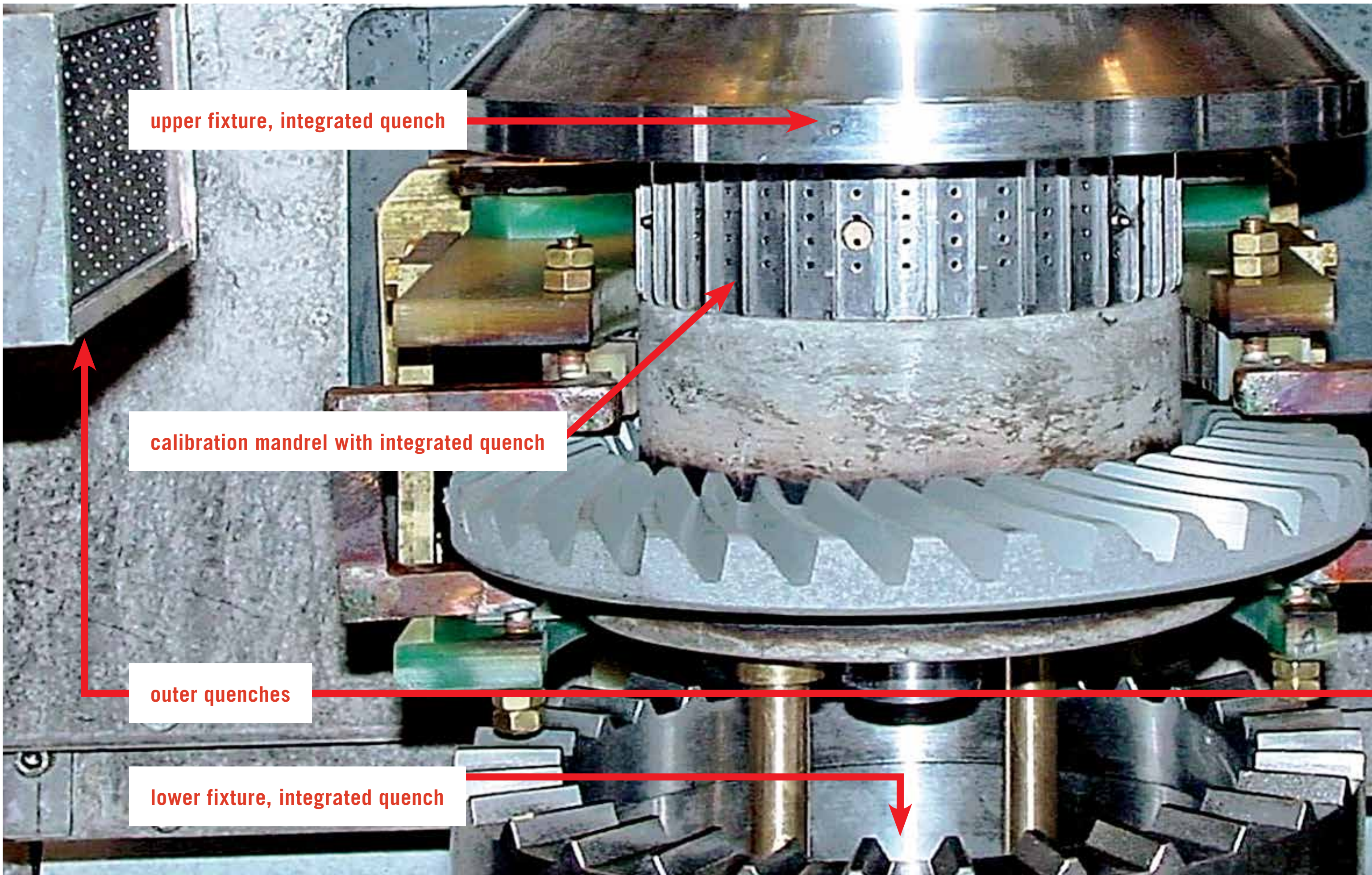


Figure 4: Four individually controllable quenches of fixture-hardening machine enable shape corrections via cooling conditions

Inductive Fixture Hardening and Tempering Process for Dimensionally Accurate Parts

By Wilfried Goy and Detlev Bartknecht

A new inductive hardening and tempering process combines the benefits of induction heating and hardening with the benefits of a press hardening process.

Automobile manufacturers increasingly require components with greater accuracy for use in sophisticated applications. To meet these increased requirements, press hardening was developed, and there are continued advancements in this field of applications.

INDUCTIVE FIXTURE HARDENING

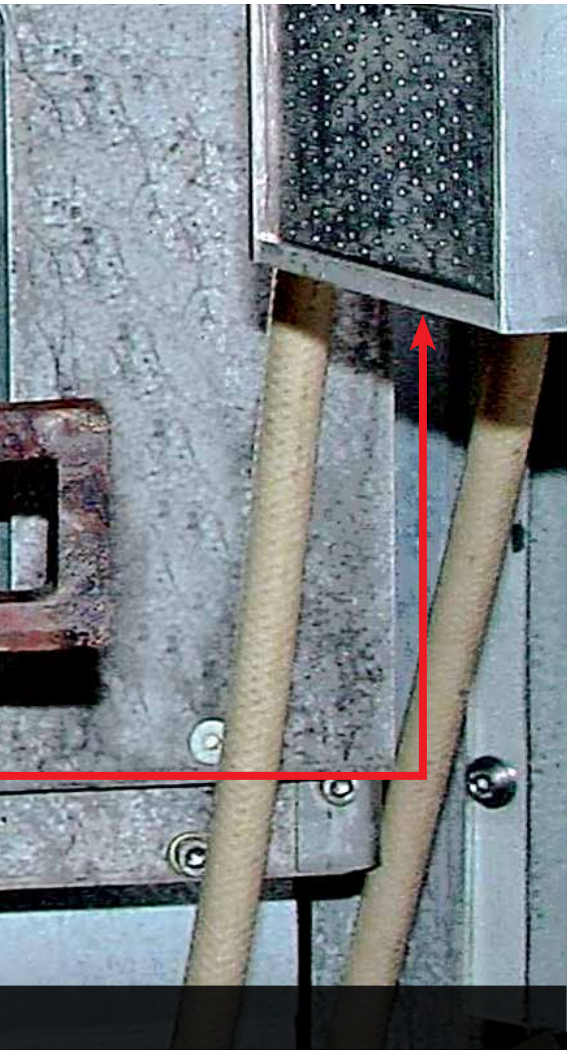
EMA-Indutec developed a new process that combines the benefits of induction heating/hardening with the advantages of a fixture or press hardening process. The benefits of induction hardening include:

- Heat created directly within a workpiece
- No transmission losses
- Energy savings
- High production rates
- Fast, easy-to-control process/heating
- No emissions

Some adverse effects of heating a workpiece to about 900-950°C followed by hardening include:

- Dimensional changes due to thermal expansion
- Distortion due to asymmetric shapes
- Distortion due to asymmetric hardness patterns
- Volume expansion (about 1 percent) due to the martensite transformation
- Tensile stresses inside the workpiece due to machining and fabrication steps prior to hardening

All preexisting internal tensile stresses are released during heating and hardening, especially in thin-walled workpieces. Eliminating these nearly unavoidable effects requires time-consuming, expensive rework. To complicate matters further, rework (such as grinding and straightening) must be carried out on hardened surfaces.



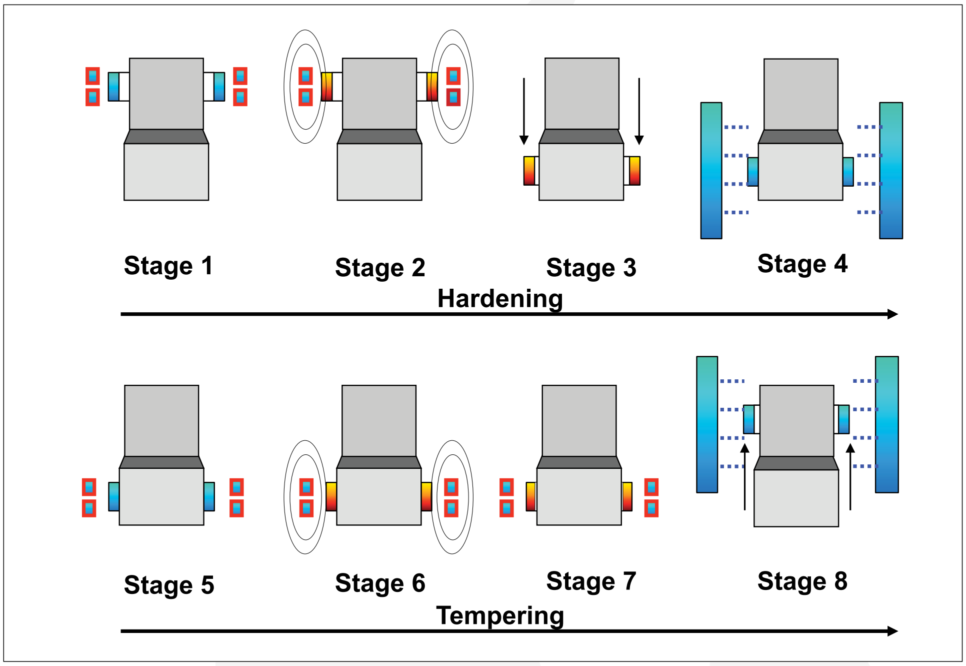


Figure 1: Inductive mandrel-hardening process stages: (1) part placed on holding device, (2) inductively heated to 900°C, (3) workpiece driven onto the calibration mandrel, (4) quench part, (5) place inductor around calibration mandrel, (6) temper part, (7) gap appears between part and mandrel, (8) remove part from mandrel

Power	60 kw
Frequency	10 (or 20) kHz
Cycle Time	60 sec. (including loading)
Surface Hardness	650-720 HV1
Case Hardening Depth	0.3-0.6 mm
Core Hardness	320-420 HV1
Accuracy:	
Circularity	< 0.05 mm
Parallelism	< 0.05 mm
Tapering/Rectangularity	< 0.05 mm

Table 1: Process parameters to harden and temper (including mandrel hardening) a 16MnCrS5 sliding sleeve

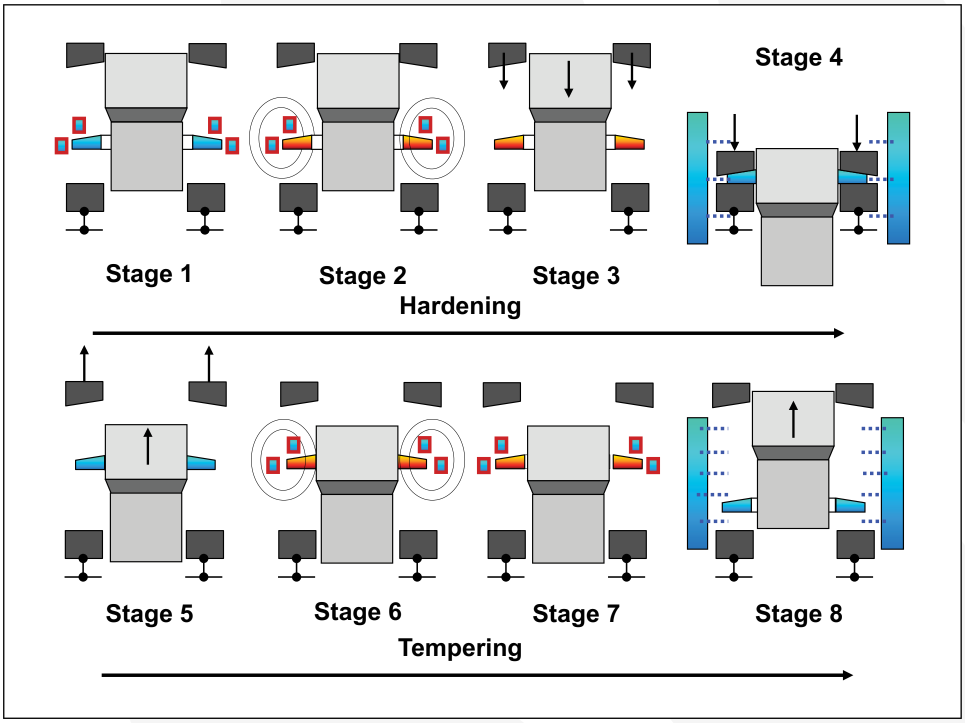


Figure 2: Inductive fixture hardening of a crown wheel

INDUCTIVE MANDREL-HARDENING PROCESS

EMA-Indutec developed induction fixture-hardening machines mainly for round and cylindrical workpieces such as sliding sleeves. The common process for handling carburized parts is shown in Figure 1.

An oval or noncircular sliding sleeve is placed onto a nonconductive centering and holding device (Stage 1) and inductively heated to about 900°C (Stage 2). After a certain dwell time to achieve a uniform, homogeneous temperature, the workpiece is driven onto the calibration mandrel (Stage 3) immediately followed by extensive cooling using a polymer-based quenching medium (Stage 4). Stages 1 to 4 illustrate the inductive hardening process resulting in a cool workpiece, which is shrunk onto the calibration mandrel made of stainless steel.

In the tempering process, an inductor is placed around the assembly of the sliding sleeve and calibration mandrel (Stage 5) and generates tempering heat inside the workpiece (Stage 6). With increasing temperature, the sliding sleeve expands marginally, creating a minimal gap (Stage 7) that enables

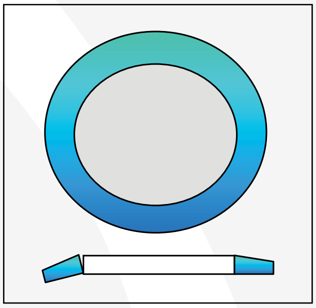


Figure 3: Irregularly shaped crown wheel

removing the sleeve from the plug without affecting the precise, accurate surface of the calibration mandrel; a spring-driven force is sufficient (Stage 8). At the end of the hardening and tempering procedure, the sliding sleeve can be cooled down to room temperature. Table 1 shows typical process parameters.

INDUCTIVE PRESS-HARDENING PROCESS

A new process was developed for handling crown wheels but is not limited to these parts. All workpieces requiring flat, even surfaces (Figure 3) can thus be corrected to accurate final dimensions while hardening. In principle, the new device works in a similar manner as a conventional machine. In addition, there are strong bottom and upper fixtures that contact the hot workpiece, pressing it while quenching. Stages 3 and 4 of Figure 2 show the additional fixtures. After quenching (Stage 4), the fixtures are no longer necessary and are removed to allow tempering (Stages 5 and 6). Process parameters and achieved results are shown in Table 2.

The new equipment provides two benefits compared with conventional fixture hardening. In most conventional processes, workpieces are heated in a gas-fired rotary hearth furnace and subsequently transported into the press. During the transfer period, parts cool down, whereas the inductor in the new machine allows heating up – from room temperature, if necessary, or to compensate temperature losses during the transfer. The time span from end of heating to first quench (which is relevant for quality) is minimized.

Also, the quenching technique is different, using four separately controllable quench circuits: through the bottom fixture, through the upper fixture, through the calibration mandrel, and from the outside (Figure 4). These four quenching options allow shape corrections, via cooling conditions such as various flow rates and different starting times, and respective dwell times. All quench systems are controlled individually by flow meters.

This device and process combines the advantages of induction hardening with the benefits of fixture hardening including:

- Integrating the process directly into the line
- One-piece-flow
- No delay on process start (no long-term heating up of a furnace)
- Energy savings due to short-term heating
- Excellent reproducibility due to good control options
- High precision of final workpiece dimensions
- Minimization of dimension failures and scrap
- Minimization of rework

Nevertheless, the process is based on carburized workpieces, so it is not necessary to change materials to higher carbon steels. The hardness patterns are not changed, therefore, the qualifying procedure is less cost-intensive compared with entirely new parts made of other materials and complete approval for a totally different process.

PLANT DESIGN WITH ROTARY HEARTH FURNACE

A layout of a conventional furnace is shown in Figure 5. Main components are a rotary hearth furnace for carburization followed by a conventional fixture hardening machine for already heated work-

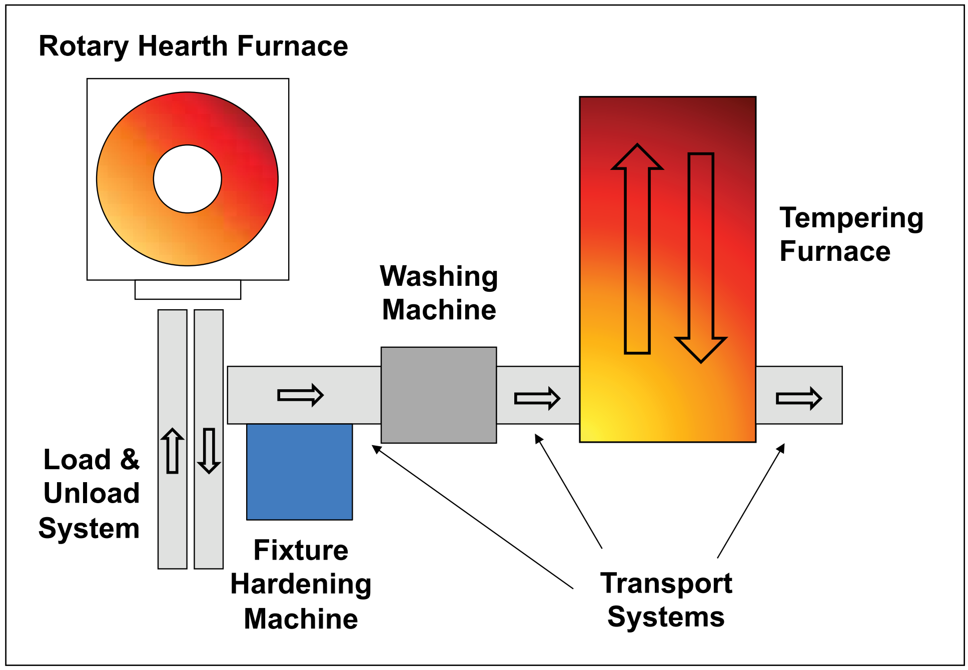


Figure 5: Conventional production plant layout

Power	250 kw
Frequency	10 kHz
Process Time	4 min.
Surface Hardness	680-780 HV30
Case Hardening Depth	0.8-1.2 mm
Core Hardness	350-480 HV30
Accuracy:	
Circularity	< 0.03 mm
Tapering (inner dia.)	< 0.03 mm
Flatness (bottom)	< 0.05 mm

Table 2: Process parameters to harden and temper (including fixture hardening) a 16MnCrS5 crown wheel

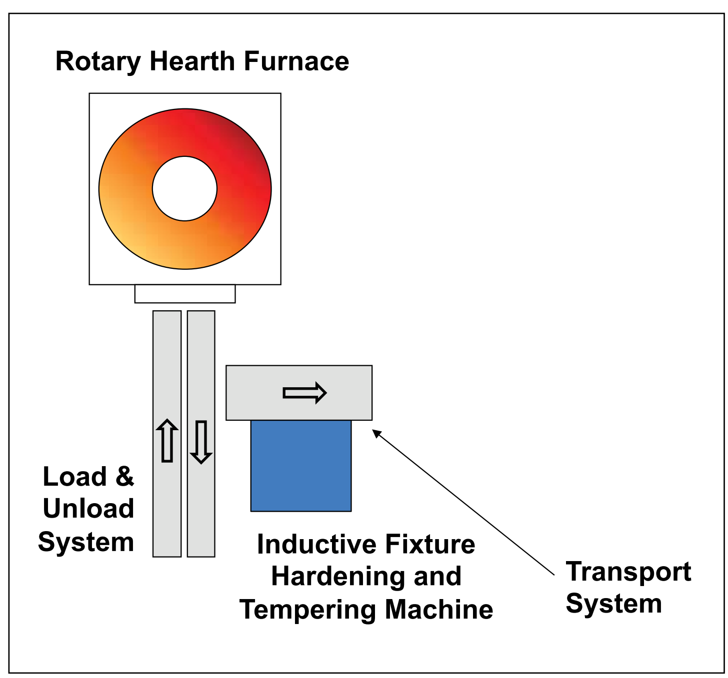


Figure 6: Inductive production plant layout

Figure 7: EMA-Indutec hardening machine

pieces. As conventional machines use oil as a quenchant, the next big component has to be a washing machine to clean oil from the parts.

A mostly gas-fired tempering furnace follows. Individually controllable transport systems are necessary between all components.

The number of components is drastically reduced in the inductive production plant (Figure 6). Only the rotary hearth furnace and the new inductive fixture remain. The washing machine is superfluous because inductive hardening usually works with water-based liquid quenchants. So there is no need for subsequent washing of the heat-treated workpieces. The second component eliminated is the huge, expensive tempering furnace. Tempering is integrated in the new process, and no separate and/or additional energy is required. The inductor inside allows heating for hardening purposes as well as for tempering without any change except power level. Thus, the number of components and intermediate transport systems is reduced resulting in a considerable reduction of programming, sources of malfunction, and maintenance.

The hearth of the new process (the assembly consisting of the induction coil, lower and upper fixtures, and calibration mandrel) can be implemented in an EMA-Indutec nearly standard hardening machine shown in Figure 7.

CONCLUSION

The new process of combining the benefits of induction heating and hardening with the advantages of fixture hardening obtains highly precise workpieces with enormously reduced or eliminated rework.

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Figure 1: Nitrocarburizing system consisting of six retort-style batch furnaces

Nitrocarburizing Gears Using the ZeroFlow Method in Large-Volume Production

By Mark Hemsath, Leszek Maldzinski, Tomasz Przygonski, and Maciej Korecki

Reliable furnace equipment design and innovative ZeroFlow control offers heat treating with lower gas consumption and the lowest emissions in gas nitriding and ferritic nitrocarburizing.

Retort-based nitriding and ferritic nitrocarburizing have been around a long time. Modern day challenges include providing known, repeatable hardness and surface case structures with the lowest possible investment and cost. While combining these factors may be difficult for equipment manufacturers, experience in designing equipment for challenging applications helps ensure meeting customer requirements. Here is a detailed look at Seco/Warwick's use of advanced automation, ZeroFlow control technique, and reliable furnace equipment designs for the production of gears for diesel engines used in trucks, buses, construction machines, boats, and other industrial applications.

AUTOMATED, HIGH-VOLUME SYSTEM DESIGN

Seco/Warwick supplied nitrocarburizing technology using its ZeroFlow method in 2013 (Figure 1) for an automated thermal treatment line for the production of a variety of gears. The line consisted of six large, front-loaded retort-style batch furnaces, a four-chamber vacuum washer, two furnaces for pre-activation in air, additional post cooling of the furnace charges, and an automatic robotic loader/unloader, which ensured charge transport within the system (Figure 2). The automated line also included safety monitoring. System work-space dimensions were 32 inches wide x 32 inches high x 60 inches long with a gross workload capacity of 4,400 pounds, which enabled a production rate of more than 2,000 pounds of gears per hour. Good equipment design and use of ZeroFlow control technology resulted in a successful project.

DESIGN FEATURES

ZeroFlow control technology enables precise control of the nitrocarburizing process, while using a minimum amount of ammonia. The carbon-carrier medium in this instance comes from methanol. Endothermic atmosphere, methane, propane, CO, and CO_2 are some other gases used for nitrocarburizing.

Historically, most gas nitriding (or nitrocarburizing) has been performed in a retort-style chamber. This enables holding the ammonia at an elevated temperature and controlling its release only via a controlled exhaust. Seco/Warwick has decades of experience with these retort systems, including horizontal retorts, vertical pit retorts, and bell-type vertical retorts. All of these furnaces have common design elements, such as a high nickel-content alloy retort to reliably contain the ammonia atmosphere at an elevated temperature without leaking. The retort must also provide a long service life and withstand detrimental gases and temperature cycling as well as continual thermal expansion and contraction. Another common feature in these systems is recirculation fans that mix the atmosphere and provide convection to assist with heating the load.

Vacuum purging is an optional feature to cut cycle time, save gases, and offer additional flexibility, which makes system tightness even more critical and design even more complex. Both horizontal and vertical loading systems can use vacuum purging.

ROLE OF CONVECTION

Gas nitriding (and the related nitrocarburizing) is a complex process. While there have been many process advancements in this area over the years, the combination of various gas reactions and understanding equipment design still present a challenge. Convection plays a significant role in nitriding and nitrocarburizing.

Using dense workloads is the most cost-effective way to heat treat. Getting the workload up to temperature is important, but because gas nitriding is a fairly low temperature process (below 600°C), radiation does not play a significant role in heating a dense load. Also, because nitriding reactions at the metal surface are temperature dependent, all parts must be at the same temperature so that they have the same time-temperature history. This requirement makes equipment design critical. Figure 3 shows a typical flow schematic of a convection system performing well. The equipment designer must make trade-offs between cost, performance, productivity, and quality. However, for gas nitriding, it is not practical to take shortcuts in design for proper convection. Therefore, a fan is not only used for mixing, but it is also used to guide flow to maximize heat transfer from the heated retort walls to the entire load in a uniform manner.

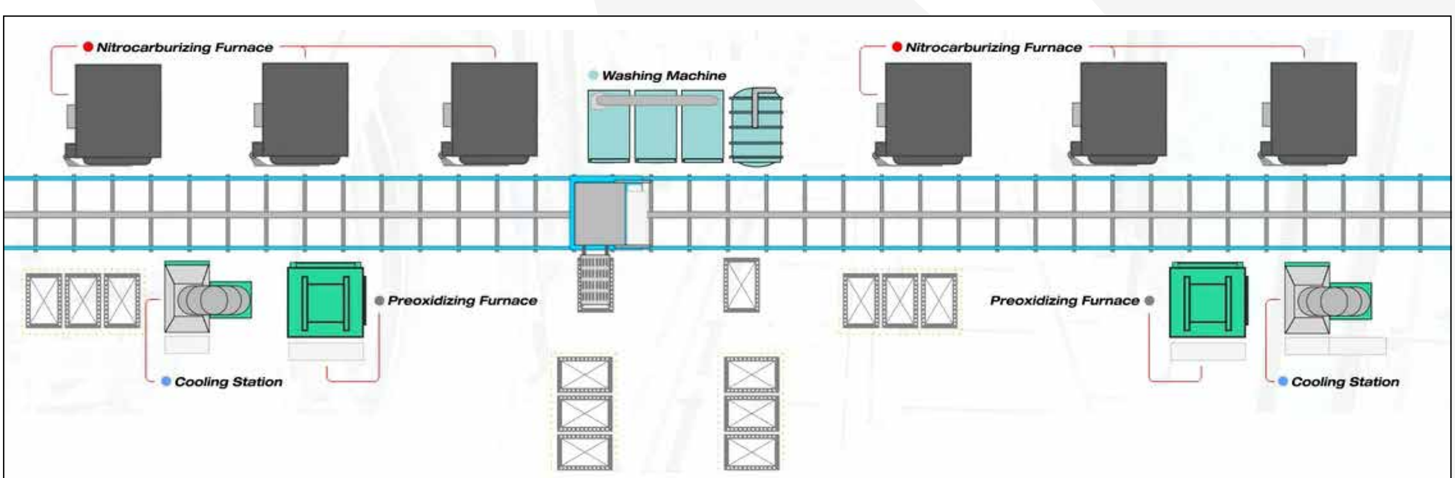
MIXING GASES IN THE LOAD

Dense loads also require aggressive mixing of the gases to maintain nitriding and carbon potentials at the surface of the metals at the required levels [1]. Systems with only a mixing fan are not as effective. As hot gases react with the metal surfaces, their compositions change. Therefore, proper, aggressive mixing within the workload is crucial.

ZeroFlow control senses the changes in overall gas composition and efficiently adjusts the nitriding potential. It is important to have a means to continuously measure the variation in nitriding potential at the sample point in the furnace using a gas-analysis system and make automatic adjustments. Proper convection and mixing ensures that the sample point sees the change in nitriding potential quickly and makes timely adjustments to the gas mixture. It is crucial that the sample point accurately reads the condition of the gases because it is necessary to adjust the nitriding potential at the part surface during heat treating. Ammonia dissociates during the metal surface reactions, and nitrogen (as well as carbon in the case of nitrocarburizing) diffuses into the steel. So, a fresh atmosphere with the correct nitriding potential must be available at the surface. Precise layer control has been demonstrated, especially in the longer second stage transport mechanism, under ZeroFlow adjustment.

Significantly, ZeroFlow control simplifies managing the nitriding process. The control system manages the correct parameters to deliver repeatable results regardless of the workload size (small, light load or heavy, densely packed load).

Figure 2: Schematic of nitrocarburizing system



With ZeroFlow, only a single gas (raw ammonia) is used. Calculations of how to add a carrier gas, required in older-style systems using nitrogen or dissociated ammonia two-part gases, are not required (see Reference [4] for a discussion of nitriding processes). The simplicity means that no extensive support from the furnace supplier is required to properly nitride, and recipes become repeatable, regardless of load size.

ZEROFLOW CONTROL SAVES GAS AND REDUCES EMISSIONS

Over the years, much has been learned about nitriding (and nitrocarburizing), mainly that nitriding potential must be adjustable to control various reaction kinetics that occur at the steel surface. To control and "mold" the desired nitrogen transport into the steel, methods were developed to adjust or maintain the nitriding potential, which is always changing if no control method is used. Initially, dissociated ammonia (75-percent hydrogen and 25-percent nitrogen) was used [2] and its percentage adjusted together with simultaneously flowing raw ammonia gas into the retort. As nitrogen became less expensive, only nitrogen was flowed with raw ammonia gas as a dilution method to adjust nitriding potential [3]. These processes worked (although they created a more complex non-equilibrium process), and the extra gases used were not a major concern. Today, using extra process gas is a concern and is an added expense.

Use of less ammonia means less storage and less ammonia emissions as well. Seco/Warwick's advanced systems offer less gas use, lower emissions, good convection design, and high-quality construction. A retort-based system also offers options to add cooling and to use vacuum to speed purging air and save on using expensive gases.

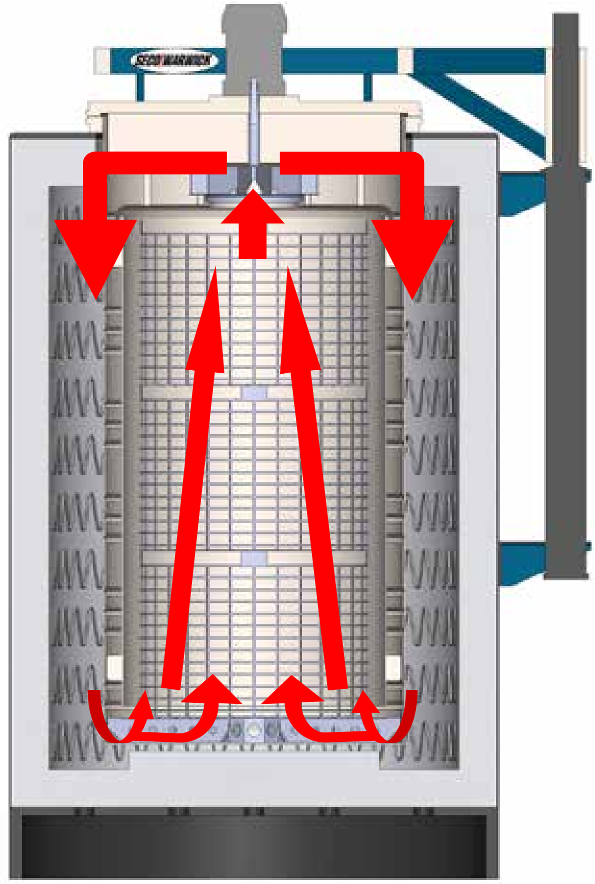


Figure 3: Schematic of pit-type retort nitrider showing gas convection flows

COOLING THE LOAD AND VACUUM PURGING

Vacuum provides a method to purge air at the beginning and end of the cycle. Seco/Warwick developed options to speed the cycle via cooling options. The vacuum-purging option is often chosen to save time and further reduce gas consumption and emissions. Retort and system design are important to allow for constant vacuum pressures. Many factors go into keeping retorts leak-free, but mainly correct alloy selection, allowance in the design for continual thermal cycling, and proper design to support the heavy gross load. The retort also commonly supports the load, further complicating the design. Seco/Warwick designed horizontal and vertical loading retorts that handle fairly heavy loads, allow for thermal expansion, and provide long service life.

Cold air added to the outside of the retort cools not only the retort, but also the furnace portion (elements, insulation, etc.) outside of the retort. This, in turn, cools the load via high convection flows inside the retort, removing heat from the workload and transferring it to the retort walls to be cooled indirectly. While this cooling method is good without the use of water, production can be further improved by directly cooling the hot gases, such as by Seco/Warwick's turbo cooler — an external heat exchanger. This system uses a high-volume fan enclosed in a pressure-tight system to remove hot gases from the retort, pass them through a high-efficiency heat exchanger, and return cold gases to the retort. Heat exchangers are typically water-cooled bundles of finned tubing, such as those used with vacuum quenching cooling systems. The result is an approximate 50-percent reduction in the cooling times, depending on the desired heat removal. In the end, the system is ready faster for the next load to be heat treated, yielding higher production rates.

CASE HISTORY: PROCESS AND RESULTS

The system referred to in Figures 1 and 2 went online in 2014 and is currently operating at full capacity, while meeting the stringent requirements of the automotive industry. It achieved the planned production goal of 1 million gears per year with 99-percent process reliability and 98-percent equipment availability. It has worked continuously with one maintenance break a year. Heat-treated parts meet specification requirements in terms of thickness and hardness of the nitrocarburized layer, structure of the compound layer, and porosity. No deficient gears were found during normal operation. Moreover, fatigue properties improved by about 50 percent (Figures 6 and 7). The heat treating line also achieved desired operation parameters including an 80-percent reduction in the consumption of ammonia from that consumed using the previous method to nitrocarburize (from 160 metric tons per year to 20 metric tons per year). At the same time, only 1 m^3 of methanol is used as the carbon source in exchange for the total elimination of fuel and process gases (methane and propane). The unit cost of heat treatment using the system was reduced significantly by going to an automated batch cell versus a continuous furnace method. This modern heat treating system plus ZeroFlow control also eliminated any environmental, safety-related, and emission of hazardous gases (NOx) issues.

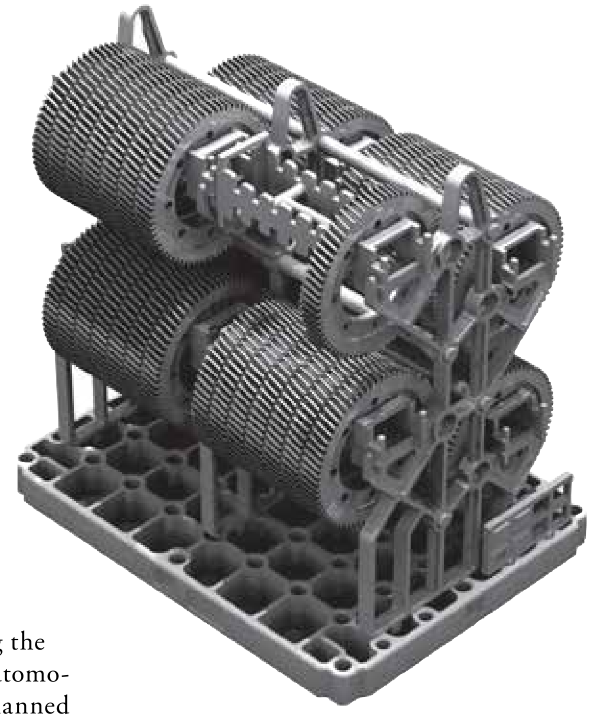


Figure 4: Gears for ferritic nitrocarburizing

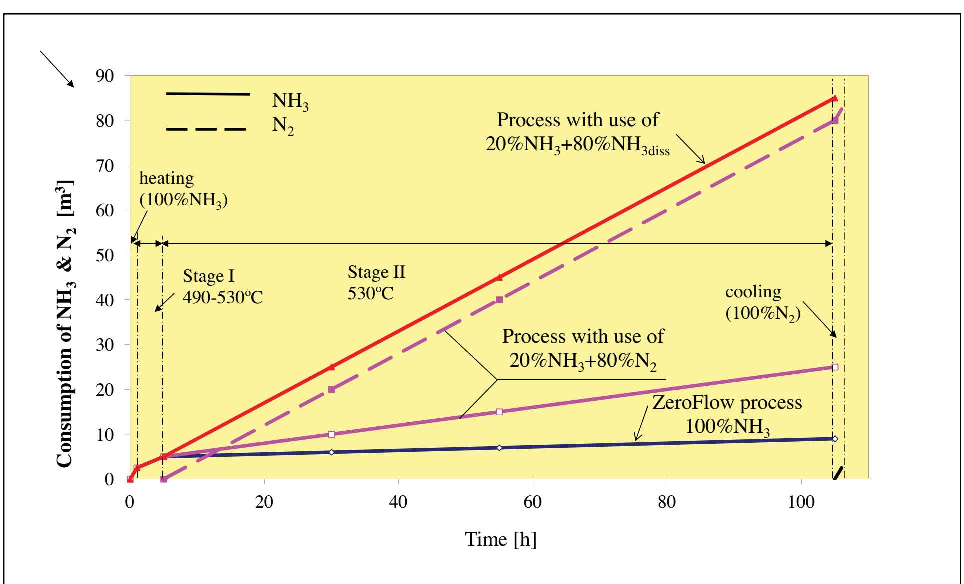


Figure 5: Process-gas consumption for nitriding at 530°C and creating a gamma prime + alpha ($\gamma' + \alpha$) layer

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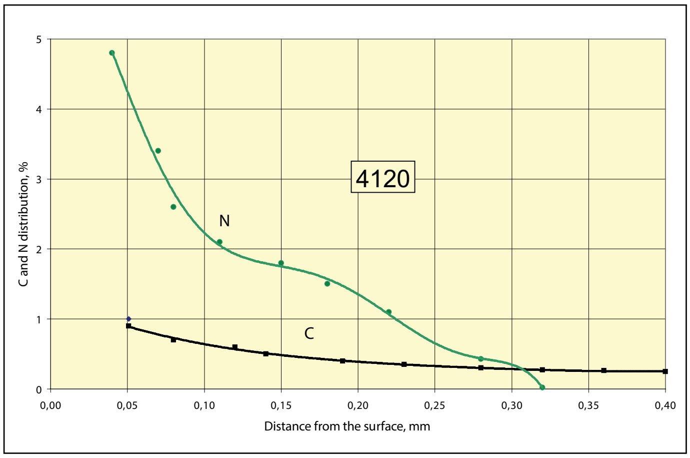

Figure 6: Nitrogen and carbon diffusion at the surface in 4120 alloy steel

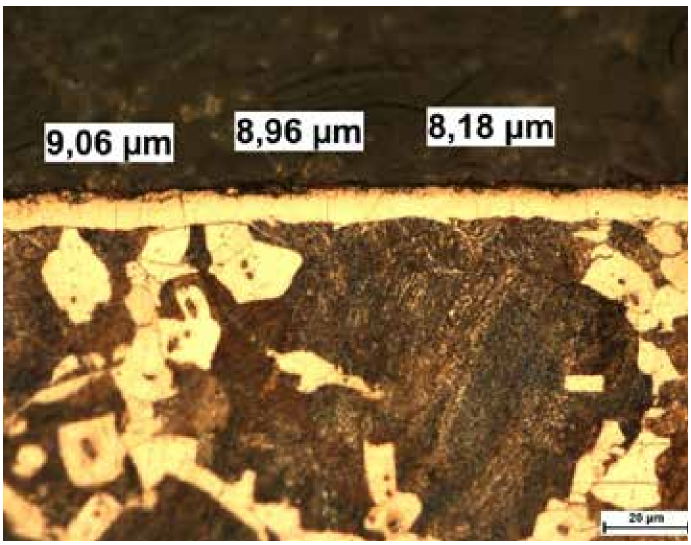

Figure 7: Microstructure of case in nitrocarburized 4120 alloy steel

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Figure 1: Large gear shafts during ion nitriding

Ion Nitriding of Ferrous and Titanium Alloys for Gear Applications

By Edward Rolinski, Tekin Damirgi, and Mikel S. Woods

The advantages of ion nitriding in many low-alloy steels and titanium alloy gears used in high-performance applications include resisting wear and fatigue.

Thermochemical surface engineering is effective in improving the performance of various gears made of ferrous alloys [1-5]. The cost of machining typical gears during the manufacturing process often exceeds 55 percent of total cost, especially when there is significant grinding after carburizing the gears [5]. Therefore, improvements in the manufacturing of gears that can lead to a reduction in machining are valuable.

Nitriding produces high hardness and compressive stresses in many low-alloy steels used for gears. It is a nearly distortion-free process, which allows for the treating of finished components, thus minimizing costs. The complex nature of the stresses at the contact area of rotating gears leads to contact fatigue and sliding friction. Nitriding is superior to other surface engineering techniques in resisting wear at gear flanks. When a high-strength alloy steel suitable for nitriding is used, a nitrided surface layer withstands high contact Herztian stress (contact stress) at gear flanks better than a deeper carburized layer in many instances [4]. Also, the maximum operating temperature for nitrided gears is higher than for carburized gears, typically 455°C versus 150°C [6]. Rolling contact fatigue (RCF) and tooth root-bending

Figure 2: Small 15-5 PH steel gear for the aerospace application after plasma nitriding. Note nitrided teeth and all the other surfaces protected from the treatment by mechanical masking. The diametral pitch was 50.

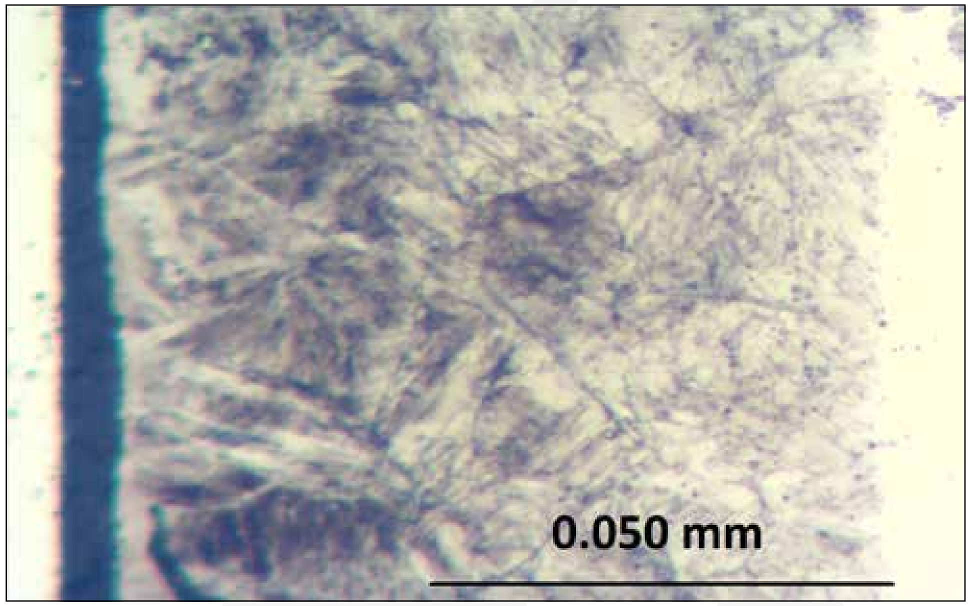

Figure 3b: Cross section of the gear teeth shown in Figure 2 at 500x, etched using nital

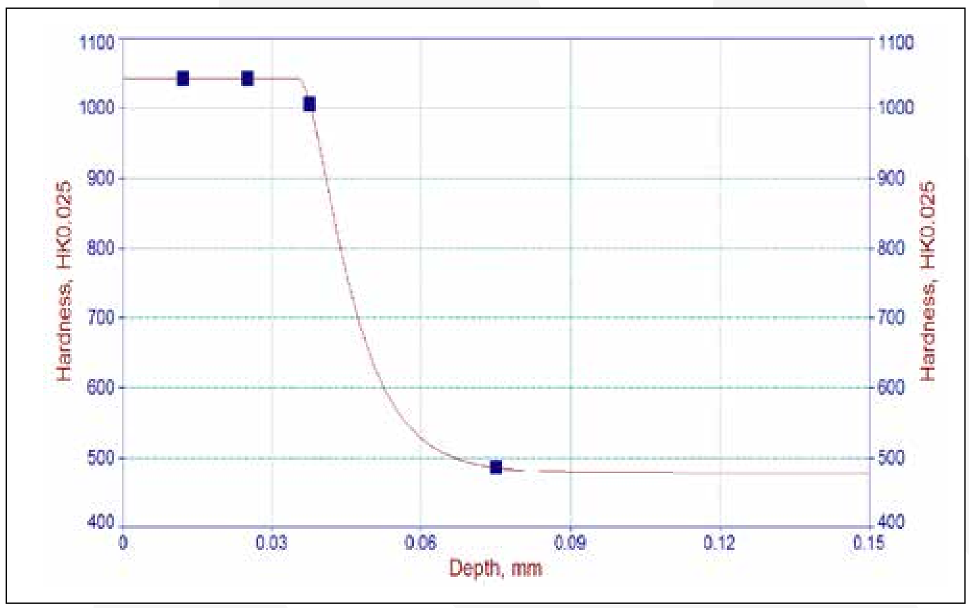

Figure 4: Microindentation hardness profile in the nitrided layer of the gear shown in Figure 2

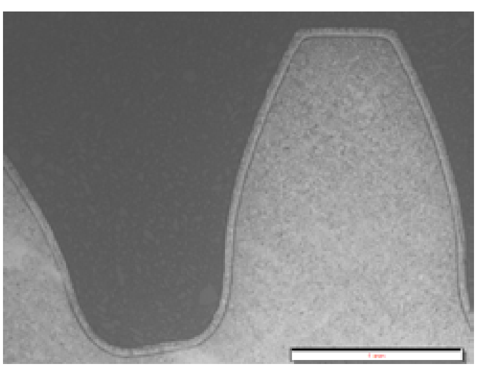

Figure 3a: Cross section of the gear teeth shown in Figure 2 at 50x, etched using Marble reagent

fatigue are primary gear failure modes [7, 8]. With the proper microstructure, certain alloy steels enable achieving a sufficiently thick, hard nitrided layer that resists high contact stresses (2068-2413 MPa, or 300-350 ksi), such as those generated in jet-engine mainshaft applications [9, 10].

In addition, most of the distress in aero-engine bearings is brought on by surface conditions, not by the so-called classical subsurface fatigue initiation [11]. A similar situation may also be considered in gear applications. Contact fatigue and negative effects of intergranual nitrides (IGN) present in the nitrided microstructure can lead to premature failure. This may also increase the spall propagation rate over that normally experienced in materials that are not nitrided [10, 11]. For high-performance, high-speed gears used in power-generation applications, nitriding enhances long-term resistance to pitting and tooth flexure [12]. These applications require a deep (>1 mm) nitrided layer that's free of IGN.

Ion nitriding is also applied to high-performance titanium alloy gears used in the aerospace industry.

NITRIDING PROCESS

The process of ion nitriding is carried out in a glow discharge with the workpiece as the cathode and the vessel wall is the anode [2]. The atmosphere is typically a mixture of nitrogen and hydrogen, occasionally enriched with argon or methane. Treated parts can be observed through a porthole (as shown in Figure 1).

High-quality nitriding requires that the nitriding temperature is at least 28°C (50°F)

Diametral pitch	Case depth, mm	Case depth, in.
90	0.013-0.025	0.0005-0.001
70	0.025-0.051	0.001-0.002
50	0.051-0.010	0.002-0.004
30	0.051-0.102	0.002-0.004
25	0.051-0.010	0.002-0.004

Table 1: Recommended case depths for small modulus (high diametral pitch) alloy steel gears

below the tempering temperature and that parts are free from decarburization because nitriding decarburized steel results in excessive growth and the case can become brittle.

Nitrided gears do not require a case as deep as that required in carburized gears. Table 1 lists recommended case depth for different high diametral pitch (DP) [13].

LOW-MODULE (FINE-PITCH) GEARS

Several unique characteristics of ion/plasma nitriding enable applying it to a variety of ferrous and nonferrous alloys [2]. Nitriding high-alloy steels, including stainless steels, are carried out at a temperature between 350°C and 600°C. Stainless steels are used in aerospace applications requiring maximum mechanical strength and durability. Many components are ion nitrided in a finished condition. Because nitriding is carried out at a temperature far lower than the phase transformation temperature, properly nitrided gears exhibit no distortion. An advantage of ion nitriding in these applications is the ease of protecting selective areas from hardening using mechanical masking [2].

Figure 5: Plasma nitriding of the AISI 4340 alloy-steel gear used in the power industry. Mechanical masking/segmented fixturing covers a portion of the outside diameter of the gear to perform selective hardening.

Uniformity of the nitrided layer around the fine-pitch tooth profile is excellent when the process is carried out using proper control (as shown in Figures 2, 3, and 4). The hardness of the nitrided layer formed in precipitation hardenable stainless steels, such as 15-5 PH, is high across the entire layer (see Figure 4). While control of the nitrided layer structure in high-alloy steels is difficult, it is achieved by proper adjustment of gas composition, pressure, plasma density, and frequency and pulsation (duty cycle).

LARGE-MODULE GEARS

Large-module gears are often made of low-

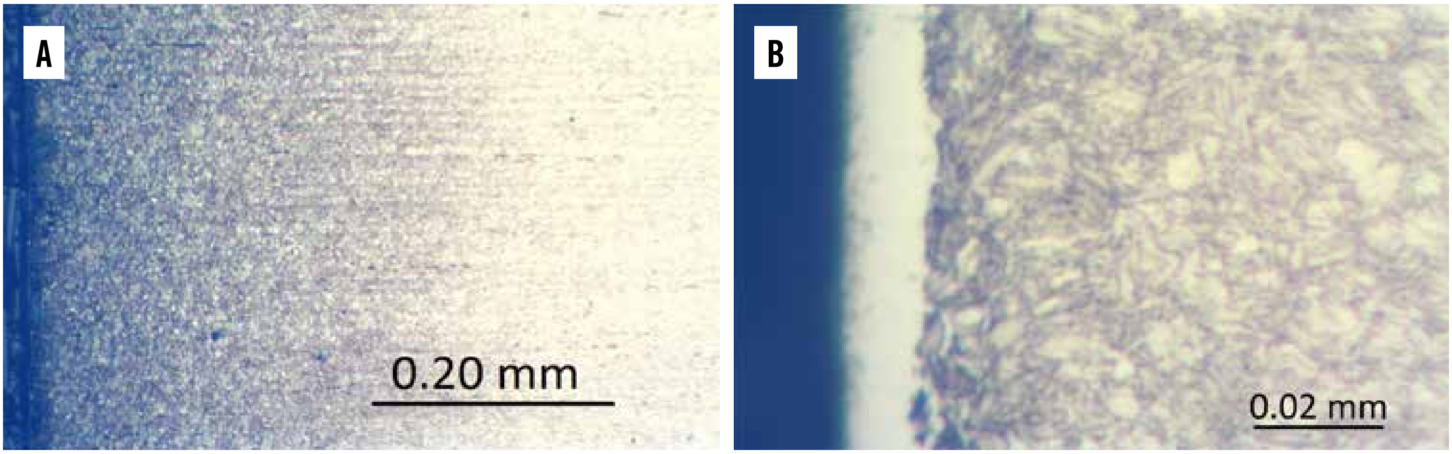

Figure 6: Cross section of the gear teeth shown in Figure 5, etched with 3% nital: (a) 50x, b) 1000x

alloy steels containing chromium and molybdenum with medium carbon content, which are excellent for nitriding. For example, consider a 4340 alloy steel gear used in the power industry (see Figure 5). The nitrided layer consists of roughly a 10-μm-thick compound layer composed of iron nitrides (Fe_4N) and approximately a 0.4-mm-thick diffusion layer (see Figures 6 and 7). The hardness gradient has a smooth transition compared with the layer in 15-5 PH steel. Mechanical masking was applied to the gear to limit nitriding to the teeth section only.

Deep nitriding is often required to enhance admissible fatigue strength values of heavily loaded gears. Figure 8 shows the cross section of such a gear after plasma nitriding. A very long nitriding cycle (>200 h) is required to achieve a 1-mm-thick case depth [14]. Despite long nitriding process times, avoiding excessive compound (white) layer thicknesses in the nitride layer structure is easily achieved because of the nature of the process — low partial pressure of nitrogen and sputtering [15]. A side effect of the sputtering in long nitriding cycles is the deposit of nitrides. This is from the dusty plasma visible on top of the gear tip, as you can see in Figure 8 [2]. The deposit is easily removed by light mechanical cleaning.

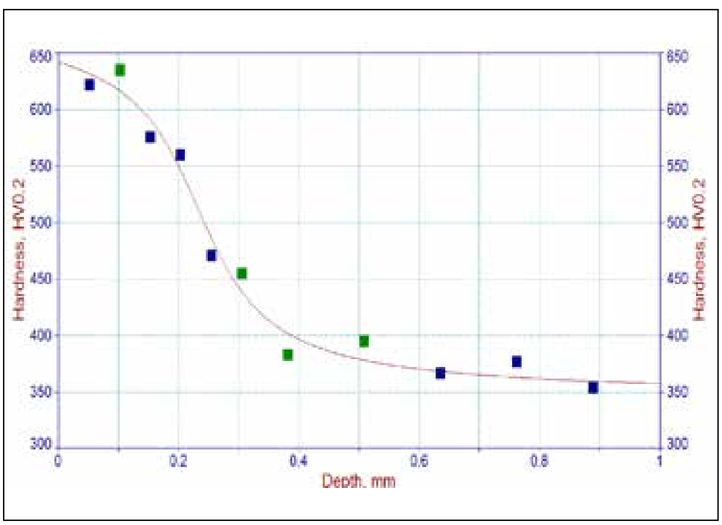

Figure 7: Microindentation hardness profile in the nitrided layer of the gear shown in Figure 5

Figure 8: Tip of the 10-mm module 3% Cr-Mo-V gear nitrided at 538°C, etched using 3% nital

Figure 9: Gear shafts made of Ti-6Al-4V alloy after plasma nitriding at 730°C in pure nitrogen: Gold color is a characteristic of titanium nitride film formed during nitriding

GAS NITRIDING

Gas nitriding of gears enables forming layers with the same depth and structure as in plasma nitriding. However, this requires good process control to avoid formation of an excessively thick compound layer containing porosity in long cycles. Also, selective treatment in gas nitriding is difficult because it requires copper plating for local protection from nitriding.

ION NITRIDING TITANIUM GEARS

Titanium alloys have specific properties, such as a high strength-to-weight ratio, as well as low magnetic susceptibility and low thermal and electrical conductivities [16]. Ion-nitrided titanium alloys also have excellent tribological and corrosion-resistant properties [17]. Therefore, nitriding is used for parts used in the most demanding applications. The process is carried out at a temperature between 680°C – 900°C, typically in pure nitrogen or a mixture of nitrogen with argon. Gear shafts in the as-nitrided condition used in aerospace applications are shown in Figure 9. It is not possible to do selective hardening of titanium products as is done with ferrous alloys due to the high chemical reactivity of titanium toward nitrogen [2]. Nitriding a titanium part imparts a gold or yellow color attributed to the presence of a thin (meaning few microns) titanium nitride (TiN) film, which is very hard. The layer underneath, composed of Ti_2N and Ti-Al-V nitrides, is about 10 μm thick (see Figure 10). The diffusion layer below the nitride layer cannot be etched easily due to its high corrosion resistance, but its thickness is determined from a microindentation hardness profile (see Figure 11). Hardness in the diffusion layer diminishes relatively quickly even though total nitrogen penetration reaches 30-40 μm in a typical nitriding cycle.

CONCLUSIONS

Ion nitriding is applied to various ferrous and titanium alloy gears. The main benefit to steel gears is the formation of a nitrided layer with a well-controlled structure at relatively low temperatures. This

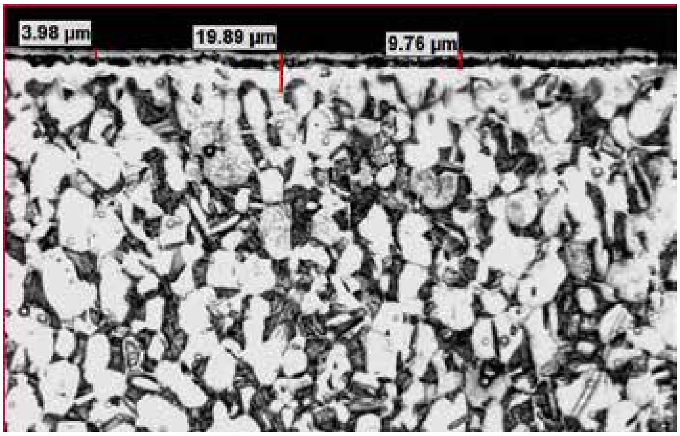

Figure 10: Cross section of gear teeth shown in Figure 9, at 200x, etched using Kroll reagent

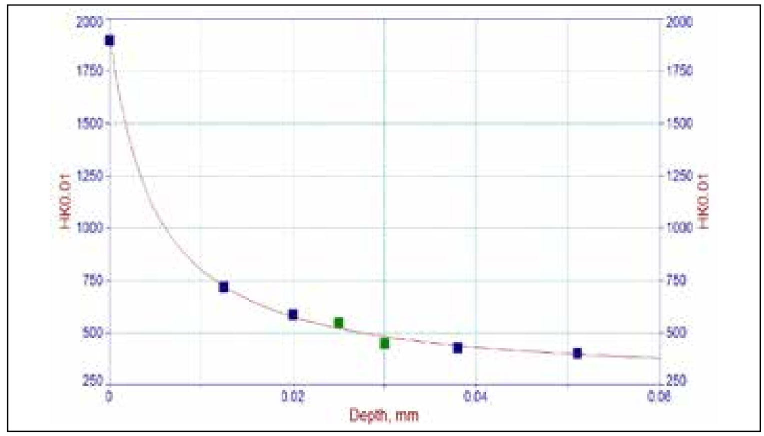

Figure 11: Microindentation hardness profile in nitrided layer of the gear shown in Figure 9. The first microindentation hardness measurement was taken at the surface.

enables using the process as a final operation, thus reducing manufacturing costs. Another benefit is the ability to apply mechanical masking for selective hardening of the product. Ion-nitrided titanium alloys also have excellent tribological and corrosion-resistant properties.

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Mikel S. Woods has been the senior VP of sales and marketing at Advanced Heat Treat Corp (AHT) for the last three years, after assuming the director of sales and marketing position for seven years. Prior to AHT, Woods was program manager at HUSCO International (Waukesha, Wisconsin) and senior/staff auditor at PricewaterhouseCoopers in Milwaukee. He has an Executive M.B.A. from the University of Wisconsin-Milwaukee and a B.B.A. in accounting from the University of Iowa. At AHT, Woods has co-authored publications on ion nitriding, gas nitriding, and ferritic nitrocarburizing, and he has played an active role in obtaining several grants associated with plasma nitriding.

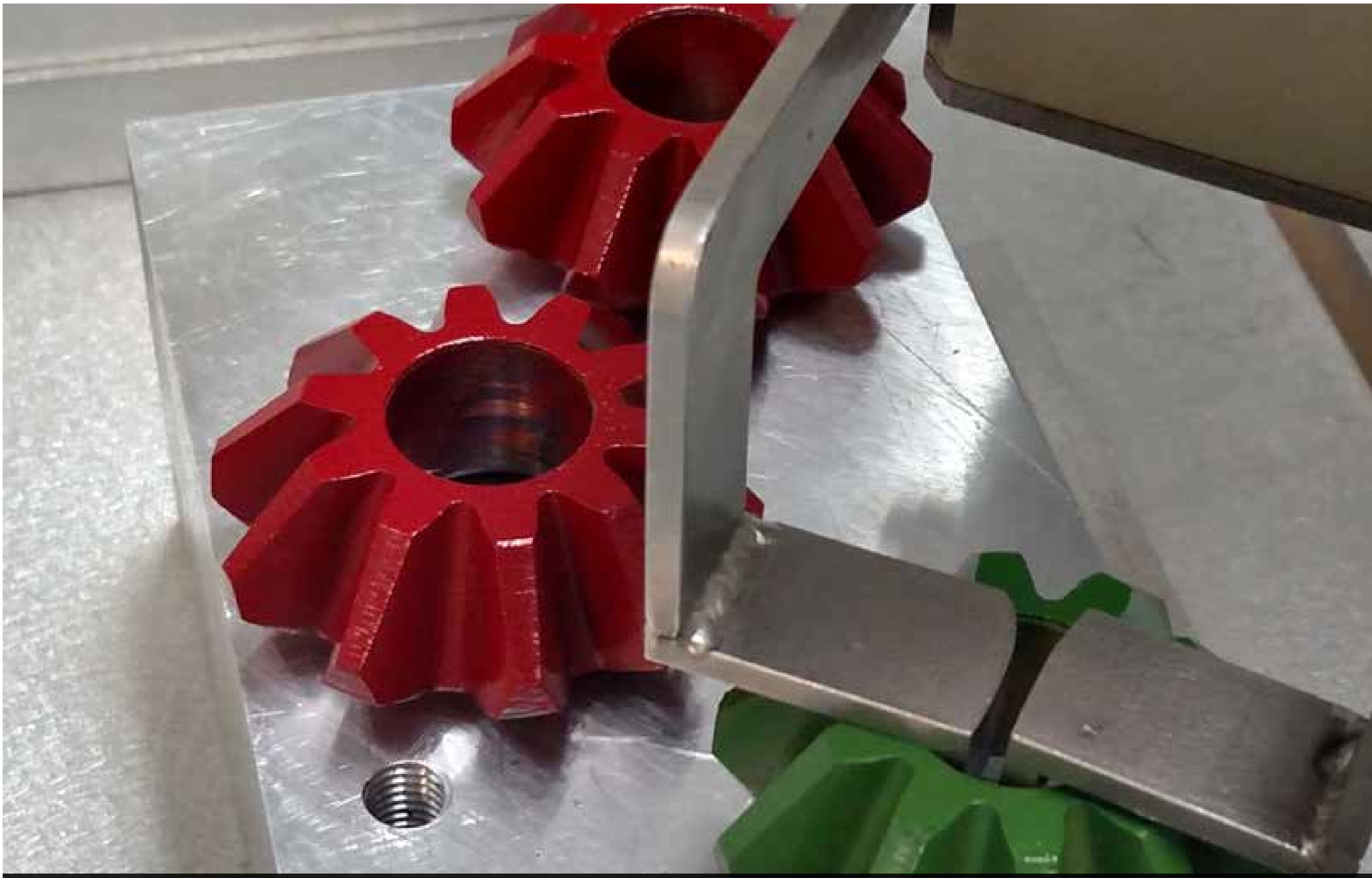

Figure 4: Robot gripper

Advanced Robotics Combined with Eddy Current Testing Offers Verification Methods for Heat-Treated Gears

By Dan DeVries

Advancements in robotics have paved the way for cost-effective, nondestructive eddy current inspection of nonsymmetrical, complex components that previously required multiple test stations.

Eddy current is a nondestructive testing technique proven for use in heat treatment and material structure verification. Modern multifrequency eddy current instruments can test for conditions such as misplaced case, shallow case, short heat, short quench, and delayed quench.

Gears, bearings, axles, shafts, and other components are heat treated to develop the required strength and durability. Heat treatment is a critical process in the manufacture of powder metallurgy components to produce the necessary performance properties for good service life in tough applications. Heat treatment in a furnace (e.g., carburizing) and by induction heating are used to harden selected areas such as gear teeth, which are subjected to high stresses in service.

Figure 1 shows a complex component consisting of a spline and gear and an eddy current coil used to test the component. For this component, the spline area may be hardened differently than the base gear area. The eddy current coil is sized to test just the spline area. To test the base, a separate larger diameter probe is required.

For parts having complex heat treat patterns, microindentation hardness testing of every part manufactured is not feasible. Rockwell hardness testing only identifies whether heat treatment results are satisfactory in the area being inspected. In addition, hardness testing leaves indentations on the part surface. Heat treatment verification is often impossible to detect using visual methods.


Photo courtesy of Schneider & Company

Compared with traditional testing methods, eddy current testing offers a fast, reliable, and repeatable method to determine whether a part has been heat treated according to specifications. Eddy current testing is a comparative test, so it does not provide hardness data but does indicate whether the part differs from a known standard (a master or group of reference standards).

Eddy current testing is based on electromagnetic induction, which was discovered by Michael Faraday in 1831. In the late 1800s, it was discovered that properties of a coil change when it is placed in contact with metals of different conductivity and permeability. In the 1950s and 60s, the technique became widely used in testing aircraft and nuclear power plant components. In the past 20 years, it has been extensively used to test components for proper heat treatment and material structure.

Eddy current systems used to verify heat treatment consist of an electronic instrument and a set of coils. Eddy current coils are usually encased in a protective structure, the entire system known as an eddy current probe. Coils are typically wrapped around the component being tested in a manner similar to a coil wound around the core of transformer.

During actual testing, two sets of coils are used — one wrapping around a reference master and one wrapping around the component being tested. Coils are driven at various test frequencies, and differences in coil responses are measured by the eddy current instrument. The component being tested is considered out of tolerance if the differences exceed a preset threshold.


Figure 1: Complex gear and eddy current probe

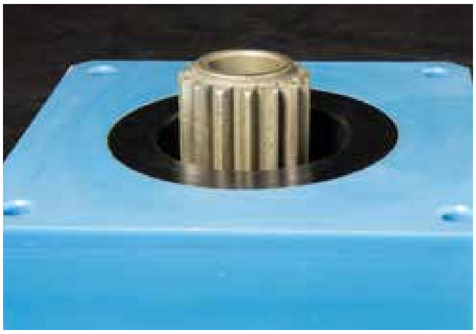
Figure 2: Gear inside eddy current probe

PROBE DESIGN CONSIDERATIONS

Similar to the principles of transformer design, it is important to have coil windings in close proximity to the component. It is also desirable to have a good fill factor, i.e., the component area versus the coil area.

Figure 2 shows how a part being tested typically fits inside an eddy current probe. The probe must align consistently (keeping a consistent coil-to-component distance) with every component. Typically, a polymer material (such as nylon) is used to insulate the winding from the component, and in a high-speed production environment, a stainless steel sleeve is often used to prevent damage to the insulating material and the coil.

PROBE MECHANICAL FIXTURING

For handheld testing, an eddy current probe is placed over the part. However, in a production environment where every part is tested, testing must be automated.

Automated eddy current testing systems are usually integrated into the production assembly line. This allows testing to be carried out in an online versus offline process, simplifying production flow. Testing stations are usually installed immediately downstream of the heat treating process, which enables flagging heat-treat process failures, such as a failed induction heating element and clogged quench ring, in real time.

The time to run the actual eddy current test is usually a couple of hundred milliseconds. When the test is complete, the probe is raised off the part. If the part passes the test, it moves down the conveyor to the next station in the production line. If the heat-treated condition falls outside acceptable parameters, the eddy current instrument communicates to the material-handling station via industrial I/O to send the part to a "reject" chute or bin. If consecutive rejects occur, the eddy current system can send an indication to the line supervisor informing them of a possible process error.

ADVANCED ROBOTICS CONSIDERATIONS

Traditional assembly-line fixturing consists of a conveyor to move parts in and out of the test cell, a mechanism to secure the part under testing, a probe actuator that can move the probe up and down, a sorting mechanism, and a reject chute or bin.

Mechanical work cells typically designed specifically for each test are efficient, robust, and have a small footprint. They are controlled via PLCs that interface with the eddy current system electronics.

Traditional mechanical work cells have some disadvantages. They are typically dedicated to a specific line and part. Any changes to the line or part require a redesign of the system. Systems can be costly and could take months to design, build, test, and install.

An alternative to a dedicated work cell approach is to use a robot that engages the part with the eddy current probe, moves untested parts into the work area, and moves tested parts out of the work area. Parts that fail the test are moved to a separate location without the need for complex sorting chutes and mechanisms.

While the concept of using robots on assembly lines is not new, the decreasing prices of smaller robotic arms make them more attractive for this type of application. Figure 3 shows a SCARA-type robot from Epson Robots (Carson, California) and a demo test station set up to test differential cam/side gears. The robot places a part into the eddy current coil closest to the robot, and a second eddy current coil holds a reference master, which is used as part of the differential test.

In traditional work cells, tests are loaded by hand and are usually validated at the beginning and end of each shift. With an automated system, verification can be done more frequently if desired.

Robot systems usually consist of a robot, a gripper, and a controller. Teaching a robot to perform the required tests is typically simple. The robot arm is moved to a specific location and the point is programmed. All locations where the robot will travel are recorded in this manner.

Figure 4 shows a unique gripper used to pick up and place gears. Grippers can be custom configured or manufactured to accommodate different component types.

ADVANTAGES OF USING ROBOTICS

Advantages of using robots like a SCARA over a traditional testing cell include flexible design parameters, ease of reconfiguration, and ease of calibrating the eddy current system.

Flexible design parameters

Inspection of complex shapes often requires complex eddy current probes or multiple probes connected to multiple instruments. Using a robot, multiple locations are inspected by simply moving the probe to a new location. Test parameters are usually changed using configuration-switching features in the eddy current test instrument.

Easy to reconfigure

If a design or inspection criteria changes, it is easy to reconfigure or reprogram the robot. The eddy current probe can be redesigned if additional eddy current testing locations are required. If a standard eddy current probe can be used, the probe is moved to the additional location.

Easy-to-calibrate eddy current systems

Eddy current systems used on production lines are periodically checked using masters that have known post-heat-treatment conditions. With conventional eddy current testing systems, the operator inserts a master into the production flow and verifies the test or "nulls" the machine to the good part. This is often done at the beginning and end of a shift. With a robotic system, the robot can be programmed to periodically pick up a master and check it or null against it. Operator intervention is not required.

In simple applications and in applications that have a very high line speed, a dedicated system can deliver better performance than a robot. The actual size of a dedicated cell may be smaller than a line using a robot.

Figure 3: Epson robot and demo gear-test station: The robot is programmed to pick up a part from the parts tray on the left and place it into the eddy current coil closest to the robot. Three colored gears on the left side of the photo are test standards used to validate the testing process.

CONCLUSION

Using advanced robotics to perform inline eddy current inspections offers advantages over a traditional mechanical work cell. Options to consider in a trade-off study between the two approaches include:

- Speed of production line
- Complexity of the part
- Number of inspections performed on each part
- Expected life of the production line
- Time to implementation

In either case, simplified electronic interfaces on eddy current instruments, PLCs, and robots make it easy to implement an eddy current test solution.

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Ipsen's Turbo^{2}Treater® furnace

Optimizing Case-Depth Uniformity in the Vacuum Carburizing Process

By Aymeric Goldsteinas and Jan Massholder

The acetylene vacuum carburizing (AvaC®) process helps to ensure consistent part quality and to improve the manufacturing costs in producing gears.

Over the past few decades, the vacuum carburizing process has been proven to produce superior part quality. In addition, the use of vacuum technology for carburizing has the most potential to improve the manufacturing process by reducing both processing time and the number of manufacturing steps required to produce a part [1]. These savings are achieved by increased productivity, resulting in lower part costs and reduced total cost of ownership.

Lower part costs are also achieved by optimizing the case-depth uniformity of parts during the vacuum carburizing process. For this, the carburizing process and influencing parameters — such as positioning of the parts within the load, uniformity of heating, and quality of thermal processing equipment used — need to be analyzed and optimized. However, it is first necessary to understand the emergence of vacuum carburizing and the advantages it offers for producing high-quality gears.

THE EVOLUTION OF LOW-PRESSURE VACUUM CARBURIZING

In the 1960s, development work began to provide a low-pressure carburizing technology that was fully competitive with gas carburizing. While, at that time, low-pressure carburizing offered myriad benefits with respect to process time, component quality, and minimized fluid burnoff and heat emissions, it still had a high amount of soot formation in the furnace. In addition, there were high maintenance requirements when propane was used as a carburizing gas with relatively high partial pressures. However, in the mid-1990s, it was discovered that acetylene had superior qualities as a reactive gas in vacuum carburizing (AvaC) [2, 3]. Table 1 shows the historical development of vacuum carburizing technology. It demonstrates that an effective combination of process development (such as AvaC) and equipment design (such as Ipsen's

Turbo²Treater® vacuum furnace) was necessary for the technology to succeed.

THE ROLE OF LOW-PRESSURE VACUUM CARBURIZING

The goal of low-pressure carburizing in vacuum furnaces is to carburize all workpieces within a load uniformly, to the same surface carbon content and to the same case depth. Low-pressure vacuum carburizing is marked by its ability to provide precise process control, which, in turn, helps result in uniform part microstructures, process repeatability, and a reduction in manufacturing and maintenance costs.

The vacuum heat-treating equipment used plays a significant role in the ability of vacuum carburizing to achieve precise process control. For example, the Turbo²Treater vacuum furnace features high quench speeds and uniform cooling and heating of parts: essential components for consistently achieving enhanced part quality and repeatability.

The Turbo²Treater vacuum furnace also offers Ipsen's patented AvaC process, which lends itself extremely well to being used in combination with high-pressure gas quenching and can be easily integrated into production lines.

THE AVAC PROCESS

The AvaC process produces twice the carbon availability compared with traditional carburizing agents, resulting in excellent carbon transfer into the parts. AvaC also has the advantage of producing an oxidation-free surface microstructure while allowing complex-geometry components to be evenly carburized. Wherever possible, it is used in combination with dry, high-pressure gas quenching as the hardening step. This provides a safe, environmentally friendly, clean, and flexible case hardening process that has the potential to reduce distortion and improve case-depth uniformity when compared with oil quenching.

The AvaC process involves alternate injections of acetylene (boost) and a neutral gas, such as nitrogen, for diffusion. During the boost, acetylene only dissociates when in contact with metallic surfaces, thus enabling uniform carburizing. At the same time, it nearly eliminates the soot and tar formation problem associated with earlier propane carburizers.

An important advantage of the process is the high carbon availability, which helps ensure extremely homogeneous carburizing, even for complex geometries and very high load densities. Overall, AvaC is a diverse process capable of processing parts with simple and complex geometries; wrought and powder metal materials; dense loading arrangements; variations in section size; and shallow, medium, and deep case-depth requirements.

As shown in Figure 1, after reaching the

Table 1: Historical development of vacuum carburizing

1960s	1970s	1980s	1990s	2000 & beyond
Process Development Begins	Process Introduction to Industry	Process Limitations Uncovered	Process Solutions Found	AvaC® Production Carburizing
R&D activities focus on finding alternatives to atmosphere gas carburizing	Ultra-high-pressure carburizing techniques developed using natural gas, 100-percent methane, and propane	R&D activities focus on methods to reduce carburizing pressure, as well as investigating gas pressure quenching as an alternative to oil quenching	R&D activities focus on finding a solution to excessive soot and tar formation by using acetylene and equipment designed specifically for low-pressure carburizing	Combination of low-pressure carburizing equipment designs using acetylene achieve production vacuum carburizing with over 95-percent up-time reliability
First vacuum carburizing patents issued	Various vacuum carburizing method patents issued	High maintenance and low up-time due to excessive soot from propane use halts commercialization	Patents issued on use of low-pressure carburizing with acetylene	Production loads are heavy, dense, and include all types of part geometry in all industries
Production loads are light, open, and with simple geometry	Production loads are heavier, denser, and include both simple and complex geometries	Lower carburizing pressures and various gas introduction methods are adopted to attempt to reduce soot formation	Combination of low-pressure carburizing with acetylene as the carburizing gas eliminates soot and tar formation (a concern in vacuum carburizing)	Modular-designed batch, semi-continuous and continuous vacuum carburizing furnaces become integrated into manufacturing and become a viable alternative to the use of atmosphere furnaces
Limitations of existing vacuum equipment identified	Equipment limitations improve with the introduction of new vacuum integral oil quench batch equipment	Plasma carburizing becomes a popular alternative to vacuum carburizing	Industry confidence and process credibility concerns addressed	Changes in material chemistry make gas quenching an economical alternative to oil quenching

carburizing temperature, the first carburizing step is initiated by injecting acetylene into the furnace to pressures between 3 and 5 torr. Carbon transfer is so effective that the limit of carbon solubility in austenite is reached after only a few minutes. As a result, the first carburizing step must be stopped after a relatively short time by interrupting the gas supply and evacuating the furnace chamber.

Deactivation of the boost event and evacuating the furnace chamber initiates the first diffusion step. During this segment, the carbon transferred into the material and the surface carbon content decrease until the desired surface carbon content is reached. Depending on the specified material case depth, additional carburizing and diffusion steps may be required. Parts are then quenched after reaching the specified case depth. This typically involves reducing the load temperature and quenching the load in the same chamber.

Control of the AvaC process for low-pressure carburizing involves an understanding of the variables that influence carbon transfer and diffusion. These include time (total boost or carburizing time, total diffusion time, and the number/duration of carburization and diffusion steps), temperature, and gas parameters (type, pressure, and flow rate). Depending on part surface area and geometry, these parameters are determined as constants resulting in homogeneous carburization.

EFFECT OF THE AVAC PROCESS ON CASE-DEPTH UNIFORMITY

A significant benefit of the AvaC process is superior penetrating power into small-diameter, long blind holes as compared with other hydrocarbon gases for low-pressure carburizing. Tests were conducted on AISI 5115 alloy steel bars with blind holes 0.11 inches in diameter by 3.55 inches long (0.28 by 90 mm) as shown in Figure 2.

Test conditions were carburized at 1,650°F (900°C) at a pressure of 3 torr and fast cooled in 2-bar nitrogen, followed by rehardening from 1,580°F (860°C) using 5-bar nitrogen quench. After sectioning, surface hardness was measured inside the blind hole at various distances from the opening.

The hardness results shown in Figure 3 indicate that the carburizing power of propane and ethylene is only sufficient to carburize in the blind hole to a depth of 0.23 inches (5.8 mm), falling off significantly up to a depth of 1 inch (25 mm) and falling to zero after 1 inch.

In contrast, vacuum carburizing with acetylene results in a complete carburizing effect along the entire length of the bore to the bottom of the 3.55-inch blind hole. Because the only atmosphere that comes into contact with the parts during the carburizing process is the hydrocarbon acetylene, the structure of the carburized case is completely free of any intergranular (internal) oxidation (IGO).

INTEGRATION OF THE AVAC PROCESS AND CUTTING-EDGE TECHNOLOGY

The AvaC process is suited for integration into production lines. As a result, it is able to offer several advantages to furnace users, including:

- High carbon transfer rate
- Uniform carburizing process, even for difficult geometries
- No intergranular oxidation, thermal radiation, flames, or conditioning of the furnace (for the AvaC process)
- Improved part quality with part-to-part and load-to-load repeatability

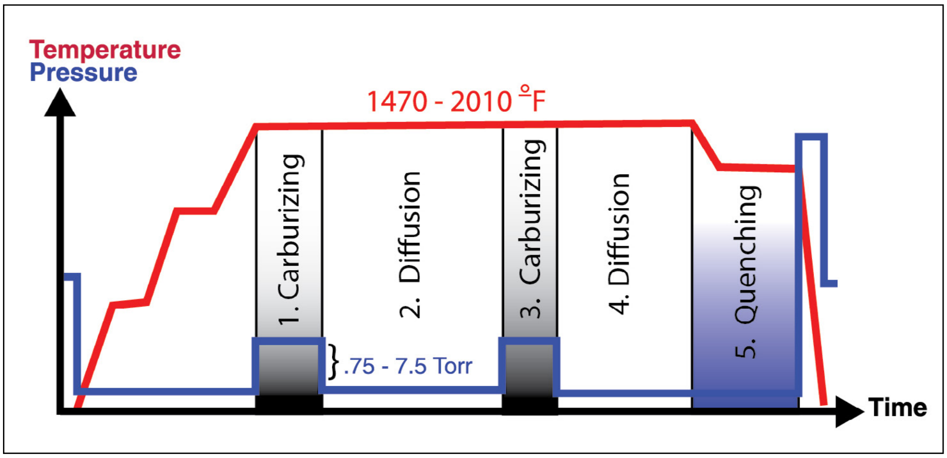


Figure 1: Typical cycle with temperature and pressure curve

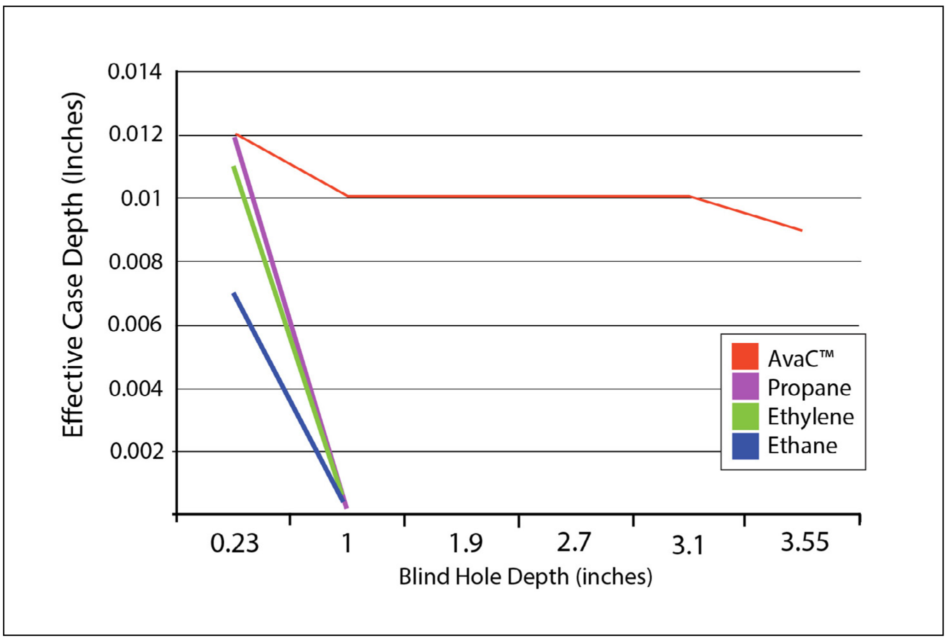


Figure 3: Surface hardness results

- Decreased cycle times due to higher carburizing temperatures and increased carbon diffusion rates
- Highly efficient due to low gas consumption
- Higher temperatures

While the AvaC process offers numerous advantages, it is important that the vacuum furnace used with the AvaC process delivers optimum efficiency and optimizes case-depth uniformity during the carburizing process. For example, the Turbo²Treater furnace features a mass flow controller designed to be compatible with acetylene gas.

In addition, the Turbo²Treater vacuum furnace provides a precise, uniform gas flow to ensure a fully optimized vacuum carburizing process. This is achieved with the furnace's vessel housing, which includes a vacuum penetration point (i.e., a multi-point fuel injection delivery system) located between the cold wall tank and the hot zone. With injector nozzles penetrating the hot zone, the manifold system precisely meters and delivers a continuous flow of process gas (such as acetylene) from outside the hot zone to the inside, which reduces the risk of hot zone contamination. This not only prevents process gas from collecting on the cold wall, but it also provides a uniform gas flow, which helps ensure consistent part quality and case-depth uniformity.

Available through Ipsen's VacuProf® controls

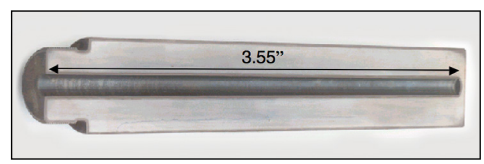


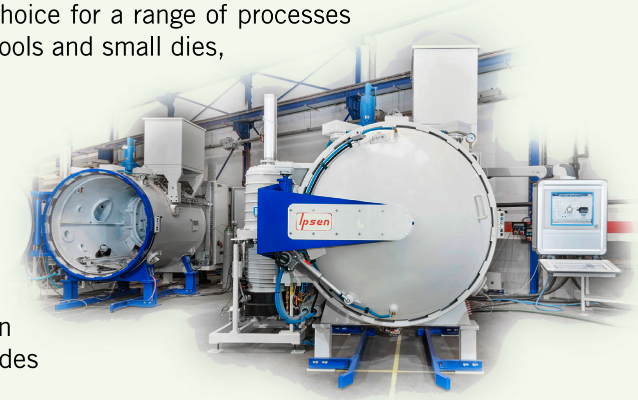
Figure 2: Example of blind hole

TURBO²TREATER: EFFICIENCY IN POWER

Ipsen's Turbo²Treater® furnace sets the standards in quality, versatility, and efficiency. Reengineered for ease of installation and global operation, the furnace offers the latest technology and technical solutions. With more than 200 furnaces sold worldwide, its reliable, cost-effective design and standardized production process helps provide quick delivery times and pass on savings directly to customers.

The Turbo²Treater furnace is used in multiple industries, including aerospace, automotive, commercial heat treating, medical, and tooling. It's a versatile heat-treating choice for a range of processes and components, including long and thin parts, multilayer loads, tools and small dies, gears, drills, and saw blades.

Offering quench pressures up to 12 bar and convection-assisted heating that speeds up cycle times and increases temperature uniformity, the furnace is ideal for hardening low-alloy steels. In addition, its alternating directional flow (i.e., top to bottom and bottom to top) helps increase quench uniformity and minimize part distortion.



The Turbo²Treater furnace also features an isothermal hold operation built-in with software that assists with distortion control and provides automatic temperature regulation.

EXPERT CONTROLS SYSTEM FOR INTUITIVE USER OPERATION

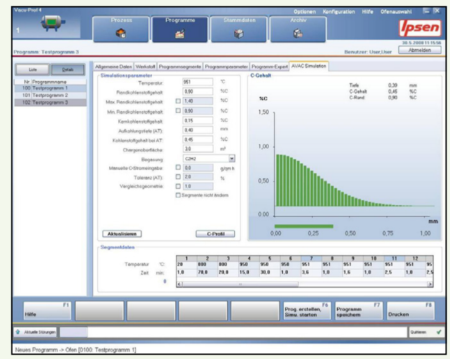
All treatment processes in the Turbo²Treater furnace are controlled by Ipsen's proprietary software, VacuProf®. This controls system allows users to achieve manufacturing time and cost savings, increased quality consistency, and improved operational reliability. In addition, all process-related data is transported to the computer system where it is then available for specific processing and conversion (e.g., logging, visualization, archiving, and reporting of errors and thresholds).

The VacuProf controls system is a dependable, powerful tool that provides:

- Easy-to-use interface with consistent user prompts and color menus
- Extensive data collection and the ability to download and print reports
- Sophisticated alarm package that monitors the furnace and suggests preventative maintenance
- Remote diagnostics and cycle monitoring
- Built-in online manual, parts list, and historical records
- Repeatable results with programmable recipes and optimization of processes

In addition, VacuProf Expert software enables a user without any prior knowledge to select the correct process for the type of steel to be treated. The user simply enters the characteristics of the steel, the load geometry, and other details, such as desired hardness and the heating and quenching characteristics. The software then recommends a possible heat treatment recipe for the specified material.

VacuProf control screen



AvaC Simulation software tab

system, complete heat treatment cycle programs with heating, treatment, and quenching segments are created with the aid of AvaC simulation software (Figure 4). The program simulates low-pressure vacuum carburizing cycles and calculates carbon profiles that are dependent on the temperature, surface carbon content, and case depth. The calculations are based on the carbon transfer characteristics of acetylene gas.

SUPERIOR QUENCHING CAPABILITIES

Parts are typically quenched after obtaining the specified case depth. Goals for quenching with reduced distortion include:

- Uniform heat extraction over the entire surface of the part
- Uniform heat extraction on every part within one load
- Material- and part-adapted timing to control the quench intensity

Today's requests to adapt the quenching intensity to the requirements for different components — specifically hardenability and minimization of distortion — lead to increased production of quality components. The Turbo²Treater furnace was designed to meet these same requirements.

The Turbo²Treater furnace attains pressures up to 12 bar using nitrogen and 8 bar using argon by utilizing a high-volume flow with vertical gas quenching. By default, the quench direction is from top to bottom. However, it can be reversed to flow from bottom to top and back. In addition, the interval at which direction changes need to occur can be set based on load temperature and time, thus allowing for a more uniform quench and part quality.

A key feature that enhances the quenching capabilities of the Turbo²Treater vacuum furnace is its use of the "Coanda Effect," which describes the flow that follows a curved surface. Integrated into the design of the hot zone baffle, this effect makes it possible for gas to enter the hot zone in a highly uniform manner, thus ensuring the same amount of quench gas impinges on all parts to ensure uniform part quality throughout the load.

The Turbo²Treater furnace's square hot zone is covered with a special high-performance carbon fiber composite (CFC) in either laminated form or as CFC with foil coating, which is capable of withstanding temperatures up to 3,600°F (2,000°C). The additional covering is particularly beneficial for high-pressure gas quenching as it protects the hot zone from the high-velocity gas stream. This significantly contributes to extending the hot zone service life, thus reducing subsequent servicing and maintenance costs.

There is significant potential to optimize and produce a more uniform quench. Implementing such features produces more uniform hardening of parts — especially gear components — with an improved microstructure and reduced distortion.

CONCLUSION

Heat treating a diverse range of parts in terms of geometries, materials, and load sizes requires precise process control. Vacuum carburizing with acetylene produces uniform part microstructures, offers process repeatability, reduces manufacturing costs, and controls and optimizes case-depth uniformity, even for complex geometries and dense loads.

The need for an advanced carburizing process led to the development of Ipsen's patented AvaC process and the Turbo²Treater vacuum furnace, which meets the industry's diverse process requirements. Refining the vacuum carburizing process enables the user to optimize the manufacturing process, which ultimately results in the production of high-quality gears with lower costs per part.

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1. D.H. Herring, Applying Just-In-Time Manufacturing Techniques to Heat Treating, *Advanced Materials and Processes*, ASM International, 1994.
2. EU Patent EP 0 818 555, March 28, 1996, JH Corp., Japan.
3. EU Patent EP 0 882 811, June 3, 1997, Ipsen International GmbH, Kleve, Germany.

ABOUT THE AUTHORS: Aymeric Goldsteinas joined Ipsen in 2009 as product development manager where his primary focus is developing innovative furnace- and process-related solutions. His extensive work in vacuum carburizing, high-pressure gas quenching, hardening, and sintering also allows him to provide in-depth technical support. Goldsteinas received his doctorate from the National Polytechnic Institute of Toulouse (INP) in Grenoble, France, and he graduated from the University of Marseille in France with a master's degree in chemistry and technology. Goldsteinas possesses a vast amount of experience, having received several patents and written numerous papers on the topics of low-vacuum carburizing and gas quenching.

Jan Massholder started at Ipsen in 2008, working as project manager in Kleve, Germany, before eventually serving as a project manager in Kyoto, Japan, and Cherry Valley, Illinois, respectively. In 2013, he became the director of business development for low-pressure carburizing, and in 2015, he transitioned to director of product management. In his current role, Massholder's primary focus is enhancing Ipsen's global product portfolio and ensuring the products fulfill customers' needs throughout various industries. Massholder received his bachelor's degree in international business and management from Arnhem Business School in the Netherlands.

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Website: www.heattreatequip.com

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Phone: 716-867-4312 • Fax: 716-867-4312
Email: summit@roadrunner.com

The W.H. Kay Company – REF #103
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Phone: 440-519-3800 • Fax: 440-519-1455
Email: sales@whkay.com
Website: www.whkay.com

Park Thermal – REF #104
257 Elmwood Ave #300, Buffalo, NY 14222
Phone: 905-877-5254 • Fax: 905-877-6205
Email: jmistry@parkthermal.com
Website: www.parkthermal.com

BATCH OVENS & BOX TEMPERING FURNACES

- 8" 18" 8" Lucifer Elec. 1250 F. ... **REF #103**
- 12" 16" 18" Lindberg Elec. 1200 F. ... **REF #103**
- 12" 16" 18" Lindberg (3) Elec. 1250 F. ... **REF #103**
- 12" 18" 12" Lucifer Elec 1250 F. ... **REF #103**
- 14" 14" 14" Gruenberg -Solvent Elec. 450 F. ... **REF #103**
- 15" 24" 12" Sunbeam (N2) Elec. 1200 F. ... **REF #103**
- 19" 19" 19" Prec.Scientific Elec. 617 F. ... **REF #103**
- 20" 18" 20" Blue-M (2) Elec. 400 F. ... **REF #103**
- 20" 18" 20" Blue-M (2) Elec. 400 F. ... **REF #103**
- 20" 18" 20" Blue-M (Inert) Elec. 600 F. ... **REF #103**
- 20" 18" 20" Despatch (Solvent) - 2 Avail Elec. 650 F. ... **REF #103**
- 20" 18" 20" Blue-M Elec. 800 F. ... **REF #103**
- 20" 18" 20" Blue-M Elec. 1200 F. ... **REF #103**
- 20" 20" 20" Grieve Elec. 500 F. ... **REF #103**
- 20" 20" 20" Michigan/Grieve Elec. 1000 F. ... **REF #103**
- 20" 20" 20" Grieve Elec. 1250 F ... **REF #103**
- 24" 24" 36" New England Elec. 800 F. ... **REF #103**
- 24" 26" 24" Grieve Gas 500 F. ... **REF #103**
- 24" 36" 24" Demtec (N2) Elec. 500 F. ... **REF #103**
- 24" 36" 24" Grieve Elec. 850 F. ... **REF #103**
- 24" 36" 24" Paulo Gas 1250 F. ... **REF #103**
- 25" 20" 20" Blue-M Elec. 650 F. ... **REF #103**
- 25" 20" 20" Blue-M Elec. 650 F. ... **REF #103**
- 25" 20" 20" Blue-M - Inert Elec. 1100 F. ... **REF #103**
- 25" 20" 25" Gruenberg Elec. 500 F. ... **REF #103**
- 26" 26" 38" Grieve (2) Elec. 850 F. ... **REF #103**
- 28" 24" 18" Grieve Elec. 350 F. ... **REF #103**
- 28" 48" 28" Wisconsin (3) Elec. 800 F. ... **REF #103**
- 30" 30" 30" Hevi-Duty Elec. 1500 F. ... **REF #103**
- 30" 38" 48" Gruenberg (2) M21 Elec. 450 F. ... **REF #103**
- 30" 48" 22" Dow Elec. 1250 F. ... **REF #103**
- 34" 19" 33" Poll.Ctrls Burnoff Gas 900 F. ... **REF #103**
- 36" 36" 35" Despatch Elec. 400 F. ... **REF #103**
- 36" 36" 120" Steelman Elec. 450 F. ... **REF #103**
- 36" 48" 36" Grieve Elec. 350 F. ... **REF #103**
- 36" 60" 36" CEC (2) Elec. 650 F. ... **REF #103**
- 37" 19" 25" Despatch Elec. 500 F. ... **REF #103**
- 37" 25" 37" Despatch Elec. 850 F. ... **REF #103**
- 37" 25" 50" Despatch Elec. 500 F. ... **REF #103**
- 38" 20" 24" Blue-M Elec. 1200 F. ... **REF #103**
- 38" 26" 38" Grieve Elec. 1000 F. ... **REF #103**
- 48" 24" 48" Blue-M Elec. 600 F. ... **REF #103**
- 48" 30" 42" Despatch Gas 850 F. ... **REF #103**
- 48" 48" 48" CEC (N2) Elec. 1000 F. ... **REF #103**
- 48" 48" 60" Gasmac Burnoff (2) Gas 850 F. ... **REF #103**
- 48" 48" 72" Despatch (2) Elec. 500 F. ... **REF #103**
- 48" 48" 72" Lydon Elec. 500 F. ... **REF #103**
- 54" 68" 66" Despatch Elec. 500 F. ... **REF #103**
- 54" 108" 72" Despatch Elec. 500 F. ... **REF #103**
- 56" 30" 60" Gruenberg Elec. 450 F. ... **REF #103**
- 60" 60" 72" ACE Burnoff Gas 850 F. ... **REF #103**
- 72" 72" 72" Michigan Gas 500 F. ... **REF #103**
- 120" 168" 120" Wisconsin Oven Gas 500 F. ... **REF #103**

BOX FURNACES

- J.L. Becker Slot Forge Furnace, 1986, Brand New, Never Used ... **REF #101**
- L & L Special Furnace Electrically Heated Box Furnace, 1991 ... **REF #101**
- J.L. Becker Box Temper Furnace, 1989 ... **REF #101**
- Sunbeam Electric Box Furnace, good running condition ... **REF #101**
- Surface 30-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
- Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
- Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
- Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
- Surface Combustion 30-48-30 Gas Fired Temper Furnace, good/ very good condition ... **REF #101**
- Surface 30-48-30 Gas Fired Temper Furnace, good/ very good condition ... **REF #101**
- 8" 18" 8" Blue-M Elec. 2000 F. ... **REF #103**
- 12" 24" 8" Lucifer-Up/Down (Retort) Elec. 2150/1400 F. ... **REF #103**
- 12" 24" 8" C.I. Hayes (Atmos) Elec. 1800 F. ... **REF #103**
- 12" 24" 12" Hevi-Duty (2) Elec. 1950 F. ... **REF #103**
- 12" 24" 12" Lucifer-Up/Down Elec. 2400/1400 F. ... **REF #103**
- 3" 24" 12" Electra-Up/Down Elec. 2000/1200 F. ... **REF #103**
- 15" 30" 12" Lindberg (Atmos) - Retort Elec. 2000 F. ... **REF #103**
- 17" 14.5" 12" L & L (New) Elec. 2350 F. ... **REF #103**
- 22" 36" 17.5" Lindberg (Atmos) Elec. 2050 F. ... **REF #103**
- 24" 36" 18" Thermnlyne (2) - Unused Elec. 1800 F. ... **REF #103**
- 36" 48" 24" Sunbeam (N2) Elec. 1950 F. ... **REF #103**
- 36" 72" 42" Eisenmann Kiln (Car) Gas 3100 F. ... **REF #103**
- 60" 48" 48" Recco (1998) Gas 2000 F. ... **REF #103**
- 60" 96" 60" Park Thermal Elec. 1850/2200 F. ... **REF #103**
- 126" 420" 72" Drever "Lift Off"-Atmos (2 Avail) Gas 1450 F. ... **REF #103**
- 13" 14" 12" ELECTRIC 1300ºF ... **REF #104**
- 10" 10" 18" ELECTRIC 2000ºF ... **REF #104**
- 22" 36" 22" ELECTRIC 1600ºF ... **REF #104**
- 12" 6" 8" ELECTRIC 2000ºF ... **REF #104**
- 12" 8" 18" ELECTRIC 2800ºF ... **REF #104**
- 20" 13" 36" ELECTRIC 1850ºF ... **REF #104**
- 12" 18" 18" ELECTRIC 1250ºF ... **REF #104**
- 4" 10" 4" ELECTRIC 2000ºF ... **REF #104**
- 22" 10" 8" ELECTRIC - C/W STAND 1250-2000ºF ... **REF #104**
- 15" 8" 30" ELECTRIC - ATMOSPHERE 1950ºF ... **REF #104**
- 11" 11" 17" ELECTRIC - CABINET 2000ºF ... **REF #104**
- 33" 40" 48" ELECTRIC 500ºF ... **REF #104**
- 18" 18" 30" ELECTRIC - GLO BAR 2900ºF ... **REF #104**
- 30" 30" 54" ELECTRIC - AGING 500ºF ... **REF #104**
- 30" 30" 54" R ELECTRIC - AGING 500ºF ... **REF #104**
- 30" 30" 54" ELECTRIC 500ºF ... **REF #104**
- 24" 18" 24" NATURAL GAS - BATCH FURNACE ... **REF #104**
- 24" 18" 24" NATURAL GAS - BATCH FURNACE ... **REF #104**
- 36" 30" 84" ELECTRIC 1200ºF ... **REF #104**
- 24" 24" 24" ELECTRIC 2000ºF ... **REF #104**
- 29" 22" 36" NATURAL GAS 1250ºF ... **REF #104**
- 12" 11" 24" ELECTRIC - BOX 2000ºF ... **REF #104**
- 24" 24" 24" ELECTRIC - GAS MAC 850ºF ... **REF #104**
- 18" 12" 12" ELECTRIC 2100ºF ... **REF #104**
- 48" 30" 36" ELECTRIC - ATMOSPHERE TEMPERING ... **REF #104**
- 50" 24" 29" NATURAL GAS 1250ºF ... **REF #104**
- 36" 18" 24" ELECTRIC 1250ºF ... **REF #104**
- 17" 17" 36" NATURAL GAS 1250ºF ... **REF #104**
- 15" 6" 10" ELECTRIC 1850ºF ... **REF #104**
- 6" DIA 48" ELECTRIC - TUBE FURNACE 1200ºC ... **REF #104**
- 7" 4" 14" GAS ... **REF #104**
- 10" DIA 18" GAS - FORGE FURNACE ... **REF #104**
- 9" 6" 15" GAS - FORGE FURNACE ... **REF #104**
- 6" 6" 15" GAS - FORGE FURNACE ... **REF #104**
- 12" 10" 20" ELECTRIC - SPEEDY MELT FURNACE 2000ºF ... **REF #104**
- 12" 9" 18" ELECTRIC ... **REF #104**
- 12" 12" 18" NATURAL GAS 1250ºF ... **REF #104**
- 14" 14" 18" ELECTRIC - GLOBAR 2500ºF ... **REF #104**
- 17" 17" 17" ELECTRIC - HITEMP KILN 2200ºF ... **REF #104**
- 35" 24" 60" ELECTRIC 1430ºF ... **REF #104**
- 10" 9" 14" ELECTRIC - FRONT DOOR LOADING 2000ºF ... **REF #104**
- 12" 12" 24" ELECTRIC - 13KW 2300ºF ... **REF #104**
- 12" 12" 24" ELECTRIC - 20KW 2000ºF ... **REF #104**
- 18" 12" 24" ELECTRIC 2000ºF ... **REF #104**
- 36" 24" 56" ELECTRIC 800ºF ... **REF #104**
- 24" 24" 36" ELECTRIC - CYCLONE 1250ºF ... **REF #104**
- 24" 36" 30" ELECTRIC RE-CIRC. BOX FURNACE 2000ºF ... **REF #104**
- 18" 20" 45" ELECT. RE-CIRC. W/ FLAME CURTAIN & BASKET 2000ºF ... **REF #104**
- 12" 12" 18" ELECT. RE-CIRC. BATCH (MATCH PAIR WITH I3958) 1250ºF ... **REF #104**
- 12" 12" 18" ELECT. RE-CIRC. BATCH (MATCH PAIR WITH I3957.) 1250ºF ... **REF #104**

CAR BOTTOM FURNACES

- Holcroft 48-144-48 Car Bottom Furnace ... **REF #101**
- Sauder 48-144-48 Car Bottom Furnace ... **REF #101**
- 48" 48" 72" GAS FIRED CAR BOTTOM 2000ºF ... **REF #104**
- 130" 72" 216" GAS FIRED CAR BOTTOM 2000ºF ... **REF #104**
- 130" 72" 215" GAS FIRED CAR BOTTOM 2400ºF ... **REF #104**
- 108" 36" 192" GAS FIRED CAR BOTTOM 2400ºF ... **REF #104**
- 72" 48" 216" GAS FIRED CAR BOTTOM 2000ºF ... **REF #104**

CHARGE CARS

- Surface Combustion 30-48 Charge Car (Double Ended), fairly good condition ... **REF #101**
- Atmosphere Furnace Company 36-48 Charge Car (Double Ended) ... **REF #101**
- Surface Combustion 30-48 Charge Car (Double Ended) ... **REF #101**

CONTINUOUS ANNEALING FURNACES

- Wellman Continuous Mesh Belt Annealing Furnace ... **REF #101**
- Aichelin-Stahl Continuous Roller Hearth Furnace & Conveying System, 1996 ... **REF #101**
- Park Thermal Continuous Mesh Belt Furnace, 2005, Excellent Condition – New – Never been used ... **REF #101**

CONTINUOUS HQT FURNACES

- Tokyo Gasden Ro Continuous Mesh Belt HQWT Furnace Line, 1989 ... **REF #101**

CONTINUOUS TEMPERING FURNACES

- Surface Combustion Mesh Belt Temper Furnace ... **REF #101**
- J.L. Becker Conveyor-Type Temper Furnace with Ambient Air Cool Continuous Belt, 1997 IQ Furnaces ... **REF #101**
- Surface Combustion 30-48-30 Pro-Electric IQ Furnace ... **REF #101**
- AFC 36-48-30 IQ Furnace with Top Cool ... **REF #101**
- AFC 36-48-30 IQ Furnace ... **REF #101**
- Surface Combustion 30-48-30 IQ with Top Cool,

Excellent Condition, 2000 .... **REF #101**
Surface Combustion 30-48-30 IQ Furnace, Excellent Condition .... **REF #101**

DRAW TEMPER FURNACES

18" 12" 30" ELECTRIC 1250ºF .... **REF #104**
16" 15" 12" ELECTRIC - BOX DRAW 1250ºF .... **REF #104**
36" 16" 24" ELECTRIC - BOX DRAW 1250ºF .... **REF #104**
12" 18" 16" ELECTRIC - BOX DRAW 1400ºF .... **REF #104**
30" 20" 48" ELECTRIC - BOX DRAW 1250ºF .... **REF #104**
24" 18" 36" NATURAL GAS ROLLER DRAW 1400ºF .... **REF #104**
30" 30" 48" NATURAL GAS 1200ºF .... **REF #104**
60" 40" 60" NATURAL GAS - DRAW FURNACE 800ºF **REF #104**
29" 16" 36" ELECTRIC - DRAW/TEMPER 1400ºF .... **REF #104**
54" 54" 150" ELECTRIC 900ºF .... **REF #104**
24" 18" 10 FEET ELECTRIC 500ºF .... **REF #104**
30" 24" 72" GAS - GRAVITY FEED DRAW 1350ºF .... **REF #104**
12" 14" 12" ELECTRIC - WATER COOLED FAN 1200ºF **REF #104**

ENDOTHERMIC GAS GENERATORS

Lindberg 1500 CFH Endothermic Gas Generator, 1992, good condition .... **REF #101**
Lindberg 1500 CFH Endothermic Gas Generator, 1996, excellent condition .... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator .... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator .... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator .... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator .... **REF #101**

EXOTHERMIC GAS GENERATORS

J.L. Becker 12,000 CFH Exothermic Gas Generator w/ Dryer, w .... **REF #101**
Thermal Transfer 30,000 CFH Exothermic Gas Generator, 1994, excellent condition .... **REF #101**

FLUIDIZING BED FURNACE

14" 30 DIA 5" ELECTRIC 1600ºF .... **REF #104**

FREEZERS

Webber 36-48-36 Chamber Freezer, 1980 .... **REF #101**
Cincinnati Sub Zero 36-48-36 Chamber Freezer, 1995 .. **REF #101**

MESH BELT FURNACES

17" 8" 10' ELECTRIC 600ºF .... **REF #104**
23" 4" 10' NATURAL GAS 1250ºF .... **REF #104**
24" 12" 96" ELECTRIC 500ºF .... **REF #104**

MESH BELT BRAZING FURNACES

Lindberg Continuous Mesh Belt Brazing Furnace .... **REF #101**
J.L. Becker 26" Mesh Belt Brazing Annealing Furnace, 2007 .... **REF #101**
10" J.L. Becker Mesh Belt Furnace with Muffle, 1988 .. **REF #101**
24" J.L. Becker Mesh Belt Furnace .... **REF #101**

MISC. EQUIPMENT

Atmosphere Furnace Co. 36-48 Stationary Holding Stations, 1987, 36"W x 48"L work area .... **REF #101**
Atmosphere Furnace Co. 36-48 Stationary Holding Stations, 1987, 36"W x 48"L work area .... **REF #101**
Atmosphere Furnace Co. 36-48 Stationary Holding Stations, 1987, 36"W x 48"L work area .... **REF #101**
Atmosphere Furnace Co. 36-48 Scissors Lift Holding Stations, 1987, 36"W x 48"L work area .... **REF #101**
Atmosphere Furnace Co. 36-48 Scissors Lift Holding Stations, 1987, 36"W x 48"L work area .... **REF #101**
Surface Combustion 30-96 Stationary Load Tables, 96-inch rail length, 15-inch rail centers .... **REF #101**
Surface Combustion 30-96 Stationary Load Tables, 96-inch rail length, 15-inch rail centers .... **REF #101**
Surface Combustion 30-96 Stationary Load Tables, 96-inch rail length, 15-inch rail centers .... **REF #101**
Surface Combustion 30-48 Scissors Lift Table, 48-inch rail length .... **REF #101**
8xxx 2.400 CFH 12 oz (2) North American 1/3HP .... **REF #103**
8xxx 3.000 CFH 12 oz (3) North American 1/2HP .... **REF #103**
8xxx 5.400 CFH 4 oz North American 1/3HP .... **REF #103**
8236 12.000 CFH 12oz (3) North American 1/2HP ...... **REF #103**
8712 15.600 CFH 37 oz, North American 5HP .... **REF #103**
8193 19.500 CFH 32 oz, Spencer 5HP .... **REF #103**
8245 23.400 CFH 8 oz. North American 1,5HP .... **REF #103**
8185 24.000 CFH 24 oz. Buffalo Forge 7.5HP .... **REF #103**
8251 45.600 CFH 16 oz. Spencer 5HP .... **REF #103**
8252 66.000 CFH 24 oz . Snencer(New) 10HP .... **REF #103**
8253 66.000 CFH 24 oz. Spencer 10HP .... **REF #103**
8250 150.000 CFH 16 oz. Hauck 15HP .... **REF #103**

OVER - UNDER FURNACES

12" 11" 48" GLO BAR ELECTRIC 3000ºF .... **REF #104**
9.5" 9.5" 18" COILED ELEMENTS ELECTRIC 2300ºF .. **REF #104**
22" 11" 14" COILED ELEMENTS ELECTRIC 2200ºF .... **REF #104**
12" 7" 30" ELECTRIC - CRESS .... **REF #104**
18" 12" 24" ELECTRIC 2100/1250ºF .... **REF #104**
12" 12" 36" ELECTRIC 2300/1250ºF .... **REF #104**

PARTS WASHERS

J.L.Becker Gas-Fired Tub Washer .... **REF #101**
48-72-48 Gas Fired Spray Washer .... **REF #101**
Dow Furnace Co. 30-48-30 Electrically Heated Spray, Dunk & Agitate Washer .... **REF #101**
Atmosphere Furnace Co. 36-48-30 Spray/Dunk Washer **REF #101**
Atmosphere Furnace Co. 36-48-30 Spray/Dunk Washer **REF #101**
Surface Combustion 30-48-30 Electrically Heated Spray Dunk/ Dunk Washer .... **REF #101**
Surface Combustion 30-48-30 Electrically Heated Washer .... **REF #101**

PIT FURNACES

Lindberg 28" x 28" Pit-Type Temper Furnace .... **REF #101**
14" 60" Procedyne - Fluidised Bed Elec. 1850 F. .... **REF #103**
16" 20" Lindberg Elec. 1250 F. .... **REF #103**
22" 26" L & N Elec. 1200 F. .... **REF #103**
28" 48" Lindberg Elec. 1400 F. .... **REF #103**
38" 48" Lindberg Elec. 1400 F. .... **REF #103**
40" 60" L & N -Steam/N2 Elec. 1400 F. .... **REF #103**
40" 60" Wellman-Steam/N2 Elec. 1400 F. .... **REF #103**
48" 48" Lindberg (Atmos) - Fan Elec. 1850 F. .... **REF #103**
20" 48" ELECTRIC 1200ºF .... **REF #104**
30" 36" NATURAL GAS 1250ºF .... **REF #104**
24" 30" ELECTRIC 1400ºF .... **REF #104**
16" 18" GAS - CYCLONE 1300ºF .... **REF #104**
28" 96" NATURAL GAS 1400ºF .... **REF #104**
24" 28" ELECTRIC - HOMO CARBURIZING 1400ºF ...... **REF #104**
16" 30" ELECTRIC SALT POT 1650ºF .... **REF #104**
22" 36" 22" ELECTRIC SQUARE PIT 1600ºF .... **REF #104**
6" 4" 16" ELECTRIC VACUUM PIT 2400ºF .... **REF #104**
24" 24" ELECTRIC 1400ºF .... **REF #104**
12" dia 18" ELECTRIC - HOMO PIT 1200ºF .... **REF #104**
30" 30" 30" ELECTRIC 800ºF .... **REF #104**
30" DIA 30" ELECTRIC - PIT CYCLONE 1250ºF .... **REF #104**
12" 20" ELECTRIC - KEYHOLE 1250ºF .... **REF #104**
4.5" 24" 4" ELECTRIC - SQUARE PIT .... **REF #104**
24" 48" 24" ELECTRIC - SQUARE PIT 1200ºF .... **REF #104**
18" 18" 18" ELECTRIC - TOP LOAD 2000ºF .... **REF #104**
16" Dia. 20" ELECTRIC - CYCLONE 1250ºF .... **REF #104**
22" Dia 26" ELECTRIC - CYCLONE 1250ºF .... **REF #104**
22"Dia 26" ELECTRIC 1250ºF .... **REF #104**
8"dia 9"deep ELECTRIC - TEMPERING 1250ºF .... **REF #104**
35" 60" GAS .... **REF #104**
28"DIA 28" ELECTRIC - CYCLONE PIT 1250ºF .... **REF #104**

VACUUM FURNACES

Brew/Thermal Technology Vacuum Furnace .... **REF #101**
Abar Ipsen 2-Bar Vacuum Furnace, 1986, good condition .... **REF #101**
24"W x 36"D x 18"H Hayes (Oil Quench) Elec. 2400 F. **REF #103**
48" Dia 60" High Ipsen (Bottom Load) Elec. 2400 F. ... **REF #103**

ATMOSPHERE GENERATORS

750 CFH Endothermic Dow Elec. .... **REF #103**
750 CFH Endothermic Insen Gas .... **REF #103**
1000 CFH Exothermic Gas Atmosphere .... **REF #103**
1000 CFH Ammonia Dissociator Lindberg Elec. .... **REF #103**
1000 CFH Ammonia Dissociator Drever Elec. .... **REF #103**
1500 CFH Endothermic (Air Cooled) Ipsen Elec. .... **REF #103**
1500 CFH Endothermic Ipsen Gas .... **REF #103**
3000 CFH Endothermic air Cooled) Lindberg Gas .... **REF #103**
3000 CFH Endothermic (Air Cooled) Lindberg (2) Gas ... **REF #103**
3000 CFH Endothermic (Air Cooled) Lindhera Gas .... **REF #103**
3600 CFH Fnclothermic (Air Cooled) Surface (2) Gas .... **REF #103**
3600 CFH Endothermic Surface Gas .... **REF #103**
5600 CFH Endothermic Surface (3) Gas .... **REF #103**
6000 CFH Nitrogen Generator (2000) Gas Atmospheres Gas .... **REF #103**
10 000 CFH Exothermic Seco-Warwick Gas .... **REF #103**

INTERNAL QUENCH FURNACES

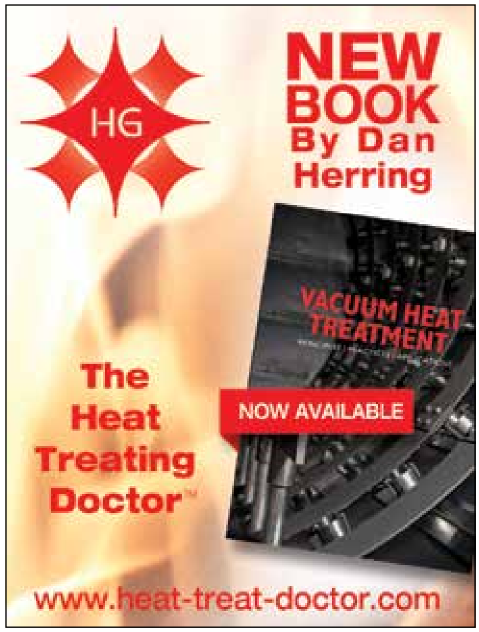
24"W 36"D 18"H Dow (Slow Cool) Line Elec. 2000 F. .. **REF #103**
24"W 36"D 1 8"H Ispen T-4 - Air Cooled Gas 1850 F. .. **REF #103**
24"W 36"D 18"H Ispen T-4 - Air Cooled Gas 1850 F. ... **REF #103**
24"W 36"D 18"H Isoen T-4 - Air Cooled Gas 1850 F. ... **REF #103**
24"W 36"D 18"H Ispen T-4 - Air Cooled Gas 1850 F .... **REF #103**
30"W 48"D 30"H Surface Allcase Elec. 1750 F. .... **REF #103**
30" 30" 48" NATURAL GAS 1750ºF .... **REF #104**
12" 10" 24" ELECTRIC - BABY PACEMAKER 1850ºF ... **REF #104**
45" 40" 72" ELECTRIC - ALUMINUM QUENCH 1250ºF **REF #104**
12" 9" 18" IPSEN 2000ºF .... **REF #104**
87" 36" 87" SURFACE COMBUSTION W/ 12,500G. QUENCH 1850ºF .... **REF #104**
62" 36" 62" SURFACE COMBUSTION W/ 9,500G. QUENCH 1850ºF .... **REF #104**
62" 36" 62" SURFACE COMBUSTION W/ 9,500G. QUENCH 1850ºF .... **REF #104**
15" 12" 30" Electric c/w load carts 1850ºF .... **REF #104**

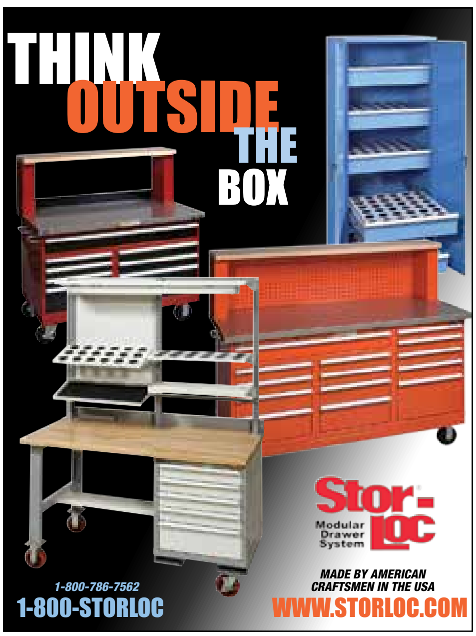
CONTINUOUS/BELT FURNACES + OVENS

5"W 36"D 2"H BTU Systems (Inert Gas) Rec. 1922ºF .. **REF #103**
12"W 48"D 2"H Lindberg (Inert Gas) Elec. 1022ºF. ..... **REF #103**
12"W 15'D 4"H Sargent&Wilbur'94(Mufflel) Gas 2100ºF. .... **REF #103**
16"W 24'D 4"H Abbott-Retort (1996) Elec 2400ºF. ...... **REF #103**
24"W 12'D 6"H Heat Industries Elec. 750ºF. .... **REF #103**
24"W 40'D 18"H Despatch Elec. 500ºF. .... **REF #103**
24"W 40'D 18"H Despatch Gas 650ºF .... **REF #103**
60"W 45'D 12"H Roller Hearth Annealer (Atmos) Gas 1700ºF .... **REF #103**
72"W 30'D 15"H Unitherm Gas 500ºF .... **REF #103**

MARKETPLACE

Manufacturing excellence through quality, integration, materials, maintenance, education, and speed.





AD INDEX

WHEN WAS VACUUM CARBURIZING INTRODUCED?

The process has been around since the 1960s. Vacuum carburizing enables more precise control of case depth and microstructure than conventional gas carburizing. The process is repeatable without the need for ancillary items such as endo generators, gas analyzers, and in-situ oxygen probes. This enables customers not familiar with conventional carburizers to install stand-alone systems that can be used for "just-in-time" production needs without all the additional equipment or expertise of operating a conventional carburizer, as vacuum furnaces are operated more like a recipe-driven CNC.

WHO WERE THE EARLY PLAYERS IN TECHNOLOGY DEVELOPMENT?

C.I. Hayes provided some of the original furnaces for the process, which started to change carburizing. In the early process, carburizing was done at higher furnace pressures (600-mb range), which caused high levels of soot. This had a negative impact on the process for a long time. In late 1990s, ECM's patented Infracarb process made the process more robust, and ECM continued developing vacuum carburizing into the mainstream high-volume production process it is today.

WHO WERE EARLY USERS OF VACUUM CARBURIZING?

Early on, many companies in the U.S. tried the process and moved back to conventional carburizing. ECM worked closely with auto manufacturers in France to develop a high-volume system on the basis of the shorter cycle time of the process that was needed to produce the required case depth on manual-transmission parts. The first known high-volume furnace was a two-cell vertical system installed in France in 1991 with gas quenching in a separate cell. Two additional vertical furnaces were installed, one in 1992 and one in 1993 with four cells each. This was the beginning of high-volume systems with internal automation and high-pressure gas quenching. After several years, manufacturers in the U.S. caught on, quickly implementing vacuum carburizing in major automotive programs for five- and six-gear automatic transmissions along with driveline components starting in 1999 and 2000.

WHAT ARE THE BENEFITS OF VACUUM CARBURIZING COMPARED WITH CONVENTIONAL GAS CARBURIZING?

Vacuum carburizing systems are safe. Cold-wall construction, small footprints, and the absence of flame curtains make it possible to start and stop the furnace as needed, and systems are clean using high-pressure nitrogen and helium. Processes can be shortened due to potential higher carburizing temperatures and increased carbon potentials available. Lower gas consumption and ease of use are big factors in justifying using these systems along with consistent results load after load, year after year in multiple heating cells. Consistent, higher quality metallurgical results are seen in higher uniformity of case depth from pitch to root line in gears.

WHO ARE THE MAJOR PLAYERS IN CONTINUING TECHNOLOGY AND EQUIPMENT DEVELOPMENT?

There are several companies continually vying for projects. Each company appears to be searching for the right niche — commercial heat treaters, aerospace, automotive, marine, energy, and other markets. ECM has been providing research-based equipment and processes for all of these markets for more than 20 years with more than 1,000 heating cells installed worldwide. Vacuum carburizing technology has not changed a great deal other than researching different gases with certain patent rights. Research and development has always been a mainstay at ECM in carburizing, vacuum equipment design for ease of operation, maintenance, and especially in the area of gas quenching.

WHAT AREAS OF VACUUM CARBURIZING REQUIRE MORE R&D?

Low distortion is most commonly associated with vacuum carburizing. There is more work required in integrating quenching technologies that have a low distortion effect on the process. Steel suppliers have done a great job over the past 10 years developing new materials for gas quenching and helping customers understand quenchability. However, large cross-sectional parts still need to be oil-quenched in most cases and still undergo low distortion. With the precision in case depth and metallurgical properties that vacuum carburizing offers, along with more uniform quenching, the process will expand into markets that require deep case depths in larger parts, providing the benefits that the automotive and aerospace markets realize today.

WHAT IS THE POTENTIAL FOR FURTHER GROWTH?

New applications will emerge as conventional carburizing users learn more about vacuum carburizing. Many gains have been made over the past 10 years with hundreds of cells being installed and thousands of parts per hour being processed that were never thought possible before. Larger loads, and in some cases, smaller loads, are on the horizon to help the technology become the main carburizing technology for the future. Also, the ease of use and maintenance of a vacuum carburizing system compared with a conventional system has swayed many decisions to move production into vacuum carburizing.

HOW DOES ECM FIT INTO THIS PICTURE?

ECM has been a leader in this market for the past 20 years and expects to remain a leader with equipment, maintenance, and gas-quench designs at the forefront of its R&D efforts. The key with any customer is to reduce risk with the implementation of any new product or process. ECM excels in this process with simulation, testing, distortion results, estimated production costs, reduced floorplans, and proven high uptime of installed equipment, which allows customers to focus on other areas of its new product launches and rely on the equipment for a repeatable process.

FOR MORE INFORMATION on ECM USA products and services, visit www.ecm-usa.com or call (262) 925-6321.