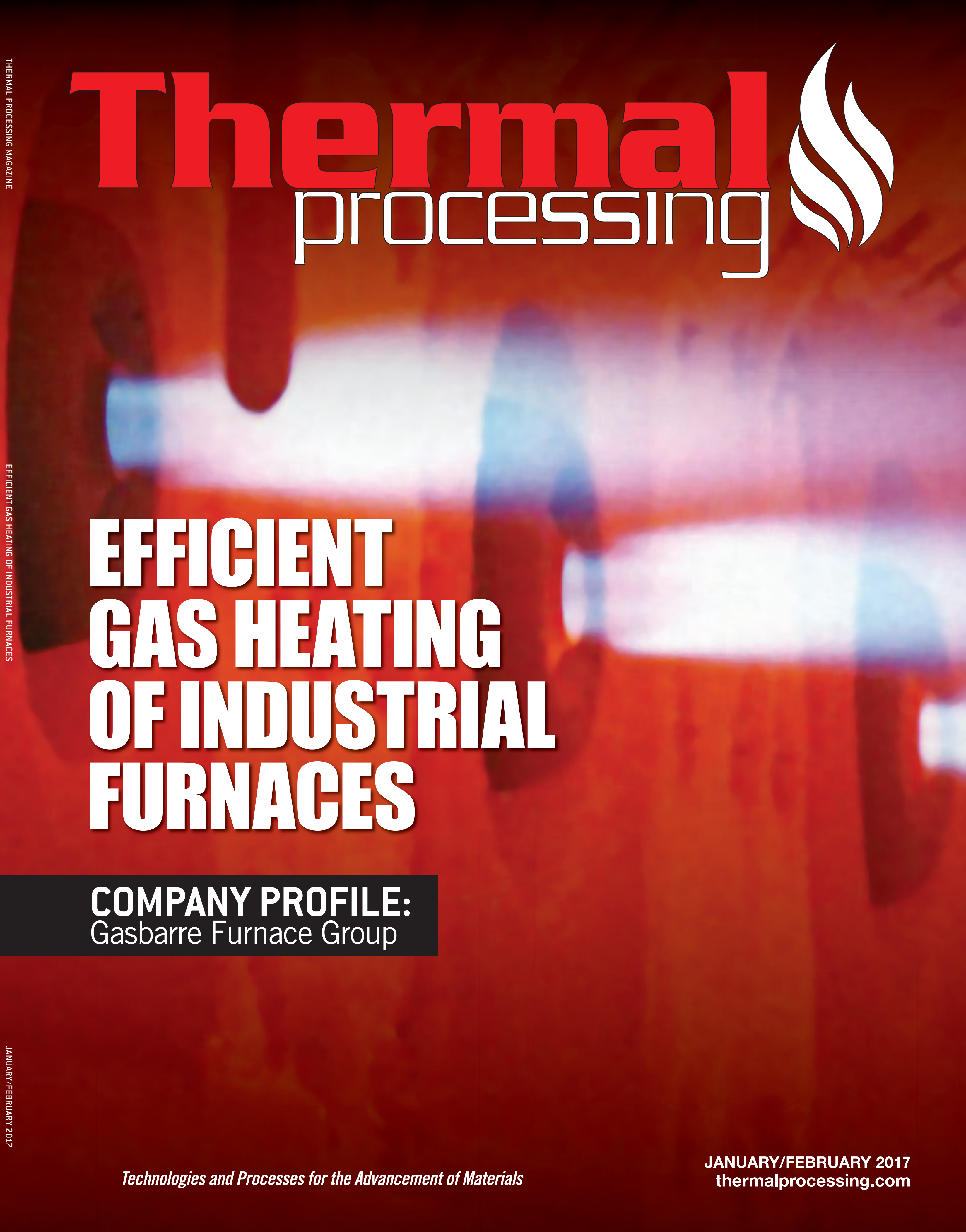


THERMAL PROCESSING MAGAZINE
EFFICIENT GAS HEATING OF INDUSTRIAL FURNACES
JANUARY/FEBRUARY 2017

# Thermal processing

# EFFICIENT GAS HEATING OF INDUSTRIAL FURNACES

## COMPANY PROFILE:
Gasbarre Furnace Group

*Technologies and Processes for the Advancement of Materials*

**JANUARY/FEBRUARY 2017**
**thermalprocessing.com**

Regardless of the industry you are in or the processes you run, *The Ipsen, Harold* blog is devoted to providing expert-curated best practices, maintenance tips and details about the latest industry news and innovations.

## Want to know what everyone else is reading?

### Here are our top blog posts of 2016 ...

**5 Quick Tips on How to Become a Brazing Superhero**
When it comes to vacuum aluminum brazing there are a lot of advantages, but you also need to know the details on how to properly braze your parts.

**Finding Leaks in Your Vacuum Furnace – Part I**
This video walks you through the step-by-step process for performing a leak check, from calibrating the helium mass spectrometer to determining which part of the furnace is the source of the leak.

**A Daily Checklist for Preventative Maintenance**
An effective method for extending the life of your vacuum furnace is following a carefully scheduled preventative maintenance plan. This post covers the tasks that should be performed on a daily basis.

**A Look Inside the Furnace: Choosing the Best Hot Zone for Your Needs**
When choosing between all-metal or graphite hot zones, it's important to consider your processes, materials, temperatures, ramp rates and uniformity ranges.

**The Importance of Validating Your Furnace:**
**Temperature Uniformity Surveys and Other Useful Tips**
Nothing is more important than validating your furnace equipment. One of the most important tests you can perform is a Temperature Uniformity Survey.

**Read the posts at www.IpsenHarold.com or scan the code to the right.**

**Scan the QR code to read the blog**

Download *Quick Scan* or *QR Droid* app to scan code

# Special Courses!

**Expanded Vacuum and Atmosphere Trainings for 2017**

Whether you've been in the industry for five months or 25 years, staying up-to-date on new methods and industry innovations is a key contributor to success. Ipsen will begin 2017 by hosting a series of three-day Ipsen U classes, as well as teaching local one-day seminars throughout the United States. These trainings focus on advancing your knowledge of atmosphere and vacuum heat-treating equipment, processes and maintenance through applied learning.

**Learn more and register at www.IpsenUSA.com/Training**

Ipsen

WISCONSIN OVEN
CORPORATION

# Horizontal Quench Furnace

## A Cost Effective Option for Your Solution Treatment Process

The Horizontal Quench Furnace utilizes an electrically operated pusher/extractor mechanism providing a quench time as low as 7 seconds, which combined with a load capacity of up to 6,000 lbs, makes it ideal for a wide range of applications.

### Benefits

- 10 standard sizes *custom sizes available*
- Gas fired or electrically heated
- Cost effective alternative to a drop bottom furnace
- Ideal for castings, extrusions, forgings, and other aluminum
- Automated controls available for easier operation
- AMS2750E compliance available
- Fully factory assembled and tested prior to shipment to reduce start-up and installation times

### Features

- High capacity recirculation system
- Quench tank water agitation pump with distribution manifold
- Combination airflow through oven chamber
- Available temperature uniformity of +/- 5° F or +/- 10° F
- Air operated vertical lift oven door & quench platform

262-642-3938 • SALES@WISOVEN.COM

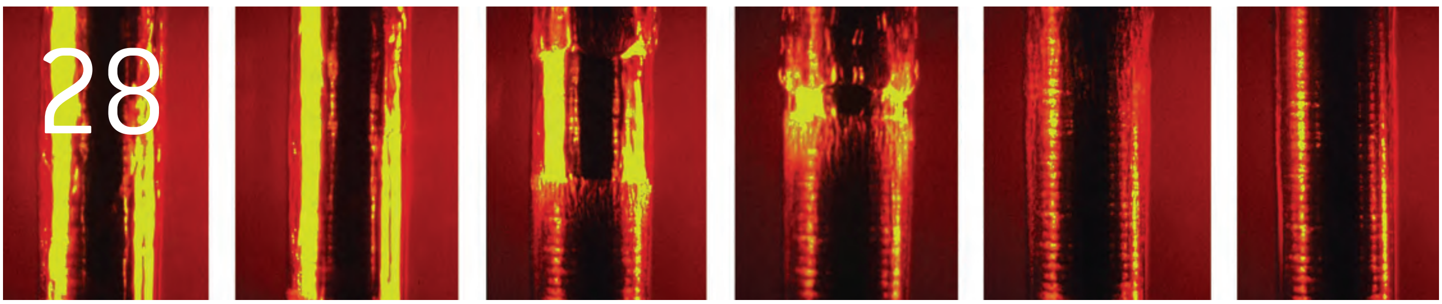
www.wisoven.com

TPS Thermal Product Solutions Wisconsin Oven Corporation is a brand of Thermal Product Solutions, LLC

# FEATURES

JANUARY/FEBRUARY 2017



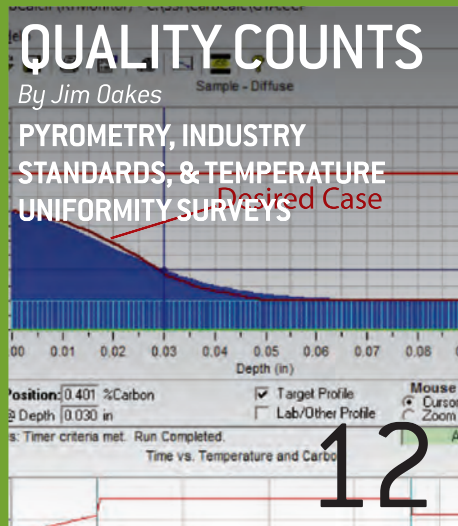




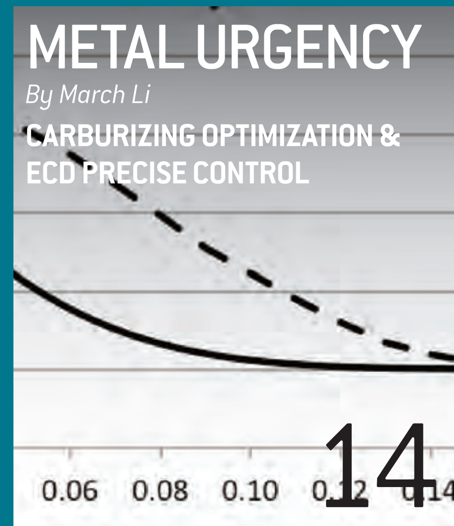
# DEPARTMENTS

JANUARY/FEBRUARY 2017
*Volume 6 / Number 1*

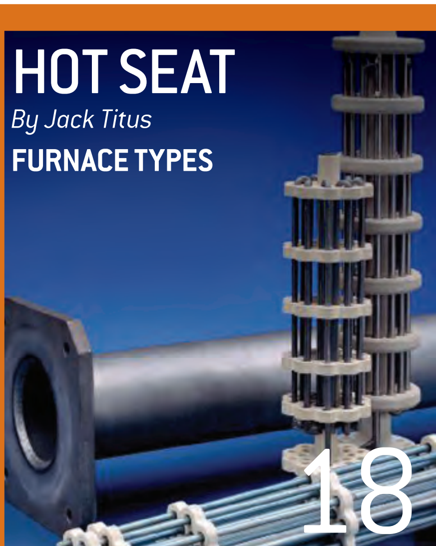






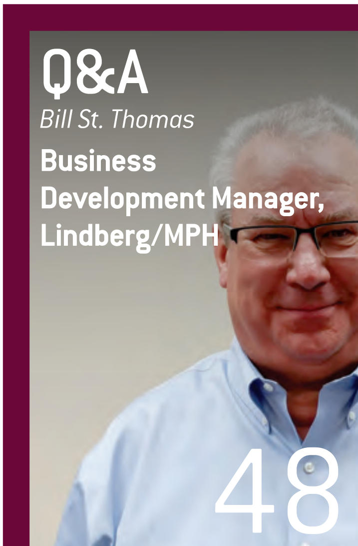














# RESOURCES

*Cover photo: WS, Inc.*



*Thermal Processing* is published semi-annually by Media Solutions, Inc., 266D Yeager Parkway Pelham, AL 35124. Phone (205) 380-1573 Fax (205) 380-1580 International subscription rates: $105.00 per year. Postage Paid at Pelham AL and at additional mailing offices. Printed in the USA. POSTMASTER: Send address changes to *Thermal Processing* magazine, P.O. Box 1210 Pelham AL 35124. Return undeliverable Canadian addresses to P.O. Box 503 RPO West Beaver Creek Richmond Hill, ON L4B4R6. 

# LETTER FROM THE EDITOR

## Welcome to our January/February issue of *Thermal Processing* magazine!

As the dust has settled from an exciting election year, as we shake off some of the uncertainties, and as we turn our focus forward, we see this upcoming year to have great potential. As your partner in the heat treating industry, we hope for more prosperous times ahead.

2017 forecasts are coming in with confidence and positive signs for the industry and the economy. This includes equipment investment, and early indicators point to growth. If you have plans to purchase new heat treating equipment, this issue of *Thermal Processing* includes two articles that you will find helpful. First, authors at WS Inc. cover economic tools to assess investments in gas heating of industrial furnaces, as well as a new technology that can both increase efficiency and reduce NOx emissions. Next, an article by Thermcraft Inc. presents detailed considerations when buying a new lab or industrial furnace and some tips that you might not have thought of.

We also bring you a technical article on the cooling curve test — a tool to compare quenchants as well as examine the condition of an oil — by author Scott MacKenzie of Houghton International. And you'll find a case study from Busch LLC discussing how a contract heat treater is using screw vacuum pumps as an alternative to vacuum generators.

In this issue, we are pleased to introduce a new *Thermal Processing* column, Maintenance Matters. Here, we will cover topics related to the maintenance of heat treating equipment. Jim Grann with Ipsen starts off the column by sharing expert advice on preventative maintenance.

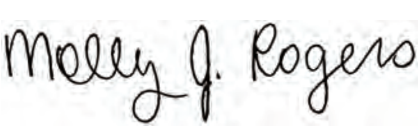
In our Quality Counts column, Jim Oakes provides insight into the Temperature Uniformity Survey (TUS) process, one of the key components to AMS 2750, to help in understanding the requirements. Hot Seat columnist Jack Titus returns to cover the different types of furnace heating elements. And March Li continues his series on carburizing optimization, presenting a method that has advantages over the traditional way of determining the carburizing factor in the Metal Urgency column.

Our company profile this issue highlights Gasbarre Furnace Group with an overview of its family of companies that includes Sinterite, C.I. Hayes, and J.L. Becker. And for our Q&A, I spoke with Bill St. Thomas about his new role at Lindberg/MPH and his thoughts on the industry.

For the companies and individuals who work hard to lead the way, strive for innovative breakthroughs, and are diligent in keeping up with the latest on how you can improve your business for your employees and your customers, we continue to reflect your accomplishments within the pages of *Thermal Processing* in order to share your successes with others who may find it beneficial as well.

We hope your year is off to a good start, and we look forward to working with you in 2017.

As always, thanks for reading!




**Molly J. Rogers**
**Editor**
*Thermal Processing* magazine
editor@thermalprocessing.com
(800) 366-2185 x205

**Thermal processing** for Gear Solutions

David C. Cooper
PUBLISHER

Chad Morrison
ASSOCIATE PUBLISHER

**EDITORIAL**

Molly J. Rogers
EDITOR

Kenneth Carter
ASSOCIATE EDITOR

**SALES**

Chad Morrison
ASSOCIATE PUBLISHER

Dave Gomez
REGIONAL SALES MANAGER

**CIRCULATION**

Teresa Cooper
MANAGER

Jamie Willett
ASSISTANT

Cole Morrison
ASSISTANT

**ART**

Shane Bell
CREATIVE DIRECTOR

Michele Hall
GRAPHIC DESIGNER

**CONTRIBUTING WRITERS**

JAMES BROCKLEHURST
JIM GRANN
MARCH LI
D. SCOTT MACKENZIE
STEVEN R. MICKEY
JIM OAKES
MARTIN G. SCHÖNFELDER
JACK TITUS
DERRICK WILSON
JOACHIM G. WÜNNING

Media solutions

PUBLISHED BY MEDIA SOLUTIONS, INC.
P. O. BOX 1987 • PELHAM, AL 35124
(800) 366-2185 • (205) 380-1580 FAX

David C. Cooper
PRESIDENT

Chad Morrison
VICE PRESIDENT

Teresa Cooper
OPERATIONS


DANIELI
CSI
CSI

# R&W Härtetechnik Chooses a Seco/Warwick Solution

Austrian commercial heat treater R&W Härtetechnik increases production capacities at its facility in Kindberg-Aumühl by purchasing an advanced heat processing system, 10.0 CaseMaster Evolution™ designed by Seco/Warwick.

CaseMaster Evolution is a hybrid solution, characterized by high precision of repeatable results. This unique two-chamber vacuum furnace is designed to run thermal processes and low-pressure carburizing with the capacity to quench in either gas or oil. This new installation will be the largest system of this kind in operation in Europe, with a load capacity of 1,500 kilograms (3,300 pounds).

"CaseMaster Evolution is the top-of-the-range product from the Seco/Warwick's vacuum business segment," said Ludger Oimann, managing director at Seco/Warwick Germany and sales development director at Seco/Warwick. "Our customers have appreciated its quality, performance, reliability, and continuity of production, and dozens of them are ordered every year. We are happy to observe a constantly increasing interest in this technology. This new generation of sealed quench furnaces can address the needs of various industries such as aerospace, automotive, machine building, bearing, and commercial heat treating represented by R&W Härtetechnik."

Today's Austrian commercial heat-treating companies are in need for advanced technologies that ensure not only flexibility, but also automated equipment that strictly controls process parameters. Following the requirements and expectations of the global industry for sustainable performance, achieving repeatability and the highest production quality is fundamental. Seco/Warwick, by providing such advanced, energy-efficient, and environmentally friendly vacuum heat treatment equipment with guaranteed process technology, is a preferred business partner that offers both standard designs and custom engineered systems to suit specific customer requirements.

"We have traditionally used atmosphere equipment," said Bernhard Waltl, managing director of R&W Härtetechnik. "However, in order to perfect heat processes by obtaining greater repeatability of results as well as reducing the consumption of technological media, we decided to choose the Seco/Warwick solution, which ensures the flexibility to quench in either gas or oil in a single device. With this new and unique system design of the CaseMaster Evolution, enabling maximum uniformity and cooling rate, R&W Härtetechnik will increase its production capacity, which in turn will contribute to strengthening the company's market position and its competitiveness."

**FOR MORE INFORMATION: secowarwick.com**

# AFC-Holcroft Awarded Associate Member of the Year by MTI

At its October Fall Meeting in Nashville, Tennessee, the Metal Treating Institute (MTI), the world's largest network of heat treaters in the world, recognized AFC-Holcroft from Wixom, Michigan, with the Associate Member of the Year Award.

Each year at its Fall Meeting, MTI recognizes the supplier within its membership who has exemplified the highest levels of support and service to MTI members and the Institute with their expertise, service, and commitment to the mission and objectives of the Metal Treating Institute.

AFC-Holcroft has played an instrumental role in delivering its expertise as a supplier serving MTI members and the heat treating industry.

"MTI has been able to serve the heat treating industry at the highest levels due to the support of suppliers members like

AFC-Holcroft," said MTI Awards Chairperson Jackie Peters. "The award was well-deserved."

President Bill Disler accepted the award on behalf of AFC-Holcroft.

AFC-Holcroft has been an MTI member since 2008 and is engaged at many levels of MTI serving as a Diamond Member Supplier and exhibiting at MTI's trade show, Furnaces North America. AFC-Holcroft also has graduated a few of their key executives from MTI's industry-leading YES Management Training Program.

MTI, established in 1933, is an international nonprofit trade association for the heat treating industry based in Jacksonville, Florida, with members in 38 states and six countries.

**FOR MORE INFORMATION: afc-holcroft.com**

# Can-Eng Furnaces Contracted To Build a System for Aluminum Automotive Structural Castings

Can-Eng Furnaces International Limited has been contracted by a European leader in the design and development of light-weighting thin-walled automotive structural castings to design, manufacture, and commission an automated T7 heat treatment system for the processing of high-integrity aluminum automotive structural castings. Can-Eng's design was chosen for this new facility as it offers inherent part handling features, which reduce floor-space requirements and energy consumption while providing predictable mechanical properties and dimensional stability of the casting.

Can-Eng is a global expert in thermal processing solutions for high-pressure die castings (HPDC) and aluminum automotive structural components. The high-volume continuous line includes integrated handling systems connected to up and downstream processes. The T7 system integrates robotic handling, Solution Furnace with Can-Eng's Precision Air Quench (PAQ™) technology, artificial aging system, and controls integrating Level II SCADA system. Can-Eng's PAQ system integrates a combination of features developed through continuous system improvements and modeling carried out in the more than 20 similar systems commissioned in recent years. Can-Eng's PAQ system uniformly delivers controlled quenching processes that provide repeatable and uniform mechanical properties and accurate dimensional results. The system is scheduled to be delivered and commissioned to the EU in the third quarter of 2017.

Can-Eng Furnaces International is a global provider of state-of-the-art thermal processing systems for ferrous and nonferrous metals and is a significant supplier to the automotive community through direct and tier supply.

**FOR MORE INFORMATION: can-eng.com**

# TPS Ships Blue M Lab Oven for Prominent Cosmetics Manufacturer

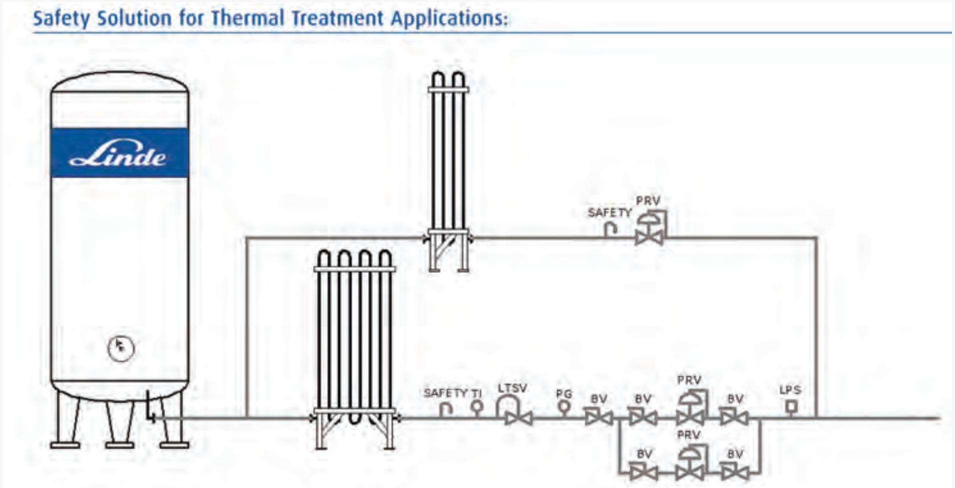
Thermal Product Solutions (TPS), a global manufacturer of thermal processing equipment, announced the shipment of a Blue M lab oven to the cosmetics industry. The lab oven will be used in the customer's aerosol lab for shelf-life testing of aerosol cans at 55°C (131°F).

The maximum temperature of this oven is 302°F, and the work chamber is 37"W x 37"D x 48"H. To create a safer interior, this oven does not have heating elements and hot spots, which are common sources of ignition if an aerosol can(s) leaks or ruptures during shelf-life testing. This also allows the customer to process larger quantities of aerosol cans. As an added engineered-to-order feature, an MSA LEL Monitor is installed that is set at 5 percent LFL. The MSA monitor will detect hydrocarbon gases that may be released during testing. Features of this Blue M oven include: intrinsically safe interior, no heating elements or heat spots that are sources of ignition, and MSA LEL monitor to detect hydrocarbon gases that may be released during testing.

Blue M is recognized as an industry leader in the design, engineering, manufacture, and after-market support of industrial and laboratory ovens that are ideal for a wide range of applications. Blue M products are available in bench top, stacked, and cabinet models to accommodate a variety of capabilities and footprints.


**FOR MORE INFORMATION: thermalproductsolutions.com**

# Linde Offers Safety Solution To Monitor Nitrogen Supply Levels




Linde LLC helps companies operating heat treatment furnaces improve safety by installing a protective-atmosphere safety monitoring system in compliance with the National Fire Protection Association's "Standard for Ovens and Furnaces" (NFPA 86).

Heat treatment furnaces depend on nitrogen supply to help operators initiate a safety purge with inert gas of the flammable atmosphere, and NFPA 86 requires proper monitoring and controls to reduce fire and explosion hazards.

The Linde safety solution is designed to monitor nitrogen supply levels and signals operators to low conditions with an audible alarm and strobe. To help ensure availability of supply for the flammable atmosphere nitrogen purge, the integral alarm panel provides indicators for low liquid-nitrogen level, low nitrogen pressure, and low nitrogen-supply temperature.

The Linde furnace safety solution can be installed on new or existing nitrogen supply systems for all common types of heat treatment furnaces and can be tailored to the needs of the operation.

Safety monitoring systems are a standard part of Linde heat treatment technology upgrades like the following:

- Furnace Gas Mixing Technology. The patented Carbojet® gas injection technology can improve the productivity of heat treatment furnaces without the use of circulation fans. The ultra-high-speed injection system improves atmosphere circulation for more homogenous mixing and improved heat transfer.
- Oxide-Free Parts Annealing. The Hydroflex® atmosphere control system offers a universal solution for clean and bright oxide-free annealing of steel, stainless steel, copper, bronze, or brass with high reliability and repeatability. Many annealing tasks can be completed with non-flammable gas mixtures containing less than 5 percent hydrogen.
- Sintering Atmosphere Control Systems. Linde offers total atmosphere control in sintering powder-metal parts with the Sinterflex® atmosphere control system. The system has effectively doubled the number of parts in-specification, resulting in significant cost savings.

With every installation, Linde application engineers conduct safety training that covers the properties of nitrogen, storage tank fundamentals, material compatibilities, and emergency procedures.

Linde offers decades of experience in heat treatment across all common furnace types from continuous to batch-type furnaces, including roller hearth, pusher, pit, or rotary-retort. Expertise spans all typical protective atmospheres — from pure nitrogen, pure hydrogen, nitrogen/hydrogen, nitrogen/hydrocarbon type atmospheres to endothermic gas, exothermic gas, and monogas atmospheres.

For information about reviewing heat treatment process safety systems, visit the Linde "Give it Gas" blog.

Linde provides industry-leading portfolio solutions for heat treatment and the ferrous and nonferrous metallurgy industries, ranging from gases and equipment to process consulting and services.

**FOR MORE INFORMATION: lindeus.com**

# Grieve Offers 1,400°F Inert Atmosphere Tempering Furnace

No. 1041 is a 1,400F° (760°C) inert atmosphere tempering furnace from Grieve used for heat treating at the customer's facility. Workspace dimensions of this oven measure 48" W x 72" D x 48" H, and 120 KW are installed in nickel chrome wire coils supported by a stainless steel frame, while a 9,600 CFM, heat-resistant alloy recirculating blower powered by a 15-HP motor provides vertical upward airflow.

This Grieve inert atmosphere tempering furnace has 7-inch-thick insulated walls comprising 5-inch-thick 2,300°F ceramic fiber blanket and 2-inch-thick 1,900°F block insulation. Features include inner walls clad with 304 stainless steel, 304 stainless steel ductwork, and a stainless steel subway-grating hearth. Other features include ¼-inch plate steel exterior reinforced with structural steel, ½-inch steel face plate at doorway, and an air-operated vertical lift door.

Inert atmosphere construction includes continuously welded outer shell, high temperature door gasket, sealed heater terminal boxes, inert atmosphere inlet, inert atmosphere outlet, inert atmosphere flow meter, and manual gas valve.

Controls on the No. 1041 include a digital-indicating temperature controller, a manual reset excess temperature controller with separate contactors, recirculating blower airflow safety switch, and a digital batch timer with alarm.

**FOR MORE INFORMATION:** grievecorp.com


# Ipsen U Offers Training for Multiple Levels of Expertise

For those who want to learn about new thermal processing methods and industry innovations, Ipsen U classes have a long-standing tradition of teaching best practices and helping improve the performance and life span of your equipment.

Ipsen begins 2017 by hosting another series of Ipsen U classes with courses available February 7-9, April 4-6, June 6-8, August 1-3, and October 3-5. These three-day courses provide attendees with a broad overview of furnace equipment, processes, and maintenance, as well as a hands-on approach to learning while receiving qualified tips directly from the experts. Past attendees have praised the instructors' "incredible amount of knowledge, hints, tips, and real-world advice."

Throughout the course, attendees are able to:

- Learn about an extensive range of topics — from an introduction to vacuum and atmosphere furnaces to heat treating, furnace controls, subsystems, maintenance, and more.
- View the different furnace components firsthand while learning how they affect other parts of the furnace and/or specific processes.
- Participate in a leak detection demonstration.
- Tour Ipsen's facility.

Regardless of where you fall on the expertise scale — maintenance, operator, engineer, project manager, or plant manager — Ipsen U instructors will provide the necessary level of information in a casual, open-forum environment. With a newly remodeled classroom, Ipsen U features comfortable seating for up to 36 attendees, as well as integrated technology with a large smartboard and two additional monitors for interactive presentations and demonstrations.


**FOR MORE INFORMATION:** ipsenusa.com

# MICO Generators from Eldec Offer Full Hardness and Short Processes for the Tool and Mold-Making Industry

Tool and mold-making professionals routinely face many challenges unique to their industry. In order to ensure the stability of the tools produced, hard grades of steel are required; however, specialists must also be able to precisely shape this material for use in creating

Continued on page 17

# Certifications and Guidelines Are Put in Place To Help Achieve Consistency and Quality of Heat-Treated Parts.

*By Jim Oakes*

IN ITS SIMPLEST SENSE, PYROMETRY IS THE measurement of temperatures. Practically speaking, in the business of heat treatment, the term also refers to the equipment, standards, and specifications that make it possible to measure temperatures — particularly, the high temperatures required for altering the properties of a part to achieve the desired metallurgical results.

To address these complications, industry leaders have developed a number of systems and guidelines that help lead to consistency and quality. One of the most important such programs is the National Aerospace and Defense Contractors Accreditation Program (NADCAP). NADCAP certification is essential to any business that wants to do heat treating work for the aerospace industry.

To ensure consistency of temperature measurement in heat treating processes, NADCAP relies on a document known as AMS 2750 (AMS = Aerospace Materials Specification). It's important to note that although NADCAP and AMS are both based in the aerospace sector, the certification and specification apply to the overall heat treatment industry and are not limited to aerospace alone. AMS 2750 covers all aspects of pyrometry in heat treatment, including:

- Controllers (calibrations, specifications, and readability requirements)
- Thermocouples (calibrations, usage, and types)
- Recording instruments (calibrations and accuracy)
- Accuracy requirements and tolerances for acceptance
- Calibration procedures
- Temperature survey procedures
- Frequency of activities

## TEMPERATURE UNIFORMITY SURVEYS

One of the key components to AMS 2750 is the Temperature Uniformity Survey (TUS). A TUS verifies the classification of your furnace and its qualified working zone, and this in turn determines your required ongoing testing schedule in order to maintain conformity with AMS 2750. Furnace classification is a key piece of information that the TUS will use to determine required frequency of testing activities. Furnace class is determined by the temperature uniformity range within the qualified working zone — put simply, in the area of the furnace that you will be using, how close are you staying to your desired temperature. The temperature uniformity range is described as a plus/minus degrees value, as shown in Figure 1. So, for example, if a furnace is meant to run at 1,900°F, and it ranges between 1,887° and 1,913°, it would qualify as Class 3. A higher-rated furnace classification means that the furnace is able to stay closer to its target temperature without variation.

| Furnace Class | Temperature Uniformity Range (Degrees F)(1) | Temperature Uniformity Range (Degrees C)(1) |
|---|---|---|
| 1 | ±5 | ±3 |
| 2 | ±10 | ±6 |
| 3 | ±15 | ±8 |
| 4 | ±20 | ±10 |
| 5 | ±25 | ±14 |
| 6 | ±50 | ±28 |

**Figure 1: Furnace classifications**

In addition to classification, AMS 2750 also uses instrumentation type to determine a furnace's mandatory testing schedule. The five instrumentation types (A-E) are defined clearly within the specification.

Put together, furnace classification and instrumentation type clearly determine the testing schedule necessary for your furnace in order to maintain certification. So, for example (see Figure 2), a Class 2 furnace with instrumentation type B is required to undergo a TUS on a monthly basis, whereas a Class 5 furnace with instrumentation type B only requires a quarterly TUS.

| Furnace Class | Temperature Uniformity | | Minimum Instrument Type | Initial TUS Interval | Number of Successful Consecutive TUS(1) | Extended Periodic TUS Interval |
|---|---|---|---|---|---|---|
| | °F | °C | | | | |
| 1 | ±5 | ±3 | D | Monthly | 8 | Bimonthly |
| | | | B, C | Monthly | 4 | Quarterly |
| | | | A | Monthly | 2 | Semiannually |
| 2 | ±10 | ±6 | D | Monthly | 8 | Bimonthly |
| | | | B, C | Monthly | 4 | Quarterly |
| | | | A | Monthly | 2 | Semiannually |
| 3 | ±15 | ±8 | D | Quarterly | 4 | Semiannually |
| | | | B, C | Quarterly | 3 | Semiannually |
| | | | A | Quarterly | 2 | Annually |
| 4 | ±20 | ±10 | D | Quarterly | 4 | Semiannually |
| | | | B, C | Quarterly | 3 | Semiannually |
| | | | A | Quarterly | 2 | Annually |
| 5 | ±25 | ±14 | D | Quarterly | 4 | Semiannually |
| | | | B, C | Quarterly | 3 | Semiannually |
| | | | A | Quarterly | 2 | Annually |
| 6 | ±50 | ±28 | E | Annually | Not Applicable | Annually |
| Refrigeration units and quench tanks do no require TUS | | | | | | |

**Figure 2: TUS intervals**

# Uniformity Surveys

However, AMS 2750 rewards success. If a furnace completes a designated number of TUSs successfully, the interval between testing can be increased. In the aforementioned example, if the Class 2 furnace with instrumentation type B were to undergo four consecutive successful TUSs, its required testing would stretch from monthly to quarterly. Having to perform fewer TUSs is a huge benefit that can lead to:

- Lower cost of labor/materials
- Increased production/reduced downtime
- Decreased time spent on documentation of the process

A TUS requires time and organization, since there are many prerequisites prior to performing the TUS. Even though a survey may only take two hours to run, it involves planning and coordination to get all the pieces in place. All the while, management and production are probably waiting for that valuable furnace time. To minimize this downtime, streamline the activities that surround the TUS in order to create an efficient process. For example:

- Organize paperwork.
- Ensure quick and easy access to maintenance logs.
- Have a prefabricated TUS rack wired in advance.
- Communicate dates for calibration of equipment.
- Develop a quick reporting technique for easy review and signoff.

Put together, these preparations can shave hours off the process. When multiplied by a number of furnaces, the financial benefits are clear.

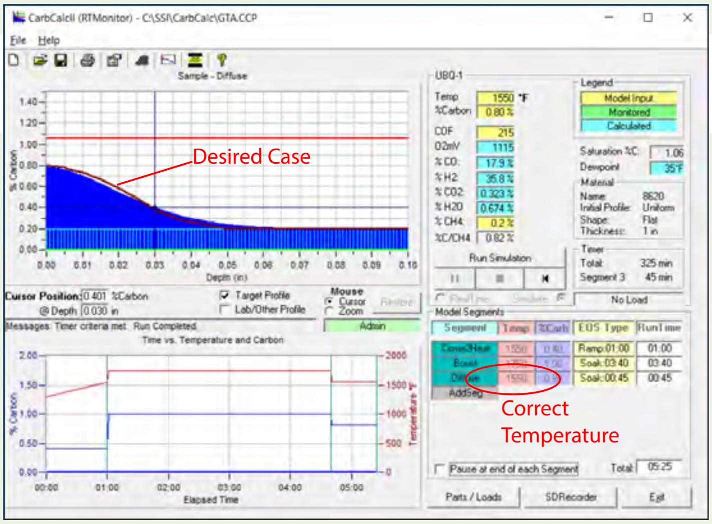



Figure 3: At desired temperature

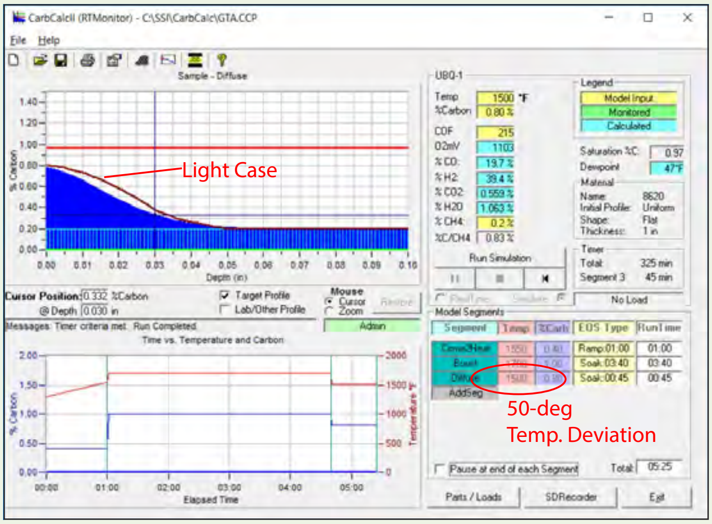



Figure 4: 50°F temperature deviation

## METALLURGY AND TEMPERATURE UNIFORMITY

There are many aspects of heat treating that can be compromised by temperatures not meeting the targets set forth by design engineers for the part performance, such as retained austenite, case depth, and low hardness.

### *Retained Austenite*

Retained austenite is a function of the austenitizing temperature, alloy content, and quench media. Retained austenite can occur when there is a gross issue with uniformity, combined with a higher-than-intended furnace temperature. As the austenitizing temperature increases, the retained austenite can increase as a result. While most post-quench sub-zero treatments can hide this type of issue, there are many manufacturing processes that are attempting to heat treat steels without a sub-zero treatment to save both time and money. In those processes, the temperature uniformity is even more critical.

### *Case Depth*

Case formation and diffusion into the steel are directly related to temperature. When the actual temperature inside the furnace is even slightly higher or lower than uniformity requirements allow, the case depth of longer processes can be significantly affected.

For example, Figures 3 and 4 show an 8620 material with a cycle of just over five hours. The desired and assumed temperature is 1,750°F for the boost phase and 1,550°F during the diffuse phase. In Figure 4, the temperature is reduced by just 50°F, resulting in light case due to the carbon not diffusing to the desired depth.

### *Low Hardness*

Many processes have reduced austenitizing temperatures in an attempt to minimize distortion. When the austenitizing temperature is lowered to close proximity of the $A_3$ or $A_{cm}$ temperatures, temperature uniformity becomes critical in preventing the formation of ferrite or carbides in the microstructure.

## CONCLUSION

Understanding the TUS process as it applies to AMS 2750E will allow you to be proactive regarding your requirements and responsibilities as a reliable heat treater. If you are familiar with your equipment and the specification, you can prepare for efficient transitions, minimize downtime, and streamline the process of TUS testing. And if you take the time to document the process for future surveys, you can save time and money in the long run by enabling yourself to identify problems before they are too late to prevent.

**ABOUT THE AUTHOR:** Jim Oakes is vice president of business development for Super Systems Inc., where he oversees marketing and growth in multiple business channels and helps develop product innovation strategies in conjunction with customer feedback. He has extensive experience working in the heat treating and software/IT industries. This article was co-authored by Matt Specter, also with Super Systems. For more information, email joakes@supersystems.com or go to www.supersystems.com.

# A Proposed Methodology Is Presented for Determining the Carburizing Factor.

*By March Li*

AS DISCUSSED IN THE SEPTEMBER/OCTOBER 2016 Metal Urgency column [1], carburizing is a nonsteady-state diffusion process and thus can be expressed by Fick's second law. For simplicity, when diffusion coefficient $D$ is considered to be independent of carbon content (equal to carbon potential) and some practical boundary conditions are specified, the diffusion equation can be solved and the carbon concentration at any time and position can be determined when base metal carbon content $C_0$, carbon potential $C_s$, and diffusion coefficient $D$ are known. In manufacturing, it is more convenient to establish the relationship between effective case depth (ECD) and carburizing time $t$. This can be directly derived from the aforementioned solution, which can be expressed as:

$$x = k\sqrt{t} \qquad \text{Equation 1}$$

where:
$x$ is ECD, $k$ is carburizing factor, which is determined by several parameters including $C_0$, $C_s$, and $D$, which is a function of carburizing temperature $T$.

Obviously, under certain carburizing conditions, i.e., when $k$ is given, the necessary carburizing time $t$ can be easily determined based on target effective case depth $x$. It seems that the task is simple: Determine $k$ values under given carburizing conditions (carburizing temperature, carbon potential setting, and carbon content of the workpiece). Once $k$ is determined, $t$ can be calculated directly from Equation 1.

It should be noted that Equation 1 is valid only when all conditions are fixed, i.e., temperature and carbon potential should keep constant during the whole carburizing process. This is rarely true for most carburizing facilities. As mentioned in previous columns, the carburized part needs to be quenched into the appropriate quenchant so that the austenite will transform to martensite. In order to minimize the quench stress and distortion, the temperature of the part should be lowered before quenching. In this case, Equation 1 is not valid, as $k$ changes with temperature.

Another bigger issue is the carbon and hardness profile within the case. In the gear industry, many gears need to experience post-carburizing processing such as grinding. If carbon potential keeps constant, the carbon content and hardness of the part drops quickly in the case. As a result, the remaining surface carbon content after grinding could be too low, which gives rise to soft surface (less than 55 HRC or 58 HRC depending on the rating) and the part cannot be used. This indicates that carburizing parameters (temperature and carbon potential) need to be adjusted such that the carbon and hardness profile in the case are flat and provide sufficient grinding stock removal. In other words, an optimized carburizing process should be set up to obtain an ideal carbon/hardness profile and to achieve minimized quench stress and distortion. Unfortunately, this makes Equation 1 invalid. Obviously, it is imperative to establish an optimized carburizing scenario, yet Equation 1 can still be used to predict the carburizing time based on the required effective case depth.

## CARBURIZING OPTIMIZATION

One practical way to get a flat profile of carbon and hardness is to set variable carbon potentials at carburizing temperature, i.e., set high carbon potential at the first stage and lower it at the second stage. Correspondingly, the first stage is called the boost phase, while the second stage is called the diffusion phase. The purpose of the boost phase is to expedite the carbon diffusion (shorten the cycle time), while the purpose of the diffusion phase is to adjust (flatten) the carbon and hardness profile. As discussed in previous columns, the highest carbon potential is limited by the maximum dissolved carbon content in austenite at the corresponding temperature to prevent potential carbide network. Typical carbon potential should be roughly 0.90 wt.% to 1.40 wt.% at 1,600°F to 1,800°F. For the diffusion phase, the carbon potential usually is set about 0.20 wt.% lower than that at the boost phase.

After carburizing, the temperature is lowered to slightly above $A_{c3}$ temperature (e.g., 1,500°F to 1,550°F) to reduce the quench stress and distortion. Correspondingly, the carbon potential is also lowered to around 0.80 wt.% in order to reach the 0.65 wt.% to 0.95 wt.% range required by AGMA standard.

Thus, the total carburizing time is the summation of three stages: boost, diffusion, and pre-quenching, i.e.:

$$t = t_b + t_d + t_q \qquad \text{Equation 2}$$

Here, $t_b$, $t_d$, and $t_q$ refer to the amount of time at corresponding stages; $t_q$ is usually about 14 hours depending on the size of the part. Past carburizing data shows that when $t_b$ is three to five times of $t_d$, the obtained carbon/hardness distribution in the case is satisfactorily flat. In comparison, Figure 1 illustrates carbon distribution within the case for a single potential carburizing process and an ideal carbon profile that offers adequate case depth for grinding. The carbon profile obtained by setting $t_b$ = (3 - 5)$t_d$ is in between these two curves. Historical data have revealed that the ratio of depth from the carburized surface to the location where 58 HRC is reached to effective case depth (i.e., from the surface to the location where 50 HRC is reached) is always more than 40 percent. This allows enough stock removal for grinding.

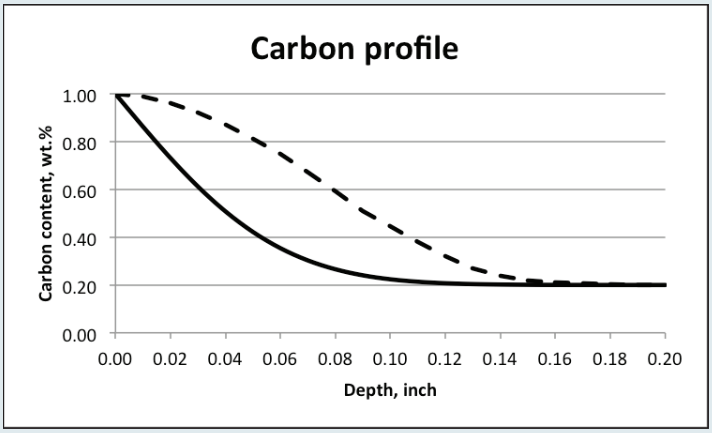



**Figure 1: Ideal (dashed curve) versus normal (solid curve) carbon profile in the carburized case for 0.20 wt.% base carbon steel at 1,725°F for 10 hours. Normal carbon profile is obtained by single carbon potential setting 1.00 wt.%, while ideal carbon profile is obtained by a different carbon potential (boost and diffusion) setting.**

## EFFECTIVE CASE DEPTH PRECISE CONTROL

By setting the boost and diffusion phases and corresponding time allocation, a flat hardness profile can be reached. Lowering the temperature before quenching minimizes quenching stress/distortion or potential cracking. These two measures optimize the carburizing process and meet both heat treatment and manufacturing requirements. However, since neither carbon potential nor carburizing temperature is constant, the required conditions for Equation 1 to be valid are lost. This implies that mathematically, there is no functional solution for Fick's second law. In other words, a similar expression to Equation 1 cannot be obtained. This makes it theoretically impossible to predict the necessary carburizing time for the part.

To solve this problem, we need to further simplify the model by ignoring some effects (such as the effect of alloying elements, grain size, and hardenability on carbon diffusion) and excluding the diffusion during carbon potential or temperature transition. This way, the whole carburizing cycle can still be considered as a single carbon diffusion process at boost temperature, except that diffusion time before quenching should be converted to an equivalent time at the boost phase, as the diffusion coefficient is smaller than that at boost temperature. This can be reached by multiplying an equivalent factor $a$, which equals to the ratio of the diffusion coefficient at the temperature before quenching to that at the boost phase. The calculation shows, depending on the temperature before quenching (1,500°F to 1,550°F), factor $a$ can be any value in the range of 0.13 to 0.70 (depending on boost temperature between 1,600°F to 1,800°F). Correspondingly, the total carburizing time will be:

$$t = t_b + t_d + at_q \qquad \text{Equation 3}$$

In order to solve the diffusion differentiation equation, carbon content at 50 HRC should be determined. Historically, this was considered to be 0.40 wt.% for carbon and low-alloy steels. Today, with more alloying elements added to the steels, i.e., to medium-alloy and high-alloy steels that are commonly used, this carbon content decreases. Per the literature, this content is in the range of 0.30 wt.% to 0.40 wt.% depending on the specific steel. This can be determined by experiment. For example, it was reported that carbon content at

50 HRC for SAE 9310 (nominal base carbon content of 0.10 wt.%) and SAE 4320 (nominal base carbon content of 0.20 wt.%) are 0.33 wt.% and 0.35 wt.% correspondingly [2].

Based on this simplification and measured carbon content at 50 HRC, the diffusion equation can be solved and functional expression can be obtained similar to Equation 1. For a specific steel with base carbon content of $C_0$, preset carbon potential $C_s$, carburizing temperature $T$ (at the boost phase), and carbon content $C$ at 50 HRC, carburizing factor $k$ can be calculated. Figure 2 shows results for base carbon content of 0.10 wt.% at different carbon potentials and temperatures with carbon content of 0.33 wt.% at 50 HRC. It demonstrates that $k$ increases with carbon potential and carburizing temperature.

Once $k$ is determined, the total carburizing cycle time $t$ can be determined based on required effective case depth per Equation 1. As long as the carburizing parameters are under control, the target ECD range can be reached precisely. Based on the total cycle time, the time at each phase can be allocated by Equation 3 and setting $t_b = (3 - 5)t_d$. This has been proven by numerous carburizing test data of different steels. For example, for SAE 9310 and SAE 4320 with ECD of 0.025 inch to 0.300 inch, which covers much of the industry application range, by setting different carbon potential and using different furnaces, the relative error of the carburizing factor between the calculated value and that through statistical regression of the real tests is consistently less than ± 5 percent and the hardness profile is satisfactorily flat [2]. This indicates that the methodology proposed in this column provides both practical carburizing optimization and precise control of effective case depth.

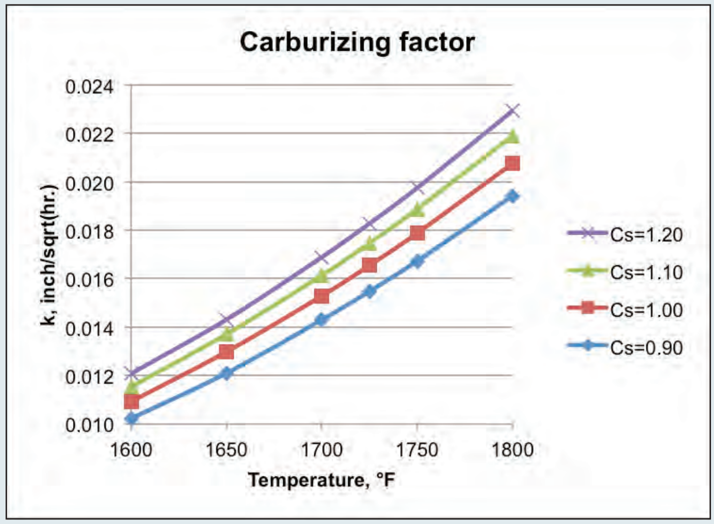



**Figure 2: Calculated carburizing factor $k$ of base carbon content 0.10 wt.% for different carbon potentials and carburizing temperatures. Carbon content corresponding to 50 HRC is 0.33 wt.%.**

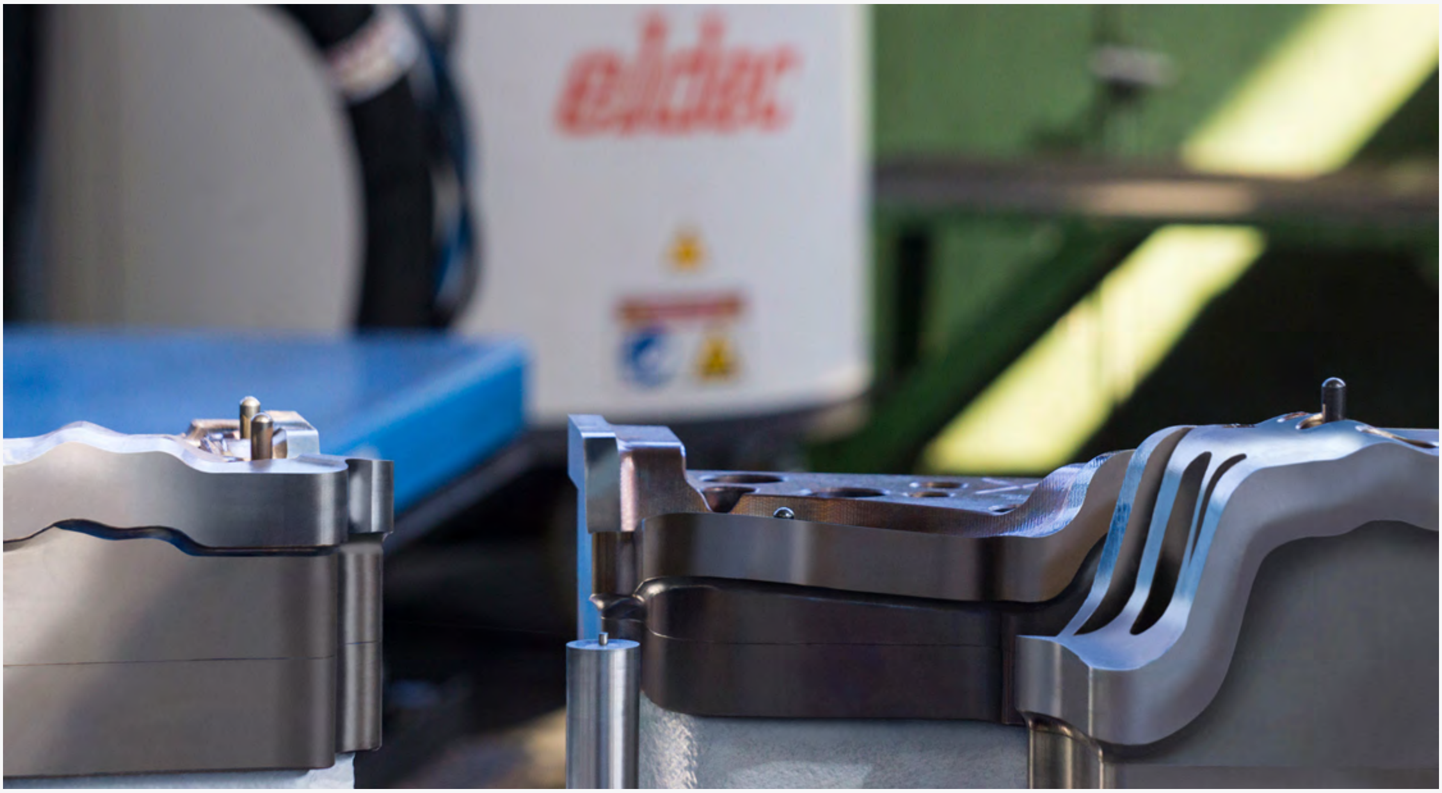
Furthermore, this methodology has several advantages over the traditional way in determining the carburizing factor. First, the traditional way applies to plain carbon and low-alloy steels, as it assumes carbon content at 50 HRC to be 0.40 wt.%, therefore cannot apply to medium- or high-alloy steels. Second, it allows temperature change only, i.e., carbon potential keeps constant (close to the maximum dissolved carbon content in austenite at the corresponding temperature). To obtain the carburizing factor, one either needs to multiply a factor (typically 0.6 to 0.7) to the calculated carburizing factor of total effective case depth or use a table based on the cumbersome conversion. On the contrary, this methodology provides a straightforward equation to calculate $k$ that allows changes with any or all carburizing parameters (such as temperature, carbon potential, and base metal carbon content). Finally, the carburizing factor determined by this methodology is more accurate than that determined by the classical way, as the latter usually gives three-decimal digits yet the former offers four digits. This higher accuracy provides cost savings and shorter lead times, especially for those parts with thick case depths, which take days of carburizing cycle time.

## REFERENCES

1. M. Li, Carbon Diffusion and Carburizing Parameter Selection, Thermal Processing, September/October 2016, p. 18.
2. M. Li, Practical Approach to Determining Effective Case Depth of Gas Carburizing, Gear Technology, March/April 2016, p. 56.

**ABOUT THE AUTHOR:** March Li is a metallurgist with a Ph.D. degree in Materials Science and Engineering. He has over 20 years of professional experience and has authored and co-authored over 30 technical publications in the material and metallurgy field. His focus centers around material selection, evaluation, and application in engineering and industry, including material strengthening and hardening, thermal processing and optimization, relationship between processing, microstructure and property, and failure analysis. He can be reached at lichun_ming@yahoo.com.

 Continued from page 11




Complex molds at Werkzeugbau Laichingen: The active parts are hardened with Eldec technologies

demanding components for things such as car-body manufacturing. In other words, quality in the toolmaking process has an enormous impact on quality in automobile manufacturing. It is clear that under these conditions the final surface hardness of the tools is essential, and additional hardening of the cutting edges is usually necessary. The production planners at Werkzeugbau Laichingen in Ulm, Germany, have been relying on technology from Eldec: Their cutting edges are hardened by mobile and robust MICO generators. This flexible technology significantly decreases and simplifies the production process.

Experts often describe toolmaking as a link between development and production with a considerable impact on the industrial value added. This is why the industry is considered a trendsetter for the continued development of production technologies — and is always in search of new solutions to improve workflows and quality. Cutting-edge hardening is no exception. This process hardens the features of the tool that later have to bear the greatest load in the punching or embossing machine. The stability of the cutting edge is decisive in determining the length of the tool life.

## BENEFITS OF INDUCTION HARDENING

Toolmakers generally use edge-layer hardening where the outermost layer of the cutting edge is heated to about 800 or 900 degrees Celsius (1,472-1,652 degrees Fahrenheit), depending on the material. The "quenching," where the real transformation takes place, then happens by natural cooling in the ambient air. As a result, the surface of the edge is harder and more resilient to wear (toolmaking typically requires a hardness of between 54 and 56 HRC), while the core of the material retains its toughness. Various methods are available to achieve these results. Toolmakers primarily use either flame hardening, the

The cutting edge is heated by induction

Continued on page 33

# Heating Element Materials Should Be Considered To Achieve Reliable Performance for Applications.

*By Jack Titus*

HEAT TREATING FURNACES CONSIST OF several subassemblies: insulation (fiber and brick), heating systems (electric and gas), material handling, quenching, atmosphere system, process and control logic, and finally, the external skeleton, the steel structure.

## HEATING ELEMENT BASICS

When natural gas is not available and the furnace atmosphere is endo gas or LPC (low-pressure carburizing), the type of electric heating elements selected becomes critical. The atmosphere or lack of it will determine which element design can provide the most reliable performance.

Other than induction heating systems, insulation-lined furnaces will most often have resistance heating elements like those used in household appliances such as electric ranges and toasters. Resistance heaters, as their name implies, produce heat because the materials — from which they are made — resist the flow of electricity, to a degree. Materials that completely oppose the flow of electrical energy are called insulators; materials that allow electrical flow are called conductors. If a material allows too much energy flow, the current or amperes will exceed the limits of a fusible link and blow a fuse or circuit breaker. The goal of the designer is to choose a material and cross-section that allows just enough resistance to electrical flow that it produces the appropriate heat required.

Metals consisting of chromium, nickel, iron, tungsten, and moly (molybdenum) are the most common element material, and the diameter or cross-section of the element determines its resistance. All other things being equal, the larger the cross-section, the lower the resistance. Therefore, heating elements for low power applications will always be small ribbons or minute-diameter wire. As the operating temperatures increase, the diameter of the element will increase, lowering the resistance and producing more current; a range of about 1/4" to 1/2" (6.35 to 12.7 mm) diameter being typical. That being said, there are applications where flat and wide elements are preferred, but still they must have the appropriate cross-section area to provide the required resistance.

## FURNACE TYPES

Endo carburizing and vacuum furnaces, especially LPC, are two of the most common recipients of heating element problems if not properly vetted. The area that receives the most attention from designers is the portion of the element that passes through the insulation and steel structure to connections outside of the chamber.

### *Atmosphere Furnaces*

It can be easier to design for atmosphere furnaces since the heating element can be inserted into a sealed tube, sometimes called a "bayonet" element. The advantage of this design is that no part of the element comes in contact with the atmosphere or furnace steel support structure. Figure 1 is typical of a bayonet element. Another advantage of the bayonet element is it can operate on 230 or 460 AC 60 Hz voltage, eliminating the need for a stepdown transformer. The radiant tube that shields the element is simply bolted to the furnace case with traditional sealing materials, so no special electrical isolation is required; all necessary electrical insulation to isolate it from the radiant tube is provided in the element assembly. Being inside the radiant tube, the element material is exposed only to air — one of the two most desirable media for metallic elements; nitrogen gas is the other.

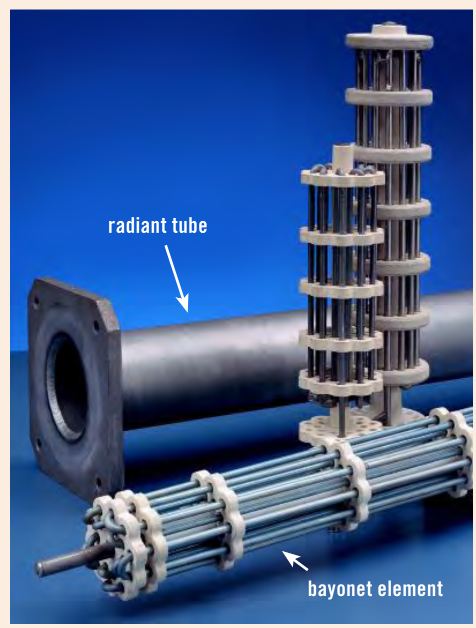



**Figure 1: Example of bayonet element (source: Custom Electric Mfg, Co.)**

Over the years, some atmosphere furnace OEMs have designed heating elements where the lead-in has passed through a small opening in the refractory into an insulator integrated into the steel casing. These designs are not reliable, as the endo atmosphere can bleed through the refractory openings and drop out soot onto the insulator, causing arcing between the lead-in and steel casing.

### *Vacuum Furnaces*

Except AFC-Holcroft's LPC-UBQ, most vacuum furnaces do not separate the heating element assembly from the furnace atmosphere. Since most vacuum furnaces are the cold-wall variety, the thermal insulation or inner chamber is supported from the steel case by spacers. The element lead-in then passes through an opening in the inner chamber without contact. The operating temperature from

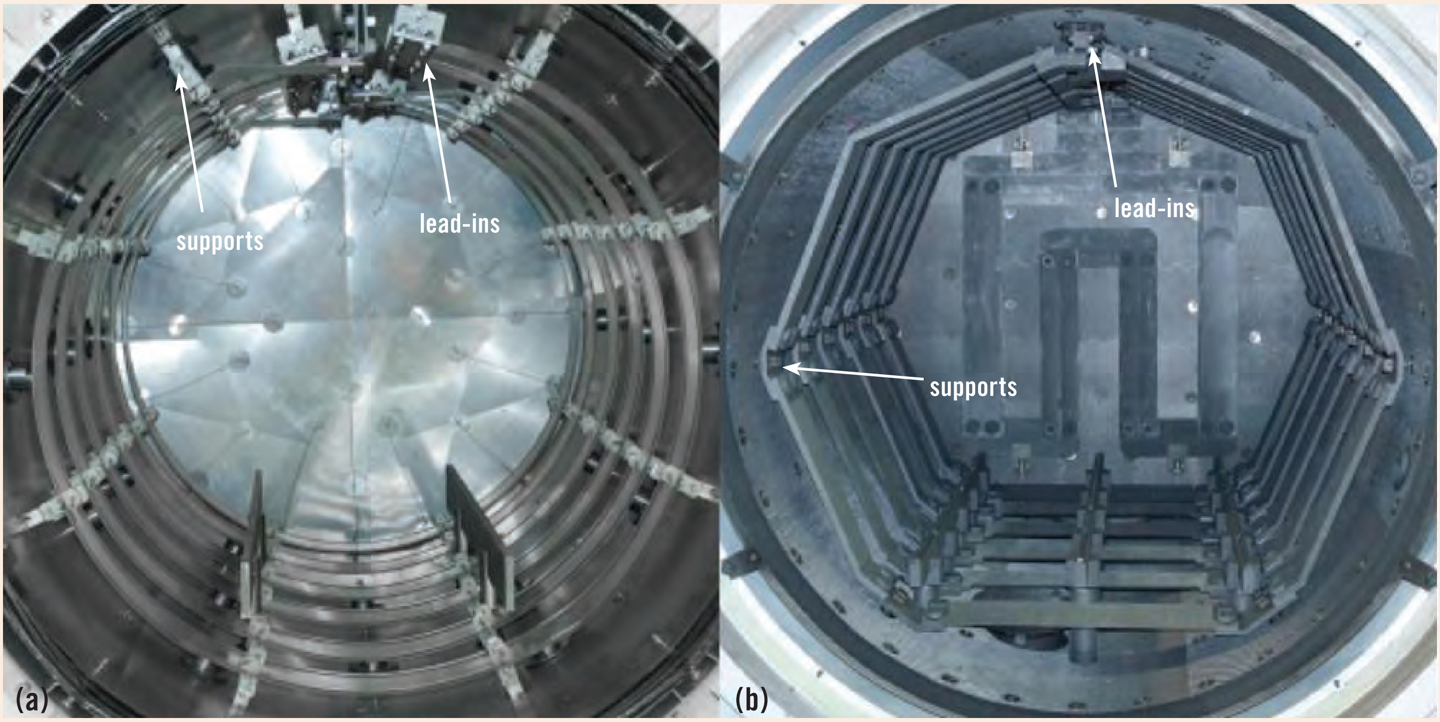



Figure 2: (a) Moly heating elements; (b) Graphite heating elements

a heat-loss standpoint will dictate the allowable space between the lead-in and the ID of the opening. However, the lead-in still must pass through the steel vessel without risking a short circuit, and this requires an insulator that can protect against the buildup of conductive precipitates like carbon when LPC is the process. Such insulators can consist of Teflon or other semi-rigid phenolic material with O-ring seals. The problem exists that if the LPC pressure and flow are not controlled properly, meaning that the surface of the load does not match the available acetylene ($C_2H_2$), the excess carbon produced from the cracked acetylene can settle on the lead-in insulator, potentially creating a short circuit and arcing between the steel vessel and copper lead-in. Going undetected, arcing can severely damage the lead-in and cause catastrophic consequences of a water leak into the vacuum chamber.

Heating elements made from graphite or moly can't just float unsupported within the insulated structure but must be secured from the frame, and somewhere in that arrangement, another insulator must be used. That additional insulator also is a potential source of short circuiting if it becomes coated with carbon or from evaporated metal when using low vacuum pressure. Metals like chromium and copper can evaporate and condense on those insulators, also creating a short circuit. Figure 2 shows two typical vacuum heating element assemblies: one with (a) moly heating elements and (b) with graphite elements. Graphite heating elements cannot operate in air above 700°F (371°C); 20 percent oxygen will start to aggressively oxidize graphite, thus they are a perfect solution for vacuum furnaces and where temperatures in excess of 2,200°F (1,204°C) are encountered.

## A THIRD ELEMENT OPTION

Silicon carbide can also be used as a bayonet element. Metallic element materials such as chromium and nickel are not suitable above approximately 2,000°F (1,093°C) especially when used as a bayonet inside a radiant tube. A bayonet element will always run hotter when located within a radiant tube. When such applications arise where a radiant tube is preferred in temperatures in excess of 2,000°F (1,093°C), a third option is a SiC (silicon carbide) element similar to that shown in Figure 3. These elements must hang to keep distortion to a minimum and be centered within the radiant tube with a suitable refractory spacer. SiC elements can be used well in excess of 2,400°F (1,316°C). When applications involve temperatures above 2,000°F (1,093°C), an RB (reaction bonded) SiC radiant tube is recommended. The drawback of RB SiC tubes is the difficulty in fabricating a suitable sealing flange since manufacturing these tubes with similar sealing methods as those incorporated in alloy tubes is difficult and costly. Having said that, AFC-Holcroft has developed a sealing configuration for alloy as well as RB tubes suitable for their LPC-UBQ furnace.

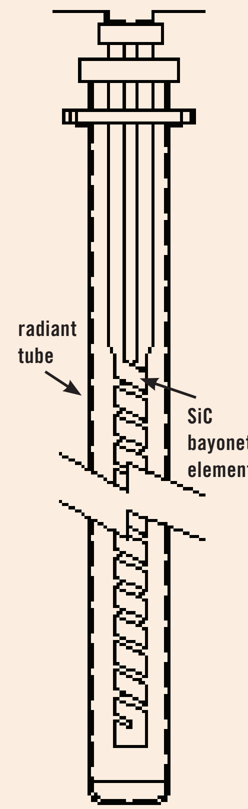



Figure 3

**ABOUT THE AUTHOR:** Jack Titus can be reached at (248) 668-4040 or jtitus@afc-holcroft.com. Go to www.afc-holcroft.com.

# Performing Regular Preventative Maintenance on Your Hot Zone Is a Key Part of Extending Its Life Span and Keeping It at Peak Performance.

*By Jim Grann*

ONE MOST COMMONLY recommended procedure for making your equipment perform more effectively is to run a cleanup cycle, which removes contaminants from within the hot zone. This column examines other recommended practices for hot zone maintenance, as well as the frequency at which these actions should be completed.

## REPAIR/REPLACE BROKEN ELEMENTS

On a daily basis, visually inspect the condition of the heating elements and shields. Look for any pieces that are missing, broken, cracked, or loose. Elements in these conditions can lead to temperature problems, such as inadequate heat and poor uniformity.

If you discover graphite elements are missing or damaged, you would generally replace the heating elements rather than repair them. This is because graphite is not extremely brittle, so you don't have to worry about accidently breaking surrounding heating elements during the replacement process.

However, all-metal heating elements are more fragile once they've been heated, so there are two common methods for handling broken elements: One option is to replace them in the same way you would a graphite element. Alternatively, all-metal elements can be repaired with an element patch, which allows you to clamp on small sections of metal that bridge the broken element. This avoids having to unbolt the heating elements between connection points and replace an entire section and reduces the chance of surrounding elements being damaged.

When you do need to repair or replace elements, having a spare parts kit on-hand can save you valuable time and allow for quick hot zone maintenance. Some basic hot zone parts you should try to keep in stock include an element strip kit, insulators, element hangers, carbon fiber composite, hearth posts, gas nozzles, nuts, and bolts.

## CHECK FOR DISCOLORATION

The heating elements and shields should also be checked daily for signs of discoloration. Discoloration in the furnace indicates contamination. If parts of the hot zone begin to show signs of discoloration, a leak check and/or furnace cleanup cycle may be required as a first step for troubleshooting the furnace and locating the source of the contamination. It is imperative that the source is identified to prevent continued discoloration and degradation of your hot zone.

## PREVENT ARCING

On a weekly basis, hand-tighten nuts, bolts, and element connectors inside the furnace. When parts become loose, they can cause arcing, which then burns away the hot zone's insulation, affects the overall quality of the heating elements, and can lead to discoloration. Hand-tightening is the recommended method to avoid over-tightening and breaking of graphite heating elements.

In addition to inspecting your hot zone for signs of broken elements, discoloration, and arcing, you should also create a tailored preventative maintenance plan. Doing so can play a critical role in maximizing the life span of your furnace and optimizing your hot zone's performance for as long as possible.

### EXPERT TIP

When replacing several heating elements at once, it is strongly recommended that you perform a conditioning cycle to allow the new elements to expand and contract at a slow ramp rate. This helps avoid damaging the element supports, hot zone, and load when you resume your normal process in the furnace.

A Temperature Uniformity Survey (TUS) may also be required to measure the temperature variation within the furnace's work zone before and after thermal stabilization.

**Figure 1: Hand-tighten nuts and bolts on a graphite heating element as part of regular hot zone maintenance**

## LIFE OF THE HOT ZONE

Preventative maintenance can extend the life of your hot zone, but when it no longer operates at peak performance, it may be time to consider replacing it. Depending on your process and parts, hot zones can last for several years or may need to be replaced more frequently. Several factors that affect the life span of a hot zone include:

- Leaks: Oxygen in the furnace can cause the hot zone to degrade faster.
- Cleanliness: Contamination in the furnace can cause hot zone degradation.
- Pressure: High-pressure gas quench, by nature, creates a turbulent environment in the furnace; therefore, the higher the pressure and larger the motor, the greater potential for wear and tear.
- Temperature: Higher temperature ranges can potentially cause more wear on the hot zone.
- Total operating time: The more cycles your furnace runs, the more frequently your hot zone will need maintenance.

## WHEN IS IT TIME TO REPLACE YOUR HOT ZONE?

You can determine if it's time by checking the heating elements monthly for signs of deterioration. Signs of arcing, cracking, and degradation on the hot zone's bottom third elements can indicate it is time for a replacement. Also, inspect the insulation for signs that it's breaking down, warping, or if the plenum frame is visible, as well as check the hearth rails for distortion and overall wear.

Certain factors during your process cycle can also serve as warning signs of a degrading hot zone, including loss of temperature uniformity, extended cycle times, heat loss, and constant discoloration of your parts or hot zone.

In the end, it is essential that regular inspection of your furnace and hot zone is incorporated into your preventative maintenance plan. Being proactive about hot zone maintenance and replacement can save you from unwanted downtime and higher operating costs — all of which can result from continuing to run cycles in a furnace that exhibits signs of degradation and heat loss.

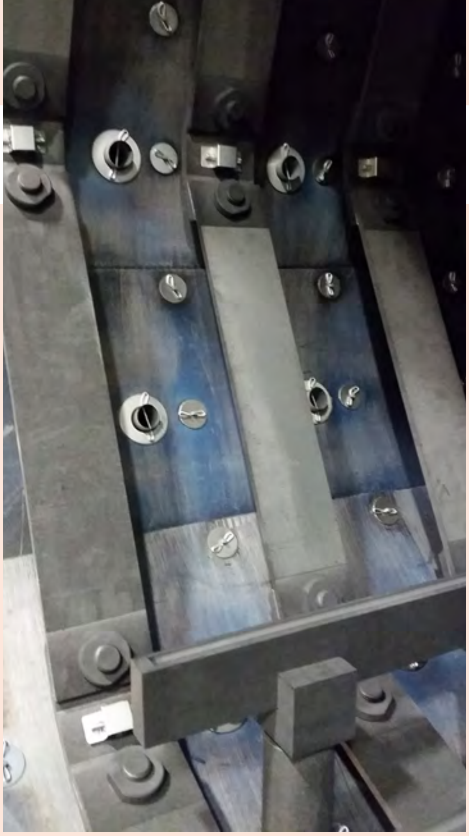


Figure 2: Hot zone exhibiting signs of discoloration

**ABOUT THE AUTHOR:** Jim Grann, Ipsen's senior technical manager, started with Ipsen in 1978, and since then, he has held roles in quality control, technical support, and Ipsen U instruction, among others. He is a technical expert who works with support services, furnace orders, inspections, and special processes. His 38 years of experience and interactions with customers around the world allow Grann to provide excellent solutions and support when troubleshooting furnace- and process-related issues.

# Gasbarre Furnace Group

Gasbarre Furnace Group includes a powerful trio of furnace-building companies that includes Sinterite, C.I. Hayes, and J.L. Becker.

Whether the solution is vacuum or atmosphere, batch or continuous, scaling a laboratory process to pilot, or commercial production, the Gasbarre Furnace Group can determine and provide the best solution for long-term success.

INDUSTRIAL THERMAL PROCESSES CAN BE ACCOMPLISHED by a wide range of equipment, with each solution having pros and cons. Clearly, the ultimate long-term success of a project is critically dependent upon selecting the most effective approach.

Recognizing this need, the Gasbarre Furnace Group has assembled a family of engineered furnace companies. Each dominates in its own markets and product offerings to ensure the customer's specific needs can be met with the best possible solution. This is accomplished by evaluating the commercial, technical, and engineering aspects of each opportunity, selecting the best overall approach, and then providing the resources to execute it.

## SINTERITE

Since 1978, Sinterite has been providing quality integrated manufacturing solutions, specializing in custom-engineered continuous belt and pusher furnaces for engineered materials requiring thermal processes under a variety of atmospheres. Sinterite designs and manufactures continuous and batch furnaces for sintering, brazing, annealing, steam treating, and drying.

Sinterite also offers the exclusively manufactured HyperCooler, a sinter-hardening system that improves variable cooling adjustment and atmosphere stability. In brazing applications, the HyperCooler is used to reduce stainless steel sensitivity.

In addition to its line of custom continuous belt and batch industrial furnaces, Sinterite is a leading manufacturer of fabricated alloy and mild steel products, providing a wide range of fabrication capabilities from powder processing to parts handling to custom projects. All of which can be tailored to meet each customer's needs and applications. The Sinterite manufacturing facility is in St. Marys, Pennsylvania.

## C.I. HAYES

Founded in 1905, and a member of the Gasbarre Furnace Group since 2003, C.I. Hayes has been providing innovative solutions and responsive service for over 100 years.


C.I. Hayes offers a diverse line of vacuum and atmosphere furnaces. Batch, as well as modular, in-line approaches, are engineered to suit processes including hardening, annealing, carburizing, brazing, and tempering.

Best known for its expertise in vacuum furnace design and capabilities, C.I. Hayes offers modular heating and quenching (oil or pressure), batch, and continuous vacuum furnaces. Common thermal processes applied include annealing, brazing, carburizing, glass-sealing, hardening, tempering, and sintering.

Featured within its vacuum product line is the C.I. Hayes Single Chamber Vacuum furnace, suited for batch processing for precise thermal recipes, and the Continuous Modular Vacuum furnace, manufactured with independent heating and quenching chambers and designed for smaller workloads that achieve near identical temperature profiles — making it highly productive and highly efficient. In addition, the C.I. Hayes' family of batch oil quench vacuum furnaces include integral sealed oil quenching for small batch tool-room applications to large production workloads with temperature capabilities to 2,400°F.

The C.I. Hayes' line of atmosphere furnaces features high-temperature pusher furnaces, capable of temperatures up to 3,000°F, tube furnaces for processing strand,

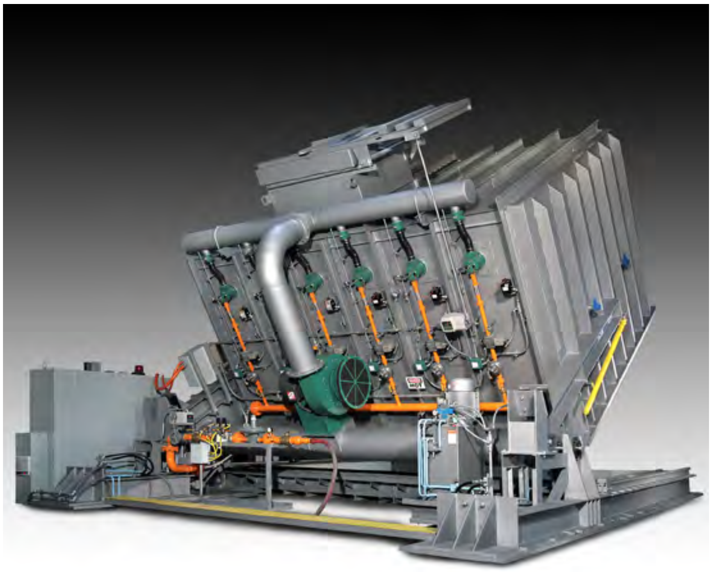
strip, or saw-blade stock, as well as several models of conveyor belt furnaces. Within the conveyor belt family and known for its distinctive design, the "humpback" conveyor belt furnace is an economical and highly efficient selection in applications that require extremely low dew points. Also in this family, C.I. Hayes offers the "solitaire" conveyor belt furnace with its compact design to accommodate brazing, soldering, and annealing of small pieces, such as valve assemblies and jewelry.

## J.L. BECKER

The newest member of the Gasbarre Furnace Group — the J.L. Becker Company — designs, manufactures, and services a full line of heat treating equipment for a wide range of thermal processes, including annealing, quenching, hardening, carburizing, ferritic nitrocarburizing, austempering, nitriding, washing, and tempering. The furnaces include batch and continuous type designs, specializing in tip-up, integral quench, box, and car-bottom furnaces.

Tip-up furnaces can be a single standalone furnace for carburizing or other atmosphere processes or as part of a line with a manipulator and a quench tank for hardening. A product experiencing high demand is the company's internal quench furnaces and companion equipment, as are Batch Austemper lines that have a movable box furnace, which can service multiple salt quench tanks, enabling the processing of different materials to achieve different metallurgical properties. Pit furnaces and box furnaces round out J.L. Becker's batch furnace line.

On the continuous side, the company offers mesh belt furnaces used for annealing, hardening, austempering, carburizing, brazing, or carbonitriding. Frequently, continuous furnaces are employed for high-volume production and can be precisely configured to ensure the installed capacity correctly matches the anticipated production needs, resulting in lower overall cost of operation.

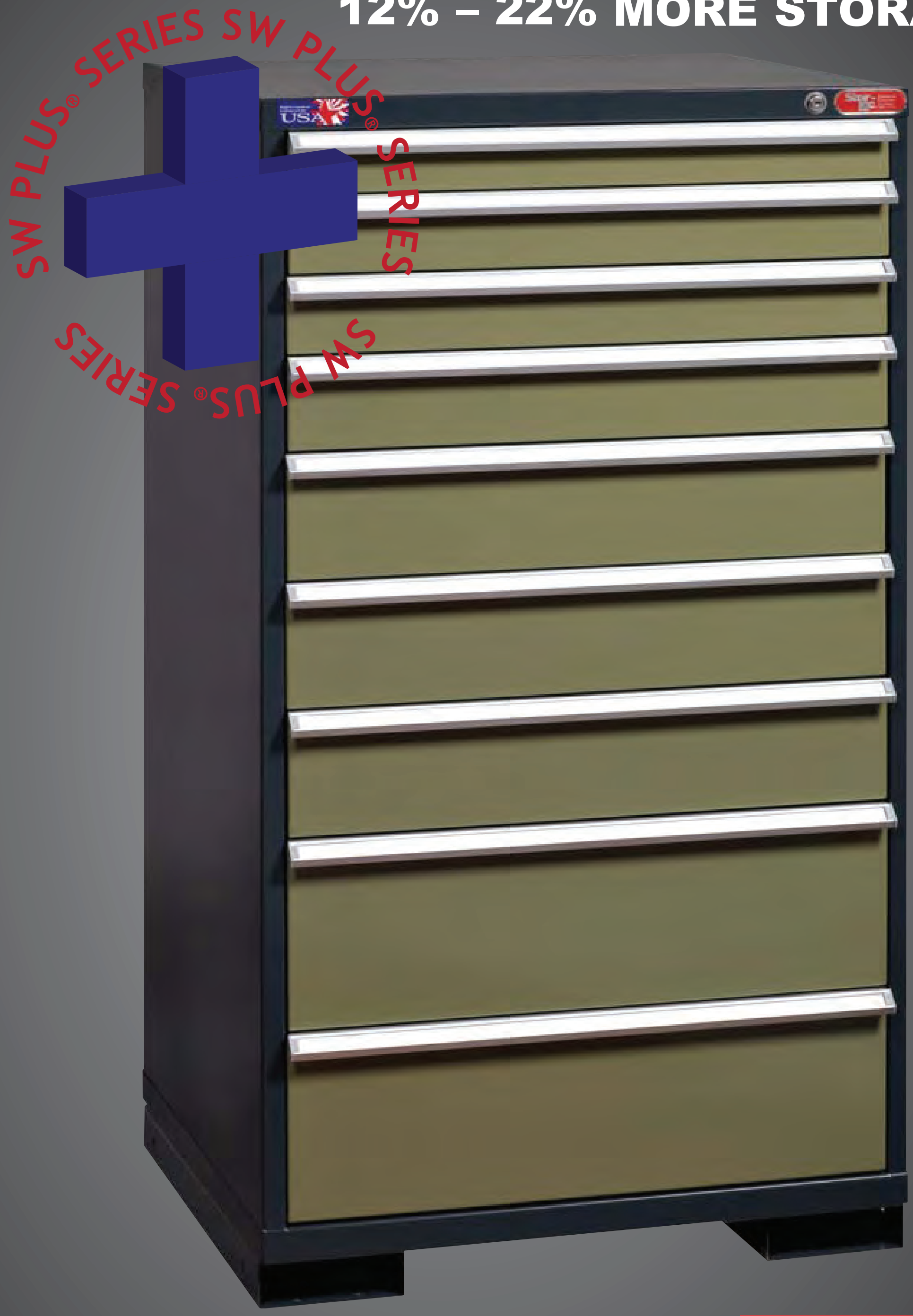


## GASBARRE FURNACE GROUP

The alliance of the GFG companies establishes a foundation for leveraging broad equipment capabilities, engineering/technology expertise, understanding of customers' commercial requirements, and the organizational resources needed to provide the best solution for each thermal processing requirement.

**FOR MORE INFORMATION:** gasbarrefurnacegroup.com

# Introducing our new
# SW PLUS +® Series
## 12% – 22% MORE STORAGE




**STOR-LOC MODULAR DRAWER SYSTEM**

880 N. Washington Ave. Kankakee, IL 60901
Toll Free: 1.800.786.7562 · Fax: 1.800.315.8769
email: sales@storloc.com

Stor-Loc® Modular Drawer System

# www.storloc.com

# Case Study: Busch LLC and Vakuum-Härterei Petter GmbH

## Dry vacuum technology in heat treatment processes offers advantages for a contract hardening company.

Vakuum-Härterei Petter GmbH (VHP) based in Quickborn, Germany, is a contract hardening facility that specializes in high-quality heat treatment under vacuum. The company has a total of nine vacuum ovens. The materials handled are mainly high-alloy steels, but non-ferrous metals are also heat-treated. The core activities of VHP are hardening, annealing, brazing, soldering, and tempering. VHP's customers include companies throughout Germany in the food, medical, forming, and transmission technology sectors. It offers custom heat treatment for individual customers, and a variety of processes and parameters are available to generate the desired surface properties with reproducible and documented results.

### BACKGROUND

Originally, the company had oil-lubricated rotary vane vacuum pumps installed that needed oil changes and replacement of all filters every six months, causing increased costs for servicing, oil, filters, and the disposal of used elements. In 2015, one of these rotary vane vacuum pumps was replaced by a Busch Cobra NX screw vacuum pump as the forepump of a three-stage system to supply a heat treatment oven. The objective was to find an efficient alternative to the vacuum generators previously used. After a year of testing, VHP is pleased with dry screw vacuum technology.

The benefits of high-quality heat treatment under vacuum include: no operating fluids present in compression chamber; increased pumping speed that allows more rapid heat treatment processes; and minimal maintenance and costs.

Vacuum technology is an indispensable part of metal heat treatment. The fundamental role of vacuum in heat treatment processes is to prevent unwanted reactions between the material components and ambient oxygen, as these may have an adverse effect on the surface properties of the metal. The pressure reduction also allows the process to be controlled more precisely. The pressure, temperature, and duration of the process can be set to suit specific materials and controlled according to material characteristics such as the vapor pressure curve. Quenching of the metal after heating is usually carried out with nitrogen, but in some cases, argon is used.



VHP has worked with vacuum technology for more than 30 years. The extensive experience gained in this sector allows the company to concentrate on complex heat treatment processes.

"The more challenging customer requirements become, the happier we are," said VHP's managing director, Frank Wallberg.

## THE CHALLENGE

VHP has traditionally used oil-lubricated rotary vane vacuum pumps to supply all the ovens. These vacuum pumps act as the forepumps of three-stage systems incorporating booster and oil diffusion vacuum pumps. This vacuum pump arrangement can achieve ultimate pressures of up to $1x10^{-5}$ mbar in the oven process chamber. If required by the process, the pressure can be increased by introducing controlled amounts of nitrogen.

## THE SOLUTION

The Cobra NX screw vacuum pump is a new development by Busch, and it has been designed specifically for heat treatment applications. No operating fluids are present in the compression chamber, making contact between the pumped medium and oil or other operating fluids impossible. This is achieved by two screw profiles, which contra-rotate in the compression chamber without making contact with each other or the housing. This simple construction makes the Cobra NX a robust and economical forepump for the vacuum supply system.

The Cobra NX was operated for a year in a three-shift system, and according to VHP directors Wallberg and Bernd Raabe, no servicing work was carried out within this period. They also observed other advantages: the power consumption remained the same as the old vacuum pump, but the substantially increased pumping speed allowed heat treatment processes to be carried out more rapidly. The low noise levels generated by the Cobra NX test unit were also a pleasant surprise. Both VHP directors agreed that the Cobra NX is the ideal forepump for their future requirements, and when ordering new ovens, will choose models equipped with Cobra NX screw vacuum pumps.

Busch Vacuum Pumps and Systems is one of the largest manufacturers of vacuum pumps, blowers, and compressors in the world. Its products are at the forefront of vacuum and low-pressure technology. The family-owned company with more than 2,700 employees worldwide offers more than 50 years of expertise in vacuum system manufacturing and can provide customized solutions for a variety of vacuum applications. Its global headquarters is in Maulburg, Germany, and it operates production plants in Switzerland, Great Britain, the Czech Republic, Korea, and in the U.S., Virginia Beach, Virginia.

**FOR MORE INFORMATION**, go to www.buschusa.com.

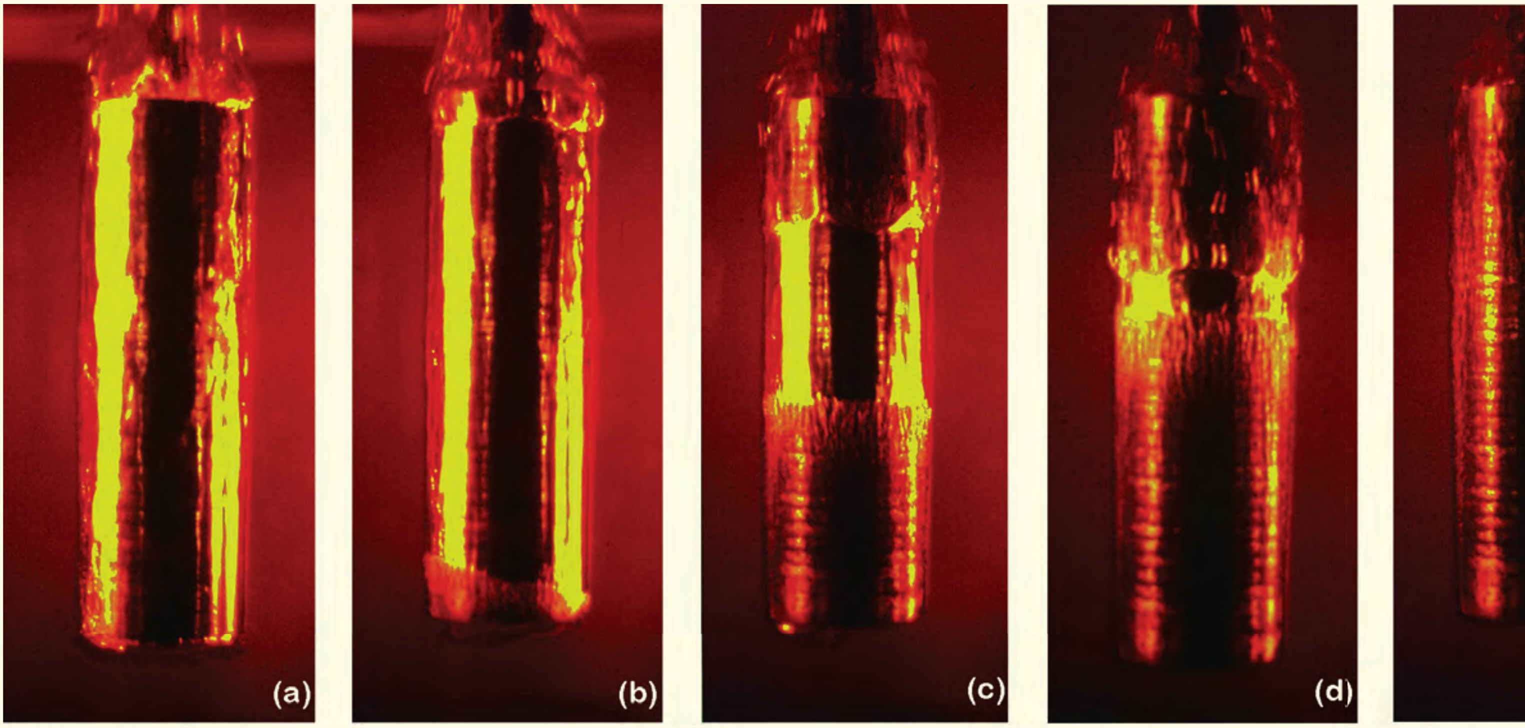



Figure 1: The mechanism of quenching of oil: (a) The moment of immersion showing the presence of a vapor film around the component; (b) After five seconds, the boiling phase commences at the corners of the component; (c) After 120 seconds, the boiling front moves along the component; (d) After 15 seconds, all three phases are present; (e) After 30 seconds, the convection phase is the dominant heat transfer mechanism; (f) After 60 seconds, the convection phase is nearly complete [1].

# Understanding the Cooling Curve Test

*By D. Scott MacKenzie*

In heat treating, the cooling curve test is often used as a tool to compare quenchants or as a method to ensure that the quenchant being used is suitable for continued use and will satisfy current requirements.

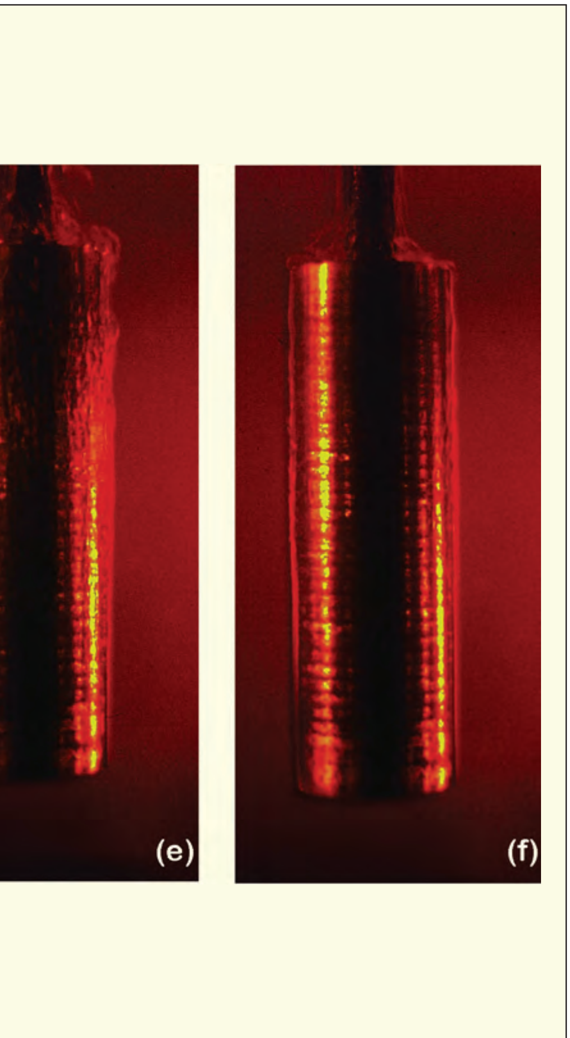
When a hot component comes in contact with the liquid quenchant, there are normally three stages of quenching. There are exceptions to this, which will be explained in each stage. The three stages of quenching are:

- Vapor stage (stage A or vapor blanket stage)
- Boiling stage (stage B or nucleate boiling stage)
- Convection stage (stage C)

The vapor stage is encountered when the hot surface of the heated component first comes in contact with the liquid quenchant. The component becomes surrounded with a blanket of vapor. In this stage, heat transfer is slow and occurs primarily by radiation through the vapor blanket. Some conduction also occurs through the vapor phase. This blanket is stable, and its removal can only be enhanced by agitation or speed-improving additives. This stage is responsible for many of the surface soft spots encountered in quenching. Strong agitation eliminates this stage. If the vapor phase persists, then non-martensitic transformation products can occur.

The second stage encountered in quenching is the boiling stage. This is where the vapor stage starts to collapse and all liquid in contact with the component surface erupts into boiling bubbles. This is the fastest stage of quenching. The high heat extraction rates are due to carrying away heat from the hot surface and transferring it further into the liquid quenchant, which allows cooled liquid to replace it at the surface. In many quenchants, additives have been added to enhance the maximum cooling rates obtained by a given fluid. The boiling stage stops when the temperature of the component's surface reaches a temperature below the boiling point of the liquid. For many distortion-prone components, high boiling temperature oils or liquid salts are used if the media is fast enough to harden the steel, but both of these quenchants see relatively little use in induction hardening.

The final stage of quenching is the convection stage. This occurs when the component has reached a point below that of the quenchant's boiling temperature. Heat is removed by convection and is controlled by the quenchant's specific heat and thermal conductivity and the temperature differential between the component's temperature and that of the quenchant. The convection stage is usually




the slowest of the three stages. Typically, it is this stage where most distortion occurs. An example showing the three stages of quenching is shown in Figure 1.

There are many methods to evaluate the extraction of heat from a quenchant. Examples include the GM Quenchometer test, ASTM D3520 [2]; and the hot-wire test. In the GM Quenchometer test, the time to cool a 12-mm nickel ball to the Curie temperature (352°C) is measured. In the hot-wire test, a Nichrome wire of a standard gauge and electrical resistance is immersed into the quenchant. A current is passed through the wire. The current is gradually increased until the burnout temperature (where the wire melts) is reached. The cooling power is represented by the maximum current sustained by the wire. In each of these cases, only one value (either the time to cool or the burnout current) is the sole measurand available to compare quenchants. No information is provided regarding the quench path.

The cooling curve test is the best procedure for characterizing the ability of a quenchant to extract heat. Cooling curves provide a complete picture of the heat extraction and cooling performance of a quenchant, as a function of surface temperature or center temperature of a probe. In this test, an instrumented probe of some material is heated to the desired temperature (usually in the austenite range) and then removed from the furnace. It is then transferred to the quenchant, recording the time verses temperature of the probe. Additional information is obtained by taking the instantaneous slope of the time-temperature curve to obtain the cooling rate curve. An example of the typical cooling rate curves for a selection of fast to slow oils is shown in Figure 2.

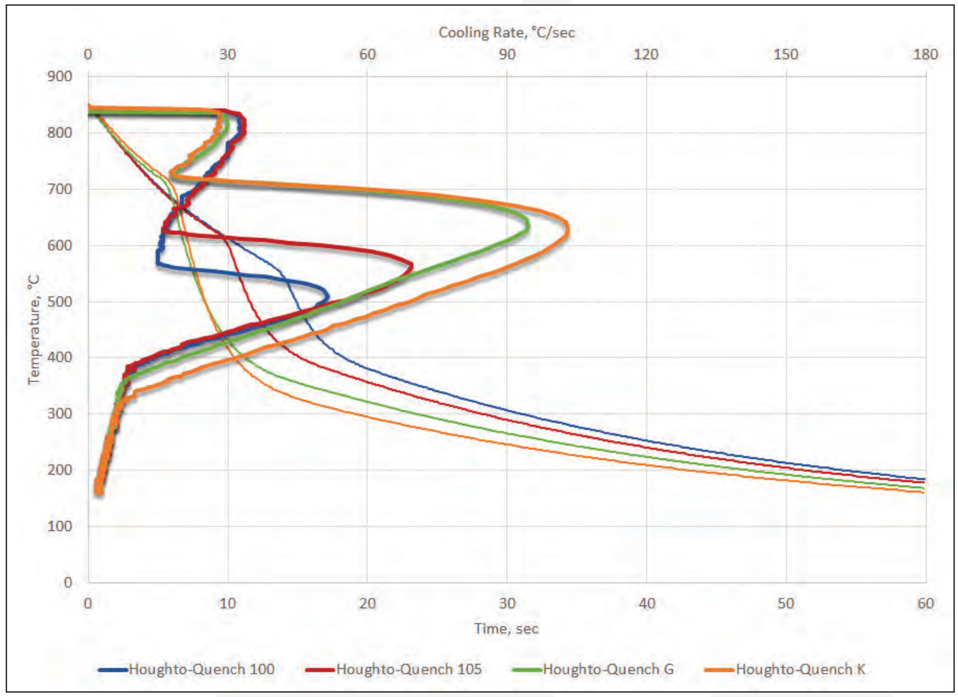



**Figure 2: Example of cooling curves and cooling rate curves of fast, medium, and slow quench oils**

Standardized test procedures are absolutely necessary to evaluate quenchant performance. This fact is recognized by ASTM [3], SAE [4], NADCAP [5], CQI-9 [6], ISO [7], and other auditing bodies for aerospace, automotive, and other industries. The use of standardized procedures for quenchant evaluation, in particular heat extraction capabilities, allows reproducible historical data collection. It allows evaluation to determine if a quenchant is suitable for a particular application or enables quality checks on current processes.

One of the first documented references on cooling curve apparatus was published by Pilling and Lynch [8]. This was an extension of the work by Le Chatelier [9]. In this study, Pilling and Lynch used a platinum-platinum rhodium thermocouple welded to the geometrical center of a 6.4 mm diameter by 50 mm probe fabricated from nickel + 5% silicon. This alloy was found to be free from the transformation effects of steel and avoided any transformations of nickel. The addition of silicon afforded oxidation resistance. They systematically examined the quenching characteristics of water, brine, soap solutions, and three different oils. They observed three dif-

| Parameter | Method | | | | |
|---|---|---|---|---|---|
| | ISO 9950 | AFNOR NFT-60778 | JIS K2242 | Z8 E 45003 | ASTM D6200 |
| Country | International | France | Japan | China | USA |
| Probe Alloy | Inconel 600 | Silver 99.999% Pure | Silver 99.999% Pure | Silver 99.999% Pure | Inconel 600 |
| Probe Dimensions | 12.5 x 60 | 16 x 48 | 10 x 30 | 10 x 30 | 12.5 x 60 |
| Vessel Dimensions, mm | 115±5 dia. | 138 dia. X 99 high | 300 ml beaker | 300 ml beaker | 115±5 dia. |
| Oil Volume, ml | 2000 | 800 | 250 | 250 | 2000 |
| Oil Temperature °C | 40 ± 2 | 50 ± 2 | 80, 120, 160 | 80 ± 2 | 40 ± 2 |
| Probe Temperature, °C | 850 ± 5 | 800 ± 5 | 810 ± 5 | 810 ± 5 | 850 ± 5 |

**Table 1: Comparison of international cooling curve standards**

| Property | Max. Cooling Rate | Temp. at Max. Cooling Rate | Cooling Rate at 300°C | Time to 600°C | Time to 400°C | Time to 200°C |
|---|---|---|---|---|---|---|
| Variation (2σ) | 2.1 | 12.7 | 8.7% of Mean | 0.4 | 0.5 | 1.3 |
| Variation (2σ) | 8.6 | 25.3 | 25% of Mean | 1.4 | 2.1 | 10.1 |

**Table 2: Bias and precision (95-percent confidence) of ASTM D6200 for single operator (top row) and interlaboratory testing (different operators with different equipment, testing the same sample, last row) [3]**

ferent modes of cooling: type A, which is now known as the vapor blanket; type B, or nucleate boiling; and type C, or convection.

Instrumented probes of many different types, shapes, and alloys are presently being used for cooling curve analysis. Presently, most standards specify either a pure silver or nickel-base Inconel 600 (UNS N06600) alloy. An early standard adopted by Japan, JIS K 2242 [10], is the Tamura probe, which measures surface temperature variation by a thermocouple located at the probe surface. Two other national standards utilize a silver probe: the French AFNOR NFT-60778 [11] and China's ZB E 45003-88 [12]. A reusable Inconel 600 probe was developed at the Wolfson Heat Treatment Center, Birmingham, U.K. [13]. This probe is the basis for ISO 9950 [7] and ASTM D6200 [3]. A comparison of the test methods is shown in Table 1.

In the United States, the most commonly used method for determining cooling curves is ISO 9950 [7] or ASTM D6200 [3]. This standard is used extensively for the characterization of cooling curve behavior of oil quenchants. It is used to determine the suitability of a quenchant for a particular application and is increasingly used as a quality control check of used oil to ensure proper quenching and to observe any oil deterioration.

Typically, the Inconel 600 probe is heated to 871°C and quenched into the desired quenchant. In the case of oil, 1-2 liters of oil is used without agitation. The temperature of the oil can vary, but is typically either 60°C for "cold" oils or 121°C for martempering oils. No agitation is used because of the difficulty in quantifying agitation.

The influence of test conditions on ASTM D6200 has been studied by Moore and Guisbert [14]. Guisbert [15] examined the precision and bias of cooling curve testing during the round robin evaluation of ASTM D6200 prior to establishment as a standard. He found that the cooling curve test of ASTM D6200 showed high repeatability and reproducibility, provided that the probes were properly calibrated. The published bias and precision of ASTM D6200 is shown in Table 2.

## APPLICATION OF THE COOLING CURVE

Typical data that can be extracted from the ASTM D6200 cooling curve test includes:

- Maximum cooling rate, °C/s
- Temperature at maximum cooling rate, °C
- Cooling rate at 300°C, °C/s
- Time to cool to 600°C, 400°C, and 200°C/s

Other data can be extracted such as the temperature at the start of boiling and the temperature at the start of convection. This data can be used to compare oils or to evaluate oils for a new process or application.

When examining in-use oils, it is important to understand the effects of "real-world" contaminates to the cooling curve. Oxidation, particulate, and water can have a considerable effect on the shape of the cooling curve.

Oxidation and fine particulate have the effect of suppressing the vapor phase and increasing the maximum cooling rate. It will also increase the temperature at which the maximum cooling rate occurs. This is because the fine particulate or precursors to oxidation that are soluble in the oil act as nucleation sites for the initiation of nucleate

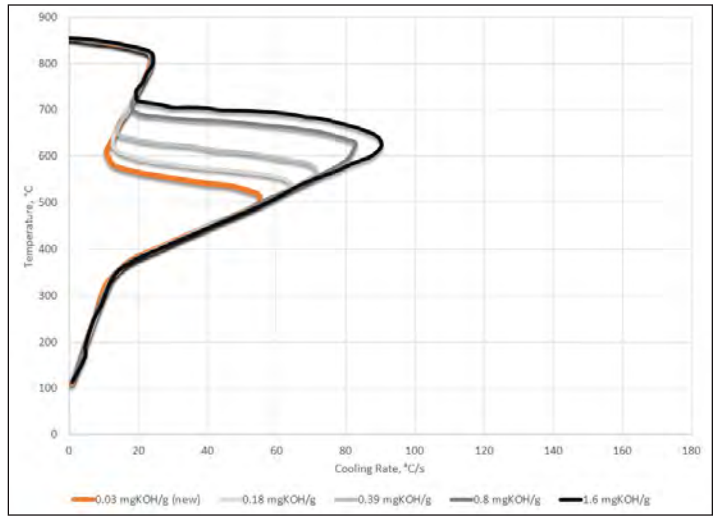



**Figure 3: Effect of oxidation on the shape of the cooling curve for a simple slow oil. The total acid number, in mg KOH/g is shown for each curve. Temperature of the quenchant was 40°C with no agitation**

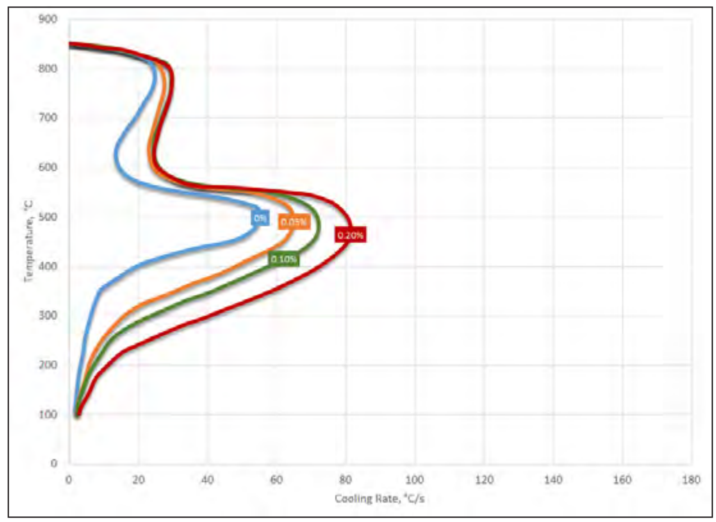



**Figure 4: Cooling curve response of a slow oil with different contents of water added; oil was tested at 40°C, with no agitation**

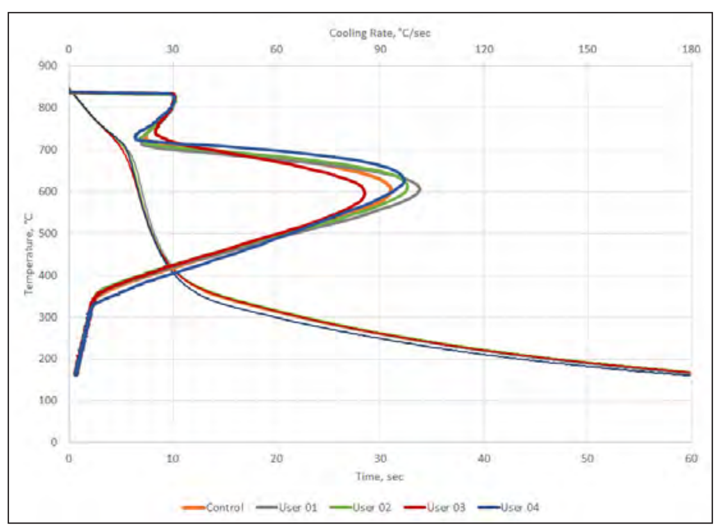



**Figure 5: Comparison of cooling curves for the same oil from four different customers, compared to new oil (control). All customers are using oil identical to the control. Oil was tested at 60°C, with no agitation**

| Property | Unit | Control | A | B | C | D | Max | Min |
|---|---|---|---|---|---|---|---|---|
| Maximum Cooling Rate | °C/s | 94.6 | 102.4 | 99.6 | 86.1 | 98.7 | 103.2 | 86.0 |
| Probe Initial Temperature | °C | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | | |
| Temp at Start of Boiling | °C | 725.0 | 713.4 | 720.7 | 736.8 | 730.1 | | |
| Temp. at Max. Cooling Rate | °C | 596.2 | 596.1 | 608.1 | 593.2 | 621.6 | 621.5 | 570.9 |
| Temp at Start of Convection | °C | 347.1 | 366.2 | 355.2 | 350.5 | 334.1 | | |
| Cooling Rate at 300°C | °C/s | 5.9 | 6.0 | 5.7 | 5.5 | 5.7 | 7.4 | 4.4 |
| Time to 850°C | s | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | |
| Time to 600°C | s | 6.8 | 7.0 | 6.8 | 6.6 | 6.7 | 8.2 | 5.4 |
| Time to 400°C | s | 10.5 | 10.7 | 10.7 | 10.6 | 10.2 | 12.6 | 8.4 |
| Time to 200°C | s | 45.7 | 45.6 | 47.3 | 46.6 | 43.2 | 55.8 | 35.6 |

**Table 3: Extracted data from the customer cooling curves in Figure 5; all oil is tested at 60°C and no agitation**

boiling. A schematic representation of the effect of fine particulate or oxidation on the shape of the cooling curve is shown in Figure 3.

While oxidation and fine particulate such as soot can yield similar cooling curve behavior, it is possible to differentiate between the causes with testing. Determining the total acid number per ASTM D664 [16] or ASTM D974 [17] will tell if the oil is oxidized. If the oil is not oxidized and has a low TAN, then the likely cause of the change in cooling curve response is due to fine particulate or soot.

Fine filtration (less than 3 µm) can reduce the effect of fine particulate. Additions of antioxidant can reduce the oxidation of the quench oil and return the curve close to normal.

Experience with poorly functioning quenching oils indicates that in at least half the cases, water gets into the oil, causing cracking, uneven hardness, and soft spots. Water can enter the oil in a number of ways, and the sources must be tracked down and eliminated. A leaky cooler might bring water into the oil or water may drip into the tank from the roof. A tiny amount of water (about 0.1 percent) can cause a bath to foam excessively and greatly increase the danger of fire.

The cooling curve response of oils containing water shows an increased maximum cooling rate with an extended vapor phase. Further, and probably the most telltale sign that water is present, is the rounding of the nucleate boiling to convection transition. It is this change in cooling curve response that is responsible for cracking of parts when water is present. A schematic showing the effect of water on the cooling curve response is shown in Figure 4.

The cooling curve test is also used as a quality control check to ensure that the oil is operating as it should. Deviations from process parameters indicate that corrective action should be taken to ensure that parts are quenched properly. For example, four cooling curves from customers using the same oil (but different applications) were selected and compared to new oil. The representative cooling curves are shown in Figure 5. All the cooling curves show similar responses. Data from the cooling curve can be used to determine if the oils meet new manufacturing specifications for the quenchant.

Extracting data from the cooling curve and applying the bias and precision from ASTM D6200, it can be determined if the customer cooling curves meet specifications for new oil. The extracted data is shown in Table 3. Inspection of the data from the cooling curves show that all the customer cooling curve data meets the requirements for new oil. However, customer 3 shows that the maximum cooling rate is a bit slower than the control, but still within the limits of error for the test. If the customer is achieving good hardness during quenching and not seeing a gradual decline in hardness over time, then the oil is acceptable for continued use. However, if the customer is observing a gradual decrease in hardness over time, then it might be appropriate to add a speed improver to his oil to recover the oil back to original specifications.

It is not unexpected that different customers would exhibit different cooling curves for the same oil. These customers use this oil (Houghto-Quench G) in a variety of applications, for different lengths of time, and under different maintenance conditions. None of these customers are reporting problems achieving hardness or properties.

There are multiple reasons why the used customer oils could show a greater scatter. Greater levels of dirt, including soot and scale, could cause differences in the cooling curve behavior of the oils. Further, recycling or recovery of the oil from washers could change the cooling curve. However, fine soot and residual washer residue would likely increase the maximum cooling rate.

This same methodology can be used to select oil for a new application or to replace an existing oil. The cooling curves are compared, and the extracted data from the curves is further compared. Additional information such as oxidation resistance and cost also enter into the decision.

## CONCLUSION

The cooling curve test is a powerful method of examining the entire quench path of the quenchant. It can be used to examine the condition of an oil to ensure that the quenching characteristics are the same as new oil and whether corrective action must be taken.

Many of the latest revisions of specifications, such as AMS 2759 [4] and auditing agencies such as NADCAP [5], require the heat treating quenchant supplier to specify in the report whether the oil is "good" or "bad." However, the supplier does not completely know the parts processed or the processes used nor does the heat treat quenchant supplier control any of the processes or parameters associated with the heat treating process. The quenchant supplier can only specify whether the used oil satisfies the manufacturing limits for new oil. Working with the customer, these limits can be modified for each application.

## REFERENCES


1. Houghton International, Inc., "Houghton on Quenching," 1991.
2. ASTM, "Standard Method for Quenching Time of Heat Treating Fluids (Magnetic Quenchometer Method)," American Society for Standards and Materials, Conshocken, PA, 88.
3. ASTM International, Standard Test Method for Determination of Cooling Characteristics of Quench Oils by Cooling Curve Analysis, Conshocken: ASTM, 2012.
4. SAE International, Heat Treatment of Steel Parts, General Requirements, Warrendale, PA: SAE International, 2014.
5. SAE International, National Aerospace and Defense Contractors Accreditation Program (NADCAP) Requirements for Heat Treating, Warrendale, PA: SAE International, 2008.
6. AIAG, Special Process: Heat Treat System Assessment, AIAG, 2011.
7. International Organization for Standardization, Industrial quenching oils — Determination of cooling characteristics —Nickel-alloy probe test method, Geneva, Switzerland.
8. N. B. Pilling and T. D. Lynch, "Cooling Properties of Technical Quenching Liquids," Trans. American Ins. Mining and Metallurgical Engineers, vol. 62, pp. 665-688, 1919.
9. H. L. Le Chatelier, "Etudes sur la Trempe de l'Acier," Rev. Met., vol. 1, p. 473, 1904.
10. Japan Metal Working Fluids Association, Heat Treating Oil, Japan Standards Association.
11. AFNOR, Industrial Quenching Oils — Determination of Cooling Characteristics — Silver Probe Test Method, Saint-Denis: AFNOR.
12. Heat Treating Oils — Determination of Cooling Ability, Z8 E 45003, Beijing.
13. Laboratory Test for Assessing the Cooling Curve Chacteristics of Industrial Quenching Media, Birmingham: Wolfson Heat Treatment Center Engineering Group Specification, 1982.
14. D. L. Moore and D. A. Guisbert, "Influence of Test Conditions on Cooling Curve Data," in Proc. 14th ASM HTS Conference & Exposition, Indianapolis, IN, 1993.
15. D. A. Guisbert, "Precision and Accuracy of the Continuous Cooling Curve Test Method," in Proc. 16th ASM HTS Conference & Exposition, Cincinnati, OH, 1996.
16. ASTM, "ASTM D664: Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration.," American Society of Testing and Materials International, West Conshohocken, PA.
17. ASTM, "ASTM D974: Standard Test Method for Acid Number and Base Number by Color-Indicator Titration.," American Society of Testing and Materials International, West Conshohocken, PA.




**ABOUT THE AUTHOR:** D. Scott MacKenzie, Ph.D., FASM, is a research scientist of metallurgy at Houghton International, a global metalworking fluids supplier. Previous to this position, MacKenzie was associate technical fellow at Boeing — performing failure analysis. At McDonnell Douglas, he was the manufacturing engineer responsible for all heat treating activities at McDonnell Douglas – St. Louis. He obtained his B.S. from The Ohio State University in 1981 and his Ph.D. from the University of Missouri-Rolla in 2000. He is the author of several books and over 100 papers, articles, and chapters. He is a member of ASM International.

 Continued from page 17

expensive laser hardening, or, alternatively, induction hardening. Why is that?

"For starters, all these methods have flexible applications," said Stefan Tzschupke, head of Business Development Generators at Eldec. "Even large, bulky components with complex geometries can be produced manually or automatically when using lasers. However, induction hardening offers significant advantages in terms of processing quality and time, as well as safety and cost. Our technology is becoming increasingly important for a growing number of toolmakers."

A quick look at the characteristics of the Eldec procedure confirms this assessment. The cutting edge is heated by induction. This way, the tool reaches the required temperature much quicker, because the heat is delivered directly to the volume underneath the surface. With flame or laser hardening, only the surface itself is heated at first.

Eldec energy sources also make it possible to precisely control power, current, or temperature, enabling users to respond optimally to special requirements as well as the ambient conditions of the process. As a result, the hardening pattern is uniform.

"Another benefit is that the process generates no toxic or explosive gases that might contaminate the workplace," Tzschupke said. "Finally, its good energy efficiency makes our technology much more environmentally friendly than flame hardening."

## SIGNIFICANT REDUCTION IN CYCLE TIME

Werkzeugbau Laichingen is a new Eldec customer that relies on the advantages of induction hardening. At its locations in Laichingen and Leipzig, the German company has comprehensive knowledge and experience ranging from tool design to complete production processes and comprehensive services for pressing and shaping tools. The specialists also provide the in-house presses for the start and phase-out of series production.

"We are able to respond to customer needs on extremely short notice, as missing or incomplete tools can cost a lot of money," said Gottlieb Schwertfeger, who is in charge of purchasing and quality management at Werkzeugbau Laichingen. "We are continuously working to improve and further shorten our production processes. In pursuit of this goal, we recently changed

The mobile system can be moved quickly to different application locations on the factory floor. Operation is easy, allowing for quick hardening processes at the cutting edges



Continued on page 37

# Buying a New Lab or Industrial Furnace

*By James Brocklehurst and Derrick Wilson*

Many considerations should be addressed when specifying a new electrical resistance heated furnace.

When the time comes to purchase a new lab or industrial furnace, there are several points that need to be considered before going out for bids. One of the first considerations should be the desired operating temperature that will be used most often. "Most often" because many new lab and industrial furnace purchasers often assume that one furnace can operate through a broad temperature range.

For instance, a common inquiry would be, "I need a furnace that can be used from 1,000°C to 1,800°C." While this request is certainly possible, the requested temperature range crosses all three temperature boundaries and price ranges that will be covered next. This is a common mistake that leads to sticker shock that can be discouraging to new furnace purchasers. Upon further discussion, users may elude to the fact that 95 percent of their processes only require a maximum temperature of 1,100°C, which would be more realistic and certainly more cost-effective at purchase time.

## TEMPERATURE RANGES

Lab and industrial furnaces can be divided into three temperature ranges, based on their heater technology. The first is based on wire heating element technology, which extends to a maximum of 1,300°C, although some special-use applications claim up to 1,400°C. The second group is based on silicon carbide (SiC) heating elements and generally has a useful upper range of 1,550°C. The third group uses molybdenum disilicide (MoSi2) heating elements that can easily reach 1,750°C and with care, can be used up to 1,800°C. Of course, with increasing

Figure 1: TransTemp transparent tube furnace

Figure 2: Vertical split tube furnace

temperatures, the pricing also increases. A rough rule of thumb indicates that if a furnace with a maximum temperature of 1,300°C costs one unit, a furnace with a maximum temperature of 1,550°C will cost two to three units, and a furnace with a maximum temperature of 1,750-1,800°C will be three to four units. This rough order of costing assumes the same general heated chamber geometry for each unit.

As a side note, the terms "furnace" and "kiln" should be explained. Basically, the terms are industry-specific jargon. The term "kiln" is most often used in ceramics processing and the cement industry, while the term "furnace" is used most often in metallurgical processing, general heating, and material characterization applications. Depending on the industry, the same unit may either be referred to as a kiln or a furnace. Generally, the terms can be used interchangeably.

## FUTURE CONSIDERATIONS

Another point to consider may be future expansion. It may be required that a furnace is ordered with specific working dimensions for existing projects, but plans may indicate that future projects will require a larger unit. Depending on time frames and cost restrictions, it might be wise to seriously consider a larger unit for the initial purchase. Unfortunately, due to a wide range of variables, there is no easy way to estimate how much more the larger unit will cost without getting an actual price quote. In some instances, doubling the working volume will add less than twice the cost and delivery time. In other instances, the cost could more than double, and the delivery could be significantly extended. If future projects dictate a higher temperature unit will be required, several factors must be evaluated.

There may be a higher cost for the increasing temperature range; the external size of the unit can increase with temperature because of the need for more insulation. You must also consider the current existing normal operating temperature parameters with respect to issues of maintenance, reliability, and temperature uniformity as compared to a higher temperature unit. Furnaces are designed to operate most efficiently and give the best uniformity at their specified operating temperature. Purchasing a 1,600°C rated furnace based on possible future applications and then using it for day-to-day operation at 600°C only creates operational issues with process control and temperature uniformity. This would be the equivalent to buying an F1 racecar to drive to town to buy groceries with the remote possibility that you may have a chance to drive in the Monte Carlo Grand Prix some day. Capital costs, reliability, low speed performance, and maintenance issues would be


Figure 3: Compact split tube furnace

such that perhaps a used VW would have been a wiser purchase, not to mention advances in technology that may occur, rendering the unit somewhat obsolete and out-of-date.

## FURNACE GEOMETRY

The next point to consider should be furnace geometry. Should you purchase a box unit or a tube unit? The box unit is great for loading samples in a batch operation, while a tube unit is generally better for a continuous application such as gas conditioning or material characterization testing that can take place inside of a process tube. Each style also has additional options to consider. With a box unit, there are several types of doors such as a simple front door (either vertical or hinged side swing) or perhaps due to special process applications, a bottom loading or elevator-type unit may be required where the samples are loaded on a base that is then raised into the bottom of the furnace. The elevator unit typically can be made more uniform and can be loaded "hot," and if designed correctly, has a faster recovery time and can be more efficient, but at the drawback of a significantly higher purchase price and possible higher maintenance costs due to moving parts.

With tube furnaces, you have the option of either a solid tube or a split tube type. If the application requires repeated access to the internal heated chamber, then a split tube is the better choice. The solid tube unit will offer a generally flatter section of radial uniformity and will cost typically 20 percent less. In some cases, the process requires that samples be shielded from direct radiation from the heaters. In this case, the solid tube unit can be designed with a thermal diffuser built in as an integral part of the heating structure, while the split tube will need a separate unit installed and supported. This thermal diffuser will also somewhat negate the advantages of quick access to the samples being processed, unless the thermal diffuser is also used as a carrier that is loaded ahead of time

Figure 4: Environmental chamber for a materials testing system

and then placed in the furnace for processing. In some cases, rather than having a flat uniform temperature in the working area, it is required to have a known temperature gradient across the work area. In this case, a tube furnace would be the most beneficial, simply adjusted solution.

## UNIFORMITY

Uniformity is another issue that must be addressed. A general rule of thumb states that the center 80 percent of the working dimensions of a furnace will exhibit a +/-5°C temperature variation. Should a greater uniformity be required, several options exist. For lower temperature units (approximately 700°C or lower), stirring fans or recirculating air heating systems would be necessary. For higher temperatures, the furnace may need to be larger in order to achieve the required temperature uniformity or "flat zone." Perhaps a different heater configuration may be recommended, or the addition of multiple heat zones may provide the solution. Unfortunately, no hard or fast rule covers all situations. It is often the case that the design requirements are specific to the user's uniformity and operating requirements.

It may be required to add some sort of forced or controlled cooling due to process requirements. Many options are available ranging from the introduction of cooled gases, to vents, fans, or a combination of all the above including special programming of the temperature controllers to achieve a controlled cool-down cycle.

## CONTROLS

Another important consideration is the type of controls desired. Will a standard single set point temperature controller work (unit ramps at an uncontrolled rate to a set process temperature and stays there until manually shut down), or will a programmable unit be required (adjustable ramp rates with hold times, soak times, and shut down after completion of the process)? In addition, some sort of data logging and/or computer interface may be desired or an over-temperature control to ensure that the unit does not self-destruct. Of course, with increasing degrees of sophistication and technology, the price will also increase. Thanks to advances in technology and electronics, many of these options are significantly less expensive than they were just a few years ago, and in some cases, one controller can perform many different functions.

## ATMOSPHERE

Another consideration should be the atmosphere that will be used in the unit, as this can have a significant bearing on purchase and maintenance costs. Normally, if the unit is going to be operating in an air atmosphere, no special considerations are required. Should the process generate off-gassing of volatile compounds, then provisions must be made for venting and perhaps protecting the inside of the furnace from chemical attack, depending on the types of gases released. If an atmosphere is required and it is a simple "blanketing gas" such as nitrogen or argon, then all that may be required is to provide a gas inlet and exhaust port in an otherwise standard furnace with the user providing a means to safely exhaust the spent gas from the work area either via an exhaust hood or exhaust manifold piping. It should be noted that when using nitrogen with the higher temperature classes, special care must be taken to prevent damage to the elements due to interaction of the nitrogen and compounds used in the silicon carbide and molybdenum disilicide heaters. Should the atmosphere be some sort of "forming gas" or explosive in nature such as hydrogen, then various safety features will be required and the use of a retort may be dictated. A retort is simply a sealed containment vessel that serves to protect the furnace from attack as well as containing hazardous compounds. A retort can significantly add to

Figure 5: Split tube furnace with vacuum-formed ceramic fiber heating elements

Figure 6: High-temperature split tube furnace with silicone carbide heating elements

the purchase price of the unit, not to mention, operational, safety, and maintenance issues.

## CUSTOMIZATION

A final item to be considered, although it might seem trivial, would be cosmetic issues. Will the vendor's standard color scheme work, or must the unit be painted a special color to match existing equipment or standards? Bear in mind that as soon as the word "custom" enters the equation, purchase prices start to increase along with lead times. Also, instead of a painted exterior, is it necessary for the unit to have a stainless steel exterior? While many companies offer both versions based on style and type of unit, the stainless versions often carry a premium, and taking a painted standard unit and converting to a stainless exterior will add significant increase in cost and delivery.

Standard products are available from most vendors of lab furnaces, while some manufacturers such as Thermcraft offer standard units as well as fully customized units that can be specified and engineered to exact customer requirements. Careful consideration will put you ahead of the curve when the time comes to begin the search for your new lab furnace.

**ABOUT THE AUTHORS:** James Brocklehurst is the regional sales manager at Thermcraft, Inc. in Winston Salem, North Carolina. Derrick Wilson is the marketing manager also at Thermcraft, Inc. For more information, go to www.thermcraftinc.com.

the processes for cutting-edge hardening, which had been taking too much time overall."

In the past, tools were mostly treated on-site by flame hardening. The alternative was laser hardening at external contractors — an additional logistical effort that has now become unnecessary due to the fast induction hardening process. Since the fall of last year, the company has used a MICO generator from Eldec as the energy source. This flexible energy container is perfect for toolmakers. A generator, cooling system, and hose bundle are packed into a compact housing available with casters if required. Users are able to easily move the machine wherever it is needed on the factory floor and an intuitive user interface with a touchscreen simplifies the configuration.

The processes at Eldec also ensure MICO generators have high stability and a long service life as they are developed for challenging manufacturing applications. Before shipping, they undergo comprehensive testing and are held to extremely high quality standards.

## DEVELOPING IN-HOUSE KNOW-HOW

"We are more than satisfied with the technology," said Schwertfeger. "We're already saving a lot of money. While we are improving our processes, we're also simultaneously developing new know-how around the technology, which will later directly benefit our customers. For example, we are optimizing the hardening and subsequent annealing processes to improve the fit and configuration of the device for the relevant active part of the tool. The quality and efficiency of the process are continuously being perfected."

The technology is being used in a wide variety of punching, bending, and forming tools. It creates a uniform hardness distribution on many straight and arched surfaces and radii. The flexibility of the applied technology is important.

For Eldec, the mentioned application example has something of a model function, since experts are seeing a lot of market potential for their flexible generators.

"Our new MICO series is providing a major solution for the energy source and cooling system," Tzschupke said. "It covers a wide range of services and can be fitted with many different tools, which gives toolmakers a lot of options for implementing perfect and efficient hardening processes. We want to bring these strengths to the market even more than before in the coming years."

**FOR MORE INFORMATION: emag.com**

On request, the required inductors (tools) are also custom made at Eldec.


An intuitive user interface with touchscreen simplifies the configuration of the MICO.


Energy source and cooling system in one: MICO generators provide users in the tool- and mold-making industry with the necessary flexibility.

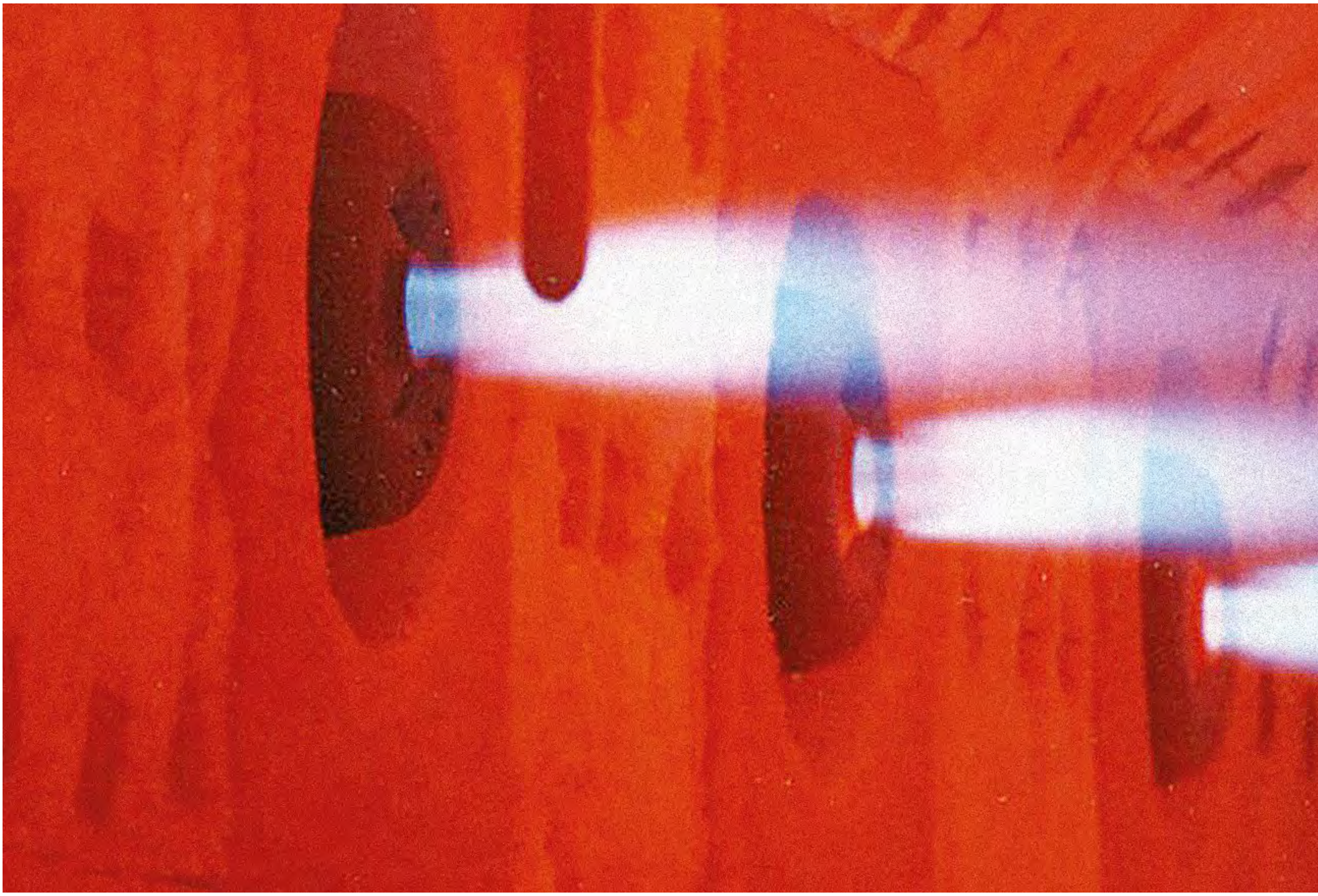
# SGL Group Introduces New Silicon Carbide Ceramics

SGL Group – The Carbon Company – introduces two new silicon carbide materials, Sigrasic® Performance and Carboprint® Si. In industrial heat treatment applications, Sigrasic® Performance is used for charging elements and systems.

The carbon-fiber reinforced silicon carbide ceramic (C/SiC) Sigrasic® Performance is pending patent approval and is produced from the carbon fiber reinforced carbon (CFC) material Sigrabond® Performance by means of a special infiltration process. With its high fiber content and low porosity, this material combines the benefits of ceramic with the favorable characteristics of carbon fiber material. The ceramic matrix protects the carbon fiber from corrosive attacks without negatively influencing the excellent mechanical properties of carbon fiber reinforced carbon. With this new product, SGL Group is reacting to the rising demand for a material for charging systems that offers unchanged excellent properties when exposed to a gas flame up to 500°C in heat treatment processes in pusher-through hardening furnaces with pre-oxidation.

Carboprint Si is a development project of SGL Group making the most of the opportunities of additive manufacturing tech-

Continued on page 43 »



# Efficient Gas Heating of Industrial Furnaces

*By Steven R. Mickey, Martin G. Schönfelder, and Joachim G. Wünning*

Even though the price of natural gas is currently low, the investment in high-efficiency gas burners makes sense economically.

There are various types of high-efficiency gas burners and radiant tubes currently on the market, and economic tools can be used to assess investments in heating technology for industrial furnaces. In addition, a revolutionary combustion technology now makes it possible to have the best of both worlds — increased efficiency and suppressed NOx emissions.

## GAS BURNER TECHNOLOGY

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

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

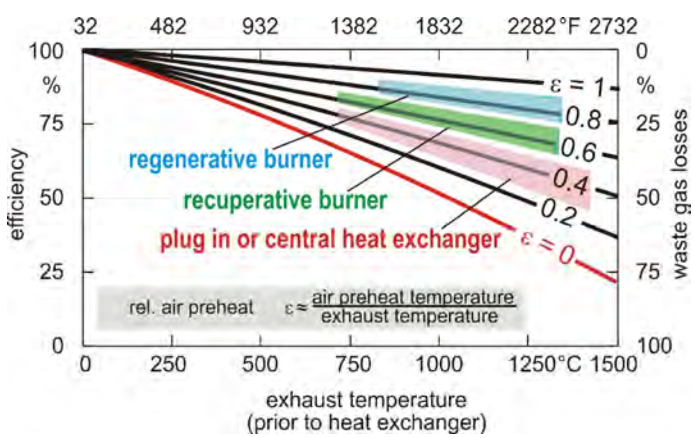
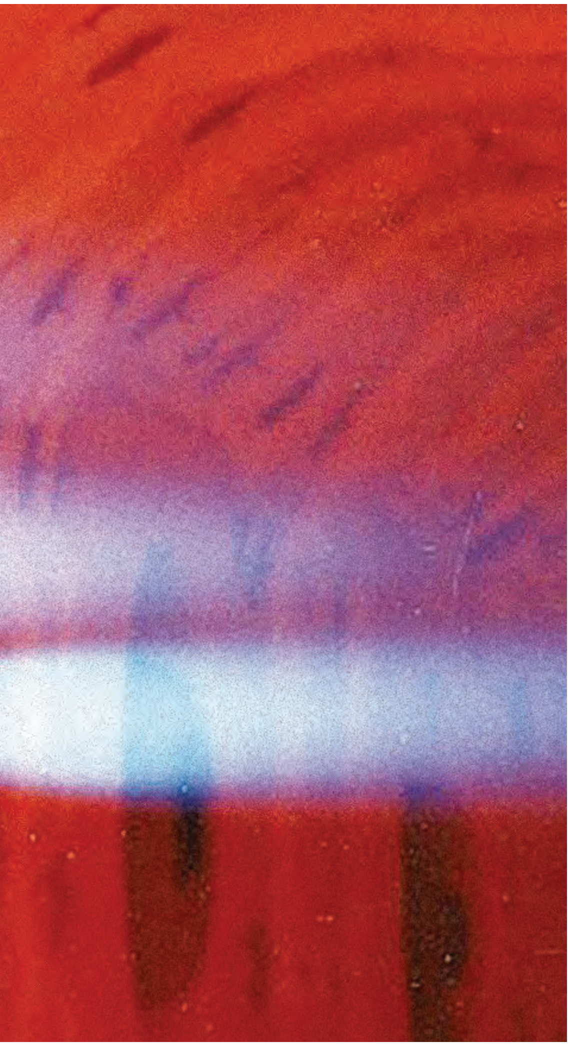



**Figure 1: Efficiency versus exhaust gas inlet temperature [2]**



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

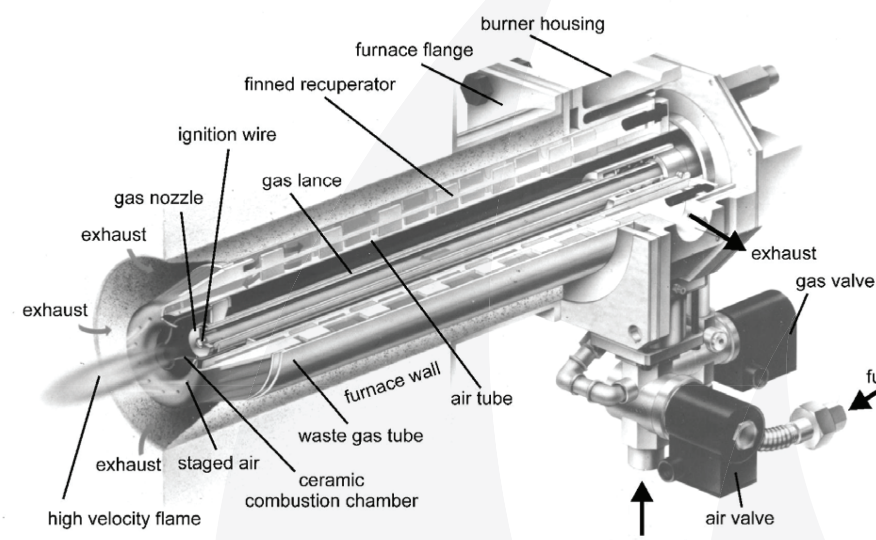


**Figure 2: Self-recuperative burner [2]**

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

There is a new generation of self-recuperative burners that does not fall within the typical range depicted in Figure 1. This burner type is known as "gap flow." With this design, the burner is equipped with many tiny tubes that serve as heat exchangers. This configuration effectively triples the heat transfer surface area, thereby increasing combustion air preheat to 75 to 80 percent of the exhaust gas inlet temperature. At the reference temperature of 1,832°F (1,000°C), this burner type has an efficiency in the range of 80 to 85 percent. It is available with either a metallic heat exchanger or a combination of a ceramic and a metallic heat exchanger. The metallic type can operate at temperatures up to approximately 1,832°F (1,000°C), whereas the ceramic/metallic type can operate at temperatures up to approximately 2,300°F (1,260°C). Figure 3 shows typical metallic and ceramic/metallic gap flow burners.

The curve labeled ε = 0.8 on the graph represents a regenerative burner. This burner type is equipped with heat storage media such as ceramic balls, discs, etc. Heat storage media is therefore in direct contact with either hot exhaust gas or cold combustion air depending on the point in the regeneration cycle. In the first half of the cycle, the hot exhaust gas heats the storage media to a very high temperature. Then, switching valves are activated, and the flow path is reversed so that cold combustion air now flows over the heat storage media. With this arrangement, the combustion air is preheated to approximately 80 to 85 percent of the exhaust gas inlet temperature. At the reference temperature of 1,832°F (1,000°C), this burner type has an efficiency in the range of 85 to 90 percent. Traditional regenerative burners fire in pairs — one burner fires while the other exhausts and vice versa. A newer type known as the self-regenerative burner integrates all the regenerators and switching valves into one self-contained unit. Each burner contains six passageways, and each passageway contains a row of ceramic honeycomb discs that serve as the heat storage media. At any point in the cycle, three passageways are exhausting, and the other three passageways

**Figure 3: Gap flow burners [2]**

are admitting combustion air. After about 10 seconds, the switching valves cycle, and the flow path is reversed. Regenerative burners are also available in either metallic or ceramic varieties. The metallic type can operate at temperatures up to approximately 1,832°F (1,000°C), whereas the ceramic type can operate at temperatures up to approximately 2,372°F (1,300°C). Figure 4 shows a cross-section of a self-regenerative burner.

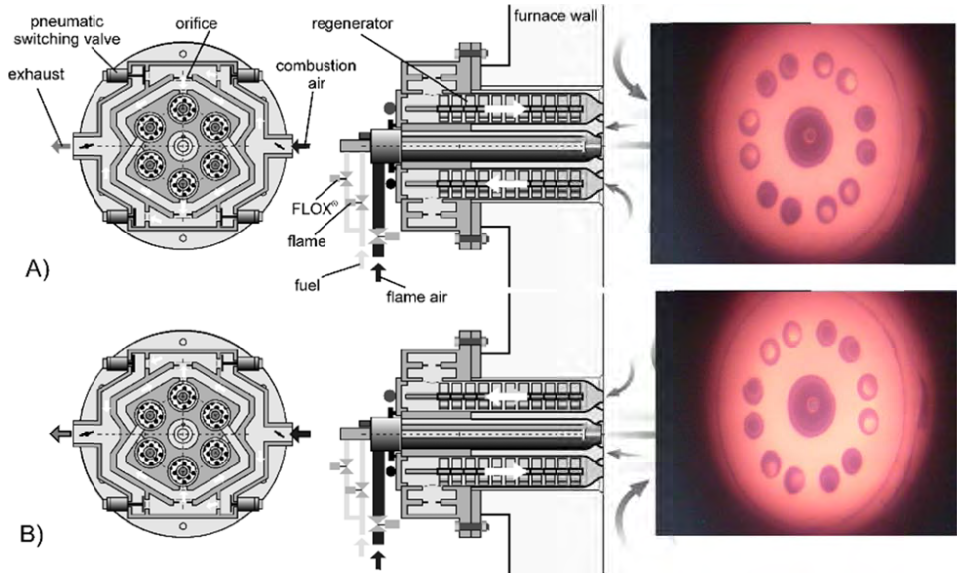


Figure 4: Self-regenerative burner [2]

## NOX REDUCTION TECHNIQUES FOR HIGH-EFFICIENCY BURNERS

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

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

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

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

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

## RADIANT TUBES FOR INDIRECT HEATING

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

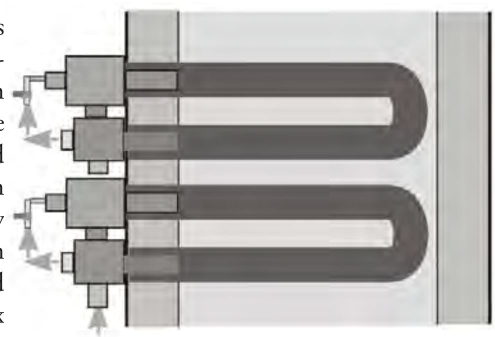


Figure 5: U-tube

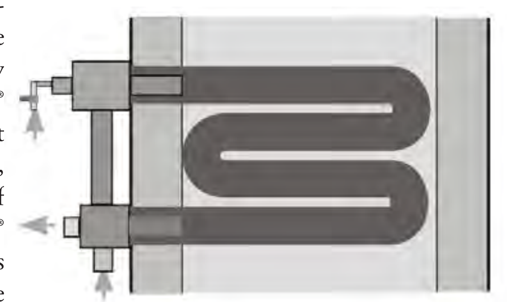


Figure 6: W-tube

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

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

In the case of a single-ended radiant tube (see Figure 7), exhaust gases flow through an inner tube and then back toward the exhaust

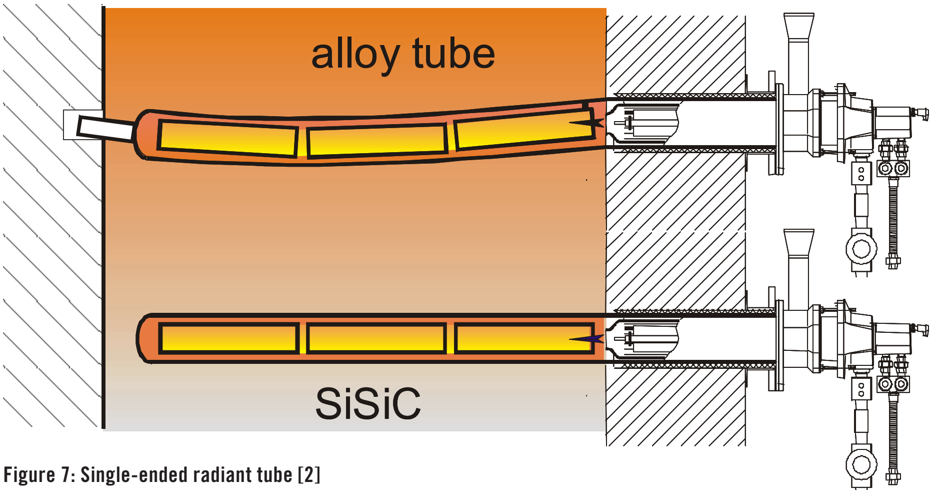



Figure 7: Single-ended radiant tube [2]

Figure 8: P-tube [2]

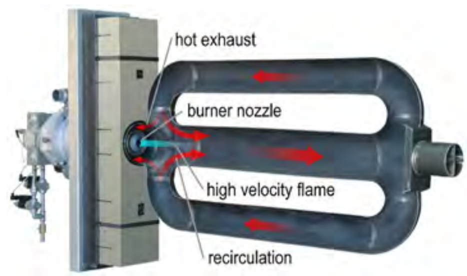



Figure 9: Double P-tube [2]

through the annulus between the inner and outer tubes. There is a critical space between the tip of the burner and the beginning of the inner tube assembly. The exhaust gases reach this point, and the high velocity burner jet creates a Venturi effect to draw a portion of the exhaust gases back into the inner tube. In this way, the exhaust gases are recirculated several times before they finally pass over the heat exchanger and out of a port on the burner.

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

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

## ECONOMICS OF HIGH-EFFICIENCY GAS BURNERS

Traditionally, when a company is contemplating whether or not to invest in new combustion technology, it is focusing on the payback time associated with the investment. The payback time is calculated by dividing the additional cost of the investment (over either the existing equipment or some baseline option) by the annual cost savings (usually as a result of mainly fuel savings). The result is a value expressed in years. Corporations normally consider a good investment to have a payback time of less than two to three years.

However, payback time alone is not a sufficient means to determine the viability of an investment. The net present value (NPV) is another important variable used by investors to make decisions. The NPV is the sum of discounted cash flows over a period of time, corrected to today's value [4].

$$\boldsymbol{NPV = -I_0 + \sum_{t=1}^{T} CF_t * (1+i)^{-t}}$$

In this example, the NPV depends mainly on the generated fuel savings (ΔCF), initial investment ($I_0$), assumed interest rate (i), and assumed life span of the equipment (T). Simply, the investment with the highest NPV is the most advantageous. It is important to note that since the assumed interest rate (i) appears in the denominator of the equation, NPV is high when interest rates are low. Therefore, today is a great time to invest in new combustion equipment.

The example shown in Figures 10 and 11 helps to further illustrate this point. The example assumes that new equipment will be installed and that the baseline equipment option consists of cold-air burners with U-tubes. The estimated efficiency is 55 percent, and there is no additional investment since this is considered the baseline option. The improved efficiency alternative is to add plug-in recuperators to the baseline equipment. The estimated efficiency for this alternative is 65 percent, and the additional investment is $20,000. This yields a payback time of 1.33 years in this example. The high-efficiency alternative is to use self-recuperative burners and P-tubes. The estimated efficiency for this alternative is 83 percent, and the additional investment over the baseline option is $80,000. This yields a payback time of 2.35 years. Therefore, the calculation of payback time alone suggests that the first option is the better investment. However, a comparison of the two investments over a period of 15 years shows that the NPV, and hence the cumulative cash flow, associated with the second option is more than double that of the first

| U-Tube with Cold Air Burner | U-Tube with Plug-In Recuperator | P-Tube with Self-Recuperative Burner |
|---|---|---|
| **Default Solution**<br>**η = 55 %**<br><br>**Additional Investment**<br>0 | **Improved Efficiency Alternative**<br>**η = 65 %**<br>**Additional Investment**<br>$ 20,000<br>**Payback Period**<br>1.33 years | **High Efficiency Alternative**<br>**η = 83 %**<br><br>**Additional Investment**<br>$ 80,000<br>**Payback Period**<br>2.35 years |

Figure 10: Sample analysis using payback time

option. Therefore, the high-efficiency option clearly is the better investment even though the payback time at first suggests otherwise. This simple example shows how important a sound economic analysis is in order to make well-founded investment decisions. Due to the fact that the life-cycle costs of furnaces are mainly determined by the fuel efficiency, higher efficiency almost always pays off in the long run, even at today's low energy prices.

## CONCLUSION

The variety of burner types have varying levels of complexity and efficiency. Most high-efficiency gas burners preheat the combustion air to increase the combustion efficiency. Traditionally, there is a tradeoff between efficiency and NOx emissions; however, FLOX® combustion makes it possible to have the best of both worlds. As illustrated, the investment in high-efficiency gas burners makes sense economically even when gas prices are low. The lifetime savings generated by increased efficiency are significant, often five to ten times the additional investment. Also, for retrofits, increased combustion efficiency can increase the capacity of a furnace in many cases. From an economic perspective, a typical example shows that payback time alone does not provide sufficient information to make a well-founded investment decision. A sound economic analysis is necessary in order to choose the best heating alternative for a furnace.

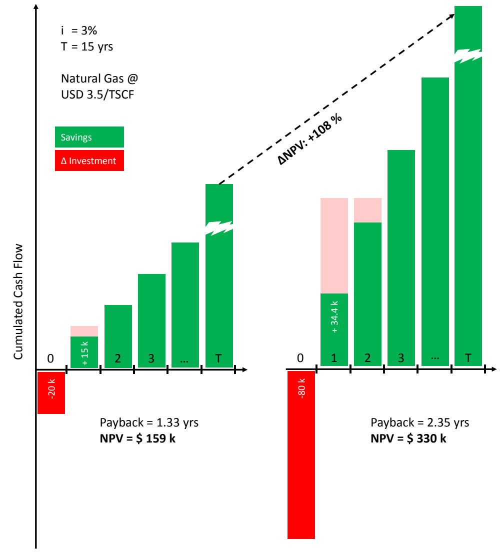



**Figure 11: Same sample analysis using NPV**

## REFERENCES


1. Joachim G. Wünning, Ambrogio Milani: Handbook of Burner Technology for Industrial Furnaces, 2nd Edition, Vulkan Verlag, 2015.
2. Images provided by WS Wärmeprozesstechnik GmbH, Dornierstr. 14, 71272 Renningen, Germany.
3. Joachim G. Wünning: Flameless Oxidation, 6th HiTACG Symposium, Essen, Germany, 2005.
4. Uwe Götze, Deryl Northcott, Peter Schuster: Investment Appraisal – Methods and Models, Springer, 2010.



**ABOUT THE AUTHOR:** Steven R. Mickey is a graduate of Cornell University with a Bachelor of Science in Mechanical and Aerospace Engineering. He has been with WS Thermal Process Technology Inc. in Lorain, Ohio, for over 15 years collectively and has served in many capacities including sales, applications engineering, and project management. WS is a manufacturer of industrial burners with integrated heat exchangers designed for high-temperature applications within the steel, automotive, and other industries.

 Continued from page 37

nologies for solutions made from carbon ceramic composites. Here, the basic structure made of carbon is established in a 3D printing process. Complex component geometries, like optimum efficiency ventilators for heat treatment furnaces, can therefore be realized without machining. By infiltrating the printed component with silicon, a carbon reinforced silicon carbide ceramic is created, which offers a high ductility in combination with resistance against corrosive atmospheres and a high abrasion resistance.

"Innovative, high-grade specialty graphite solutions are essential for building high-performance, high-temperature furnaces," said Manfred Golling, senior application manager for Industrial Applications at SGL Group. "Our products prove themselves with their outstanding thermal stability, high mechanical strength, as well as good thermal and electrical conductivity. With this newly developed silicon carbide ceramics solutions we are expanding our product range with efficient and highly reliable solutions."

The continuous adaption and improvement of SGL Group's versatile customer-orientated specialty graphite solutions is part of the company's path forward to foster megatrends like mobility, energy supply, and digitalization.

**FOR MORE INFORMATION:** sglgroup.com

## IBC Manufacturing Facility Achieves Re-Certification of ISO 9001:2008/AS9100:2009

IBC Advanced Alloys Corp. (IBC), a leading beryllium and copper advanced alloys company, recently announced that it has achieved a re-certification of its ISO 9001:2008 and AS9100:2009 Rev. C standards for quality management systems at its Wilmington, Massachusetts, facility, where it produces precision cast beryllium-aluminum products.

"This re-certification is vital to IBC's ability to serve customers in the aerospace and other industries where quality management is a mission-critical requirement," said Major General Duncan Heinz (USMC, ret.), president and CEO of IBC. "It validates our team's commitment to establish and deploy best practices across our manufacturing systems, and helps ensure that we consistently deliver to our customers the services and product solutions they expect."

The re-certification means that IBC is registered as certified by the International Aerospace Quality Group (IAQG) in the Online Aerospace Supplier Information System (OASIS) database as having met all of the quality management system requirements of its customers in the aerospace and other sectors.

The company said that its Wilmington facility is now working toward achieving the ISO 9001:2015 and AS9100:2016 (Rev D).

**FOR MORE INFORMATION:** ibcadvancedalloys.com

## Omega Engineering Announces Relocation of World Headquarters

Fifty years ago, Omega Engineering, Inc. was a small privately held company that was woman-owned and operated. Today, it's a leading global manufacturer and supplier of process measurement and control products, operating out of brand-new world headquarters. The move to the high-tech facility in Norwalk, Connecticut, represents a major transition for the firm, which for five decades has been headquartered in Stamford, Connecticut.

The move coincides with the recent appointment of Joe Vorih as president. These exciting twin developments are ushering in a new era for the firm — an era that's deeply rooted in Omega's rich, pioneering history.

Founded by Betty Ruth Hollander in 1962, Omega Engineering has grown from a small family-owned catalog company specializing in thermocouples, to a leading global provider of thousands of measurement and control products.

Acquired by Spectris Plc in 2011, Omega offers more than 100,000 state-of-the-art products for temperature, humidity, pressure, strain, force, flow, level, pH, conductivity, data acquisition, and electric heating and primarily sells them directly to buyers. The depth of expertise in this highly specialized industry allows the company to offer an extremely high level of technical support and customization.

The move to Omega Engineering's new facility is symbolic of the next step in this company's journey. The new corporate office is located in a five-story, 412,000-square-foot building in one of Norwalk's busiest retail and commercial areas. The open floor plan is designed with collaborative workspaces, where employees can take advantage of the latest technological advances. Facilities include a cafeteria, fitness center, picnic areas, and shuttle service to nearby train stations.

"We're extremely excited about this next step in the evolution of our company, but our guiding principle remains unchanged," Vorih said. "We're absolutely committed to provide the very best instrumentation products and customer service. This has been the building block of our success over the last five decades and will remain our top priority in the years to come. Fresh leadership and new facilities will ultimately help us serve our customers better as we expand our product lines and enhance our service systems."

**FOR MORE INFORMATION:** omega.com

**Heat Treat Equipment – REF #101**
Phone: 734-331-3939 • Fax: 734-331-3915
Email: john@heattreatequip.com
Website: www.heattreatequip.com

**Premier Furnace/BeaverMatic Inc. – REF #102**
23850 Freeway Park Drive
Farmington Hills, Michigan 48335
Phone: 248-596-9000 • Fax: 248-596-9001
Email: sales@premierfurnace.com

**The W.H. Kay Company – REF #103**
30925 Aurora Road, Cleveland, OH 44139
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

54" wide x 72" long x 84" high, Despatch Walk-In Oven Gas, 500 F. .......... **REF #102**
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**
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" 108" 72" Despatch Elec. 500 F. .......... **REF #103**
56" 30" 60" Gruenberg Elec. 450 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**
24" wide x 48" long x 18" high, Lindberg batch temper, Gas, 1400 F. .......... **REF #102**
30" wide x 48" long x 26" high, BeaverMatic batch temper, Gas, 1400 F. .......... **REF #102**
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 1300°F .......... **REF #104**
10" 10" 18" ELECTRIC 2000°F .......... **REF #104**
22" 36" 22" ELECTRIC 1600°F .......... **REF #104**
12" 6" 8" ELECTRIC 2000°F .......... **REF #104**
12" 8" 18" ELECTRIC 2800°F .......... **REF #104**
20" 13" 36" ELECTRIC 1850°F .......... **REF #104**
12" 18" 18" ELECTRIC 1250°F .......... **REF #104**
4" 10" 4" ELECTRIC 2000°F .......... **REF #104**
22" 10" 8" ELECTRIC - C/W STAND 1250-2000°F .......... **REF #104**
15" 8" 30" ELECTRIC - ATMOSPHERE 1950°F .......... **REF #104**
11" 11" 17" ELECTRIC - CABINET 2000°F .......... **REF #104**
33" 40" 48" ELECTRIC 500°F .......... **REF #104**
18" 18" 30" ELECTRIC - GLO BAR 2900°F .......... **REF #104**
30" 30" 54" ELECTRIC - AGING 500°F .......... **REF #104**
30" 30" 54" R ELECTRIC - AGING 500°F .......... **REF #104**
30" 30" 54" ELECTRIC 500°F .......... **REF #104**
24" 18" 24" NATURAL GAS - BATCH FURNACE .......... **REF #104**
24" 18" 24" NATURAL GAS - BATCH FURNACE .......... **REF #104**
36" 30" 84" ELECTRIC 1200°F .......... **REF #104**
24" 24" 24" ELECTRIC 2000°F .......... **REF #104**
29" 22" 36" NATURAL GAS 1250°F .......... **REF #104**
12" 11" 24" ELECTRIC - BOX 2000°F .......... **REF #104**
24" 24" 24" ELECTRIC - GAS MAC 850°F .......... **REF #104**
18" 12" 12" ELECTRIC 2100°F .......... **REF #104**
48" 30" 36" ELECTRIC - ATMOSPHERE TEMPERING .......... **REF #104**
50" 24" 29" NATURAL GAS 1250°F .......... **REF #104**
36" 18" 24" ELECTRIC 1250°F .......... **REF #104**
17" 17" 36" NATURAL GAS 1250°F .......... **REF #104**
15" 6" 10" ELECTRIC 1850°F .......... **REF #104**
6" DIA 48" ELECTRIC - TUBE FURNACE 1200°C .......... **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 2000°F .......... **REF #104**
12" 9" 18" ELECTRIC .......... **REF #104**
12" 12" 18" NATURAL GAS 1250°F .......... **REF #104**
14" 14" 18" ELECTRIC - GLOBAR 2500°F .......... **REF #104**
17" 17" 17" ELECTRIC - HITEMP KILN 2200°F .......... **REF #104**
35" 24" 60" ELECTRIC 1430°F .......... **REF #104**
10" 9" 14" ELECTRIC - FRONT DOOR LOADING 2000°F .......... **REF #104**
12" 12" 24" ELECTRIC - 13KW 2300°F .......... **REF #104**
12" 12" 24" ELECTRIC - 20KW 2000°F .......... **REF #104**
18" 12" 24" ELECTRIC 2000°F .......... **REF #104**
36" 24" 56" ELECTRIC 800°F .......... **REF #104**
24" 24" 36" ELECTRIC - CYCLONE 1250°F .......... **REF #104**
24" 36" 30" ELECTRIC RE-CIRC. BOX FURNACE 2000°F .......... **REF #104**
18" 20" 45" ELECT. RE-CIRC. W/ FLAME CURTAIN & BASKET 2000°F .......... **REF #104**
12" 12" 18" ELECT. RE-CIRC. BATCH (MATCH PAIR WITH I3958) 1250°F .......... **REF #104**
12" 12" 18" ELECT. RE-CIRC. BATCH (MATCH PAIR WITH I3957.) 1250°F .......... **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 2000°F .......... **REF #104**
130" 72" 216" GAS FIRED CAR BOTTOM 2000°F .......... **REF #104**
130" 72" 215" GAS FIRED CAR BOTTOM 2400°F .......... **REF #104**
108" 36" 192" GAS FIRED CAR BOTTOM 2400°F .......... **REF #104**
72" 48" 216" GAS FIRED CAR BOTTOM 2000°F .......... **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

24" wide x 48" long x 18" high, Lindberg batch temper, Gas, 1400 F .......... **REF #102**
30" wide x 48" long x 26" high, BeaverMatic batch temper, Gas, 1400 F (NEW) .......... **REF #102**
18" 12" 30" ELECTRIC 1250°F .......... **REF #104**
16" 15" 12" ELECTRIC - BOX DRAW 1250°F .......... **REF #104**
36" 16" 24" ELECTRIC - BOX DRAW 1250°F .......... **REF #104**
12" 18" 16" ELECTRIC - BOX DRAW 1400°F .......... **REF #104**
30" 20" 48" ELECTRIC - BOX DRAW 1250°F .......... **REF #104**
24" 18" 36" NATURAL GAS ROLLER DRAW 1400°F .......... **REF #104**
30" 30" 48" NATURAL GAS 1200°F .......... **REF #104**
60" 40" 60" NATURAL GAS - DRAW FURNACE 800°F .......... **REF #104**
29" 16" 36" ELECTRIC - DRAW/TEMPER 1400°F .......... **REF #104**
54" 54" 150" ELECTRIC 900°F .......... **REF #104**
24" 18" 10 FEET ELECTRIC 500°F .......... **REF #104**
30" 24" 72" GAS - GRAVITY FEED DRAW 1350°F .......... **REF #104**
12" 14" 12" ELECTRIC - WATER COOLED FAN 1200°F .......... **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**
Rolock Inc. 2000 CFH Endothermic Gas Generator...... **REF #102**

## 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**
Seco Warwick 2000 CFH Exothermic Gas Generator...... **REF #102**
Sunbeam 2000 CFH Exothermic Gas Generator ...... **REF #102**
Alhern 6000 CFH Exothermic Gas generator ...... **REF #102**
J L Becker 6000 CFH Exothermic Gas Generator...... **REF #102**
JL Becker 6000 CFH Exothermic Gas Generator...... **REF #102**

## FLUIDIZING BED FURNACE

14” 30 DIA 5” ELECTRIC 1600°F ...... **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 600°F ...... **REF #104**
23” 4” 10’ NATURAL GAS 1250°F ...... **REF #104**
24” 12” 96” ELECTRIC 500°F ...... **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**
Premier Furnace 14” wide mesh belt Aluminum Brazing Furnace 1400 F...... **REF #102**
Alhern 20” wide mesh belt Copper Brazing, Annealing Furnace 2100 F ...... **REF #102**
J L Becker 20” wide mesh belt Copper Brazing, Annealing Furnace 2100 F. ...... **REF #102**
JL Becker 20” wide mesh belt Copper Brazing, Annealing Furnace 2100 F. ...... **REF #102**
Alhern 28” wide mesh belt Copper Brazing, Annealing Furnace 2100F. ...... **REF #102**

## 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**
Airco Flo meter panel# 1 ...... **REF #102**
Airco Flo meter panel# 2 ...... **REF #102**
Smart Skim unit...... **REF #102**
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 3000°F ...... **REF #104**
9.5” 9.5” 18” COILED ELEMENTS ELECTRIC 2300°F ...... **REF #104**
22” 11” 14” COILED ELEMENTS ELECTRIC 2200°F ...... **REF #104**
12” 7” 30” ELECTRIC - CRESS ...... **REF #104**
18” 12” 24” ELECTRIC 2100/1250°F ...... **REF #104**
12” 12” 36” ELECTRIC 2300/1250°F ...... **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 1200°F ...... **REF #104**
30” 36” NATURAL GAS 1250°F ...... **REF #104**
24” 30” ELECTRIC 1400°F ...... **REF #104**
16” 18” GAS - CYCLONE 1300°F ...... **REF #104**
28” 96” NATURAL GAS 1400°F ...... **REF #104**
24” 28” ELECTRIC - HOMO CARBURIZING 1400°F ...... **REF #104**
16” 30” ELECTRIC SALT POT 1650°F ...... **REF #104**
22” 36” 22” ELECTRIC SQUARE PIT 1600°F ...... **REF #104**
6” 4” 16” ELECTRIC VACUUM PIT 2400°F ...... **REF #104**
24” 24” ELECTRIC 1400°F ...... **REF #104**
12” dia 18” ELECTRIC - HOMO PIT 1200°F ...... **REF #104**
30” 30” 30” ELECTRIC 800°F ...... **REF #104**
30” DIA 30” ELECTRIC - PIT CYCLONE 1250°F ...... **REF #104**
12” 20” ELECTRIC - KEYHOLE 1250°F ...... **REF #104**
4.5” 24” 4” ELECTRIC - SQUARE PIT ...... **REF #104**
24” 48” 24” ELECTRIC - SQUARE PIT 1200°F ...... **REF #104**
18” 18” 18” ELECTRIC - TOP LOAD 2000°F ...... **REF #104**
16” Dia. 20” ELECTRIC - CYCLONE 1250°F ...... **REF #104**
22” Dia 26” ELECTRIC - CYCLONE 1250°F ...... **REF #104**
22”Dia 26” ELECTRIC 1250°F ...... **REF #104**
8”dia 9”deep ELECTRIC - TEMPERING 1250°F ...... **REF #104**
35” 60” GAS ...... **REF #104**
28”DIA 28” ELECTRIC - CYCLONE PIT 1250°F ...... **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 inch wide, 48 inch long, 18 inch high, Lindberg, Gas, 1850 F. ...... **REF #102**
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 1750°F ...... **REF #104**
12” 10” 24” ELECTRIC - BABY PACEMAKER 1850°F ...... **REF #104**
45” 40” 72” ELECTRIC - ALUMINUM QUENCH 1250°F **REF #104**
12” 9” 18” IPSEN 2000°F ...... **REF #104**
87” 36” 87” SURFACE COMBUSTION W/ 12,500G. QUENCH 1850°F ...... **REF #104**
62” 36” 62” SURFACE COMBUSTION W/ 9,500G. QUENCH 1850°F ...... **REF #104**
62” 36” 62” SURFACE COMBUSTION W/ 9,500G. QUENCH 1850°F ...... **REF #104**
15” 12” 30” Electric c/w load carts 1850°F ...... **REF #104**

## CONTINUOUS/BELT FURNACES + OVENS

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

# MARKETPLACE

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

# AD INDEX

| COMPANY NAME | PAGE NO. |
|---|---|

## PLEASE TELL US A LITTLE ABOUT YOUR BACKGROUND.

I started in the heat treating industry back in the late 1960s working for one of my uncles re-bricking heat treating and melting furnaces while attending college. I later graduated from Schoolcraft College and Wayne State University both in the Detroit area.

I initially joined Lindberg Furnace in 1977 and sold atmosphere, vacuum, aluminum heat treating, melting, induction heating, laboratory, and customer-designed furnaces in Michigan and several surrounding states until 1989. Since then, I have worked for other major furnace manufacturers in the U.S. and Europe. This will be the start of my 40th year in this market, and it has always been fun and rewarding in many ways.

I am a life member of ASM, charter member of the Heat Treating Society, and an AFS member for many years. I have chaired programs and presented many papers for ASM and FNA conferences for a variety of topics.

## WHAT'S YOUR NEW ROLE WITH LINDBERG?

I recently re-joined Lindberg/MPH as business development manager (BDM) for North America. As BDM, I will be participating with our national sales manager and field sales team and supporting their efforts. I have a firm understanding of the automotive, aerospace, aluminum, commercial heat treating, forging, hot stamping, energy/oil field, and medical markets in regards to heat treating. I plan to use that knowledge and key relationships in bringing equipment orders to Lindberg and our other thermal processing equipment divisions.

## TELL US MORE ABOUT LINDBERG.

Lindberg/MPH is owned by Thermal Product Solutions (TPS), a leading American manufacturer in thermal processing products and test solutions with brands including Baker Furnace, BlueM, Gruenberg, Tenney, Lindberg, Lunaire, MPH, and Wisconsin Oven.

Lindberg/MPH is a leading manufacturer of standard and custom industrial heat treat furnaces, including pit, box, integral quench, vacuum, and belt-type for the ferrous and non-ferrous markets. Founded in 1917, the company has more than 75,000 industrial furnace installations worldwide, and its equipment is backed by a full range of customer support services and the most extensive replacement parts inventory in the industry.

Lindberg/MPH probably covers the largest range of customers by having a wide range of products from small lab R&D testing furnaces to large-scale/high-production systems.

For many years, Lindberg was known as the leading provider of batch pit and box-type atmosphere vacuum and I/Q furnaces. Lindberg also participated in the forge and foundry markets with annealing, normalizing systems such as car bottoms, belt, and roller hearths.

In the last 30 years, there have been many mergers with other thermal equipment makers such as aluminum melt and heat treat furnaces, batch ovens, and lab-type furnaces for R&D applications.

Lindberg offers full service for installation, rebuilding, evaluation, and upgrading older systems. Lindberg is the only company that offers a three-year warranty on our new equipment.

## WHAT ARE THE INDUSTRY'S BIGGEST CHALLENGES YOU SEE?

Across the board, most companies no longer have the staff to support new heat treating equipment selection with companion equipment, turn-key installation with start-up and validation. So equipment makers are now being asked to provide those services both up and downstream from the heat treat furnaces.

Most of the newer heat treating systems today incorporate some level of automation, robotics, energy savings, and data retrieval. In addition to just the furnace, there may be a need for a loader/feeder system, pre/post-washing, storage and trigger tables, atmosphere supply or blending panels, closed-loop water systems, heat exchangers, and rust prevention. Today's equipment provider needs to be a partner in providing these functions to the customer.

## WHAT'S YOUR CUSTOMER PHILOSOPHY?

Typically, my philosophy hasn't changed in 40 years. I always listen to the customer. Customers always provide us with current problems or issues that define our task and eventual solution. Those may be: higher capacity or temperature requirements, lower energy costs, better use of existing floor space, material changes, and new processes such as vacuum, nitriding, and FNC.

## GIVE US AN EXAMPLE OF HOW YOU SOLVED A CUSTOMER'S PROBLEM?

A customer came to us with a need for a new nitriding project, which was new for them. They needed not only the furnace and programmable control system, but also required the dissociated ammonia atmosphere and had to incinerate the process gases. We were able to provide a solution for all of those requirements. They were satisfied that they could find all of the solutions from a single source.

## HOW HAS EQUIPMENT EVOLVED?

In the past 15 years, there have been changes in several types of equipment, for example:

For atmosphere furnaces, the chamber sizes and load weights in I/Q furnaces have both increased. Multi-heating chamber systems are popular to increase production in smaller chamber sizes. Endothermic gas generators are once again popular with turndown features and air-cooled heat exchangers. Air-cooled fans have replaced water-cooled units. Nitriding is again being used for corrosion and high-wear applications for gears.

For vacuum furnaces, vacuum carburizing with oil quenching is popular for transmission and smaller components for standard steel grades. Bottom-loading furnaces are larger due to an increase in jet engines. High-pressure gas quenching is being considered.

For aluminum furnaces, fast quench furnaces with water and PAG systems are common for a wide range of aluminum components for aerospace and automotive markets.

**FOR MORE INFORMATION:** go to www.lindbergmph.com or email bill.stthomas@lindbergmph.com