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VOLUME 5 • NO. 7 **NOVEMBER 2022**

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Energy Smart Cooling

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Holy Bible, Lamentations 3:22-23

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NOVEMBER 2022

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Improving Your Use of Radiant Tubes, Part 1

Radiant tubes are prevalent in heat treating applications. They are very simple devices: basically, a pipe that enters and exits the work chamber. Geometrically simple — but the considerations of how they should be applied, the optimal materials for their construction, and the best burner to use present a myriad of challenges and opportunities for improvement.

By John Clarke, Technical Director, Helios Electric Corporation

P10 Steel Sustains

The American steel industry is the cleanest of the leading steel industries in the world. This article explores several reasons for the American steel industry's leadership in decarbonization.

By Kevin Dempsey, President & CEO, American Iron and Steel Institute

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The DFARS Interim Rule and What It Means for Heat Treaters

As the next installment in this series of articles on cybersecurity, this third article will give you a better understanding of the Department of Defense's DFARS interim rule and its requirements.

By Joe Coleman, Cybersecurity Officer, Bluestreak Consulting™

P40 DUAL PERSPECTIVES:

How does government policy regarding ESG in the U.S. and nuclear power initiatives in Europe impact in-house heat treaters?

Thomas Schneidewind, editor-in-chief of heat processing magazine, and Doug Glenn, publisher and founder of Heat Treat Today, answer this month's heat treat industry question.

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In this issue, we look to our European information partner for updates on industry events around the globe and a glimpse into the modernization and retrofitting process for a foundry in Switzerland.

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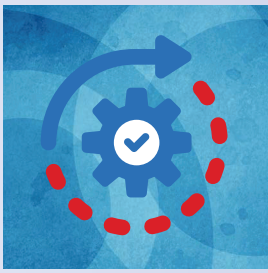
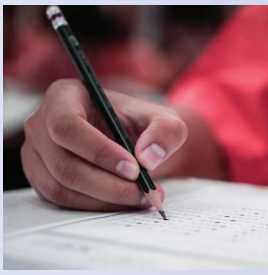


P16 How Things Work: Thermocouples

Heat Treat Today is launching a How Things Work periodic content series. The first topic is the basics of thermocouples. Thermocouples are the bread and butter of the heat treating world. How many of the following questions are news to you? Take a deep dive into the topic and read this question and answer session between Doug Glenn, publisher and founder of Heat Treat Today, and Eric Yeager, director of Corporate Quality at Cleveland Electric Laboratories.



P24 Thermocouple Trivia by the Dozen

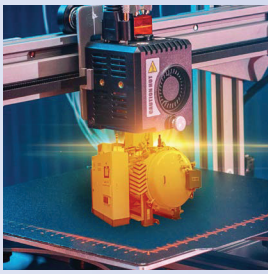
Thermocouples are ubiquitous. Whether you are 20 days or 20 years into the industry, you know the essential role they play in ensuring heat treat processes are running efficiently, accurately, and dependably. This quick trivia questionnaire will test your thermocouple knowledge on a dozen either obscure or obvious facts about thermocouples.

By Heat Treat Today editors

P25 Termopares: Doce datos menudos

Los termopares son ubicuos. Sin importar que tu experiencia en la industria sea de 20 días o 20 años, conoces bien el papel esencial que juegan en asegurar que los procesos de tratamiento térmico avancen de manera eficiente, precisa y confiable. Este breve cuestionario evaluará tu conocimiento de los termopares en una docena de datos entre obvios y triviales.

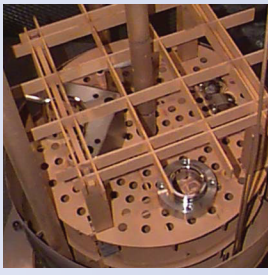
Por Heat Treat Today los editores



P28 Heat Treat Future with AM and 3D Printing

All the buzz in our industry seems to indicate that additive manufacturing (AM) and 3D printing are the next hot topics in heat treat, particularly in vacuum heat treat. Heat Treat Today decided to find out how these new technologies are shaping the industry. Read what five heat treat industry leaders had to say about how their companies are preparing for the next generation of AM and 3D printing.

By Heat Treat Today Editorial Team



P34 CFC Fixture Advantages and Challenges in Vacuum Heat Treatment, Part 1

What happens when a lead engineer sticks his head in new advancements in materials from NASA? For the author of this article, it means the successful research and development of a new generation of workpiece carriers and fixtures made from "a high-tech ceramic matrix composite of very strong carbon fiber," that is, CFC.

Dr. Jorg Demmel, Founder, Owner, and President, High Temperature Concept

Doug Glenn, Publisher
Heat Treat Today

Letter from the Publisher

Top 10 Energy Truths Worth Remembering

Immediate credit for the content of this column goes to Mark Mills, author of *The Cloud Revolution: How the Convergence of New Technologies Will Unleash the Next Economic Boom and a Roaring 2020s*, and podcast host of *The Last Optimist*, the source for most of the below content. (See episode #20, "Congress & the 'Groundbreaking' Energy Spending Act: Top 10 Truths to Keep in Mind.")

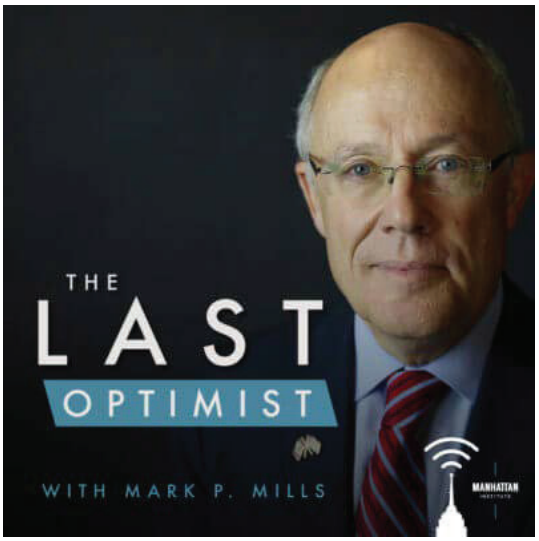
Heat Treat Today interviewed Mr. Mills not long ago. If you'd like to listen to, watch, or read that interview, go to our website and search for "Mark Mills" or Bing/Google search for "**Heat Treat Radio** #73 Mark Mills."

Here are some interesting thoughts from *The Last Optimist* podcast, episode #20.

1. Energy transformations are slow. In the last 20 years, the Western world has spent over $5 trillion to avoid using hydrocarbons, but reduced the percentage share by only 2%, from 86% to 84%. Remarkably, the burning of wood, today, provides 500% more energy to the world than all the world's solar panels combined. Burning wood will most likely not change in the near future; in fact, more wood is burned today than 20 years ago.

2. Economic growth always produces more demand for energy. Wealthy economies use 500–5000% more energy per capita than poor economies. Ironically, wealthy economies use energy more efficiently than poor economies but consume vastly more. The implication: the wealthier we become the MORE energy we will consume.

3. The shale revolution (mostly happening in America) is the world's biggest energy revolution. From 2005-2020, the amount of energy provided from shale was TWICE the amount of energy produced from wind and solar arrays combined. This is the largest increase in energy supply in the history of the world, anytime, anywhere. The next closest "revolution" was the Saudi oil fields, but the shale fields have produced nearly DOUBLE the amount of energy.



4. Green energy is NOT carbon free. According to a study done by Volkswagen, the first 60,000 to 70,000 miles of driving a diesel-powered Volkswagen emits less CO_2 than driving an electric vehicle. Its only AFTER that many miles that the vehicle is a net saver of CO_2.

5. Energy tech cannot emulate the digital tech performance curve. The exceptionally high reductions in cost of computers and other digital technologies have been unprecedented in world history. Unfortunately, those who claim that green energy developments will see the same drastic reduction in costs are misled and ignore, at their own peril, the physics of energy conversion and transmission. That's not to say there won't be significant improvements in energy technology; in fact, there have already been and will continue to be vast improvements, but not to the scale of information/digital technology.

6. The energy transition hardware radically increases the demand for physical minerals and thus mining. The need for green energy minerals, the materials needed to build green energy materials like solar panels, electric vehicles, and wind farms, is 1000% higher than building similar hydrocarbon-based hardware. In other words, the push for green energy will require a drastic increase in the need for minerals, requiring mining, which is currently a carbon intensive activity. HTT

Scan QR code to listen to The Last Optimist *podcast.*

You don't want to miss the final four thoughts from Doug in which he addresses:

7. Energy transition policies

8. The cost of green energy

9. Who is the OPEC of green energy minerals

10. The one measure of an economy's prosperity

Read them on his Publisher's Page on www.heattreattoday.com/publisher.

The 30-minute podcast from which this information comes is well worth a listen.

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Karen Gantzer, Senior Editor/ Associate Publisher
Heat Treat Today

Message from the Editor

The Life-Giving Encouragement of Connection

Well, the **Heat Treat Today** team is still riding high from our time at Furnaces North America a few weeks ago in Indianapolis. If you've had the opportunity to meet, talk, or work with any of us, you know how passionate we are about the industry, our work in helping you become better informed, and most importantly all of you! We truly love people and building relationships.

Being with many of you and connecting in person is energizing for us! It sure was a full week, but we came home with overflowing emotional tanks because we not only experienced FNA as a team together, but we were also able to have meaningful conversations with you! So, I thought it would be fun for you to hear special FNA highlights from several of the **Heat Treat Today** team.

*Team Photo: **Heat Treat Today** Team: (back row): Michelle Ritenour, Ellen Porter, Sarah Maffet, Bethany Leone, Lauren Porter, Alyssa Bootsma; (front row): Karen Gantzer, Doug Glenn, Mary Glenn*

Bethany Leone, our managing editor shared: "Breaking bread with **40 Under 40** people in the concessions, sharing chocolate with attendees in the booth, and clinking glasses with the **Heat Treat Today** family in the evening. It is the joining together and hearing the humanity of so many special people in our lives, whom I only email behind Calibri Light Font Type size 11.

"FNA was more. More fun, more lively, more meaningful than I thought. As someone who enjoys anonymity, it was a surprising joy to meet more people face-to-face and strategize ways that the editorial team could help readers and authors. The work to be done beneath my feet was more than I imagined, so much so that I couldn't leave our booth the first day, save for lunch! Those 'more' memories continue to flood my mind, even as I type 'I'm so sorry I missed you' to the many people I didn't get to meet."

A common theme amongst our team was walking the floor and visiting with you.

Lauren Porter, production manager and first-time attendee said: "For me, the highlight of FNA was walking around the exhibit hall on Tuesday morning feeling the room fill with energy! Seeing so many people I had met — but never face to face — was really fun."

This year we gave away **Heat Treat Kids** shirts. They were a hit with both attendees and staff Alyssa Bootsma, social media editor/copy editor, expressed her favorite memories: "I LOVED handing out the **Heat Treat Kids** T-shirts. It brought so much joy to those parents and relatives. I also loved having lunch with some of the **40 Under 40** honorees. We had fun conversations, and it was great to meet them.

Wilder Porter

Ben Bootsma

"Of course, I absolutely loved being with the **Heat Treat Today** team. You all are such a joy to be around. It was also great to be able to meet people on the show floor or catch up with people we met last year at the Heat Treat Show."

The first lady of **Heat Treat Today**, Mary Glenn, said: "I loved having everyone together and hearing how our magazines are helping businesses grow!"

Administrator Ellen Porter shared: "Working with our Team, in person, is such a great feeling of community. That feeling only builds when you get to go to a show and see all the smiling faces of the people we email with regularly, in the greater Heat Treat World. It was great!"

Closing our reflections is our publisher and founder Doug Glenn whose sentiments are shared by us all: "Having (almost) the entire team in one place at one time was really fulfilling and enjoyable. Being a remote company, the opportunities we have for face-to-face interactions are very limited. The time at FNA was especially enjoyable because not only were we together, but we also shared a common mission: get to know our customers and prospects so that we can be better informed about how to help them. The dinner we had together (with a couple of spouses and two honored guests) was also a wonderful time.

"Another major highlight is the satisfaction of seeing the show so successful since this was the first time that **Heat Treat Today** was the official media sponsor. It seems that our audience showed up and was quite engaged. Getting to meet a handful of our **40 Under 40** honorees was also a super memory for me."

Until the next time; thanks for the memories! HTT

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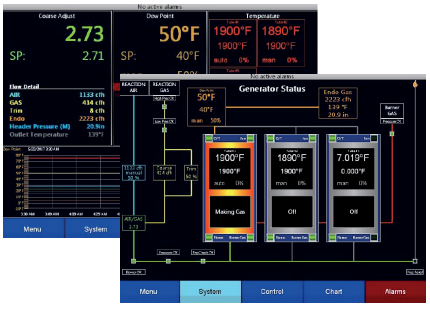

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COMBUSTION CORNER

John Clarke, Technical Director, Helios Electric Corporation

Improving Your Use of Radiant Tubes, Part 1

Radiant tubes are prevalent in heat treating applications. They are very simple devices: basically, a pipe that enters and exits the work chamber. Geometrically simple — but the considerations of how they should be applied, the optimal materials for their construction, and the best burner to use present a myriad of challenges and opportunities for improvement. As all heat treaters know, radiant tubes represent a significant expense as well as an opportunity to save on maintenance costs and improve furnace performance.

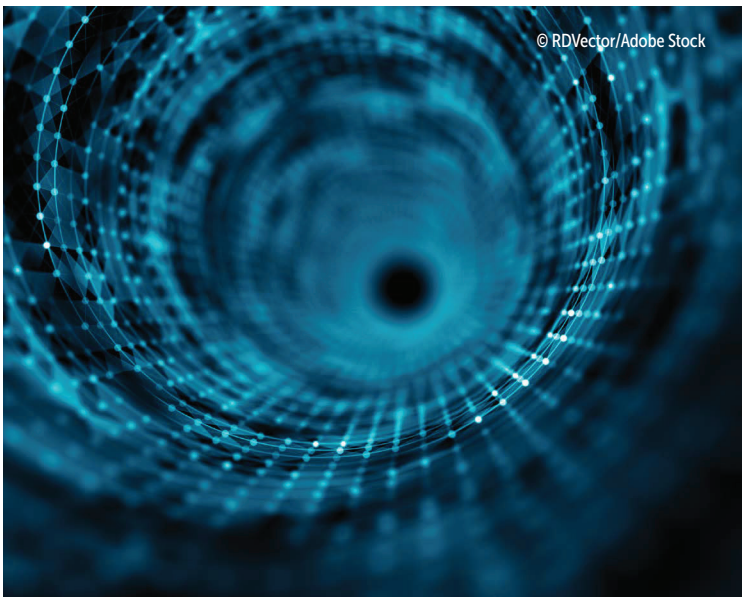
In the coming months, I hope to challenge the reader to spend some time researching opportunities to improve their use of radiant tubes — that is to improve their performance, both heating rates and efficiency, as well as to extend their life and perhaps improve the uniformity of the furnace being heated.

I apologize in advance if I sound like an economist — "It is this way, but on the other hand . . ."There are a lot of factors to consider when planning to upgrade your radiant tubes, their associated burners, recuperators, mountings, and supports.

To start, let's answer a simple question: Why do we use radiant tubes? Two reasons come to mind: to protect the furnace atmosphere from the products of combustion and/or to diffuse the release of heat within the furnace or oven chamber to maximize temperature uniformity. In many heat treating applications, even a very small leak will contaminate the furnace atmosphere, damaging the work being processed.

How do we size radiant tubes? Again, it is obvious that we need to have sufficient heated external surface area to transfer the heat to the furnace chamber. This heat transfer will occur through convection and radiation, with the latter mode being more significant as the furnace temperature rises. The rate of convective heat transfer will depend on mass and velocity of air or atmosphere passing over the tubes. The radiant heat transfer rate is a function of the difference between the tubes' surface temperature and the temperature of the furnace and work being heated. The good news with radiant heat transfer in closed furnaces is that all surfaces in the furnace participate to a degree with the transfer of heat to the work.

There are many shapes for radiant tubes: U-shaped, W-shaped, three legged, as well as systems where the firing and exhaust occur at the same opening, including P-tubes and single-ended tubes. Each has its advantages and disadvantages, which we'll discuss in future articles.



How about materials? Again, we have a lot of choices. The tubes can be centrifugally cast, fabricated from sheet, or made of some ceramic or composite material. The formulation of each material varies greatly, and it is important that the material is suitable for the use temperature and chemical composition of the furnace atmosphere as well as always being compatible with the common products of combustion.

How are the radiant tubes installed? Are the ends welded to a mounting plate, or perhaps a packing gland is employed to seal the tube while allowing some expansion or contraction? Both methods are commonly applied successfully. Composite tubes may have a flange that is clamped at the mounting location, or they may use a packing gland. The tubes may have internal supports within the furnace to prevent sagging. The tubes can be hung vertically, located to the side of, or placed under and over the work being heated.

How long should my radiant tubes last? Simply answered, for as long as practical. As a young person, I was mortified when I dropped a hammer in a customer's pusher carburizing furnace, and it broke an alloy tube. When I confessed to the plant metallurgist, he laughed and told me the tube I broke was over twenty years old. Other customers may be satisfied if their tubes last 18 months, so there is no simple answer. That said, there may well be opportunities to extend the life of the radiant tubes in your specific application.

We will revisit many of these discussions in later articles, but hopefully this column has whetted your appetite for the next discussion in December: What typically occurs inside the radiant tube? After all, this is the Combustion Corner.

HTT

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Steel Sustains

By Kevin Dempsey, President & CEO, American Iron and Steel Institute

The American steel industry is the cleanest of the leading steel industries in the world. Of the major steel-producing countries, the U.S. has the lowest CO_2 emissions per ton of steel produced. By contrast, Chinese steel production creates carbon emissions that are nearly twice that of the U.S. per ton of steel produced. The global steel industry contributes 8% of total world greenhouse gas (GHG) emissions, whereas the U.S. steel industry only accounts for 1–2% of total U.S. GHG emissions.

There are several reasons for the American steel industry's leadership in decarbonization. A key factor is that the American steel industry has adopted electric arc furnace (EAF) technology at a much more accelerated rate than the global industry. Nearly 71% of the steel produced in the U.S. in 2020 was from EAFs, compared to only 26% globally.

In addition, the American steel industry operates blast furnaces that are among the most carbon efficient in the world. Integrated steel mills in the U.S. are almost entirely fed by domestically sourced iron ore pellets compared to CO_2-intensive sintered ore used in China and elsewhere. This results in significantly lower emissions of CO_2, as well as lower emissions of NOx, SO_2, and particulate matter.

Also, the emissions factors associated with the energy mix used for steelmaking in the United States are lower than in other steel-producing locations in the world, with much more reliance on natural gas and renewable energy. This cleaner energy mix helps produce steel with the lowest CO_2 emissions. The American steel industry is continuing to invest in clean energy to provide the electricity needed to run our mills — a number of steel producers in the U.S. have announced several projects that employ renewable energy to supply all or most of specific facilities' energy requirements.

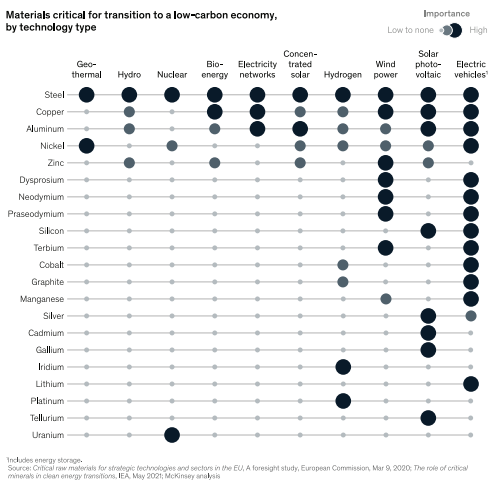
The steel industry in the U.S. also continues to make other key investments to further decrease its carbon emissions and advance its leadership position on sustainability. For example, American steelmakers have made investments to increase the use of direct reduced iron (DRI) and hot briquetted iron (HBI), which can lower emissions for both integrated blast furnace-basic oxygen furnace steel mills and EAF steel mills. Additionally, new DRI and HBI facilities are being designed and have recently been built to be hydrogen-ready once clean hydrogen is available on an industrial scale and commercially viable.

Steel is a critical component in the continued development of all clean energy technologies to reduce America's carbon footprint. According to a recent study by McKinsey & Co[1], steel is the only material critical to all low-carbon technologies. Wind, solar, and tidal renewable energy systems, zero-emission electric vehicles, electric grid transmission, hydrogen production, and carbon capture systems all highly depend on steel. For example, steel comprises over 70% of the weight of a typical wind turbine. Grain-oriented electrical steel (GOES) is a critical and irreplaceable material used in the production of power and distribution transformers that will be necessary for the greening and modernization of the domestic electric grid. American non-oriented electrical steel (NOES) is used for electric motors, including those that will power the growing electric vehicle market.

The American steel industry and its construction partners have also proactively and voluntarily published verified Environmental Product Declarations, which report the carbon footprint and other potential environmental impacts for nearly every steel construction product available in the marketplace today. Furthermore, when steel construction products have outlived their current intended use, they can be recycled into new steel to be used for any variety of new products. Today's steel beam can become tomorrow's refrigerator, soup can, or car door.

Sustainable steelmaking is the American steel industry's number one commitment — for our customers and all Americans. Our entire industry is continuing to make key investments and innovations to further decrease carbon emissions and advance our leadership position on sustainability. HTT

While steel will be crucial as an infrastructure enabler for all technological transition, specific elements will play an important role in each technology.



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[1] Marcelo Azevedo, Magdalena Baczynska, Patricia Bingoto, Greg Callaway, Ken Hoffman, "The raw-materials challenge: How the metals and mining sector will be at the core of enabling the energy transition," McKinsey & Company, January 10, 2022, www.mckinsey.com/industries/metals-and-mining/our-insights/the-raw-materials-challenge-how-the-metals-and-mining-sector-will-be-at-the-core-of-enabling-the-energy-transition.

About the Author:
Kevin Dempsey is the president and chief executive officer of the American Iron and Steel Institute, a leading advocacy group representing electric arc furnace and integrated American steel producers. He previously served as senior vice president of public policy and general counsel to the Institute, during which AISI achieved landmark policy successes on trade, tax, and infrastructure, and successfully showcased the steel industry's sustainability accomplishments and steel innovations in the automotive and construction markets.

For more information
*Contact Kevin at **www.steel.org***

ProTech Thermal Services is a Southern California based furnace manufacturer. We provide a wide range of solutions for many makes and models of industrial heat treating equipment. ProTech manufactures Vacuum, Atmosphere and Retort Furnaces, as well as Rebuilt and Replacement Hot Zones, to meet our customers' needs.

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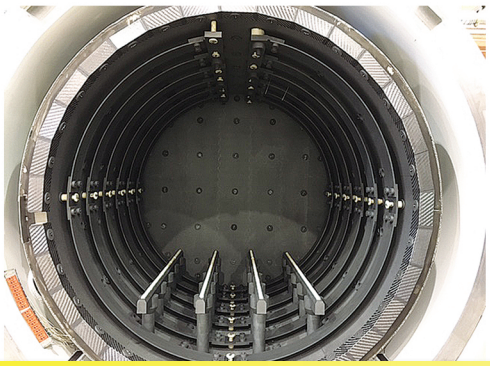
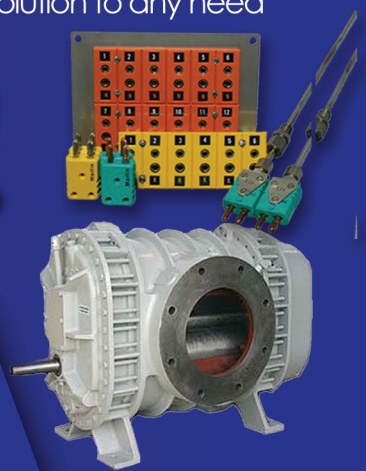


ProTech Thermal Services started in 1998 by selling parts as an aftermarket support option for heat treaters. The company began to expand in line with the ever growing demand for more support in the industry.

ProTech boasts several departments:

- Capital Equipment
- Controls & Automation
- Combustion Support
- Aftermarket Parts & Service
- Pumping Systems
- Instrument Calibration

Each department offers customers a solution to any need whether it be OEM or aftermarket.



Phone: (951) 272-5808
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Email: sales@protechthermal.com

Heat Treat Today News Chatter

Business briefs from around the industry

A Few Dozen Quick Heat Treat News Items To Keep You Current

Heat Treat Today *is pleased to highlight the announcements of heat treat-related growth and achievement throughout the industry by sharing them in* ***News Chatter****, where we feature representatives, transactions, moves, and kudos from aerospace, automotive, medical, energy, and other sectors of manufacturing. Here are just a few of the news items that appeared in the* **Heat Treat Daily** *during the past few months as well as "new" news items.*

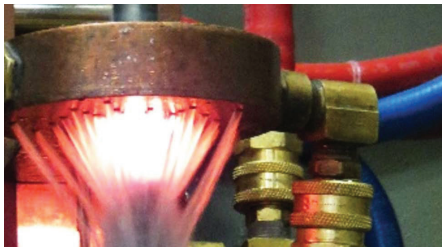
Subscribe to the **Heat Treat Daily** *e-newsletter at heattreattoday.com/subscribe and receive 1–2 news items from around the heat treat industry 5 days a week. Submit your news items to editor@heattreattoday.com.*

EQUIPMENT CHATTER

› A global leader in power technologies purchased a vacuum furnace from **SECO/VACUUM**, a North American furnace provider. The equipment will be used for specialized nuclear operations.

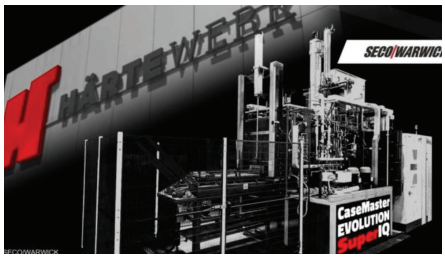
SECO/VACUUM vacuum furnace for nuclear operations

› **Advanced Heat Treat Corp.** has expanded their induction hardening capabilities at its Cullman, AL location. The heat treatment, UltraGlow® Induction Hardening, will be a new service there.



UltraGlow® Induction Hardening at AHT

› **Härtewerk Chemnitz GmbH** purchased a horizontal, two-chamber furnace low-pressure carburizing and oil quenching system from **SECO/WARWICK**.

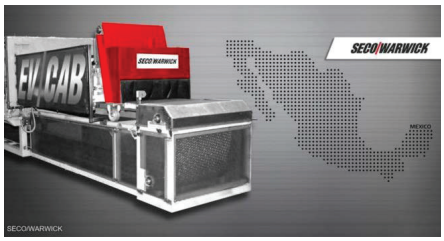


Super IQ furnace for Härtewerk Chemnitz GmbH

› **PEMCO Conversions – Airborne Maintenance and Engineering Services** updates heat treat capabilities with **DELTA H® Technologies**, **LLC's** Dual Chamber Aerospace Heat Treating (DCAHT®) system.

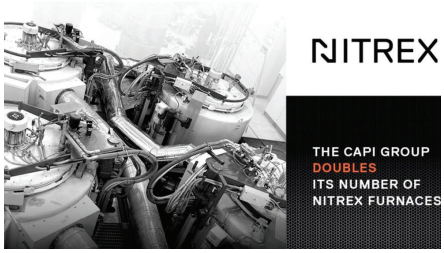
PEMCO Conversion's new DCAHT®'s system

› An international automotive conglomerate has selected **SECO/WARWICK's** controlled atmosphere brazing line to process EV batteries for their factory in Mexico.



SECO/WARWICK EV/CAB line for Mexico factory

› The **Capi Group** has boosted its nitriding/nitrocarburizing capacity with two **Nitrex** heat treat furnaces.



New furnaces from Nitrex

› **L&L Special Furnace Company, Inc.** provided a box furnace for processing ceramic matrix parts to a U.S. manufacturer. The GHH3350 furnace will be used for military and aerospace applications by the Midwest plant.

GHH Series Box Furnace for Ceramic matrix composites

› A North American heat treat service provider, **ThermTech**, obtained furnaces from multiple companies in order to expand production capabilities. Partner companies are **Gasbarre Thermal Processing Systems**; **Ipsen, USA**; **Williams Industrial Service**; and **AFC-Holcroft**.

› **Aalberts surface technology Group** ordered two furnaces from **SECO/WARWICK**. Aalberts will use the vacuum furnaces in their hardening of large dimension elements.

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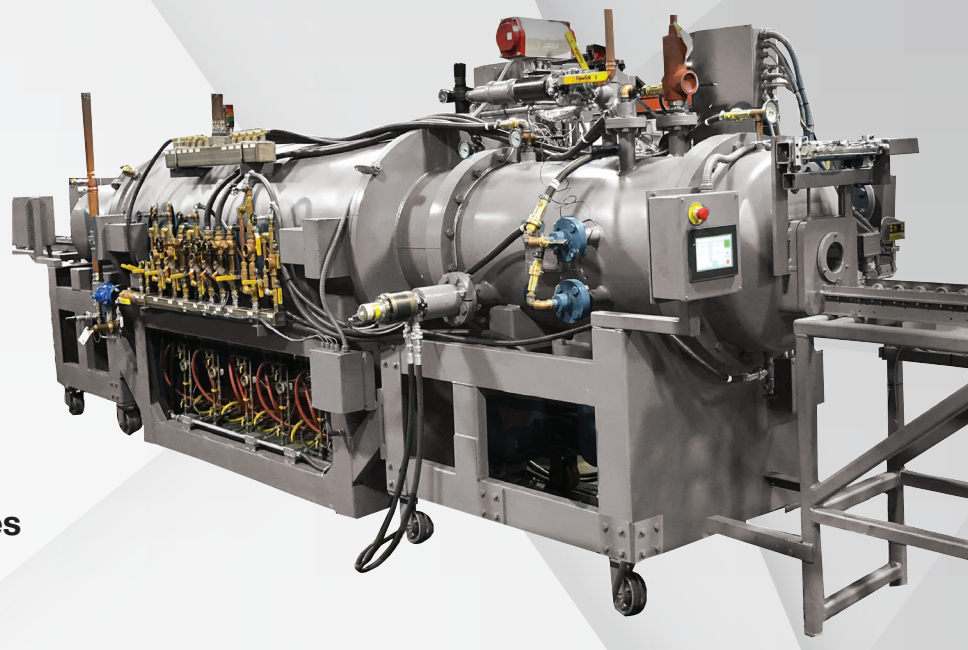

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› Tool manufacturing company ordered two new power supplies from **Magnetic Specialties, Inc.** to be used in its brazing furnace.

New power supplies for brazing furnace

› **Edwards Air Force Base** received two new dual chamber furnaces. **Delta H** provided the two Defender Series aerospace heat treating systems, specifically serving the armed forces.

New heat treat furnaces at Edwards Air Force Base

PERSONNEL AND COMPANY CHATTER

› **Brighton Science** and **Hubbard-Hall** partner to provide the Infinity Surface Cleaning Intelligence Program, which is designed to aid manufacturers to prepare surfaces and prevent problems.

Brighton Science + Hubbard-Hall "Better results. Less chemistry."

Infinity Surface Cleaning Intelligence

› After more than 35 years at *Industrial Heating*, **Kathy Pisano** retired. Many will miss her and her work in the heat treat industry.

Kathy Pisano retires from Industrial Heating

› **Thermal-Vac Technology, Inc.** announced the completion of a new microgrid from **Verdant Microgrid, LLC**. Collaboration with the following companies ensured the project's completion: **Eos Energy Enterprises** of Edison, NJ; **Stronghold Engineering, Inc.** of Perris, CA; and **GridSwitch Asset Management Services** of Moon, PA.

› **Nextracker LLC**, a provider of utility-scale solar trackers, and BCI Steel, a Pittsburgh-based steel fabricator, announced the reopening of the historic Bethlehem steel manufacturing factory. This factory, located in Leetsdale, PA, is to produce solar tracker equipment for large-scale solar power plants.

KUDOS CHATTER

› **Doug Peters**, CEO of **Peters' Heat Treating**, received the Winslow Award, an honor that is given to an individual or business that has made valuable economic improvements.

Greater Meadville Area Day dinner

'Such great support'

Winslow Award winner Peters credits family, community

By Keith Gushard
MEADVILLE TRIBUNE

WOODCOCK TOWNSHIP — "My goodness," a visibly moved J. Douglas Peters said after arriving at the podium.

Peters, 69, chief executive officer of Peters Heat Treating and a community volunteer, received the 2022 Winslow Award at The Country Club of Meadville on Wednesday evening. The award, initiated in 1969, was presented at the close of the Greater Meadville Area Day dinner held by the Economic Progress Alliance of Crawford County.

The Winslow Award honors an individual, group, business or industry that has made a significant contribution to the economic growth of the greater Meadville area.

It's named for Dr. Harry C. Winslow, an area physician and business leader who received the inaugural award on his 85th birthday from the Meadville Area Industrial Commission, a predecessor organization of the alliance.

"In 1979, my wife, Jackie, was one of the few people who

See PETERS, Page A2

INSIDE: Pittsburgh Penguins radio broadcaster Bourque speaks at annual award dinner, Page B1

Winslow Award recipient Doug Peters hugs emcee John Sebok during the Greater Meadville Area Day dinner sponsored by the Economic Progress Alliance of Crawford County at The Country Club of Meadville.

Doug Peters receives 53rd annual Winslow Award

› **Heat Treat Today** announces young leaders in the annual heat treat industry awards. The **40 Under 40 Class** of **2022** recognizes individuals in the heat treat industry who deserve recognition and appreciation and represent leadership qualities.

› **Texas Heat Treating, Inc.** announces that both Round Rock and Texas Heat Treating Ft. Worth just completed ISO 17025 lab audits. The audits came back with no findings.

› A two chamber vacuum oil quench furnace has received Nadcap accreditation. **Solar Manufacturing** designed the furnace for **Solar Atmospheres of Western PA**.

Solar Atmospheres of Western PA's Nadcap accredited furnace

› **Vac-Met, Inc.** has been acquired by **Solar Family of Companies.**

Pictured left to right: Bob Hill, President, Solar Atmospheres of Western PA and Vac-Met; William Jones, Owner/CEO, Solar Family of Companies; Joe White, Vice President of Operations, Vac-Met

› **Ayla Busch** was honored with the **German Leadership Award 2022**. This award was presented at the annual alumni convention of the **Collège des Ingénieurs** and is an award for innovative corporate leadership in the German economy.

Lars Wagner, COO at MTU Aero Engines AG, presents Ayla Busch with the award. Source: Andreas Schwarz.

Save the Date:
June 12-16, 2023

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DÜSSELDORF GERMANY

Invitation from the publisher

Dear Industry Supplier:

I'd like to invite you to join me in Dusseldorf, Germany for the world's largest and most impressive heat treating trade show in the world – Thermprocess 2023 – June 12-16. This event is held every four years. I've had the pleasure and privilege of attending nearly every event since 1999 and have never been disappointed.

If you're a supplier to the industry and do business in Europe, Asia, Africa, Latin or South America, this event is a no-miss, never-forget event that will be well worth your time.

Please set aside June 12-16 on your calendar and please contact me if you're interested in joining me as an exhibitor (or visitor) at Thermprocess. Heat Treat Today is setting up a North American Group Participation. As a group, the show organizer, Messe Düsseldorf, can assist us with booking our booths and providing additional exhibitor support services to ensure a smooth and worry-free exhibiting experience.

Please let me know ASAP if you are interested in exhibiting at this quadrennial event. Trust me, it will be an event you will not quickly forget.

Let me know if you have any questions.

Sincerely,

Doug Glenn

Doug Glenn
Publisher/Founder/Owner
Heat Treat Today

CONTACT

doug@heattreattoday.com

724-923-8089

How Things Work

Thermocouples

Interview with Eric Yeager, Director of Corporate Quality, Cleveland Electric Laboratories and Doug Glenn, Publisher and Founder, **Heat Treat Today**

Heat Treat Today *is launching a How Things Work periodic content series. The first topic is the basics of thermocouples. Thermocouples are the bread and butter of the heat treating world. How many of the following questions are news to you? Take a deep dive into the topic and read this question and answer session between Doug Glenn, publisher and founder of* **Heat Treat Today,** *and Eric Yeager, director of Corporate Quality at Cleveland Electric Laboratories.*

What is a thermocouple?

Doug Glenn (DG): In this industry, and I suppose in a lot of industries, they often refer to thermocouples as T/Cs.

Let's start off with one of the very most basic questions: What is a thermocouple?

Eric Yeager (EY): A thermocouple is a device that measures temperature. It contains no moving parts, has no power source and it does not contain any hazardous materials like liquid mercury or anything like that.

DG: Right. That's interesting you say that, and it's actually good that you say that, because some of our residential consumer thermometers (which a thermocouple is kind of like a thermometer in one sense) do have hazardous materials like mercury.

EY: Absolutely, absolutely.

How does a thermocouple tell temperature?

DG: So, there are no moving parts or anything of that sort. How, exactly, does a thermocouple tell the temperature?

EY: All metals that exist, when introduced to a temperature gradient (so, if you had the length of metal A and you introduce it to a temperature gradient, which would be a difference from one end to the other) will produce a microvoltage. That microvoltage is the potential that is known as the "absolute Seebeck effect" and that's the basis on which the single thermocouple element functions.

DG: So, when you say the single thermocouple element, what do you mean by that?

EY: That would be one leg — either your positive leg or your negative leg — or it could be any actual wire that exists, and as long as you introduce a temperature gradient, it will produce some microvoltage. With thermocouples, there are set standards for what those materials are manufactured from, but any wire will create a microvoltage or an EMF output.

DG: So, let's say we took a copper wire from our house, and we put one end on top of a candle (just for heat's sake); you're saying that within the span of that wire, there is going to be a voltage of some sort.

EY: Correct. And that's actually called the absolute Seebeck effect or EMF.

DG: EMF, electromotive force. And Seebeck, if I understand correctly, he was the guy that discovered this stuff, right?

EY: He's one of them. Peltier was involved and I think a gentleman named Thompson. But it was all around the same time — they kind of all collaborated with one another.

DG: You mentioned, with a thermocouple, if you have a section of wire material, add heat to one end, there's going to be a voltage of some sort, a millivoltage in this case, a very small voltage, but a voltage, nonetheless. But you mentioned one leg. Explain more about the one leg; because, typically, isn't there just one piece of wire in there?

EY: Right, correct. A thermocouple consists of two dissimilar metals, two dissimilar wires. For example, in a type K thermocouple, one leg would be chromel and the other leg would be alumel, and when you join those two dissimilar metals together, the net voltage between the two combined dissimilar metals is what is used to measure the output of the thermocouple. This conversion of thermal energy to electrical energy is known as the Seebeck effect.

DG: So, let's say you stick a piece of copper wire over a candle that's burning at 400 degrees, or whatever the candle might be burning at, you're going to get a certain voltage across there or within the wire.

EY: Along the length of that wire, yes.

DG: So, if the temperature of that candle is twice the temperature (let's say you double the temperature of the candle) the voltage across the length of that wire is now different, yes?

EY: It's proportional. So, the greater amount of heat energy you apply, the greater amount of EMF will be generated.

DG: And that wire, typically, for the useful life of the wire, does not change? It's always the same? If it's at a 100- or 1000 °F, that voltage is one; if it's 2000, it's that; it doesn't ever dissipate over time, does it?

EY: No. It only degrades when a contaminate is introduced to the material.

DG: Gotcha. Because it then prevents the flow, I assume.

EY: Correct. And it's not as pure. So, that's one of the effects as you see something that's called "drift" over time, over use.

Why do dissimilar materials/metals produce a millivolt signal?

DG: Now, you said, though, that in a type K, and I know that in almost all thermocouples we've got two dissimilar metals. If one wire can tell you an output of the voltage, why do you need two dissimilar metals in order to get a different type of voltage?

EY: It's basically the sum of the two materials; combine the voltage generated from the entire length of the wire of the two thermal conductors.

You have to have a signal path. You have to have a source for your voltage to start and a voltage for it to end into your instrumentation and so you have to have some way to read that temperature gradient and it's typically done with two dissimilar metals to create a greater and more stable EMF.

When a lot of the cable or wire manufacturers create, say, a melt of chromel, they test that, and actually test it against a pure platinum wire so as to return the voltage back to the instrument to measure the actual EMF for the single leg output.

How important is the joining of these dissimilar metals?

DG: Now, you talked about the joining of the two dissimilar metals. How exactly how does that need to be done? Can they be welded together, and if they're welded together, doesn't the metal that's used in the weld mess it up? And does it have to be just at a point, or can it be along a length that they are joined together?

EY: It's important to have the purest, most secure junction when joining the two dissimilar metals. It's typically done by welding the metals together without adding any filler material. That's especially important when you have something that has a very low EMF output, which is like your noble metal thermocouples. That's where purity is essential. Loose connections from twisted or crimped junctions also might cause intermittencies under thermal expansion and affect the thermocouple output signal.

DG: So, typically, they are welded together without a filler; they're just welded together.

EY: Correct. You just bring a TIG torch in, give it a quick zap, and it melts the two wires together. Once you get that nice little joint or junction, you can run and complete the assembly.

DG: Okay. We already talked about why there are different millivolt readings at different temperatures, because basically it's the difference in the heat.

EY: Correct. As the temperature increases, there's a direct correlation to the microvoltage output from that particular wire or wire pair.

DG: And I asked about how important are the joining of these materials. Typically, you don't want it over a wide section, right? Does it matter if it's a spot weld, instead? What would happen if you had one that was an inch or two inches long? Is that a big deal?

EY: It's best to keep it as small and concise as possible, because it could form a heat sink later on when you're in application; typically you just want a small nice round junction. For example, you want the junction to be about twice the diameter of the single thermal element. So, if it was a 20 thousandths-diameter wire, you want it 40 thousandths in diameter.

Thermocouples welded to a workload; wouldn't that weld introduce some "interference" in the millivolt signal?

DG: Aren't some T/Cs welded? I think I've heard that sometimes they'll take thermocouple wire that will be joined and then welded to, or in some way applied right to, a load. If you were applying it directly to a workload, wouldn't that extra metal kind of mess up the millivolt?

EY: You would think so, but as long as they're kept as close as possible, and the workpiece that you're welding to is kept isothermal or actually uniform in temperature between the two welded junctions, it won't have a detrimental effect on the thermoelectric output. But you want to make sure that the workpiece is uniform in temperature because you have a temperature gradient across where those two junctions are welded to the material, and it can have a slight effect. That's essential to basically ensure that your workpiece is isothermal.

DG: What do you mean by isothermal?

EY: Uniform in temperature across the entire workpiece between the welded beads. The workpiece will become the welded bead, but it won't create any additional EMF output to the combination because it's the combination of the length — it measures the temperature across the entire length of the wire not necessarily at the bead.

It's kind of a common misconception that the bead creates all the EMF, but it's actually along the length of the wire.

DG: It is along the length of the wire. I always thought that the temperature was measured basically at the bead, at the joint.

EY: Well, that's where it starts, but it's combined along the length of the wire.

In the heat treating world, what is the most popular T/C and what are the materials from which it is made?

DG: So, in the heat treat world, what's the most popular T/C and what are the materials it's made from?

EY: I would say it's definitely the type K and those two materials are chromel and alumel as we previously discussed. It's probably the most popular due to the low cost and the wide temperature range capability. Basically, you can go from 32°F all the way up to 2450°F. It won't last very long at those temperatures, but it's the most common and the most versatile. I would say type K is the most popular.

How long do type K thermocouples last in a furnace/application?

DG: The factors: you were talking about them not lasting all that long. This is probably a loaded question, but if you're in an average heat treat application, what's a typical lifespan of a type K?

EY: To be honest with you, that's the question that everybody wants to know. And truthfully, it depends on the application. It depends on thermal cycling, it depends on how well the thermocouple thermoelements are protected from the environment, for example, whatever protection tube you put it in, if it's an MGO, or an exposed bead. All of those things are contributing factors. Really, it's very, very application dependent. For example, I've seen type K control thermocouples last for 5 years but that's basically at a stable temperature without any thermocycling and a constant, nice, clean environment. But I've seen units that get consumed rapidly at the elevated temperatures, like I mentioned, 2450°F. They don't last very long there but they do measure.

DG: So, the undesirable conditions for those things would be a lot of thermocycling up and down, so, it's going to fail faster, I assume?

EY: Correct. And temperature of course: the higher temperature, the greater degradation in the material. That pretty much stands for any thermocouple type.

DG: I want to ask a couple questions that aren't on here just because I'm curious about this. A lot of times, you'll have the spot weld where you put them together, that's called the bead?

EY: Yes. Or junction. Either/or.

DG: So, the bead or the junction — that's obviously bare wire, right? Assuming we're actually using to put it on a workpiece. You've got the bead and then you've got, obviously, a little bit of bare wire at least. Is the rest of that wire covered or is it often not covered?

EY: It must be covered because it could short somewhere along the length of the wire. It could be either a soft wire insulation, like a ceramic fiber or a REFRASIL® or even a fiberglass-type insulation depending upon the temperatures. What I actually prefer is an MGO-style thermocouple where it has a metallic outer sheath surrounded by a magnesium oxide insulator that prevents it from shorting out. So, for example, if you just ran straight wire and had any kind of airflow or thermal expansion, it could short out somewhere along the length of the wire. Basically, a thermocouple will measure from the closest

measuring junction to the instrumentation. Therefore, if it's shorted out, you'd get a false reading.

DG: So, if you had it attached to the load and it runs over here but it touches something else just before it goes out to the outside of the furnace or whatever, you're going to measure that spot closest to the temperature wall, so it doesn't give you anything on the load.

EY: What's very common is people will run the software thermocouples through a door of a furnace where it closes on the door, that's where it shorts out. HTT

*Read the full interview online when you search *"Eric Yeager"* on **www.heattreattoday.com!***

About our expert:
Eric Yeager is the director of Corporate Quality at Cleveland Electric Laboratories. He's been with Cleveland Electric Labs for 17 years and is working on year 18. In that time, he has been director of quality and runs their accredited thermocouple calibration laboratory. Eric is involved with ASTM and is a subcommittee chairman for E2011, which is the calibration section of the thermocouple standards. He also was technical consultant on some of the rewrite of the latest AMS2750.

Thermocouple Trivia by the Dozen

Thermocouples are ubiquitous. Whether you are 20 days or 20 years into the industry, you know the essential role they play in making sure heat treat processes are running efficiently, accurately, and dependably. This quick trivia questionnaire will test your thermocouple knowledge on a dozen either obscure or obvious facts about thermocouples.

If you have any facts of your own about thermocouples, our editors would be interested in sharing them online at www.heattreattoday.com. Email Bethany Leone at bethany@heattreattoday.com with your own trivia!

Thermocouple Trivia

1. **What thermocouple type potentially has the longest life (but is also the most expensive)?**
   - (a) Type K (Chromel-Alumel)
   - (b) Type N (Nicrosil-Nisil)
   - (c) Type R (Platinum-13% Rhodium)
   - (d) Type J (Iron-Constantan)

2. **What is something you might find at home that uses a thermocouple to control its temperature?**
   - (a) Your oven
   - (b) Your toaster
   - (c) Your water heater
   - (d) All of the above

3. **What do you need to know when purchasing thermocouples for your heat treat furnace or oven?**
   - (a) The length of the thermocouple
   - (b) The process application you are running
   - (c) The type of thermocouple best suited for the application
   - (d) All of the above

4. **Who was Thomas Johann Seebeck?**
   - (a) The person credited with describing the scientific theory behind thermocouples
   - (b) An advocate for the elimination of thermocouples in furnaces and ovens
   - (c) A German physicist who was responsible for helping develop rockets for the United States
   - (d) None of the above

5. **What would be the best thermocouple to use to control the temperature of an oil quench tank?**
   - (a) Type R (Platinum-13% rhodium)
   - (b) Type S (Platinum-10% rhodium)
   - (c) Type K (Chromel-Alumel)
   - (d) Type J (Iron-Constantan)

6. **Why use an over temperature (aka "excess temperature") device on your furnace or oven?**
   - (a) For better process control, it is always helpful to have more than one thermocouple in the furnace/oven
   - (b) To prevent the furnace temperature from running away and damaging the equipment
   - (c) An obsolete device no longer required by NFPA 86 standards
   - (d) A method of ensuring the process being run in the furnace stays close to the set point temperature

7. **How are thermocouples used in the heat treat industry?**
   - (a) As temperature control devices
   - (b) As part of a safety system designed to prevent the furnace/oven from running away and damaging itself
   - (c) To ensure that temperature, the most important process parameter, is maintained within limits necessary to successfully run a heat treat process
   - (d) All of the above

8. **Why use type K versus type N thermocouples?**
   - (a) Because type K has better accuracy
   - (b) Because type K has better temperature limits
   - (c) Because type K is more expensive
   - (d) None of the above

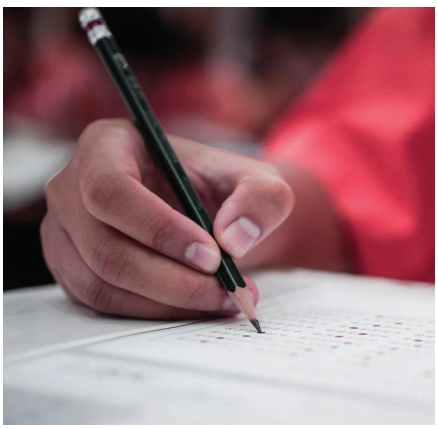
9. **Thermocouples produce what type of voltage?**
   - (a) PPM (parts per million)
   - (b) EMF (electromotive force)
   - (c) EMP (electromagnetic pulse)
   - (d) mV (millivolt)

10. **What are some of the most common reasons why a thermocouple "drifts" or fails in a heat treat furnace or oven?**
    - (a) Age
    - (b) Running at temperatures higher than its rated use temperature
    - (c) The wrong thermocouple type is used
    - (d) All of the above

11. **What is a common problem seen in thermocouples that fail in service?**
    - (a) Green rot (oxidation of chromium)
    - (b) Metal dusting (aka "catastrophic carburization")
    - (c) Grain growth
    - (d) All of the above

12. **Complete the sentence: Types S, R, and B noble metal thermocouples are generally specified for use . . .**
    - (a) . . . when temperatures exceed the upper recommended operating temperatures of base metal thermocouples.
    - (b) . . . after failing compliance on three SATs .
    - (c) . . . if the furnace only processes automotive parts.
    - (d) . . . to safeguard against low temperature readings in large loads.

Check your answers on page 26.



Termopares: Doce datos menudos

Traducido por: Shawna Blair

Los termopares son ubicuos. Sin importar que tu experiencia en la industria sea de 20 días o 20 años, conoces bien el papel esencial que juegan en asegurar que los procesos de tratamiento térmico avancen de manera eficiente, precisa y confiable. Este breve cuestionario evaluará tu conocimiento de los termopares en una docena de datos entre obvios y triviales.

Si quisieras aportar otros datos interesantes relacionados con los termopares, nuestros editores te invitan a compartirlos para ser publicados en línea en www.heattreattoday.com. Puedes hacerlos llegar a Bethany Leone al correo bethany@heattreattoday.com

Datos varios de los termopares

1. ¿Cuál es el tipo de termopar que más larga vida puede llegar a tener (aunque también es el más costoso)?

(a) Tipo K (chromel-alumel)
(b) Tipo N (nicrosil-nisil)
(c) Tipo R (platino-13% rodio)
(d Tipo J (hierro-constantan)

2. ¿Cuál de estos electrodomésticos que podrías tener en casa utiliza un termopar para controlar la temperatura?

(a) El horno
(b) La tostadora
(c) El calentador de agua
(d) Todas las anteriores

3. ¿Qué debes saber a la hora de comprar termopares para tu horno de tratamiento térmico?

(a) La longitud del termopar
(b) La aplicación propuesta del proceso a realizar
(c) El tipo de termopar que mejor se adapta a la aplicación
(d) Todas las anteriores

4. ¿Quién fue Thomas Johann Seebeck?

(a) La persona a la que se le atribuye la teoría científica en la que se fundamentan los termopares
(b) La persona que abogó por la eliminación de los termopares en hornos
(c) Un físico alemán responsable de apoyar en el desarrollo de cohetes para los Estados Unidos
(d) Ninguna de las anteriores

5. ¿Cuál termopar sería el más indicado para controlar la temperatura de un tanque para temple en aceite?

(a) Tipo R (platino-13% rodio)
(b) Tipo S (platino-10% rodio)
(c) Tipo K (chromel-alumel)
(d) Tipo J (hierro-constantan)

6. ¿Por qué motivo se implementaría en un horno un dispositivo de protección contra temperatura en exceso, o "sobre" temperatura?

(a) Para lograr un mejor control del proceso es favorable utilizar en el horno o caldera más de un termopar
(b) Serviría para impedir que la temperatura del horno se disparara ocasionando daños al equipo
(c) Un dispositivo obsoleto que la norma NFPA 86 ya no exige
(d) Permitiría asegurar que el proceso que se adelante en el horno se mantenga cercano al punto de temperatura establecido

7. ¿Cómo se utilizan hoy en día los termopares en la industria del tratamiento térmico?

(a) Como dispositivos de control de temperatura
(b) Como parte de un sistema de seguridad diseñado para evitar que la temperatura del horno se dispare ocasionando que el horno se destruya
(c) Como mecanismo que asegura que la temperatura, el parámetro más importante de un proceso de tratamiento térmico, no se salga de los límites indicados para lograr un resultado exitoso
(d) Todas las anteriores

8. ¿Por qué motivo se utilizaría un termopar tipo K en lugar de uno tipo N?

(a) Porque el tipo K es más exacto
(b) Porque el tipo K tiene mejores límites de temperatura
(c) Porque el tipo K es más costoso
(d) Ninguna de las anteriores

9. ¿Qué tipo de voltaje generan los termopares?

(a) PPM (parte por millón)
(b) EMF (fuerza electromotriz)
(c) EMP (pulso electromagnético)
(d) mV (milivoltios)

10. ¿Cuáles son algunas de las causas más comunes de que la calibración del termopar de un horno o caldera de tratamiento térmico se desvíe o falle?

(a) Edad
(b) Manejo a temperaturas superiores al límite recomendado
(c) Utilización del termopar equivocado
(d) Todas las anteriores

11. ¿Qué problema comúnmente se observa en los termopares que fallan en el uso?

(a) Moho verde (oxidación de cromo)
(b) Metal dusting (carburización catastrófica)
(c) Crecimiento de grano
(d) Todas las anteriores

12. Complete la frase: Los termopares de metales nobles Tipo S, R y B por lo general se especifican para uso. . .

(a) . . . en casos en los que las temperaturas superan la máxima recomendada para operar los termopares de metales base.
(b) . . . luego de caer en incumplimiento en tres pruebas SAT (prueba de exactitud del sistema, por sus siglas en inglés).
(c) . . . cuando la caldera solo se usa para procesos de piezas automovilísticas.
(d) . . . para prevenir que se baje demasiado la temperatura en cargas grandes.

Revisa tus respuestas en la página 26

Trivia Key

Compare your answers on page 24 with the key below. How did you stack up in thermocouple knowledge? See where your skills measure up in the scale below.

Learn more about thermocouples in the interview between Doug Glenn and Eric Yeager on page 16 or check out the reference list at the bottom of this page.

Answers

1. **What thermocouple type potentially has the longest life (but is also the most expensive)?**
   (c) Type R (Platinum-13% Rhodium)

2. **What is something you might find at home that uses a thermocouple to control its temperature?**
   (d) All of the above

3. **What do you need to know when purchasing thermocouples for your heat treat furnace or oven?**
   (d) All of the above

4. **Who was Thomas Johann Seebeck?**
   (a) The person credited with describing the scientific theory behind thermocouples

5. **What would be the best thermocouple to use to control the temperature of an oil quench tank?**
   (d) Type J (Iron-Constantan)

6. **Why use an over temperature (aka "excess temperature") device on your furnace or oven?**
   (b) To prevent the furnace temperature from running away and damaging the equipment

7. **What are thermocouples used for in the heat treat industry?**
   (d) All of the above

8. **Why use type K versus type N thermocouples?**
   (d) None of the above

9. **Thermocouples produce what type of voltage?**
   (d) mV (millivolt)

10. **What are some of the most common reasons why a thermocouple "drifts" or fails in a heat treat furnace or oven?**
    (d) All of the above

11. **What is a common problem seen in thermocouples that fail in service?**
    (d) All of the above

    Green rot is only found in type K & E

    Dusting / carburization would be type C

    Grain growth in platinum

    ***Though, the biggest problem with thermocouples is how they are made, tested, and certified.**

12. **Complete the sentence: Types S, R, and B noble metal thermocouples are generally specified for use . . .**
    (a) . . . when temperatures exceed the upper recommended operating temperatures of base metal thermocouples.

Thermocouple Knowledge Scale

0–4 Correct	5–9 Correct	10–11 Correct
 "Back to the Books"	 "Thermocouple Wiz"	 "Fluent in 'Thermocouplese'"

References

[1] Alexander, Colleen Stroud, et al. "Application of Ribbon Burners to the Flame Treatment of Polypropylene Films." *Platinum Thermocouple - an Overview | ScienceDirect Topics*, 20 June 2008, https://www.sciencedirect.com/topics/engineering/platinum-thermocouple.

[2] "Introduction to Thermocouples." *A Perfect Alliance Between Expertise and Know-How*, RDC Control, 16 Dec. 2017, https://rdccontrol.com/thermocouples/thermocouples-101/introduction-to-thermocouples/.

[3] Nash, William, and Eric Yeager. "Industrial Heating Magazine: How Long Should My Thermocouple Last?" *Cleveland Electric Laboratories*, 13 Sept. 2021, https://clevelandelectriclabs.com/industrial-heating-magazine-how-long-should-my-thermocouple-last/.

[4] REOTemp Instruments. *Thermocouple*, 2011, https://www.thermocoupleinfo.com/.

[5] Staff, Editorial. "Thermocouples Green Rot Effect." *Inst Tools*, 20 Nov. 2019, https://instrumentationtools.com/thermocouples-green-rot-effect/.

[6] "Thomas Johann Seebeck." Editors of Encyclopaedia, *Encyclopaedia Britannica*, Encyclopaedia Britannica, Inc., 5 Apr. 2022, https://www.britannica.com/biography/Thomas-Johann-Seebeck.

[7] "What Are Thermocouples Used for?" *Enercorp Instruments What Are Thermocouples Used for Comments*, 2020, https://enercorp.com/what-are-thermocouples-used-for/.

Heat Treat Today would also like to thank the following for their expert input: **Dan Herring, The Heat Treat Doctor®, The HERRING GROUP, Inc.**; **Hank Prusinski, Summit Aerospace Products Corp.;** and **Andrew Bassett, Aerospace Testing and Pyrometry.**

Clave de Doce datos menudos

Compara tus respuestas de la página X con la clave a continuación. ¿Cómo te fue en conocimiento de termopares? Califica tus habilidades de acuerdo a la escala que encontrarás líneas abajo.

Para aprender más acerca de los termopares, lee la entrevista entre Doug Glenn y Eric Yeager en la página 16, o revisa la lista de obras referenciadas al final de esta página.

Respuestas

1. **¿Cuál es el tipo de termopar que más larga vida puede llegar a tener (aunque también es el más costoso)?**
   (c) Tipo R (platino-13% rodio)

2. **¿Cuál de estos electrodomésticos que podrías tener en casa utiliza un termopar para controlar la temperatura?**
   (d) Todos los anteriores

3. **¿Qué debes saber a la hora de comprar termopares para tu horno de tratamiento térmico?**
   (d) Todos los anteriores

4. **¿Quién fue Thomas Johann Seebeck?**
   (a) La persona a la que se le atribuye la teoría científica en la que se fundamentan los termopares.

5. **¿Cuál termopar sería el más indicado para controlar la temperatura de un tanque para temple en aceite?**
   (d) Tipo J (hierro-constantan)

6. **¿Por qué motivo se implementaría en un horno un dispositivo de temperatura excesiva, o "sobre" temperatura?**
   (b) Serviría para impedir que la temperatura del horno se disparara ocasionando daños al equipo

7. **¿Cómo se utilizan hoy en día los termopares en la industria del tratamiento térmico?**
   (d) Todas las anteriores

8. **¿Por qué motivo se utilizaría un termopar tipo K en lugar de uno tipo N?**
   (d) Ninguna de las anteriores

9. **¿Qué tipo de voltaje generan los termopares?**
   (d) mV (milivoltios)

10. **¿Cuáles son algunas de las causas más comunes de que la calibración del termopar de un horno o caldera de tratamiento térmico se desvíe o falle?**
    (d) Todas las anteriores

11. **¿Qué problema comúnmente se observa en los termopares que fallan en el uso?**
    (d) Todas las anteriores

    El moho verde solo se encuentra en los tipos K & E

    Dusting / carburización sería tipo C

    Crecimiento de grano corresponde a platino

    ***No obstante, el problema más grande de los termopares radica en su fabricación, proceso de prueba y certificación.**

12. **Complete la frase: Los termopares de metales nobles Tipo S, R y B por lo general se especifican para uso . . .**
    (a) . . . en casos en los que las temperaturas superan la máxima recomendada para operar los termopares de metales base..

Escala de Conocimiento de Termopares

0–4 respuestas correctas	5–9 respuestas correctas	10–11 respuestas correctas
 "Vuelve a la Primaria"	 "Mago en Termopares"	 "Hablante Nativo de Termoparé"

Referencias

[1] Alexander, Colleen Stroud, et al. "Application of Ribbon Burners to the Flame Treatment of Polypropylene Films." Platinum Thermocouple - An Overview ["Aplicación de quemadores de cinta al flameado de película de polipropileno." Termopar de platino - un resumen.] | ScienceDirect Topics, 20 June 2008, https://www.sciencedirect.com/topics/engineering/platinum-thermocouple.

[2] "Introduction to Thermocouples." A Perfect Alliance Between Expertise and Know-How [¨Introducción a Termopares. Una alianza perfecta entre la experticia y el conocimiento¨], RDC Control, 16 Dec. 2017, https://rdccontrol.com/thermocouples/thermocouples-101/introduction-to-thermocouples/.

[3] Nash, William, and Eric Yeager. "Industrial Heating Magazine: How Long Should My Thermocouple Last?" [¨Revista de Calentamiento Industrial: ¿Cuánto debería durar mi termopar?¨] Cleveland Electric Laboratories, 13 Sept. 2021, https://clevelandelectriclabs.com/industrial-heating-magazine-how-long-should-my-thermocouple-last/.

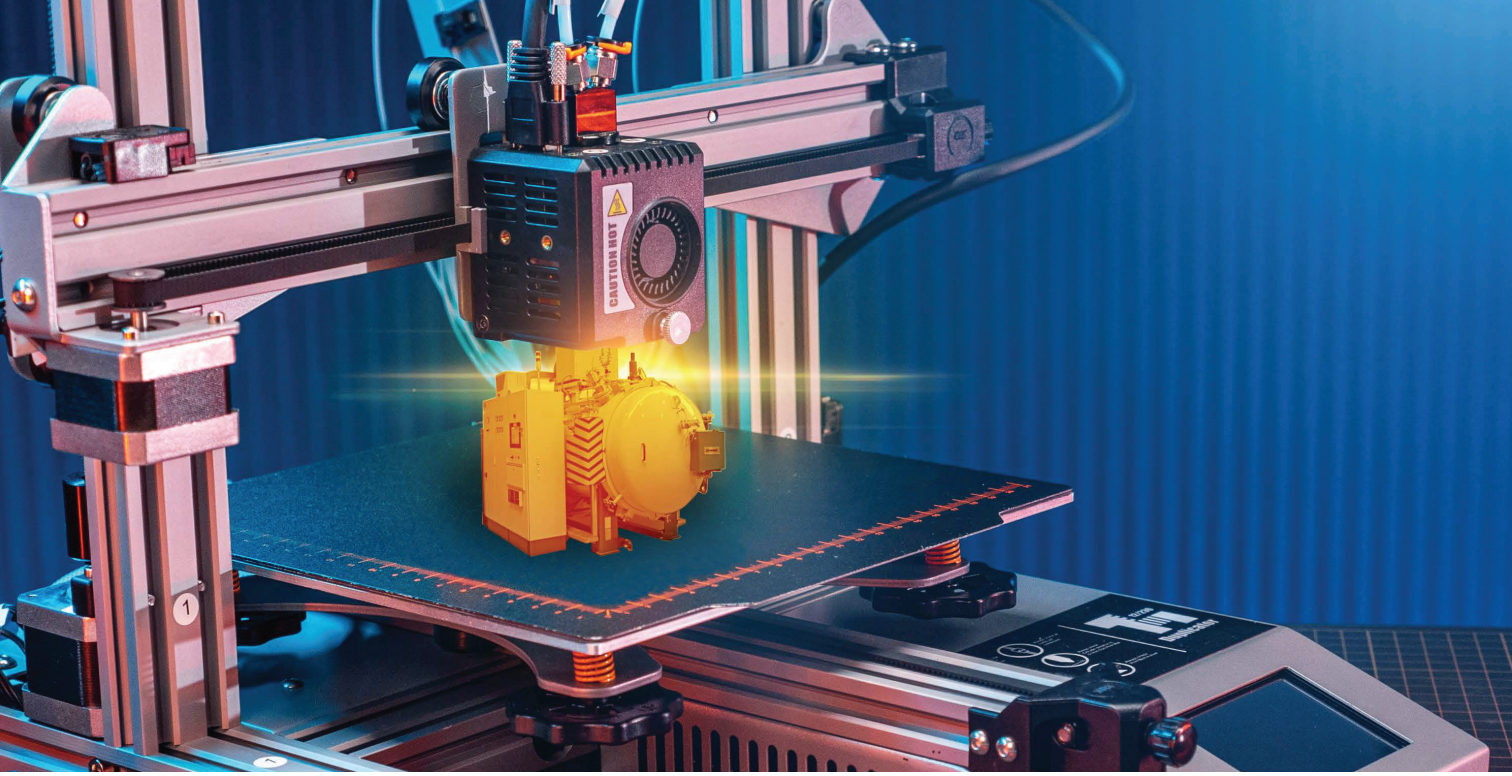
[4] Staff, Editorial. "Thermocouples Green Rot Effect." [¨Efecto moho verde en termopares¨] Inst Tools, 20 Nov. 2019, https://instrumentationtools.com/thermocouples-green-rot-effect/.

[5] REOTemp Instruments. Thermocouple [Termopar], 2011, https://www.thermocoupleinfo.com/.

[6] "Thomas Johann Seebeck." Editors of Encyclopaedia, Encyclopaedia Britannica, Encyclopaedia Britannica, Inc., 5 Apr. 2022, https://www.britannica.com/biography/Thomas-Johann-Seebeck.

[7] "What Are Thermocouples Used for?" [¨¿Para qué se utilizan los termopares?¨] Enercorp Instruments What Are Thermocouples Used for Comments, 2020, https://enercorp.com/what-are-thermocouples-used-for/.

Heat Treat Today agradece la colaboración de estos expertos: **Dan Herring, The Heat Treat Doctor® del HERRING GROUP, Inc.**; **Hank Prusinski, Summit Aerospace Products Corp.; y Andrew Bassett, Aerospace Testing and Pyrometry.**



Heat Treat Future with AM and 3D Printing

By **Heat Treat Today** *Editorial Team*

All the buzz in our industry seems to indicate that additive manufacturing (AM) and 3D printing are the next hot topics in heat treat, particularly in vacuum heat treat. **Heat Treat Today** *decided to find out how these new technologies are shaping the industry. Read what five heat treat industry leaders had to say about how their companies are preparing for the next generation of AM and 3D printing.*

Dennis Beauchesne, General Manager, ECM USA, Inc.

What changes have you made to accommodate the AM/3D printing marketplace?

The most important changes relate to the build plate size and how it connects to our standard size systems. Build plates are ever-changing, it seems, as customers have new applications and mostly larger build plates are being requested. In addition, the process parameters — such as temperature and time at temperature and quantity of material — are important. These two items have the most to do with reconfiguring equipment for the AM market. We have also been able to implement our wide range of automation and robotics skills into this equipment as the market scales up for high production.

How will your products and/or services change to accommodate this marketplace?

We are/will be introducing equipment that is in-line with standard-build plate dimensions along with reducing operating costs.

Share how 3D printing or AM products/services help heat treaters.

Recent debind and sinter applications have involved, as previously mentioned, complete robotics to handle parts after printing, to debind, to sinter, and then to process specialized by ECM, such as low-pressure carburizing. ECM has also provided equipment to provide all three processes in the same furnace without moving the load or requiring the furnace to cool and reheat. This reduces work processing time along with less handling and less utility cost.

Mark Hemsath, Vice President Sales, Furnaces and Heat Treating Services, Nitrex

What changes have you made to accommodate the AM/3D printing marketplace?

Nitrex Vacuum Furnaces, through its GM Enterprises acquisition, has moved heavily into additive manufacturing via large production MIM furnaces, which are able to both remove large amounts of powder binders and sinter the parts in the same process. We are in the process of installing and/or starting up five furnaces for these markets, and we have recently employed even more advanced concepts on high volume wax removal. A further trend is on higher value materials, like nickel and cobalt alloys and titanium, necessitating diffusion vacuum levels for processing. Nitrex Vacuum has had this experience already for many years, so moving to smaller scale 3D designs comes with years of experience.

How might your products and/or services change to accommodate this marketplace?

Smaller units are a trend to keep an eye on. We have over a decade of learning from the large units we offer, and this will allow us to compete in these lower volume markets (i.e., 3D) via our proven expertise.

Several facts/ideas that we are keeping top of mind are:

- Large potential in the future (whole new market starting to evolve)
- Redesign the product to meet the new needs
- Good for rapid prototyping and quick low volume parts
- Furnaces need to be available with fast delivery

3D printing is finding a tremendous niche in fast part production, sourced internally or sourced quickly. These parts may cost more per piece, but having them fast is often more important, and 3D offers this ability to cut weeks or months off of supply chain sourcing.

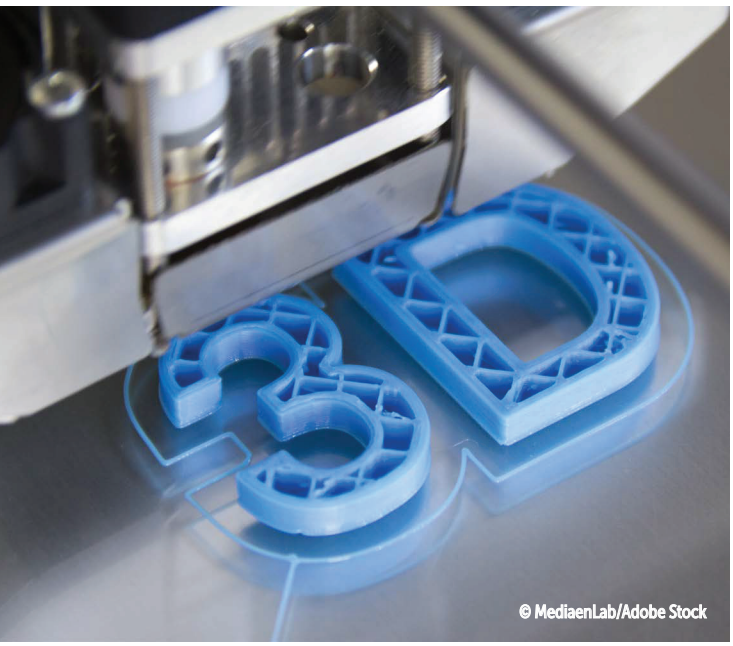
Share how 3D printing or AM products/services help heat treaters.

The AM sector is still in growth mode. How we help is to give a full-service solution to those customers who want to really increase their volume yet use vacuum in the process. Vacuum helps to transport the binder vapors away from the parts and into the traps for removal. Full binder removal adds to the quality of the parts, as does vacuum sintering of the final parts. We have supplied a few systems over the years with higher, diffusion vacuum levels. As powder materials evolve to higher value materials, there is more interest in diffusion vacuum, and we recently supplied such a system.

What do readers need to know about AM/3D to make decisions today?

Vacuum is the proper way to debind and sinter.

Additionally, 3D printing started slow and there were many technologies evolving. Now, it has started to really grow, and the need for smaller furnaces that can offer the same quality as MIM parts produced in high volumes will be a need for 3D part makers, in medium to low volume parts. This may involve furnaces for sinter only, debind and sinter, or even sinter and heat treat. We can see the need to both sinter 3D parts in a small furnace and also heat treat them with special added processes and surface treatments.



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Phil Harris, Marketing Manager, Paulo

What changes have you made to accommodate the AM/3D printing marketplace?

Adding a hot isostatic press has been the most notable change Paulo has made to serve the growing AM market. It goes a step further than that though; heat treatment of AM parts has rapidly evolved, and the desire for custom cycles and more data has caused us to make instrumentation changes and do more R&D type work. Understanding the full production path of the parts and doing our part to reduce the time parts are spending in post-processing steps, including offering stress relief, HIP, EDM, and vacuum heat treatment in a one-stop-shop.

How might your products and/or services change to accommodate this marketplace?

As trials continue and boundaries are pushed for both additive and the accompanying thermal processing, we're constantly keeping an eye on what's next. Investing in equipment that's capable while maintaining and instrumenting it to provide the data and reliability the market needs is the name of the game. Of course, open communication with additive manufacturers and printer designers makes this far easier. We value communication with printer manufacturers as it helps us understand demand for our services in terms of build plate size, since, as we all know, furnaces and HIP vessels aren't one size fits all!

Share how 3D printing or AM products/services help heat treaters.

Additive parts have become commonplace and we're now regularly providing HIP, stress relief, and solution treating for them. A more interesting example is for parts printed in Inconel 718; we've developed a combined HIP and heat treat (or High Pressure Heat Treat) cycle which was able meet material properties specifications when the traditional processing techniques were not. This is where we feel the real cutting edge is when it comes to heat treatment of additive parts; the slow cooling HIP cycles developed for casting decades ago aren't always optimal for today's additive parts.

Trevor Jones, President, Solar Manufacturing, Inc.

What changes have you made to accommodate the AM/3D printing marketplace?

There are several methods for 3D printing and we as heat treaters and vacuum furnace manufacturers generally classify those methods into two basic groups: those that use liquid binding polymers and those that do not.

For the group who does not use liquid binding polymers, there are no changes thus far to the design of the vacuum furnace that must be made. One significant caution is insuring there is no loose powder on the surface or cavities of the parts. Residual powder on or in the parts could have adverse effects on the parts themselves and to the vacuum furnace. The loose powder can liberate from the part during the heat treat or quench steps during the process and contaminate the vacuum furnace. The powder in the furnace is then considered FOD (foreign object debris) for subsequent heat treatments processed in that furnace. The powder could also accumulate over time and cause an electrical ground the heating elements or the quench motor, clog the heat exchanger, contaminate vacuum gauges and hot zone insulation, among other issues.

For the group that does contain liquid binding polymers, in addition to the comments about avoiding loose powder on or in the parts, care must also be taken to accommodate for the vaporization of the binder that occurs during heating of the parts. The binder, in its vapor form, will condense at cooler areas in the vacuum furnace. The condensed areas are potential contamination points and could have all the same issues and concerns of loose powder as described above. The binder collection locations, whether at intentional or non-intentional places, will also have to be routinely cleaned to maintain ideal

binder collection, optimum vacuum pumping, and overall furnace performance.

How might your products and/or services change to accommodate this marketplace?

With the growth of 3D printing using liquid binder polymers, Solar Manufacturing has taken what was learned from the furnace modified at Solar Atmospheres of Western PA for MIM and AM processing and applied it to a new furnace product line specific for the debind and sinter applications. Solar Manufacturing collaborated with our affiliate company, Solar Atmospheres of Western PA, in modifying an existing vacuum furnace to accommodate the debind and sintering processes. A modified hot zone was installed, and a dedicated binder pumping port was added that helps minimize and target the condensation of detrimental binders evaporating out of parts containing binders. The modified Solar Atmospheres furnace is extremely valuable in gaining knowledge about various aspects of the process and learning what works, and what does not work, in furnace and recipe design. Combining the knowledge and experience of process development of Solar Atmospheres with the advanced Engineering Design Team at Solar Manufacturing, we believe we have a furnace design that modernizes and simplifies the debinding process while minimizing traditional maintenance issues.

Share how 3D printing or AM products/services help heat treaters.

We developed a process of debinding and sintering stainless steel parts with our affiliate company Solar Atmospheres in Souderton PA. The project started out with our Research and Development group to develop the process for the client's parts. As the trials scaled up, test coupons became test parts, eventually full-size loads. There are always challenges to scaling up from test parts to production loads and we were able to provide the support the customer needed through that transition. The R&D efforts were successful, and the client ended up purchasing multiple furnaces, which was the end goal for both parties.

Additionally, Solar Atmospheres is currently vacuum stress relieving a 3D component for a major U.S.-based aerospace company that is in use in aircraft today. Also, numerous large-scale components destined for deep space.

What do readers need to know about AM/3D to make decisions today?

Bob Hill, president of Solar Atmospheres of Western PA, reminded us to "realize and acknowledge that AM is still in its infancy stage. Therefore, many metallurgical uncertainties still exist for the multiple printing processes that exist. Understanding this new kind of metallurgy for each printing process, while developing standards and specifications unique to additive manufacturing, is still a huge obstacle. Until this is accomplished, AM will not be the 'disruptive' technology that all the experts predict it will be."

If your business is printing parts with liquid polymer binders, you should seriously consider how you plan on debinding and sintering the parts ahead of time. Printed parts in the "Green" or even "Brown" state are fragile and if you are going to ship the parts somewhere else for the debind and sinter steps, extreme care must be taken to prevent the parts from fracturing during transit. Although the shipping can be safely and successfully accomplished, ideally a furnace is available at the print shop to immediately perform the debind and sinter process to avoid those potential shipping difficulties. The other forms of 3D printing that do not contain liquid polymers generally do have this issue.

Ben Gasbarre, Executive Vice President, Sales & Marketing, Gasbarre Thermal Processing Systems

What changes have you made to accommodate the AM/3D printing marketplace?

From our inception, Gasbarre has had expertise in the powder metallurgy industry, which requires debind and sinter applications similar to that in the AM and 3D printing markets. Our ability to supply equipment for both powder and parts producers has set us up for quick adoption into this market. While considerations need to be made specific to AM, our focus has been on technical support and helping the market grow to higher volume applications.

How might your products and/or services change to accommodate this marketplace?

As adoption of these technologies grow, the volume at which parts need to be produced will grow. Our line of continuous processing equipment in both vacuum and atmosphere applications are well suited. Whether it be debind

and sinter, annealing, or stress relieving, we have equipment and expertise that can grow from early production to high volumes.

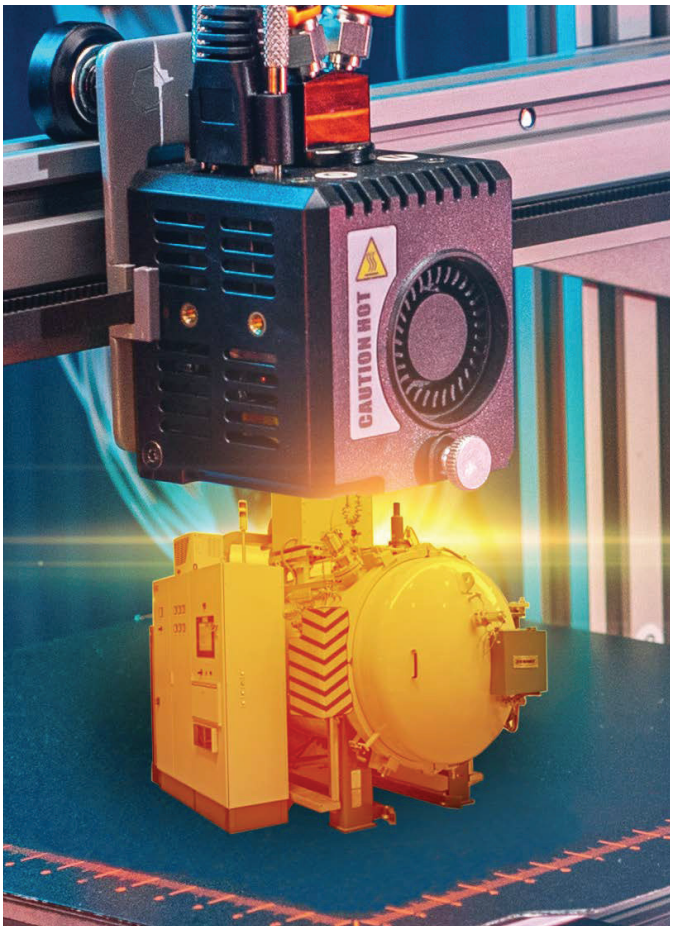
Share how 3D printing or AM products/services help heat treaters.

Overall, Gasbarre is here to be a resource and support the growth of the additive market. Whether that be through new equipment, servicing existing equipment, or involvement in the industry organizations, we have the expertise to drive success today and into the future!

What do readers need to know about AM/3D to make decisions today?

Additive manufacturing is such a dynamic technology, it is difficult to state one specific item. There is the potential for significant growth opportunities for new applications, but also the potential replacement of traditional manufacturing methods. We also know there is substantial backing for the technology by both private industry and government entities. Like other emerging technologies in the automotive and energies sectors, additive manufacturing isn't a matter of if, but when it'll achieve wide scale adoption and high-volume applications.

It is amazing how the list of materials being utilized with this technology is growing. While metals and alloys have not been the majority of the market, it is rapidly growing. With that growth, there is a wide variety of applications and thermal processing requirements for those materials. As well, the different additive and 3D printing processing methods (i.e., binder jetting, powder bed fusion, etc.) leads to a similar diversity in thermal processing requirements. HTT



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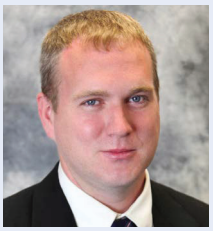

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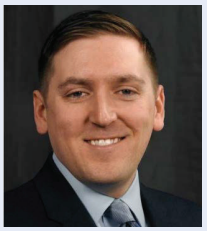

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CFC Fixture Advantages and Challenges in Vacuum Heat Treatment, Part 1

By Dr. Jorg Demmel, Founder, Owner, and President, High Temperature Concept

What happens when a lead engineer sticks his head in new advancements in materials from NASA? For the author of this article, it means the successful research and development of a new generation of workpiece carriers and fixtures made from "a high-tech ceramic matrix composite of very strong carbon fiber," that is, CFC.

Introduction: From NASA to Industrial Heat Treatment

In the mid-1990s, a development in materials from NASA moved into my focus. I was an associate and lead engineer at the Fraunhofer Institute in Stuttgart, Germany, so I posed the question: Could CFC material (carbon fiber-reinforced carbon) substitute for non-abrasion-resistant and brittle graphite as the material used for workpiece carriers in the soldering process of drills? The answer: yes.

The story did not end here. This project, which included the automated handling of the drills in some continuous furnaces, was just the first accomplishment. What ensued was a successful research and development of a new generation of workpiece carriers and fixtures made from CFC ("Carbon Fiber Carbon").

Material Properties and Main Advantages of CFC

CFC (aka, CFRC, or C/C), which stands for carbon fiber-reinforced carbon, is a high-tech ceramic matrix composite of very strong carbon fibers (or fiber rovings) in a compensative carbon (graphite) matrix.

Material properties of some relevant heat treatment fixture materials were evaluated, and some are shown in Figure 1.

These CFC properties have the following positive effects when used as CFC fixtures for heat treatment:

- Because of their low density, CFC fixtures have a *lower weight* than their steel alloy counterparts (about five times), which reduces the efforts for manual handling.
- Because of the increased strength of CFC at high temperature, the fixture weight can be reduced further. Additionally, fixture volume can be reduced — in some applications dramatically — so that, when combined with a specific CFC fixture design, *furnace capacities* can be increased up to 100%.

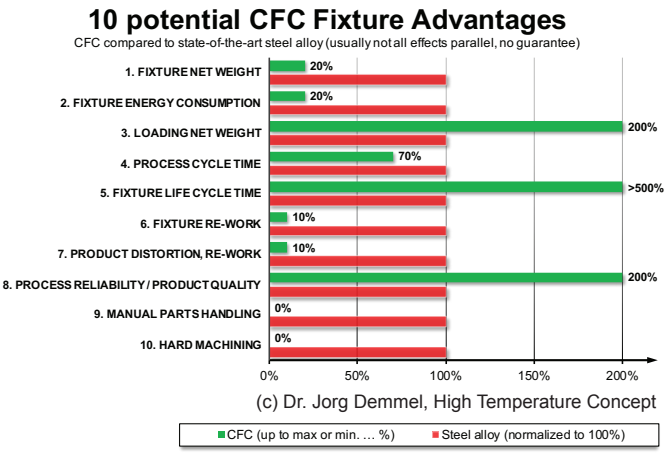

Figure 2. CFC fixture advantages in heat treatment

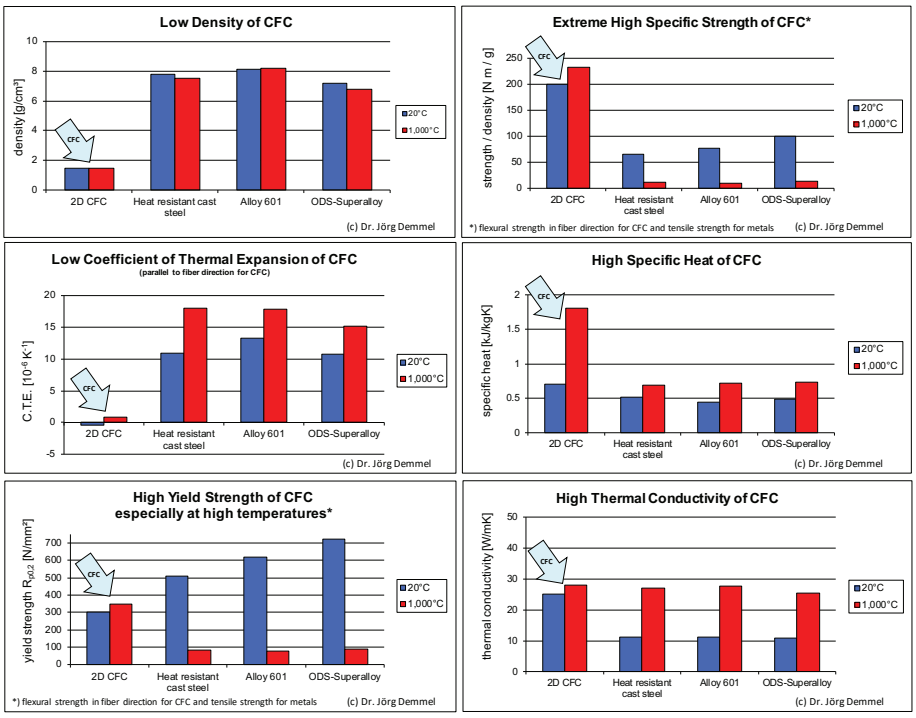

Figure 1. Left to right for 2D CFC SGL Sigrabond Performance, heat resistant austenitic cast alloy steel ASTM A297-HK (ISO G-X 40 CrNiSi 25-20; 1.4848), wrought and annealed Ni alloy Inconel 601 UNS N06601 (NiCr23Fe15Al; 2.4851) and mechanically alloyed Fe alloy, oxide dispersion strengthened Plansee PM ODS 2000 (Cr Al 21 6; 1.4768).

- The following characteristics of CFC fixtures are responsible for the longer fixture life cycles (up to greater than five times), less workpiece distortion and rework, and make an *automatic workpiece handling* possible for the first time ever: the low CTE (coefficient of thermal expansion) value for CFC in the direction of the fiber, the fact that CFC is chemically inert in vacuum or certain protective atmospheres, has an excellent thermal shock resistance, and it doesn't grow, creep, or age like metals.
- Although the specific heat of CFC is higher, the *energy consumption* can be reduced and *shorter heating up and cooling down times* can be reached, resulting in up to 30% *shorter process cycle times* for the same workpieces.

Figure 2 shows all potential advantages of CFC fixtures compared to state-of-the-art steel alloy; a short payback time of the investment with high profitability are possible.

CFC Fixture Suitability in Vacuum Heat Treatment

Since CFC is made of carbon, it is not made for high temperatures above 752°F (400°C) in air or atmosphere with high percentages of oxygen, water vapor, hydrogen, or carbon dioxide for long periods of time. Therefore, vacuum or protective gas atmospheres are, in general, a suitable environment for CFC fixtures.

Table 1 shows the relative reaction rates for graphite according to H. Marsh in *Introduction to Carbon Science, 1989* in the "reaction controlled" Zone I up to 1472°F (800°C) under oxygen, steam (H_2O), carbon dioxide, and hydrogen.

Table 1 is a good first fit for an estimation for the reaction rates and oxidation resistance of CFC in different atmospheres. The reaction rates increase to higher temperatures: Zone II 1472°F–1832°F (800–1,000°C) "transition area btw. reaction and diffusion" and later Zone III > 2012°F (1,100°C) "diffusion controlled," as noted in Marsh. Figure 3 shows the effect following the carbon combustion reaction after equation (1), following Marsh.

Industrial experience shows that CFC under vacuum of < 10^{-2} mbar at 1472°F or 1832°F (800°C or 1000°C) at a low dew point < -4°F (-20°C) (< 0.1 % vapor content) lasts at least 5,000 hours (real process time). At 3632°F (2000°C), the life is about 2,000 hours. Dew points of about 0°C (about 0.6 % vapor) cause

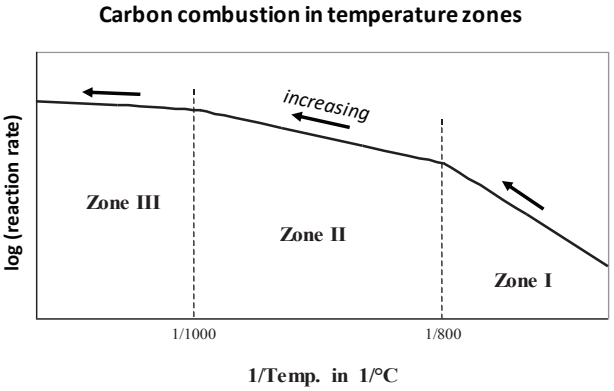

Figure 3. Burning rates of graphite as a function of temperature

reaction	relative reaction rates
(1) $C + O_2 \rightleftarrows CO_2$; $\Delta_R H = -393.5 \frac{kJ}{mol}$; $\Delta_R G < 0$	1 x 10^5
(2) $C + H_2O \rightleftarrows CO + H_2$; $\Delta_R H = +131.3 \frac{kJ}{mol}$; $\Delta_R G < 0$ above 674°C	3
(3) $C + CO_2 \rightleftarrows 2\ CO$; $\Delta_R H = +172.4 \frac{kJ}{mol}$; $\Delta_R G < 0$ above 700°C	1
(4) $C + 2\ H_2 \rightleftarrows CH_4$; $\Delta_R H = -74.9 \frac{kJ}{mol}$; $\Delta_R G < 0$ below 546°C	3 x 10^{-3}

Table 1. Reaction rates and activation energies for graphite (800 °C; 0.1 bar). Equation (1) is the main combustion reaction, which has the strongest effect and is strongly exothermic (negative change of reaction enthalpies Δ"H). Reaction (2) is the so-called water gas reaction which shows the endothermic oxidation of carbon with vapor. Equation (3) is the Boudouard reaction which occurs endothermic above 700 °C. According to the Boudouard equilibrium the C0/CO₂ ratio increases with increasing temperatures and decreasing pressures. Reaction (4) is the methane formation reaction: hydrogen reacts with carbon at temperatures above about 700 °C to CH4. Below 546 °C methane decomposes in carbon and hydrogen.

higher reaction rates and reduce lifetime to about 800 to 1,000 hours.

Unwanted Contact Reactions

Contact reactions between the CFC fixtures and the workpieces, primarily made of steel, can lead to changes in the workpieces: for example, carburization of the workpiece in contact with the CFC. It is important to avoid these contact reactions since the properties of the workpieces must under no circumstances be changed in an uncontrolled manner. Neither the chemical composition nor mechanical properties nor the surface may change beyond the permissible tolerance limits. The CFC fixture should also not be subject to any changes that could adversely affect its properties and, above all, its service life.

The following materials, consisting of mainly workpiece materials made of steel, were used in direct contact with CFC, especially in heat treatment and brazing. CFC 1501G (SGL), CF222 (Schunk), or CX-27C1 (GTD, Toyo Tanso) were used as CFC workpiece carrier materials. Table 2 gives an overview of the results. The symptoms columns with "none" indicate no problems. The colored cells showed problems. The last column references the application or the results.

The contact partners and processes in which unwanted contact reactions occurred in the field test (colored in Table 2) and which are not confidential (**bold** font) are examined more closely in Part 2. See Figure 5 which shows some contact reactions on tempered steel drills after vacuum hardening at 2066°F (1130°C) under vacuum of 0.3 mbar (0.3 hPa or 225 mm Hg or "micron").

Figure 6 shows some heavy melting reactions of high-speed steel after vacuum hardening at 2264°F (1240°C) under vacuum of 0.1 mbar (0.1 hPa or 75 mm Hg or "micron").

The carbon transmission mechanism with unwanted carburization, along with eutectic reaction of some workpieces made of steel with CFC, and some technical solutions will be explained in Part 2 of this article. HTT

CFC quality	workpiece material	prozess	T_{max} in °C	atmosph./ cooling	number cycles	symptoms workpiece	symptoms CFC	evidence / example
CF222	C10, 16MnCr5; X15CrNiSi25-20 (carrier mat.)	case hardening	950	$H_2/N_2/CO$	appr. 600 [5]; today > 2,500	none	none	Fig. 4 top left (Prewi comp.)
CF222, 1501G, CX-27C1	34CrNiMo6, 16Mn5, 51CrV4 and 34Mn5	annealing	870	$H_2/N_2/CO$	appr. 500 [5]; today > 4,000	none	none	Fig. 4 top middle (Wiha)
CF222, 1501G	**34CrNiMo6 (1.6582)**	**vacuum hardening**	**1,130**	**0,3 mbar, 10 bar N_2**	**up to 20**	**partial melting**	**gluing, dissolution**	**Figures 5** confidential
1501G, CX-27C1	NiCr23Fe	vacuum brazing	1,120	10^{-2} mbar	appr. 500; today > 2,500	none	none	Fig. 4 top right (Modine)
CF222, 1501G	**HS 6-5-2 (1.3433), HS 6-5-2-5**	**vacuum hardening**	**1,240**	**0,1 mbar, 6 bar N_2**	**appr. 10**	**melting (droplets)**	**melting, dissolution**	**Figures 6**
CX-27C1	HS 6-5-2, X100CrMoV5	CVD coating	1,000	400 mbar, Ar, He	appr. 100; today > 2,000	none	layer on CFC	Fig. 4 below right (TTC)
CX-27C1	Titanium and Ti alloys	HIP	1,000	10^{-5} mbar	appr. 50; today > 1,000	none	none	Figure 4 below left (Rolls-Royce)
CF222	hard metal made of 95% Fe, 0,8% C, 4% Ni, 1% Mo	sintering	1,150	H_2, N_2, 1 bar	appr. 2	melting; but, atmosphere problems	dissolution	confidential

Table 2. Contact/carburization test results from field trial, updated 2022

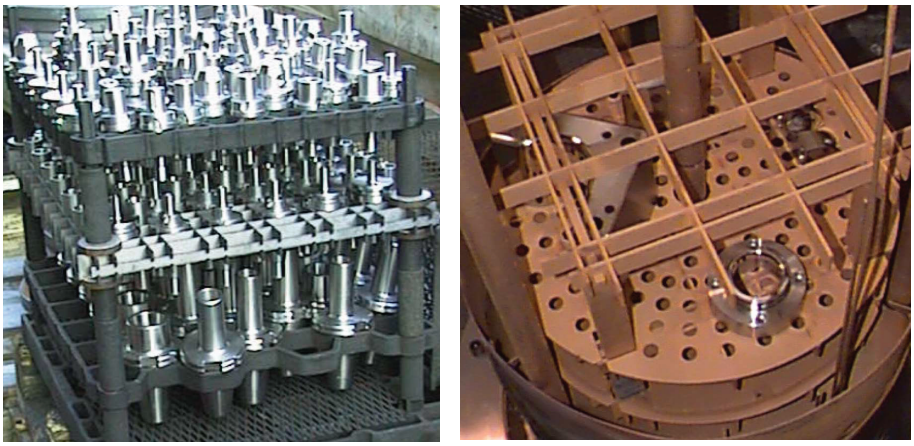

Figure 4a and 4b. From left to right: CFC level grid (case hardening, oil quench); CFC-Rack CVD-Coating

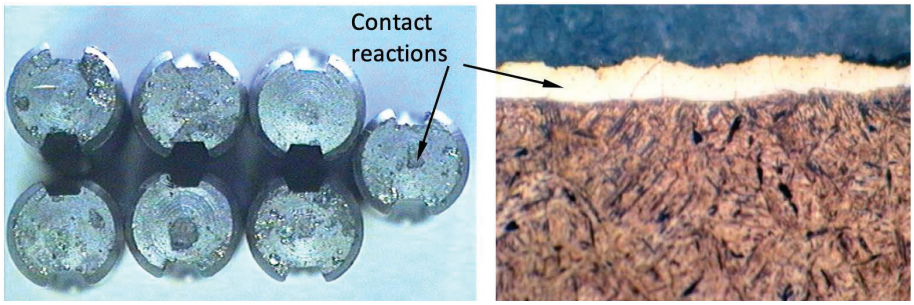

Figure 5. Contact reactions on drill blanks (1.6582) with SiC-coated CFC (Schunk CF222P75 and SGL 1601YI); Scale left about 2:1 and right microsection about 400:1

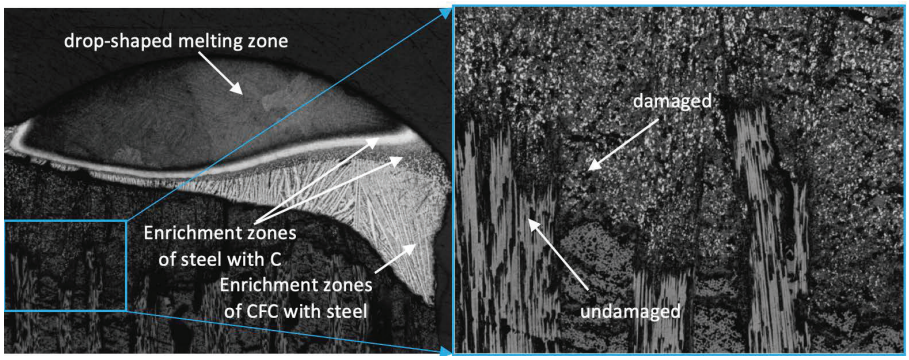

Figure 6. 1.3343 after contact with CFC CF222 at 2282°F (1250 °C) (left approx. 25:1; right detail 100:1)

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About the Author:

Dr. Jorg Demmel is the founder, owner, and president of High Temperature Concept. He received his Engineering Doctorate in the field of CFC workpiece carriers for heat treatment and served in different leading positions for Volkswagen before moving to the U.S. In this article, Demmel draws on his dissertation, "Material scientific aspects of the development of new Fixtures for high temperature processes made of fiber-composite ceramics C/C and other high temperature materials" (Technical University Mining Academy Freiberg, Germany, 2002/3), and his personal experiences.

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The DFARS Interim Rule and What It Means for Heat Treaters

Joe Coleman
Cybersecurity Officer
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Introduction

As the next installment in this series of articles on cybersecurity, this third article will give you a better understanding of the Department of Defense's DFARS interim rule and its requirements.

DFARS Interim Rule

On September 29, 2020, the Department of Defense (DoD) published the DFARS (Defense Federal Acquisition Regulation Supplement) interim rule 2019-D041, Assessing Contractor Implementation of Cybersecurity Requirements, with an effective date of November 30, 2020. These new clauses are an extension of the original DFARS 252.204-7012 clause that has been required in DoD contracts since 2018.

The interim rule implements the NIST SP 800-171 DoD Assessment Methodology and the CMMC (Cybersecurity Maturity Model Certification) framework. The interim rule requires contracting officers to take specific action prior to awarding contracts, giving task or delivery orders, or extending an optional period of performance on existing contracts on or after November 30, 2020.

DFARS 252.204-7019 Clause: Notice of NIST SP 800-171 DoD Assessment Requirements

All DoD contractors in the Defense Industrial Base (DIB) must complete a self-assessment using the DoD's NIST 800-171 Assessment Methodology and generate a points-based score. If the self-assessment score falls below 110, contractors are required to create a POAM (Plan of Action and Milestones) and indicate by what date the security gaps will be remediated and a score of 110 will be achieved as part of the Supplier Performance Risk System (SPRS). At the time of a DoD contract award containing the new 7019 clause, a DoD contracting officer will verify that a score has been uploaded to the SPRS.

DFARS 252.204-7020 Clause: NIST 800-171 DoD Assessment Requirements

Along with the 252.204-7012 and 7019 clauses, the 7020 clause is approved for use in all DoD contracts. This new clause requires that contractors provide the government with access to its facilities, systems, and personnel when it is necessary for the DoD to conduct or renew a higher-level Assessment. The higher-level Assessments are the Medium and High Assessments. The self-assessment conducted as part of the 7019 clause is called a Basic Assessment.

A Medium Assessment is conducted by DoD personnel and will include a review of your System Security Plan (SSP) and how each of the requirements are met and to identify any language that may not adequately address the security requirements.

A High Assessment is conducted by DoD personnel onsite at the contractor's location and will leverage the full NIST SP 800-171A (Assessing Security Requirements for Controlled Unclassified Information) to determine if the implementation meets the requirements by reviewing evidence and/or demonstration such as recent scanning results, system inventories, baseline configurations and demonstration of multi-factor authentication and/or two-factor authentication.

Along with that, this rule also requires that contractors flow down their requirements from 7019 to their subcontractors and suppliers. Just as the DoD may choose not to award a contract due to noncompliance, you may not be able to use a subcontractor or supplier due to their noncompliance.

DFARS 252.204-7021 Clause: Cybersecurity Maturity Model Certification (CMMC) Requirements

This DFARS clause establishes CMMC into the federal regulatory framework. This requires that CMMC is to be included in all contracts, tasks or orders, and solicitations, with very few exceptions. The level of CMMC that is required will be determined by the DoD and added into the Request for Proposal. Contractors must maintain the appropriate CMMC level for the duration of any contract and the requirements must be trickled down to your subcontractors and suppliers. The CMMC certification is required at the time of contract award.

Watch For the Next Cybersecurity Desk Installment

My next article, number four in the series, will be: "General Cybersecurity Best Practices and What You Should and Should Not Do." HTT

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DUAL PERSPECTIVES: Europe vs. North America

Changes are inevitable, and the world today is changing so rapidly that it's constantly keeping us on our toes. Do two men from different parts of the world, both with significant experience in the heat treating community, have vastly different perspectives on the happenings in the industry? Thomas Schneidewind, editor-in-chief of heat processing magazine, and Doug Glenn, publisher and founder of Heat Treat Today, will answer a pressing, heat treat industry question in each issue. Thomas's expertise lies in the European market while Doug's resides in the North American market. Will their views align? Read to find out.

How does government policy regarding ESG in the U.S. and nuclear power initiatives in Europe impact in-house heat treaters?

Thomas Schneidewind, Editor-in-Chief, heat processing magazine

The energy crisis paralyzes Europe.

The European Union has been arguing for a long time about which energy is green. Finally, the European Commission classified both nuclear energy and gas-fired power plants as green energy production. This was a compromise between France and Germany in the discussion about the taxonomy that regulates in which energy sources investments should be made. Today, environmental associations are suing against this compromise, considering neither nuclear energy nor gas-fired power plants to be green energy.

However, the discussion is long outdated. The Russian war of aggression on Ukraine has changed energy policy. Many nuclear power plants in France are at a standstill. Germany no longer receives gas from Russia, and the sabotage of the Nord Stream 1 and 2 pipelines is a politically motivated attack on the European energy market. Today, Europe is suffering from a major energy crisis. There has never been such a crisis in the energy sector in Europe since the Second World War. There is too little energy on the European market. At the moment, the focus is on security of supply.

This crisis threatens the existence of energy-intensive companies such as heat treatment shops. The hardening industry is also coming under pressure because it cannot pay the high electricity and gas prices. Entrepreneurs must find short-term solutions to cushion the cost shock, and ensure the survival of their business —with a view to the long-term goal of decarbonization. Because in the future, process heat must be CO_2 free. A clear trend in this context is the switch from gas-heated industrial furnaces to electrically heated systems, whether resistance heating or induction. Managers must face these diverse issues today and respond quickly.

Experts and practitioners will be talking about sustainability, materials, processes, and innovations in heat treatment at several events this fall. For example, in October, after a two-year pandemic break, the Hardening Congress (HK) was finally held again in Cologne. Here, too, the energy crisis was a dominant topic. We are talking about the future of Europe which must compete with the U.S. Many investment decisions are being put on hold because the uncertainty in Europe is currently too large. Europe, but especially Germany, faces a new recession.

Doug Glenn, Publisher, Heat Treat Today

Tremendously.

A distinctive mark of the U.S. is that we've trusted the Market — what Adam Smith called the "Invisible Hand." We haven't believed that economies need to be planned or managed; attempts to manage or plan an economy result in more damage than good. We've believed that if proper natural or biblical law guardrails are established and enforced, the economy would run itself, self-adjusting as necessary. Today, many have lost faith in the Market. Instead, we put our faith in political processes and political leaders to handle the economy.

Because we've lost faith in the Market, questions such as the one we're addressing today make sense to ask. Government policy should have nothing to say about the type of energy we use, the people we hire, or the ideals we hold. Nonetheless, that is NOT the world we live in, so let's address the question.

Nuclear Power Initiatives

This is really not an initiative; it is more of a "de-initiative" — a closing down of nuclear power plants in Europe (except France) — and the incentive to do so is not economic. According to those who know, nuclear is the cheapest, most reliable form of energy, vastly less expensive than "renewables." So, in the hands of the Market, nuclear and natural gas generation power plants would win the day. Nuclear is being abandoned for purely political reasons. The effect on heat treaters and all other consumers of electricity: higher prices for energy, either in the form of explicitly higher prices per BTU or higher taxes to incentivize more expensive "renewable" energy sources.

Environmental, Societal, and Governance

As far as ESG goes, government policies in these areas will only increase the cost of doing business.

ONE of the three categories represents an area where the government might have a right to be heard: environmental. But even there, government's scope is vastly overplayed — that is, if you have faith in the Market! Societal and governance are recent (non-economic) constructs being forced on businesses, NOT for the benefit of the end-consumer, but for the benefit of a vocal minority who believe the world should be a certain way and are using government policies to make it so.

For in-house and commercial heat treaters, ESG pressures and government recommendations or policies will raise the cost of doing business and ultimately the cost of the final product for consumers with very little measurable benefit for anyone.

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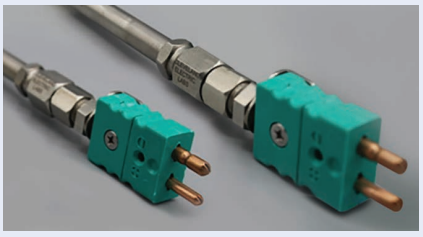

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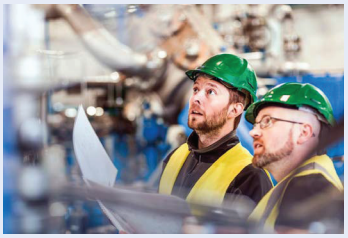

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Heat Treat Today *is partnering with* **heat** processing*, a Vulkan-Verlag GmbH publication that serves mostly the European and Asian heat treat markets. Together, we are sharing the latest news, tech tips, and cutting-edge articles that will serve our audience — manufacturers with in-house heat treat.*

In this issue, we look to our European information partner for updates on industry events around the globe and glimpse into the modernization and retrofitting process for a foundry in Switzerland.

Four Upcoming Trade Fairs

"From 23 to 25 November 2022, the four regional Indian metal trade fairs Wire India, Tube India, METEC India and India Essen Cutting & Welding will open their doors at the Bombay Exhibition Centre in Mumbai. Wire, cable, tube and pipe products are indispensable for investments in India's growing infrastructure as well as house, road, bridge and canal construction."

Read More: *"Metal industries look forward with excitement to regional trade fairs in Thailand and India"* at heat-processing.com

Four Upcoming Trade Fairs

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Read More: *"ABP: Modernization at Vonroll Casting with Retrofit"* at heat-processing.com

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"Mona Neubaur, Minister for Economy, Industry, Climate Protection and Energy of North Rhine-Westphalia opens the ecoMetals Day. . . . More than 25 Green Steel, Green Energy and Circular Economy pioneers from companies, associations, science and politics will present top-class lectures and panel discussions. They will illustrate why decarbonization . . . is a joint task that can only be solved in close cooperation with the energy and digital industries."

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- 30"W x 30"H x 48"L, 1750°F, Electric, Surface Combustion
- 30"W x 24"H x 48"L (60"L actual), 1450°F, N2 Atmosphere
- 10'6"W x 6'H x 35'L, Gas Fired, 1650°F, Drever, Atmosphere
- 36"W x 36"H x 72"L, Surface Combustion, 1750°F, Gas Fired
- 48"W x 48"H x 96"L, L & L Special Furnace, 2200°F, Gas Fired
- 15"W x 12"H x 18"L, Lindberg Sinterall, 2100°F, H2 Atmos.
- 30"W x 30"H x 48"L, Surface Combustion, 1450°F, Gas
- 36"W x 30"H x 48"L, Surface Combustion, 1250°F, Gas

BELT OVENS
- 18"W x 5"H x 10'L, 500°F, Electric, Despatch
- 30"W x 15"H x 10'L, Grieve, 400°F, Electric
- 18"W x 23"H x 12'L, Jensen, 550°F, Gas Fired

INTEGRAL QUENCH FURNACES
- 36"W x 36"H x 48"L, Surface, Electric, 1750°F Combustion
- 24"W x 18"H x 48"L, 1850°F, Gas Fired, Ipsen T-8, 2 Zones
- 30"W x 20"H x 48"L, Gas Fired, 1750°F, Surface Combustion
- 36"W x 36"H x 48"L, Surface, Gas, 1750°F
- 36"W x 36"H x 48"L, AFC, Gas, 1750°F
- 30"W x 30"H x 48"L, Surface/J.L. Becker, 1750°F, Top-Cool, Gas Fired
- 24"W x 18"H x 36"L, Ipsen T-4, 1850°F, Gas Fired
- 30"W x 30"H x 48"L, Lindberg, 1800°F, Electric

ROLLER HEARTH FURNACES
- 60"W x 13"H x 40'L, Electric, 1600°F, Atmosphere, Wellman

ROTARY HEARTH FURNACES
- 50" Dia, 18"W x 9H Door, Electric, 1600°F

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- 100 kW, 10 kHz Inducto-Heat
- 300 kW, 3/10 kHz Inducto-Heat BSP5
- 100 kW, 3/10 kHz Inducto-Heat BSP
- 150 kW, 3/10 kHz Tocco Inductron II
- 100 kW, 10 kHz Ajax/Tocco, 48" Scanner
- 150 kW, 3/10 kHz Ajax/Tocco, 48" Scanner

WALK-IN OVENS
- 72"W x 72"H x 120"L, CEC, 1000°F, Gas Fired

WALK-IN OVENS (cont.)
- 48"W x 72"H x 48"L, Precision Quincy, 1000°F, Gas, Solvent
- 55"W x 60"H x 30"L, 350°F, Electric, Precision Quincy
- 48"W x 72"H x 48"L, 1250°F, Gas Fired, TPS - 4 Available
- 72"W x 78"H x 117"L, Despatch, 500°F, Electric, Solvent Rated
- 48"W x 72"H x 84"L, Grieve, 850°F, Electric, Atmosphere
- 48"W x 72"H x 48"L, Grieve, 500°F, Electric, Double Ended
- 48"W x 48"H x 72"L, Grieve, 650°F, Electric
- 48'W x 72"H x 60"L, Grieve, 500°F, Gas
- 36"W x 60"H x 48'L, Grieve, 350°F, Electric
- 36"W x 72"H x 48"L, Gruenberg, 300°F, Electric
- 30"W x 76"H x 48"L, Precision Quincy, 1000°F, Electric
- 72"W x 75"H x 120"L, Grieve, 450°F, Electric
- 68"W x 72"H x 72"H, Gruenberg, 500°F, Electric

CABINET OVENS
- 36"W x 48"H x 24"L, Electric, 600°F, Blue M, Class "A"
- 25"W x 20"H x 20"L, Electric, 650°F, Inert Gas, Blue M
- 48"W x 36"H x 24"L, Electric, 500°F, Inert Gas, Blue-M
- 25"W x 20"H x 20"L, Blue M, 1300°F, Electric
- 20"W x 20"H x 18"L, Blue M, 1100°F, Electric, Atmosphere
- 36"W x 36"H x 36"L, Grieve, 500°F, Electric, Double Chamber
- 36"W x 36"H x 36"L, Grieve, 850°F, Electric, Double Chamber

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- 28" Dia x 28"Deep, Lindberg, 1250°F, Gas
- 38" Dia x 48"Deep, Wisconsin, 1250°F, Electric, 2 Avail.
- 38" Dia x 48"Deep, Lindberg, 1250°F, Electric, 3 Avail.

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- 18"W x 11"H, SS Belt Washer, Electric, W/R & Blow-Off
- 12"W x 12"H, SS Belt Washer, Electric, W/R and Blow-Off
- 36"W x 36"H x 48"L, AFC, Dunk & Spray Batch Washer, Gas Fired
- 30"W x 20"H x 48"L, Surface Combustion Spray Only, Gas Fired
- 32"Dia x 18"H, ADF, Pass Thru Batch Washer, Electric
- 36"W x 18"H, SS Belt Washer, Gas, W/R/Blow-Off
- 24"W x 18"H, SS Belt Washer, Electric, W/R/Blow-Off

MISCELLANEOUS
- 48"W x 36"H 48"L, Despatch Quick Quench Drop Bottom, Electric 1000°F
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MTI Technical Standards Committee

Within any heat treating operation, quality drives everything, including quotes, contract review, and overall production. The #1 influences on quality are the technical specifications: the ones designed by the AMEC Committee in aerospace; the Nadcap checklist heat treaters must audit; and CQI-9 specifications in the automotive industry, which are overseen by AIAG. There are also major influences from ASTM in hardness testing and ISO 9000 and AS 9100 in quality department operations.

Needless to say, there are a plethora of specifications, data, and information required in the quality department to operate a heat treat plant. Sometimes it can seem impossible to keep up with all of the changes.

This is where the Metal Treating Institute's Technical Standards Committee becomes so valuable to any heat treat plant. The MTI Technical Standards Committee was established during the MTI's Winter Strategic Planning Committee meeting in 2015. After plentiful discussion on challenges facing heat treaters, the leadership felt heat treaters needed to be involved in the specification groups, giving them a voice in the design of the specifications and keeping them updated as specifications were being reviewed or changed.

The committee is now made up of 25 people from commercial heat treaters and suppliers. The committee meets three to four times a year to discuss all the specifications and audit checklists under review or issues needing improved. The committee thus determines any actions steps needed to make sure specifications maintain high levels of quality and safety without becoming onerous or cost prohibitive.

From each of the committee meetings, five to six key leaders on the committee provide a full report on each technical standard group's activity via a virtual Zoom meeting. The volunteer work and member reports on committee activities have become very valuable to quality departments by giving real time information on potential changes in specifications that could have a big impact on equipment purchases or overall quality process for audits.

Many of the specifications the MTI Technical Standards Committee has covered over the last seven years include AMS2759 (and all the slash specs), pyrometry with AMS2750, CQI-9 in the automotive industry, and hardness testing specs with ASTM.

In the MTI Technical Standards Committee, heat treaters have the power to find out the full details of specifications as they are reviewed prior to approval — *not* when the auditor shows up at audit time. Volunteering for one of these committee groups like AMEC, Nadcap, ASTM or CQI-9 includes getting to be part of the spec writing process and influencing what the final specification requires.

MTI would like to say thank you to the co-chairs of the MTI Technical Standards Committee: Ed Engelhard from Solar Atmospheres and Bob Ferry from FPM Heat Treating for providing to the industry their leadership of this very important committee. MTI would also like to thank the following companies for supporting their quality team's involvement in the committee:

- Applied Thermal Technologies, Inc.
- Aremac Heat Treating East, LLC
- Cincinnati Steel Treating
- Continental Heat Treating, Inc.
- Euclid Heat Treating, Co.
- Gasbarre Thermal Processing Systems
- Ipsen
- King Tester
- Midwest Thermal-Vac
- Pacific Metallurgical, Inc.
- Paulo Products
- Peters' Heat Treating, Inc.
- Pinson Valley Heat Treating
- Southwest Metal Treating Corp.
- Super Systems Inc.
- ThermTech
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- Winston Heat Treating

If you have any questions or would like more information on MTI's Technical Standards Committee, feel free to contact Tom Morrison at tom@heattreat.net

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24" x 16' x 12"	Lewco (New)	Elec 350°F
32" x 24' x 12"	OSI Slat Belt	Gas 450°F
36" x 20'	Cast Belt-Surface	Gas 1750°F
48" x 20' x 48"	Thermation	Gas 500°F
60" x 40' x 14"	Wellman Roller Hearth (Atmos)	Elec 1650°F
2000 #/HR	AFC Pusher Hardening (Atmos)	Gas 1750°F

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24" x 36" Lindberg Charge Car (Manual)
36" x 48" Surface Scissor Lift (2)
36" Diam. Viking Rotary Table Washer Elec
Garden City Alloy "Plug" Fans (2) - 1350°F
30" x 48" x 36" Surface Washer Gas
30" x 48" x 30" Surface Washer (2) Gas
(2) Bell & Gossett "Shell & Tube" Heat Exchangers
30" x 30" x 30" Subzero -105 to 375°F Elec.
30" x 48" Lindberg Charge Car
30" x 48" x 30" Surface D&S Washer Gas
AFC Pusher Line (Atmos.) Gas 1750°F
36" x 48" AFC Scissor Lift(6) Elec
36" x 48" Charge Car(DE) AFC - Elec (2)
36" Wide Table- Rotary Hearth (Atmos.) Elec 1850°F
36" x 48" x 36" AFC D&S Washer Gas
36" x 48" GoFF Shot Blaster Elec
36" x 48" Holcroft Charge Car (DE)
24" Wide Table Surface Rotary Hearth Gas 1750°F
SBS Air/Oil Collers (8)

OVENS/BOX TEMPERING

8" x 18" x 8"	Lucifer	Elec 1250°F
12" x 16" x 18"	Lindberg (3)	Elec 1250°F
14" x 14" x 14"	Blue-M	Elec 1050°F
14" x 14" x 14"	Blue-M	Elec 650°F
14" x 14" x 14"	Gruenberg (solvent)	Elec 450°F
19" x 19" x 19"	Despatch	Elec 850°F
20" x 18" x 20"	Blue-M	Elec 400°F
20" x 18" x 20"	Despatch	Elec 650°F
20" x 18" x 20"	Blue-M	Elec 650°F
20" x 18" x 20"	Blue-M (2)	Elec 800°F
20" x 20" x 20"	Grieve	Elec 1000°F
22" x 42" x 22"	TM (Vacuum)	Elec 750°F
24" x 24" x 36"	New England	Elec 800°F
24" x 24" x 48"	Blue-M	Elec 600°F
24" x 36" x 24"	Demtec (N2)	Elec 500°F
24" x 36" x 24"	Grieve	Elec 1000°F
25" x 20" x 20"	Blue-M	Elec 650°F
24" x 36" x 48"	Gruenberg	Elec 500°F
24" x 120" x 30"	Pollution Control Burn-Off	Gas 850°F
25" x 20" x 20"	Blue-M (Inert)	Elec 1100°F
26" x 26" x 38"	Grieve (2)	Elec 850°F

OVENS/BOX TEMPERING (CONT.)

30" x 30" x 60"	Gruenberg	Elec 450°F
30" x 30" x 48"	Process Heat	Elec 650°F
30" x 38" x 48"	Gruenberg (Inert) (2)	Elec 450°F
30" x 48" x 24"	Selas	Elec 1450°F
30" x 48" x 30"	Surface (2)	Elec 1400°F
30" x 48" x 24"	Ipsen	Gas 1250°F
30" x 48" x 30"	Lindberg (2)	Elec 1400°F
30" x 48" x 76"	P-Quincy	Elec 1000°F
36" x 36" x 36"	Blue M Environment Chamber	(-18°C to +93°C)
36" x 36" x 60"	P-Quincy	Gas 500°F
36" x 42" x 72"	Gruenberg	Elec 450°F
36" x 48" x 30"	Lindberg	Elec 1250°F
36" x 48" x 30"	AFC (2)	Gas 1250°F
36" x 48" x 36"	TPS (Environmental)	Elec -40°C to +200°C
36" x 60" x 36"	CEC (2)	Elec 650°F
36" x 108" x 36"	Wisconsin	Elec 1250°F
37" x 25" x 37"	Despatch	Elec 500°F
37" x 25" x 37"	Despatch	Elec 1000°F
38" x 20" x 26"	Grieve	Elec 500°F
48" x 48" x 20"	Lindberg (Hyd. Press)	Elec 1250°F
48" x 48" x 72"	Blue-M	Elec 600°F
48" x 34" x 52"	Heat Mach. (2)	Elec 350°F
48" x 48" x 72"	P-Quincy	Gas 1000°F
48" x 48" x 48"	Trent	Elec 1400°F
48" x 48" x 48"	L+L (Atmos)	Elec 1200°F
48" x 48"x 60"	Blue-M	Elec 400°F
48" x 48" x 72"	Grieve	Gas 650°F
48" x 48" x 72"	P-Quincy	Gas 450°F
60" x 60" x 60"	P-Quincy	Gas 500°F
60" x 96" x 72"	P-Quincy	Elec 450°F
60" x 84" x 84"	P-Quincy (Car)	Gas 750°F
84" x 60" x 66"	Wisconsin	Elec 350°F
72" x 120" x 72"	P-Quincy	Gas 1000°F
96" x 192" x 96"	Despatch	Gas 650°F
96" x 360" x 48"	Sauder Car Bottom	Elec 1400°F

ATMOSPHERE GENERATORS

500CFH	Ammonia Dissoc. Drever	Elec
500CFH	Endothermic Lindberg	Gas
750CFH	Endothermic Ipsen	Gas
800CFH	Endothermic Surface	Gas
1,000CFH	Exothermic Gas Atmos.	Gas
1,500CFH	Endothermic Lindberg (Air)	Gas
3,000CFH	AFC - (2) Air Cooled	Gas
3,000CFH	Endothermic Lindberg (4) - Air	Gas
3,600CFH	Endothermic Surface	Gas (2)
6,000CFH	Exothermic Modern Equipment	Gas
6,000CFH	Gas Atmos. Nitrogen Generator	Gas

BOX FURNACES

12" x 24" x 10"	Lindberg (Atmos.)	Elec 2000°F
12" x 24" x 10"	Lindberg (Atmos.)	Elec 2500°F
12" x 24" x 12"	Hevi Duty (2)	Elec 1950°F
17" x 14.5" x 12"	L&L (New)	Elec 2350°F
18" x 36" x 18"	Lindberg (Retort)	Elec 2050°F
18" x 36" x 18"	Lindberg (Atmos)	Elec 2500°F
18" x 36" x 18"	Lindberg (Fan)	Elec 1850°F
20" x 48" x 12"	Hoskins	Elec 2000°F
30" x 48" x 30"	Surface (RTB)	Elec 1750°F
36" x 48" x 30"	Surface (RTB- Atmos)	Gas 1850°F
36" x 84" x 24"	Lindberg	Gas 2000°F
48" x 96" x 48"	L&L	Gas 2200°F
60" x 216" x 48"	IFSI (Car Bottom)	Gas 2400°F
72" x 120" x 60"	CEC(2002)	Gas 1750°F
96" x 360" x 48"	Sauder Car Bottom	Elec 1400°F
126" x 420" x 72"	Drever "Lift-Off" (2) (Atmos.)	Gas 1450°F

PIT FURNACES

14" Dia x 60"D	Procedyne Fluid Bed	Elec 1850°F
22" Dia x 26"D	L + N (2)	Elec 1200°F
22" Dia x 36"D	L + N	Elec 1400°F
28" Dia x 48"D	L + N Nitrider	Elec 1200°F
38" Dia x 48"D	Wisc Oven (2)	Elec 1250°F
38" Dia x 48"D	Lindberg (3)	Elec 1250°F
72" Dia x 72"D	Flynn + Dreffein (2) (Atmos.)	Elec 1400°F
43" Dia x 36"D	Lindberg	Elec 1250°F

VACUUM FURNACES

12" x 20" x 12"	Abar	Elec 2400°F
24" x 36" x 18"	Hayes (Oil Quench)	Elec 2400°F
48" x 48" x 24"	Surface (2-Bar)	Elec 2400°F

INTEGRAL QUENCH FURNACES

24" x 48" x 18"	Ipsen T-8 (2 Zone)	Gas 1850°F
30" x 48" x 20"	Surface (2)	Gas 1750°F
30" x 48" x 24"	Surface	Gas 1750°F
30" x 48" x 30"	Ipsen T-9	Gas 1750°F
30" x 48" x 30"	Surface "Top Cool"	Elect 1750°F
30" x 48" x 30"	Surface	Elect 1750°F
36" x 48" x 36"	Surface	Gas 1750°F
36" x 48" x 36"	Surface	Elec 1750°F
36" x 48" x 36"	AFC	Gas 1850°F

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