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VOLUME 6 • NO. 2 MARCH 2023

Heat Treat Today

Technology, Tips & News for Manufacturers with In-House Heat Treat

Annual
Aerospace Heat Treating

2 Special Focus HIP for Heat Treat Articles

Discover Current Challenges and Capabilities of HIP

In this Issue

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"We believe people are happier and make better decisions when they are well informed."

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The Lord's loving kindnesses indeed never ceases,
For His compassions never fail.
They are new every morning;
Great is Your faithfulness.
Holy Bible, Lamentations 3:22-23

VOLUME 6 • NO. 2

MARCH 2023

@Heat Treat Today @HeatTreatToday @HeatTreatTodayOfficial

Doug Glenn, Publisher
Heat Treat Today

Letter from the Publisher

Heat Treat Green Is Coming

Depending on where you live, "green" starts to appear outside in March.

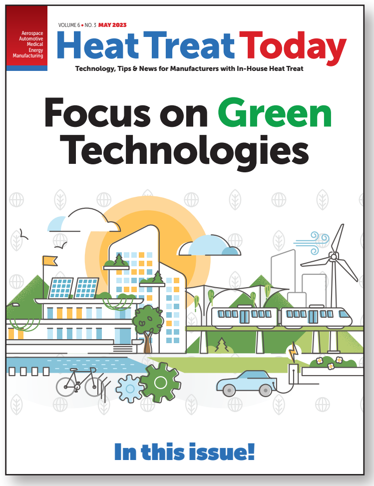
Such is the case this March with **Heat Treat Today**. Our efforts are "greening up" around here as well. With the push for sustainability and environmental corporate responsibility, we've decided to start the industry's first and only "green" heat treat annual magazine edition *and* quarterly e-newsletter. The **Heat Treat Today** team has been working on these items for several months now, but we are officially announcing them this month and encouraging you to watch for them both in May.

Whether you've been mandated to make your in-house heat treat operation more sustainable, or you want to do it simply because it's the right thing to do, we're here to help.

NEW Green Technologies in Heat Treat Annual Print Edition

Heat Treat Today's May print magazine will be the inaugural yearly focus on Green Technologies in North American heat treat. We'll have articles and special editorial sections focused on sustainable technologies currently or soon-to-be available in the North American heat treat industry. This highly-focused issue will give industry suppliers a chance to shout loud and far about the technologies they have that will help you make your in-house heat treat operation more sustainable and productive. We anticipate topics such as:

- Induction heating equipment
- Electrical furnaces and ovens, including vacuum furnaces
- High-efficiency gas-fired equipment
- High-efficiency burners
- Efficiency-maximizing control systems
- Energy-saving insulating materials
- Emission control or capture
- Eco-friendly quench media
- Economizing cooling systems
- Industrial gas economizing systems
- High-efficiency radiant tubes
- High-efficiency heating elements



Potentially, there will be many other topics added to this list. There should be something for everyone who is interested in making their in-house heat treat operations, or commercial heat treat shop, more sustainable. I hope you look forward to receiving your copy and enjoying the content . . . in May!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NEW Quarterly Heat Treat Green E-Newsletter

Sustainable technologies come into the market more than once a year, so, **Heat Treat Today** is launching a new quarterly e-newsletter this May that focuses on sustainable heat treat technologies for the North American marketplace. This e-newsletter, aptly named **Heat Treat Green**, will also focus on emerging and currently available sustainable technologies and products that will help your heat treat operations reduce environmental waste in a responsible manner. We anticipate that this e-newsletter will be deployed in the months of February, May, August, and November each year.

Do You Have a Green Story To Tell?

In both the annual magazine edition and the quarterly e-newsletter, we'd be interested in publishing your in-house heat treat sustainability story if you have one to tell. Our readers benefit from hearing what other manufacturers are doing to make their heat treat operations more sustainable. Many chief compliance officers or others in your organization responsible for promoting sustainable practices are typically quite interested in telling their sustainability stories. If that's you or your company, we'd like to help you get the word out to the North American heat treat industry. Please contact our editors at *editor@heattreattoday.com*, and we'll be sure to be in touch.

Finally, if you're a supplier to the North American heat treat industry and your product has a sustainability story to tell, you also should contact our editors: *editor@heattreattoday.com*.

Keep your eyes peeled for **Heat Treat Green**! HTT

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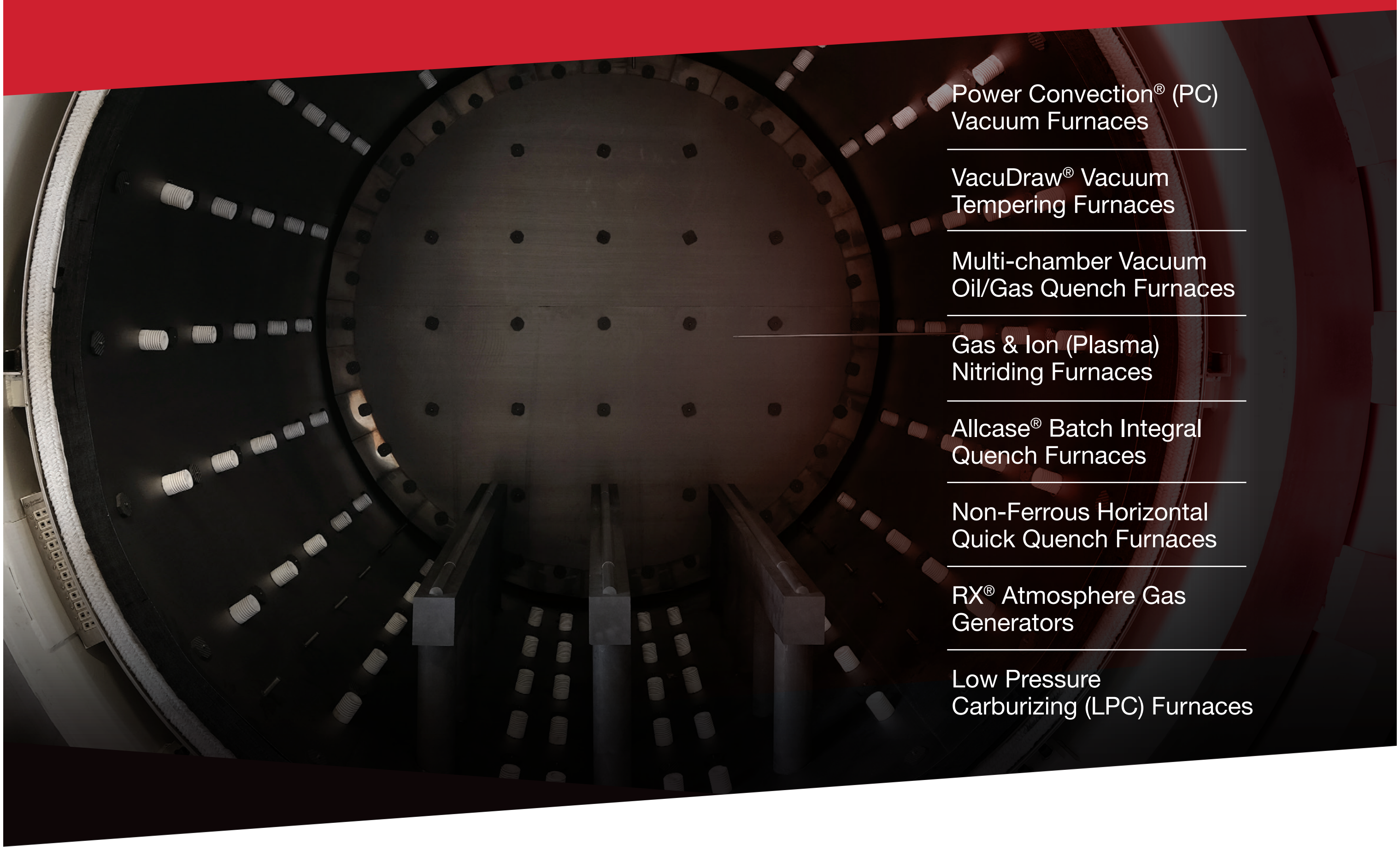
For Aerospace Heat Treating



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Bethany Leone, Managing Editor
Heat Treat Today

Message from the Editor

Self-Healing Properties

Let's talk Ancient Roman engineering. Aqueducts (elevated bridges made of concrete) stretched for miles to convey water from hilltops down to citizens and industries in city centers. Scientific studies covered by the *University of Utah Blog, Engineering and Technology, and National Geographic* have shown many cases where these concrete structures and other 2,000-year-old concrete Roman piers submerged in water have not just survived but thrived; it's an ancient technology that's stronger than modern methods.

Chemical reaction with the salty seawater is believed to be one reason for the lasting success of maritime concrete: seawater filters through the concrete, interlocking minerals grow within the structures, and the concrete ages with strength because of this added cohesion between the minerals and concrete. Additionally, assumptions for the ancient concrete's strength pointed to pozzolanic materials as the strengthening composition.

But recently, researchers have identified "self-healing properties" of Roman concrete across applications — maritime piers, aqueducts, and roads, to name a few. The key component? Bright, white mineral fragments called "lime clasts" made of various calcium carbonate forms that were created under high heat. When cracks fractured into the concrete and broke across the lime clasts, water could enter and react with the material, creating a calcium-saturated solution. This solution can: recrystallize as calcium carbonate, thus filling the crack that allowed the water to enter in the first place, or react with pozzolanic materials, thus further strengthening the concrete.

Reading this research on ancient building methods, I remembered the "self-healing" that has recently been introduced to metallurgy by Rice University. Researchers developed a sulfur-selenium alloy that is corrosion-resistant and, when used as a coating for steel, could repair perforations when heat was applied (sometimes it even self-repaired without heat application). In moments like these, I look at my pinewood table and my ceramic mug and want to yell, "It's alive!!"

Seeing these miraculous properties of technologies helpfully explained by material scientists and researchers does not lessen the amazing abilities that heat, water, and minerals continue to have after thousands of years. This excitement also does not stand alone but builds on the extensive knowledge of physics and chemistry as well as logic (no good engineer can do without that!) and creativity. Self-healing, while a trendy word, is not a tool that the engineer can use all on its own.

This liveliness in the world is ancient and present, integrated with other experiences, and also personal; as humans, we know the extent of "self-healing" and the interventions that are required to fully heal. There are points in life — perhaps childhood, apprenticeships, sports, or simply facing the daily grind — when it becomes necessary for someone to heal us, help us, and sometimes temper us. And, as an engineer or engineering-minded reader, you know that this is natural and *good*.

As we pull out *another* bar of chocolate to watch *another* video about how practical visionaries are developing technologies like self-healing materials for real-world solutions, we may see the heat treat industry under pressure to adapt old methods of processing parts to gain better results with new alloys. Especially in the open-mouth-gaping-at-new-technologies times we find ourselves in human history, we can still remember that however mind-blowing the discoveries — even in the face of something so crazy-sounding as "self-healing" — we can be like the Ancient Romans and (thoughtfully) embrace the miraculous material reality, too. HTT


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Furnace Classifications and How They Relate to AMS2750

By Douglas Shuler, Owner & Lead Auditor, Pyro Consulting LLC

What is the connection between AMS2750 specifications and furnace classifications? With tight specifications, what does the heat treater need to know to be compliant? Follow along as we take a brief look into this often-overlooked topic.

AMS2750 is the specification that covers pyrometric requirements for equipment used for the thermal processing of metallic materials. AMEC (Aerospace Metals Engineering Committee) is one of the committees which oversees the changes and revisions of AMS2750. There are five main sections in the technical requirements of the specification: sensors, instrument calibrations, thermal processing classification, SAT (system accuracy testing), and TUS (temperature uniformity surveys). Additionally, there are quality provisions that detail what happens if a calibration or test is either past due or fails.[1]

Revisions to the original requirements have occurred over the years, with the newest being Revision G. The structure of Revision G has carried over from Revision F and has remained the current structure of the AMS2750 specification. This structure includes furnace classes, which are based on the minimum requirements for temperature uniformity.

Furnace classes are defined in Figure A of Revision D Figure 1.

Originally, furnace classes were based on temperature uniformity, but also subzero transformation, refrigerated storage of aluminum alloys, and embrittlement relief.

AMS2750 Revision C was released in May 1990 and started to implement the class and instrumentation type structure and differentiated between furnaces for heat treating parts versus furnaces for heat treating raw materials. Furnaces for heat treating parts were classified based on uniformity, but also on a readability requirement. Furnaces for heat treating raw materials were classified based on a readability requirement alone.

AMS2750 Revision D was released in September 2005 and continued to define equipment class (Figure A)* and instrumentation type (Section 3.3.1.1)*. It also clarified chart recorder resolution

Continued on page 45

Furnace Classes

Furnace classes are defined in Figure A and are based on the minimum requirements for temperature uniformity. Instrumentation types are based on the level of instrumentation used to control, record, or indicate the desired temperature. Frequencies for system accuracy tests, temperature uniformity surveys, and controlling, monitoring, and recording instrument calibrations are based on the furnace class and instrumentation type.

Furnace Class	Temperature Uniformity Range
1	±5F or ±3C
2	±10F or ±6C
3	±15F or ±8C
4	±20F or ±10C
5	±25F or ±14C
6	±50F or ±28C

Figure 1. AMS2750G furnace class uniformity tolerances

Instrument Accuracy Requirements

Control Type	Process Temperature Uniformity Requirement	Indicated Accuracy (1)
A OR AA	±5°F (±3°C) ±10°F (±5°C) ±15°F (±8°C) ±25°F (±15°C)	±2°F (±1°C) (2) ±2°F (±1°C) (2) ±2°F (±1°C) (2) ±5°F (±3°C) (3)
B	Subzero Transformations	1 scale division or 5° (3°C) whichever is less (4)
C	Refrigerated Storage Of Aluminum Alloys	1 scale division or 5° (3°C) whichever is less (4)
B	Embrittlement Relief	±5°F (±3°C) (3) (4)

Figure 2. Original AMS2750 instrument accuracy requirements, no class structure

Furnaces For Heat Treating Parts

Uniformity Requirement	Reliability Requirement
±10°F (±6°C)	±2°F or ±1°C
±15°F (±8°C)	±3°F or ±1.5°C
±25°F (±14°C)	±5°F or ±3°C*

*±10°F or ±6°C for 1800°F (982°C) and above

Furnaces For Heat Treating Raw Materials

Equipment Class	Reliability Requirement
1	±5°F OR ±3°C*
2	±10°F OR ±6°C

*±10°F or ±6°C for 1800°F (982°C) and above

Figure 3. AMS2750 Revision C: distinguishment between furnaces for heat treating parts versus raw materials

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Reverse Engineering Aerospace Components: The Thought Process and Challenges

By Jonathan McKay, Heat Treat Manager, Thomas Instrument

You can take the aircraft apart, but can you put it back together? Reverse engineering, as anyone who has ever taken apart the TV remote will tell you, is more complicated than it first appears. It is, however, far from impossible. Learn the essential steps to reverse engineering, the role of heat treating, and the challenges the thought process presents.

Reverse engineering (RE) is the process of taking a component or design and dissecting it all the way down to the raw material. Reverse engineering can range from a singular component such as a piston or gear, to multiple components that make up an overall assembly such as an engine or mechanical actuator. This process allows engineers to analyze and gain an understanding of a component's overall function and design through deductive reasoning. RE can range in the type of analysis, from geometric measurements and material analysis to electrical or mechanical testing. Each analysis reveals clues of how something can be reproduced. The idea of reverse engineering is to look beyond what's in front of you and find the unexposed clues that can show why something was designed or possibly the thought process of the original designer.

Reverse engineering typically happens through a third-party manufacturer usually not affiliated with the original equipment manufacturer (OEM). Often this is done because the original manufacturer no longer supports the product, or the original design is outdated and needs to be modernized to improve efficiency, functionality, or life expectancy. To put this in perspective, the U.S. Airforce received its first B-1 Bomber in 1984. Since then, over 100 aircrafts have been delivered. After nearly 50 years the aircraft is still flying, but many OEM manufacturers have moved on to newer programs, thus allocating their capabilities and capacity towards the present and future market demands. This creates a market for fabrication of replacement components and assemblies to support aging platforms. In most cases, the OEM's retain proprietary data thus creating a need for RE processing.

With aerospace products in particular and specifically aging aircrafts, one will encounter obsolescence issues. The goal is to maintain the aircraft with replacement parts that conform to all form, fit, and function requirements while also assuring they have proper life expectancy with respect to maintenance cycles. With this in mind, you typically work with low volume production and invest more time into the design and planning phase of the process. When engaged in this process, it is critical that one understands and implements a fabrication plan that will yield a product that is equivalent or better than that of the OEM. Some engineers would say "Well, let's make it bigger and better," but with aerospace components this is not always the case. Typically, the main focus is to replicate the original design intent to the best of your ability because you have a specific footprint and weight to maintain as well as functionality. The exchangeability of the original design and RE design is key. The reverse engineered product needs to possess the same functional and physical characteristics and be equivalent in the performance, reliability, and maintainability. This allows both items to be exchanged without concern for fit, performance, or alterations to its adjoining component(s).

Another key point in RE processing could be to limit long lead phases by minimizing the need for additional qualification testing where possible. As plating, heat treat, or materials begin to deviate from the initial design, you must consider requalification testing to prove those changes are not detrimental to the application and do not cause more harm than good. Sometimes engineers create features within a design that are meant to be a weak point; this prevents a more critical component from breaking or being destroyed. When you begin to make deviations, it may push the weak point closer to the critical component.

While there are certainly many steps to RE, the essential steps include:

1. Collect as much data as possible from an external standpoint without destroying or disassembling; i.e., note the overall measurements, orientation, special features, electrical or mechanical properties, etc. It is also a good idea to analyze mating components and/or the system in which the component is utilized. Mating parts are a big part of the discovery; the mating parts can help determine what alternate materials, plating, heat treat, or finishes can be used.
2. Start creating preliminary drawings with detailed dimensions, notes, and features that were inspected from Step 1.
3. Slowly disassemble the part (if an assembly) and inspect key features and create preliminary drawings for sub-assembly components. In some cases, it helps to reassemble the product to ensure an understanding of how it goes back together in order to

Continued on page 45

Heat Treat Today News Chatter

Business briefs from around the industry

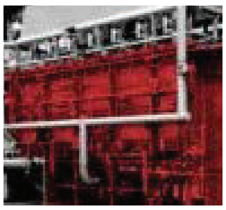
A Few Dozen Quick Heat Treat News Items To Keep You Current

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 one to two news items from around the heat treat industry five days a week. Submit your news items to editor@heattreattoday.com.*

EQUIPMENT CHATTER

› The **Philadelphia Mint** began the process of upgrading each of its five heat treating furnaces. **SECO/WARWICK Group's** subsidiary in Meadville, PA, will handle the upgrades.



Upgrades for five heat treat furnaces for Philadelphia Mint

› **Boeing** landed an order for 100 787 Dreamliners from **United Airlines**. Deliveries of the aircraft are set for 2024.

787 Dreamliner for United Airlines

› An EV manufacturer ordered a vacuum furnace from **SECO/VACUUM** for in-house gear prototyping.

› A North American producer of mining, construction, and material handling products added a continuous quench and temper furnace system from **CAN-ENG Furnaces International Limited**.

Continuous quench and temper furnace system for a North American producer

› A Swiss commercial heat treater ordered a brazing furnace to be used for nickel and silver from **SECO/WARWICK**.

SECO/WARWICK's brazing furnace for Swiss heat treater

› **Tenova LOI Thermprocess** has completed the production optimization of a new Twin-Chamber Melting Furnace (TCF®) at E-Max Billets in Kerkrade, the Netherlands.

TCF® for aluminum scrap recycling

› A firearms manufacturer ordered a continuous conveyor furnace from **Wisconsin Oven Corporation**. The oven will be used for heat treating aluminum parts prior to quenching.

Continuous conveyor furnace for leading firearms manufacturer

› An Asian thread rolling die conglomerate selected a **SECO/WARWICK** vacuum furnace. The Vector® will be used for vacuum hardening and tempering fastener dies.

Heat treated flat thread rolling dies

COMPANY/PERSONNEL CHATTER

› Automaker **Stellantis** halts production at its Belvidere, Illinois, site. Layoffs included about 1,350 workers.

Halt on Illinois site production

› **L&L Special Furnace Co., Inc.** announced that they are under new ownership, **Specialized Thermal Solutions, Inc.**, beginning in 2023.

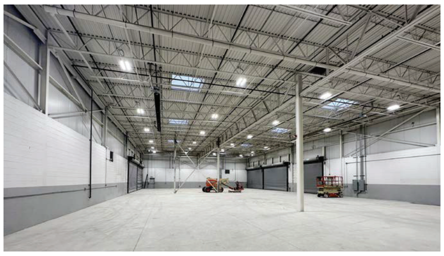
L&L Special Furnace Co., Inc. under new ownership

› **Abbott Furnace Company** announced that it has partnered with **Obsidian Technical Group** for sales and service support across much of the eastern United States.

› Robert Roth, president and CEO of **RoMan Manufacturing, Inc.**, announced the appointment of **Nelson Sanchez** as RoMan's new president, effective January 1, 2023. Sanchez is the first non-family member to hold the office.

Nelson Sanchez, new president of RoMan Manufacturing, Inc.

› Solar Atmospheres of Michigan, formerly **Vac-Met**, purchased 18,000 square feet of plant space in Chesterfield, MI.



New location for Solar Atmospheres of Michigan

› Hubbard-Hall hired **Aaron Mambrino** as chief financial officer. Her expertise lies in driving process changes to create operational synergies, developing strategic partnerships, and LEAN manufacturing.

Chief Financial Officer for Hubbard-Hall, Aaron Mambrino

› John Savona, vice president of **Americas Manufacturing and Labor Affairs, Ford Blue**, will retire on March 1, after more than 33 years. **Bryce Currie** will step into the role.

Savona with Ford 30+ years

› AFC-Holcroft welcomed employees and their families, company retirees, and invited guests to view their newly renovated building as part of an open house.

Bill Disler, President & CEO of AFC-Holcroft, during the open house

› Solar Atmospheres of California participated in the "Spark of Love" toy drive in coordination with the San Bernardino County Fire Department.

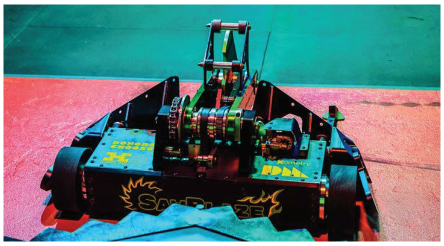
Christmas toys for kids in Southern CA

› Raytheon Technologies expands Bengaluru operations with opening of **Pratt & Whitney India Engineering Center**. The facility is co-located with **Pratt & Whitney's India Capability Center** and **Collins Aerospace** engineering and global operations centers.

Opening of Pratt & Whitney's India Engineering Center

KUDOS CHATTER

› Desktop Metal is sponsoring SawBlaze on a new season of **BattleBots**. The completely rebuilt robot is aided by the design freedoms and fast turnaround times of metal 3D printing.



SawBlaze on Discovery Channel's TV show, "BattleBots"

› Ipsen USA announced that 2023 represents a milestone anniversary. This year marks 75 years since Harold Ipsen founded the company.

› Solar Atmosphere's Michigan and Western Pennsylvania facilities have recently been awarded Nadcap Merit status for vacuum heat treating and brazing.

› Borikengineers, a **FIRST Tech Challenge** robotics team, mentored by **Pratt & Whitney** employees in Puerto Rico, has advanced to the Qualifiers' Finals Competition in the FIRST Tech Challenge DC Qualifier. The team won the Judges Choice Award.

Borikengineers, Judges Choice Award winners

Heat Treat Today Erratum Notice

When we make a mistake, we make every attempt to correct it as soon as possible. In February 2023's **Annual Air & Atmosphere Furnace Systems** magazine, we included an image in the article "How Tip-Ups Forever Transformed Brake Rotor Manufacturing" that we did not have permission to publish. We also incorrectly cited the source. The image should have been attributed to **Woodworth, Inc.**

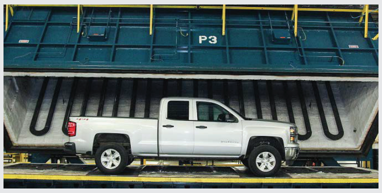


Photo source: Woodworth, Inc.

Woodworth, Inc. has 44 large tip-up furnaces capable of processing over 100,000 lbs. per load. **Woodworth** has installed capacity to process more than 22 million brake rotors annually.

Woodworth, Inc. currently operates three plants in the United States (Pontiac, Homer, and Flint, MI) and a fourth facility located in Puebla, MX.

www.woodworthheattreating.com

The Debate Continues: ±.1°F

Are you trying to find a way to measure .1°F to meet AMS2750 standards? It is clearly important to ensure that aerospace components are manufactured in a way that ensures reliable part performance, but the difficult transition to implement the standard has drawn out the debate on the value added by this strict requirement.

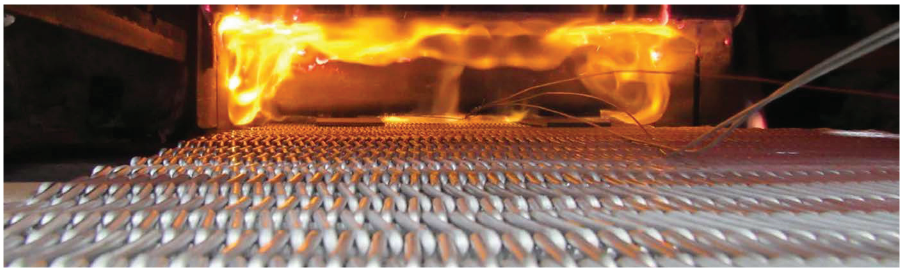
In this Q&A with Andrew Bassett, president and owner of Aerospace Testing & Pyrometry, Inc., read how the decision to commit to ±.1°F readability unfolded, how to contend with the practical challenges the decision brought, and whether or not this aerospace standard will be modified in the future.

This Q&A will be available in March 2023 as a **Heat Treat Radio** *podcast episode.*

How Did the ±.1°F Standard Come To Be?

Being part of the AMS2750 subcommittee, one of the questions that came up for us during the Rev F rewrite was .1°F readability — how can we fix the flaw that's been in the standard ever since the day that AMS2750 came out? With instrumentation, for instance, you have ±2°F (the equivalent would be 1.1°C). At 1.1°C, the question became, If your instrumentation does not show this .1 of a degree readability, how can you show compliance to the standards?

Then, it morphed into other issues that we've had in the previous revisions where we talk about precise temperature requirements. For example, take system accuracy testing: You're allowed a hard number ±3° per class 2 furnace or .3% of reading, whichever is greater. With anything over 1000°F, you're going to be able to use the percentage of reading to help bring your test into tolerance. In that example, 1100°F, you're about 3.3 degrees. If your instrumentation doesn't show this readability, how are you going to prove compliance?



Source: Aerospace Testing & Pyrometry, Inc.

Originally, the first draft that we proposed in AMS2750F was that *all* instrumentation had to have .1°F readability. We got some feedback (I don't know if I want to say "feedback" or "pitchforks and hammers") that this would be cost-prohibitive. Most instrumentation doesn't have that readability and it would be really costly to go out and try to do this. We understood that. But, at the end of the day, we said: The recording device is your *permanent* record, and so that's what we're going to lean on. But we still had a lot of pushback.

We ended up putting a poll out to AMEC and the heat treating industry to see what *their* opinions were. We said that with the .1° readability (when it came to a percentage reading), recording devices would read *hard tolerances*. So, for instance, an SAT read at 3° would be just that, not "or .3% of reading."

There was a third option that we had put out to the community at large, and it came back as the .1° readability for digital recorders, so we ran with the .1° readability.

When it was that big of an issue, we didn't make the decisions ourselves; we wanted to put it out to the rest of the community. My guess is not everyone really thought the whole thing through yet. Now people think, "Now I need to get this .1° readability."

Again, during the meetings, we heard the issues. Is .1° going to really make a difference to metal? If you have a load thermocouple that goes in your furnace and it reads .1° over the tolerance, does it fail the load? Well, no, metallurgically, we all know that's not going to happen, but there's got to be a line in the sand somewhere, so it was drawn at that.

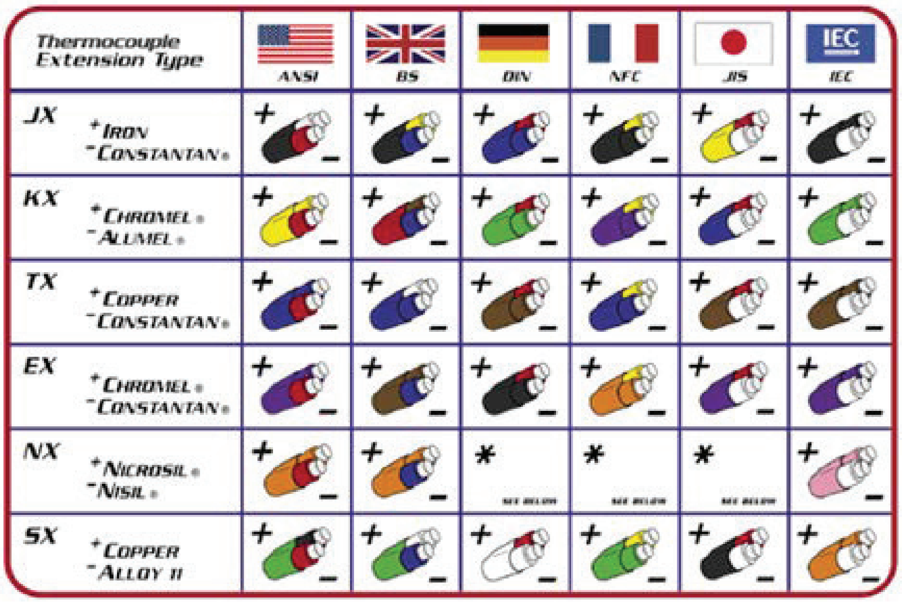
That's a little bit of the background of the .1° readability.

Does ±.1°F readability really matter?

In most heat treat operations, one degree is not going to make a difference. That hard line in the sand had to be drawn somewhere, and that was the direction the community wanted to go with, so we went with that. Yes, we understand that in some metals, *10* degrees is not going to make a difference, but we need to have some sort of line in the sand and that's what was drawn.

Is it accurate to have ±.1°F when some furnaces are classified for ±5 and some thermocouples are rated at ±2?

To answer this question, we can even go a lot further and start talking about budgets of uncertainty. If you look at any reputable thermocouple manufacturer or instrument calibration reports that



Thermocouple extension types (Source: Martin Reeves)

are ISO 17025, they have to list out their measurements of uncertainty, and that gives you only the 98% competence you're going to be within that accuracy statement.

On the recording side of things, we went away from analog instrumentation. The old chart papers, that's all gone, and we required the digital recorders with that .1° readability, as of June 30, 2023.

Again, the first draft was *all* instrumentation. That would be your controllers, your overtemps, and we know that limitation. But everyone does have to be aware of it. We still allow for this calibration of ±2 or .2%.

If you are doing a calibration on a temperature control calibration point at 1800°, and the instrument only reads whole numbers, you are allowed ±2 (or 3.6° if I'm using the percentage of reading), but if the instrument does not read in decimal points for a controller or overtemp, you would have to round that down to ±3°, tossing .6 out the window.

I shouldn't say we *like* to bury things in footnotes, but this was an afterthought. In one of the footnotes, in one of the tables, it talks about instrumentation calibration that people need to be aware of.

Is .1°F readability here to stay?

When the .1° readability came out in Rev F, we gave it a two-year moratorium: heat treaters still had two more years. Then, when Rev G came out, exactly two years to the date, we still had a lot of customers coming to us, or a lot of suppliers coming back to us saying, "Hey, look, there's a supply shortage on these types of recorders. We need to buy some time on this." It ranged from another year to 10 years. Now, as of June 30, 2023, that requirement is going to come into full play now. Like it or not, that's where the standard sits.

If we did roll this back and say alright, let's just do away with this .1° readability

ANSI Code	ANSI MC 96.1 Color Coding		Alloy Combination		Maximum T/C Grande temp. range	EMF(mv)Over Max.temp.range	IEC 584-3 Color Coding	IEC Code
	Thermocouple	Extension	+ Lead	- Lead				
K			NICKEL-CHROMIUM Ni-Cr	NICKEL-ALUMINUM Ni-Al	-270 to 1372℃ -454 to 2501°F	-6.458 to 54.886		K
J			IRON Fe (magnetic)	CONTANTAN COOPER-NICKEL Cu-Ni	-210 to 1200℃ -346 to 2193°F	-8.095 to 69.553		J
T			COPPER Cu	CONTANTAN COOPER-NICKEL Cu-Ni	-270 to 400℃ -454 to 752°F	-6.258 to 20.872		T
E			NICKEL-CHROMIUM Ni-Cr	CONTANTAN COOPER-NICKEL Cu-Ni	-270 to 1000℃ -454 to 1832°F	-9.835 to 76.373		E
N			NICROSIL Ni-Cr-Si	NISIL Ni-Si-Mg	-270 to 1300℃ -450 to 2372°F	-4.345 to 47.513		N
S	NONE ESTABLISHED		PLATINUM-10% RHODIUM Pt-10%Rh	PLATINUM Pt	-50 to 1768℃ -58 to 3214°F	-0.236 to 18.693		S
R	NONE ESTABLISHED		PLATINUM-13% RHODIUM Pt-13%Rh	PLATINUM Pt	-50 to 1768℃ -58 to 3214°F	-0.226 to 21.101		R
B	NONE ESTABLISHED		PLATINUM-30% RHODIUM Pt-30%Rh	PLATINUM-6% RHODIUM Pt-6%Rh	0 to 1820℃ 32 to 3308°F	0 to 13.820		B

Thermocouple color code chart (Source: Pelican Wire) issue, we still have to worry about the people processing in Celsius. Remember, we're pretty much the only country in the world that processes in Fahrenheit. The rest of the world has been, probably, following these lines all along. If we rolled this back, just think about all the people that made that investment and moved forward on the .1° readability and they come back and say, "Wait a minute. We just spent $100,000 on upgrading our systems and now you're rolling it back, that's not fair to us."

Personally, I don't think this is going to go away; it's not going to disappear. It's going to keep going down this road. Maybe, if people are still struggling with getting the types of devices that can have that .1° readability, then maybe another year extension on it. I haven't gotten enough feedback from aerospace customers that say, "Hey, I can't get the recorder." I mean, I've seen some lead times of Yokogawa and Honeywell and Eurotherm that are pretty extensive, even as of today.

You know, we've seen programmable logic controllers and some high logic controllers that now can show the .1° readability, but they automatically round up at .5°. Are you now violating the *other* requirements of rounding to E29?

With the ball already rolling, it would be very interesting to see how many suppliers are being hit on this requirement, when Nadcap starts publishing the audit findings. The audits will give a good indication of the future. If there are a lot of "yeses" on it then, obviously, a lot of suppliers haven't gone down this road. My guess is, for the most part, anybody that's Nadcap accredited in heat treating — and this goes across chemical processing, coatings, and a few other commodities — has caught up to this.

I'm conflicted on both sides. I want to help the supply base with this issue but I'm also on the standards committee that writes the standard. I think because we're so far down the road — this requirement has been out there since June 2022 — I don't see anything being rolled back on it, at this point. If we did roll it back, we have to look at it both ways. At the end of the day, the intentions of the standard were to fix a flaw, and it spiraled. HTT

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Status from the Industry: What's Hip in HIP?

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

In the past, manufacturers with in-house heat treat have turned to hot isostatic pressing (HIP) technology to decrease porosity and increase densification in their processed parts. Now, in 2023, is there anything new HIP can offer heat treaters? To find out, **Heat Treat Today** *asked seven HIP equipment suppliers and heat treat users to enlighten us on the world of HIP as it is today.*

What are the recent, cutting-edge developments in HIP?

Matt Fitzpatrick, Sales Engineer, Engineered Pressure Systems, Inc.

Matt Fitzpatrick, sales engineer at Engineered Pressure Systems, Inc., shares, "Self-diagnosing alarms, failures, and power as well as medium consumption savings are key developments in the HIP industry. Enhanced uniform cooling joins with the development of materials (ceramics, metals, insulation fibers) to improve equipment uptime and reduce cycle time. Self-diagnosing alarms may play a key role in HIP's future. Each HIP control system has alarms to alert when parameters are not met. The future will be in determining why the parameters are not being achieved. For instance, future control systems may be able to diagnose a bad thermocouple, a failed motor solenoid valve, a leaking high pressure valve, etc.

"Unfortunately, there are not very many HIP systems purchased every year. It takes time to develop this technology. A good example would be the automotive industry: sensors tell technicians exactly where the problem in the vehicle is. As the PLCs and computers become more advanced, the specific software programs that are developed for the HIP system — in conjunction with advancements with sensors in motors, pumps, valves, transducers, meters, and components — will make it easier and less time consuming to develop complex troubleshooting programs.

"To some heat treaters, HIP can be an unnecessary evil, given its expensive, long cycle times. HIP, however, cannot be eliminated, because it is the only process that attains the densification required in the aerospace, medical, and high-performance automotive industries."

Cliff Orcutt, Vice President, American Isostatic Presses, Inc.

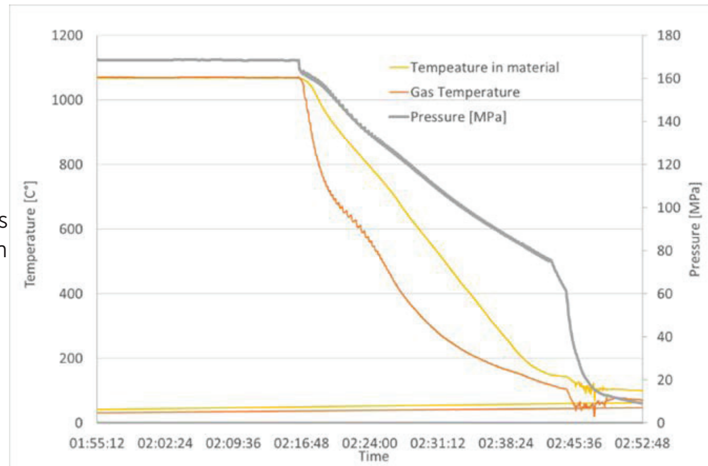
"HIP technology is very mature and reliable," **Cliff Orcutt**, VP of American Isostatic Presses, Inc. assures, "however, the cost to use the process is always one major hurdle preventing its use. AIP is working hard to develop lower cost equipment that can still maintain excellent results and bring higher pressure capabilities to the market. We are also expanding our footprint further into the toll HIP arena with similar goals of lower cost and faster turnaround services. Our new facility opening in Columbus, OH, this spring will also provide a world class development resource to help interested manufacturers determine whether the process can be applied to their parts."

Chad Beamer, Applications Engineer, Quintus Technologies

Quintus Technologies' **Chad Beamer** points to the versatility of HIP: "HIP continues to make its mark in many industries by offering a path to consolidate powders and eliminate process related defects for 100% pore and void free material for improved product integrity. With the continued demand for this special process, Quintus Technologies has several key developments driving industry growth due to the expanding functionality of the equipment. The voice of the client consistently demands production efficiency, reduced environmental impact, and improved process reliability. Modern HIP equipment is delivering on this front, creating a promising future for HIP.

"HIP systems equipped with rapid cooling and quenching functionality (URC®/URQ®) are facilitating lean manufacturing with increased productivity by shortening the cooling segment over conventional cooling, while also offering the opportunity to consolidate thermal post processing steps. HIP systems with URC® can cool at rates up to 932°F/min (500°C/min), and compact HIP units with URQ® furnaces are capable of cooling more than 5400°F/min (3,000°C/min). This leads to the opportunity to combine several thermal processing steps into one process performed under pressure. The combined, or integrated, heat treatment approach inside the HIP vessel is known as High Pressure Heat Treatment™ (HPHT™).

"Developments with the controllability of HIP are further expanding the use of HPHT. The cooling rate of the HIP can be steered using thermocouples to set the desired cooling rate from either process gas or component temperature feedback. Steered cooling driven by the component temperature is interesting when considering different thicknesses of parts in the HIP. The machine can therefore autonomously steer the temperature based on the thickest component to achieve desired material properties. See an example of steered cooling from component temperature feedback in the graph above.



Example of steered cooling for a nickel base super alloy. Cooling rate set at 30°C/min controlled by a load thermocouple (Source: Quintus Technologies)

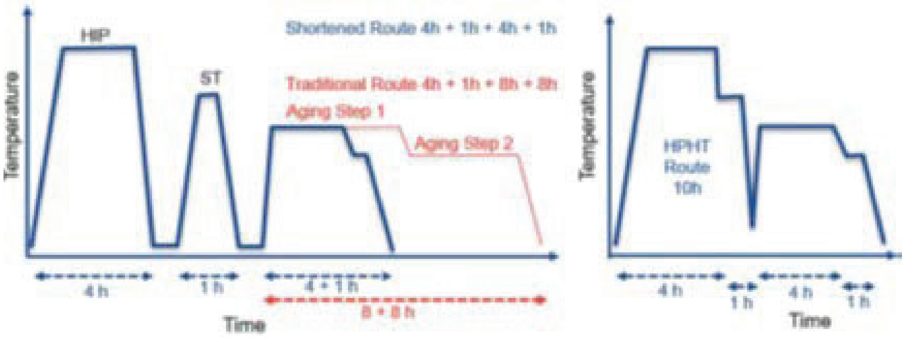


Illustration of (a) conventional (red solid line) and shortened (blue dotted line) post-treatments for EBM Alloy 718 investigated in this work; (b) combined post-treatment steps inside the HIP vessel. (Source: Goel et al., University West in Sweden)

"The tailoring of HIP cycles is a new area of development too. Due to the excellent controllability in a modern HIP tailored heating, sustaining, and cooling segments can be programmed and precisely executed. This is an area of interest for materials needing high cooling rates or having a tight tolerance on heating and cooling rate requirements. An excellent example of a tailored HIP cycle can be seen in recent work by Goel et al., at the University West in Sweden (see illustrations above), capturing the possibility to significantly reduce the treatment time for additively manufactured Inconel 718.

"Quintus has also been working to reduce discoloration and oxides on the surface of parts by improving equipment and best practice in terms of clean HIP operations. This is not an easy challenge to overcome. HIP is performed at very high pressures, often above 1000 atmospheres, using high purity Argon gas (>99.99x). Because of the need for additional gas volumes to achieve desired system pressure during regular HIP, the total pressure of contaminants can become high. Despite these challenges it is now possible to produce materials that have a high affinity for oxygen e.g., aluminum, titanium, and chromium, with significantly less oxidation. This can lead to improvement in fatigue and corrosion resistance fulfilling design criteria and gives great opportunities for more sustainable post-HIP.

"Developments with the digitalization of HIP equipment are also playing a role in meeting the demand of the Industry 4.0 mindset. Integration of the equipment into digitalized production lines enables product and process improvements. Digitalization of high-pressure equipment offers many benefits as it creates opportunities to streamline and save time with preventative maintenance tasks, provides valuable insights and trends into the health of the equipment, expands collaboration, improves uptime, and saves cost."

Humberto Ramos Fernández, Founder and CEO, HT-MX Heat Treat & HIPing

"In 2023," **Humberto Ramos Fernández**, founder and CEO of HT-MX, comments, "HT-MX will continue to establish itself as the main HIP supplier and expert in Latin America. Additionally, with our Honeywell Aerospace approval, we will be pursuing at least three more OEM approvals not only in the aerospace industry but medical and automotive as well."

Phil Harris, Marketing Manager, Paulo

Phil Harris, marketing manager at Paulo, highlights HIP's customization: "The primary focus has been on providing customized HIP cycles that either deliver superior mechanical properties for customers or reduce the need for post-HIP to streamline the supply chain and speed up turnaround. We've been successful in both and are always looking for opportunities to collaborate on such endeavors."

Leah Tankersley, Marketing Manager, Aalberts surface technologies

Leah Tankersley, marketing manager, Aalberts surface technologies, says, "We added HIP services to our portfolio in 2020. We have two wire-wound HIP vessels, and plan to expand further with a third unit ready to ship from Sweden soon. Each unit boasts the latest HPHT technology. They are equipped with the proprietary Uniform Rapid Cooling (URC) feature. Our HIP technology has the ability to combine stress relief, HIP, solution, and age in a single process. HPHT HIP streamlines the steps involved in material densification and heat treatment. The URC feature enables all processed components to cool uniformly in a controlled environment, resulting in minimal thermal distortion and non-uniform grain growth."

Doug Puerta, CEO, Stack Metallurgical Group

Doug Puerta responds for Stack Metallurgical Group: "Stack has been active in supporting the advancement of HPHT. Our newest HIP unit, a Quintus QIH-122, includes Uniform Rapid Cooling (URC) technology which enables cooling rates equivalent to what we achieve with traditional gas quenching. This technology not only allows for improved productivity, but also enables the combination of a traditional HIP cycle with stress relieving, solution annealing, or even aging, all in one HIP unit."

In the next five years, what advancements should manufacturers with in-house heat treat operations expect from HIP technology?

"In terms of cycle times," **Matt Fitzpatrick** of Engineered Pressure Systems, Inc. says, "HIP systems are limited by how fast materials can be heated and cooled. In the next five years, reduced maintenance, improvements with furnaces and heat shields, and faster cycle times will occur at both the materials and design levels."

Cliff Orcutt, from American Isostatic Presses, Inc., sees globalization in HIP's future, "We don't expect much change other than to see it expanding into new geographic regions and being applied to more products. The main problem affecting our industry is not deficiencies in the HIP equipment or process, but rather how to use it beneficially in a profitable manner. In the next five years

I think countries, such as India, will begin to implement it much more widely as the process becomes better known. As more companies implement it their competition must follow to stay on the same page."


American Isostatic Presses, Inc. HIP equipment (Source: AIP)

Chad Beamer, from Quintus Technologies, shares the optimistic outlook, "Quintus is witnessing significant growth potential for HPHT, including the addition of this post-process HIP and heat treatment strategy into industry standards. Also, the demand placed by many industries on surface cleanliness requirements to reduce oxidation and discoloration of sensitive material systems will help drive forward clean HIP techniques. These advancements along with delivering new and upgrading existing HIP equipment with machine digitalization will meet the current and future demands placed by the heat treat market and OEMs."

And what about HIP in Mexico? **Humberto Ramos Fernández** of HT-MX responds, "Being located in Mexico, the main advances in HIP in our environment will be mostly geared towards near shoring manufacturing for high added value parts. HT-MX´s HIP service is just one example of a high tech and high complexity process being used in Chihuahua to manufacture high end products and thus we expect near shoring to bring in more opportunities for these kinds of parts to be manufactured and assembled in Chihuahua and Mexico."

Leah Tankersley of Aalberts surface technologies, says, "As a provider of HIP services, we cannot speak to the advancements in HIP technology per se, but we are seeing material advancements and development of new alloys in AM. These advancements will impact HIP cycles and lead to development of more unique cycles for AM that differ from traditional cycles developed for castings. We're also seeing ASTM International AM Center of Excellence Consortium members from the AM value stream come together to collaborate on standardization of requirements for AM materials data which includes post processing/hot isostatic pressing. We are one of the founding members of this consortium.

Aalberts teams up with Quintus Technologies.
(Source: Aalberts surface technologies)

"Additionally, we are working with Quintus to beta test their remote assistance field service support through AR equipment and technology."

Doug Puerta, Stack Metallurgical Group, thinks, "In the next five years, I expect we'll continue to see aerospace and medical OEMs evaluate and approve HPHT for additional combined-cycle applications. Ultimately, with span time being so important to our customers (and their customers), combining cycles and reducing span is a really big deal."

What is the #1 thing manufacturers with in-house heat treaters should know about HIP technology right now?

Safety first, says **Matt Fitzpatrick** at Engineered Pressure Systems, Inc. (EPSI): "Good safety and maintenance programs and experienced operators and technicians are key to a successful HIP system. Confined space rules and regulations, oxygen monitoring, nondestructive testing (NDT) inspections of the vessel assembly components, good maintenance, and end-user HIP plant safety programs are key. Training is provided with every system regardless of whether it's a HIP system, CIP system, or WIP system. Before delivering a system, EPSI offers training for safety, maintenance, system operation, controls, and system parameters. Then during installation and startup, training occurs. When startup is completed, we offer training at the client's site. Generally, this is mutually agreed on during the contract phase and delivery."

"There is not just one thing," **Cliff Orcutt** of American Isostatic Presses, Inc. says, "because HIP has so many different applications. For instance, HIP can be used to heal castings, make parts directly from powders, diffusion bond materials together, or pressure infiltrate materials. HIP can be applied to metals, ceramics, composites, and even plastics. I guess really the number one thing they should know is how to contact a reputable HIP company that can provide the information and technology they require."

Chad Beamer of Quintus Technologies points to HIP's benefits for both end customers and heat treaters, "Modern HIP units differ significantly from conventional HIP units. The technology has advanced over the decades offering expanded functionality and improved performance. As for all production processes, lean manufacturing is key to improving product quality, minimizing costs, and maximizing productivity. Reducing waste and increasing throughput should always be a focus.

"The addition of modern HIP with HPHT capability and clean HIP functionality as part of the production chain are HIP advancements that will facilitate robust and lean processes through reduction of yield losses, logistics, and quality-

QIH 60 URC® hot isostatic press (Source: Quintus Technologies)

related costs. This is not only of strong interest to heat treaters, but also to the end customers in several industries. And with a broad product line of compact, medium, and large HIP capabilities available, commercially in-sourcing the technology to complement other heat treat equipment is now feasible for many companies."

Humberto Ramos Fernández speaks directly to in-house heat treaters, "In-house heat treaters must know that, although similar, HIP is not heat treatment. Various aspects of the process are similar but there is a learning curve that must be transitioned and experience in heat treat doesn't necessarily automatically translate into the HIP experience."

Aalberts' **Leah Tankersley** plainly states, "HIP is an expensive investment."

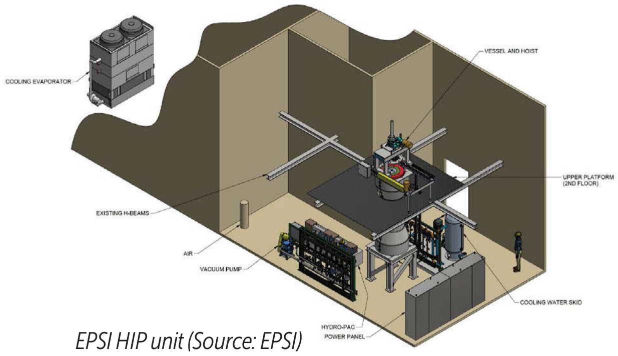
"Ironically," says **Doug Puerta** of Stack Metallurgical Group, "One of the misconceptions is that modern HIP systems offer HPHT as an alternative to general heat treating. The intent of technology is for use when conventional HIP and heat treatment is required for a given application. When HIP is not required, heat treating is performed in a traditional vacuum furnace. The economics don't really support heat treating in a HIP unit when a HIP segment is not included."

Stack HIP equipment (Source: Stack Metallurgical Group)

How is HIP benefiting heat treaters in the industry today?

Matt Fitzpatrick, from Engineered Pressure Systems, Inc., says, "First, we employ heating and cooling software program models to help with cycle times, though cycle time generally depends on the material being processed."

Fitzpatrick continues, "Loading and unloading a HIP cycle can be time consuming. We have developed tooling



EPSI HIP unit (Source: EPSI)

that helps operators prepare a HIP cycle and test the thermocouples prior to being loaded into the HIP vessel. In addition to reducing time, this tooling ensures that the load is prepared properly and won't damage the furnace while it goes into the vessel."

Cliff Orcutt, American Isostatic Presses, Inc., replies, "We have many clients that use our HIP systems to improve the properties of AM parts, as sintering alone has a limited upper range for density achievement. By utilizing HIP they are able to achieve near theoretical density and remove voids that can degrade performance or affect surface post finishing. In many cases when you have improvement in properties it can allow redesign with less material usage to improve cost efficiency and help the environment."

Chad Beamer of Quintus Technologies explains, "HIP is a well-established process that has played a role in delivering advanced materials and components since the 1960s. Originally developed as a diffusion bonding process, its use has expanded to the densification of castings and additively manufactured components as well as the consolidation of powder to produce billets of material or complex near net shapes. Several industries benefit from its use today including aerospace, space, power generation, medical, oil and gas, and nuclear to name a few.

"The process offers several benefits related to material performance. One of the main demands for HIP is to eliminate process-related defects in materials for improvement in mechanical properties. Dynamic properties such as fatigue and creep performance are significantly improved, as is ductility and fracture toughness. The elimination of internal defects leads to reduced mechanical property scatter offering more predictive properties. The outcome can offer extension of a component's lifecycle as well as potential weight-savings and cost reduction. Another benefit of HIP is for the enhancement of surface quality. The absence of internal defects provides a path to produce machined and polished surfaces free of surface connected imperfections for improvement in mechanical properties and corrosion resistance, as well as optical properties for aesthetically critical applications.

"For heat treat service providers there is motivation to invest in HIP capabilities as it provides a natural complement to existing heat treatment equipment often offering a one-stop shop at many facilities. It also broadens the availability and flexibility of HIP and HPHT services to the industry which is an exciting opportunity.

"As for an OEM's decision to insource HIP, the benefits are broad. The capabilities of modern systems lead to significant reduction in the production cycle time, savings in overall handling and cost, especially with custom HIP cycles. It also provides a path to gain more control of processing techniques with the opportunity to develop novel approaches while improving control of the intellectual property that is developed."

Humberto Ramos Fernández, HT-MX responds, "For high value parts, such as

HT-MX in Chihuahua, Mexico (Source: HT-MX)

HT-MX team (Source: HT-MX)

aerospace engine components, lead times mean money. Being able to reduce, by weeks, the turnaround time for HIP parts in Mexico means that working capital for these parts is significantly reduced allowing our customers to enjoy these savings."

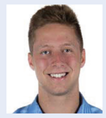
Paulo's **Phil Harris** says, "HIP, in conjunction with customized cycles, is allowing our customers to deliver parts which were previously not possible. Specifically, the ability to meet material property requirements with additive parts. Where traditional HIP cycles (designed for castings) left them short of tensile requirements, we've been able to achieve the necessary properties, winning both of us more work in the process. This success in turn drives the adoption of additive manufacturing."

Leah Tankersley, Aalberts surface technologies adds, "Our customers benefit from the latest HPHT HIP technology to improve the materials characteristics of their parts. HPHT HIP helps clients reach 100% theoretical density after HIP, improve tensile strength, and improve creep rupture properties.

"Our URC technology allows clients to reduce lead times with the ability to combine stress relief, HIP, solution, and age into one cycle which saves time by reducing the number of individual process steps and handling of parts. If clients choose to not do stress relief in the HIP, stress relief can be done in the vacuum furnaces that are just 50 feet away from the HIP system in our facility."

Stack Metallurgical Group's **Doug Puerta** replies, "We've had the good fortune to introduce several of our clients to the benefits of HIP. While HIP has long been mandated in quality-critical industries such as aerospace, orthopedic implant, and power generation, there are other applications where significant performance gains can be achieved through HIP." HTT

For more information, contact the experts:



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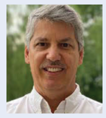

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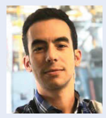

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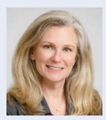

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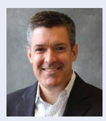

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CFC Fixture Advantages and Challenges in Vacuum Heat Treatment, Part 2

Scan code to view Part 1

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

What are the factors that lead to carburization and carbon transmission? How can heat treaters avoid these unwanted reactions? The November 2023 print magazine featured Part 1 of this technical evaluation of CFC fixtures in vacuum heat treatment. In Part 2, discover the challenges of CFC fixtures and the steps heat treaters can take to mitigate these challenges.

Introduction

The main advantages of CFC fixtures were introduced in "CFC Fixture Advantages and Challenges in Vacuum Heat Treatment, Part 1," which was released in Heat Treat Today's November 2022 publication. This included a discussion of the limits of CFC in vacuum and protective atmosphere heat treatment. Successful applications of CFC workpiece carriers in heat treatment were presented along with field test results that included a brief discussion of undesired contact reactions (i.e., carburization and melting of parts). In Part 2 of this paper, the mechanisms involved with carburization and carbon transmission due to direct contact of parts with CFC fixtures will be further explained.

Mass Transfer from CFC Fixtures

The mass transport of carbon from CFC fixtures into steel parts at high temperatures will be examined in the following areas:

1. Reactions in oxygen (i.e., the reaction medium)
2. Transport of carbon in CFC during exposure to oxygen
3. Transfer mechanism into the steel parts
4. Diffusion of carbon into the steel parts
5. Part reactions (melting, carbide formation)

CFC samples were tested in contact with steel samples under laboratory conditions in a vacuum of 7.5 x 10-7 Torr (1 x 10-6mbar). Results of the contact with CFC for steel samples at different temperatures are presented below (Figure 1). It is important to note that:

- Sample (0) is the reference sample and had no exposure to the contact test.
- Sample (0') is the back side of Sample (0).
- Sample (1) is the contact side at 1922°F (1050°C).

All three samples are visually identical, therefore only one is shown. Sample (2) at 1967°F (1075°C) and Sample (3) at 2012°F (1100°C) exhibited a distinct visual surface pattern after CFC contact. This was analyzed by Glow Discharge Optical Emission Spectroscopy (GDOES) and the test location (gray spot) clearly observed on Samples (2) and (3). For Sample (4) run at 2057°F (1125°C), the CFC was found to have adhered to the steel surface.

The carbon content in 10mm depth measured with GDOES (see the profiles in Figure 1) increased from initially 0.29 weight-% for the 1922°F (1050°C) test, although nothing was visible on metal surfaces. For carbon contents, see Table 2.

Reaction	Relative Reaction Rates
(1) $C + O_2 \rightleftarrows CO_2$; $\Delta_R H = -393.5 \frac{kJ}{mol}$; $\Delta_R G < 0$	1×10^5
(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	3×10^{-3}

Table 1. Reaction rates and activation energies for graphite (800°C; 0.1 bar)

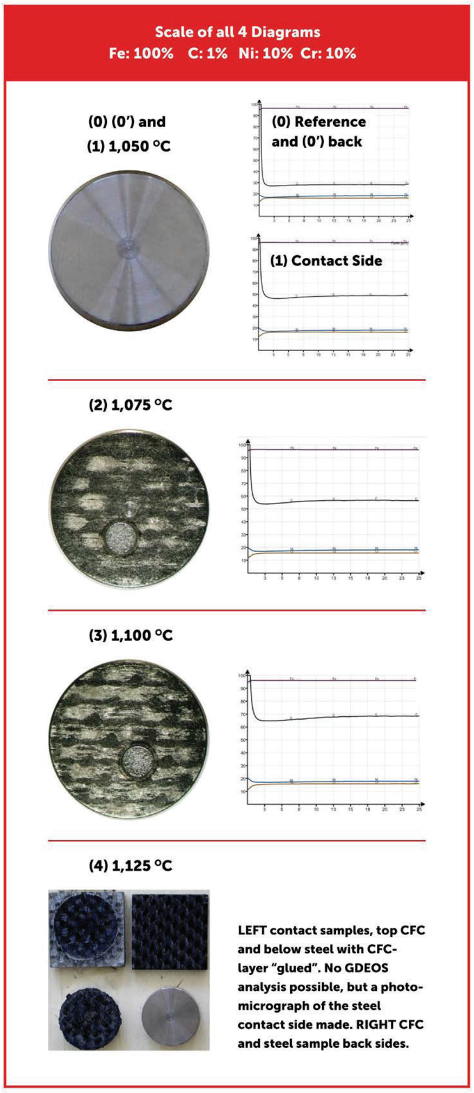

Figure 1. 1.6582 steel samples and GDEOS depth profile analysis

CFC Reactions with Oxygen

The chemical reactions of CFC with various gases are essential in Step 1 (referenced in Part 1 of this article) and an indicator of chemical–thermal suitability.

In the case of the unwanted contact carburization considered above is similar, in a sense, to carburization of steel in contact with carbon powder or granulate. However, the actual carburization mechanism, which occurs between approximately 1616°F and 1697°F (880°C and 925°C), does not take place directly via the carbon contact

Test no.	Ref. (0)	(1)	(2)	(3)	(4)
Temp in °C	20	1,050	1,075	1,100	1,125
C-Content in Weight - %	0.29	0.47	0.56	0.67	N/A

Table 2. Carburizing of 1.6582-samples in 10 µm depth after CX-27C1-contact (GDOES)

but is based on the fact that solid carbon reacts with atmospheric oxygen according to Equation 1 on page 26 to form carbon dioxide (CO_2).

Carbon monoxide (CO) is then formed from CO_2 by the Boudouard reaction (Equation 3). At high temperatures and low pressures (see Figure 2), almost only CO is present.

Transport of Carbon

The carbon carrier must be transported to the surface of the parts.

The cases considered in Part 1 of this article were conducted in vacuum, that is in the absence of a carburizing atmosphere. The laboratory tests were even carried out in a vacuum as low as 7.5 x 10^{-7} Torr (1 x 10^{-6}mbar). Nevertheless, part surface reactions were observed.

Transfer Mechanism into the Steel Parts

Theoretically, carbon from the CFC fixtures can be transferred into the steel via solid phase (as opposed to gaseous phase) reactions. Gas particles can be adsorbed by surfaces via physisorption and/or chemisorption.

The author's personal research experience has shown that metal samples usually oxidize after a short time, even in a high vacuum of 7.5 x 10^{-7} Torr (1 x 10^{-6}mbar). In particular, elements such as iron, molybdenum, and chromium have a strong ability to chemically adsorb oxygen or CO.

Furthermore, there is a disproportionately large amount of adsorbed oxygen in the CFC samples. CFC has open porosities as high as 30%. CFC in industrial practice is never completely evacuated. So, there is a disproportionately large amount of oxygen present in CFC fixtures.

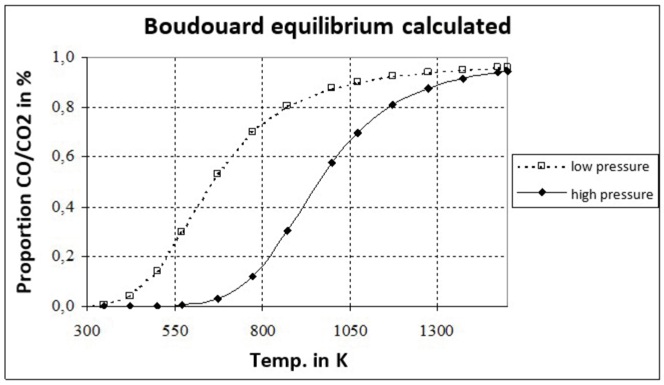

Figure 2. Boudouard equilibrium

It can be assumed that oxygen repeatedly escapes from the CFC and is initially available in the contact area. Proof of this can be provided by the GDOES analysis. Outside the contact areas, no (gas) carburization took place (as evidenced by the non-contact side of steel samples).

The oxygen and carbon surplus combined with close contact lead to complete reaction of oxygen creating carbon dioxide as in Equation (1). Because of the carbon surplus, almost only carbon monoxide is produced as shown in Equation (2). Because of the very close contact between CFC and steel, C-adsorption by gamma iron and desorption of carbon dioxide as in Equation (5) takes place:

$$(5)\quad 2\,CO + Fe^{\gamma} \rightarrow C^{\gamma-Fe}_{solved} + CO_2$$

Since carbon dioxide immediately comes in contact with carbon in the CFC again, carbon monoxide is produced according to Equation (3). In other words, carbon dioxide regenerates immediately and the reaction starts again.

Direct carbon transfer from CFC to metal via solid phase is very unlikely since carbon atoms in CFC are firmly bound in rings.

Diffusion of Carbon in the Steel Parts

In solids, the surface diffusion usually takes place at significantly higher diffusion rates than in the bulk material. The thermodynamic driving force of diffusion or carburizing reactions is the difference in carbon activity for a specific concentration in the austenite to that of the reaction medium. The carbon activity is the ratio of the vapor pressure of the carbon in state under consideration to vapor pressure of pure carbon (graphite/CFC). Alloying elements of the steel influence the activity of the carbon.

Part Reactions (Melting and Carbide Formation)

Steel can begin to melt if, at the given values for temperature and pressure, a partially liquid phase is reached, that is, the solidus line in the phase diagram is exceeded. At even higher temperatures, the liquidus temperature can be reached and steel is completely liquid.

According to metastable iron-carbon diagram phase diagram (Figure 3), a steel such as SAE/AISI 4340 (34CrNiMo6) alloy (DIN 1.6582) with around 0.47% by weight percent carbon does not begin to melt at 1922°F (1050°C), the exposure temperature for Sample (1), or Sample (2) at 0.56% and 1967°F (1050°C) for Sample (3) with 0.67% for 2012°F (1100°C). The iron-iron carbide phase diagram applies to steels with less than 5% (by mass) of alloying elements and thermodynamic equilibrium, so it is an accurate representation for a SAE/AISI 4340 (34CrNiMo6) alloy.

Element	Kind of Elements	Reaction Start	Reaction Product
Al	Metal (Group III)	800°C; ϑ_{melt} = 660°C	Al_4C_3; $Al_2(C_2)_3$ (saline)
B	Metalloid (III)	1,600°C	$B_{13}C_2$ und $B_{24}C$ (adamantine, covalent)
Ba	Alkaline Earth Metal (II)	400°C	BaC_2 (saline)
Be	Alkaline Earth Metal (II)	900°C	Be_2C (saline)
Co	Metal (VIII. Subgroup)	218°C; ϑ_{melt} = 1,321°C for approx. 2.5% C	No Carbides
Cr	Metal (VI. Subgroup)	Approx. > 500°C	Cr_3C_2, *Cr_7C_3*, *$Cr_{23}C_6$* etc., often with Fe in solid solution *$(Cr, e)_7C_3$**
Cu	Transition Metal (I. Subgroup)	ϑ_{melt} = 1,083°C	M_2C_2; some solubility > ϑ_{melt}
Fe	Metal (VIII. Subgroup)	1,147°C	Fe_3C (cementite)*
Hf	Metal (IV. Subgroup)	1,300°C	HfC^+
Mg	Alkaline Earth Metal (II)	1,200°C	Mg_2C_3, MgC_2 (saline)
Mn	Metal (VII. Subgroup)	ϑ_{melt} = 1,533°C for approx. 3.5% C; < 400°C	Mn_3C, Mn_5C_2, Mn_7C_3, *$Mn_{23}C_6$* i.a.*+
Mo	Metal (VI. Subgroup)	approx. 650°C	*Mo_2C^+*; MoC, a- und η-MoC_{1-x}
Nb	Metal (V. Subgroup)	815°C	NbC, Nb_2C (saline)
Ni	Metal (VIII. Subgroup)	ϑ_{melt} = 1,325°C for approx. 1.9% C	No Carbides
Pt	Precious Metal (VIII. Subgroup)	——	some solubility > ϑ_{melt}
Si	Metalloid (IV)	1,200°C	SiC
Ta	Metal (V. Subgroup)	1,300°C	TaC^+
Ti	Metal (IV. Subgroup)	< 500°C from 10% C	*TiC^+*
V	Metal (V. Subgroup)	< 500°C; ϑ_{melt} = 1,231°C	VC, *V_4C_3*, βV_2C etc.+
W	Metal (VI. Subgroup)	approx. 1,000°C (δ)	β-, δ, γ-phase, WC, *W_2C*, and $Fe_3W_3C^+$
Zr	Metal (IV. Subgroup)	750°C	ZrC^+

* : Metalloid Carbide. + : Metallic Carbide. *Italics are strong carbide formers and the most common carbides.*

Table 3. Reactions between C and metal

A calculation of the solidus temperature shown on the iron-iron carbide diagram (Figure 3), which is dependent on the carbon content and alloying elements, yields a value of 2703.2°F (1,484°C) (J').

For an SAE/AISI 4340 (34CrNiMo6) steel (DIN 1.6582) with 0.3% C and one for 0.5% C, the calculated solidus temperature is 2640°F (1449°C). This is shown on the J'-E' blue dotted line in Figure 3. In other words, a lower solidus line (cf. dashed blue line in Figure 3) and thus a slight reduction in austenite phase region.

The iron-carbon diagram also indicates that melting of surfaces that have absorbed carbon (e.g., Sample No. 2) will occur at 1967°F (1075°C). This value is within approximately 90°F (50°C) of the temperature used (dotted line E'-C'-F'). From this information we can conclude that the observations seen in Figure 1 are not the result of melting, but rather imprints due to surface softening.

The melting (c.f., Figure 1) observed in Test No. 4, which occurred at 2057°F (1125°C) is likely due to partial carburization of the steel surface and exceeding the solidus temperature. A micrograph confirms eutectic melting and high carbon content, which could also be indirectly confirmed by hardness measurement.

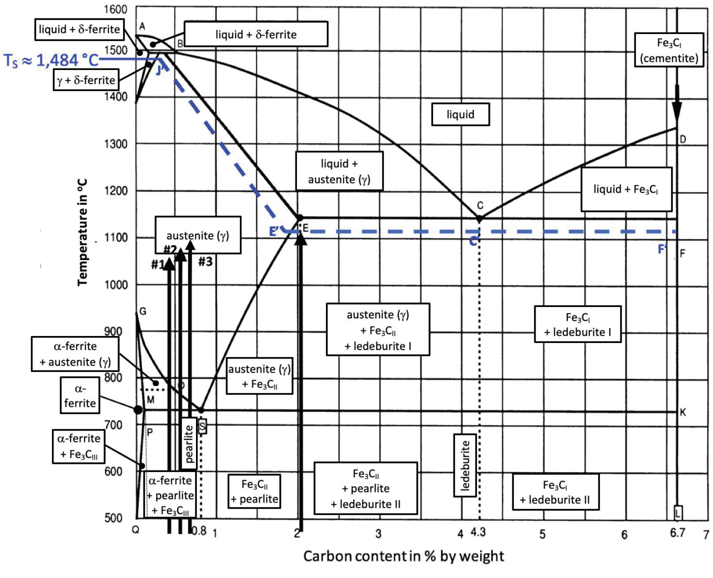

Figure 3. Metastable equilibrium diagram Fe-Fe3C for steel (good fit for 1.6582)

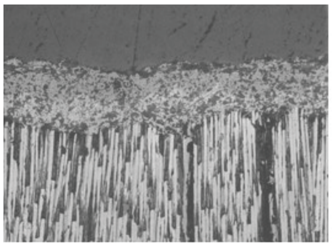
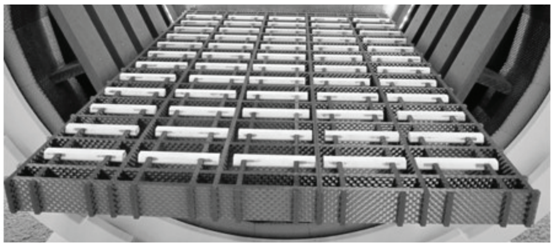

Figure 4. Yttrium-stabilized zirconium oxide layer with an average layer thickness of 110μm on CF222 material. The photograph on the right shows a hybrid CFC fixture. (Source: GTD Technologie Deutschland)

Carbide Formation

Additional reactions can occur between carbon absorbed from the CFC fixtures and the steel parts due to either separation of carbides (e.g., iron carbide in the form of secondary cementite) or carbide formation with alloying elements such as Ti, V, Mo, W, Cr, or Mn (listed in decreasing tendency to form carbides).

Table 3 lists various elements in alphabetical order that react with carbon above the specified temperatures to form reaction products mentioned, primarily carbides. It should be noted that the temperatures listed apply only to pure metals and pure carbon. As such, they provide only rough approximations of a temperature at which a reaction might begin.

Countermeasures

There are several measures to avoid these unwanted reactions:

- Ceramic oxide coatings such as aluminum oxide (Al2O3) or zirconium oxide (ZrO_2) layers placed onto the CFC
- Hybrid CFC fixtures having ceramics in key areas to avoid direct contact with metal workpieces
- Alumina composite sheets
- Boron nitride sprays
- Special fixtures made of oxide ceramics

An yttrium-stabilized zirconium oxide layer (93/7) was applied to CF222 by thermal plasma spray and tested successfully (see Figure 4).

Summary

It is important to consider the specific process conditions in advance so that unwanted reactions — from carburization to catastrophic melting of the workpieces — can be avoided. Effective countermeasures can be taken. HTT

(Photo Source: Dr. Jorg Demmel, High Temperature Concept)

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Dr. Jorg Demmel is the founder, owner, and president of High Temperature Concept. He received his doctorate in engineering in the field of CFC workpiece carriers for heat treatment and has served in key positions for Volkswagen before moving to the U.S.

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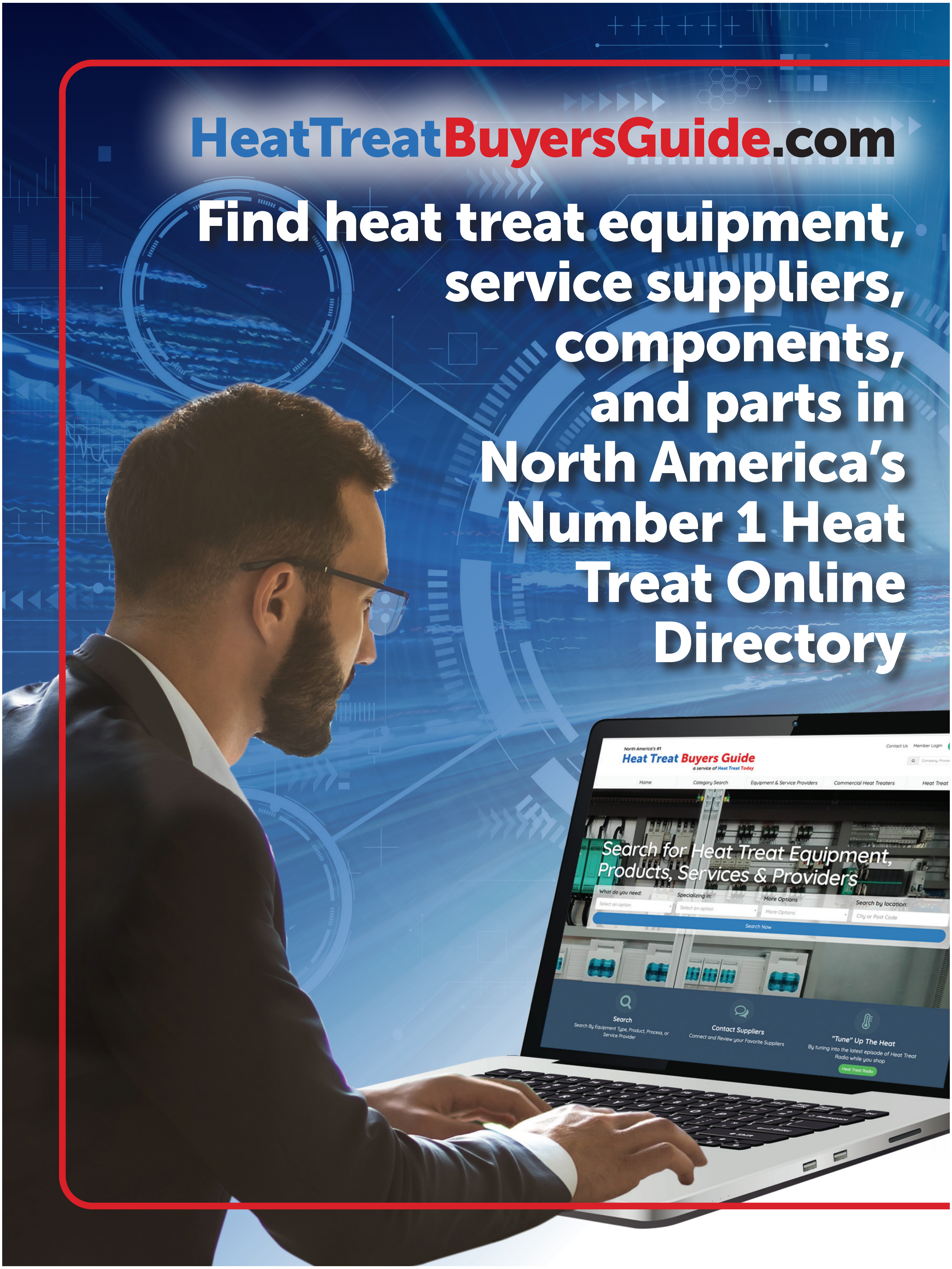
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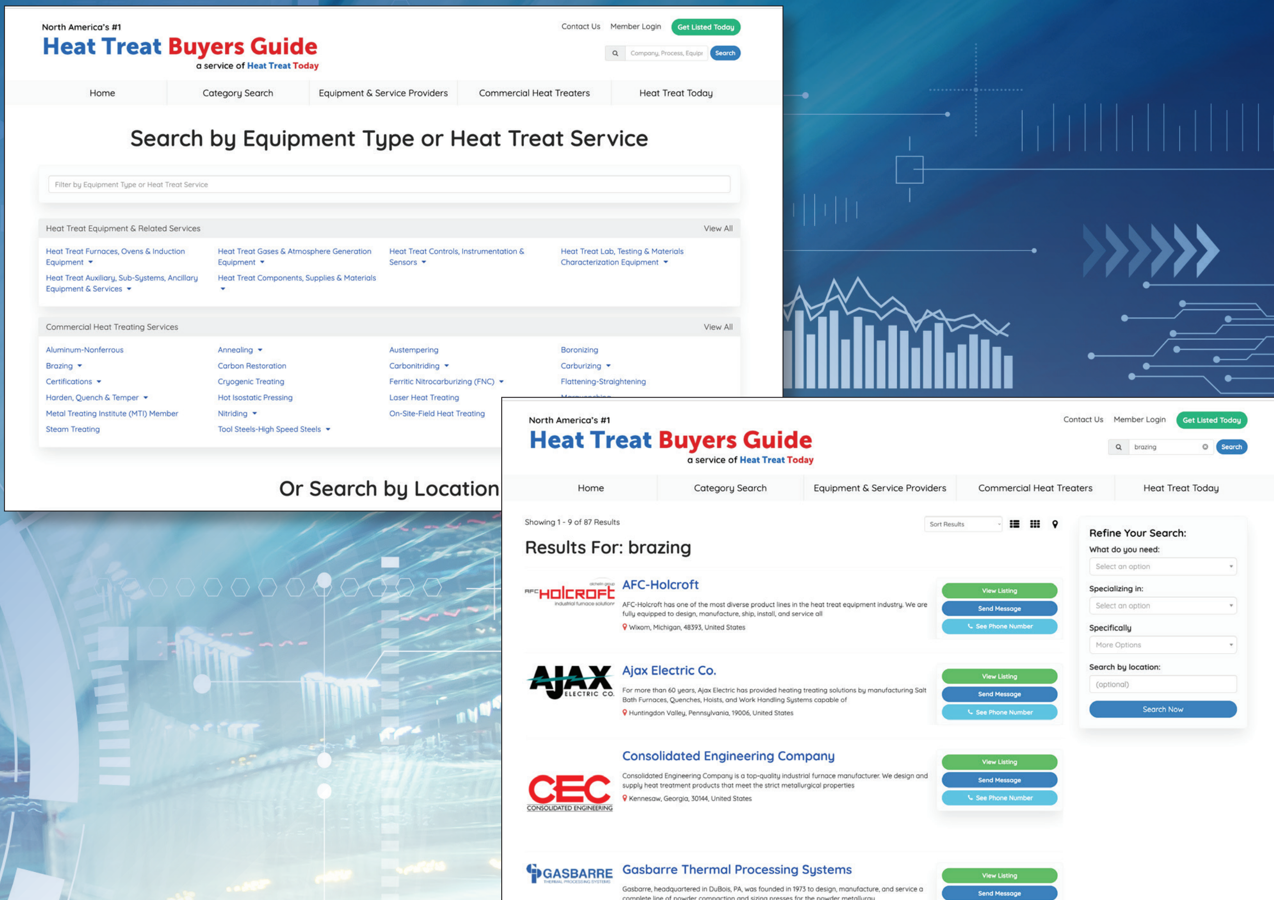
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How Clean Is Clean Enough?

How clean is clean enough? Insufficient cleaning before heat treating can interfere with results; insufficient cleaning after heat treating can impact perception of the part. Discover four methods of measuring part cleanliness that can take place within your heat treat operations in this article provided by SAFECHEM Europe GmbH.

Previously* we talked about the importance of cleaning for demanding heat treat applications — in particular gas nitriding, or ferritic nitrocarburizing (FNC), low pressure carburizing (LPC), and brazing. So, if cleaning is a non-negotiable for certain heat treatment processes, one might ask: how clean is clean enough?

The basic definition of clean is removing unwanted substances, particles, and contaminations. However, when applied to surface cleaning, "clean enough" is determined by what you want to do next in your processing. Parts are generally clean enough if satisfying outcomes can be achieved in the subsequent application.

First, Do You Know the Expectations?

Unlike measuring hardness, monitoring or determining part cleanliness is by no means a straightforward matter.

There are two different kinds of contaminations to consider:

1. Particle contaminations
2. Film-type contaminations

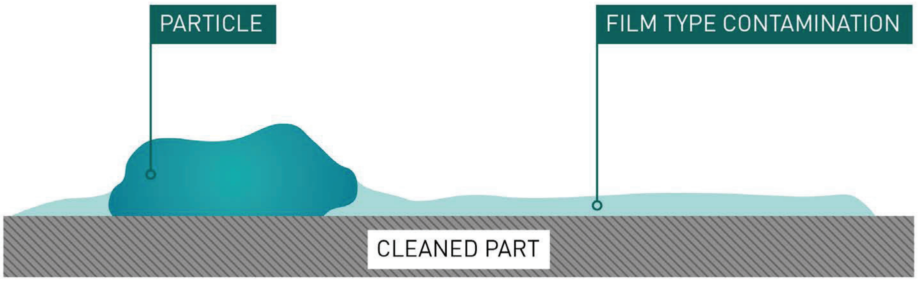
Whereas there are industry definitions or standards for particle contaminations (e.g., VDA-19 or ISO-16232 for the automotive industry), standards for film-type contaminations are not yet fully established.

This inadequacy also explains why many companies do not fully know what to expect when it comes to cleanliness, and they do not fully grasp the potential impact that insufficient cleaning could cause.

Especially when it comes to the heat treat industry, it is important to differentiate between the component cleanliness requirements before and after heat treatment.

Film-type contaminations are the primary factor which could negatively impact heat treat results. Requirements on particle contaminations (VDA-19) usually come from the automotive industry and need to be ensured/monitored after heat treatment.

Therefore, a distinction must be made between a) surface requirements for heat treatment and b) client cleanliness requirements on the final components.



Types of contamination

* To view the first installment of this article, go to **Heat Treat Today** and search "To Clean or Not To Clean?"

What Is the Right Measurement Method?

The analysis of film-type contaminations and particle contaminations are two different subject matters. Measurement methods for one cannot replace the measurement methods for the other. Often, it is quite common for companies to have requirements on both film-type contaminations (e.g., surface energy in dyne/cm or mN/m) and particle contaminations (e.g., max. particle load) in their component drawings.

Some common measurement methods for determining contaminations include:

1. White wipe test: A simple visual inspection test using a clean and dry white wipe to wipe across the surface for the detection of colored residues. Because contaminations can negatively impact heat treat results, inspection should take place prior to heat treatment. The test is limited to colored particles whose size can be perceived by the eye.
2. Water break free test: An easy test to check if oil droplets might be present on the surface is when parts are rinsed with clean water at an angle. If there are contaminations, water will separate around those areas, showing a "break" in the water surface.
3. Dyne testing: This method is commonly used for measurements of film-type contaminations. Dyne inks and fluids are applied to a substrate for measurement of its surface energy. The surface energy (measured in dyne/cm or mN/m) can be identified

Cleanliness Measurement Methods

Method	Information On Particles/ Film Type Contamination?	Complexity	Application
White Wipe Test	Both, On Low Level	Low	On Site
Water Break Test	Film Type	Low	On Site
Test Ink	Film Type	Low	On Site
Contact Angle	Film Type	Medium (Special Device Needed)	On Site
Fluorescence	Film Type	Medium (Device Needed)	On Site
Millipore Filter Measurements/ Solvent Extraction Test	Both	High	Laboratory
TOC	Film Type	High	Laboratory
IR	Film Type	High	Laboratory
XPS	Film Type	High	Laboratory
REM/EDX	Particles	High	Laboratory
TOF-SIMS	Both	High	Laboratory

Cleanliness measurement methods

as the highest dyne solution that wetted out the substrate surface. The higher the dyne level, the better the adhesion of the surface for painting, coating, or bonding. However, the test does not provide information on the types of contaminations present.

4. Millipore filter measurements/solvent extraction test: This measures surface contamination on parts as a weight per 0.1 m^2. Samples are obtained by flushing the cleaned part with an organic solvent where particulates are collected on a filter disc (solvent will be evaporated off later). The test can determine the nature, number, sizes of particles, and if there are reflecting/ non-reflecting metallic particles. Moreover, oil film on parts can be measured after evaporation of the extraction solvent. For automotive, aerospace, or electrical, the level of cleanliness typically ranges between 0.01–0.001g per cm^2.

In general, these methods differ in their complexity and informative value, and also if they can be carried out on site or off site (e.g., in a laboratory). The table below provides an overview of common measurement methods:

Determining Cleanliness — An Art and a Science in Itself

As you now see, the variances and potential limitations of different measurement methods can add to the complexity of cleaning validation. Consider the following:

- Should you measure a specific surface area, or the entire part? And how do you measure pre-assembled components with different parts molded together?
- It might be easy enough to measure surface cleanliness, but what about blind holes and crevices?

Visual inspections have many shortcomings. It is subjective, time-consuming, and does not cover total level of contamination. The quality of inspection will very much depend on the operator. While automated particle counting is efficient and objective, it does not offer insights on specific contaminants.

Extraction methods targeting non-volatile residues (NVR) can help determine a total level of contamination, but not spot contamination. It does not account for inextricable contaminants either, which could impact part functionality.

Meaningful Measurement Begins with Understanding the Big Picture

This is why, in order to measure and monitor cleanliness in a meaningful and reliable way, you should consider:

- What potential contaminations could come about in your process/facilities?
- What contaminants are you looking to remove?
- What are the next processing steps?
- What are the risks involved in removing the contaminants?
- What are the risks associated with the potential residue?

Since every test has its own limitations, you should be mindful of the test specifications, too — for example, how it is conducted, result variability and reproducibility, as well as biases.

Cleaning can be a crucial step in heat treat, but more cleaning does not always equal better. More cleaning also implies more costs, more time, more resource usage. What's really key is understanding what you, or your clients, are trying to achieve.

As you see, cleaning and measurement require expertise and knowhow — context is everything. Reach out to a cleaning specialist or trusted cleaning solutions expert for advice. If insufficient component cleanliness seems to be affecting your heat treat results, our cleaning specialists, along with our partners, would be happy to advise. HTT

(Photo Credit: SAFECHEM Europe GmbH)

For more information:

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Overcoming Challenges and Finding Success in Latin America's First HIP Batch

By Humberto Ramos Fernández, CEO, HT-MX Heat Treat & HIPing

In December 2022, the first HIP batch on Latin American soil was performed. The journey to success in HIP, as any HIP user will agree, is a bumpy road. What are the challenges that aerospace manufacturers with in-house heat treating should be aware of when considering HIP processing? Learn how HT-MX Heat Treat & HIPing — the heat treater who ran the first HIP batch in Latin American history — navigated the transition from small tooling jobs to HIP processing for aerospace parts.

From Simple Tooling to Aerospace Heat Treat

Writing this story as the first Latin American company to offer Nadcap accredited hot isostatic pressing brings a flood of memories and images to mind. HT-MX's beginnings were simple, but also filled with challenges, failures, and lessons. When the company began, we were certain that, though small, we

HT-MX team

Como se logró la primera horneada de HIP en Latinoamérica

Por Humberto Ramos Fernández, CEO de HT-MX Heat Treat & HIPing

En diciembre de 2022, se realizó la primera horneada de HIP en suelo latinoamericano. El camino hacia el éxito en HIP, como cualquier usuario de HIP estará de acuerdo, es un camino lleno de baches. ¿Cuáles son los desafíos que deben tener en cuenta los fabricantes aeroespaciales con tratamiento térmico interno al considerar el procesamiento HIP? Aprenda directamente de HT-MX Heat Treat & HIPing, un tratador térmico que ejecutó la primera horneada de HIP en la historia ae Latinoamérica, cómo navegaron la transición desde trabajos pequeños de herramentales hasta el procesamiento HIP para piezas aeroespaciales.

De herramientas simples al tratamiento térmico aeroespacial

Escribir esta historia de como llegamos a ser la primera compañía latinoamericana en ofrecer prensado isostático were still a "heat treat plant" and not just a shop.

Being located in Mexico means that there were large companies with headquarters located far away — potential customers — that would be deciding on their heat treat supplier close to their location. We worked hard *to be* and *to present* ourselves as being very professional. But a lesson soon learned was that achieving trust with partners takes a lot more than a good speech and a clean plant.

Unsurprisingly, the first jobs were simple tooling work, like quench and tempering tooling and carburizing gears. A junior engineer and I would drive around in my old hatch-back to local machine shops and pick up a small shaft or gear and bring it back to the plant. We would get so excited when we got the case depth right.

With minimal resources, we decided to complete quality control ourselves. We became friends with a quality manager from a local company, and he came over to help on weekends and after 6:00pm until the audit date came. His knowledge is still in use at HT-MX to this day. I remember celebrating with a "Carne Asada" (a Mexican style barbecue)

HIP system at HT-MX

en caliente acreditado por NADCAP trae a la mente una avalancha de recuerdos e imágenes. Los comienzos de HT-MX fueron simples, pero también llenos de desafíos, fracasos y lecciones. Cuando comenzamos la compañía, estábamos seguros de que, aunque éramos pequeños, éramos una "planta de tratamiento térmico" y no solo un taller.

Estando ubicados en México quiere decir que hay grandes plantas con corporativos lejos de aquis — clientes potenciales — que estarían decidiendo sobre su proveedor de tratamiento térmico lejos de nuestra ubicación. Trabajamos arduamente para ser y presentarnos como profesionales y confiables. Pero pronto aprendimos que lograr la confianza con los clientes requiere mucho más que un buen discurso y una planta limpia.

Como era de esperar, los primeros trabajos fueron trabajos simples de herramentales, algunos templados y revenidos de herramentales y carburizado de engranes. Recuerdo como un ingeniero junior y yo dábamos la vuelta en mi viejo hatchback alrededor de talleres locales y recogíamos un pequeño eje o engranaje y lo llevábamos de regreso a la planta. Nos emocionábamos mucho cuando lográbamos la when we finished that first audit, thinking we had just made a huge step forward, not realizing how far away we still were from our vision.

But as time passed, we turned our attention to the aerospace industry in Chihuahua, a city with four OEMs. We received the AS9100 certification and started working on Nadcap accreditation. This required time, but by then, a pretty strong engineering team was in action, and successfully obtained Nadcap accreditation in late 2019. Again, we celebrated with a Carne Asada, this time, with a better understanding on where we were and what future challenges we needed to face.

Taking On Hot Isostatic Pressing

The pandemic hit. Boeing's 737 Max crisis continued to impact the industry. Moving into aerospace was slow with limited volume, especially compared to what we had seen in the automotive and oil and gas industry. But by now, international companies *were* more willing to transfer heat treat operations to Mexican suppliers, and we were ready, beginning with running aluminum batches, precipitation hardening, annealing, and other standard processes. It was during this early start to serve the aerospace industry that we heard about hot isostatic pressing (HIP).

Around 2019 during an aerospace cluster event, an OEM with a local presence approached us with their HIP requirements. I had only heard of HIP, but I was immediately interested — until I found out how much one of those machines cost!

But good financing through government programs helped make this HIP project a reality. Timing was not the best, as the federal election in Mexico caused a temporary Mexican currency depreciation, handicapping the project at its beginning.

Getting the proper certifications and validations proved to be a long and complex process, too. Theoretically, we knew what to expect, in terms of getting the Nadcap checklist approved, but the reality was a little different. Gaining Nadcap certification slowly builds a certain culture into any company in its day-to-day activities. Translating that culture into a completely different business unit, new crew, and new process proved to bring its own challenges.

HIP Challenges: Pressure, Temperature, Thermocouples, and Argon Supply

Heat treating usually handles temperature, atmosphere control (or lack of), and regular traceability requirements. HIP, however, adds a few new dimensions to what we usually see: internal pressure, very high temperatures — up to 3632°F (2000°C) — and argon supply. It was the first time HT-MX dealt with a process that incorporated up to

HT-MX Nadcap certification

profundidad de capa correcta.

Con recursos mínimos, decidimos implementar el sistema de calidad nosotros mismos. Nos hicimos amigos de un gerente de calidad de una empresa local, venía a ayudarnos los fines de semana o después de las 6:00 p.m. hasta que llegó la fecha de la auditoría. Su enseñanzas aún se usan en HT-MX hasta el día de hoy. Recuerdo celebrar con una "Carne Asada" cuando terminamos esa primera auditoría, pensando que habíamos dado un gran paso adelante, sin darme cuenta de lo lejos que aún estábamos de nuestra visión.

Con el tiempo, dirigimos nuestra atención a la industria aeroespacial en Chihuahua, una ciudad con cuatro OEMs. Recibimos la certificación AS9100 y comenzamos a trabajar en la acreditación NADCAP. Esto requirió tiempo, pero para entonces contábamos con un equipo de Ingenieros bastante sólido y obtuvimos con éxito la acreditación de NADCAP a finales de 2019. Nuevamente, celebramos con una Carne Asada, esta vez con una mejor comprensión de dónde estábamos y qué futuros desafíos tendríamos que enfrentar.

Entrándole al Prensado Isostático en Caliente

La pandemia llegó. La crisis del 737 Max de Boeing continuó afectando a la industria. Empezar en sector aeroespacial fue lento y con un volumen limitado, especialmente en comparación con lo que habíamos visto en la industria automotriz y de oil&gas. Pero para entonces, las empresas internacionales estaban más dispuestas a trasladar las operaciones de tratamiento térmico a proveedores mexicanos, y estábamos listos, comenzando a procesar aluminio, endurecimiento por precipitación, recocido y otros procesos estándar. Fue durante estos inicios en la industria aeroespacial que escuchamos hablar del prensado isostático en caliente (HIP) por primera vez.

Alrededor de 2019, durante un evento del Cluster Aeroespacial de Chihuahua, un OEM con presencia local se acercó a nosotros con sus requerimientos de HIP. No conocíamos mucho de HIP, pero de inmediato me interesé . . . ¡hasta que descubrí cuánto cuesta una de esas máquinas!

Pero un buen financiamiento a través de programas gubernamentales ayudó a hacer realidad este proyecto de HIP. El momento no fue el mejor, ya que las elecciones federales en México causaron una depreciación temporal de la moneda mexicana, lo que obstaculizó el proyecto al principio.

Obtener las certificaciones y validaciones adecuadas resultó ser un proceso largo y complejo también. Teóricamente, sabíamos qué esperar en términos de obtener la aprobación para el checklist de NADCAP, pero la realidad fue un poco

30,000 psi and also used a lot of high purity argon.

Pressure has its own challenges, though the HIP press takes care of those challenges. Still, the internal workings on these kinds of presses are fundamentally different than that of a regular heat treat furnace. Yes, you need to heat it up, but apart from that, it's not even a furnace but a press. Understanding how the machine works, what happens inside with all that pressure, how it affects the components undergoing hot isostatic pressing, and how it affects the baskets you're using is a critical learning curve.

High temperatures change everything about running these types of cycles. We work with metals, which means temperatures range between 1832°F and 2372°F (1000°C and 1300°C). This has an impact on thermocouple selection, calibration, and more; with the company's thermocouple product suppliers based in the U.S., this entails more challenges and extra costs. I have lost count on those urgent same-day trips to the border to retrieve critical spares in time. It's an 800-km/498-mi roundtrip! We have fortunately found a great supplier that has offered the technical feedback we needed, and we have started to finally understand and control our thermocouple consumption. Although, I must be honest here, we still have a lot to learn in this aspect.

Then, there's the argon supply. HT-MX never expected it to be a challenge, but it turns out getting the proper supplier — one that understands the requirements and is willing to work with you from validation to production — is key. You might be able to start your validation process using argon transported in

diferente. Obtener la certificación de NADCAP construye lentamente una determinada cultura en cualquier empresa en sus actividades diarias. Traducir esa cultura a una unidad de negocio completamente diferente, con un nuevo equipo y un nuevo proceso, demostró traer sus propios desafíos.

Retos en el HIP: presión, temperatura, termopares y argon

El tratamiento térmico generalmente trata de temperatura, control de la atmósfera (o la falta de ella) y los requisitos regulares de trazabilidad. HIP, sin embargo, agrega algunas dimensiones nuevas a lo que normalmente vemos: presión interna, temperaturas muy altas, de hasta 3632°F (2000°C) y suministro de argón. Fue la primera vez que HT-MX lidiaba con un proceso que incorporaba hasta 30,000 psi y también usaba mucho argón de alta pureza.

La presión tiene sus propios desafíos, aunque la prensa de HIP se encarga de ellos. Aún así, el funcionamiento interno en este tipo de prensas es fundamentalmente diferente al de un horno de tratamiento térmico regular. Sí, necesitas calentarlo, pero aparte de eso, no es ni siquiera un horno, sino una prensa. Comprender cómo funciona la máquina, qué sucede dentro con toda esa presión, cómo afecta a los componentes sometidos a prensado isostático en caliente y cómo afecta a las canastas y fixtures que estás utilizando, es una curva de aprendizaje crítica.

Las altas temperaturas cambian todo sobre el funcionamiento de estos tipos de ciclos. Trabajamos con metales, lo que significa que las temperaturas oscilan entre 1832°F y 2372°F gas containers but eventually you will need to switch to liquid argon. That proved to be more difficult than expected. There are not many projects requiring these kind of alliances locally. Getting the right supplier was key and more of a challenge than expected. And then came the lessons on efficiently using the liquid argon, avoiding excessive venting of the tank, and being all around smart with the HIP schedule. This has been a constant learning process, one that has high costs.

Final Hurdles: Certifications, Current Events, and Energy Costs

Once our company had the Nadcap certification, we still needed to get the OEM's approval for the HIP process, then the approval for the specific version of the HIP process, and then the actual approval for the part numbers.

These approvals were handled by the headquarters' engineering department and not locally. It was a time-consuming process, with several test runs, lab testing, multiple audits, visits, and more testing, etc. And while all of this was happening, we still had to design the operation, locate critical suppliers not available in Mexico, create alliances with suppliers, etc. Writing this down in a few lines makes it seem simpler and quicker than it really was.

Additionally, in instances like this, Mexican companies, especially small ones, face much more scrutiny than U.S. or European-based companies, and must prove themselves in every single step. It makes sense, even if it feels a little unfair, as HT-MX had no proven track record of high tech processes such as HIP. It does cost extra time, extra care, and sometimes extra testing, but it is the reality we face and we must overcome the extra hurdles.

While navigating HIP approval, the pandemic hit. Months later, the war in Europe began with significant impacts on the cost of energy. Our main clients were high volume and low margin, and with energy prices rising, our competitiveness began to diminish. To adapt and evolve, we decided to add some smaller furnaces for smaller parts, invest in training and increased sales efforts, and focus on AMS/Nadcap-based customers, letting go of major clients. Slowly, things began to turn around.

The First Official HIP Batch in Latin America History

In December 2022, HT-MX ran the first official HIP batch in Latin American history. It was a long time coming. I always thought that running that first batch would feel like reaching the Everest summit. When the day came, it just felt like reaching Everest's base camp. We still have a long way to go to be truly an established HIP supplier. Now, it's back to climbing and shooting for that summit, that summit that will perpetually precede the next summit.

There are still several challenges: stabilizing new processes and improving established ones. But I am confident we will move forward in this new stage. And I am so looking forward to the next Carne Asada. HTT

(Photo Source: HT-MX Heat Treat & HIPing)

(1000°C y 1300°C). Esto tiene un impacto en la selección de termopares, calibración y más; con los proveedores de termopar basados en EUA, esto implica más desafíos y costos adicionales. He perdido la cuenta cuantos viajes urgentes de ida y vuelta por refacciones a la frontera he hecho. ¡Es un viaje redondo de 800 km! Afortunadamente, hemos encontrado un gran proveedor que nos ha ofrecido la retroalimentación técnica que necesitábamos, y finalmente hemos comenzado a comprender y controlar nuestro consumo de termopares. Aunque, debo ser honesto aquí, todavía tenemos mucho que aprender en este aspecto.

Luego está el suministro de argón. En HT-MX nunca esperamos que fuera un desafío, pero resulta que conseguir el proveedor adecuado, uno que entienda los requisitos y esté dispuesto a trabajar contigo desde la validación hasta la producción, es clave. Es posible que puedas iniciar tu proceso de validación usando argón transportado en contenedores de gas, pero eventualmente necesitarás cambiar a argón líquido. Eso resultó ser más difícil de lo esperado. No hay muchos proyectos que requieran este tipo de alianzas a nivel local. Conseguir el proveedor adecuado fue clave y resultó ser un desafío mayor de lo esperado. Y luego vinieron las lecciones sobre cómo utilizar eficientemente el argón líquido, evitar el excesivo venteo del tanque y ser inteligente con el calendario de HIP en general. Esto ha sido un proceso de aprendizaje constante, uno que tiene altos costos.

Últimos obstáculos: certificaciones, eventos globales y costos energéticos

Una vez que nuestra empresa obtuvo la certificación NADCAP, todavía necesitábamos la aprobación de los OEM para el proceso HIP, luego la aprobación para la versión específica del proceso HIP y luego la aprobación real para los números de parte.

Estas aprobaciones fueron manejadas por el departamento de ingeniería del corporativo y no localmente. Fue un proceso que consumió mucho tiempo, con varias pruebas, pruebas de laboratorio, múltiples auditorías, visitas y más pruebas, etc. Y mientras todo esto sucedía, todavía teníamos que diseñar la operación, localizar proveedores críticos que no estaban disponibles en México, crear alianzas con proveedores, etc. Escribir esto en pocas líneas parece más simple y rápido de lo que realmente fue.

Además, en casos como este, las empresas mexicanas, especialmente las pequeñas, enfrentan mucho más escrutinio que las empresas estadounidenses o europeas, y deben probarse en cada paso. Tiene sentido, aunque se siente un poco injusto, ya que HT-MX no tenía un historial comprobado de procesos de alta tecnología como HIP. Cuesta tiempo extra, cuidado adicional y a veces pruebas adicionales, pero es la realidad que enfrentamos y debemos superar los obstáculos adicionales.

Mientras navegábamos en la aprobación de HIP, llegó la pandemia. Meses después, comenzó la guerra en Europa con impactos significativos en el costo de la energía. Nuestros principales clientes eran de alto volumen y bajo margen, y con el aumento de los precios de la energía, nuestra competitividad comenzó a disminuir. Para adaptarnos y evolucionar, decidimos agregar algunos hornos más pequeños para piezas más pequeñas, invertir en capacitación y aumentar los esfuerzos de ventas y enfocarnos en clientes basados en AMS / NADCAP, dejando ir a clientes principales. Poco a poco, las cosas comenzaron a mejorar.

La Primera Horneada Oficial de HIP en la Historia de Latinoamérica

En diciembre de 2022, HT-MX llevó a cabo la primera horneada oficial de HIP en la historia de Latinoamérica. Tomo bastante tiempo. Siempre pensé que hacer esa primera horneada se sentiría como llegar a la cima del Everest. Cuando llegó el día, solo se sintió como llegar al campamento base del Everest. Todavía nos queda mucho camino por recorrer para ser realmente un proveedor de HIP establecido. Ahora, volvemos a escalar y apuntamos a esa cima, esa cima que perpetuamente precederá a la próxima cima.

Todavía hay varios desafíos: estabilizar nuevos procesos y mejorar los establecidos. Pero estoy seguro de que avanzaremos en esta nueva etapa. Y estoy muy emocionado por la próxima Carne Asada. HTT

About the Author:

Humberto Ramos Fernández is a mechanical engineer with a master's degree in Science and Technology Commercialization. He has over 14 years of industrial experience and is the founder and current CEO of HT-MX Heat Treat & HIPing, which specializes in Nadcap-certified controlled atmosphere heat treatments for the aerospace, automotive, and oil and gas industries. With customers ranging from OEMs to Tier 3, Mr. Ramos has ample experience in developing specific, high complexity secondary processes to the highest requirements.

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Heat Treat Tomorrow — Hydrogen Combustion for Heat Treating: Reality or Smoke?

Interview sponsored by Nel Hydrogen

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

Doug Glenn, publisher of **Heat Treat Today**, *continues the discussion of hydrogen combustion with a panel of five industry experts. In the year since the first installment of this interview in August 2021, what changed? Justin Dzik, Fives North American Combustion, joins the panel this time. Veteran panelists include Jeff Rafter, Selas Heat Technology Co., Joe Wuenning, WS Thermprocess Technic GmbH, Perry Stephens, Electric Power Research Institute, and John Clarke, Helios Electric Corporation. Below is an edited excerpt from this thought-provoking discussion.*

What Has Changed for Hydrogen Combustion Between 2021 and 2022?

Doug Glenn (DG): It's been about a year since we spoke last, so the question is: What has changed? In the last 12 months, have we seen any major changes in hydrogen combustion technology application?

Jeff Rafter, Selas Heat Technology Company, LLC

Jeff Rafter (JR): I think I would say, probably, that the dominant change over the last 12 months has just been general interest in momentum. We're now seeing inquiries and interest from a variety of different industries. A lot of people are preparing for the future and starting to think about decarbonization in a bigger sense, and then watching that interest be amplified by geopolitical events, but we're now getting to a place where parts of the world sincerely have more motivations.

It's now not just an environmental protection motivation, but we're also seeing a need to continue operations as fuel supplies, in some parts of the world, have now been called into question.

Dr.-Ing. Joachim G. Wünning, WS Thermprocess Technic GmbH

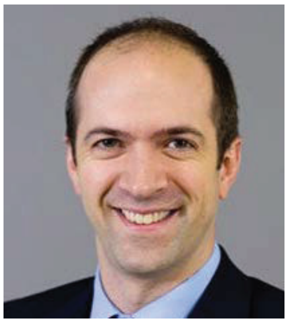
Joe Wuenning (JW): Of course. Here, we are closer to Ukraine-Russian war. Germany is directly very much dependent on Russian gas and the real fear here for companies is that they have to shut down in the Fall because of gas shortages. So, that intensified the thinking about the future. One issue which became less important is the price. At the moment, the people think: do we even get gas, and don't think what it costs for it. Before, it was a big discussion if prices would go up by 5% or 10%; now, everybody is happy if they will get it and so, basically, we have no more jobs within Europe where that is not a point of discussion.

What can we do? Some people think about electrifying, of course, but we still produce electricity from gas, so that is not really the solution alone, and we don't know what the electricity grid will do in the future, so flexibility has become a major player also. So, not only hydrogen, but can we also do ammonia? Can we do other things? What are the options which keep us independent and don't make us dependent so much on one source as it is now, at the moment?

Perry Stephens, Electric Power Research Institute (EPRI)

Perry Stephens (PS): I would echo what Jeff said. I think we're seeing not only sort of a general greater interest, but the leadership of Fortune 500 companies which are global in nature as well. And seeing all of these geopolitical situations occur, they are wanting to think through stabilizing their future energy supplies and understanding that the impacts of climate are beginning to really push down to their suppliers a desire to decarbonize all of their final energy pathways. So, they're beginning to make inquiries in terms of how they can change over equipment and what needs to be done.

From a technology standpoint, we're beginning to understand a bit more what elements of hydrogen combustion or blended hydrogen with natural gas, for example, have impacts on what parts of overall systems and what areas may have significant costs or performance impacts for which we may need to do a bit of additional research, so we're beginning to understand where those impacts may be as well. I think, finally, we're beginning to see some results of research that sort of tells us, on an economy-wide basis, the drivers for demand for hydrogen and sort of under various scenarios how much hydrogen might be needed for various economic sectors, including the industrial sector.



Justin Dzik, Fives North American Combustion

Justin Dzik (JD): Honestly, what we've seen is the growing acceptance across not only just industry but government and society that we need to transition from where we are with natural gas or conventional fuels to lower or zero carbon intensity. So, depending on where you are in the world, the exact timeline varies, but there is increasing focus on how we get from where we are to where we've got to go. Hydrogen is the purer, noncarbon footprint fuel so that's obviously the ideal state. We've also received an increased amount of inquiries and interest in hydrogen, specifically on combustion equipment, and not only just from industry but from utility companies even here in the states talking about blending fuel and putting hydrogen in the natural gas lines and what effect that has on industry as well as some of the residential implications it might have — going forward — for their users.

John Clarke, Helios Electric Corporation

John Clarke (JC): I believe we're kind of living through that old Chinese curse — "May we live in interesting times!" — because we have seen disruptions, both on our energy supplies and our energy costs. In the U.S., we were tracking Henry Hub prices approaching $10 and now, all of a sudden, we had a fire in pre-port and the price of natural gas fell 30%. But I think the long-term trend (and the trends are being recognized by everybody) is that we are in an international market, not only for oil, but for natural gas, as well. I think we've seen the effect really come home.

The other thing that's going on, too, is the price of gasoline and transportation in the U.S. has skyrocketed and we're now experiencing the kind of prices that Europe has lived with for years and years and years. I think all these factors, these externalities, are going to drive interest in *any* alternative. Hydrogen for combustion, but hydrogen also for fuel cells and for automobiles. We're kind of entering a period where I think our technological focus needs to be "all of the above" and I think there's an acceptance throughout industry and industry leaders that that's the path we have to be on to protect our businesses going forward.

Are There Any New Hydrogen Combustion Applications for Heat Treating?

DG: So, it seems like the consensus, is, from a year ago, the interest — and to a certain extent some of the technologies are advancing, but at least the interest — is very much being advanced. So, it's becoming more and more of an issue.

Let's talk specifically and, Perry, I'm going to address this one to you first if you don't mind: Have we seen in the last 12 months any new applications and/or industries that are aggressively adopting it? There is one that pops to my mind that's been very obvious.

PS: Probably the one you're thinking about is the steel industry that has a specific nuance of steel production that huge amounts of fossil fuels, natural gas, and cooking coal, are involved in the production of raw steel and so in that reduction reaction, hydrogen can serve as a chemical-reducing agent. So, it not only introduces thermal inputs but also serves as a thermochemical-reducing agent to actually remove the oxides from the ore that allow you to liberate pure iron content that eventually becomes steel. Plus, a significant amount of process-related emissions that come from steel production make it a target industry, so they've been fairly aggressive, particularly in Europe, with a couple projects where hydrogen is involved. And the fact that, as we grow the use of steel, high-strength steel, and a lot of applications, globally, there will be a need to add new iron units into the system. A lot of steel is now recovered scrap steel that is melted through electric arc furnaces, but we need to add additional iron content. So, direct reduced iron processes are beginning to take a close look at hydrogen as a reducing agent and also for thermal inputs.

Quickly, beyond that, in most industrial settings, there is a lot of mobile equipment, and that mobile equipment uses a variety of diesel, compressed gas, propane and so forth, and those applications are particularly easy to convert to be hydrogen-type applications because they're relatively small in both size and captive space; they compete with electric equipment in that space and so those two technologies will come forward.

As far as other industries, the petrochemical industry uses a lot of hydrogen — they're used to it. They'll continue to look at both liberated hydrogen from process and other sources of hydrogen for their end-product production for process heating as well as inputs into the production of various synthetic fuels and other synthetic products that they make in the petrochemical industry.

So, those are the two — steel and petrochemical — in my view, probably most aggressively looking at hydrogen. Others may have other experience, as well.

JD: Yes, absolutely. To echo what Perry said, the steel industry with their green steel initiative is really pushing forward. From our experience, a lot of interest is coming from the aluminum industry, as well. We play heavily in the aluminum industry, specifically on the melting side, and some major companies are interested in adopting hydrogen firing, especially the ones coming out of Europe and their interest really comes from what happens when you fire hydrogen fuel, and it interacts with the molten bath. There are a lot of material concerns with hydrogen, right? Not just in aluminum, but in titanium firing, as well. Those types of metals tend to have an affinity for hydrogen which could have a detrimental effect on the final product. So, really there are pilot scale tests, full scale tests, and all kind of undertaking right now. Obviously, the focus is in Europe, but a lot of European companies have plants in the U.S., so we're seeing a lot of these efforts drift into our territory here in the U.S. and being administered out of the European headquarters.

JW: We've seen a lot of projects in the last 12 months. We have various customers who told us they want to try hydrogen in their furnace with a hundred burners; so, they test two of them with hydrogen and see what happens — see what the emissions are, see what the burner life is, do they have varying parts? That is a part we do with many customers. It's quite inexpensive to just try to see what happens. We also have two big research projects where we can do more thorough testing with a university, not only switching to hydrogen but also seeing what happens if we switch back and forth. So, if we

Heat Treat RADIO

have hydrogen coming in, it goes to hydrogen, it should automatically adjust without human interference. That is a little bit more challenging, but we see no real major problems towards that because, of course, we will not have hydrogen as a cheap fuel tomorrow, but we have to introduce it slowly if we have excess electricity converted to hydrogen and then get into the grid but therefore the burner systems have to be able to handle that — the change in compositions; not only switching but also the change in compositions.

On the other hand, we are using hydrogen now in our lab for quite some time and the people in the lab get more and more used to it. I think they think it's more and more rather the better fuel than natural gas, cleaner fuel the more they work with it, and I think not really too many people are concerned now that it could be a replacement if the hydrogen would be easily available.

JC: The thing I have seen is a little off the core of your question, but I've seen a couple of municipalities dealing with some of their distribution challenges, and that I've seen in the last year where they recognize that hydrogen is a potential opportunity to save on carbon emissions. But what would it take and at what percentages can you introduce what kind of impact will it have on common appliances? That is a trend, too, and I think the middle between the production and the utilization is going to be a serious challenge for us in the U.S. and it's an impediment if we're trying to advance the front. You know, we have to advance on all three fronts simultaneously if we're going to achieve an effective market. I've seen some very encouraging work now being considered at the local distribution level.

JR: I guess I would say what's different is that the dominant pattern over the last couple of years that we've seen is primarily most of the interest came from industries that were highly energy intensive which usually travels with a high temperature process. So, it goes without saying that many of the early adopters were glass, steel, other metals. But what we've seen in the last 12 months is now a general interest shift, and we're starting to field inquiries and take on demonstration projects and things that we would traditionally consider low-temperature heating: baking applications, food production, metal finishing. And it tells me that, again, momentum is building.

I think, in general, industries beginning to be comfortable with the concept of decarbonization and low carbon fuels, whether it's ammonia, whether it's hydrogen, but, again, the recognition is that we're only going to get so far until we see some more significant advancements in the generation of hydrogen and the distribution of hydrogen. Again, I think that remains probably the largest hill that we have to crest before we really get through some significant decarbonization impacts.

DG: It seems that everybody really loves the concept; it's just the matter of producing it and getting it where it needs to be. HTT

You won't want to miss the rest of this interview. To watch, listen, or read in its entirety, search "Hydrogen Combustion Panel" heattreattoday.com/radio.

Heat Treat Tomorrow – Hydrogen Combustion for Heat Treating: Reality or Smoke

Continued from page 8

(Table 4)*, print and chart speed (Table 5)*, and testing frequencies for SAT (Tables 6, 7)* and TUS (Tables 8, 9)* for the processing of parts versus raw materials.

AMS2750 Revision E was released in July 2012 and continued to build on the clarity presented in Revision D by adding an instrumentation type table (Figure 3)* instead of a simple text description in the body of the specification.

Moving to AMS2750 Revision F, the specification saw a major rewrite and restructuring where the tables were moved from the end of the document to the first area text that called out the specific table. Revision F also put into place a sunset date for analog instruments.

That brings us to the current revision of AMS2750, Revision G, which has carried forward the structure of Revision F and only sought to further clarify the intent of the requirements.

Over the years, the technology of sensor, instrument, and furnace manufacture and capability has continued to produce better and tighter controls for the process of heat treating. The evolution of AMS2750 has recognized these advancements and has kept pace with them in technology. The understanding of the origins of AMS2750 and how it has evolved is vital in understanding its application to today's heat treat special processes.

**Specified figure, table, or section is associated with the AMS2750 revision being discussed.*

(Photo Source: Heat Treat Today)

References

[1]Andrew Bassett. "Heat Treat Radio #38: Andrew Bassett on AMS2750F (Part 1 of 3)" https://www.heattreattoday.com/media-category/heat-treat-radio/heat-treat-radio-andrew-bassett-on-ams2750f/.

About the Author:

In 2009, Douglas (Doug) Shuler became the owner of Pyro Consulting LLC and also began working with Performance Review Institute (PRI), first as an instructor and course developer and later as an auditor for the Nadcap program. As a lead auditor for Nadcap, he has conducted over 380 Nadcap special process and aerospace quality management system audits on behalf of the Aerospace Primes over the past 10+ years. Doug continues to focus on instruction, training, and education for the heat treat industry, developing courses, authoring exams, and employing the PIE method: "Procedures that Include all requirements, and Evidence to show compliance."

For more information:

Contact Doug at dgshuler@pyroconsulting.net

Continued from page 10

optimize the assembly process once new components are manufactured.

4. Evaluate the product(s). Conduct material analysis to acquire chemical and mechanical property data. This will aid in defining the appropriate layout for machining, material conditioning (i.e., heat treatment), external finishes/coatings, etc.

While the design and planning phase may pose some challenges, the more critical challenges that occur during reverse engineering are in the execution of the manufacturing, assembly, and qualification testing. To elaborate, once you begin machining and processing components, there may be special methods of manufacturing that require discovery because standard methods may not have worked when the OEM produced it. When this happens, you go back and forth on updating and fine-tuning the process plans, fixturing, programs, etc. Sometimes this means scrapping parts and starting over or validating if parts are still usable for prototyping. Along the same lines, when the process progresses into the assembly and testing phase, engineers typically discover variability, errors, or weak points that require adjustments. In those cases, the engineer's drawings must be revised. A large percentage of these issues can be limited through experience with similar components or assemblies, but in most cases, there is a lot of analysis and some trial-and-error involved in the manufacturing, assembly, and testing phase that is not apparent upon initial RE processing. HTT

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DLA. "Master List of Technical and Quality Requirments Version 14."

MIL-STD-280A. "Handbook for definitions of item levels, item exchangeability, models, and related terms." DOD Washington, D.C. 20301.

Special thanks to David V. Jones and Thomas R. Blackburn IV at Thomas Instrument for their input on this topic.

About the Author:

Jonathan McKay, a mechanical engineer, is the heat treat manager at Thomas Instrument, a company specializing in reverse engineering critical aerospace components. At the company, he is manning the establishment of heat treat operations, has created procedures and process plans for Thomas Instrument to be an approved heat treater for an aerospace prime, and has attained Nadcap accreditation for heat treat.

For more information:

Contact Jonathan at Jonathan.McKay@thomasinstrument.com

DUAL PERSPECTIVES: Europe vs. North America

Changes are inevitable, but the world today is shifting oh so rapidly, keeping us on our toes. Two men from different parts of the world, both with significant experience within the heat treating community, reflect on the implications of these changes in the heat treat industry. With each new topic, will their views align?

The experts are Thomas Schneidewind, editor-in-chief of **heat processing** magazine, and Doug Glenn, publisher and founder of **Heat Treat Today**. Thomas's expertise lies in the European market while Doug's resides in the North American market.

Has digitalization come to heat treat operations? If so, how?

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

Have you heard about the speaking furnace in the smart heat treat operations in Kleinachenbuchbach?

You are right! There is no speaking furnace and no city with this name — not as far as I know. But if you think about the future of hardening shops or just have a look in the R&D departments of furnace builders, you will get an idea what the heat treat shop will look like in twenty years. Two topics will clearly shape the industry: decarbonization and digitalization. Decarbonization is the leading theme; digitalization is its enabler.

Digitalization is an important catalyst that makes decarbonization possible. It enables us to create and play out a multitude of scenarios in the shortest possible time, to exchange information globally in seconds, to free ourselves from time-consuming routine work, and to conserve, develop, and pass on knowledge gained from experience. Further, artificial intelligence (AI) has already started to augment all of our businesses, and this trend will continue to accelerate over the next years. Every company needs to think of itself as a technology company, redesign its processes, and ensure its employees have the skills needed for a world where we increasingly collaborate and work with capable and intelligent machines.

Digitalization is a key to success for small and medium-sized enterprises in the heat treatment industry and a key to change the traditional heat treat shop into a smart, green, and profitable company. As the owner of a heat treat operation, you can concentrate on your business. While you talk to clients, do business, and invest in green technologies, maybe someday you will talk to your furnace and it will give you answers to much bigger questions than those connected to temperature, time, and hardness.

Doug Glenn, Publisher,
Heat Treat Today

The answer to the question is a simple "yes." Depending on what is meant by "digitalization," it has been in heat treat operations for a number of years. The proliferation of digital chart recorders, for example, is clear evidence of that digitalization.

What digitalization will mean in the future is a mystery. One might say that digitalization is an ever-expanding final frontier, a place where we will be able to explore strange new worlds, to seek out new life and new civilizations, to boldly go where no man has gone before! (I hope you Trekkies appreciate that reference.)

It is, more seriously, an ever-evolving, strange new world, which currently is not widely embraced in the North American heat treat industry. Where we do see more of it is in larger companies with in-house heat treat operations. These larger companies have the IT and engineering horsepower to invest in deeper and deeper levels of digitalization.

Today, *it is common* for heat treat furnace manufacturers to perform computer upgrades and equipment troubleshooting remotely. *It is rare*, however, *to see* equipment servicing being performed via augmented reality (AR) where an on-site maintenance person or engineer wearing something similar to holographic glasses is helped by a "field" service technician who is hundreds or even thousands of miles away. But this type of AR-assisted field service *does* happen. For example, a hot isostatic press manufacturing company is promoting their ability to perform remote AR-based service. To view a video, scan the code below or do a web search for: "Cutting edge technology allows Quintus Technologies to deliver optimum technical support." Pretty inspiring.

News from Abroad

Heat Treat Today partners with two international publications: heat processing, a Vulkan-Verlag GmbH publication that serves mostly the European and Asian heat treat markets, and Furnaces International, a Quartz Business Media publication that primarily serves the English-speaking globe. Through these partnerships, 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 at new tech in Japan, a low emission material in Germany, an alliance of specialists in Mexico, and an executive move in a global industrial gas company.

ArcelorMittal Low Carbon Emission Wire Rod for C.D. Wälzholz GmbH & Co. KG

"As part of their business partnership, ArcelorMittal will supply C.D. Wälzholz GmbH & Co. KG with low carbon emissions wire rod from the Hamburg plant in the future. These steels are produced on the basis of scrap and renewable electricity (100 percent). The low carbon footprint of 504 kg CO2/t of steel is confirmed with an official Environmental Product Declaration (EPD). The delivery of the first 20 tons took place . . . at the cold rolling company's site in Hagen, Germany. Wälzholz uses the material to manufacture heat treated profiles for industrial applications."

Read More: *"Waelzholz purchases low carbon emissions wire rod from ArcelorMittal"* at heat-processing.com

Delivery of the first low-carbon emissions wire rod coils at Wälzholz in Hagen, Germany (Source: ArcelorMittal)

Hugh Grant, New Director for Linde

"Linde plc announced that its Board of Directors has elected Hugh Grant as a new director of Linde plc, effective January 23, 2023. Grant will serve on the Nomination and Governance and the Human Capital committees. Grant, a Scottish national, is a highly regarded former executive and director who brings substantial global experience to the Linde plc Board of Directors. He served as Chairman, President, and Chief Executive Officer of Monsanto Company, a global provider of technology-based solutions and agricultural products that improve farm productivity and food quality, from 2003 until 2018, when he led the sale of Monsanto to Bayer AG."

Read More: *"Linde Board Elects Hugh Grant as New Director"* at heat-processing.com

Hugh Grant, Director, Linde (Source: gasworld.com)

New Tech for Shinkansai Steel Co., Ltd.'s 74-ton Electric Arc Furnace

"Designed by Danieli Automation, Q-One uses the latest digital power electronics technology to maintain the EAF power-factor values close to unity. The power-feeding system that will be installed at Sakai will have a five-unit configuration with a total maximum power of 54,6 MVA."

Read More: *"Danieli to supply patented tech to Japanese EAF"* at furnaces-international.com

New tech for Shinkansai Steel Co., Ltd. plant (Source: Furnaces International)

Heat Treat Shop

Heat Treat Today believes that people are happier and make better decisions when they are well informed. To get a sense of what options the market has for you, check out some of the heat treat components, parts, services, and supplies listed below. These products have been featured in our monthly e-newsletter called **Heat Treat Shop**, where manufacturers with in-house heat treat departments — especially in the aerospace, automotive, medical, and energy sectors as well as general manufacturing — can easily share this information.

Want to see your product listed here? Contact Doug Glenn at **doug@heattreattoday.com**.

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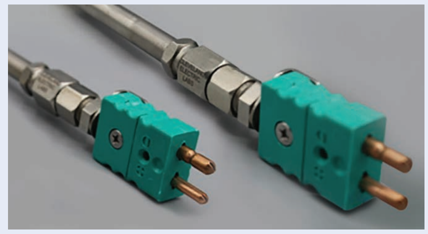

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Provides optimal burner system control with modular over pressure protection options for added safety. Our versatile, reliable products are backed by inventory, technical support, and training.

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AFC-Holcroft

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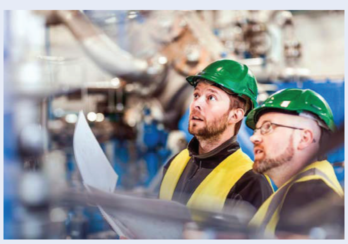

Prolong the life of your heat treat equipment with hot or cold equipment inspections. Identify issues before they develop into costly repairs and downtime. Comprehensive documentation provided. Download "Service" leaflet for more.

https://afc-holcroft.com/company/downloads

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Elektrogas

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Heat Treat Shop

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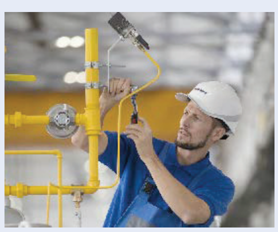

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CYBERSECURITY DESK

Have You Entered Your NIST 800-171 Self-Assessment Score into SPRS Yet?

Joe Coleman
Cybersecurity Officer
Bluestreak Consulting™

Introduction

This sixth article in the series from the Cybersecurity Desk will give you a better understanding of how to submit your basic NIST 800-171 self-assessment score into SPRS (Supplier Performance Risk System).

Why Should You Do This?

The Defense Federal Acquisition Regulation Supplement (DFARS) 252.204-7020 is one of the three newly released clauses (after the original 252.204-7012) of the DFARS 252.204-70 series (7019, 7020, 7021) in November 2020. DFARS 252.204-7019 is the "Notice of NIST 800-171 DoD Assessment Requirements"; whereas DFARS 7020 consists of the requirements alone. DFARS 7020 requires you to submit your basic NIST 800-171 self-assessment score to SPRS. Contractors and service providers are to provide the government access to its facilities, systems, and personnel any time the Department of Defense (DoD) is renewing or conducting a Medium or High assessment.

Once your self-assessment score has been submitted and accepted into SPRS, you will be eligible to be awarded contracts. Your score must remain in SPRS throughout the duration of the contract(s). You'll need to show that you are working towards full compliance.

If a self-assessment score submitted to SPRS is required in order to win a contract, and you don't have a self-assessment score in the system because you don't have CUI, does that mean you will lose the contract? Maybe.

The requirement for NIST SP 800-171 DoD self-assessment is being enforced whether or not you have CUI. So, it makes sense to get started on this ASAP to position your company for additional business. Plus, having better cybersecurity controls in place is definitely a business best-practice.

How To Submit Your Basic Self-Assessment Score to SPRS

There are two ways to submit your basic self-assessment score to SPRS.

Option 1: Using email to send the information. Submitting your self-assessment score via email to SPRS includes the following steps:

- **Get an accurate NIST 800-171 Self-Assessment and Score.** Conduct the self-assessment and obtain your score using cybersecurity professionals that carefully follow the required DoD Assessment Methodology for NIST Special Publication (SP) 800-171A.
- **Identify your SPRS "Scope of Assessment."** Your SPRS score submission will fall into one of three categories: Enterprise, Enclave, or Contracts.
- **Determine your expected completion date.** The "Plan of Action Completion Date" must be determined according to your compliance project timelines.
- **Find your commercial and government entity CAGE codes.** Your CAGE codes represent the part(s) of your organization included in the assessment and represented in the final System Security Plan (SSP) document.
- **Provide a brief description of the SSP format and system architecture.**
- **Submit your self-assessment score to SPRS.** To submit your score, send an email (optionally encrypted and signed) to **webptsmh@navy.mil** with the subject line "SPRS Self-Assessment Score Submission" in the exact format specified below:
  - Assessment date
  - Assessment score
  - Scope of assessment
  - Plan of action completion date
  - Included CAGE(s) codes
  - Name of System Security Plan (SSP) assessed
  - SSP version/revision
  - SSP date
  - Wait for email confirmation

Option 2: Using the PIEE (Procurement Integrated Enterprise Environment). Register a PIEE account at **https://piee.eb.mil/**. Once your business is registered, choose the SPRS link and follow all instructions. You will need to provide all the same information as shown in Option 1.

Funding & Cost Sharing May Be Available for Heat Treaters

With the huge push for stricter cybersecurity practices by the government and many businesses, cost sharing and funding sources have been identified that may cover a substantial percentage of the costs associated with these critical cybersecurity projects. Every state has at least one MEP (Manufacturing Extension Partnership). Many states are more than willing to help out with the cost of implementation. HTT

Scan to download a list of cybersecurity acronyms.

Heat Treat Today's
MTI MEMBER PROFILE

Ohio Metallurgical

In 1947, amidst a global war that touched every corner of the world, a small heat treat company emerged to serve the thriving and diverse manufacturing market of northeast Ohio. That company, Ohio Metallurgical (Ohiomet), was started by William Latiano and Frank Monaco with only a few salt pots in Lorain, but grew into a larger plant in Elyria, adding vacuum, shaker, and integral quench furnaces. Years later in 1977, Don Gaydosh, who was the general manager at the time, purchased 70% of the company, along with fellow employee Jerry Pragg. In 1990, John Gaydosh followed in his father's footsteps and is the current president and owner.

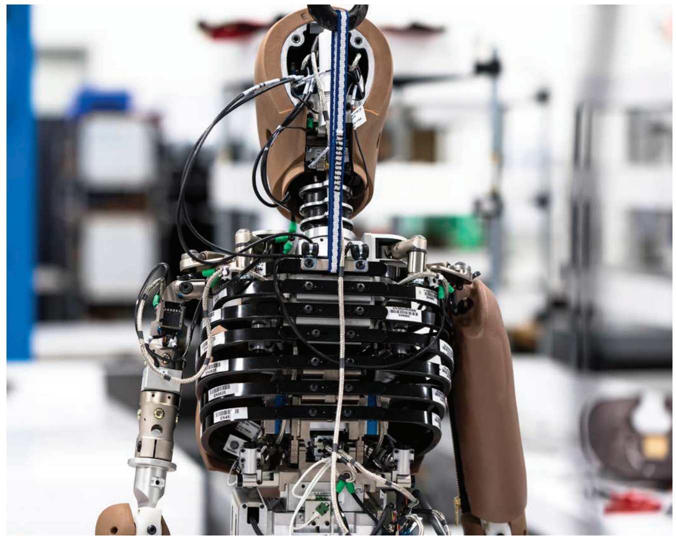
The company has now grown to include 78 employees who are trained in four core values: Be client focused, be dependable, do business with integrity, and always be improving.

One way they accomplish their first value is by scheduling production based on the client's need. In order to be dependable and operate safely, efficiently, and with high quality, the company invests in new equipment and controls. Since 1990, almost all equipment has been replaced completely, though a few older furnaces are still in use but with upgraded, modern controls.

To implement their fourth value of always improving, Ohiomet regularly updates its control systems to reduce operator errors and increase accuracy. Using an in-house customized SCADA software package, they monitor furnaces in real-time, so the operators and supervisors can be notified if process parameters are outside of preset parameters.

With their updated equipment and software, the company serves the automotive, aerospace, military, and mining industries, and more. While the integral quench lines containing 12 IQ furnaces make up the largest part of their business, they also offer multiple types of processes and services from one location. In addition to their IQ lines, they have vacuum furnaces capable of 2-bar nitrogen gas quench, bright age hardening, tempering, and annealing, all of which are qualified to meet AMS2759 specifications and are Nadcap accredited.

In addition to these processes, Ohiomet has both automatic and manual straightening equipment, induction equipment with various frequencies for use on vertical and horizontal scanners, and bell furnaces performing atmosphere annealing and stress relieving. A Nadcap accredited, modern quality control laboratory contains multiple automated microhardness testers along with a metallograph with digital imaging capabilities.

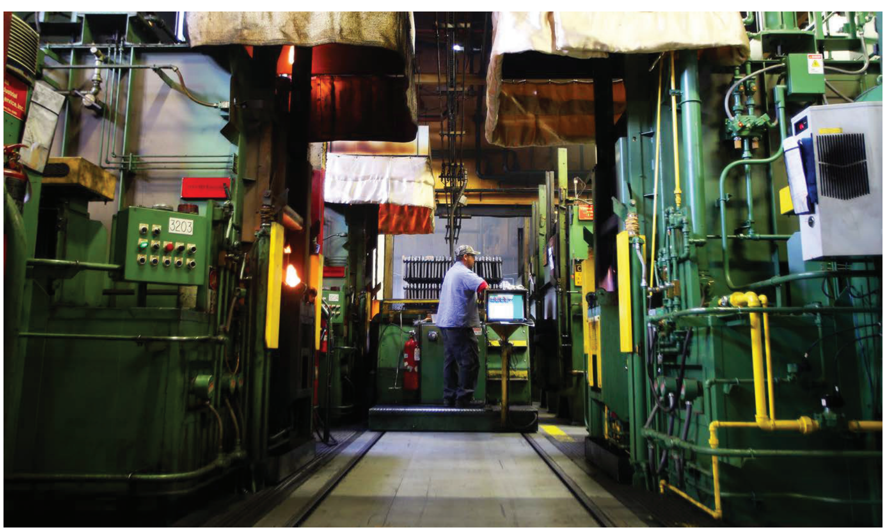


Ohiomet heat treats ribs used in crash test dummies

Among the unique items they have been heat treating are the ribs used in crash test dummies. They harden and temper the steel crash test dummy ribs and the ribs are fitted with sensors to detect how extensive the damage would be in a real car wreck.

While remembering their humble beginnings, Ohiomet looks to the next five to ten years anticipating an increase in automation, not only in material handling, but also for machine control, allowing them to continue fulfilling their founding principle of serving the manufacturing market of northeast Ohio.

(Photo Source: Ohiomet)



Heat treat operations at Ohiomet

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For more information, contact

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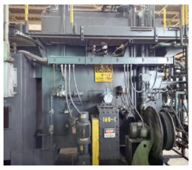
Gas-Fired Temper Furnace



Serial Number:	02615 (manufactured 2004)
Max Temperature:	1450°F
Burners:	Maxon 800,000 BTU
Workable Dim's:	36" wide x 72" deep x 36" high
Rated:	480 V, 3-Phase, 60 Cycle, 40 Amp
Max Fuel Demand:	1000 CFH
Controls:	SSI controls
General:	3" x 5" rollers, 8" fiber lined Recirculating fan: Garden City Fan, 20 HP

AFC IQ Furnace with Top Cool




Max Fuel Demand:	Natural Gas – 1,200,000 BTU's
Max Temp:	1800°F
Max Load:	3,500 pounds
Power:	480V, 3-Phase, 60 Hz, 70 Amps
Working Dim's:	36" wide x 48" deep x 36" high
Quench Tank:	3,500 gallon capacity
Flow Meters:	Nitrogen, endo, natural gas, air
Controls:	Allen Bradley PLC SSI Touchscreen (missing) Honeywell digital controls Atmosphere Engineering flow controls
General:	System 1 rear handler Oil heaters Dual Cartridge continuous filtering system

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Batch Temper Furnaces

C0189	Williams Industrial Batch Temper Furnace (30"W x 48"D x 30"H, 1250°F, gas)
U3697	B&W Temper Furnace (36"W x 72"D x 36"H, 1400°F, gas)
U3737	Wisconsin Oven Batch Temper Furnace (24"W x 48"D x 24"H, 1250°F, elect, 48kw, 66amp)
U3764	Lindberg Batch Temper Furnace (33"W x 65"D x 36"H, 1400°F, gas)
U3765	Sunbeam Batch Temper Furnace (30"W x 57"D x 34"H, 1200°F, gas)
U3782	Williams Batch Temper Furnace (36"W x 72"D x 36"H, 1450°F, gas)
U3785	Unique Batch Temper Furnace (40"W x 40"D x 51"H, 1200°F, gas)
U3789	Industrial Furnace Batch Temper Furnace (36"W x 60"D x 40"H, 500°F, gas)
V1170	Grieve Batch Temper Furnace (48"W x 48"D x 48"H, 1100°F, gas)
V1182	Wisconsin Oven Temper Furnace (24"W x 18"D x 36"H, 1250°F, gas)
V1196	Surface Combustion Temper Furnace (36"W x 72"D x 36"H, 1600°F, gas)
V1199	Williams Temper Furnace (36"W x 72"D x 36"H, 1600°F, gas)

Batch High-Temp Furnaces

UV1130	Onspec High-Temp Batch Furnace (72"W x 96"D x 48"H, 2400°F, gas)
V1165	Park Thermal Batch Temper Furnace (36"W x 60"D x 24"H, 1850°F, elect)
V1185	Cooley High Temperature Batch Furnace (12"W x 32"D x 16"H, 2000°F, elect)

Car Bottom Furnaces

V1166	Rockwell Car Bottom Furnace (60"W x 121"D x 72"H, 1000°F, gas)
V1179	Tilt-Up Car Bottom Furnace (8'W x 16'D x 8'H, 1600°F, gas)
V1200	Armil Car Bottom Furnace (8'W x 23'D x 4'H, 1750°F, gas)

Internal Quench Furnaces

C0187	Pacific Scientific Straight-Thru Furnace (24"W x 36"D x 18"H, 1750°F, gas)
C0193	Surface Combustion IQ Furnace (30"W x 48"D x 30"H, 1850°F, gas)
U3687	Surface Combustion IQ Furnace with Top Cool (36"W x 72"D x 36"H, 1750°F, gas)
U3718	Surface Combustion IQ Furnace (36"W x 48"D x 36"H, 1750°F, gas)
U3768	AFC IQ Furnace with Top Cool (36"W x 48"D x 36"H, 1800°F, gas)
UV1082	Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850°F, gas)
V1173	AFC IQ Furnace with Top Cool (36"W x 48"D x 36"H, 1800°F, gas)
V1193	Surface Combustion IQ Furnace (36"W x 48"D x 30"H, 1800°F, gas)
V1195	Surface Combustion IQ Furnace (36"W x 72"D x 36"H, 1800°F, gas)

Vacuum Furnaces

C0170	Seco Warwick Vacuum Carburizer Furnace (36"W x 48"D x 32"H, 2300°F, elect)
C0179	Vacuum Industries Vacuum Furnace (24"W x 36"D x 24"H, 2100°F, elect, 171kw)
U3759	Abar Ipsen Vacuum Furnace (36"W x 48"D x 30"H, 2500°F, elect)
U3803	Abar Ipsen Vacuum Furnace 6-Bar (36"W x 30"H x 72"D, 2500°F, elect)
U3831	Surface Combustion Vacuum Furnace 2-Bar (36"W x 48"L x 36"H, 2400°F)
V1131	Abar Vacuum Furnace 2-Bar (24"W x 60"D x 24"H, 2450°F, elect, 150kw)
V1138	Ipsen Vacuum Furnace 5-Bar (24"W x 36"L x 14"H, 2400°F, elect, 112.5kw)

Mesh Belt Brazing Furnaces

UV1035	Seco Warwick Mesh Belt Brazing Furnace (18"W x 12"H x 10' heated, 2100°F, elect, 120kw)

Pit Nitriding Furnaces

U3727	Surface Combustion Nitriding Pit Furnace (27"Dia x 35"D, 1050°F, electric, 90KW)

Roller Hearth & Rotary Furnaces

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

Steam Tempering Furnace

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

Heat Treat Lines

U3687	Surface Combustion IQ Furnace Line (36"W x 72"D x 36"H, 1750°F, gas)
UV1082	Holcroft IQ Furnace Line with Top Cool (36"W x 48"D x 30"H, 1850°F, gas)

Scissors Lifts, Holding Tables, Conveyors

U3690	Surface Combustion Scissors Lift (36"W x 72"D)
U3779	AFC Scissors Lift (36"W x 48"D)
UV1086	Holcroft Scissors Lift & (2) Holding Tables (36"W x 48"D)

Ovens - Cabinet & Batch

U3699	Wisconsin Cabinet Oven (25"W x 24"D x 25"H, 650°F, elect, 12kw)
U3752	Precision Quincy Batch Oven (36"W x 36"D x 36"H, 500°F, gas)
U3753	Blue M Batch Oven (24"W x 20"D x 20"H, 1300°F, elect, 25amps)
U3754	Blue M Batch Oven (16.5"W x 16"D x 20"H, 482°F, elect, 3kw)
U3792	Grieve Batch Oven (24"W x 24"D x 24"H, 1250°F, elect)

Ovens - Walk-In

C0195	Grieve Walk-In Oven (60"W x 72"D x 72"H, 500°F, elect)
U3788	Wisconsin Walk-In Oven (96"W x 240"D x 96"H, 650°F, gas)
U3791	Jensen Walk-In Oven (72"W x 72"D x 72"H, 600°F, gas)
U3797	Steelman Walk-In Oven (96"W x 96"D x 96"H, 450°F, gas)
U3799	Walk-In Oven (72"W x 72"D x 72"H, 800°F)
U3802	Sahara Walk-In Oven (48"W x60"D x 55"H, 500°F, elect)
V1181	Grieve Walk-In Oven (52"W x 76"D x 72"H, 750°F, elect)

Charge Cars

U3688	Surface Combustion DE Charge Car (36"W x 72"D)
U3762	Surface Combustion Charge Car DE/DP (36"W x 72"D)
U3763	JL Becker Charge Car DE (30"W x 48"D)
UV1085	Holcroft Charge Car DE/DP (36"W x 48"D)
V1194	Surface Combustion S/D/A Washer (42"W x 72"D x 42"H, 190°F, gas)
V1198	Surface Combustion Charge Car (36"W x 72"D)

Washers

C0134	Surface Combustion Washer SDA (60"W x 60"D x 48"H, 180°F, gas)
U3689	Surface Combustion Washer - spray only (36"W x 72"D x 36"H, elect) with holding station
U3711	AFC Holcroft Washer SD (24"W x 36"D x 24"H, gas)
U3800	Ipsen - Spray/Dunk Washer (36"W x 48"D x 24" H, elect)
UV1084	Holcroft Washer SD (36"W x 48"D x 30"H, 190°F, elect)
V1194	Surface Combustion S/D/A Washer (42"W x 72"D x 42"H, 190°F, gas)

Endothermic Gas Generators

C0194	Lindberg Endothermic Gas Generator (1500 CFH, 1950°F, gas)
U3594	Atmosphere Furnace Endothermic Gas Generator (3000 CFH, gas)
U3635	Lindberg Hydryzing Endothermic Gas Generator (6000 CFH, gas)

Exothermic Gas Generators

C0196	JL Becker/Gasbarre Exo-Generator w/dryer (4000 cfh)
U3652	Surface Combustion Exothermic Gas Generator (10,000 CFH, gas)

Salt Bath Furnace

C0173	Upton Salt Bath Furnace (60"W x 96"D x 72"H, 1100°F, gas)

Nitrogen Gas Generators

C0154	South-Tek Systems Nitrogen Generator (2,138 CFH)
C0155	South-Tek Systems Nitrogen Generator (1,000 CFH)

Ammonia Dissociators

U3767	Nitrex Ammonia Dissociator 500cf
V1180	CI Hayes Ammonia Dissociator (500 cfh)

Heat Exchanger Systems

U3787	SBS Air-Cooled Heat Exchanger, 2 fans
V1197	SBS Oil Cooler
U3801	MRM/SBS Heat Exchanger, 1 fan
V1197	SBS Oil Cooler

Water Chiller

U3710	Koolant Koolers Chiller (HCR 20,000 PR-MB)

Water Cooling Systems

U3565	Hytrol Conveyor - Roller (48"W x 10'D each)
U3646	HydroThrift, Duplex Pump Base, Water Cooling System
U3690	Surface Combustion Scissors Lift (36"W x 72"D)
U3779	AFC Scissors Lift (36"W x 48"D)
UV1086	Holcroft Scissors Lift & (2) Holding Tables (36"W x 48"D)

Leak Detectors - Vacuum

U3804	Varian 938-41 Vacuum Leak Detectors

Holding & Cooling Stations

Many other holding & cooling stations - ask for details

Baskets & Boxes

Extensive inventory of heat treat baskets and boxes

Transformers

Extensive inventory of all types of transformers for any and all applications

Since 1936

Celebrating 87 Years

THE W. H. Kay company

Used Heat Treating Furnaces and Ovens

BELT FURNACES/OVENS

18" x 4' x 2"	Grieve	Elec 500˚F
32" x 24' x 12"	OSI Slat Belt	Gas 450˚F
48" x 20' x 48"	Thermation	Gas 500˚F
2000 #/HR	AFC Pusher Hardening (Atmos)	Gas 1750˚F

MISCELLANEOUS

- Combustion Air Blowers (All sizes)
- 12" Diam. x 48" Mellen Tube FCE. Elec 2300°F
- 24" x 36" Lindberg Charge Car (Manual)
- 36" x 48" Surface Scissor Lift (2)
- 24" x 36" x 24" Ipsen D&S Washer Gas
- 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 (2)
- 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)
- 48" x 53" x 48" Guyson Spindle Blaster Elec
- 36" Wide Table- Rotary Hearth (Atmos.) Elec 1850˚F
- 36" x 48" Holcroft Charge Car (DE)
- 24" Wide Table Surface Rotary Hearth Gas 1750˚F
- SBS Air/Oil Coolers (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
25" x 20" x 20"	Blue-M (Inert)	Elec 1100˚F
26" x 26" x 38"	Grieve (2)	Elec 850˚F
30" x 30" x 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

OVENS/BOX TEMPERING (CONT.)

30" x 48" x 30"	Surface (2)	Gas 1400˚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"	Selas	Gas 1450˚F
30" x 48" x 30"	Lindberg (2)	Elec 1400˚F
36" x 36" x 36"	Blue M Environment Chamber	(-18˚C to +93˚C)
36" x 36" x 48"	Blue M	Elec 600˚F
36" x 36" x 60"	P-Quincy	Gas 500°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"	Grieve (Inert)	Elec 1250˚F
36" x 48" x 36"	TPS (Environmental)	Elec -40˚C to +200˚C
36" x 48" x 36"	Wisconsin (New)	Elec 1250˚F
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
40" x 52" x 63"	Despatch	Elec 650˚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"	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
40" x 52" x 63"	Despatch	Gas 650°F
60" x 60" x 60"	P-Quincy	Gas 500˚F
60" x 96" x 72"	Grieve	Elec 450°F
60" x 96" x 72"	P-Quincy	Elec 450˚F
60" x 120" x 72"	P-Quincy	Elec 450˚F
72" x 120" x 72"	Grieve	Elec 1050°F
84" x 264" x 84"	Lewco (2010)	Elec 500°F
72" x 120" x 78"	Despatch	Gas 500˚F
96" x 192" x 96"	Despatch	Gas 650˚F
72" x 216" x 72"	Lewco	Gas 500°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
4,000CFH	Exothermic Wellman	Gas

ATMOSPHERE GENERATORS (CONT.)

3,600CFH	Endothermic Surface	Gas (2)
6,000CFH	Exothermic Modern Equipment	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 (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 84" x 24"	Lindberg	Gas 2000˚F
60" x 216" x 48"	IFSI (Car Bottom)	Gas 2400˚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	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"	Gas 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

THE W. H. Kay company

Heat Treating Furnaces and Industrial Ovens

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