Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

VACUUM HEATING / CRYOGENICS

CONSIDERATIONS FOR SELECTING VACUUM FURNACE HOT ZONE INSULATION MATERIALS

COMPANY PROFILE ///

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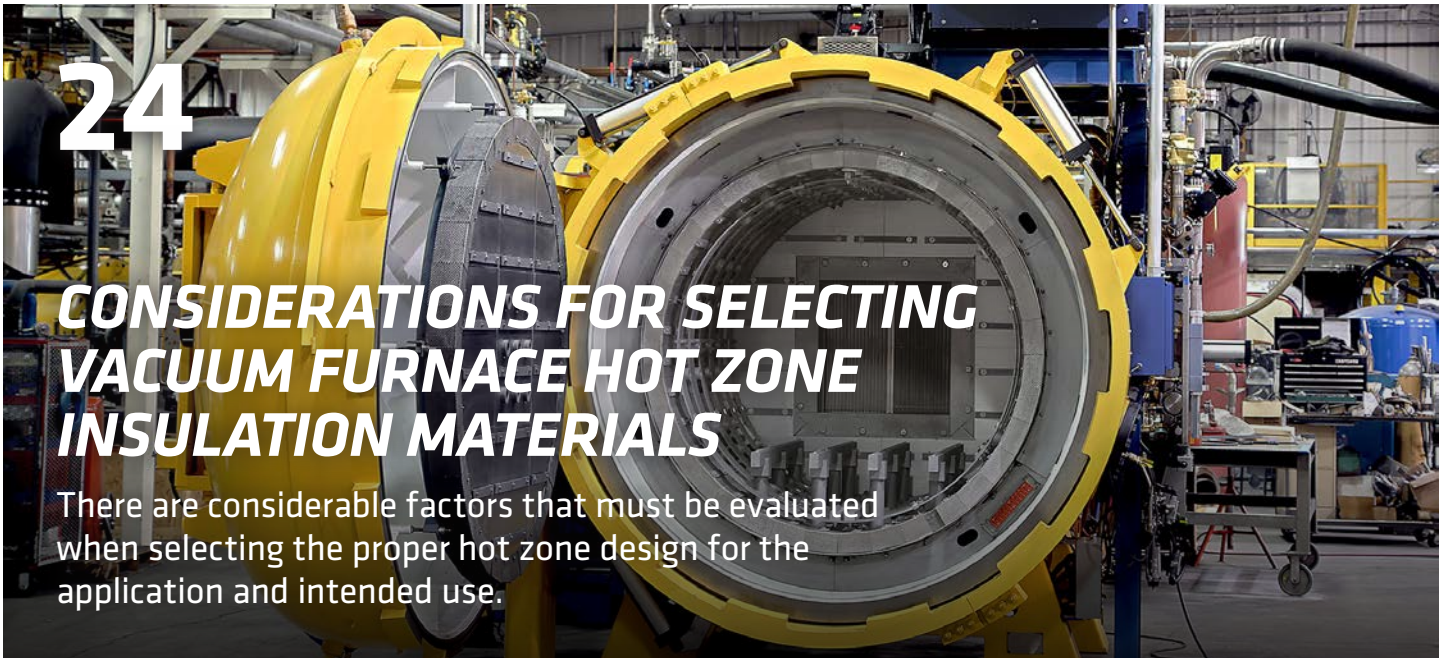

COVER PHOTO: SOLAR MANUFACTURING (1), SHUTTERSTOCK (1) / ILLUSTRATION BY RICK FRENNEA

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FROM THE EDITOR ///

Ready, set, 2023!

As we enter 2023, please make sure you stay quiet and don't make any sudden movements.

All kidding aside, we all have our fingers crossed that this year will bring some good things our way.

Ever since *Thermal Processing* began, we have always tried to confront the challenge head-on of bringing you the best industrial heat-treat news, and this year should be no different. We will continue our promise to share all the latest facts and innovation about the heat-treating world.

And if you're traveling to some of the big trade shows scheduled in 2023, make sure you look for *Thermal Processing*, as we plan to participate in quite a few of them.

To get you primed for what's sure to be a stellar year for the industry, our first issue of the year takes a look at vacuum heating and cryogenics.

This month's cover story from Solar Manufacturing's Reàl J. Fradette looks at considerations for selecting vacuum furnace hot zone insulation materials. This quick read will be of interest to any company wanting to know more about the variations in hot zone insulation.

On the subject of cryogenics, Michael Pate, president of Down River Cryogenics, shares his insights on how the use of a proprietary cryogenic processing technique can achieve longer tool life.

Our last Focus article looks at how integrated rupture disk assemblies can protect cryogenic systems from over-pressurization.

After you digest those articles, make sure you check out what our columnists have cooked up for January as well. They are always sharing some fascinating information.

And since it is the first month of the year, I will take this opportunity to remind all of you that I am always on the lookout for articles and other submissions. It's a great way to share your expertise while shining a spotlight on you and your company at the same time. Hit me up if you have an article idea.

Thanks again for helping us through 2022, and we look forward to making 2023 even better.

Happy New Year, and, as always, thanks for reading!

KENNETH CARTER, EDITOR
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THERMAL PROCESSING MEDIA PORTAL

Thermal Processing's online portal is your gateway to social media news and information resources from manufacturers and service providers in the heat-treating industry. You'll find links to social media as well as webinars, blogs and videos.

This quick-and-easy resource is just a click away at thermalprocessing.com.

Thermal processing

Can-Eng Furnaces will provide a continuous quench and temper furnace system for a producer of mining products. (Courtesy: Can-Eng Furnaces International Limited)

Can-Eng furnace system commissioned

Can-Eng Furnaces International Limited was recently contracted to engineer and commission a continuous quench and temper furnace system for a North American producer of mining, construction, and materials handling products. The purchase of this equipment is part of a larger plant expansion and initiative to bring foreign outsourced manufacturing in house. This move is not only to improve part quality but also to help eliminate overall shipping costs and reduce supply chain issues which have been plaguing many industries over the past couple of years.

This equipment will be part of an automated manufacturing cell and fed automatically from upstream handling equipment. Special considerations have been made to precisely control the quench temperature to reduce hardness variations and improve overall part quality. The multizone belt style temper furnace employs high efficiency natural-gas-fired heating and recirculation systems that have been proven to provide the ultimate in temperature uniformity in even the most demanding of applications. All pieces of equipment are accessible for control and monitoring through the equipment's Can-Eng engineered control system that uses an Allen Bradly PLC and HMI.

Can-Eng Furnaces International Ltd. is a global provider and leader in the design of state-of-the-art thermal processing systems. Headquartered in Niagara Falls, Ontario, Canada, Can-Eng is an ISO 9001:2015 certified company.

MORE INFO www.can-eng.com

Philadelphia Mint enters into contract with Seco/Warwick

The Philadelphia Mint has asked for furnace upgrades from Seco/Warwick, the partner with proven experience and cooperation with national mints.

The Philadelphia Mint was established by the Coinage Act of 1792, when Philadelphia was the nation's capital. It was the first public building constructed under the direction of the recently formed United States government. The machinery was powered by a horse walking circles in the basement. The minting technology has seen a few upgrades since then.

Seco/Warwick Group's American subsidiary, located in Meadville, Pennsylvania, recently began the current round of upgrades, a refurbishment of all five of the Mint's heat-treating furnaces, one furnace per year.

The heat-treating furnaces were installed there by Seco/Warwick USA from 1994 through 2000. Their function in the minting process is to anneal, clean, and dry the coin blanks to soften the metal prior to striking into coins, extending the service life of the striking dies.

All five furnaces are 4,000 pound-per-hour rotary retort furnaces outfitted with Seco/Warwick's patented Whirl-A-Way Quench™ system, as well as a hopper feeder, a batch burnish barrel, and a batch/continuous drum drier. The furnaces are showing their age after a quarter century and the Mint opted for a comprehensive refurbishment.

"Our partner has plenty of coin to heat-treat, but they don't have any to burn," said Marcus Lord, Seco/Warwick USA managing director. "These waste-heat recovery and combustion efficiency upgrades are going to save them a mint while cutting carbon and NOx emissions nearly in half."

To reduce energy consumption, Seco/Warwick is replacing insulation, roof pan-

SEND US YOUR NEWS Companies wishing to submit materials for inclusion in Thermal Processing's Update section should contact the editor, Kenneth Carter, at editor@thermalprocessing.com. Releases accompanied by color images will be given first consideration.

The small letter at the nape of George Washington's neck in the image above is a mint mark. The "P" indicates that the coin was struck at the Philadelphia Mint. (Courtesy: Seco/Warwick)

els, and radiant tubes as well as upgrading the loading systems with an improved, more user-friendly design. New, more energy-efficient burners are being installed, along with recuperators to preheat the combustion air to improve energy efficiency and use less natural gas.

Mechanical improvements include replacing drive motors and two-speed gear boxes. The retort can over-heat and warp if the rotary retort unexpectedly stops before the cool-down cycle. As a failsafe, Seco/Warwick added a pneumatic backup motor that can run the gearbox off the Mint's compressed air reservoir during a power outage.

Beyond upgrades to legacy systems, mints around the world are also upgrading their heat-treating capabilities to improve the strength and longevity of their stamping dies by installing Vector® high-pressure gas quench vacuum furnaces. Many of these newer systems include options of high vacuum, convection heating, as well as Seco/Warwick's patented PreNITLPC® technology, which makes thin layer nitriding possible.

MORE INFO www.secowarwick.com

Aluplast purchases second Nitrex nitriding system

Aluplast-ZTG, an Altest company, recently bought a second Nitrex nitriding system. The Bulgarian aluminum extruder experienced a big manufacturing boost after installing new extrusion presses to meet customer demand for its extrusion profiles used in residential and commercial construction.

The first nitriding furnace, a compact N-EXT-412, had been in operation since 2011. The new second furnace, a model N-EXT-612, it is the same as the first one but bigger, capable of processing a load of extrusion dies weighing up to 1,300 pounds (600 kg).

A good relationship, trust in Nitrex's technology to deliver superior and consistent nitrided die results, the dependability of its technical services, and a short delivery delay all helped Aluplast decide to purchase the N-EXT-612.

"We work very well with our Nitrex colleagues; they have always responded to our issues with speed and competence, for which we thank them," said Atanas Novakov, aluminium production plant manager. "Due to the increase in our production, we have ordered a second turnkey Nitrex system so that we can meet our needs. Our good relationship and the superior work of the nitrider made us choose Nitrex again as our partner."

"The N-EXT-612 furnace is equipped with the Nitreg® process technology and recipes specially designed for nitriding H11 and H13 steel extrusion dies. It also has an INS neutralizer to keep the process clean and green," said Marcin Stokłosa, project manager at Nitrex.

The nitriding system includes remote access software and complies with the AMS 2759/10 standard for controlled nitriding as well as the AMS 2750 standard in terms of pyrometry and temperature distribution. Moreover, the system is equipped with an ammonia sensor for leak detection and an ammonia filter to purify the supply gas used in the process by eliminating any oil content, thereby prolonging the system's service life.

The order was placed in the third quarter of 2021, and operations began in the fourth quarter of the same year.

MORE INFO www.nitrex.com

BriskHeat's Federico retires; Thompson new president, CEO

BriskHeat, a leading provider of flexible surface and immersion heating products, controllers, and insulators, recently announced the retirement of Domenic Federico after serving as president and chief executive officer for 22 years. The company has named Mike Thompson president and CEO, effective Jan. 1, 2023. Thompson has been with the company for 27 years, the last 15 as senior vice president of manufacturing.

During his years at BriskHeat, Federico led the company to tenfold growth. Under his leadership, BriskHeat has expanded from 100 employees to more than 900, based in six countries. In 2018, he led the sale of BriskHeat to Sweden-based NIBE Industrier, a global group of manufacturing companies with more than $3.7 billion in annual revenue and 15,000 employees worldwide.

Mike Thompson

"The real strength of BriskHeat over the years is in the people and the team we've been able to put together," Federico said. "You must value your people to grow your business. The team we have in place now will forge on and expand, which means continued growth and opportunities for everyone at BriskHeat."

Thompson brings 27 years of experience with BriskHeat to his new role. He has held key positions in manufacturing and sales. As BriskHeat continues to grow, Thompson will lead the company into its next era, which will include a new production facility in Costa Rica.

"As BriskHeat moves into the future, I believe we're going to be reflecting on Domenic's vision," Thompson said. "We will build on our current success and continue to drive revenue growth. We will accomplish this through further market diversity and expanded customer base applications. My vision for BriskHeat is to be the world's top, one-stop source for all surface heating solutions, temperature controls, and insulating needs."

"I leave the company in the best of hands with Mike Thompson," Federico said. "NIBE is a fantastic partner, so together, I believe they'll continue to take BriskHeat to new heights."

Since 1949, BriskHeat has provided a full range of surface and immersion heating solutions used for freeze protection, condensation prevention, flow/viscosity control, vacuum bake-out, composite curing, and temperature process control. BriskHeat's primary manufacturing facilities and headquarters are in Columbus, Ohio.

MORE INFO www.briskheat.com

The official opening ceremony of the extensive facility renovation of AFC-Holcroft took place in November 2022. (AFC-Holcroft)

AFC-Holcroft celebrates HQ grand reopening

Following an extensive, nearly yearlong full facility remodel, AFC- Holcroft held a formal ribbon-cutting ceremony at their world headquarters building in Wixom, Michigan. In addition to the celebration by the company's employees, representatives of Berndorf AG were on hand, as were CEO Christian Grosspointner, and CFO Martin Rode from the AICHELIN Group, arriving from Austria. Locally, representatives from the City of Wixom, Lakes Area Chamber of Commerce, and other invited guests also took the opportunity to join the event.

Prior to the actual ceremonial cutting of the ribbon, AFC-Holcroft CEO Bill Disler escorted the guests on a tour of the renovated facility, highlighting some of the innovative features and environmental improvements incorporated into design.

A main focus of the renovation was to make the building more environmentally friendly, specifically with regard to heating and cooling. The walls of the entire production area were replaced with insulated wall panels, and numerous windows were added to provide more natural light. The roof system was renewed and insulated, and the overhead warehouse doors were also modernized to contribute to the new high-efficiency ventilation/heating systems. These measures improve the comfort and general working environment of the building while improving energy efficiency by around 35 percent.

At the same time, investments in IT infrastructure were also made. In the conference rooms throughout the building, new technology was added to support the latest in video conferencing to improve the security of IT infrastructures and to create a more seamless work environment. A dedicated testing and development area specific for process control equipment was created, allowing a virtual environment where furnace process control functions can be developed, simulated, and tested

prior to being deployed in the field.

Individual workstations were redesigned for improved ergonomics and outfitted with motorized desktops to create an option for standing desks. All new décor and creative storage furnishings were purchased, with new cubicle walls topped with glass to give the space a more open look and feel. The interior lighting was replaced by Smart LED lighting, and noise cancelling technology is used throughout the offices.

"From the very beginning, every employee had a chance to offer ideas and input into features and details of the facility, and all suggestions and feedback were given thorough consideration," Disler said. "The positive collaboration between our internal teams, our builder, and our interior designer helped us achieve all the objectives in a very short time."

In addition to improving the comfort and energy consumption in the manufacturing areas, the entire production floor and shipping/receiving areas were analyzed for improved workflow, and consideration given to improving use of stored manufacturing supplies and inventory.

Beyond the facility, other areas received attention. In addition to reconfigured parking areas, the property was re-landscaped, and an outside patio was added to offer more opportunity to enjoy nature. The land itself now features a popular bicycle/walking path which integrates into the community's Metropark system, easily accessed from the front of the property.

"Even without the added complications of supply chain disruptions and other issues, it takes a lot of effort to complete a project like this on-time or on-budget, but our teams did both," Disler said. "As a solid company with over 100 years of forward-thinking history, this investment was about much more than obtaining more space—it also creates a fresh, collaborative, and energy-efficient environment both for the current generation and the next to come."

MORE INFO www.afc-holcroft.com

Abbott Furnace partners with Obsidian Technical

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

Obsidian is a privately held company founded by brothers Eric and Jason Jossart, who previously owned Atmosphere Engineering, a product and systems manufacturer in the heat-treating industry. They are now leveraging their extensive knowledge and their relationships to support manufacturers and customers in the industry.

Abbott purchased their first Atmosphere Engineering product in 2007; although there were some problems, Eric and Jason stood by their product and promptly addressed any issues that arose. That was the beginning of a great relationship. Eric and Jason sold

Atmosphere Engineering in 2017.

Obsidian launched in 2022 to help heat treaters stay up-to-date and operational by providing a wide range of services, including product introduction, training, technical support, installation, and equipment upgrade services.

Dustin Yetzer, technical sales manager said, "Eric and Jason have always supported Abbott wherever they were. They have participated in our annual symposiums, sold us our first endothermic gas generator flow control system, and helped us with several projects over the years. We are grateful to continue the partnership with them and the Obsidian team."

"We always enjoyed working with Abbott in the Atmosphere Engineering days. The technical team at Abbott was regularly looking for new solutions to improve their designs continuously," said Jason Jossart, VP of technical services at Obsidian. "As an innovative product manufacturer, it was great to help develop those solutions with Abbott. We are excited about working together with everyone at Abbott and look forward to supporting their customers in the industry."

MORE INFO www.abbottfurnace.com

Tenova supplies TCF furnace to Netherlands

Tenova LOI Thermprocess, one of the leading companies in supplying industrial furnace systems for the heat treatment of metals, has successfully completed the production optimization of a new twin-chamber melting furnace TCF® at E-Max Billets in Kerkrade, The Netherlands. The furnace achieved the agreed performance parameters and is now the sole melting unit for higher contaminated scrap at the plant.

Tenova LOI Thermprocess was awarded a contract for the engineering, supply, erection, and commissioning of another twin-chamber melting furnace TCF® (TFC) and a melting and casting furnace (MCF) for the production upgrade and modernization of the customer's plant.

The previously operating two-chamber melting furnaces, which were also supplied and installed by Tenova LOI Thermprocess in 1990, were successively removed from current production and are now being demolished after 32 years of operation and 1.5 million metric tons of molten aluminum.

Tenova LOI Thermprocess has successfully completed the production optimization of a new twin-chamber melting furnace TCF® at E-Max Billets in Kerkrade, The Netherlands. (Courtesy: Tenova)

The new TCF achieves a daily output of 150 tonnes of liquid aluminum, reduces metal loss, and specific natural gas consumption per ton of molten aluminum by more than 20 percent.

Moreover, compared with former installations, the efficiency of the modern TCF technology allows for the treatment of higher contaminated scraps.

Regarding the remaining scope of work of the contract, the tiltable MCF will also be operating starting in spring 2023. As a new technology, this MCF can melt scraps with light contaminations of organics in a single furnace chamber. Special processing ensures less metal loss and safe integrated post- combustion, thereby reducing overall emissions, granting a sustainable and economic production of liquid aluminum.

MORE INFO www.tenova.com

Heat Treat 2023 names Tompkins as keynote speaker

Dr. Stefanie Tompkins will be the featured keynote speaker on the opening day of Heat Treat 2023. Tompkins is the director of the Defense Advanced Research Projects Agency (DARPA). Prior to this assignment, she was the vice president for research and technology transfer at Colorado School of Mines.

Heat Treat 2023 will be October 17-19, 2023, in Detroit, Michigan. It is the event that bridges research with industry and is a premier conference and expo for heat-treating professionals, attracting global innovators, researchers, influencers, and decision makers from around the globe. This year's conference and expo will feature:

» Latest research and industry insights offered during more than 125 technical presentations.

» Two-and-a-half days of face-to-face networking opportunities with approximately 200 heat-treat exhibitors/companies.

» Co-location with ASM's Annual Meeting, "International Materials, Applications and Technologies (IMAT)" conference and expo, providing Heat Treat attendees with access to 100 materials-related exhibitors and more than 400 additional technical presentations and workshops. Special crossover keynotes and technical sessions are planned.

» Continued co-location with Motion + Power Technology Expo 2023 with access to an additional 300 exhibitors.

»"Basics of Heat Treating" education courses.

» VIP guided industry tour.

» Student/emerging professionals initia-

tives, including free college student registration, Fluxtrol Student Research Competition, and the new ASM Heat Treating Society Strong Bar Student Competition.

Abstracts for Heat Treat 2023 are due February 17, 2023.

MORE INFO www.asminternational.org

Swiss heat treater chooses Vector for vacuum brazing

A major Swiss commercial heat treater has ordered a Seco/Warwick Vector® vacuum furnace, one of the Group's flagship products.

This furnace with a large working chamber, efficient pumping system, isothermal quenching, and directional cooling will increase the production capacity of the commercial heat treater, which is mainly known for its service in the field of nickel and silver brazing.

The Vector vacuum furnace on order solves the customer's problem with hardening larger size parts (the furnace work zone is 900 x 900 x 1,200) and will significantly increase the efficiency of the current hardening plant. It will improve and increase the processing capacity of the hardening process, thanks to high energy savings, the efficiency of the graphite chamber as well as the purity and speed of the process. The furnace will also have an impact on increasing production economics.

"Our furnace also extends the customer's service range," said Maciej Korecki, vice president of the vacuum furnace segment, at Seco/Warwick Group. "Thanks to the cooling capacity of 15 bar, it is possible to process parts that require very fast cooling. Thanks to the high vacuum operation, Vector also allows the system to perform more difficult brazing processes with either nickel or silver. This is our second installation with this partner. Previously, we delivered a solution from the Seco/Warwick furnace family of a similar size, in a non-pressurized version."

Vector is the most common choice of commercial heat treaters not only in Europe but around the world. Versatility, efficiency, and excellent process economy mean that professional commercial heat treaters most often order this type of vacuum furnaces.

Vector comes in several sizes and configurations. In the version ordered by the Swiss, a large working zone with the potential to adjust to an oversized load utilizes the advantages of a round heating chamber. Thanks to the use of a system consisting of two mechanical pumps and a diffusion pump, the furnace executes very efficient processes at a very good vacuum in both medium and high ranges. The efficiency of the processes carried out is also influenced by the possibility of cooling at 15 bar.

Thanks to the inverter control, users can switch on the optimal cooling power in the appropriate process segment. The great

advantages are also low heat losses and good temperature distribution in the heating chamber. The Vector vacuum furnace has numerous options, such as convection, directional cooling or isothermal quenching, increasing the versatility of the solution and the processes carried out.

Commercial heat treaters face the problem of many types of materials, a wide range of processes, and various technologies every day. This is one of the most experienced groups of recipients when it comes to vacuum heat treatment. Seco/Warwick will deliver to Switzerland a solution that, thanks to its unique capabilities, will cope with this demanding environment. In addition, it provides both a large variety in the types of treated parts and components and the technologies that they require for quality results. The Vector vacuum furnace system on order is as versatile as the commercial heat treaters in the metal treatment market.

MORE INFO www.secowarwick.com

ITS counts wicket ovens among its thermal offerings

The purpose of a wicket oven is to cure a coating applied to one side of a tinplate, aluminum, or steel sheet. The wicket oven derives its name from the wicket carrier that actually supports the non-coated side of the material in a vertical orientation while transported through each zone of the oven.

Wicket ovens are engineered to accommodate various material sheet sizes, cure times, and temperatures. International Thermal Systems has solutions, with the experience needed to design and manufacture a custom wicket oven to support customers' manufacturing needs.

International Thermal Systems (ITS) also designs and builds equipment that reduces energy use. For example, ITS manufactures wicket ovens with higher-density insulated walls. Adding thicker high-density insulated walls has been shown to minimize shell loss by approximately 30 percent.

International Thermal Systems designs and manufactures custom wicket ovens. (Courtesy: International Thermal Systems)

ITS wicket oven features include:

» Provides the highest possible product quality.

» Minimizes rejection rates and ghosting on sheet.

» Lowers energy use.

» Minimized customers' total operating cost.

ITS can provide a new wicket oven, a retro fit for an existing oven or a custom solution.

ITS works with global customers to determine their needs, develop the right solution, then install and start up the equipment. Customers can then count on ITS expertise to maximize the efficiency of their equipment.

ITS is a global original equipment manufacturer of industrial ovens, furnaces, and aqueous washers for automotive, aerospace, power generation, battery manufacturing, building products, foundry, ice builders, and metal packaging industries.

MORE INFO www.internationalthermalsystems.com

BriskHeat selects Costa Rica for Latin American operations

BriskHeat, a North American manufacturing company, has selected Costa Rica as the site to establish its Latin American operations and, thus, serve its end customers in the western world in less time.

BriskHeat manufactures heating parts, controls, and accessories for applications in various industries, including semiconductors, pharmaceutical and medical, transportation, agriculture, and aviation/aerospace, as well as food and injection molding, among many others. With its Costa Rican operations, the company will primarily supply the semiconductor industry with future growth opportunities in the consumer goods and life sciences sector.

Costa Rica's facility will produce thermal blankets and insulation for heating and gas line insulation, condensation prevention, and gas/fluid uniformity. BriskHeat's current high-volume facilities in other locations are near capacity, so this expansion will help BriskHeat grow and reduce delivery times.

"Costa Rica serves as a location for 47 multinational advanced manufacturing companies that carry out a wide variety of operations," said Manuel Tovar, the Minister of Foreign Trade. "Briskheat selected our country as the site for its first Latin America operations — a vote of confidence that recognizes Costa Rica's role in secure, transparent, sustainable, and resilient supply chains. We celebrate this new investment, which will create close to 250 new and quality jobs, as it contributes to our national development."

BriskHeat is headquartered in the United States and was founded in 1949; it operates a manufacturing plant in Vietnam. Costa Rican operations — specifically, in the Green Park Free Zone in Alajuela — will now be added to their international locations.

BriskHeat plans to hire about 50 people during the remainder of 2022 and, by the end of 2023, it expects to have more than 200 employees in Costa Rica.

MORE INFO www.briskheat.com

INTERNATIONAL FEDERATION OF HEAT TREATMENT AND SURFACE ENGINEERING

Major conferences planned for 2023

The ECHT 2023 Conference will be in Genova, Italy, at Magazzini del Cotone in May 2023. (Courtsey: Shutterstock)

5TH INTERNATIONAL CONFERENCE ON HEAT TREATMENT AND SURFACE ENGINEERING OF TOOLS AND DIES (HTSE-TD)

Hangzhou, China | April 24-27, 2023

This conference in Hangzhou, China, will finally resume the HTSE-TD series. The last meeting was in January 2021 and held online. The call for papers is posted at:

http://htse-td.allconfs.org/meeting/index_en.asp?id=6861. The due date for abstracts has been extended to January 31, 2023.

Abstracts should be sent to Lihui LIU, mailto:chta@chta.org.cn

ECHT23

Genova, Italy | May 29-31, 2023

AIM recently announced the ECHT 2023 Conference will be in Genova, Italy, at Magazzini del Cotone, May 29-31, 2023.

ECHT 2023 will cover all relevant topics for the heat treatment and surface engineering community. The conference will include a special focus on sustainability.

Sustainability, with its three pillars — environmental, economic, and social dimensions — is playing a key role to address ongoing and future challenges. The metallurgical and mechanical industries are leading the way in creating a healthy development model for the environment and for future generations. Presentations and papers from industry, university, and research centers on the topic will encourage the discussion and increase awareness on the matter.

›› **More info:** www.aimnet.it/echt2023.htm

HEAT TREAT 2023

Detroit, Michigan | October 17-19, 2023

This event will be co-located with IMAT 2023 in Detroit and cover many topics of interest. Abstracts are due February 17, 2023. If an

The 5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies will be in Hangzhou, China, in April 2023.

abstract is accepted into the Heat Treat 2023 technical program, the author will be encouraged to submit a full manuscript (6-8 pages) by the deadline date. Complimentary full conference registration will be offered to authors (presenting author only) who submit a full manuscript for the proceedings.

SPOTLIGHT ON MEMBERS

Meduna

Meduna vakuová kalírna s.r.o. is a heat-treating business in the Czech Republic. Founded in 1999 by Miroslav Meduna, Meduna provides heat-treatment services such as consulting on the proper heat treatment of metallic materials, metallographic analysis, and various heat-treating techniques, including salt, oil, and vacuum quenching. It also provides various carburizing techniques such as low-pressure carburizing, nitriding, and nitrocarburizing. Its priorities are high quality of provided services, short lead times, and social responsibility.

›› **More info:** kalirna@kalirna.cz or www.kalirna.cz

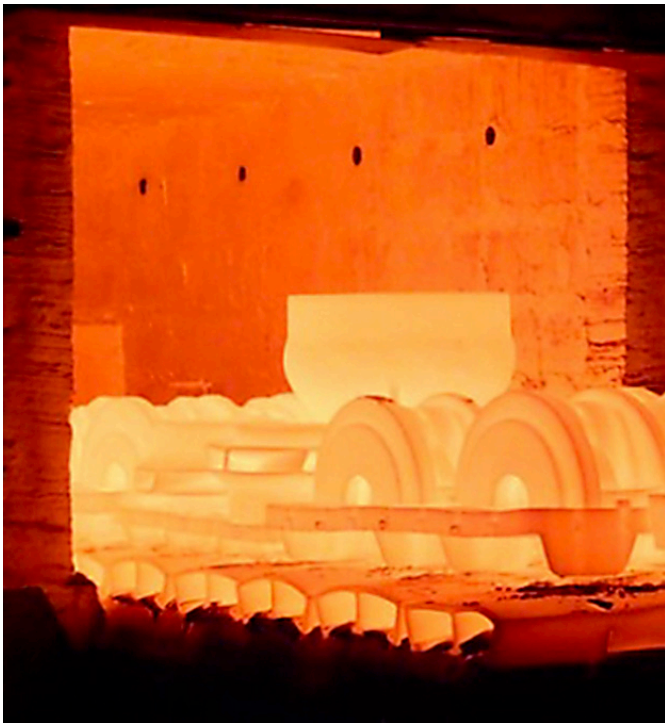
UPCOMING IFHTSE EVENTS

APRIL 24–27, 2023
5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies
Liangzhu Dream Town, Hangzhou, China

OCTOBER 17–19, 2023
Heat Treat 2023
Detroit, Michigan | www.asminternational.org/web/heat-treat

NOVEMBER 13-16, 2023
28th IFHTSE Congress
Yokohama, Japan

For details on IFHTSE events, go to www.ifhtse.org/events



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MEMBER SPOTLIGHT

Fireye offers flame safeguard, combustion controls

Fireye's roots go back to the 1930s, when the company offered the first commercial/industrial electronic flame safeguard control — a photoelectric device designed to detect the presence of an oil flame in less than a second.

Fireye is a leading manufacturer of flame safeguard controls and burner management systems for commercial and industrial applications throughout the world. Its products can be found in a variety of public buildings, commercial properties, power plants, pulp and paper mills, petrochemical facilities, and food processing plants.

Fireye is a part of Carrier.

Fireye's roots go back to the 1930s, when the company offered the first commercial/industrial electronic flame safeguard control — a photoelectric device designed to detect the presence of an oil flame in less than a second. The company was the first to develop infrared scanners to monitor gas and oil flames, the first to develop a scanner that discriminated between signals from adjacent burners, and the first to create a completely solid-state programming control. It has set new standards with a micro-processor-based, auto diagnostics program that communicates in five different languages.

In the company's labs and research facilities, the Fireye engineering staff constantly evaluates and tests new ideas. It looks for ways to improve current products, as well as develop new product entries into related markets of combustion control and management. Fireye has maintained ISO 9001 certification since 1996. The Fireye brand is very customer centric, and it supports customers through open communications. The company depends on satisfied customers, and it listens carefully to what the market is saying.

Fireye's manufacturing centers are state-of-the-art facilities for designing, fabricating, assembling, and testing electronic products.

IHEA's 2023 Annual Meeting will be held at Atlantic Beach, Florida.

Over the years, it has constantly reinvested in manufacturing capability to ensure that it keeps pace with new technologies and global competition. Fireye maintains 20 offices worldwide.

That means the best people in the flame safeguard and combustion control industry are everywhere, providing quick and responsive service to its customers worldwide.

›› **More info:** www.fireye.com

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TRIRATNA SHRESTHA
MANAGER OF METALLOGRAPHIC LABORATORY AND CENTRAL COATINGS LABORATORY /// METCUT RESEARCH INC.

Measuring resistance to crack extension for strong metals with relatively low toughness.

Linear-elastic fracture toughness testing

Materials fracture occurs in all sectors of the economy — aerospace, nuclear, medical, transportation, oil and gas, petrochemical, commercial and residential buildings, etc. The annual economic cost of material failure is estimated to be in the billions in the United States and trillions globally. Some of the known historic failures are the tanker *SS Schenectady*, whose hull split in the middle; Aloha airlines; World War II Liberty ships (which had all-welded hulls); Boston molasses tank failure; F-111 aircraft; and the I-35 bridge in Minneapolis among others.

There are well-established techniques to measure conventional materials strengths such as yield strength, hardness, etc. However, material structure cannot solely rely on yield strength for design and performance.

Another materials strength property that is widely used these days is fracture toughness. Measuring fracture toughness is advantageous in quantitative analysis as it allows structural life assessment, and provides a safety factor and inspection criteria. Since World War II, there have been significant improvements in understanding fracture mechanics by measuring materials' fracture toughness. Fracture mechanics, a field of study that includes fracture toughness, deals with the effect of defects on the load-bearing capacity of materials and structures. The approach is practical as it takes into consideration that all materials and structures have inherent defects. Practically, there are no defect-free engineering materials; defect should be part of any design and fit-for-service assessment. This technique is an advancement to the approach that only considered conventional materials strength. Defects in materials can be voids, inclusions, secondary phases, dislocations, grain boundary, and grain misfits in microstructural level. In macrostructural levels they can include surface finish, notches, scratches, materials boundaries, cracks, and environmental degradation.

Due to the lack of technology to quantify a variety of defects individually, all defects instead are treated as a notch and sharp crack. Griffith in the 1920s initially used an energy balance approach to quantify fracture mechanics in a stressed plate with a crack. George Irwin in 1950 used the stress intensity factor (K) to predict fracture behavior as $K = \sigma \sqrt{\pi a_c}$, where σ is the tensile stress and a_c is the critical crack length. In the linear-elastic approach, stress intensity factor is the proportionality constant that characterizes stress fields ahead of a crack tip [1]. To predict failure or fracture events, there is need to determine K, which is a function of materials properties, stresses, and defect size. K can be calculated by closed form analysis (theory of elasticity, numerical technique), finite element, estimation, handbooks, and experimental.

TESTING

Different organizations such as American Society for Testing and Materials (ASTM), the Japan Society of Mechanical Engineers (JSME), the International Institute of Standard (ISO), and the British Standard Institute (BSI) have developed standards for measuring fracture toughness. Some of the early standards date to the 1970s. Fracture toughness under monotonic loading against temperature is measured for LEFM per ASTM E399 –Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness (K_{IC}) of Metallic Materials. All standards published by different organizations have the same basic instrumentation for introducing cracks and measuring load and displacement, but there are subtle differences. The specification features specimen, specimen preparation and precracking, test fixturing and instrumentation, test procedure, test result evaluation, validity checks, and reporting [2]. The objective of fracture testing is to conduct a laboratory test and relate its behavior to a structural component.

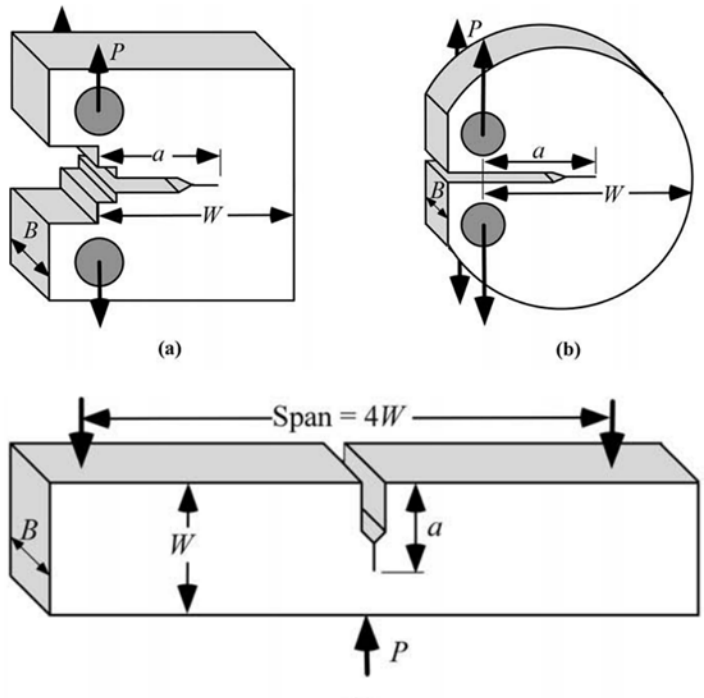


Figure 1: Standard fracture mechanics test specimens: (a) compact, (b) disk-shaped compact, and (c) single-edge-notched bend SE(B). [3]

To conduct a fracture testing, one must select a specimen, introduce a crack in the specimen, get a test machine and instrumentation, test to failure and get failure data, relate failure data to a critical K, then repeat the test for a range of temperatures. There is a variety of test specimens. Standard ones are compact — C(T), disk-shaped compact, and single edge bend — SE(B), (Figure 1). There are other special specimen geometries, such as arc-shaped tensile — A(T), middle tension (MT), and arc-shaped bend — A(B). Specimen geometry can

Figure 2: MTS 640.20 fracture mechanics grip. [4]

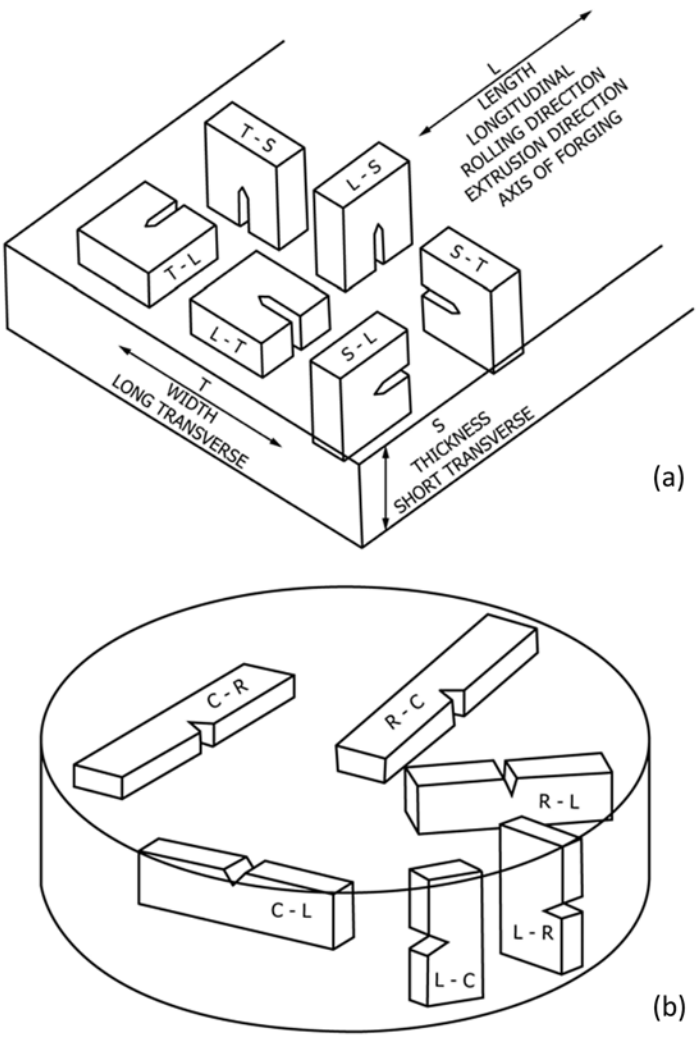


Figure 3: Crack plane identification per material form and orientation: (a) plates and slabs, and (b) cylindrical form and tubes [2].

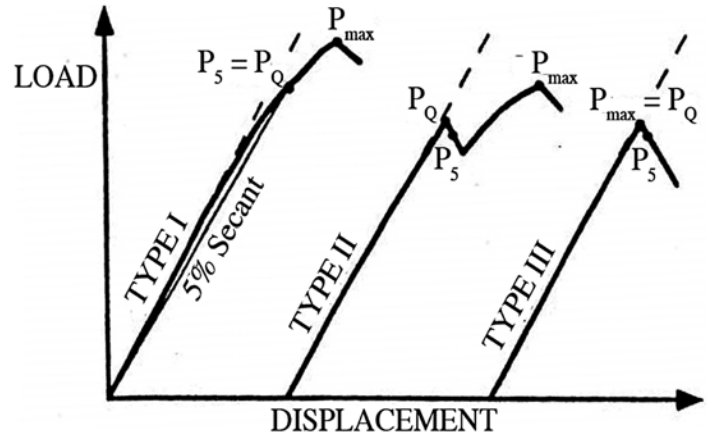
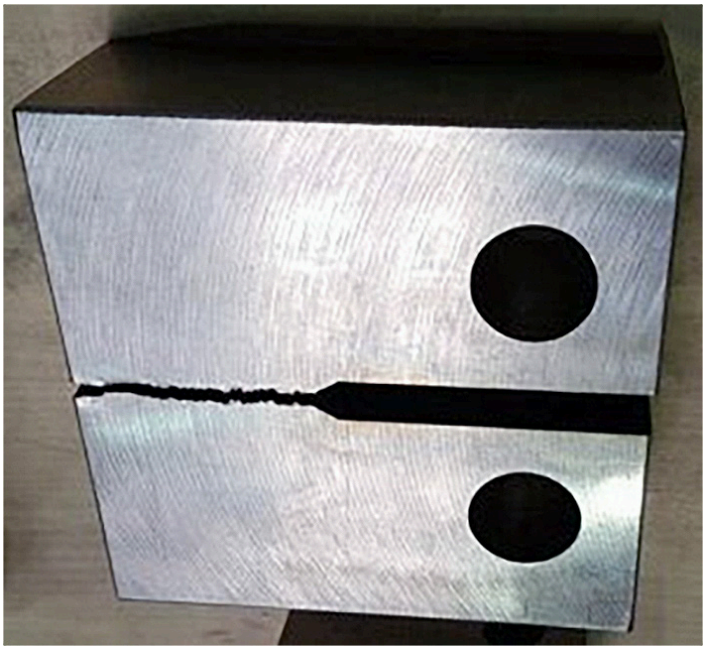


Figure 4: Three significant types of load-displacement curves encountered in plane strain test.

be decided based on the dimensions of available material. Typically, SE(B) is preferred for a sample with weldment, C(T) for plates and slabs, and disk-shaped compact is preferred for rods. The SE(B) can use simplified single fixture, while other dimensions will need specialized fixture per specimen dimensions. Special clevises are used to pin load compact specimen, (Figure 2). Specimen dimensions are scaled geometrically — a 1T sample has a thickness of one inch and a width of two inches. Regardless of specimen geometry, they all have three characteristics: crack length (a) along with thickness (B) and width (W). For most setup, width is twice the thickness and the ratio of crack length to width is approximately 0.5.

Due to texture in materials and their difference in strength relative to their orientation, crack orientation must be specified. Fracture toughness is sensitive to microstructure and prior materials processing. Certain crystallographic planes are more prone to crack propagation, while certain processing can alter microstructure to arrest crack and define plastic zone. Similarly, certain orientations are more prone for defect formation, coalesce, and growth. Thus, all specimen orientation must be identified while reporting material toughness. Specimen orientation used by ASTM is shown in Figure 3. Two letters are required to identify the orientation of fracture mechanics samples. The first letter denotes the principle tensile stress perpendicular to the crack plane for Mode I test. The second letter indicates the plane of crack propagation. Letters L, T, and S signify longitudinal, transverse, and short transverse orientation, respectively. Similar convention is used for cylindrical structure, where C, R, and L are identified as circumferential, radial, and longitudinal, respectively.

Precracking and cyclic loading in servo-hydraulic frames are done in load control. The load cell must be calibrated and have analog-to-digital conversion. The crack thus produced must be sufficiently sharp, which is an attempt to mimic defects present in a material. Fixturing must be designed for good mechanical performance based on specimen geometry. Servo-hydraulic test frames are best suited for these tests as it has better control, and it can generate variety of loading wave forms. The crack thus produced must have a small plastic zone at the tip compared to facture plastic zone and the tip radius must be smaller than the radius at failure. One must be considerate of maximum *K* during fatigue loading while introducing initial crack. The max *K* differs where the intended toughness is K_{IC} for linear-elastic, or J or CTOD for elastic-plastic mechanics. Along with load, displacement or crack growth is measured during the test. A variety of displacement gages can be used, such as mechanical, clip gage, linear variable differential



Fracture toughness measurement is orientation specific, so it requires materials testing in mutiple directions, which can be costly.

transformer (LVDT), laser, and capacitance.

Heating or cooling is performed in a furnace or cold box. Soak times are dependent on specimen thickness; the rule of thumb is 30 minutes/inch. Temperature should be controlled to ± 3°C. The test, monotonic loading, is done in displacement or crosshead traverse control with controlled rate while measuring load and displacement. Measurements are done digitally by computer. Load rate must be between 30 – 150 ksi.in$^{1/2}$/min — slow enough to avoid dynamic effects and fast enough to avoid time dependent effects. Continue loading specimen until the specimen fractures or a maximum load is passed. Three types of load-displacement behavior in a K_{IC} test are shown in Figure 4. Identify the highest load up to a 5 percent secant crossing (P_Q) and the highest load (P_{Max}). Initial crack length (a_o) is measured at three evenly spaced locations, then apparent fracture toughness (K_Q) and P_Q are calculated. Subsequently, K_Q is calculated per Equation I. The $f(a/W)$ is a dimensionless function whose individual values for material and temperature can be found in relevant ASTM specification, and in the U.S. Air Force Material Command's Damage Tolerant Design Handbook [5]. It can also be calculated per Equation II for C(T) samples.

Due to the sensitivity of K_{IC} to crack size, specimen thickness, relative plastic zone at crack tip, possible technician error, instrumentation malfunction, ASTM E399 requires a validity check to ensure confidence of the measured value. The test results must go through three validity check criteria: (i) crack size to specimen width ratio must be ≥ 0.45 and ≤ 0.55, (ii) $P_{max} \leq 1.10\, P_Q$, and (iii) a, $B \geq 2.5(K_Q/\sigma_{YS})^2$. If validity checks are satisfied, $K_Q = K_{IC}$. However, at the end of the day, if K_{IC} test is invalid, a stress ratio (R_S) can be calculated to see extend of invalidity. R_S is the nominal stress at crack tip divided by the yield strength. In a compact specimen, R_S less than 1.0 indicates linear-elasticity, greater than 2.0 indicates fully plastic behavior, and in between 1.0 and 2.0 indicates nearly elastic to nearly fully plastic behavior. Though invalid, test results are still beneficial in material selection, design considerations and property comparison.

$$K_Q = \frac{P_Q}{B\sqrt{W}} f\left(\frac{a}{W}\right)$$

Equation I

$$K_Q = \frac{P_Q}{BW^{1/2}}\left[29.6\left(\frac{a}{w}\right)^{1/2}\right] - 185.5\left(\frac{a}{w}\right)^{\frac{3}{2}} + 655.7\left(\frac{a}{w}\right)^{\frac{5}{2}} - 1017.0\left(\frac{a}{w}\right)^{\frac{7}{2}} + 638.9\left(\frac{a}{w}\right)^{\frac{9}{2}}$$

Equation II [6]

TEST FAILINGS

Fracture toughness measurement is orientation specific, so it requires materials testing in mutiple directions, which can be costly. For certain forms of materials, it is impossible to obtain compact sample design in all orientations, especially for plates and welded structures; thus, test engineers prioritize orientation that is considered the weakest. The ASTM E399-based K_{IC} is Mode I loading plane strain condition where crack tip plastic zone is relatively small compared to specimen thickness. Its applicability is limited to linear-elastic materials with limited ductility. As such, the technique is not applicable for many engineering materials that show plasticity, such as low-strength structural materials. With few exceptions, all engineering materials are selected with a certain degree of plasticity. Due to strict specimen dimension of requirement per ASTM E399, some test specimens can be impractically large and cannot be tested. Say we have a tool steel with KQ of 140 ksi and yield strength of 22 ksi — per one of the validity criteria, crack length has to be 81 inches and width of 162 inches. That is a very large dimension for a valid K_{IC} test. For some materials, valid K_{IC} tests are only applicable at room temperature or lower temperature where materials do not fail with void formation and coalesence. Side grooving can be done after pre-cracking to remove areas of low triaxiality on the surface and to produce relatively straight crack plane but is not allowed per E399.

For nonlinear materials with larger plastic zone, plasticity corrections are made and toughness is measured per ASTM E1820 and British Standard 7448.

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Understanding the relationship between properties and quench rate.

Quench factor analysis: quench factor determination

In this column, we will discuss the determination of the quench factor as it is used in quench factor analysis. This will lead into a discussion of determining the time-temperature-property (TTP) curve to be used in quench factor analysis.

INTRODUCTION

The quench factor, τ, is defined as:

$$\tau = \int \frac{dt}{C_t}$$

where τ is the quench factor, t is the time (sec), and C_t is the critical time. The collection of the C_t points, also known as the C-curve, is like the time-temperature-transformation curve for continuous cooling.

In general, the C_t function is described as [1]:

$$C_t = K_1 K_2 \left[exp\left\{ \frac{K_3 K_4^2}{RT(K_4 - T)^2} \right\} \exp\left\{ \frac{K_5}{RT} \right\} \right]$$

where C_t is the critical time required to precipitate a constant amount of solute. The meaning of each of the constants are described in the previous article.

To determine the parameters K_1, K_2, K_3, K_4, and K_5, it is first necessary to have the C-curve. C-curve data is scarce, and of limited availability. Some coefficients for the C_t function are shown in the previous column and in [2]. Once the C-curve, or time-temperature-property curve, is obtained, the values of the coefficient are obtained by repeated iterations (and minimum error) until the best fit to the C-curve is achieved [3].

One of the problems with the equation for the C-curve is its complex nature and dependence on K_2–K_5. Different sets of K_2–K_5 can provide similar fits to the data, with similar errors, but can provide wildly different time-temperature-property curves [4]. Fitting the time-temperature-property coefficients is severely non-linear, and results in errors regardless of the method used. Independent physical data offer much better fits to the data and result in reduced errors in the C-curve. Data such as the solvus temperature (K_4), solute diffusivities (K_5) and enthalpy for precipitation (K_7) substantially reduce the fitting errors and non-linearity and offer physical meaning to the data and fit. Use of many data points (> 10) reduces the errors. Combining interrupted quench data and continuous cooling data is very effective in reducing C-curve errors.

One additional source of error is some aluminum alloys have competing precipitates forming during quenching and aging. For instance, many types of precipitates may be observed in a single sample. The precipitates may be at the grain interior or at the grain boundary. There may be different precipitates present (θ and S). They could also be different coherency (incoherent and semi-coherent). This results in multiple C-curves, like the pearlite and bainite curves in time-temperature-transformation diagrams for steels. Quench factor analysis, as created by Evancho and Staley [3], assumes only one primary precipitate.

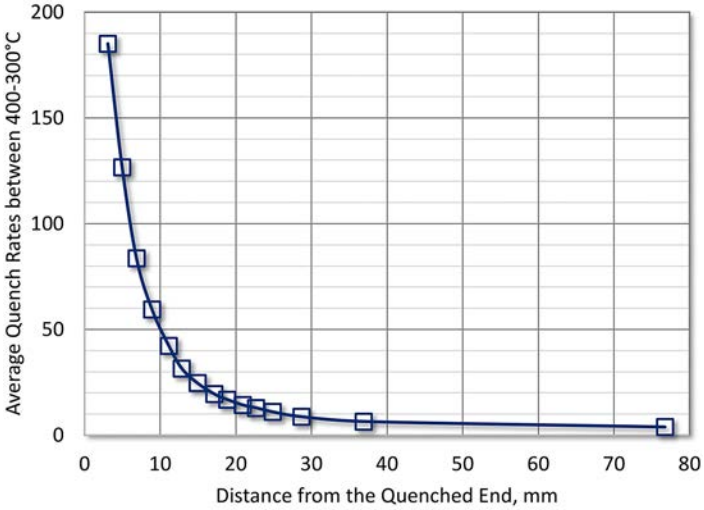

Figure 1: Cooling rate as a function of distance from the quenched end for an aluminum Jominy end-quench sample. Cooling rates were taken as the average from 400-300°C [7].

DETERMINATION OF PROPERTY DATA AS A FUNCTION OF QUENCH RATE

From the previous discussion, the modeling of aluminum alloys is dependent on the data generated through interrupted quench data or from continuous cooling data. Typically, it is necessary to measure the quench path of several sheets of material, and then measure the properties after processing. The quench factor is determined for each quench path and associated with the measured properties. Typically, hardness and tensile properties have been used.

The Jominy end quench [5] provides a method of determining both the quench factor and the C-curve. The Jominy end-quench test has many advantages for determining quench sensitivity of aluminum and other alloys such as titanium [6]. The method offers many advantages over traditional quenching of sheet and plate. The observed quench rates vary from 200°C/s at 3 mm from the quenched end to less than 3°C/s at 78 mm from the quenched end [7] (Figure 1). Further, it is a data-rich specimen. Once quenched, and hardness and conductivity has been measured, the specimen can be sliced at specific locations for TEM and DSC analysis [8] [9].

Properties are then related to the quench factor by the equation:

$$p = p_{max} exp(K_1 Q)$$

where p is the property of interest, pmax is the maximum property

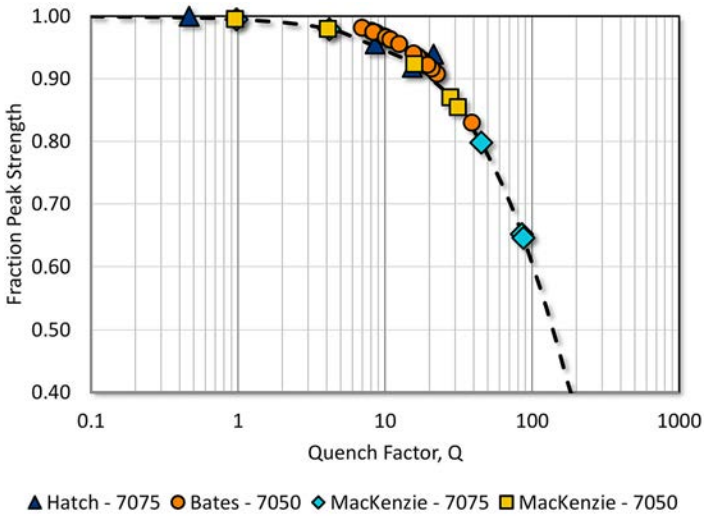

Figure 2: Comparison of quench factors generated by the Jominy end quench by MacKenzie [9], compared to interrupted quench data generated by Fink and Wiley [11] and Bates [12].

attainable with infinite quench rate, and K_1 is -0.005013 (natural log of 0.995).

By rearranging the above equation, the quench factor, Q, can be determined for hardness on the Jominy end quench:

$$Q = \frac{1}{K_1} ln\left(\frac{H_{VN}}{H_{max}}\right)$$

where H_{VN} is the hardness at a specific location on the Jominy end quench bar, and H_{max} is the maximum hardness. The maximum hardness, H_{max}, is generally an average of the first several hardness indentations.

Therefore, for a specific set of processing conditions, the quench factor can be determined for multiple quench rates, using the Jominy end quench. The data generated can be used to predict properties occurring in similar material and similar operating conditions. This is illustrated in Figure 2. In this figure, the percentage of the attainable property from hardness (7075-T6 and 7050-T6 from the Jominy end quench), is compared with that obtained by Hatch [10] by quenching individual panels and measuring the yield strength. This method allows for the determination of the quench factor without knowledge of the C-curve.

For a specific set of processing conditions, the quench factor can be determined for multiple quench rates, using the Jominy end quench.

CONCLUSION

In this short column, we have illustrated methods of determining the quench factor as a function of quench rate. In the next column, we will discuss a method of determining the C-curve, and the different coefficients in the C-curve equation.

Should you have any questions regarding this article, or have suggestions for any additional columns, please contact the writer or the editor.

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ISSUE FOCUS ///

VACUUM HEATING / CRYOGENICS

CONSIDERATIONS FOR SELECTING VACUUM FURNACE HOT ZONE INSULATION MATERIALS

There are considerable factors that must be evaluated when selecting the proper hot zone design for the application and intended use.

By REÀL J. FRADETTE

Over the years, there have been many variations of hot zone insulation designs for vacuum furnace hot zones and can include the following configurations and materials. This article will summarize these designs with performance results in vacuum and power efficiency:

» **a:** Graphite foil facing backed by 2”-3” Kaowool insulation.

» **b:** Graphite foil facing backed by 2” PAN graphite felt.

» **c:** Graphite foil facing backed by 2” Rayon graphite felt.

» **d:** Standard Graphite board (2”) with foil facing.

» **e:** New GMI Graphite board (2”) with foil facing [1].

» **f:** All Metal (3 molybdenum, 2 stainless steel shields).

» **g:** All Metal (5 molybdenum shields).

How a vacuum furnace hot zone is insulated and selected is based on several factors including:

» **1:** Desired ultimate vacuum level.

» **2:** Maximum processing temperature.

» **3:** Overall thermal efficiency and power losses.

» **4:** Overall cycle time.

» **5:** Minimal part surface contamination.

Analyzing the above factors individually, the following can be summarized:

	Hot Zone Materials	Max Operating Temperature	Max Bake-Out Temperature
a	Graphite foil facing backed by 2"-3" Kaowool insulation	2,200°F	2,400°F
b	Graphite foil facing backed by 2" PAN graphite felt	2,400°F	2,600°F
c	Graphite foil facing backed by 2" Rayon graphite felt	2,400°F	2,600°F
d	Standard Graphite board (2") with foil facing	2,400°F	2,600°F
e	New GMI Graphite board (2") with foil facing [1]	2,400°F	2,600°F
f	All Metal (3 molybdenum, 2 stainless steel shields)	2,400°F	2,600°F
g	All Metal (5 molybdenum shields)	3,000°F	3,200°F

Table 1

	Hot Zone Materials	Hold 1,750°F	Hold 2,000°F	Hold 2,250°F
a	Graphite foil facing backed by 2"-3" Kaowool insulation	452°F	548°F	640°F
b	Graphite foil facing backed by 2" PAN graphite felt	490°F	574°F	659°F
c	Graphite foil facing backed by 2" Rayon graphite felt	456°F	544°F	616°F
d	Standard Graphite board (2") with foil facing	517°F	572°F	622°F
e	New GMI Graphite board (2") with foil facing [1]	334°F	367°F	405°F
f	All Metal (3 molybdenum, 2 stainless steel shields)	538°F	683°F	825°F
g	All Metal (5 molybdenum shields)	430°F	572°F	714°F

Table 2

1 DESIRED ULTIMATE VACUUM LEVEL

Many processes only require what might be called “soft vacuum” with an operating level in the mm Hg range or 10^{-3} to 10^{-4} Torr range. This can normally be achieved with any insulated hot-zone design. Hot-zone materials for (e) would easily meet this requirement.

Other processes require a super-clean environment with vacuum levels in the 10^{-5} Torr range or higher. These processes could be performed in the (b) through (e) hot zones.

Processes requiring a vacuum of 10^{-6} Torr or better normally require an all-metal hot zone design (f) and (g) to achieve the required vacuum levels and produce super-clean work.

2 MAXIMUM PROCESSING TEMPERATURE

Table 1 illustrates the relative maximum operating temperatures that are typically available with each hot-zone configuration.

Although some of the hot zones are often heated above the normal operating temperatures, these are the recommended normal processing temperatures.

3 OVERALL THERMAL EFFICIENCY AND POWER LOSSES

The efficiency of a particular hot zone is determined by the power losses being radiated from the outer support ring to the inner cold wall of the vacuum chamber. The outer support ring temperature varies based on the insulating materials. The ring temperature is most critical in that it is raised to the fourth power when calculating power losses. The relative outer ring holding temperatures for the different configurations are shown in Table 2.

Figure 1 illustrates several things. These include:

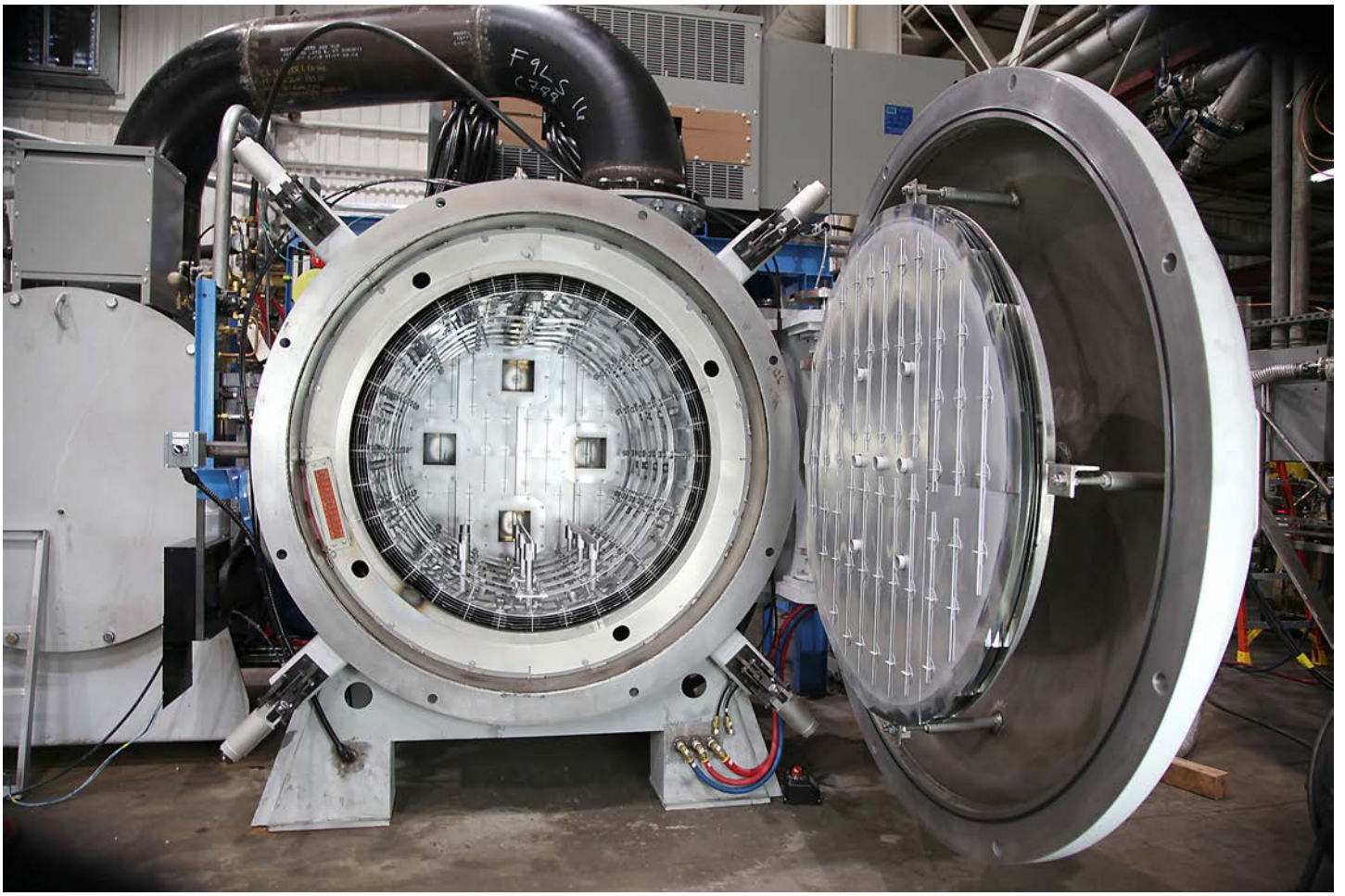
» **a:** Rayon graphite felt is more efficient than PAN graphite felt.

» **b:** The GMI board material [1] is more efficient than any other insulations or shield combinations. This board material also grows more efficient as the temperature rises.

» **c:** The all-metal hot zones are most inefficient.

Table 3 illustrates the projected relative power losses and wall density for the HFL-3648 Furnace when holding at 2,000°F. The furnace has a working hot zone that measures 36” W x 36” H x 48” D.

With Table 3, we can conclude the following:



Example of an All-Metal Hot Zone. (Courtesy: Solar Manufacturing)

» **a:** The Rayon Felt hot zone is approximately 12.8% more efficient than the PAN hot zone.

» **b:** The GMI Board [1] hot zone is approximately 61.8% more efficient than the Rayon hot zone and approximately 66.7% more efficient than the PAN hot zone.

» **c:** The all-metal hot zone (f) is the least power efficient of all the various insulation configurations.

4 OVERALL CYCLE TIME

The overall cycle time for a furnace is based on several factors. These include:

» **a:** Vacuum pumping capacity.

» **b:** Insulation moisture absorption characteristic of the insulation, most critical when the furnace door is open too long, especially on humid days.

» **c:** Efficiency of insulation to overcome recurring losses when heating the workload.

» **d:** Workload mass and thickness of parts being processed.

» **e:** Gas cooling system recirculating volume capability and cooling gas used based on process requirements.

» **f:** Type of insulation used in the hot zone.

5 MINIMAL PART SURFACE CONTAMINATION

When working with felt-insulated vacuum furnaces, moisture, water, and pick-up can

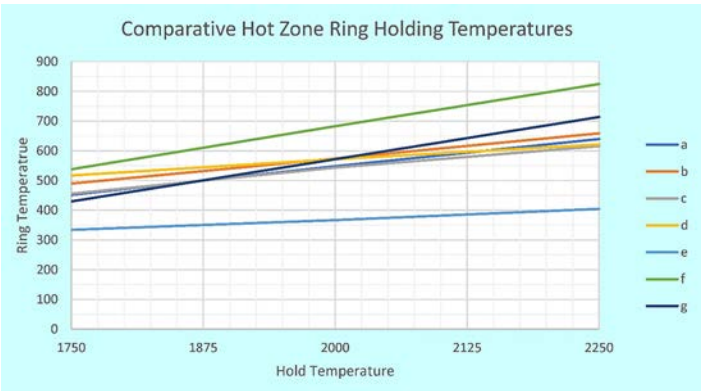


Figure 1

	Hot Zone Materials	HFL-3648 kW/Hr loss at 2,000°F
a	Graphite foil facing backed by 2"-3" Kaowool insulation	35.90
b	Graphite foil facing backed by 2" PAN graphite felt	40.49
c	Graphite foil facing backed by 2" Rayon graphite felt	35.32
d	Standard Graphite board (2") with foil facing	40.18
e	New GMI Graphite board (2") with foil facing [1]	13.50
f	All Metal (3 molybdenum, 2 stainless steel shields)	62.37
g	All Metal (5 molybdenum shields)	40.18

Table 3

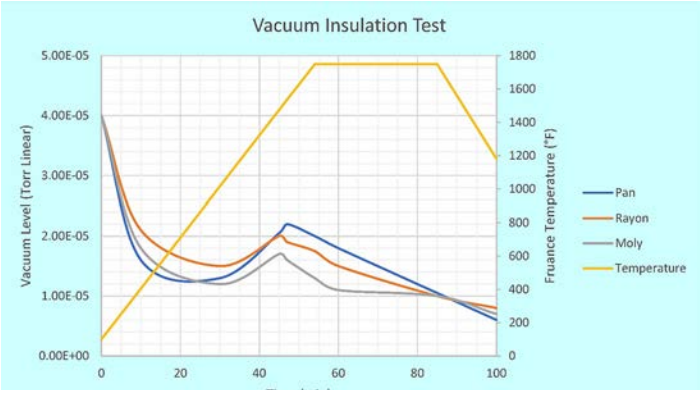


Figure 2

become key sources of oxygen contamination. For comparative testing, samples of PAN and Rayon felt stacks, top insulation for the hot zone only, were prepared for testing in a lab furnace. The furnace cycle for each stack ran with a clean titanium test piece in the furnace. This was compared to an all-metal shield test package. After each run, alpha-case analysis via metallurgical evaluation determined the level of contamination from moisture pickup for both PAN and Rayon insulation compared to the clean all-metal hot zone.

The vacuum levels for each insulation package shown in the following chart, when compared to the standard all-metal hot zone, show less effective vacuum levels, indicating the presence of more residual gas. It should be noted that the humidity and dew point was considerably higher on the date of Rayon testing than the PAN test date. With this fact in evidence, the results in Figure 2 indicate the PAN insulation is much more sensitive to moisture pick-up than Rayon-based felt.

The resultant alpha case measurements also support this conclusion considering the titanium sample used in the Rayon insulation testing produced a similar alpha case result to the all-metal hot zone, even though the Rayon felt stack suffered more severe humidity that the PAN test samples. (Comments based on a limited test.)

The results in Table 4 illustrate that the all-metal hot zone is superior and required for most super-clean applications.

Insulation Type	Alpha Case Depth (inch x 10^{-2})
Pan Felt Insulation	0.319
Rayon Felt Insulation	0.250
All-Metal	0.216

Table 4

Hot Zone Materials (cost least to most expensive)	
a	Graphite foil facing backed by 2"-3" Kaowool insulation
b	Graphite foil facing backed by 2" PAN graphite felt
c	Graphite foil facing backed by 2" Rayon graphite felt
d	Standard Graphite board (2") with foil facing
e	New GMI Graphite board (2") with foil facing [1]
f	All Metal (3 molybdenum, 2 stainless steel shields)
g	All Metal (5 molybdenum shields)

Table 5

6 CONCLUSIONS

As is illustrated in this presentation, there are considerable factors that must be evaluated when selecting the proper hot zone design for the application and intended use.

One remaining consideration, which was not included above, is the relative cost for each different configuration. Listing each hot zone from least expensive to most expensive, we have Table 5.

The comments in Table 5 should help future buyers in selecting the right vacuum furnace hot zone design for their specific application.

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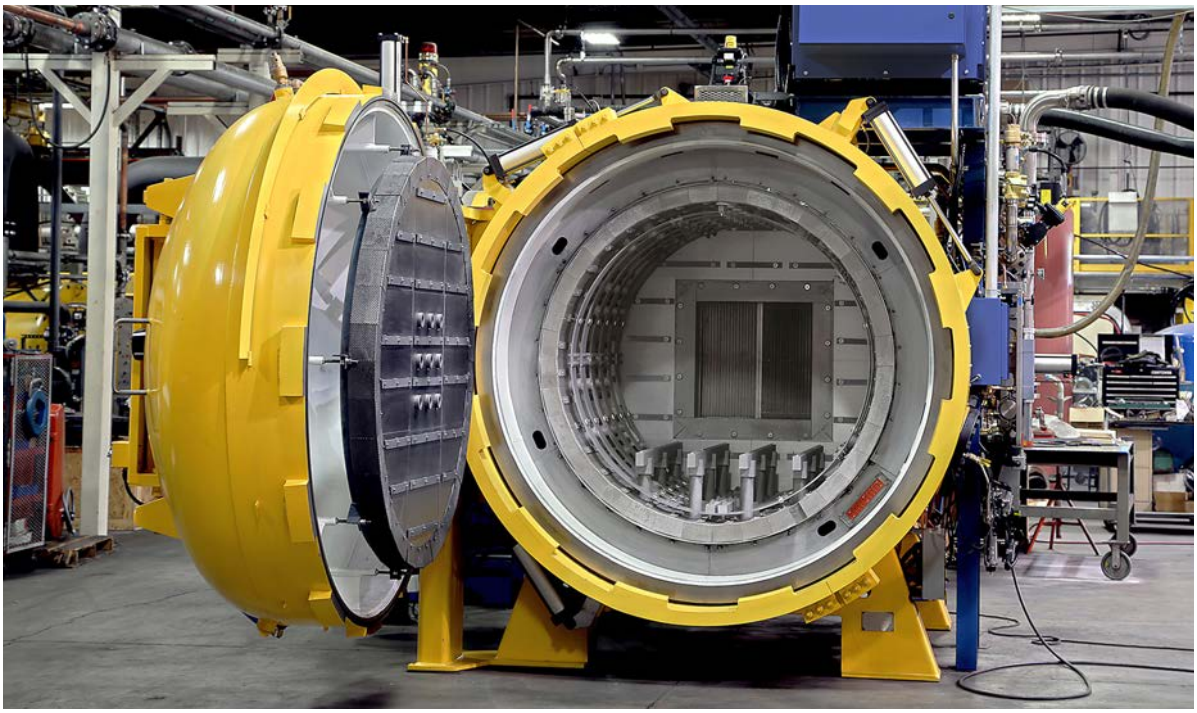


Example of an Insulated Hot Zone. (Courtesy: Solar Manufacturing)

CRYOGENIC PROCESSING FOR LONGER TOOL LIFE

Proprietary techniques developed to cryogenically process metals, alloys, and other materials have moved the process from the realm of science fiction to a much-needed fact to prolong tooling life.

By MICHAEL PATE

In almost every industrial trade magazine, there will appear an occasional article about "cryogenics." Thermal Processing has devoted an annual issue to cryogenic processing for several years now. A *Thermal Processing* article published in 2021 was perhaps the most scholarly and professionally written article in recent years. I have been researching cryogenics for the last 25 years. My research has included articles from the late 1930s to the present. Recent research has benefited from advances in analytical technology and measurement that now allow the cryogenically induced changes, especially in steel alloys, to be scientifically demonstrated in ways that are practically irrefutable.

THE BASICS OF CRYOGENIC PROCESSING

Among the most commonly observed changes are: 1) complete conversion of austenitic grain formations to martensitic grain formations, 2) Moving the naturally occurring carbides in ferrous metals from body-centered molecular structure to face-centered molecular structure, 3) eliminating internal stresses, 4) decreases in the coefficient of friction, 5) greater thermal conductivity, and 6) greater electrical conductivity.

This article will show what you, as a professional industrial user, can expect from having your tooling, knives, cutters, dies, punches, gears, chains, sprockets, etc., cryogenically processed.

Down River Cryogenics, LLC, has been providing cryogenic processing services to industrial and commercial clients for more than two decades. A large, loyal base of repeat customers is the cornerstone of its business. Therefore, it is more practical to discuss the actual results experienced by peers and competitors who have long-term experience with the company's proprietary cryogenic process. To maintain confidentiality, no clients are specifically named.

A few common questions about this process include:

Q: Why does freezing tooling/parts/materials (i.e. equipment) make any difference?

A: By changing the wear and stress characteristics of your equipment, your lines stay running longer, with lower maintenance, less frequent replacement of wear parts, and parts that operate cooler, stay sharp longer, and increase profits.

Q: Does cryogenic processing make steel harder?

A: A hardness change of two to three Rockwell C scale points is sometimes experienced. The particular alloy involved is the determinant factor. Cryogenic processing when done with our propriety techniques will not increase brittleness or other factors associated with unpredictable hardness changes.

Q: How is dimensional stability affected?

A: Dimensional stability is enhanced because the process relieves induced and kinetic stress.

Q: Is this some kind of coating?

A: No, the cryogenic process produces molecular-level changes that completely permeate the item. It can't be ground, polished, rubbed off, or chemically removed. Under typical operating conditions, the change is permanent.

Tooling Type	Percent Increase
Bandsaw Blades (metal cutting)	300
Bandsaw Blades cutting soft woods	280
Cold Saws (metal cutting)	250–400
Cold Saws (wood cutting)	250–400
Stamping Dies	310
Brush Cutter Blades	230
Sawmill Chipper Knives (soft woods)	380
Punch press tooling	320–425
Sawmill Chipper Knives (hard woods)	270
Plasma Torch Tip Consumables	360
Veneer Lathe Knives	200
Roller Chain	275–325
Paper Cutting Knives (Circular)	330
Paperboard Score Knives	340
Abrasive Slurry Pumps	200
Hot Tar Pumps	200
Molder Knives	400
Planer Knives	250

Figure 1: Average use life percentage increase with Down River Cryogenics Processing. (Figures rounded to nearest 5 percent)

Q: Does cryogenics cause color changes?

A: Yes. Most steels will have a slight gold surface color that will fade with use.

Q: Does the process have application for carbide items?

A: Yes. The process increases the strength of the bonding agents, so the parts have a wear life increase between 200 to 300 percent.

Q: Will this process make my tooling harder to resharpen?

A: The resharpening will not be affected except that a cryogenically processed tool will resharpen with less metal removal. Many customers find sharpening time is also reduced — as is chip out from collision with debris.

Q: What is the primary agent that creates the cryogenic change?

A: Liquid nitrogen creates the cryogenic processing temperature between minus-300°F and minus-316°F. This super-cold environment causes molecular changes that positively affect the processed items.

Q: Don't very cold temperatures make cracks in metals?

A: If the item being processed was simply plunged into the liquid nitrogen, the item would have a tendency to crack. Proper cryogenic

processing requires a descent from ambient to process temperature that takes several hours. If a cryogenic processor tells you they can have a 24-hour turnaround, you should keep looking.

Q: How is the cryogenic temperature maintained?

A: Liquid nitrogen is introduced into the cryogenic processing chamber through a proprietary technique. Liquid nitrogen boils at minus-316°F to minus-320°F, depending on atmospheric pressure, requiring the cryogenic processor to be extremely well insulated. Through a continuously monitored and adjusted computer-driven routine, the densely insulated chamber is filled with liquid nitrogen at precise, temperature-controlling intervals.

Q: Does this process work on non-metallic materials?

A: Cryogenic processing has positive effects for certain plastics including nylon, HDPE, UHMW, LDPE, and rayon. Cryogenics cannot be applied to cellular foam plastics.

Q: Are there factors that influence the actual results cryogenic processing imparts?

A: Absolutely. The initial qualities that make an item useable and applicable are not altered. Poor quality equipment is still poor quality, and poor workmanship does not change. Other factors including feed rate, tool speed, coolant delivery, specific applications, and simple basics such as proper maintenance and hygiene make a difference — cryogenically processed or not. Good workplace practices always make a difference. Figure 1 shows a partial list of items regularly processed by Down River Cryogenics.

The benefits are not limited to ferrous metals. Gears made from HDPE typically double in use life, and plastic bushings in a plant that require daily wash down run three times longer than untreated bushings. TiN coating, carbonitriding, hard-chrome plating, and spray-metal coatings benefit from a longer life after being cryogenically processed. Brass, aluminum, copper, stainless steel, cast iron, cast steel, and zinc are regularly cryogenically processed to good effect.

THE HISTORY OF CRYOGENICS

The very word, "cryogenics," creates images more based in science fiction than practical science. This unfortunate association led to an aura of snake oil and dubious operators making promises of magic wand miracles but producing very few useable results. To an extent, this is understandable as cryogenic service providers expect their customers to buy a product they can't see or touch. Until science caught up with practice, it was a leap of faith for many early customers.

Since the mid-1930s, the Holy Grail of wear reduction and increased life for consumable steel tooling has been a successful, efficacious, repeatable, and affordable cryogenic process. Specifically, finding a technique known as deep cryogenic processing, safely subjecting items to temperatures ranging from minus-300°F to minus-316°F. There have been many different attempts to expose tooling and wear parts to cryogenic temperatures as an adjunct to heat treatment or to substitute for heat treating.

Cryogenic processing is an old idea. It is reported that Swiss watch makers in the 1400s would take leather pouches of brass watch parts to the Alpine snowpack and bury them in the snow for the winter. The temperatures would remain below minus-30°F for several months. The molecular changes in the watch parts caused by prolonged exposure to Alpine cold was significant enough to make watches with a greater time-keeping accuracy and longer use life.

Various scientists and many entrepreneurs have sought to develop a viable way to use the cryogenic process. Discovering a method to increase the wear resistance and use life of steel tooling without creating embrittlement, fracturing, over hardening, or imparting stress has been an ongoing search for nearly a hundred years.

Soviet-era scientists tried immersing items in liquid nitrogen.

A processor is loaded. (Courtesy: Down River Cryogenics)

A cryogenic processor. (Courtesy: Down River Cryogenics)

While claiming success for this method, no peer-reviewed science was ever offered to back it. After the collapse of the Soviet Union, Russian scientists have come forward to dispute these claims, primarily saying stress fractures were common with the sudden immersion technique.

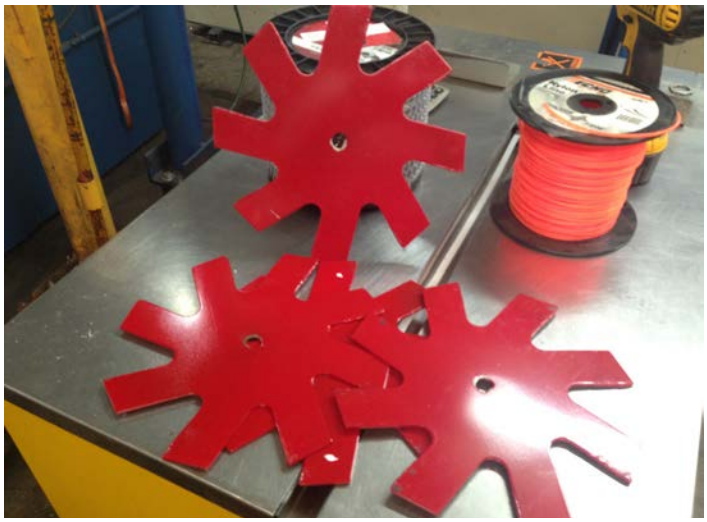
In England, hanging of items in a wire basket suspended over liquid nitrogen to be pre-cooled before being immersed in liquid nitrogen has been used with limited positive results. Still, the immersion of metals in liquid nitrogen without a slow ramp down to the required temperature produces micro cracks and marginal improvements.

Dr. Randall F. Barron at Louisiana Technical University at Monroe was among the first to scientifically document the changes deep cryogenic processing produced. His seminal research article printed in the May 1974 issue of the TAPPI Journal caused a reawakening of interest in cryogenic science for industrial applications. His stunning revelations of extended tool life, stress reduction, and greater thermal and electrical conductivity, all without a significant increase in hardness, was the dawning of a new age of cryogenic technology. Following that publication, many entrepreneurs have tried to commercialize Dr. Barron's findings. Most have failed.

IMPROVING THE TECHNOLOGY

As above, many companies in the later part of the 20th century mar-

Liquid nitrogen dewars are staged for a process. (Courtesy: Down River Cryogenics)



Turf Aererator blades after processing. (Courtesy: Down River Cryogenics)

keted equipment specifically for cryogenic enhancement of tooling and consumable parts. Few remain in business. Most of them made great looking machinery. Unfortunately, they failed to replicate Dr. Barron's results. Much like the California Gold Rush, a lot of people tried; few succeeded. Failure in the cryogenic processing business is more the rule than the exception. A typical start-up cryogenic processing business has a predicable life of about 18 months.

In the United States, the interest in cryogenics became more focused on non-industrial applications. These have included motor sports parts, metal baseball bats, gun barrels, fishing line, golf balls and clubs, pantyhose, and other items that have no critical industrial potential whether the cryogenic process worked or failed. A driver who gains a few more yards off the tee is an interesting parlor trick, but it doesn't improve your production.

In Europe and Asia, the use of cryogenic processing became an industrial practice where mere success of any kind was an acceptable norm. Lower quality tooling could be improved enough to be useable and perhaps competitive with higher quality products.

Attempts to insert the cryogenic process into the heat treatment cycle have produced good results but at great expense and unpredictable improvement. Processors have found that applying the cryogenic process to items in the heat-treating cycle requires a degree of control and precision most cannot achieve. This is due to the fact that every type of alloy requires a different technique. The end results can be positive, but technically challenging, to produce.

Down River Cryogenics discovered more direct methods were more reliable and much easier for its customers to use. This is why the company processes tooling that its customers would normally just put into service as is. By introducing the cryogenic process at that stage, customers' workflows aren't interrupted; everything is familiar; equipment setup remains the same, and they can focus on their bottom line.

RECENT RESEARCH

In the last 25 years, cryogenic processing has become the topic of many scholarly papers and dissertations. The author of this article participated in a paper published in 2021, in The International Journal of Engineering Science titled "Quantifying Deep Cryogenic Treatment Extent and Its Effect on Steel Properties." This research was headed by Dr. Paul L. Funk, et al., at the University of New Mexico, Las Cruces Department of Mechanical and Aerospace Engineering in conjunction with the USDA-ARS Cotton Research Lab.

The paper discusses the laboratory analysis of items cryogenically processed using the proprietary process developed by Down River Cryogenics, LLC, in Jefferson, Arkansas. In addition to extensive laboratory examinations, several hundred cryogenically processed items were provided to normal end users for evaluation in their typical operating environment.

The authors observed significant increases in use life—exceeding 200 percent without exception and with greater improvements in some applications.

As the researchers discovered, a scientifically developed and regulated cryogenic process is necessary to produce quantifiable, positive, and industrially viable results. The changes created on the molecular level include carbide particle distribution changing from body centered to face centered, elimination of retained austenite, a complete formation of martensitic grain structure, a great reduction of retained and imparted stress, a reduction of the coefficient of friction, greater conduction of heat, reduced electrical resistance, and longer actual tool use life.

COST EFFECTIVENESS

The items in the above list regularly being cryogenically processed all have a single commonality: Cryogenically processing them is cost effective. Customers say that $1 spent for cryogenic processing typically returns $3 to $4 in reduced downstream costs. The benefits enjoyed by long-term industrial cryogenic users are increased tool life, less downtime for tooling changes, improved product quality, less money spent on replacement tooling, and an improved safety margin due to less tooling handling.

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ABOUT THE AUTHOR

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INTEGRATED RUPTURE DISK ASSEMBLIES

FOR CRYOGENIC EQUIPMENT AND STORAGE SYSTEMS

Custom engineered, miniature rupture disk assemblies like those from BS&B Systems protect cryogenic systems and tanks from over pressurization. (Courtesy: BS&B)

Custom-engineered, miniature rupture disk assemblies protect cryogenic systems and tanks from over pressurization.

By JEFF ELLIOTT

Today, cryogenics is used to provide convenient storage of large quantities of industrial gases such as nitrogen, oxygen, carbon dioxide, argon, helium, and hydrogen that are vaporized from liquid to gas at time of use in support of many industrial processes ranging from steelmaking to medical systems and welding. Additionally, cryogenic equipment provides stable, cold temperatures required to preserve biological samples, support superconducting magnets such as those used in medical imaging systems and particle physics experiments, as well as to support novel surgical procedures and materials research.

Within these systems, liquefied gases such as helium, hydrogen, nitrogen, carbon dioxide, and oxygen are kept at very low temperatures since the boiling points for these gases are very low, ranging from minus-78.5°C (minus-109.3°F) for liquid carbon dioxide to minus-269°C (minus-452.2°F) for liquid helium. Due to its physical properties, as temperature rises, a very small amount of liquid can expand rapidly into a very large volume of gas.

For example, the expansion ratio of nitrogen is 694—with 1 liter of liquid nitrogen becoming 694 liters of gaseous nitrogen at standard temperature and pressure (ambient conditions). If the insulation or other cooling methods used to maintain cryogenic temperature conditions for a liquid are lost, a rapid buildup of pressure will occur in any closed tank or vessel in which the liquid is contained.

For these reasons, cryogenic systems are equipped with pressure relief devices such as rupture disks to protect against rapid pressure rise caused by a sudden increase of heat into cryogenic systems, cryogenic shippers, cryostats, cannisters, and associated piping. For applications that use superfluid helium to cool superconducting magnets in magnetic resonance imaging equipment, particle accelerators, and for semiconductor processing, rupture disks protect against the sudden catastrophic loss of insulating vacuum or insulating nitrogen in the storage vessel or experimental enclosure.

The rupture disk, which is a one-time-use membrane made of various metals including exotic alloys, is designed to activate within milliseconds when a pre-determined differential pressure is achieved. However, given the critical reliability of the equipment in operation and during storage/transport, this demands high-integrity, pressure-relief technology.

As a result, OEMs are increasingly turning to integrated rupture disk assemblies with all components combined by the manufacturer, as opposed to loose rupture disk and holder devices that leave much to chance. These assemblies are being tailored to the application, miniaturized, and use a wide range of standard and exotic materials, as required. This approach ensures the rupture disk device performs as expected, enhancing equipment safety, reliability, and longevity while simplifying installation and replacement.

SEPARATE COMPONENTS VS. INTEGRATED ASSEMBLIES

Traditionally, rupture disks began as standalone components combined with the manufacturer's separate holder device at the point of use. The installation actions of the user contribute significantly to the function of the rupture disk device. When installed improperly, the rupture disk may not burst at the expected set pressure. There is a delicate balance between the rupture disk membrane, its supporting holder, and the flanged, threaded, or other fastening arrangement used to locate the safety device on the protected equipment.

With the availability of integrated, miniaturized rupture disk solutions tailored to the application in a variety of standard and exotic materials, OEMs like BS&B can enhance equipment safety, compliance, and reliability even in extreme work conditions. (Courtesy: BS&B)

For this reason, an integrated rupture disk assembly is often a better choice than separable parts. Available ready-to-use and with no assembly required, integrated units are certified as a device to perform at the desired set pressure. The one-piece design allows for easier installation and quick removal if the rupture disk is activated.

The assembly includes the rupture disk and housing and is custom-engineered to work with the user's desired interface to the pressurized equipment. The devices are typically threaded or flanged, or even configured for industry specific connections such as CF/KF/Biotech industry clamp connections/VCR couplings. The rupture disk and holder are combined by the manufacturer by welding, bolting, tube stub, or crimping based on the application conditions and leak tightness requirements.

There are additional advantages to this approach. Integrated assemblies prevent personnel from using unsafe or jury-rigged solutions to replace an activated rupture disk to save a few dollars or rush equipment back online. The physical characteristics of increasingly miniaturized rupture disks as small as 1/8" can also make it challenging for personnel to pick up the disk and place it into a separate holder.

"Cryogenic equipment OEMs are driven to deliver the safest operation as well as longest life and lowest cost of ownership to their customers," said Geof Brazier, managing director of BS&B Safety Systems Custom Engineered Products Division. "The use of an integral assembly maximizes the longevity, proper function and trouble-free service of the pressure relief technology."

INTEGRATED ASSEMBLIES – RUPTURE DISK DESIGN

According to Brazier, the most important considerations in rupture disk device design are having the right operating pressure and temperature information along with the expected service life, which is often expressed as a number of cycles the device is expected to endure during its lifetime. Since pressure and cycling varies depending on the application, each requires a specific engineering solution.

"Coming up with a good, high reliability, cost-effective, and application-specific solution for cryogenic equipment involves selecting the right disk technology, the correct interface (weld, screw threads, compression fittings, single machined part) and the right options as dictated by the codes and standards," Brazier said.

Because user material selection can also determine the longevity of rupture disks, the devices can be manufactured from metals and alloys such as stainless steel, nickel, Monel, Inconel, and Hastelloy.

According to Brazier, for a wide range of industries, it can be important for rupture disks to have a miniaturized reverse buckling capability in both standard and exotic materials.

"Where economics is the driver, reverse buckling disks are typically made from materials such as nickel, aluminum, and stainless steel," he said. "Where aggressive conditions are required, more exotic materials like Monel, Inconel, Hastelloy, titanium, and even Tantalum can be used."

In almost all cases, "reverse buckling" rupture disks are used because they outperform the alternatives with respect to service life.

If the insulation or other cooling methods used to maintain cryogenic temperature conditions for a liquid are lost, a rapid buildup of pressure will occur in any closed tank or vessel in which the liquid is contained. (Courtesy: BS&B)

In a reverse buckling design, the dome of the rupture disk is inverted toward the pressure source. Burst pressure is accurately controlled by a combination of material properties and the shape of the domed structure. By loading the reverse buckling disk in compression, it can resist operating pressures up to 95 percent of minimum burst pressure even under pressure cycling or pulsating conditions. The result is greater longevity, accuracy, and reliability over time.

"The process industry has relied on reverse buckling disks for decades," Brazier said. "Now the technology is available to OEMs in miniature form as small as 1/8" burst diameter from BS&B. Until recently, obtaining disks of that size and performance was impossible."

However, miniaturization of reverse buckling technology presents its own unique challenges. To resolve this issue, BS&B created novel structures that control the reversal of the rupture disk to always activate in a predictable manner. In this type of design, a line of weakness is also typically placed into the rupture disk structure to define a specific opening flow area when the reverse type disk activates and also prevents fragmentation of the disk "petal."

"Reverse buckling and, therefore, having the material in compression does a few things," Brazier said. "No. 1, the cyclability is much greater. Second, it allows you to obtain a lower burst pressure from

OEMs like BS&B use threading and several other connection types to attach the rupture disk assembly to the application. (Courtesy: BS&B)

thicker materials, which contributes to enhanced accuracy as well as durability."

Small nominal size rupture disks are sensitive to the detailed characteristics of the orifice through which they burst. This requires strict control of normal variations in the disk holder.

"With small size pressure relief devices, the influence of every feature of both the rupture disk and its holder is amplified," Brazier said. "With the correct design of the holder and the correct rupture disk selection, the customer's expectations will be achieved and exceeded."

Due to cost, weight, and other considerations, Brazier said BS&B has increasingly received more requests for housings that are made out of plastics and composites.

Because customers are often accustomed to certain types of fittings to integrate into a piping scheme, different connections can be used on the housing. Threading is popular, but BS&B is increasingly using several other connection types to attach the rupture disk assembly to the application. Once the integral assembly leaves the factory, the goal is that the set pressure cannot be altered.

"If you rely on someone to put a loose disk in a system and then capture it by threading over the top of it, unless they follow the installation instructions and apply the correct torque value, there is still potential for a leak or the disk may not activate at the designed burst pressure," Brazier said. "When welded into an assembly, the rupture disk is intrinsically leak tight and the set-burst pressure fixed."

While OEMs have relied on rupture disks in their cryogenic equipment, the availability of integrated, miniaturized rupture disk solutions tailored to the application in a variety of standard and exotic materials can significantly enhance equipment safety, compliance, and reliability even in extreme work conditions.

ABOUT THE AUTHOR

Jeff Elliott is a Torrance, California-based technical writer. He has written about industrial technologies for the past 20 years. For more information, go to www.bsbsystems.com.

UNDERSTANDING THERMAL PROPERTIES FROM ATOM TO APPLICATION

When a material is processed, Laser Thermal's non-contact optical technique can detect changes, whether that is in the microstructure, grain size, orientations, or chemistry, for example. (Courtesy: Laser Thermal)

Laser Thermal manufactures optical equipment for making simple, rapid, and accurate thermal measurements of materials.

By KENNETH CARTER, Thermal Processing editor

To get accurate temperature measurements when thermal processing materials, the common practice is to use infrared sensors; however, those sensors often cannot pinpoint specific, crucial areas of a sample that may be problematic and need further characterization.

After years of research, the experts behind Laser Thermal have developed a method to measure the thermal properties of a material with a non-contact thermal conductivity measurement tool using optical technologies.

"The equipment we sell measures the thermal properties of materials; when anything changes in a material based on processing like heat treatment, the morphology, structure, or phase of the material often changes in such a way where the thermal conductivity changes," said Patrick Hopkins, CSO and co-founder of Laser Thermal. "So, the equipment that we manufacture and the testing that we do serves two purposes: One is to tell you what the thermal conductivity of the material is — that's primarily how the technique and company was born. The second is to tell you that something has changed in the processing from your parent material. This is often used as more of a quality control metric rather than as an absolute measurement."

NON-CONTACT OPTICAL TECHNIQUE

When a material is processed, Laser Thermal's non-contact optical technique can detect changes, whether that is in the microstructure, grain size, orientations, or chemistry, for example, according to Hopkins.

"The technique that we utilize is a way to sense that something has changed during processing and relate that back to the thermal processes and the temperature of the sample," he said.

The technology developed by Laser Thermal is optical, according to John Gaskins, CEO and co-founder.

"It's based on lasers; we use lasers to measure the temperature changes on the surface of the sample, and we can relate temperature changes to thermal properties," he said. "If anything changes in the material that will change its ability to conduct heat, we can sense that. And it's an all-optical technique that can be used to detect material changes with resolution from the nanoscale to the macroscale, and, additionally, it's fully automated. It's a way that we can do high throughput material screening of processed materials."

Although Laser Thermal's technique serves a similar function as pyrometry, the measurement principle is fundamentally different, according to Gaskins.

"It's in the same realm as pyrometry in that we are sensing temperature changes, but it's an optical technique in that we look at reflectivity," he said. "We're not looking at thermal emission; we don't rely on needing to know emissivity or surface finish. It's looking at the changes in reflectivity of the sample surface. Pyrometry is primarily just sensing the emissivity of material."

CREATING A NEW PRODUCT

The measuring technology offered by Laser Thermal stems from the company's zeal to embrace new advances in optical technologies in order to create new products, according to Hopkins.

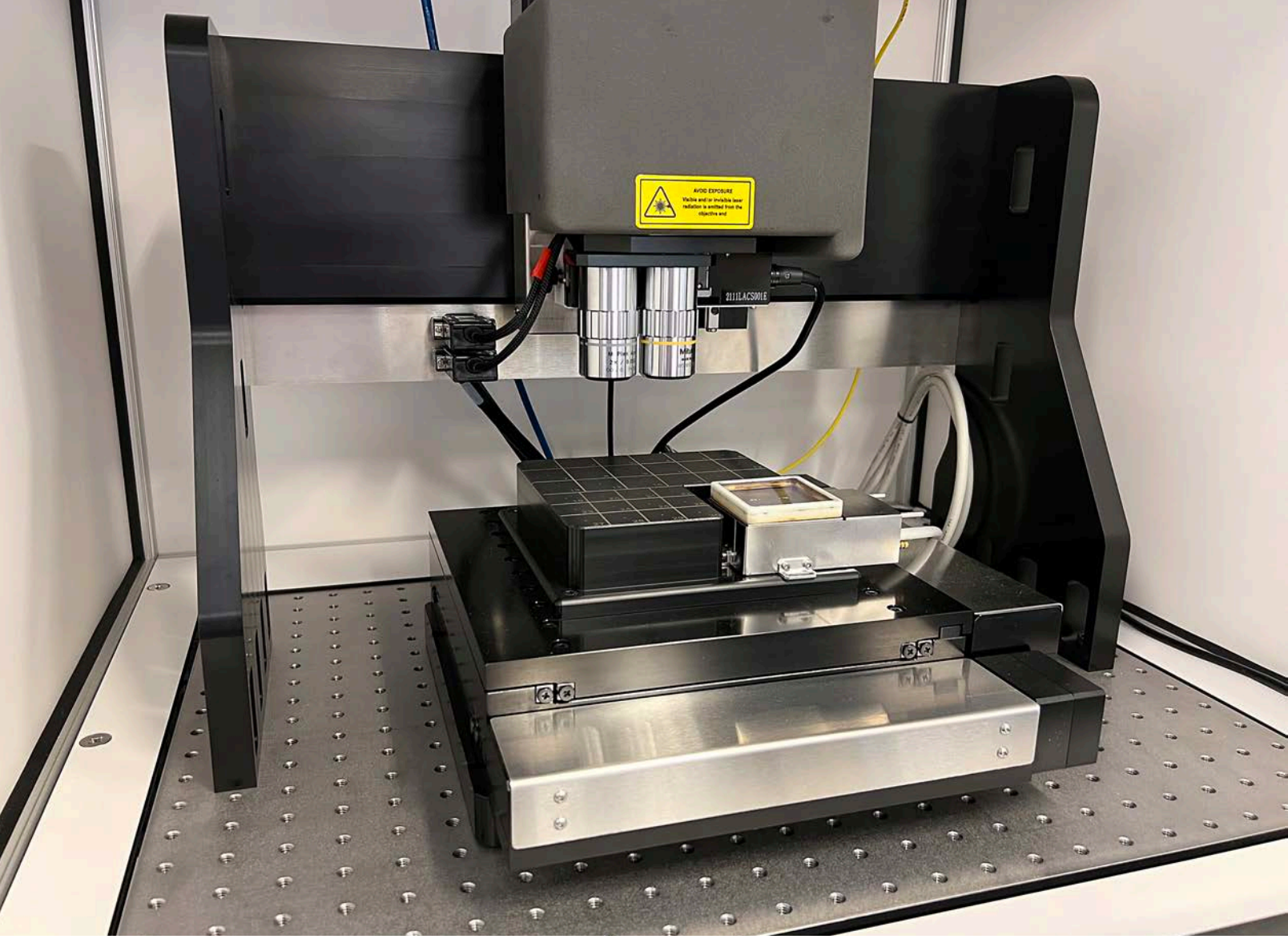
Laser Thermal has developed a method to measure the thermal properties of a material with a non-contact thermal conductivity measurement tool using optical technologies. (Courtesy: Laser Thermal)

"One of the things that we have emphasized as a company is that there are a lot of contact measurements for thermal properties, and there are a lot of non-contact measurements for temperature, but there are almost no commercially available non-contact measurements other than maybe laser flash for thermal conductivity," he said. "One of the things that we are always looking to do is to continue to innovate to create thermal measurement technologies that are useful for our customers."

This is particularly useful for processes involving high temperatures where it is essential to monitor microstructural evolution as materials go from molten to solid phases during quenching, giving customers the needed information about what happens to their materials during the manufacturing process, according to Hopkins.

Unlike pyrometry and macroscopic techniques, Laser Thermal can interrogate localized changes in material microstructure in a non-contact manner, Hopkins said, including when materials are melting or going through other phase transitions.

"We can, for example, interrogate very specific regions of a sample that may get very hot and melt as opposed to looking at the entire block of material," he said. "We have resolution that can be on the order of, or less than, a grain size and see how the thermal properties of those isolated regions are changing."



Laser Thermal has been manufacturing and selling thermal conductivity measurement systems and doing service contract measurements of thermal conductivity of materials since 2020. (Courtesy: Laser Thermal)

BEYOND TRADITIONAL METROLOGY

This allows for a level of resolution both in terms of time and space that isn't possible with traditional metrologies, according to Gaskins.

"We have this spatial resolution that can be on the order of microns, which basically means that you can combine the advantages of pyrometry where you're looking at overall hotspots and temperature change, with some flavor of microscopy, and that you can now interrogate locally how different regions are changing as they're going through a heat-treated process," he said. "Given that it is non-contact, we have the ability of monitoring materials as they're changing both in-situ and post treatment, but really it's the real time and automated aspect that allows you to do high-throughput material testing. Our techniques don't need to know anything about the material as it's going through the heat-treat process. We can, in real time with very high throughput, interrogate the material's response with resolution on the order of microns to millimeters."

Laser Thermal's mission is to manufacture and supply its microscope measuring systems to laboratories and companies that need them, but Laser Thermal has the ability to accept outside samples and measure them in house as well, according to Hopkins.

"People can send us samples, but we're manufacturing microscopes; we're manufacturing equipment that we sell and deliver as a standalone measurement tool in people's labs or in manufacturing lines," he said. "However, we have customers who don't have a need for a full system, and so they'll just send us materials for testing."

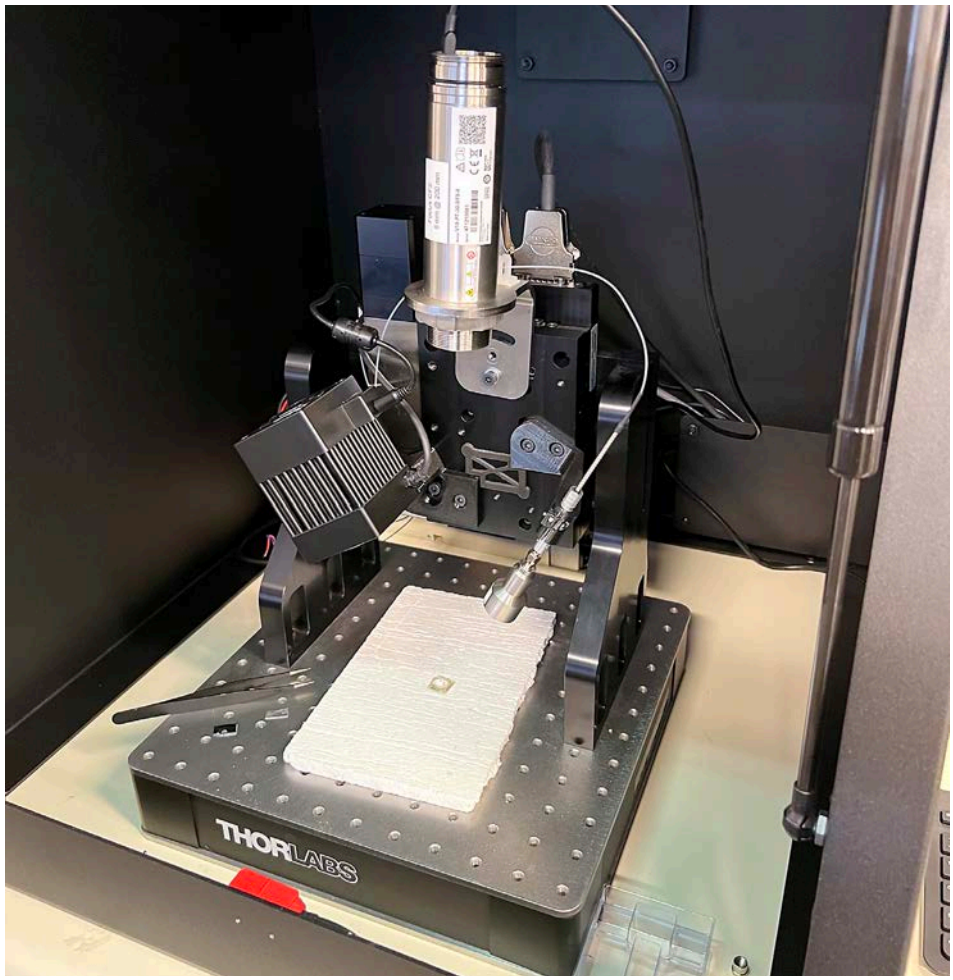
> ***"Being able to disseminate that tool to a wider community took a real advance in understanding and in engineering to be able to create this tool that you can put into industry, into academia, and into research labs outside of the specialty lab."***

GAME-CHANGING EQUIPMENT

What Laser Thermal can offer the heat-treat industry is still a relatively new process, and both Gaskins and Hopkins recognize that their technology could be a significant game changer for the com-

panies in need of high-quality, detailed thermal measurements.

"A large contingent of our customer base lives in the semiconductor metrology space," Gaskins said. "But as we've begun to roll out more on the high-temperature side of things, it has certainly become relevant to heat treating. Even inside the semiconductor electronics market, there are all sorts of different anneals and heat treatments that are going on that oftentimes are causing things to react with each other — causing microstructures, phases, and compositions to change on scales that have not been able to be interrogated up to this point. And there's no real knowledge of what those impacts are on heat transfer. We've also seen, as we've begun to offer high-temperature testing, that our customers are just interested in understanding things like: 'When I do take a material to temperature, what are the thermal properties at temperature?' Because that directly relates to how the microstructure's going to evolve, how that part is going to come out, or being able to model and understand how long a part has to be at a certain temperature before it evolves into the phase needed."



Unlike pyrometry and macroscopic techniques, Laser Thermal can interrogate localized changes in material microstructure in a non-contact manner. (Courtesy: Laser Thermal)

YOUNG COMPANY – YEARS OF RESEARCH

Laser Thermal officially began as a company in 2020, but its roots go back at least 10 years when Gaskins and Hopkins were developing thermal conductivity measurement tools for materials at the University of Virginia, according to Hopkins.

"Our expertise was in methods and measurement of temperature and thermal properties of materials to try to evaluate how microstructure and processing would impact thermal properties," he said. "In 2015, we developed a technique and filed for a patent on a way to make a very streamlined non-contact thermal conductivity measurement tool."

Five years later, Laser Thermal was born — a company based on contract testing and developing equipment for thermal conductivity measurement systems.

"Since 2020, we've been manufacturing and selling thermal conductivity measurement systems and doing service contract measurements of thermal conductivity of materials," Hopkins said.

It's been a particular point of pride, according to Hopkins, to have been able to evolve the company from its research development to full commercialization in such a short time.

"Being able to disseminate that tool to a wider community took a real advance in understanding and in engineering to be able to create this tool that you can put into industry, into academia, and into research labs outside of the specialty lab," he said. "A really big achievement was spinning out the company to actually get this equipment and these microscopes that we sell out into the field and out into the public. That really is exciting to see."

OLD PROBLEMS, NEW SOLUTIONS

Because Laser Thermal is bringing to the industry a new and innovative way to measure thermal processing, oftentimes Gaskins said they are solving problems that customers have had for a while with no solution in sight.

"Usually our approach toward that is, if it's material measurement or maybe a slightly different variation on what we normally do, usually our methodology is to say, 'send it to us,'" he said. "We'll do a little bit of interrogation, and then if there's a solution for this problem, then we can work together to understand whether it's a consistent materials-testing relationship or whether there's enough interest there to create some modification on what our standard tools are."

That sort of arrangement often can bring about a co-development idea between Laser Thermal and a client, according to Gaskins.

As the industry learns of what Laser Thermal can offer, Hopkins expects more companies to express interest in the innovative technology.

"For us, the relevance is in creating metrologies that inform companies about high-temperature properties — via what are typically difficult measurements — to facilitate an understanding of properties at high temperatures, understanding properties through melt, and understanding properties in the liquid phase, because that has a whole implication on different products and how castings are formed," he said. "For us, high temperature is probably the place in the thermal market where we're going to place the biggest emphasis on product development. In 10 years' time, I imagine that will be where we'll have the largest impact on the thermal processing market."

MORE INFO laserthermal.com

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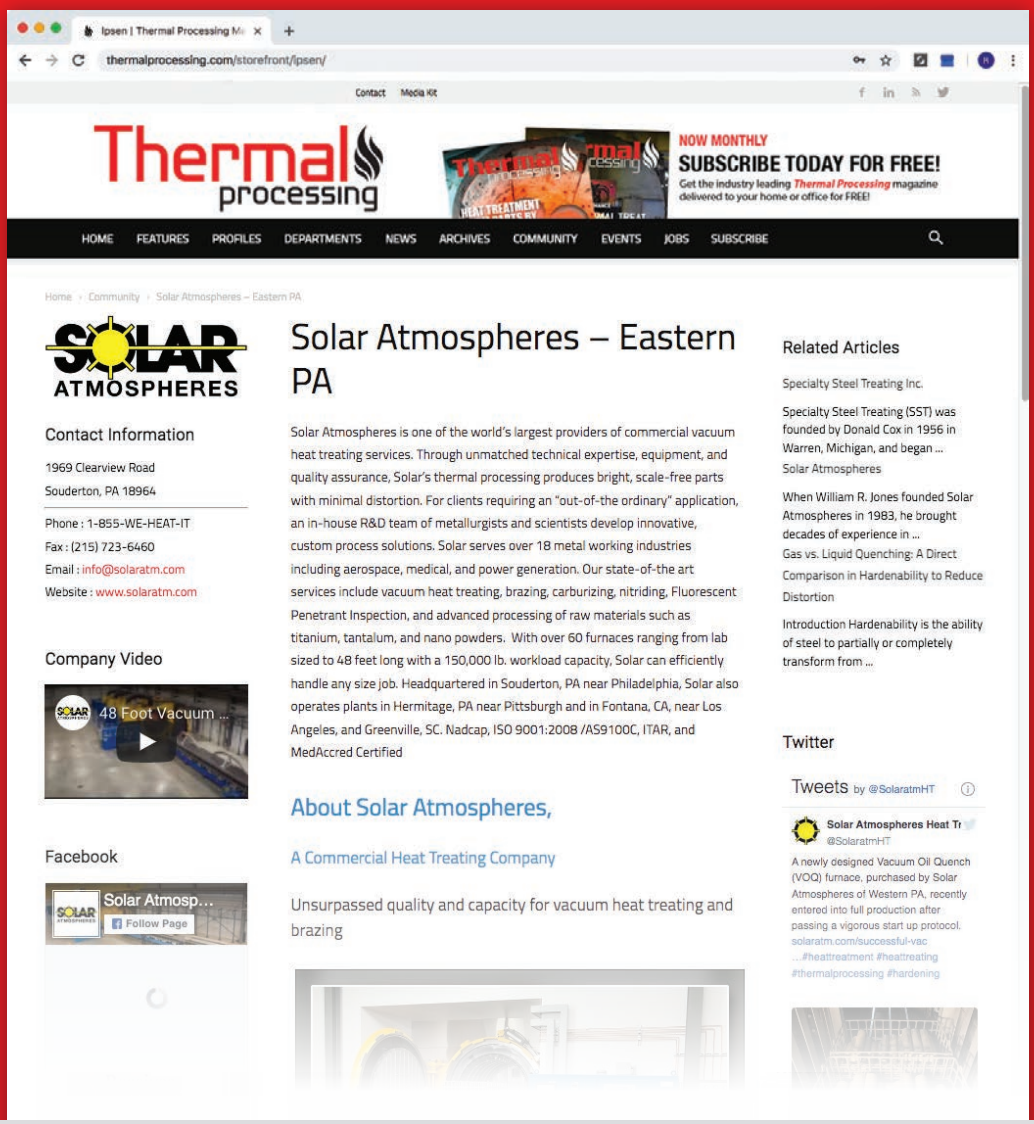

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"Heraeus is well known for its quality products, which results in more reliable equipment and less downtime for our customers."

Tell us about yourself and Heraeus.

I have worked for Heraeus now for almost 14 years supporting customers with the design and build of infrared systems for thermal applications. Heraeus is a family-owned company that's over 170 years old, and we are very proud of that. Heraeus has more than 13,000 employees with 12 business units including Heraeus Noblelight, which manufactures infrared and ultraviolet equipment. We are truly a global company and have manufacturing all over the world including North America. We design and build our own infrared heating products and UV products. Our North American head office is in Gaithersburg, Maryland, where we have manufacturing and testing capabilities. We supply many different industries and apply our infrared technology to many different applications. Our focus is on making sure we have the right equipment for the application and not just using something because it kind of fits.

Heraeus is constantly developing and looking at new products and new ways to do things, which is exciting to be a part of.

What are Heraeus Noblelight's goals?

Heraeus Noblelight wants to continue to grow sustainably as a partner for infrared and UV technology in the global target markets. Our focus is on the development of customer-specific systems. We are continually investing in product and employee development. Not only do we see the need to be environmentally responsible, we also have a desire to use our resources wisely.

What sets Heraeus apart from other companies?

Heraeus is well known for its quality products, which results in more reliable equipment and less downtime for our customers. We are known for our experience. We are known for our flexibility, and we are known for our engineering and design capabilities. This is extremely beneficial for working on unique applications and developing new heating processes. We have the knowledge from working on many unique applications, and we are always looking for new and better ways to apply our technology. All of these attributes mean we can help our customers to have a better-quality product going out the door.

What tools do you use when working on a new heating application?

With infrared heating, testing is often required to properly design a system. We have a lab where testing can be done; we offer rental equipment where customers can use infrared modules and electrical controls at their location to prove out a process. We also run simulations such as ray tracing and computational fluid dynamics to aid in optimizing a design. These are all very effective ways to ensure the right technology is applied.

Where do you see infrared technology fitting into the changing energy landscape?

Infrared has been used for thermal processing for many years, and it is continually evolving. In manufacturing, infrared heating can be used for a variety of purposes such as preheating materials before processing, drying or curing coatings or adhesives, and welding components, just to name a few. Infrared heating can provide a quick and efficient way to heat materials without heating the air around them, which can reduce energy consumption and improve the efficiency of manufacturing processes. It can also provide a more precise and controllable form of heat, allowing manufacturers to target specific areas or materials for heating.

Based on the current challenges we are seeing in the energy market and the need to be more efficient, electric infrared is a great solution for thermal processing. We are seeing a push for more focused heating sources as well as higher output and more controllability. Faster heat up times and better temperature controllability means less scrap and lower overall costs.

We expect to see that demand for more focused heating and better control to be the main drivers in our development of new products and solutions.

What trends have you observed in the thermal-processing industry?

Regulations on the limitation of volatile organic compounds (VOC) have been in force for a long time, requiring coating manufacturers to use fewer solvent-based components. As companies make the switch to more environmentally friendly coatings and water-based products, the challenge is that often heating, drying, or curing the coatings requires more energy. Infrared is a very efficient way to increase the temperature quickly and shorten the ramp rate. With our instant on-and-off equipment and accurate temperature control, we can greatly reduce energy consumption.

We see this trend continuing and, therefore, see an increased demand for heating solutions.

Looking ahead, what are your expectations for the coming year?

I think it is important to focus on the positives that are happening, including a lot of manufacturing that is coming back to North America and the potential this brings. Thankfully, with our internal manufacturing capabilities, we are poised to grow using our knowledge to support customers for their heating applications.

MORE INFO www.heraeus-noblelight.com

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