INDUSTRIAL HEATING

The International Journal of Thermal Processing

FEBRUARY 2018

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INSIDE

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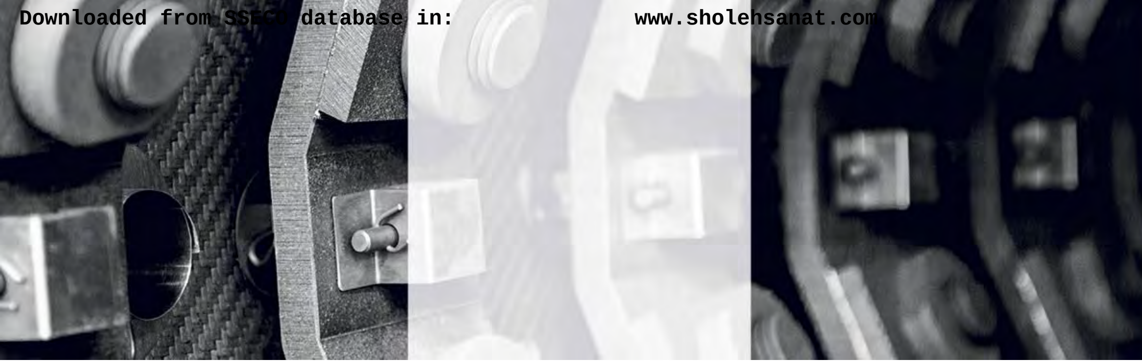

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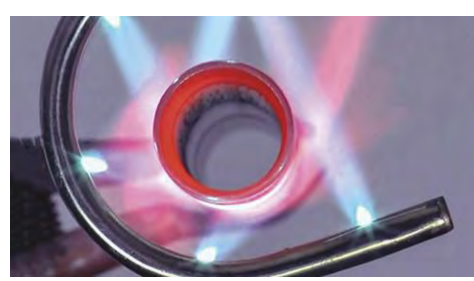

On the Cover:
Hand brazing is best left to the "torch-brazing athletes" (p. 36).

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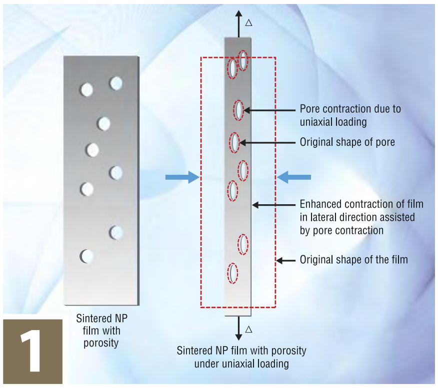

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Nonferrous News: Good and Not so Good

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When I look over the news of the day in the nonferrous segment, three things stand out: good times, advancements and illegal activity. Let's look at some examples of each.

Good Times

Our desire is always to emphasize the good news, so that's where we start. The stock pickers are very bullish on Alcoa in 2018, and the share price has already gone up 30% in just a month (as of Jan. 10).

Ducker Worldwide is predicting that aluminum in vehicles is and will continue to be on the rise. They predict that aluminum doors will go from less than 5% in 2015 to 20% of the North American fleet in 2020. Hoods are predicted to be 71% aluminum by 2020 compared to 50% in 2015. Bumper beams will go from 33% in 2015 to 54% in 2020.

Facilitating this increase in automotive usage is the recent announcement by Novelis that its highly formable, heat-treatable alloy (Advanz™ 6HF - e/s200) is now available in North America. This alloy has been successfully applied in Europe, and it crosses over a bit into the advancements category.

Also, Aleris recently announced the opening of a $400 million auto-body sheet production center in Kentucky, which is its first in North America able to finish aluminum auto-body sheet. This expansion included two continuous annealing lines and a wide coil mill.

With Alcoa's recent decision to close a Texas smelter and divest a smelter in Italy, primary aluminum production will happen elsewhere. To that end, the government of Guinea has approved a Chinese investment of more than $2.8 billion in a bauxite mine, an aluminum smelter and refinery. Guinea has about one-third of the known bauxite reserves, but development has been slow due to riots and unrest.

At least partly due to the fact that investors have become bullish on commodities, copper has had a good price run over the past year, increasing 31%. Copper demand will be driven by electric vehicles, solar and wind power, energy-efficient appliances, and the auto and construction industries. The nonferrous metal has historically been a good market indicator.

Advancements

Additive manufacturing continues to be part of what's new. One of the recently announced advancements is from Vader Systems, which is using molten aluminum droplets rather than powder. Because this process is 10 times less expensive than powders, it (when commercialized) will make additive manufacturing affordable to an expanded market, including automotive.

Battery technology is definitely a growing area – in general and for nonferrous in particular. This month's article from CAN-ENG talks about the role of nonferrous materials in electric vehicles. Researchers in China have reportedly developed an aluminum-graphene battery that can be fully charged in five seconds and last for two hours. It has a better operating temperature range and can retain 91% of its capacity even after 250,000 charge/discharge cycles.

Other advancements include a move to make aluminum production greener because, although valuable for lightweighting, aluminum is very energy-intensive to produce. New alloys, such as aluminum-scandium, are being developed for various high-performance applications.

Not so Good

We have discussed this relative to rare-earth metals in the past, but there are new concerns about shortages in "technology metals" such as cobalt, lithium and manganese. These minerals are crucial for batteries used in electric vehicles. An article "Will Tesla Die for Lack of Cobalt?" in *The Wall Street Journal* believes the market will take care of the problem.

Primary aluminum is being produced all over the world, especially since little to none is smelted here in the U.S. Domestic producers of finished aluminum products, however, are taking exception to the importation of semi-finished goods. In recent months, antidumping cases have been filed targeting aluminum foil, extrusions and sheet.

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Losing Faith in Government

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It isn't often that I agree with anything published by the Center for American Progress, but their Nov. 30, 2017, paper citing inequities in campaign contributions to members of Congress was spot-on. Such "bribery" distorts policymaking and makes government less responsive and accountable to U.S. citizens.

Half a dozen years ago, lobbyists' annual giving to members totaled $29 billion (latest data I found) and, in round numbers, was distributed:

- Finance/insurance/real estate – $4.3 billion, or 15% of the total
- Health – $4.2 billion, or 15%
- Communications – $3.5 billion, or 12%
- Energy and natural resources – $3.1 billion, or 11%
- Transportation – $2.2 billion, or 8%
- Agribusiness – $1.3 billion, or 4%
- Defense – $1.2 billion, or 4%

There were 12,281 "registered lobbyists" in 2014, with the actual number exceeding 100,000. You see, there is a lot of paperwork and disclosure to be registered with government. (I know because I was an unregistered lobbyist on the Hill representing the sole U.S. maker of nuclear warheads for the second half of the Cold War. In that time, my client and I gave a $200 campaign contribution to a senator from Mississippi … and nothing else to anyone!)

The nation has too many federal employees (about 3 million non-military that are not susceptible to removal and are, in actuality, immune to firing) and associated self-interest groups, including unions and other economic "dependencies" requiring protection. This latter category includes the media, which has evolved as a government "sales organ."

Yet another millstone citizens must carry is the 98% re-election rate of Congressional members that perpetrate the inefficiencies and corruption in governance. For example, it is still a fact that nearly 75% of all government spending is officially described as "uncontrollable" or "mandatory," a falsehood told by aforementioned parties with vested interests. Know that cost-of-living allowances (COLAs) increases spending automatically so as to avoid scrutiny in budget processes where removals are termed "cuts."

One unknown abuse of power the public does not understand is the "Independent Counsel," technically named by a three-judge panel upon request of the Attorney General, which is free to spend taxes and paid labor without accountability. It was established as a means for the Legislative Branch to "examine" the Executive Branch, an invitation to abuse of power.

As President Madison warned, such unchecked power violates the Constitution and "preservation of liberty requires that the three great departments of power should be separate and distinct." Elected politicians do not do their jobs to rectify this ever-growing slate of problems, and that is largely because Washington, D.C. is "an island surrounded on all sides by reality," as described by President Reagan.

Furthermore, Congress must end its practice of lumping all appropriations together in a single bill, a technique used to force "objectionable" items into tax-funded law. The practice does require Constitutional change to remove this corruption. The line-item veto to remedy this political habit could excise much pork-barrel spending as would requiring an annual balanced budget.

One matter needing Constitutional change is term limits on all elected members of the legislative branch. Another needed change in each government branch is a regular review and retirement of executive functions not needed for proper operations. Yet another item, only known tangentially to the public today, is the need to immediately expose and remove all instances of high-level appointees in any of the three branches leaking any information (as is done with impunity by employees for political gains and internal power struggles). All matters mentioned here are practices by federal personnel and agencies, and they are strong contributors to the dissipation of public confidence in government.

As is my usual practice, I recommend that readers contact their elected representatives and urge action to correct the "whatever" that is at the focus of these issues. It has been my growing worry that most of these matters go unattended. This is what I call "the ultimate American problem" because a growing portion of the population is uninformed, ill-informed or stupid. Time is growing short for action. America is in crisis.


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Aluminum Heat Treatment Revisited: Common Concerns and How to Resolve Them

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When heat treating aluminum and aluminum alloys, it is important to understand the challenges we face and why absolute control of process and equipment variability is so very critical. To aid the heat treater in this regard, The Doctor has gathered together in one place the most commonly reported process problems along with some recommendations on how to resolve them. Let's learn more.

Heat-Treat-Related Issues

The most commonly reported problems with heat treatment of aluminum include concerns over:

- Improper racking of parts – This results in distortion due in large part to the inability of the quenchant to extract the heat at a sufficient rate to achieve the desired mechanical properties. Racking may also create thermally induced distortion (since the creep strength of aluminum is poor). Proper racking (Fig. 1) avoids these issues.
- Excessive heating/ramp rates – These contribute to thermal distortion and should be avoided. Proper racking of parts helps uniform heating.
- Higher-than-anticipated residual-stress levels – Heat treatment not only affects mechanical properties but also directly influences residual-stress levels. Some of the various causes are differential cooling during quenching between surfaces and interior regions (including post-solidification cooling of castings), ramp rates and changes in temperature at intermediate steps. Residual stress is a function of (large) differential cooling rates, section thickness, abrupt changes in section size and material strength. It is important to understand that stresses induced by quenching are many times more pronounced than stresses from other types of processes (including casting).
- Variation in time/temperature/quench parameters – These ultimately result in changes to mechanical and/or physical properties, both part-to-part and load-to-load. These include slow part transfer times, improper (slow) quench, overheating, underheating or changes in time-temperature parameters during precipitation hardening. For example, larger particles or precipitates result from longer times and higher temperatures.
- Overheating – The concern is incipient or eutectic melting (Fig 2, online only). For example, solution heat treatment involves temperatures close to the melting point of many aluminum alloys (especially the 2xxx series, often only a few hundred degrees below their melting point). Proper temperature is needed to promote dissolution in the solid state of the alloying elements present.
- Underheating – This results in loss of mechanical properties due to inadequate supersaturation. When the aging temperature is low and/or the aging time is too short, solute atom gathering zones (GP zones) are not easily formed, which leads to low strength after aging.
- Inadequate quenching resulting in distortion – The problem/challenge is the movement of part(s) into the quench, especially when manual quenching is critical. Parts must enter smoothly. (The heat-treat shop term is that you want to avoid "slapping" the quench with the

Fig. 1. Proper part racking

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part.) Uniform heat transfer across the part avoids differential cooling and differential thermal strain. Horizontal changes in heat transfer are often more insidious than vertical ones. Keeping the quenchant at the proper temperature, controlling its rate of rise, ensuring uniform flow and optimizing the process for the chosen quenchant (e.g., air, water, polymer) are critical. For example, the cooling rate of polymers can be varied to suit a specific application by changing concentration, temperature and the degree of agitation, which affects both uniformity of heat transfer and quench rate during the nucleate boiling stage. Maintenance of the quenchant is also important. Parts of complex shapes such as forgings, castings, impact extrusions and components produced from sheet metal may be quenched at slower quenching rates to improve distortion characteristics.

- Surface blistering/high-temperature oxidation – These conditions are best described in The Heat Treat Doctor column "High Temperature Oxidation – A Case Study," *Industrial Heating*, February 2016.
- Overaging – This may result in loss of mechanical properties. When the aging temperature is high and/or the aging time is long, the critical nucleus size of the phase precipitated from the supersaturated solid solution can be increased, resulting in low strength properties after aging.
- Underaging – This may also result in loss of mechanical properties.
  - Improper natural aging – Times may vary from around five days for the 2xxx series alloys to around 30 days for other alloys. The 6xxx and 7xxx series alloys are considerably less stable at room temperature and continue to exhibit changes in mechanical properties for many years. With some alloys, natural aging may be suppressed or delayed for several days by refrigeration at -18˚C (-1˚F) or lower. It is common practice to complete forming, straightening and coining before aging changes the material properties appreciably. For example, conventional practice allows for refrigeration of 2014-T4 rivets to maintain good driving characteristics.
  - Improper artificial aging – Artificial aging (aka precipitation heat treatment) is a lengthy, low-temperature process. Temperature control is critical along with maintaining a minimum temperature uniformity of ±6˚C (±10˚F). The targeted uniformity should be ±4˚C (±7˚F).
- Inadequate time at temperature – The consequence is failure to achieve mechanical properties. Too short a time will result in inadequate supersaturation; too long a time often manifests itself in part distortion.
- Inadequate temperature uniformity – This may result in an inability to achieve or may alter mechanical properties. The typical process temperature uniformity requirement is ±6˚C (±10˚F), with ±3˚C (±5˚F) preferred for most aerospace applications.
- Improper cold working after solution treating – This often results from a lack of understanding of the response of the alloy in question. For example, cold working of 2xxx series alloys in the as-quenched condition greatly increases its response to later precipitation treatment.
- Inadequate cooling rate if annealing solution-heat-treated product – A maximum cooling rate of 20˚C (40˚F) per hour must be maintained until the temperature is reduced to 290˚C (555˚F). The cooling rate is unimportant below this temperature.

Casting-Related Issues

It should be mentioned in passing that there are a number of ingot defects in the mill state that can influence subsequent heat treatment and mechanical properties. Some of these include:

- Porosity/midline porosity – due to lack of mass feeding, hydrogen segregation or surface oxide layers (often due to air pockets)
- Inclusions – casting impurities (due to grain refiners or air pockets) in the form of carbides, borides and oxides to name a few
- Macro or microsegregation – inhomogeneous solute composition and hard intermetallic and second-phase particles. Proper homogenization helps negate this concern.
- Deformation/shrinkage – due to stress/strain induced by cooling conditions
- Hot tears – due primarily to feeding issues
- Issues related to rolling (sheet or plate) or stretching (extrusion, bar and plate) to produce higher mechanical properties. If the higher properties are required, however, reheat treatment should be avoided.

Other related issues can be found in the online version.

Summary

The solution to most aluminum heat-treatment-related problems is to understand what can go wrong; establish good practices and procedures; be consistent (and repeatable) in the execution of these procedures; monitor the process in as close to real-time as possible; and maintain furnace records and time-temperature charts to confirm that the intended practices were indeed performed.

Finally, be sure that the testing methods used to confirm that the parts are good are robust and adequate to ensure proper performance in the field. Heat treaters have heard this all before, but nowhere is it more critical than in the heat treatment of aluminum and aluminum alloys.

References available online


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BOS Services Company

Family-Owned and Operated Heat Treater

BOS Services Company is proud of its heritage. Founded in 1968 by Henry J. Srsen, the Willoughby, Ohio-based company is now in its third generation of family ownership. To boot, BOS Services is celebrating its 50th anniversary in 2018.

Henry, who worked at commercial heat treater Euclid Heat Treating, decided to start his own company with just one car-bottom furnace and a grit blast cabinet to clean up the metal after the heat-treating process. BOS Services was the end result of Henry's hard work and tenacity and the fulfillment of a lifetime dream. Henry's wife, Gloria, took over the company following his death.

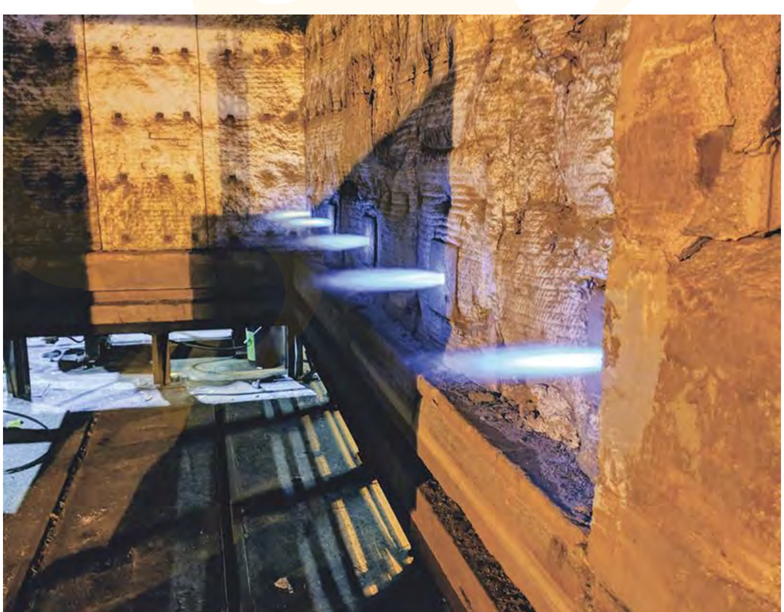
Now, five decades later, BOS Services has three car-bottom furnaces and daily operations are handled by Henry's daughter, Kim, and grandson, Brian Zayicek. The furnaces range in size from 50 feet x 15 feet x 15 feet to 27 feet x 10 feet x 7 feet to 12 feet x 5 feet x 5 feet. BOS Services has recently upgraded the furnaces by installing new controllers on all three. In addition, thermocouples are constantly checked to remain within industry standards.

This longtime MTI member also boasts two 12-foot-diameter table blasters, one conveyor blasting machine and one 30- x 18- x 17-foot blasting room. The blasting room can accommodate parts up to 50 feet long and loads up to 50,000 pounds. All of this equipment is housed in a 20,000-square-foot facility 15 miles east of Cleveland.

BOS Services uses this equipment to heat treat parts – particularly steel weldments – that go on to be used in large construction and mining equipment. They also temper steel bar stock and steel plate. The company's blast cabinets are used for cleaning up the scale that forms on the steel during heat treatment, leaving a surface ready for paint.

Other than construction and mining, BOS Services proudly serves the manufacturing, medical and food industries, and it processes both large and small jobs. The company strongly believes in one-on-one conversation with the customer to ensure that all heat-treating and metal-cleaning requirements are met. More than anything, BOS Services prides itself on quality service – the hallmark of a family-operated company.

Visit www.bosheattreating.com for more information on BOS Services Company.



MTI Events

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FNA 2018

Oct. 8-10: FNA 2018;
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Furnaces North America 2018 (FNA 2018), presented by the Metal Treating Institute (MTI) in partnership with *Industrial Heating*, is the heat-treating industry's marquee event this year. FNA 2018 brings attendees from over 35 states and 17 countries together for learning/training via technical sessions, business opportunities through the trade show and networking events.

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Blasdel Enterprises has a not-so-typical origin story.

The Greensburg, Ind.-based company was actually established as an expansion of WB Panel Co. in 1982. Bill and Jackie Blasdel acquired the assets of Industrial Ovens Co. and Ceramic Oven Co. to form Blasdel Enterprises. Just four years later, the company built a 30,000-square-foot facility that allowed for further expansion.

Today, Blasdel designs and manufactures industrial ovens and UL 508-rated control panels. The company's industrial oven line includes electric and gas infrared ovens, high-volume/high-velocity air ovens, convection ovens and thermoforming ovens. Blasdel added a gas catalytic oven line in 2014. This new IHEA member also supplies auxiliary equipment such as conveyors and pick-and-place loaders.

With 10 employees, Blasdel builds its equipment to customer specifications and offers free product testing with customer confirmation prior to shipment. The company manufactures all of its oven systems in-house, where it is well-equipped with machine tools, fabrication equipment and AutoCAD. As a result, it can control quality, delivery, costs and design specifications to provide the best value for customers. Blasdel's range of ovens is utilized in a vast array of industries, including:

- Aerospace
- Appliance
- Automotive
- Chemical
- Construction
- Electronics
- Machinery
- Medical
- Mining
- Solar
- Wind energy


Thermoforming oven system with double-sided parts loader

Blasdel evaluates heating, curing and drying processes in its testing laboratory, along with various control features and material-handling options appropriate for clients' industrial heating and processing needs. To meet short and large production run requirements, the company builds batch systems as well as indexing and continuous conveyor systems. The flexibility of any industrial oven can be enhanced through the integration of independent control zones, special material-handling systems and automated loading systems.

The bulk of Blasdel's business is in the manufacture of industrial infrared ovens. The equipment is built to withstand many years of operation with dependable performance in less-than-perfect operating conditions. Medium-wave infrared, specifically, is a signature technology for Blasdel. These ovens are being used in a variety of applications and industries and on substrates including aluminum, carbon fiber, composites and steel.

After 35 years of business, Blasdel Enterprises is still focused on customer service and satisfaction. A UL-508A-rated control panel shop for both the United States and Canada, the company has the capacity to meet the needs of any size corporation while providing affordable, energy-efficient, custom-designed equipment.

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Equipment & Business News

EQUIPMENT NEWS

Heat-Treatment Line

Austria-based **voestalpine Tubulars GmbH & Co.** successfully commissioned a new heat-treatment line supplied by **SMS group**. Designed for seamless tubes with outside diameters between 60.3 and 273 mm (2.4 and 10.7 inches), it can process steel grades with alloying contents of up to approximately 20%. The line consists of a walking-beam-type austenitizing furnace, an SMS quenching head,

a cooling table for normalizing, a tempering furnace, a cooling bed and two sawing stations for sample cutting. This equipment allows voestalpine Tubulars to perform heat treatments such as quenching, tempering and normalizing.
www.sms-group.com

Walking-Beam Furnace

ANDRITZ received an order from Swiss Steel AG for the supply and installation of a new walking-beam furnace with an output of 150 tons/hour for heating continuous-cast billets at the company's Emmenbrücke plant in Switzerland. Start-up is scheduled for the fourth quarter of 2019. The heating technology was designed such that scaling and surface decarburization are as low as possible; heat consumption is kept to a minimum in spite of the need for high-temperature uniformity; and the NOx and CO emissions are reduced to the maximum possible extent. www.andritz.com

Galvanizing Furnace

Fives received an order from China's Shougang Jingtang United Iron & Steel to design and supply a new galvanizing furnace and inductors dedicated to the production of ultrahigh-strength steels. The Stein Digiflex furnace will be equipped with a FlashCooling system operating at 75% of hydrogen in order to reach optimal cooling performance. In addition, the system offers operational flexibility in terms of cooling rate and temperature cycle control. Fives has also engineered a selective oxidation system to accurately control the oxidation process. www.fivesgroup.com

Analysis System, EAF Software

Tenova received an order from **TimkenSteel** for its proprietary off-gas-based technology package, which includes a NextGen off-gas analysis system, iEAF process-control software and Water Detection technology. Tenova's equipment will be installed as a fully integrated technology solution on TimkenSteel's top charge EAF at its Faircrest Plant in Canton, Ohio. When fully implemented, the combined technologies will bring a number of operational, safety and environmental benefits. www.tenova.com

Heat-Treat Systems

In 2017, **AFC-Holcroft** received a large number of orders for complete UBQA (universal batch quench austemper) lines from companies serving a variety of industries. In addition, sales were strong for AFC-Holcroft's flagship UBQ (universal batch quench) systems, EZ endothermic gas generators, rotary-hearth furnaces, pusher furnaces and mesh-belt equipment. These orders came from the U.S., Canada and Mexico as well as Australia, Europe and Asia. www.afc-holcroft.com

Furnace System

PyroGenesis Canada Inc., a company that designs and manufactures plasma waste-to-energy systems, received an order from a North American auto-parts manufacturer for a DROSRITE furnace system. The DROSRITE system is a salt-free, cost-effective, sustainable process for maximizing metal recovery from dross, a waste generated in the metallurgical industry. PyroGenesis' patented process avoids costly loss of metal while reducing a smelter's carbon footprint and energy consumption. Delivery of the system is scheduled for the second quarter of 2018. www.pyrogenesis.com

Metal 3D-Printing Systems

Sciaky Inc. sold four electron-beam additive-manufacturing (EBAM) systems. The systems will be utilized to 3D print titanium structures for aerospace applications and to produce large parts for ground-based military vehicles and warships. All four systems will be delivered around mid-2018. www.sciaky.com

BUSINESS NEWS

Solar Atmospheres Adds Tensile Testing Services

Solar Atmospheres of Western PA added tensile testing to its range of mechanical testing services. The company recently took delivery of a new Tinius Olsen 300SL Universal testing machine and installed it in a temperature-controlled environment. In addition, Solar Atmospheres of Western PA purchased a new Haas Model TL-1 CNC lathe to custom-machine test specimens. Both units are located in a new 10,000-square-foot facility adjacent to the company's 75,000-square-foot vacuum heat-treating production facility in Hermitage, Pa. Solar Atmospheres of Western PA traditionally outsourced all tensile testing by utilizing locally accredited independent laboratories, but a delay of 24 to 48 hours before the lab even received the specimens was normal. To receive tensile results faster and more efficiently, the company decided to bring tensile testing in-house.

Sintavia Breaks Ground on Advanced Manufacturing Facility

Sintavia LLC broke ground on a new 55,000-square-foot advanced manufacturing facility in Hollywood, Fla., that is expected to open later this year. According to Sintavia, the $15 million plant is the first of its kind to employ lean manufacturing principles for large-scale metal additive manufacturing. The facility is expected to result in 110 new jobs for skilled technicians and support personnel. It will house over $25 million of advanced manufacturing equipment, including metal printers, hot isostatic presses, vacuum furnaces, a metallurgical and mechanical lab, post-processing equipment and a CT scanner.

Perryman Increases Titanium Melting Capacity

Perryman Company will more than double its current titanium melting capacity through the addition of two new furnaces, one electron beam (EB) and one vacuum arc remelt (VAR). They will both be installed at Perryman's existing melting facilities on its California, Pa., campus. Installation will begin in late 2018, and the furnaces are expected to be fully operational by mid-2019. Once complete, the company's total melt capacity will exceed 26 million pounds.

Liberty House Acquires South Carolina Steel Plant

Liberty House completed the purchase of Georgetown steelworks in South Carolina from ArcelorMittal. The 600,000-squre-foot plant, which serves the automotive and construction markets, includes a 540,000-metric-ton/year electric-arc furnace and a 680,000-metric-ton/year rod mill. Liberty House plans to restart melting and rolling operations in spring 2018. The company will initially rehire 125 former employees at Georgetown and eventually build the workforce to 250.

Höganäs Acquires Division of H.C. Starck

Höganäs AB signed an agreement to acquire H.C. Starck Group's Surface Technology & Ceramic Powders (STC) division. STC manufactures high-alloyed and gas-atomized metal powders for a broad range of technologies, including additive manufacturing, hot isostatic pressing and metal injection molding. The company operates as a legally separated stand-alone division within the H.C. Starck Group and has two production facilities in Germany. According to Höganäs, the acquisition will enable it to access new customer segments within the additive-manufacturing and aerospace markets and adds a complementary geographic fit with STC's strong presence in Europe.

Tenaris Opens Seamless Pipe Mill in Texas

Tenaris unveiled its $1.8 billion state-of-the-art seamless pipe mill in Bay City, Texas. The 1.2 million square-foot mill, which has the capacity to produce 600,000 tons of OCTG annually, incorporates a high level of automation and cutting-edge technologies into its production processes. The project, which was first announced in 2013, has generated more than 600 jobs and more than 1,500 during the construction phase.

GE Additive Opens AM Center in Munich

GE Additive opened its first international Customer Experience Center in Munich. The new facility, co-located with GE's European Technology Center, allows customers to experience every aspect of the additive-manufacturing (AM) process from design to prototyping to operations. Customers benefit from hands-on training and instruction at the facility, covering additive design, machine operations and support. The Customer Experience Center, a $15 million investment, will include 10 AM machines from Germany's Concept Laser and Sweden's Arcam EBM.

Commercial Metals Company to Acquire Rebar Steel Mills from Gerdau

Commercial Metals Company (CMC) entered into a definitive agreement to acquire certain U.S. rebar steel mill and fabrication assets from Gerdau S.A. for $600 million. The acquisition includes 33 rebar fabrication facilities in the U.S., as well as steel mills located in Knoxville, Tenn.; Jacksonville, Fla.; Sayreville, N.J.; and Rancho Cucamonga, Calif. The mills have a combined annual mill rolling capacity of 2.5 million tons. The acquisition will increase CMC's annual rebar and fabrication capacity. The company will have approximately 7.2 million tons of global melt capacity at the close of the transaction, which is expected by the end of 2018. CMC said it plans to invest in the facilities to create efficiencies utilizing its expertise in the latest innovations for steel manufacturing and fabrication.

Mazda, Toyota Choose Alabama for Manufacturing Plant

Mazda and Toyota selected Huntsville, Ala., as the site of their new joint-venture manufacturing plant. The new facility will have the capacity to build 300,000 vehicles annually, with production split evenly between Mazda's crossover model that will be newly introduced to the North American market and the Toyota Corolla. The $1.6 billion investment is expected to create up to 4,000 new jobs.

Equipment & Business News

INDUSTRY EVENTS

March 5-7
MIM 2018; Irvine, Calif. www.mim2018.org

March 11-15
TMS 2018 Annual Meeting & Exhibition; Phoenix, Ariz.
www.tms.org/tms2018

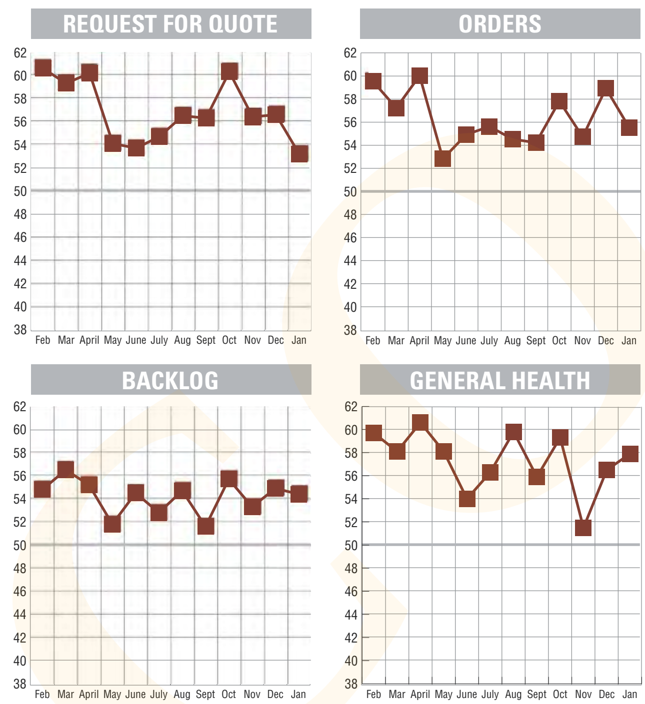
April 16-20
Wire & Tube 2018; Düsseldorf, Germany
www.wire-tradefair.com / www.tube-tradefair.com

April 23-25
IHEA Annual Meeting/MTI Spring Meeting; Scottsdale, Ariz.
www.ihea.org / www.heattreat.net

April 23-26
Rapid 2018; Fort Worth, Texas www.rapid3Devent.com

May 1-3
Ceramics Expo; Cleveland, Ohio www.ceramicsexpousa.com

ECOMOMIC INDICATORS



Values above 50 indicate growth or increase. Values below 50 indicate contraction or decrease.
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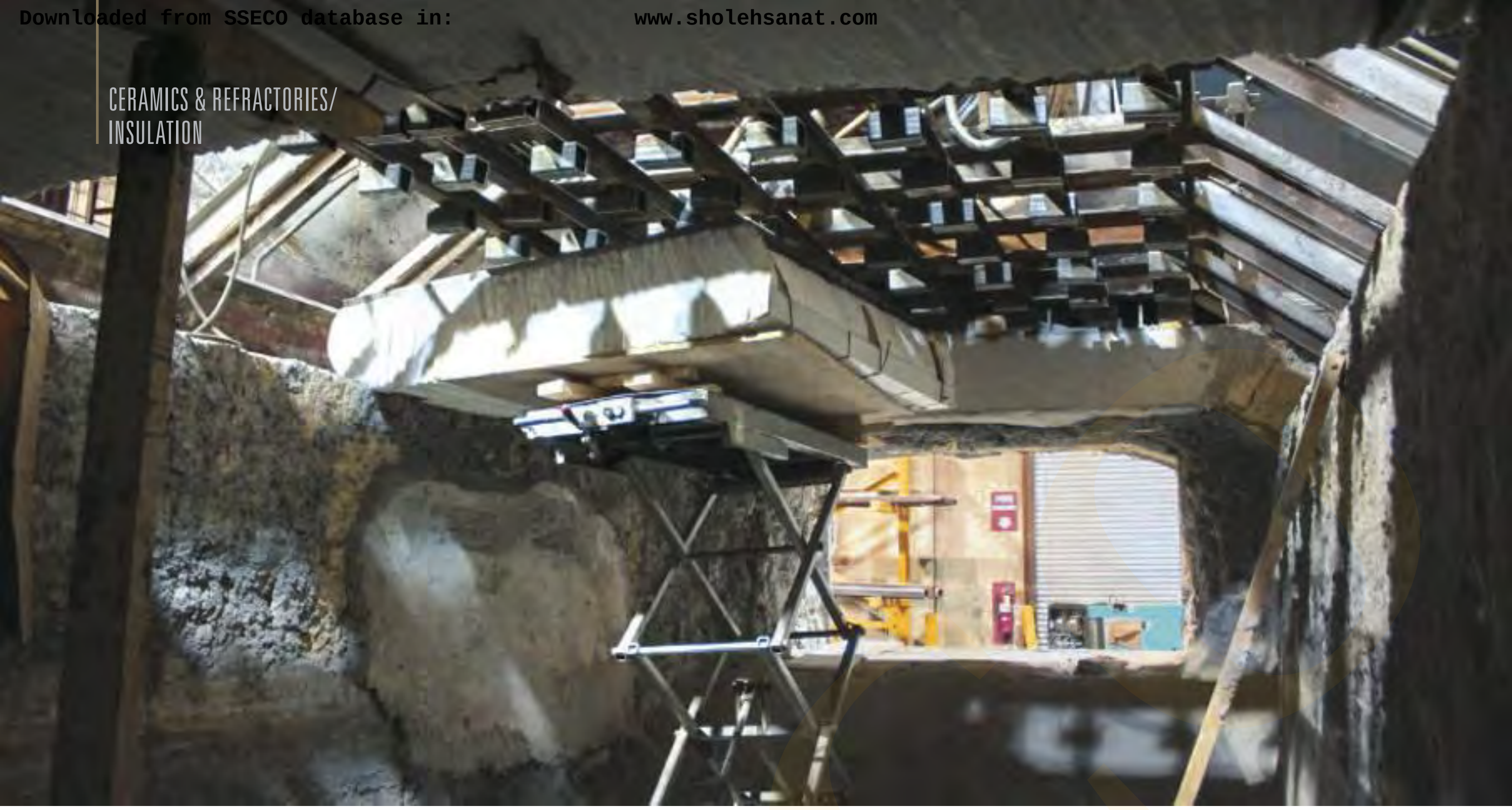


Refractory Improves Productivity by Increasing Aluminum Casting Furnace Capacity

Jerry Fireman – Structured Information; Needham Heights, Mass.

Indalco Alloys is a division of Lincoln Electric Company that produces aluminum weld wire and redraw rod. The company operates a melting furnace and two holding furnaces that feed a continuous-casting machine through a trough system.

In the past, the company experienced problems with spinel growth that reduced the working volume of its furnaces and made them difficult to clean when switching alloys. Other problems in the furnaces included refractory wear on hearths and cracking in walls.

Les Thoms, rod mill manager for Indalco Alloys, tried Stellar's Thermbond refractory to repair a few areas of the melting-furnace walls. Thoms noted that the spinel growth and difficulty in cleaning disappeared in the area where the new refractory was used. Over a few years, he replaced the walls and hearths of all three furnaces with Thermbond.

Thermbond provided superior resistance to penetration, which made it possible to reduce the thickness of the walls and hearths. This increased the capacity of the melting furnace by 18% and the holding furnaces by 25%. The new roof refractory material also provided superior insulating capabilities, which reduced the natural gas consumption by greater than 15%, saving almost $7,500 in fuel per month, based on an average 2015 unit cost of $0.2509/m^3.

Casting its own aluminum rod enables Lincoln Electric to hold extremely tight tolerances in the chemical composition of its aluminum metal-inert-gas (MIG) wire and tungsten-inert-gas (TIG) welding products. The company predominately makes 4043, 5356 and 5183 alloy wire.

Problems with Spinel Growth

When Thoms first arrived at Indalco in 1999, the foundry had problems with spinel growth on its furnace refractories. Spinel, which is a crystalline form of magnesium-aluminum oxide, reduced the capacity of the furnaces and made them difficult to clean efficiently.

The company changes alloys as frequently as once per day, and the furnaces must be scraped clean each time. Washing out the furnace between alloys typically takes 60-90 minutes per washout.

"When we were having spinel problems, we frequently had to perform a second and sometimes even a third washout to fully remove the previous alloy," Thoms said. "This was very time-consuming. Another issue with the previous refractory

Fig. 1. Installation of ceramic tiles in hearth

Fig. 2. Roof panel

was that repairs required ripping out and replacing a section of old material. Then we had to dry out the repair, which took about a week."

Stellar provided Indalco with samples of its Thermbond refractory, and it was tested in spots on the furnace that needed repair. The patched areas did not show any signs of spinel growth. The refractory was used for additional repairs over the next year and decided that the areas that had been patched performed so much better that it could justify replacing the walls of all three furnaces with the new refractory.

Jim Scott, Ontario sales director for Stellar Materials, suggested that the greater ability of the new refractory to resist penetration combined with high insulating properties of the microporous insulation would make it possible to reduce the thickness of the refractory walls from 11.5 to 10 inches. This increased the capacity of the two holding furnaces by about 10% from 32,000 to 35,000 pounds.

Thermbond is a family of engineered refractories that consists of a two-part system, including dry formulation and liquid activator. These materials are supplied as pre-measured components that are added together to form a unique chemically bonded refractory. One advantage is that it is considerably more resistant to cracking than conventional refractories.

Another advantage of this material in aluminum foundry applications is that it is completely and naturally non-wetting to aluminum without the use of additives. This means that oxides don't penetrate the lining and can easily be removed during nightly cleaning operations without damaging the underlying refractory, ultimately resulting in a longer lining life. Other refractories typically use additives to achieve non-wetting characteristics, which eventually oxidize out of the products causing them to lose their effectiveness.

Spinel no Longer an Issue

The new refractories have been in place on the walls for about 15 years. Spinel is no longer an issue. The elimination of spinel growth saves considerable time in cleaning the furnace when changing alloys. In some cases, Indalco can now completely clean the furnace with a single washout. They have also seen reductions in maintenance costs with the new refractories. These refractories have required only minor repairs during the biannual shutdowns in some years and in other years no repairs at all have been needed.

"With our new refractory we don't have to tear anything out, we simply add a patch," Thoms said. "Then we do a small dry-out based on the size of the patch. The typical time required for the dry-out is only about 30 hours. So we get the furnace back into production five or six days sooner than in the past."

These improvements spurred Indalco to look for other areas where refractories could be upgraded. A number of issues were previously experienced with the furnace hearths. When changing alloys, it is necessary to drag a rake across the hearth. When t-bars are dropped into the melting furnace or scrap into the holding furnaces, they often hit the hearth, which in the past frequently created dents or chips. Over time, the hearths developed crevices and potholes, which increased the time required for cleaning. These defects in the surface also made it necessary to use a relatively thick refractory in order to avoid damage to the lining.

Installing Stellar's engineered precast tiles on the hearth made it possible to reduce the hearth thickness from 12 to 8 inches. These cast and fired shapes were ordered to fit the specific dimensions of the three hearths. The tiles are formulated to yield high abrasive wear resistance, excellent mechanical strength, resistance to temperatures up to 2700°F (1482°C) and thermal-shock conditions. Indalco installed the first hearth tiles in a furnace in 2004. Four years later, the hearth was in such good condition that the company put the tiles into its other two furnaces. To date, these refractories are all still in use and have required only minor repairs.

Furnace Capacity Increased 25%

Changing the walls and the hearths of the three furnaces has provided a substantial increase in production. In the past, each cast produced 32,000 pounds, while today each cast generates 40,000 pounds of product without requiring capital investment or additional labor costs.

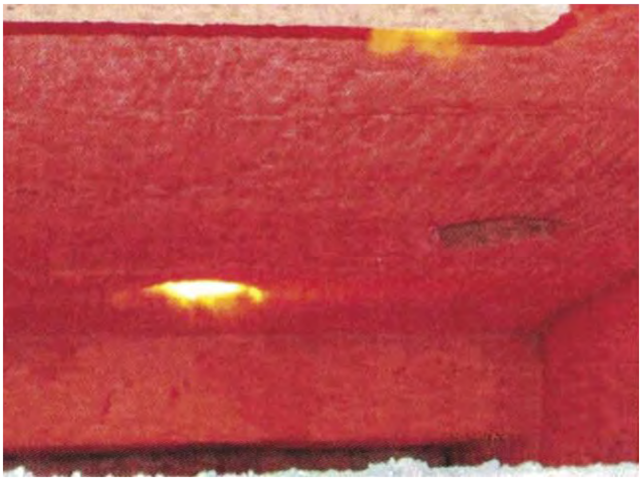


Fig. 3. Roof panels in service

Reduced Energy Costs

Indalco was also able to substantially reduce fuel costs by changing the dense roof lining of all three furnaces to Stellar's Maftec® insulating fiber. Designed for continuous-use applications up to 1600°C, it is a polycrystalline alumina fiber that does not change molecularly through the temperature range until it melts at 1850°C.

Comprised of a pure mullite chemistry, Maftec demonstrates exceptional chemical resiliency to the fluxes and other chemistries present within aluminum furnaces. An added benefit is that the fiber diameters range between 5 and 7 microns, effectively preventing fiber from being respirated.

"After switching to the Maftec roofs we saw substantial improvements in fuel efficiency," Thoms said. Historically, 0.1532 cubic meters of gas was required per pound of rod produced by the foundry. After installing the new roofs, the amount of gas required per pound was reduced by 20% to 0.1224 cubic meter."

"Switching to new refractories has helped us substantially improve the operation of our aluminum casting operations," Thoms concluded. "The higher performance of the new refractories helped us increase the capacity of our furnaces by 33%. We have saved considerable additional time during washout for alloy change and by greatly shortening the dry-out time required after repairs. This means we have more time for melting and casting. Finally, we have achieved substantial cost reductions through the superior insulating properties of the new furnace roofs. All in all, by substantially improving our refractories we have made a considerable improvement in our competitive position."

For more information: Contact Stellar Materials, LLC, 7777 Glades Road, Suite 310, Boca Raton, FL 33434; tel: 561-330-9300; web: www.thermbond.com

Fig. 6. Aluminum heat-treat system

Manufacturers Adapting for Aluminum Heat Treatment's Evolving Demand

Graeme Kirkness and Tim Donofrio – CAN-ENG Furnaces International Ltd.; Niagara Falls, Ontario, CANADA

Back-to-back years of record automobile sales are infrequently realized, celebrated and almost mythical in today's modern, highly competitive world. One outstanding year is hoped for, planned for and often expected. Two consecutively across an entire industry is nothing short of spectacular and a sign that, as a group, something is being done right and well.

As is often the case, however, record breaking is quickly followed by downturn, forcing adaptation and innovation based on the consumer's shifting wants and demands. Once again, the automotive industry finds itself preparing for this unenviable position.

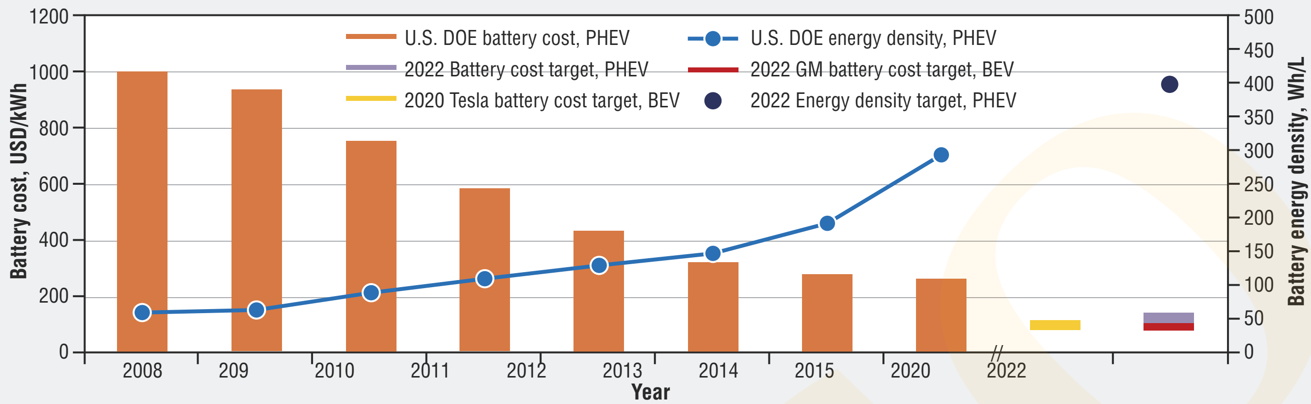
One is hard-pressed to find an industry, that isn't Internet-based, being forced to undergo monumental shifts with the frequency of the automotive industry, particularly due to reasons beyond their control. Increasing consumer awareness has already driven one shift within the automotive industry – lightweighting – and is starting to drive another – electrification.

Since the introduction of Audi's all-aluminum body in the 1994 A8 (Fig. 1), automakers have steadily replaced ferrous castings and weldments with equivalent nonferrous components. Originally driven by weight reduction (in pursuit of fuel economy), these nonferrous components offer improvements in compositional and mechanical properties; none more so than thin-walled structural aluminum components. Despite being around for over a decade, demand and expectations of thin-walled structures have matured to where demand exceeds capability as the automotive industry is pushed toward the greater challenges of electrification by consumer demand.

Desire for electric cars is quickly gaining consumer momentum, and automakers are rapidly shifting focus to developing affordable, efficient electric vehicles (EVs) for the mass market. This is where aluminum structural components will further serve the automotive industry. Lightweighting directly benefits electric vehicles in two crucial areas: weight and driving distance (battery life).

Until EV batteries can be lightened, the weight must be overcome elsewhere. Body panels, chassis and further structural components are the likely candidates for lightweighting via

Fig. 1. Audi A4 frame



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = watt-hours per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100,000 units for each manufacturer. Sources: U.S. DOE (2015 and 2016) for PHEV battery cost and energy density estimates; EV Obsession (2015); and HybridCARS (2015).

Fig. 2. Battery density

plastics, aluminum, magnesium and carbon-fiber-based components. While advances in high-pressure die-casting (HPDC) processes, production and material sciences have enabled the implementation of thin-walled castings, their ultimate success is dependent on their mechanical (and crash worthiness) properties being exactly as specified, which is dependent on capable post-casting thermal processes, or heat treatment.

Electrification: Aluminum's Double-Edged Sword

Electrification, the apparent future of the automotive industry, is the beacon of growth for aluminum components in an increasingly penetrated and crowded market. It's a beacon that simultaneously serves notice of technology beginning to look for what's next. Currently, aluminum structural-component use is sufficiently prominent within the automotive industry such that certain components (shock towers, cross members, rear rails and door pillars) are produced at such high volumes they are essentially standard in luxury vehicles.

As lightweighting integration costs decrease, we will see the expansion of use across the full range of lightweight vehicles. As the industry progresses toward electrification, these high-volume production requirements could transition to additional components. "Could" is an understatement because the eventual path of electrification component requirement is unknown.

This uncertainty does not, however, prevent preparation of this industry shift. One need only look at the change in EVs to understand inevitable steps. While environmental concerns may be the marketing appeal of EVs, greatly increased driving distance is the practical appeal of EVs and provides valuable insight into aluminum components' future in the automotive industry.

The force behind the increased driving range of EVs is increased battery densification, as demonstrated in Figure 2. However, a side effect of this increased density, and aluminum's opportunity, is the increased battery weight. Electric vehicles need to make up this weight elsewhere, be it through balancing front and rear weight or through new, electric/hybrid vehicle-specific components, such as battery/high-voltage housings. Here is where thin-walled aluminum components have the greatest potential for growth.

Moving forward, it is important to remember that nothing is certain or set in stone. Initially, aluminum-based lightweighting components are well positioned to support the transition to electrification. The International Energy Association (IEA) predicts that there will be 715 million electric vehicles in 2040, a drastic increase from the approximately 1 million vehicles in 2015. This rapid growth is where "problems" or decreased opportunities for aluminum materials, most notably engine blocks, will be realized. Hybrid and electric vehicles require either smaller or (more drastically) no engine, which is currently the main component for aluminum within "light vehicles" today.

Looking to the future, it seems likely that with shifting technology new materials will be developed, possibly requiring reduced aluminum content in favor of opportunities to integrate carbon fibers, magnesium and 3D-printed components. These opportunities and potential problems highlight an increasing need for modern, flexible aluminum heat-treating equipment.

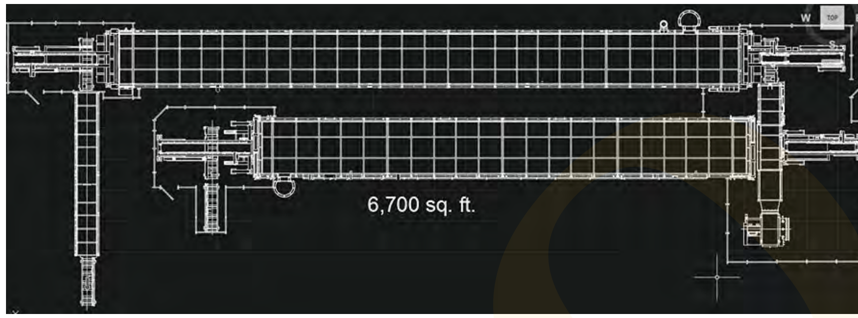


Fig. 3. Traditional aluminum heat-treat line

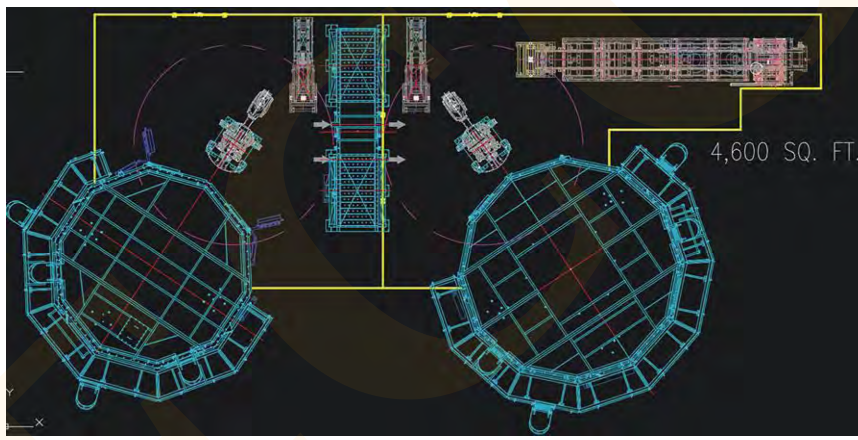


Fig. 4. Rotary heat-treat system

Modern Aluminum Structural Component Heat-Treatment Systems

The needs and expectations of new heat-treating systems have rapidly shifted over the past decade and are shifting yet again. Increasing metallurgical, process and product knowledge combined with increasingly integrated supply chains have greatly impacted how furnace engineers develop modern aluminum-component heat-treatment systems. Heat-treatment systems no longer have dedicated buildings or wide-spanning floor space. Space is limited and, more importantly, valuable. The more flexible floor space available within a single production facility, the greater the built-in future-proofing for capacity and/or process changes.

Traditional heat-treatment systems (Fig. 3) were large, linear systems occupying (and wasting) valuable floor space. Systems like those depicted in Figure 3 would frequently occupy several thousand square feet, with substantial portions of floor space unoccupied and, therefore, underutilized. Steadily encroached upon by the increasing needs of an overall production facility, modern systems must be more tightly integrated (Fig. 4), occupying 35% less space than traditional systems – all while production requirements are increasing.

During the early introduction of thin-walled aluminum structural components, developers of customized heat-treatment systems were exposed to production volumes of 150,000 pieces/year. By 2005, systems were requested with production rates of 500,000 pieces/year, and by 2017, requested production rates have doubled to 1,000,000 pieces/year. While these increased production rates demonstrate market growth and production centralization, it is the accompanying detail of these requests that demonstrates the increased demands on capacity and flexibility of modern systems.

Of the keys to the success for both compact solutions and overall system flexibility, none may be more important than tightly integrated material-handling systems. Initially, introducing robots into heat-treatment cells allowed for individual part or fixture handling. Gone are the days of manual handling thin-walled structural castings 10 times before being prepared for delivery; costly, excessive work-in-process inventories (WIP); and centralized heat-treatment systems that consume thousands of square feet of floor space and bottom-line profit.

Today, engineers are challenged to develop systems that eliminate the need for large, centralized heat-treatment systems, multiple handling scenarios and costly WIP inventories. Advanced thin-walled aluminum structural casting heat-treat systems now receive castings directly from the HPDC cells, thereby eliminating the need for added labor, dunnage and storage. Traditionally, these systems have been identified as basketless heat-treatment systems (BHTS).

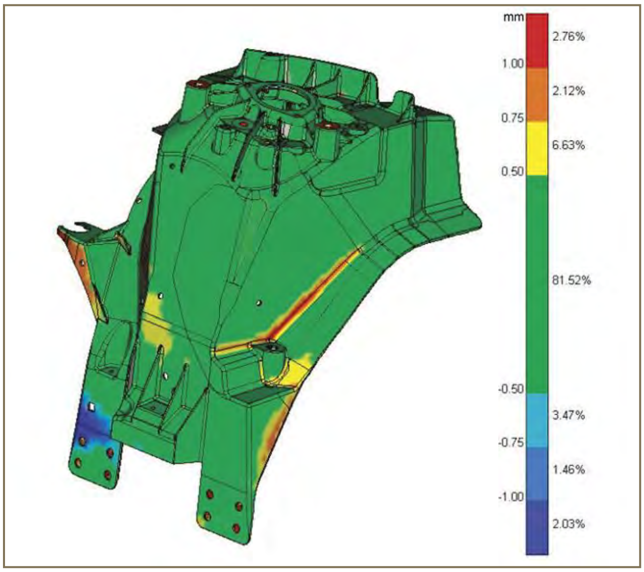


Fig. 5. Mechanical properties and dimensional accuracy is more predictable

These modern systems receive castings directly from the casting cell (in some cases recovering the remaining heat from the casting operation), while the controls systems track their valuable critical processing-parameter history throughout the entire process via unique part serialization (2Dmatrix). This tracking feature allows each part to be historically evaluated and audited for proper processing parameters such as solution temperatures, precision air quenching (PAQ™) and artificial aging temperatures.

Today's structural-component casting heat-treatment systems are designed for rapid heating and uniform soaking cycles, which greatly reduce the systems' overall size. This is accomplished through the elimination of large steel component carriers and fixtures that consume tremendous amounts of heating energy and capital and maintenance costs. In addition, engineers are utilizing state-of-the-art forced-air modeling tools and advance recirculation designs to provide efficient processing technologies.

HPDC aluminum structural castings develop their final properties through thermal processes. One of the most important parts of the process is quenching. In this process, the component is rapidly discharged from the solution furnace to a precision air quench (PAQ™). Traditional processes would receive large batches of castings for quenching, producing non-uniform cooling and ultimately unpredictable mechanical properties. Today's modern, space-efficient heat-treatment systems are harnessing the benefits of robotic handling to manage the rapid quenching transfer required while also benefiting from the PAQ of smaller, individual lots where quenching results in more predictable mechanical properties and casting dimensional accuracy (Fig. 5).

As previously stated, flexibility is the single greatest need of modern aluminum heat-treating equipment. With the addition of vision to robotic material-handling systems, a single heat-treatment cell is no longer limited to being a single T5, T6 or T7 process. Now cells can be multi-process along with multi-part.

Utilizing vision and interconnectivity with a PLC, material-handling systems can now determine a part's required heat-treatment process – all based on prior programming. Additionally, these multi-process cells still occupy smaller footprints than traditional heat-treatment cells. IH

For more information: Contact Graeme Kirkness and Tim Donofrio, Can-Eng Furnaces International, Ltd., 6800 Montrose Road, P.O. Box 628 Niagara Falls, Ontario Canada L2E 6V5; tel: 905-356-1327; fax: 905-356-1817; e-mail: jsaliba@can-eng.com; web: www.can-eng.com

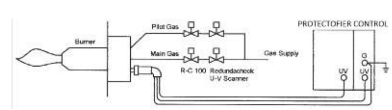


Fig. 1. Example of a torch-brazing operation

Torch Brazing by Hand

Dan Kay – Kay & Associates; Simsbury, Conn.

Brazing is one of three joining techniques in our manufacturing world that uses heat and a molten filler metal to create complex assemblies from simple starting pieces. The other two processes are welding and soldering.

When brazing, the base material being joined is not melted. Only the brazing filler metal (BFM) that is added to the joint is melted, and this molten BFM is then drawn into the joint by capillary action. Effective brazing requires heat, cleanliness of the parts being joined and, in the case of torch brazing by hand, special operator skills are needed.

Torch-Brazing Requirements

Torch brazing, or flame brazing, as some people prefer to call it (sidebar), involves the use of a non-oxidizing flame. The flame should wrap around the entire joint (if possible) in order to evenly heat the base metal in the entire joint area so that the heat in the base metal is able to melt a BFM that is touched to its surface rather than having the torch flame melt the BFM.

This process of torch brazing has proven to be useful in joining a wide range of base metals, including aluminum, copper, copper alloys and many other nonferrous metals, in addition to the many ferrous alloys on which it is commonly used. When this heating is done properly, the molten BFM can be drawn completely into and through the joint, the evidence for which should be a tiny meniscus (fillet) of BFM at both ends of the joint.

Figure 1 shows a typical example of a torch-brazing operation in which the torch flame is held at a convenient distance from the part so that the flame will wrap around the joint as much as possible and not just heat one small spot. Then, as the flame is moved slowly down the fitting, the molten BFM will also be drawn down through the fitting by capillary action because BFM likes to follow the heat and flow toward it.

A typical brazing torch might look like the one in Fig. 2 and generally consists of a metal mixer-body into which two different gases are fed. These two gases are typically oxygen (or perhaps just compressed air) and a combustible fuel gas (e.g., acetylene, propane, etc.). They enter the torch body through separate gas lines/hoses and are then blended before exiting out of the curved tip of the torch body, where that blended gas is then ignited and burned (Fig. 1). The gas flow rates are controlled by the two knobs on the mixer body.

Surfaces Must be Clean Before Brazing

Here is a rule of brazing: BFM will not flow over or bond to oil, dirt, greases or oxides. Any of those materials contaminating a surface can, and will, prevent proper brazing from happening. Do not depend on the torch heat to burn off the surface contaminants, and brazing flux will not clean off those contaminants.

Torch Not Used to Melt BFM

Too many torch brazers make the mistake of using the torch flame to directly heat and melt the BFM. This molten BFM then sits on the outside of the joint and, because the inside of the joint has not been heated sufficiently, the BFM may start to run down over the outside surfaces of the metal or merely form a cap on the outside of the joint when the torch heat is removed.

Fig. 2. A typical brazing torch with a single-hole torch tip

These so-called "cold joints" do not properly seal the joint and may leak in service. Remember that the torch should not be used to melt the BFM but to heat the joint so that the heat inside the metal will melt the BFM.

Torch-Tip Variations

A torch tip may have a single hole in it (Fig. 2) or perhaps several holes in its tip (Fig. 3). The dual-tipped torch shown in Fig. 3 uses multi-flame ("rosebud") tips that allow much more even heating of all the joint surfaces of a component since the joint can now be heated from two sides at the same time.

Figures 4 and 5 show photos of unique torch tips that can literally apply torch flames completely around the periphery of the assembly being brazed to uniformly heat the entire joint up to brazing temperature.

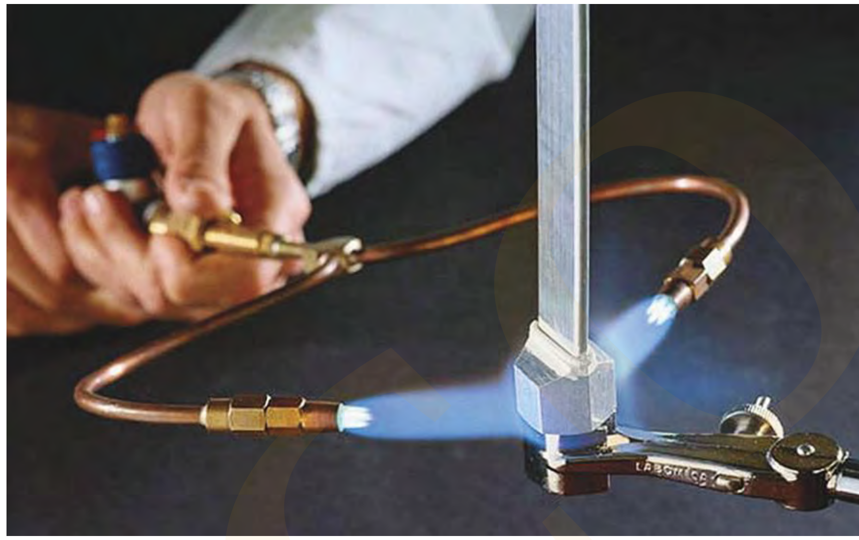


Fig. 3. Dual-tipped torch using multi-flame "rosebud" tips *(courtesy of Uniweld Products, Inc.)*

Correct Torch-Brazing Sequence

It is very important that specific steps be taken to ensure that you will have good success when brazing with a torch. These steps include the following:

1. The joint surfaces should fit together with a smooth slip-fit. It can be difficult to try to braze parts that have either a very sloppy (loose) fit or one that has such a tight press-fit that the BFM cannot get into the joint.
2. The surfaces being joined must be thoroughly cleaned prior to being assembled.
3. All surfaces should be coated with flux, which keeps clean surfaces clean and prevents those surfaces from oxidizing during heating.
4. Proper torch tips should be used for the type of gases being used.
5. The torch flame should be adjusted so that it is non-oxidizing.
6. The torch flame should be used to heat the base metals to brazing temperature rather than merely trying to melt the BFM with the flame.

Torch Brazing vs. Flame Brazing

Many people prefer to use the term "flame brazing" instead of "torch brazing" when they are describing this brazing technique. That's OK. These two terms, referring to the same process, can be used interchangeably. The term "torch brazing" places emphasis on the tool being used (a torch), whereas the other term emphasizes the means of heating (a flame). Here in the U.S., we tend to emphasize the equipment (i.e., torch braze, furnace braze, etc.).

It should be noted that in some other countries the word "torch" is often used to refer to a flashlight. So, perhaps to avoid any confusion about the use of the word "torch," they may choose to refer to this brazing process as flame brazing. In this article, I use the term torch brazing when referring to this joining technique.

Become a Torch-Brazing "Athlete"

Effective torch brazing – like professional sports – requires skill, dexterity, fearlessness, quickness in learning and the ability to effectively apply what has been learned. In sports, we see that the very skilled players are the ones out on the field or court, whereas the want-to-be players are sitting on the bench. The rest of us who may not have those skills are content to be spectators in the stands.

In a similar way, not everyone is capable of being a good, effective torch brazer. Treat torch brazing as a special skill that must be learned and should only be done by people who are very comfortable with holding and using a torch. They should be fearless (but respectful) of the hot flame only a few inches from their hands and be able to easily and quickly grasp how to manipulate the torch to effectively heat up a component assembly without overheating it, while at the same time feeding BFM into the joint with the other hand. A torch-brazing athlete should be able to judiciously and comfortably balance those tasks so that the molten BFM will be evenly drawn into the joint by capillary action and effectively fill the entire joint area being brazed.

Yes, it takes a torch-brazing athlete to do all this effectively. It should not, in my opinion, be done by someone who may have become "qualified" for the torch-brazing job strictly through seniority in their shop. Torch brazing is a unique skill, and those doing it should have become "qualified" only through actual training and thorough testing that verifies they are indeed expert and comfortable when performing that task.

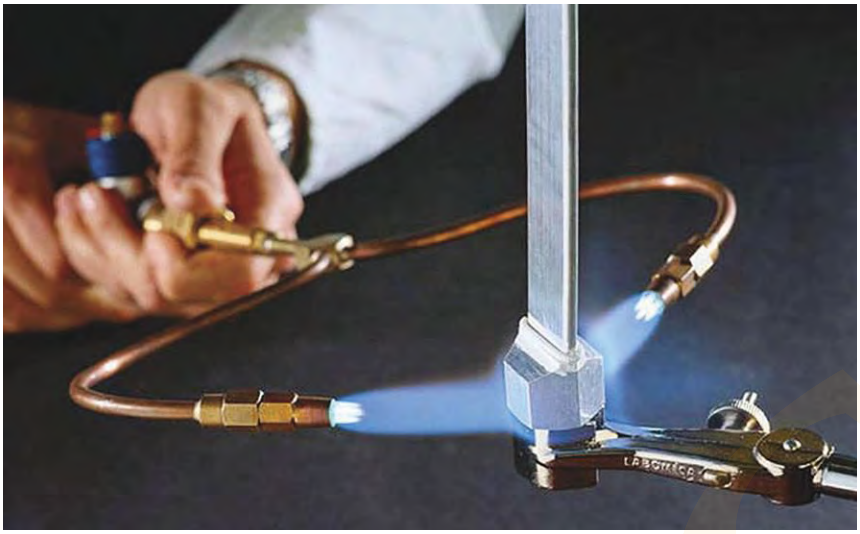


Fig. 5. Unique torch tip that can apply flames completely around the periphery of the assembly being brazed to uniformly heat the entire joint.

2. The surfaces being joined must be thoroughly cleaned prior to being assembled.
3. All surfaces should be coated with flux, which keeps clean surfaces clean and prevents those surfaces from oxidizing during heating.
4. Proper torch tips should be used for the type of gases being used.
5. The torch flame should be adjusted so that it is non-oxidizing.
6. The torch flame should be used to heat the base metals to brazing temperature rather than merely trying to melt the BFM with the flame.
7. Sufficient BFM should be fed into the joint during heating to completely fill it.
8. The flux should be removed after brazing by thoroughly rinsing the joint surface with hot water.
9. Visually inspect the joint to be sure the BFM has flowed around and through it and the joint meniscus is small and concave in shape.

Torch Training

Brazing with a hand-held torch can be very effective when done properly and when performed by someone who is well trained in the technique. Torch training is available and torch-certification courses exist to help people gain the expertise to conduct this process well. But please be aware that not everyone is suited to handling a torch or comfortable doing so. As described in the sidebar, it is very important to find the people in your shop who can be "torch-brazing athletes." Focus your training on them. You'll be glad you did.

Conclusion

Torch brazing allows effective localized heating and joining of metal components without the need for heating up the entire assembly. But when heating in localized areas, special skills are required to properly heat those areas uniformly (without distortion) so that good-looking, strong, permanent bonds are created between those metal components being joined. For people with the proper skills and with the proper training, torch brazing is a wonderfully effective joining process.

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The Impact of Thermal Oxidizer Sizing on Melt-System Capacity

Brian Wendt and Adam Halsband – Epcon Industrial Systems, LP; The Woodlands, Texas

It is important to understand rate-limiting factors when sizing a secondary aluminum-recovery system.

Driven by new regulations as well as consumer performance requirements, the demand for cast, extruded and machined aluminum parts has increased globally. Aluminum parts producers are looking to metals-recovery systems to control the costs of primary and secondary aluminum purchases and to mitigate operating costs by capturing value from byproducts.

Understanding the true rate-limiting factors when configuring and sizing a metals-recovery system is critical to realizing the full potential of the system. Additionally, managing energy within the system will have a large impact on the operating costs and uptime/maintainability of the system.

Historically, parts producers have focused on dryer and melt-furnace capacities as the rate-limiting factor when sizing the system. The practical reality is that vent-stream emissions may be the real rate-limiting factor controlling your overall recovery system's capacity. Figure 1 provides a high-level overview of the major components found in modern metals-recovery systems.

One of the first steps when evaluating a potential metals-recovery project should be to understand the expected fluids and contaminants in the feedstock. Given these input conditions, a concurrent analysis of the thermal-processing load for the drying system and the expected constituents in the vent stream can be conducted. From these calculations, an estimate of the projected emissions loading from the operation can be determined.

Based on the findings from these emissions calculations, the appropriate air-pollution control system can be sized. Thermal oxidation of these vent streams is a proven solution to mitigate the VOC emissions from these sources. In addition, many lessons have been learned on these specific applications through the years, allowing them to be better optimized.

Dealing with particulate matter on the inlet, avoiding formation of hazardous air pollutants (HAPs) at the discharge of the unit and withstanding the abrasive atmosphere within the system are all challenges that have been overcome successfully. Despite these system application improvements, however, even the most efficient drying system will produce some level of particulate-matter emissions.

Choosing a design that limits the potential for emissions will reduce the demand on the downstream particulate-matter removal system. It also will reduce any subsequent loading on the downstream thermal oxidizer. Within the thermal oxidizer itself, burner placement and orientation, the combustion chamber configuration and the design of primary and secondary heat exchangers all will contribute to a system that can operate in the face of the particulate-matter loading that one can realistically expect to see during standard operation.

In absolute terms, we are seeing relatively low natural gas costs. Nonetheless, at the scale of many captive recycling operations, recovering waste heat from the process can produce a significant annual cost savings and an overall reduction in facility emissions.

A perfect example of the cost-savings benefits of secondary heat recovery in aluminum scrap recycling can be found in an installation at a merchant metals-recycling operation in Arkansas. The existing system was an early design pretreatment system with rudimentary drying technology.

The custom-engineered system upgrade included a thermal oxidizer equipped with a quad-downflow inlet plenum, axial-mounted down-fired burner and primary and secondary heat exchangers (Fig. 2). This configuration maximized turbulence in the combustion chamber, resulting in excellent destruction efficiency. At the same time, it protected the burner from potential particulate carryover.

The energy saved from the introduction of primary and secondary heat recovery resulted in a payback for the new thermal energy system (oxidizer and dryer heat source) of less than one-and-a-half years. This payback was achieved at a still relevant fuel value of $3.85/MMBTU.

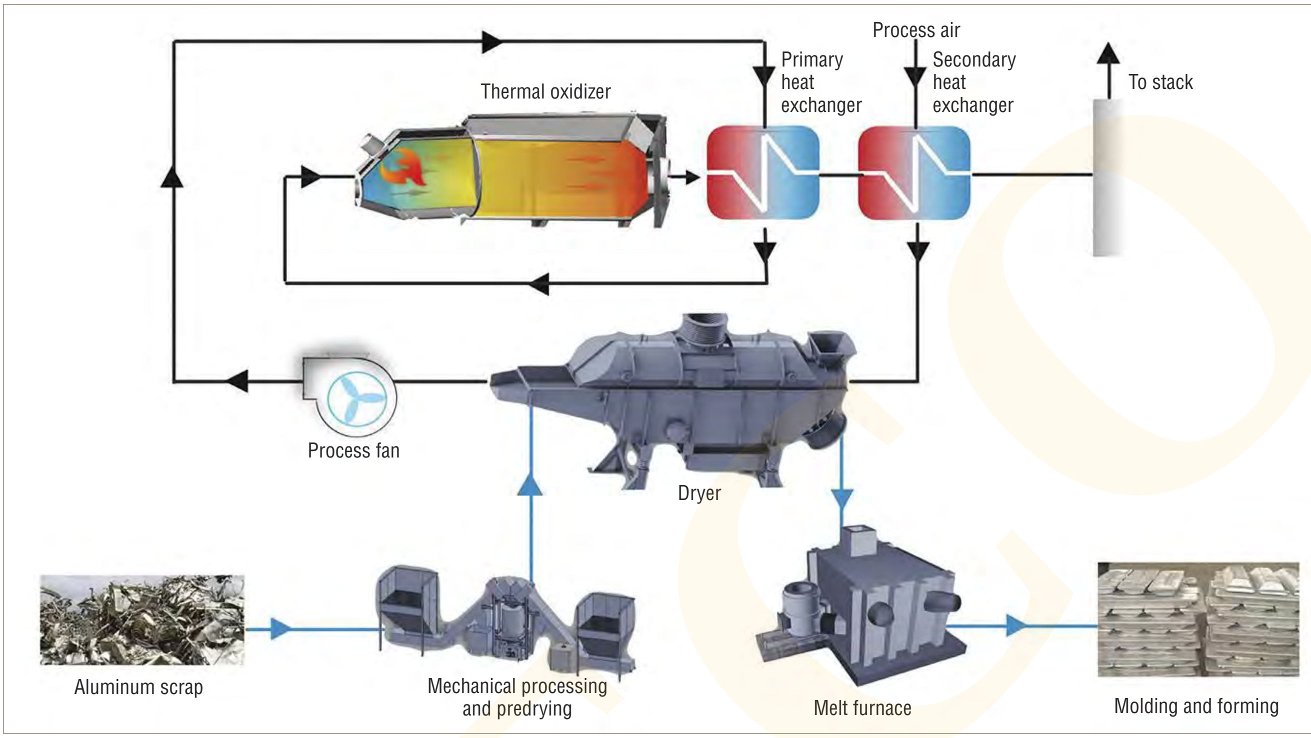

Fig. 1. This diagram provides an overview of the major components found in a metals-recovery system.

Today, we are seeing advances in aluminum-scrap pretreatment drying technology that not only result in reduced particulate carryover but also a combined increase in VOC loading, a reduction in permittable emissions levels, and an uptick in demands for even higher system uptime and serviceability.

In response to these changes, thermal-oxidizer designs have evolved along with the advances in pretreatment drying technology. Understanding and projecting loading and sizing remains a critical part of the system configuration. The latest systems being deployed incorporate multipass modular heat exchangers to maximize system energy efficiency as well as serviceability. Additionally, large-diameter stainless steel shell-and-tube heat exchangers provide a good balance of wear resistance, life expectancy, maintainability and initial procurement cost.

Figure 3 highlights the latest recuperative thermal-oxidizer design for a global, Tier 1 aluminum parts producer. This system is part of an integrated melt system being supplied by a metals-recovery systems provider. The system is sized to support pretreatment of 3 metric tons per hour of aluminum chips through a jet-drying system.

The thermal-oxidizer system includes primary heat recovery to minimize energy consumption. Also, packaging features minimize the overall system footprint while at the same time easing maintenance and service. The unit's modular, two-pass secondary shell-and-tube heat-exchanger configuration eases maintenance. Strategically placed access doors and large-diameter stainless steel tubes help maximize service life. In addition, the modular design simplifies installation and allows for a quick changeout in the future when the heat exchanger is no longer serviceable.

A key design element is the insulated stack. At 65 feet tall and with a diameter of 42 inches, the design and materials of construction were critical to meeting the customer's performance requirements and capital budget.

Fig. 2. This custom-engineered configuration, which includes a thermal oxidizer equipped with a quad-downflow inlet plenum, axial-mounted down-fired burner and primary and secondary heat exchangers, maximized turbulence in the combustion chamber. This resulted in good destruction efficiency and protected the burner from potential particulate carryover.

An insulated design allowed engineers to optimize materials selection and reduce the overall project capital cost.

Conclusion

Understanding and applying best practices in aluminum scrap-recycling systems are key to realizing the full potential of the recovery system. Recognizing that a 1% deviation in contaminant levels can translate to more than a 2% change in metals recovery highlights the value in investing in modern recovery technologies.

By focusing on properly sizing and configuring the thermal oxidizer early in the design process, operators will be able to realize the full potential of the metals-recovery system and avoid wasted melt-furnace capacity. The capacity through the system can only be as great as the emissions limits permit. Whether for a new system or a retrofit of an existing plant, focusing on addressing emissions-control rate-limiting factors will help ensure overall project success.

For more information: Contact Brian Wendt, project engineer, or Adam Halsband, manager of marketing and business development with Epcon Industrial Systems, LP, P.O. Box 7060, The Woodlands, Texas 77387; tel: 936-273-3300; web: www.epconlp.com.

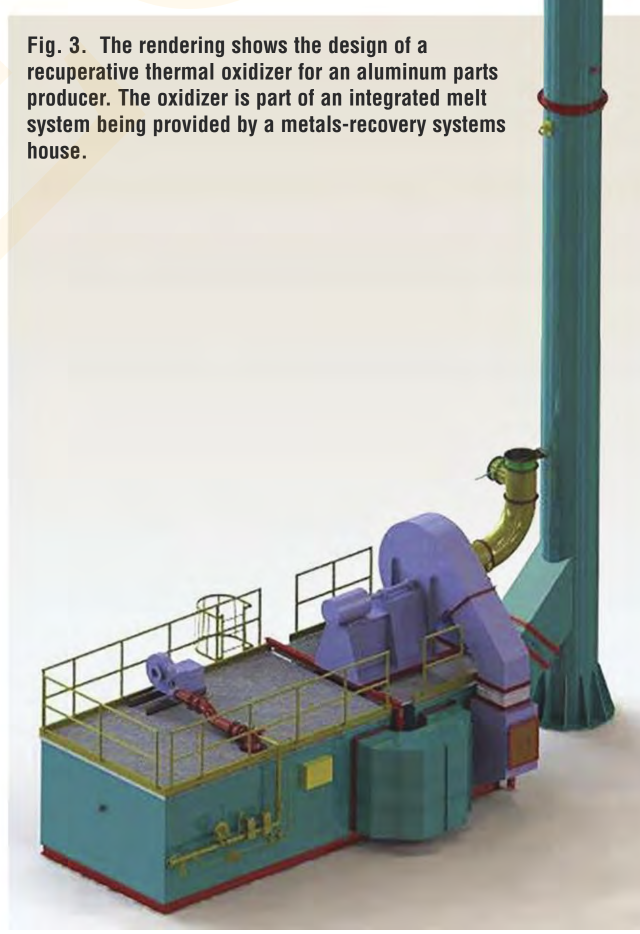

Fig. 3. The rendering shows the design of a recuperative thermal oxidizer for an aluminum parts producer. The oxidizer is part of an integrated melt system being provided by a metals-recovery systems house.

Thermal Processing Products

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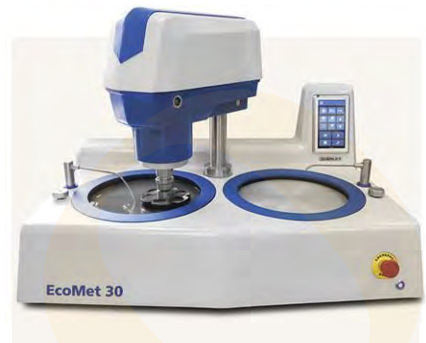

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U3556 Pacific Industrial Batch High-Temp Furnace (24"W x 36"L x 18"H, 2800°F, electric)
U3637 Pacific Scientific Batch Temper (30'W x 48'D x 24'H, 1600°F, gas-fired)
U3643 Surface Combustion Temper Furnace (30'W x 48'D x 42'H, 1400°F, electric, 81kw)
U3645 Surface Combustion Hi-Temp Furnace (42'W x 60"D x 24"H,1850°F, gas-fired)
V1013 Thermolyne High-Temp Batch Furnace (10'W x 14'L x 9"H, 2000°F, electric)
V1067 Seco Warwick Batch High-Temp Furnace (24"W x 24"H x 36"D, 1800°F, electric)
V1130 Onspec Slot Forge Furnace (72'W x 96'D x 48"H, 2000°F, gas-fired)

Batch Oil Quench Furnaces

C0086 Huber Car Bottom Furnace (10'4"W x 12'9"D x 8'H, 1800°F, gas-fired)

Car Bottom Furnaces

C0071 Gas Mac Car Bottom Furnace (7'8"W x 12'6"D x 7'0"H, 1150°F, gas-fired)

Drop Bottom Furnaces

C0069 Enviro-Pak Drop Bottom Furnace (48'W x 48'D x 48"H, 1200°F, electric)
U3543 Despatch Drop Bottom Furnace (4'W x 6'L x 4'H, 1200°F, electric)

Internal Quench Furnaces

C0064 Lucifer IQ Furnace (18"W x 24"D x 18"H, 1900°F, electric)
U3569 Surface Combustion IQ Furnace (24"W x 18"H x 36"D, 1750°F, gas-fired)
U3606 Dow/AFC IQ Furnace (30"W x 48"L x 24"H, 1850°F, gas-fired)
V1046 Surface Combustion IQ Furnace (87'W x 87'L x 36"H, 1850°F, gas-fired)
V1047 Surface Combustion IQ Furnace (62'W x 62'L x 36"H, 1850°F, gas-fired)
V1062 Surface Combustion Super IQ Furnace (36"W x 72"D x 36"H, 1950°F, gas-fired)
V1082 Holcroft IQ Furnace with Top Cool (36"W x 48"D x 30"H, 1850°F, gas-fired)
V1092 Surface Combustion Allcase IQ Furnace (30'W x 48'L x 30'H, 1850°F, gas-fired)

Mesh Belt Brazing Furnaces

C0102 JL Becker Mesh Belt Brazing Furnace (30'W x 24'5" heated L x 10"H, 2050°F, electric)
C0103 JL Becker MB Brazing Furnace w/Exo & Dryer (30'W x 24'5" heated L x 10"H, 2050°F, electric)
U3529 CI Hayes Mesh Belt Brazing Furnace (18"W x 6"H x 8' heating, 2100°F, electric)
U3592 JL Becker Mesh Belt Brazing Furnace (12"W x 6"H, 2100°F, electric)
V1035 Seco Warwick Mesh Belt Brazing Furnace (18"W x 12"H, 2100°F, electric)

Mesh Belt Tempering Furnaces

C0044 CGS Moore Mesh Belt Curing Oven (22'W x 20'L x 10"H, 500°F, gas-fired)
C0073 Heat Machine Mesh Belt Tempering Furnace (24'W x 10'L x 12"H, 1250°F, gas-fired, PT2501)
C0074 Holcroft Mesh Belt Tempering Furnace (24'W x 176'L x 12"H, 750°F, gas-fired, PT3136)
C0075 Industrial Heating Mesh Belt Tempering Furnace (24'W x 22'L x 12"H, 950°F, gas-fired, PT3630)
C0079 Internat'l Thermal Flat Wire Continuous Furnace (9'W x 10"H, 24' heating, 17' cooling, 650°F, gas-fired)
C0080 Surface Combustion Mesh Belt Temper Furnace (18"W x 11"H, 13' long, 1000°F, gas-fired)
C0081 Park Thermal Mesh Belt Temper Furnace (17.5"W x 7"H, 15'8" long, 900°F, gas-fired)
C0083 Eltropuls Plasma Furnace System (56"Dia x 80"D, 1022°F, electric)
C0090 Hengli Mesh Belt Sealing Furnace - Atmosphere (5.9"W x 3.5"H, 2100°F, electric)
U3638 American Gas Furnace MB Temper Furnace (31"W x 5"H, 17' heated length, 1100°F, gas-fired)
V1022 Surface Combustion Mesh Belt Tempering Furnace (42"W x 36'D x 12"H, 1350°F, gas-fired)

Pit Furnaces

V1088 Leeds & Northrup Pit Furnace (24" ID x 30" deep, 750°F, electric)

Roller Hearth & Rotary Furnaces

U3550 PIFCO Powered Roller Hearth Temper Furnace (21"W x 12'L x 18"H, 1000°F, electric)
V1009 Ipsen Continuous Temper Roller Hearth Furnace (24"W x 10'L x 18"H, 1350°F, electric)
V1091 Finn & Dreffein Rotary Hearth Furnace (13'3"ID x 5'3"ID x 4'W x 2'8"H, 2275°F, electric)

Steam Tempering Furnace

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

Tip Up Furnaces

C0043 Industrial Furnace Tip-Up Furnace (8'W x 22'4"D x 6'H, 1800°F, gas-fired)

Vacuum Furnaces

C0013 CI Hayes Oil Quench Vacuum Furnace (24'W x 36'D x 18"H, electric)
C0027 Pacific Scientific Vacuum Temper Furnace (24"W x 36"D x 24"H, 1450°F, electric)
C0111 Lindberg Vacuum Furnace (15'W x 24'L x 12"H, 2400°F, electric)
U3612 AVS Vacuum Annealing Furnace 2-Bar (18'W x 24'D x 12"H, 2400°F, electric)
U3635 Lindberg Hydryzing Gas Generator (6000 CFH Endo, gas)
V1004 CI Hayes Vacuum Furnace, Oil Quench (18"W x 30"L x 12"H, 2400°F, electric)
V1128 Ipsen Vacuum Furnace (18"W x 32"D x 12"H, 2400°F, electric)
V1131 Abar Vacuum Furnace (34'W x 60"D, 2250°F, electric)
V1135 Abar Vacuum Furnace 2 Bar (72'Dia x72'Deep, 2400°F, electric)
V1136 Surface Combustion Vacuum Furnace, 2-Bar (26'W x 36'L x 22"H, 2400°F, electric)
V1138 Ipsen Vacuum Furnace, 5-Bar (24'W x 36'L x 14"H, 2400°F, electric)

Endothermic Gas Generators

C0093 JL Becker Modular Endo Gas Generator (3-4000/6-8000/9-12000 CFH)
U3594 AFC-Holcroft Gas Generator (3,000 CFH Endo, gas)
V1021 Surface Combustion Gas Generator (2,400 CFH Endo, gas)
V1075 Lindberg Gas Generator (3000 CFH Endo)
V1105 Surface Combustion Gas Generator (5,600 CFH Endo, 1950°F, gas)
V3512 Surface Combustion Gas Generator - 5,600 CFH Endo

Exothermic Gas Generators

V1036 Seco Warwick Gas Generator (3,000 CFH Exo, gas)

Material Handling - Conveyors

U3565 Conveyor - Roller (48"W x 20'L)

Ovens - Cabinet

C0037 Grieve Cabinet Oven (36"W x 36"L x 36"H, 650°F, electric)
U020 Blue-M Oven/Ref (20"W x 20"H x 18"D), (-4°F/400°F)
U3625 Lindberg Atmosphere Oven (38'W x 38'D x 38"H, 850°F, electric)
U3629 Cabinet Oven (30'W x 30'D x 36"H, 750°F, electric)
U3642 Blue-M Cabinet Oven (36"W x 36"D x 36"H, 650°F, electric)

Ovens - Walk-In

C0035 Park Thermal Walk-In Oven (48"W x 48'D x 60"H, 500°F, electric)
C0038 Despatch Walk-In Oven (54"W x 108"L x 72"H, 500°F, electric)
C0039 Gehnrich Walk-In Oven (72"W x 96"L x 72"H, 400°F, electric)
C0108 Park Thermal Walk-In Oven (90"W x 144"D x 72"H, 850°F, gas-fired)

Freezers

V1129 Webber Freezer (-120°F, electric)

Blowers

U018 Twin City Blower (20 HP, RBA-SW, Class 22)

Charge Cars

U3621 Dow Charge Car, DEDP (66"W x 60"D x 54"H)
V1051 Surface Combustion Charge Car (DEDPER, 87"W x 87"L)
V1085 Holcroft Charge Car (DE/DP, 36"W x 48"D)
V1112 Surface Combustion Charge Car, SE, 30"W x48"D

Compressors

U023 Spencer Turbo Compressor

Scissors Lifts & Holding Stations

V1086 Holcroft Scissors Lift & (2) Holding Tables

Heat Exchanger Systems

U030 Graham Systems Heat Exchanger - Plate
V1104 SBS Heat Exchanger

Holding & Cooling Stations

V1113 Forced Cool Station (30"W x 48"D x 30"H)
Many other holding stations - ask for details

Water Cooling Systems

U3404 JL Becker Cooling Tower with Tank (Tower: 51"W x 36"L x 64"H, Tank: 72"W x 84"L x 66"H)
U3595 JL Becker 2-Tank Water Cooling System (tank: 72"L x 36"W x 37"H, 2 Dayton 1HP Motors)
V1038 Bell & Gossett Shell & Tube Heat Exchanger with Tank

Washers

V1052 Surface Combustion BIQ Washer (87"W x 87"L x 36"H, 180°F, gas-fired)
V1084 Holcroft Spray/Dunk Washer (36"W x 48"D x 30"H, 190°F, gas-fired)
V1101 Surface Combustion Spray Washer (36"W x 48"D x 30"H, 180°F, electric, 58kw)

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Baskets & Boxes

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Heat Treat Lines

V1137 T-6 Annealing & Aging Furnace Line
C0109 Dowa Thermotech Carburizing, Wash, Temper Furnace Line (26"W x 49"D x 24"H, 1800°F)

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- Managing your own schedule - how often, when and where you conduct audits
- The opportunity to experience different cultures by auditing all over the world

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- Hands-on experience with some of the following heat treating processes: steels, aluminum, titanium, heat resisting alloys, brazing, carburizing and nitriding
- Familiarity with AMS 2750 and Industry Specifications; Heat Treating Equipment and testing of heat treated material or products.

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1,000CFH	Exothermic Gas Atmos.	Gas
1,500CFH	Endothermic Lindberg (Air)	Gas
2,000CFH	Ammonia Dissoc. Drever (3)	Elec
3,000CFH	Endothermic Lindberg (3) - Air	Gas
3,600CFH	Endothermic Surface (2)	Gas
5,600CFH	Endothermic Surface (3)	Gas
6,000CFH	Gas Atmos. Nitrogen Generator	Gas

BOX FURNACES

12" × 24" × 10"	Lindberg (Atmos.)	Elec 2000°F
12" × 24" × 10"	Lindberg (Atmos.)	Elec 2500°F
12" × 24" × 12"	Hevi Duty (2)	Elec 1950°F
12" × 32" × 12"	L&L (Retort)	Elec 2000°F
13" × 24" × 12"	Electra Up/Down	Elec 2000°F
17"×14.5"×12"	L&L (New)	Elec 2350°F
18" x 30" x 13"	Hevi-Duty	Elec 1850°F
18" x 36" x 18"	Lindberg (Fan)	Elec 1850°F
20" x 48" x 12"	Hoskins	Elec 2000°F
24" × 48"× 24"	Hevi-Duty	Elec 2350°F
36" × 48"× 36"	CEC (Atmos-N_2)	Elec 2000°F
36" × 72"× 42"	Eisenmann (Car Bottom)	Gas 3100°F
60"×216"×48"	IFSI (Car Bottom)	Gas 2400°F
60"×156"×60"	Lindberg Car Bottom	Gas 1850°F
64"×180"×68"	Swindell-Dress. Car Bottom	Gas 2350°F
126"×420"×72"	Drever "Lift-Off" (2) (Atmos.)	Gas 1450°F

PIT FURNACES

14" Dia × 60"D	Procedyne Fluid Bed	Elec 1850°F
72" Dia x 72"D	Flynn + Dreffein (2) (Atmos.)	Elec 1400°F

VACUUM FURNACES

15" × 24" x 10"	Ipsen - VFC 224	Elec 2400°F
24" × 36" x 18"	Hayes (Oil Quench)	Elec 2400°F
48" x 48" x 24"	Surface (2-Bar)	Elec 2400°F
60" Dia x 96"H	Ipsen "Bottom Load"	Elec 2400°F

INTEGRAL QUENCH FURNACES

24" × 36" × 24"	AFC (Top-Cool-Line)	Elec 1850°F
30" × 48" × 20"	Surface (2)	Gas 1750°F
Just Added 30" × 48" × 30"	Surface (Line)	Elec 1750°F
30" × 48" x 30"	Surface	Gas 1750°F
48" × 72" × 36"	Lindberg (Top Cool)	Gas 1850°F

BELT FURNACES/OVENS

12" × 120" × 15"	Grieve (Solvent)	Elec 450°F
24" × 18'L	Thermal Basic Belt Line	Gas 1750°F
32" × 24' × 12"	OSI Slat Belt	Gas 450°F
36" × 24' × 8"	Surface Cast Belt (Line)	Gas 1750°F
36" × 28' × 22"	Lewco (2)	Elec 350°F
60" × 144" × 6"	Diamond Engr.	Elec 800°F
60" × 40' × 14"	GE Roller Hearth (Atmos)	Elec 1650°F
60" × 40' × 14"	Wellman Roller Hearth (Atmos)	Elec 1650°F

MISCELLANEOUS

Combustion Air Blowers (All sizes)		
24" × 36"	Lindberg Charge Car (Manual)	
Just Added 30" × 48"	Surface Charge Car (DE-SYS.I)	
30" × 48"	Surface Charge Car (SE-ER)	
Just Added 30" × 48"	Surface Charge Car (DE-ER)	
24" × 36" × 24"	Salt Quench Tanks (2)	Elec 1000°F
30" × 48" × 30"	Surface Washer	Gas
Wilson Hardness Testers (Superficial)		
(2) Bell & Gossett "Shell & Tube" Heat Exchangers		
26" x 15' x 15"	Belt Washer/Dryoff	Gas
36" x 48"	AFC Charge Car (DE)	Elec
30" x 30" x 30"	Subzero	-105 to 375°F Elec.

MISCELLANEOUS *(continued)*

AFC Pusher Line (Atmos.)		Gas 1750°F
36" Wide Table – Rotary Hearth (Atmos.)		Elec 1850°F
30" x 48"	Surface Roller Table	
36" x 48"	Holcroft Charge Car (DE)	
30" x 48" x 30"	Surface Washer (D&S)	Elec Just Added
48" x 60" x 60"	Steel "Roll-in" Carts (3)	
54" Dia x 108" H	Ebner Bell (Atmos.)	Gas 1650°F

OVENS/BOX TEMPERING

8" × 18" × 8"	Lucifer	Elec 1250°F
12" × 16" × 18"	Lindberg (3)	Elec 1250°F
14" × 14" × 14"	Blue-M	Elec 1050°F
14" × 14" × 14"	Gruenberg	Elec 1200°F
14" × 14" × 14"	Blue-M	Elec 650°F
14" × 14" × 14"	Gruenberg (solvent)	Elec 450°F
15" × 24" × 12"	Sunbeam (N_2)	Elec 1200°F
20" × 18" × 20"	Blue-M	Elec 400°F
20" × 18" × 20"	Despatch	Elec 650°F
20" × 18" × 20"	Blue-M	Elec 650°F
20" × 18" × 20"	Blue-M (2)	Elec 800°F
22" × 18" × 15"	Precision Quincy	Elec 1000°F
24" × 20" × 20"	Blue-M	Elec 1000°F
24" × 26" × 24"	Grieve	Gas 500°F
24" × 24" × 24"	Grieve	Elec 650°F
24" × 24" × 36"	New England	Elec 800°F
24" × 24" × 48"	Blue-M	Elec 600°F
24" × 36" × 24"	Grieve	Elec 500°F
24" × 36" × 24"	Demtec (N_2)	Elec 500°F
24" × 36" × 24"	AFC (N_2)	Elec 1250°F
24" × 36" × 24"	Trent	Elec 1400°F
25" × 20" × 20"	Blue-M	Elec 650°F
24" × 36" × 48"	Gruenberg	Elec 500°F
25" × 20" × 20"	Blue-M (Inert)	Elec 1100°F
26" × 26" × 38"	Grieve (2)	Elec 850°F
30" × 30" × 60"	Gruenberg	Elec 450°F
30" × 30" × 48"	Process Heat	Elec 650°F
30" × 38" × 48"	Gruenberg (Inert) (2)	Elec 450°F
30" × 48" × 30"	Surface (3)	Elec 1400°F
30" × 48" × 36"	Surface (Atmos)	Elec 1400°F
30" × 48" × 30"	Surface	Elec 1250°F
36" × 36" × 36"	Grieve (Solvent)	Elec 500°F Just Added
36" × 36" × 36"	Blue M Enviroment Chamber (-18°C to +93°C)	
36" × 42" × 72"	Gruenberg	Elec 450°F
36" × 48" × 24"	L&L (Inert)	Elec 1200°F
36" × 48" × 36"	Grieve	Elec 350°F
36" × 48" × 36"	AFC	Gas 1250°F
36" × 60" × 36"	CEC (2)	Elec 650°F
36" × 84" × 36"	Lindberg (1996)	Gas 800°F
37" × 25" × 37"	Despatch	Elec 500°F
38" × 20" × 26"	Grieve	Elec 500°F
42" × 54" × 30"	L&L	Elec 1200°F
42" × 72" × 36"	Lindberg	Elec 1250°F Just Added
42" × 72" × 36"	Despatch	Elec 1350°F
48" × 30" × 48"	Precision Quincy	Elec 550°F
48" × 48" × 60"	Precision Quincy	Elec 500°F
48" × 34" × 52"	Heat Mach. (2)	Elec 500°F
48" × 48" × 48"	TPS - Environmental	Elec 392°F
48" × 52" x 60"	Despatch	Elec 500°F
48" × 48" × 48"	Lindberg (Argon Atmos)	Elec 1400°F
48" × 48" × 72"	Grieve (Like New)	Elec 1000°F Just Added
48" × 48" × 60"	Grieve	Elec 500°F
50" × 50" × 50"	Grieve	Elec 1250°F
55" × 30" × 60"	Precision Quincy	Elec 350°F
68" × 72" × 72"	Gruenberg (4)	Elec 450°F Just Added
72" × 120" × 72"	Grieve	Gas 500°F
72" × 180" × 72"	Precision Quincy	Elec 450°F
72" × 252" × 60"	Precision Quincy "Car Oven"	Gas 500°F Just Added
84" × 156" × 84"	Steelman (Solvent)	Gas 500°F
108" × 96" × 65"	Eisenmann (4)	Gas 1200°F

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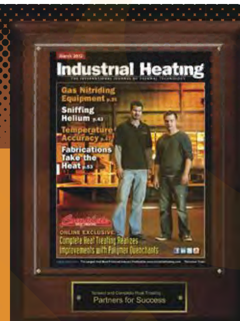

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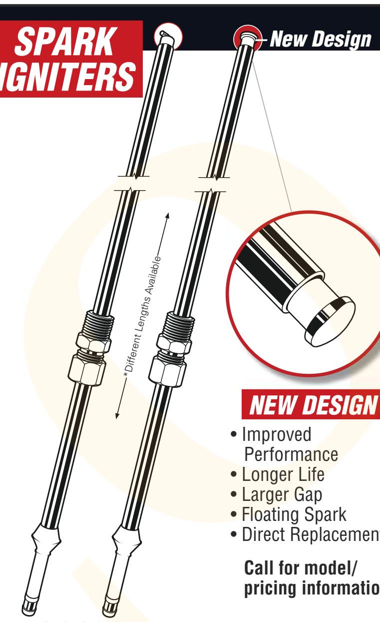

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Heat Source 2 Bar, 1800˚C, 20 w x 10 h x 30 dep, Graphite, with debind, new PLC touch screen controls

Abar HR 26 2 Bar: 2400˚F, 18" x 24" x 36" graphite hot zone, High vacuum, 2 bar Pressure Quench

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Borel 18 x 24 x 36 Hydrogen Retort Furnace: 1832˚F

TM 12 x 12 x 20: graphite hot zone, high vacuum, internal quench, 5 psig positive quench

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