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**INDUCTOTHERM GROUP**
Editorial Opportunities for HTPro in 2014

The editorial focus for HTPro in 2014 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

June       Process Control
September  Surface Engineering
November   Atmosphere/Vacuum Heat Treating

To contribute an article to one of these issues, please contact Frances Richards at frances.richards@asminternational.org. To advertise, please contact Erik Klingerman at erik.klingerman@asminternational.org.
We Need to Change the Perception of Heat Treating

Heat treating is an extremely important technology and is critical to help solve many engineering problems and meet industrial demands for improved materials performance. Traditionally, heat treating process development has advanced incrementally through empirical trial and error (experience-based progress), and even through serendipitous discoveries. Such advancements are very time consuming, highly inefficient, usually only marginally effective, and can be costly. In addition, it is unfortunate that manufacturers are decimating their internal experienced technologists and metallurgists; gone is the mentoring system to support the growth and capability of fresh new technical talent.

We must change this heat treating paradigm from experience-based technological evolution to a faster, more effective science-based technological revolution to meet ever increasing market demands. Traditional equilibrium and isostructural-based process systems are no longer adequate to meet desired more stringent part performance specifications.

Heat treating is a multivariant technology, and many dynamic reactions occur simultaneously, which defy simple analyses. We must drive development of science-based technology to even higher levels through the use of simulation-based engineering and science (SBES). Numerical outputs from models and simulation provide data on degrees of freedom, possibly characterizing alternative solutions. Simulation techniques lend themselves to direct animation that can provide additional detailed visualization of properties and high-speed process dynamics. We now have a far better understanding of deformation mechanisms and of the best use of optimum reaction pathways for maximum part strengthening. These smart tools provide the capability to produce tailored heat treat processes and designer-specific materials that provide product engineers even greater flexibility to handle the increasing market demand of “more for less.”

How do we change the paradigm? I believe this involves two objectives:

1. Change the design and manufacturing perception of heat treating from a burdensome and difficult part of the product manufacturing process to a clear understanding of the need for heat treatment from a technological standpoint—maybe even changing the term heat treating to thermal engineering.

2. Foster a closer, more proactive working relationship between materials scientists and product and manufacturing engineers through better communication—creating a team approach to defining the optimum material for the application and the thermal process required to achieve required performance attributes.

The bottom line is that whatever it is called and no matter how it is perceived, we simply can’t do without heat treating.

George D. Pfaffmann, FASM
Ajax-TOCCO Magnethermic Corp.

It’s Not Too Early to Think About the ASM HTS/Surface Combustion Emerging Leader Award

The ASM HTS/Surface Combustion Emerging Leader Award was established in 2013 to recognize an outstanding early-to-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award was created in recognition of Surface Combustion’s 100-year anniversary in 2015.

The award acknowledges an individual who sets the “highest standards” for HTS participation and inspires others around him/her to dedicate themselves to the advancement and promotion of vacuum and atmosphere heat treating technologies.

Rules for submitting nominations:
- Candidates must be a member and an active participant in ASM International and HTS.
- Nominees must be 40 years of age or younger and employed full time in the heat treating industry for a minimum of five years.
- Candidates must be submitted by an ASM International member.
- Three letters of recommendation must be submitted with the nomination form.
- Nominations should clearly state the nominee’s impact on the industry and/or service and dedication to the future of the HTS.

The award shall be presented to one recipient every two years at the General Membership Meeting at the HTS Conference and Exposition. Recommendations must be submitted to ASM Headquarters no later than April 1 in the year in which the award is to be presented. The first award is to be presented in 2015. Winner receives a plaque and $4000 cash award funded by Surface Combustion.

A selection committee consisting of five members will be appointed every two years by the HTS Awards and Nominations Committee. Three members of the selection committee will be appointed by Surface Combustion. The selection committee will submit a report for approval by the HTS Awards and Nominations Committee and the HTS Board, which shall include the rationale and documentation used for award selection.

For rules and nomination form for the ASM HTS/Surface Combustion Emerging Leader Award, visit the Heat Treating Society Community website at http://hts.asminternational.org and click on Membership & Networking and HT Awards. For additional information, or to submit a nomination, contact Sarina Pastoric at 440/338-5151, ext. 5513, or email sarina.pastoric@asminternational.org.

Heat Treating Society Looking for Volunteers

Get Involved!
Serve on a Heat Treating Subcommittee!

The HTS Technical Programming Committee is seeking enthusiastic, committed members to serve on various technical subcommittees, which develop, promote, and execute programming for HTS events. The committee is currently looking for members in the following technical subcommittees: Applied Energy, Quenching and Cooling, Vacuum, Atmospheres, Research and Development, Cryogenics, and Brazing.

Interested members should review the Subcommittee Best Practices on the HTS website and contact natalie.nemec@asminternational.org.
5th International Conference on Thermal Process Modeling and Computer Simulation

ASM Heat Treating Society and International Federation for Heat Treating and Surface Engineering (IFHTSE) are co-sponsoring the 5th International Conference on Thermal Process Modeling and Computer Simulation (ICTPCS), which is collocated with the AeroMat 2014 Conference at the Gaylord Palms Resort & Convention Center in Orlando, Fla.

ICTPCS was originated by IFHTSE.

The ICTPCS technical program consists of 64 presentations covering the broad field of thermal process modeling. Several papers deal strictly with computational issues of efficiency, accuracy, and solver methods. The majority of presentations involve modeling applications of various processes including:

- Surface treatments such as carburizing, nitriding, thermal spraying, and cladding
- Immersion quenching processes in liquids that boil
- Gas quenching
- Phase transformations during heating and cooling
- Induction hardening and spray quenching
- Controlled cooling of castings and forgings
- Welding

Conference presenters comprise a distinguished mix of U.S. and international experts from academia and industry.

Keynote presentations include:
- Immersion quenching with transient boiling
  Dr. Sabine Denis of Université de Lorraine, Nancy, France
- Distortion, stresses, and defects in solidifying castings
  Prof. Christoph Beckermann of the University of Iowa, Iowa City
- Modeling of additive manufacturing processes
  Dr. Howard Kuhn of the University of Pittsburgh

Registrants to ICTPCS will have complete access to AeroMat technical sessions and the exposition.

TECHNICAL PROGRAM

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<tr>
<td>8:00 – 10:00 a.m.</td>
<td>Distortion &amp; Residual Stress I</td>
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<td>BREAK</td>
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<td>10:30 a.m. – 12:00 p.m.</td>
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<tr>
<td>8:00 – 10:00 a.m.</td>
<td>Distortion &amp; Residual Stress II</td>
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<td>Phase Transformation III</td>
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<td>Quenching I</td>
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<tr>
<td>10:30 a.m. – 12:00 p.m.</td>
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For more information, to register, or to make housing arrangements, visit www.asminternational.org/htmodeling.
Demystifying Induction Tempering

The Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute (WPI) in Massachusetts is conducting a cutting-edge research project aimed at demonstrating the benefits and limitations of induction tempering versus furnace tempering. Results will enable manufacturers that use a tempering process for their products to choose the optimal technology required to reduce tempering cycle time and process costs while maintaining or improving product quality.

“This is the first time a project like this is being undertaken,” says CHTE member Lesley Frame, manager of materials engineering and development at Thermatool Corp., East Haven, Conn. “Currently, widely available, detailed comparative data for induction and furnace tempering does not exist. The industry has been reliant on dated gas furnace-tempering data, which does not provide a sufficient guide for developing induction heat treating recipes.”

Tempering requires a balance between desired hardness and tensile strength, while increasing toughness and maintaining a uniform microstructure. Further, industry requires minimized residual stress and distortion in heat treated parts. Because stresses and distortion are affected by temperature changes, it is necessary to understand how internal stresses might develop during rapid-heating processes like induction tempering.

This study will provide CHTE members with information on the best recipe to maximize part performance. The expectation is that members will be able to apply the data to process designs to improve efficiency and productivity and eliminate trial-and-error experimentation.

Rick Sisson, WPI professor of mechanical engineering and director of CHTE, said the project will take the guesswork out of decision-making and help industry work more effectively. “For the first time, industry will have the answers it needs to determine when furnace tempering will best meet application needs and when induction tempering is the best process,” explains Sisson.

Research objectives

One of the project’s main goals is to compare induction and furnace tempering processes at a fundamental level in terms of the effects of power (kW), frequency (kHz), temperature, and time on the microstructure and hardness of quenched and tempered steel. In the study, 1 ft long by 0.5 in. diameter (300 by 13 mm) AISI 1045 carbon steel and AISI 4140 alloy steel rods are being tested. Steel microstructures will be characterized using optical and scanning electron microscopy, x-ray diffraction, and transmission electron microscopy.

Microstructures, residual stress distribution, and mechanical properties (hardness, impact toughness, and torsional properties) of induction-tempered steel samples and furnace-tempered samples will be compared. Based on hardness test results, impact toughness and torsional fatigue behavior of selected samples will be determined and correlated with the microstructure.

Induction-tempering tests will be conducted at Thermatool Corp. and furnace tempering will take place at CHTE. Results are expected in late 2014.

Induction tempering offers an alternative to furnace tempering.

About CHTE

The CHTE collaborative is an alliance between the industrial sector and university researchers to address short-term and long-term needs of the heat treating industry. Membership in CHTE is unique because members have a voice in selecting quality research projects that help them solve today's business challenges.

Member research process

Research projects are member driven. Each project has a focus group comprising members who provide an industrial perspective. Members submit and vote on proposed ideas, and three to four projects are funded yearly. Companies also have the option of funding a sole-sponsored proprietary project. In addition, members own royalty-free intellectual property rights to precompetitive research, and are trained on all research technology and software updates.

CHTE also periodically undertakes large-scale projects funded by the federal government or foundations. These endeavors keep members informed about leading edge technology.

CHTE current research portfolio

Other projects now in progress include:

Nondestructive testing, alloy life improvements, gas quench steel Hardenability, and cold spray nanomaterials.

For more information about CHTE, its research projects, and member services, visit wpi.edu/+chte, call 508/831-5592, or email Rick Sisson at sisson@wpi.edu or Diran Apelian at dapelian@wpi.edu.
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INDUCTION COUPLED HIGH MAGNETIC FIELD EXPANDS PROCESSING ENVELOPE FOR HEAT TREAT INNOVATIONS

TRADITIONAL HEAT TREATING PROCESSES HAVE REACHED A PLATEAU AND ARE NO LONGER GOOD ENOUGH.

Aquil Ahmad®, Metallurgical Consultant, West Bloomfield, Mich.

Increasing demand from the durable goods market (e.g., automotive, agriculture, aerospace) for lighter weight, more efficient, and highly durable products requires a significant increase in material/component strength and performance capability. Traditional thermally activated processes used to improve materials strength and performance have evolved empirically and are largely isothermally based, equilibrium reactions. Using this approach, heat input, flow, and its redistribution are driven only by an applied elevated-temperature differential. Therefore, the desire to accelerate thermal transfer requires the application of higher surface temperatures and longer times, which can result in several undesirable effects and other process capability limitations.

Advanced induction thermal capabilities

Continual improvement of induction heating technology has increased the ability to selectively focus and provide a highly controlled internal thermal profile of a part, enabling optimization of specifically programmed, thermally driven metallurgical reactions for maximum strengthening results. Notably, the latest innovations in equipment versatility and FEA-modeled hardware tooling provide an unmatched, precise capability to accelerate processing speeds and produce novel metallurgical microstructurally enhanced strength (ultra-grain refinement approaching the nanoscale plus unique beneficial microstructure morphology) in a part.

Induction heating generates heat (with truly no limit on achievable temperature) within the part’s subsurface. The depth of heat distribution can be programmed and dynamically profiled to produce desired metallurgical results, which are achieved by the efficient use of environmentally clean electrical energy. The part’s internal heat profile can be optimized using a wide range of in-situ computerized process-control parameters. Therefore, processing can be customized to provide optimally driven reactions for improved part performance.

Induction heating thermal dynamics are vastly different from those applied in traditional isothermal systems. In cases of short heating times (1 to 2 seconds or...
scale experiments. Superconducting magnet to conduct large-
by 9-in. long uniform field strength

Integrated induction heating and quench-

less) and complex dynamic thermal geo-
metric profiles, these dynamics cannot be
accurately recorded nor can they graphi-
cally display the part’s internal thermal re-
response and reactions. The dynamics
inhibit a more complete understanding
and evaluation of the multiple reaction is-
issues involved, limiting the ability to estab-
lish an optimal process. However,
because induction heating is electrically
applied and fully electronically controlled,
it can be mathematically modeled and ob-
jectively simulated (via “what if” studies).
The resultant graphics display provides a
detailed representation of the dynamic
interactions involved to help better un-
derstand the process.

Challenges and limitations of under-
standing the process are fully addressed,
and actual dynamics can be simulated by
using the latest induction computer
modeling programs—including fully
coupled, electromagnetic/thermal and
FEA/FED modeling. This approach
enables graphical display of complex
thermal logistics and subsequent inter-
reactive reactions to understand the
process, make adjustments, and identify
optimal reactions/process parameters/
dynamics to improve part performance.
Coupling material science and simula-
tion process engineering provides an ad-
vanced understanding and review of
viable alternative solutions.

High magnetic field processing (HMFP)

A new high magnetic field processing
(HMFP) and thermomagnetic field pro-
cessing (TMFP) facility at Oak Ridge Na-
tional Laboratory, Tenn., includes an
industrial-scale HMFP facility with an in-
tegrated induction heating and quench-
ing capability for conducting industrial
experiments (Fig 1). Coupling a high
magnetic field environment with an ap-
plied induction elevated temperature ca-
\ability offers an enabling disruptive
\\nology. This approach enables
\achieving stronger, more durable compo-
dents and materials with improved per-
formance. Induction heating plus a high
magnetic field processes parts much
\\nster than thermal processing alone be-
cause the magnetic field alters the phase
\\nlibrium diagram (Fig. 2). It shifts
\phase-transition temperatures, and phase
\solubilities increase with increasing tem-
\\nperature. Other benefits include:
\- Accelerated phase transformations
\- Enhanced nucleation and growth
during phase transformation
\- Smaller grain size
\- Less segregation during solidification
\- More homogeneous microstructure
\- and properties
\- Higher strength and plasticity
\- Lower residual stresses
\- Faster diffusion

Such a technology offers the means to
\make significant major science and tech-
\\nological advancements in developing the
\next generation of novel structural and
\functional materials for use in a broad
\range of transportation and mili-
\\ary applications.

All materials are influenced by high
magnetic fields, so all material systems
\metallic through polymeric and
\protein will respond to an induction
\thermal high magnetic field (ITHMF)
\environment. Major improvements in
\performance (from 15 to 300%) can be
\manifested in mechanical and/or physi-
cal properties. For example, an ITHMF
\(9\ T\) processed Hy Tuf vacuum arc
\remelted high-strength, low-alloy steel
\(\text{Latrobe Specialty Steels Co., Pa.}\) has an
equivalent ultimate tensile strength and
double the toughness of a more expen-
sive conventionally processed 250
\\nmaraging steel grade.

Development of nanocrystalline and tex-
tured and/or novel microstructures and
reaction paths is made easier and faster
through the synthesis and catalytic chem-
ic effect of the extreme ITHMF envi-
\onment. In addition, the deformation
\behavior (magnetoplasticity) of materials
\appears to be influenced by high mag-
\\nnetic fields, potentially enabling high- and
\low-cycle fatigue damage mitigation (life
\extension), superplastic behavior at am-
\\ntemperature, residual stress relief,
\and other visionary applications. It might
\even be possible to make classically brit-
tle materials formable under high mag-
\netic fields. Therefore, the ITHMF
\environment has an impact on phase
\\nlibria and kinetics and represents a
\new synthesis/catalysis paradigm and a
\deformation/life enhancement processing
\breakthrough technology. HTPro

Acknowledgement: The authors thank
Dr. Gerard Ludtka and Dr. Gail Ludtka,
Oak Ridge National Laboratory, Tenn., for
input from their research on this technol-
yogy conducted at ORNL.

For more information: George Pfaffmann
is vice president of technology, Ajax
TOCCO Magnethermic Corp., 30100
Stephenson Hwy., Madison Heights, MI
48071, 248/691-2281, gpaffenmann@
Modern industrial heat treating operations have sophisticated IT architectures, where significant amounts of data in GB/TB per year are generated including characteristics of input material (chemistry, prior material quality, charge dimensions, quantity, and configuration), process parameters (furnace temperature, carbon potential, and quenching oil-temperature variation with time) and product quality (hardness, microstructure, case depth, and distortion) are generated. These manufacturing data are primarily used for process audits and troubleshooting specific batches that have quality issues.

Much of this collected data goes unused. However, it could be significantly leveraged to generate process insight and optimize processes to improve manufacturing efficiency and product quality for an overall reduction in operational and energy costs. Figure 1 illustrates that this could be achieved in a closed loop, where the manufacturing data together with heat treating knowledge can be synthesized with physics and data-based modeling approaches to generate insight for process optimization and control. Actionable outcomes at different phases of the loop are also shown in the figure. For example, many surprises about process and product can emerge from process analysis and modeling, where the insight generated from this approach could directly impact product quality and design recommendations. This could enhance key process efficiency metrics—namely, operational and energy costs, productivity, and quality.

This approach is an expanded, generic view of a typical smart-manufacturing circle[1] comprising Data-Analyze-Model-Apply. Big data, data analytics, and data-based modeling approaches (neural network, principal component analysis, and other advanced statistical methods) are emerging as key areas to analyze manufacturing operations. Data-based approaches are effective to generate predictions within a current operating regime from which data are derived.

In contrast, physics-based models can also lead to an optimum operating condition, which is far removed from current conditions. Physics-based models for heat treating operations incorporate mass and energy conservation, laws of heat transfer, metallurgical thermodynamics, and chemical reactions and kinetics. Some important physics-based models with respect to carburizing include thermal models, diffusion kinetics, quenching models, residual stress, and distortion models. A judicious synthesis of these two approaches and modeling methodologies is far more effective than focusing on individual components of the process.

Case studies
Coil batch annealing. This generic approach was effectively demonstrated by the significant improvement in first-pass yield of an industrial batch annealing operation in a secondary cold-rolling mill[2]. The operation had many operating challenges including the need to process coils with high variability from different sources, pressure to maintain a low inventory level, and a lack of a process model that could customize cycle design for individual coil stacks. As a result, more than 50% of annealed coils failed to meet target quality requirements, resulting in product downgrade, or rework that added significant cost to meet product quality. The situation was expected to be-

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*Member of ASM International
come worse as more stringent quality specifications in mechanical properties (e.g., hardness variations across the coil) were anticipated.

Three recommendations were offered after examining the operation by combining results of process analytics with process model (phenomenological and neural-network) simulations: (1) classifying coils in a different manner for stacking in the furnace charge, (2) establishing new chemical composition specifications for coils to be annealed, and (3) creating new model-based process cycles (temperature and soaking time) for different coil classes. The integrated approach reduced overall rejection rates and downgrading rates for two major products by 44 and 60%, respectively, thereby enabling the desired tightening of quality specifications. The reduction in rework and downgrading also significantly reduced the plant’s specific energy consumption. Achieved benefits were monitored and sustained for more than one year[2].

Automated coil batch annealing. In another study, an automated batch annealing operation in an integrated steel plant was analyzed and optimized[3]. The modern operation was equipped with a model-based control system, which simulated the process and derived optimized recipes before heat treating individual stacks of coils. In the study, process and quality data were analyzed and compared with physics-based models, which showed that the thermal model used in the control system was very conservative in estimating heat transfer across the coils. As a result, process cycle time did not vary with the thickness of the coil stack. In addition, the control system was only based on thermal differential across the coils, so nonisothermal effects arising from complex precipitation/recrystallization/grain growth mechanisms were not captured. Because of the nonisothermal effect, accelerated annealing kinetics with a reduction in heating rate was observed through physics-based modeling and laboratory kinetics experiments. An appropriate thermal conductivity model and nonisothermal models were used to create transfer functions for the process recipe derived from the control system to modify the resulting recipes. This approach was validated on an industrial scale, and overall productivity of the 1-million ton/year integrated steel plant was improved by 9%[3] together with a considerable reduction in specific energy cost.

Batch carburizing. In a recent study, a carburizing operation of a modern heat treating shop was analyzed, modeled, and optimized. The heat treating operation has 12 quench-sealed furnaces for heat treating transmission components such as gears and shafts. About 500 MB of data comprising charge characteristics (dimensions, number of parts, charge configuration, and weight), process parameters (furnace temperature-time and carbon potential-time records of various segments, and oil temperature-time) and quality (case depth, microstructure, hardness, and retained austenite) were extracted for the operation for a one-year period. All data were recorded with different periodicity. For example, furnace process data were recorded every minute, whereas quality data were recorded per batch. Raw process data (time, temperature, and carbon potential) were transformed from a per minute basis into a per batch basis with the mean and standard deviations values. Subsequently, process data were merged with charge
and quality data for analysis. The reconciled and merged data were used for further analyses.

Some key analyses included:
- Checking inputs and quality against specifications
- Checking the consistency of various recipes
- Principal component analysis (PCA) to find key input variables that impact quality parameters
- Using neural networks to relate input variables with quality
- Using first principle models (including diffusion kinetics) for consistent validation and selection of recipes

The operation had very high emphasis on product quality, with every normal batch meeting the specified product quality. However, minor process parameter variations were observed, which were correlated to case-depth variation (within the quality specification). Results of detailed data analysis and the diffusion model indicated that recipes with overlapping specifications could be rationalized to reduce the number of required recipes. Furthermore, principal component analysis helped in segregating process parameters having less influence on quality data. This was used to build a robust mathematical model. An artificial neural network model was built based on key parameters, which could predict 98% of the case depth for any combinations of process parameters within an uncertainty of 20%, which was consistent with the plant data. In addition, process parameters were optimized using dif-
fusion kinetics and neural network modeling.

Major deployable outcomes included a new operating regime, new recipes, and a recipe selection methodology. The study projected a 12.5% productivity increase, together with ease of operation (lower number of recipes), specific energy consumption, and 90 MT per year of carbon footprint reduction, which is equivalent to 15 automobiles with an average of 12,000 miles/year at 26 mpg fuel efficiency.

These examples demonstrate the effectiveness of the approach and the value realized at the shop floor, which justify the efforts needed for executing such projects. Better use of this methodology requires standardization of data, models, and an analysis approach. Although most modern processes have transitioned to IT infrastructures where data is collected, data consolidation and standardization remains an issue. Modeling approaches have not matured into standard software products, such as in-design, finite element analysis (FEA), and computational fluid dynamics (CFD). Selecting the right approach, developing models, and analyzing results to generate deployable solutions requires a significant level of technical expertise with an understanding of first principles and mathematical modeling. The greatest limitation in this area is finding the technical talents with the necessary level of expertise.

Conclusion
A significant amount of data is generated from modern manufacturing operations, which can be effectively leveraged together with heat treating first principles understanding for analytics, modeling, and optimization of heat treating operations aimed at reducing specific energy consumption and improving productivity and product quality for an overall reduction in operating costs. The approach is proven with value realized on the shop floor, but it has not completely matured for standard deployment due to a lack of necessary technical expertise.

References

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Keep the Heart of Your Vacuum Furnace System Healthy and Pumping

The heart of the vacuum furnace system is just as critical as the heart of the human body. Just as it is important to keep your heart healthy and pumping, it is crucial to keep your vacuum furnace system healthy and pumping. Get the best performance out of your vacuum furnace by selecting the most appropriate pumping system for your process and by following simple tips.

First, the basics ...
Vacuum furnace systems utilize various types of pumping system combinations to evacuate atmospheric pressure from the vacuum chamber to required ranges for specific processes. Since the heart of the furnace is the vacuum system, it is essential to maintain the pumping system as specified in the operator's manual, taking into consideration any special accommodations that the type of process being conducted may require.

There are typically three subsystems included in each vacuum furnace pumping system: the roughing pump, the vacuum booster pump and the diffusion pump. These pumps are usually classified as mechanical and diffusion vapor pumps.

Mechanical pumps and blowers, often referred to as roughing pumps, are utilized during the initial pump-down phase of the vacuum furnace from atmospheric pressure to a predetermined pressure level.

A diffusion pump is utilized to achieve a lower system pressure than what is typically achieved by a mechanical pump and booster package alone. The diffusion pump cannot operate ... visit IpsenUSA.com/Pumping to read the rest of this article and to learn more about maintaining your pumping system and a pump's worst enemy.

Read the article at IpsenUSA.com/Pumping