The Institutional Initiatives section of the U.S. heat treating industry’s recently revised Technology Roadmap focuses on important nontechnical issues. This focus is a reminder that there are many other issues that are necessary to achieve the full benefits of Vision 2020.

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This is the final article in the series highlighting the work to update the 1997 Heat Treating Technology Roadmap developed to help achieve the technology challenges incorporated in the Vision 2020 goals. The intent of these articles has been to improve the industry member’s understanding of the important research initiatives that are needed to achieve the Vision 2020 and to offer examples of critical research that has been done and is being implemented in industry.

The Research & Development Committee of the ASM Heat Treating Society (HTS) has revised the 1997 Technology Roadmap technical research initiatives into four categories: Equipment & Hardware Technology, Process & Materials Technology, Energy & Environment Technology, and Institutional Initiatives. Subcommittees were formed to review each of the original sections of the 1997 Roadmap and to update them to current requirements. This article addresses institutional issues that will play a key role in achieving the Vision 2020, including the vital role played by the Center for Heat Treating Excellence (CHTE) and our universities.

The examples offered in the five-part Roadmap Update series clearly show that the research needed to achieve the Vision 2020 has been started. Institutional issues are also being addressed, as this article points out. However, much work—in both the technical and institutional arenas—still needs to be done!

Institutional initiatives vs. technology initiatives
To update the 1997 Technology Roadmap, the R&D Committee reconsidered each recommended research and development initiative in the original document. Similar initiatives were combined, some were eliminated, some were added, and an effort was made to clarify each initiative. New to the updated Roadmap, the subcommittees collected items that were not research issues and put them in a separate section called Institutional Initiatives. These issues include health and safety, training needs, baseline emissions data, and baseline energy consumption. They are key to achieving the Vision 2020, but do not require focused technical research to be achieved.

In addition to these institutional issues, there are numerous other issues identified in the Vision 2020 document that fall outside of the technology challenges. These include global standards, employees, industry regulations, tort reform, and profitability. These also need to be addressed to achieve the full Vision 2020 for the industry.

Just as in the technology sections covered in previous articles, advances have also been made in the nontechnical areas. The remainder of this article focuses on training, workforce preparation, and education issues.

PERSONNEL QUALIFICATION

Heat treat certification: Preparing for industry expertise
The heat treating industry has always been interested in continuous improvement and building credibility and confidence in the value-added services that we provide the manufacturing sector. As in any business, we all rely heavily on our staff to deliver a high-quality, reliable product or service. In this light, a subgroup of the HTS Education Committee headed by Arvid A. Casler, Federal-Mogul Corp., Skokie, Ill., and Chicago Regional Chapter Educational Advisor, has been developing a competency-based concept for the heat treat certification of individuals.

As component failures can and have resulted from improper heat treating, it is important that we ensure that heat treating personnel have a certain level of competency. It is the expectation of this committee that this certification will improve heat treating reliability among practicing heat treating personnel and provide customers as well as employers with clear expectations regarding their competency and proficiency. Individuals possessing this
THE INDUSTRY FUNCTIONING AS A ‘LEARNING ORGANIZATION’

An organization that discusses the core disciplines that make it a learning organization. Worcester Polytechnic Institute (WPI) Heat Treating Excellence (CHTE) at the establishment of the Center for development of a shared vision, is a keystone to a successful organization. A learning organization. Roadmap-to a large extent is striving to function as some of these core disciplines, and the heat treating industry has been following. The heat treat industry: A ‘learning organization’

In his renowned book, The Fifth Discipline, author Peter Senge discusses the core disciplines that make an organization a learning organization: personal mastery, mental models, shared vision, and team learning. The heat treating industry has been following some of these core disciplines, and to a large extent is striving to function as a learning organization. Roadmapping, an activity that requires the development of a shared vision, is a keystone to a successful organization. The establishment of the Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute (WPI) is another key milestone for our industry, in that it explicitly commits the industry to work collaboratively to advance the knowledge base and to invest in the future by providing the infrastructure for the educational development of our future leaders.

The ‘hope and sparkle’: CHTE provides the infrastructure where theory and practice come together, where innovation thrives, and where the “bridges” between industry and university are established and traversed. CHTE has been a successful model in that companies have joined forces to ensure that resources are available to carry out research to advance our understanding in key heat treating processes. In doing so, however, several intangible benefits have resulted. For example, many faculty members at various universities are working on critical heat treating process R&D projects through CHTE; namely, University of Connecticut, Ohio State University, Northwestern University, and the Metal Processing Institute at WPI. Moreover, these faculty members affect a whole network of students, and are anchors for recruiting intellectual capital to our industry. Intellectual capital resides with people (graduate and undergraduate students), and they will only be attracted to the industry if the hope and sparkle are present. CHTE provides both. Students do not gravitate toward a research area unless there is excitement, energy, commitment (including tangible resources), and opportunities. It is important to keep in mind what Winston Churchill said:

The empires of the future are the empires of the mind.

In the next three sections of this article, specific CHTE projects are highlighted to give you a taste of the types of research projects faculty members are carrying out in collaboration with CHTE member companies.

A CHTE PROJECT
Understanding, controlling, and optimizing quenching

Quenching is one of the most important processes in heat treatment, and can improve the properties and performance of metallic alloys. The speed of the quenching process is typically the most important parameter in producing the desired properties. The challenge of materials engineers is to...
select the quenching parameters needed to achieve the required material properties, while minimizing the introduction of stresses, which can lead to wasted material and time.

Quenching characterization involves the determination of the heat extraction rate of a fluid when cooling a piece of metal. There are several commercial quench probes available to characterize quenchants. They work by collecting time/temperature data generated by immersing a heated thermal probe into a heated quenchant. Further processing of the data yields a cooling curve. The most widely used probes are the IVF probe (IVF Industrial Research & Development Corp., Mölndal, Sweden), the Drayton probe (Drayton Probe Systems International, Stoke-on-Trent, Staffordshire, England), and the Liscic-Nanmac probe (Nanmac Corp., Framingham, Mass.).

**New probe:** A new quenchant characterization system, the CHTE Quench Probe System, has been developed to collect the temperature vs. time data for metallic probes quenched in liquid- and gas-based quenchants. The main feature of this characterization system is the ability to change the probe tip. The tip can be fabricated from any metallic alloy that is of interest for heat treating and quenching. Analysis of the quenching data can provide cooling rates as well as heat transfer coefficients that may be used for further analysis of a quenched component. WPI Professor Rick Sisson and his research team at CHTE (Fig. 1) have been spearheading this project over the past few years.

The CHTE Quench Probe System and the probe/connecting rod assembly are shown in Fig. 2. The cylindrical probe measures 0.375 in. (9.5 mm) in diameter and 1.5 in. (38 mm) long. Its tip is removable and can be made of any material that is to be quenched. A K-type thermocouple is placed at the geometric center of the probe tip to measure the time/temperature history. Since the CHTE probe is very small and the Biot number, (Bi = hL/k), is less than 0.1, the surface heat transfer coefficients can be calculated using a Lumped Parameter analysis or Newtonian cooling approximation. Heat transfer coefficients for CHTE probes made of different metallic alloys quenched in several media are shown in Fig. 3.

**Effective heat transfer:** Heat transfer during quenching is a very complex process and varies nonlinearly with temperature. Some other parameters, such as surface roughness of the quenched part, part geometry (whether the part is cylindrical or a flat plate, for example), orientation of the part during quenching, and the fluid agitation in the vicinity of the part surface, also greatly influence the heat extraction rate during quenching. To characterize the quenching process, the rate of heat transfer can then be given in terms of an effective heat transfer coefficient, h_{eff} = function of (temperature, surface condition, part geometry, orientation, and agitation). Isolating the effect of the different parameters gives this expression:

\[ h_{eff} = h(T) \times f(s) \times f(G) \times f(O) \times f(A), \]

where h(T) is the surface heat transfer coefficient as a function of temperature for a standard quench specimen, f(s) is the correction factor for part surface condition or roughness, f(G) is the correction factor for part geometry, f(O) for part orientation, and f(A) for fluid agitation in the quench tank.

The 22 publications that have resulted from this one project and that have been presented at 11 conferences in a total of four countries comprise a good example of the degree of dissemination that is taking place, of the
students and researchers who are engaged, and of the contribution to the advancement of our knowledge base.

**A CHTE PROJECT**

Promoting e-business in heat treating

Several organizations today use computer automation in order to serve their customers, improve efficiency, reduce costs, and positively impact their industry. Tools to assist decision-making, mechanisms for efficient storage and retrieval of data, and a means to promote worldwide exchange of information are some of the goals identified by these organizations.

At CHTÉ, these goals were addressed through the development of a Web-based decision-support system trademarked QuenchMiner and a database system trademarked QuenchPAD. Both focus on the analysis of experimental heat treating data. This set of enabling toolkits for heat treating was developed by a team headed by Prof. Rick Sisson. Students from WPI’s Computer Science Department who had an interest in artificial intelligence, neural networks, and database management systems were among those recruited.

**Toolkits:** QuenchPAD is a Quenchant Performance Analysis Database. It stores the details of the experiments performed at CHTE with the goal of characterizing quenchants. Users can retrieve experimental details by querying the database.

QuenchMiner goes a step further by promoting worldwide access to QuenchPAD information, and also by computationally estimating parameters such as cooling rates and heat transfer coefficients based on existing experimental data to enhance decision support. This promotes electronic commerce (e-business) through faster and more sophisticated information retrieval and decisionmaking.

The main aim of QuenchMiner is to provide at-a-glance information to CHTE members — materials suppliers, equipment manufacturers, auto-makers, commercial heat treating companies, universities, researchers, aerospace agencies, and others. The information helps to connect these different categories of users, assisting them in several important aspects of heat treating knowledge exchange and business decisionmaking.

**INSTITUTIONAL INITIATIVES**

- Address health and safety issues in the heat treating industry, such as risk reduction management (fire, ingestion, injuries), in-plant air quality, ergonomics, and safe limits for barium, amines, and other substances.
- Identify heat treating industry training needs in areas such as basic metallurgy and furnace safety. Identify which courses are currently available and which ones are needed to fill any gaps.
- Develop baseline emissions data for heat treating equipment to use as benchmarks for future emission reductions and to establish best practices.
- Compile baseline data on heat treating equipment energy consumption to use as benchmarks for future energy savings and to establish best practices.

*Note:* Although the Institutional Initiatives are not direct research initiatives, they are complementary and critical for advancement of Vision 2020 goals.

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**Fig. 3**—Heat transfer coefficients as a function of temperature for steel and aluminum CHTE probes quenched in various media. Fast oil has the highest heat extraction rate and nitrogen gas the lowest. Note that gas quenching performance could be improved significantly by increasing the gas pressure and by using a gas or mixture of gases having a high thermal conductivity.

**Fig. 4**—This QuenchMiner screen highlights the tool’s basic search function. In response to user-specified search criteria — in this case, “experiments conducted on part material SS304 with mineral oil T7A as a cooling medium” — QuenchMiner retrieves the experimental input conditions and results from the QuenchPAD tool.

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**Figures:**

1. Heat transfer coefficients as a function of temperature for steel and aluminum CHTE probes quenched in various media.
2. Graph showing surface heat transfer coefficients for different materials and heat treating conditions.
3. Table summarizing heat treating parameters for various metals and quenchants.
4. Screen capture of QuenchMiner tool interface.
A comprehensive database system with more than 500 materials and several widely used furnaces (CHT-bf) enable the programs to be quickly put to use.

A separate Database Manage-
ment feature helps users add new data seamlessly.

Benefits to industry: Current practice in the heat treating industry is to specify cycles based on experience and historical “rules of thumb.” A great deal of guesswork is involved, especially when working with a single load of multiple part numbers, and it certainly is not an efficient way to run a modern facility. On many occasions, cycles may be longer than necessary and parts may be soaked longer than required. Nonuniform heating of parts (due to inefficient part loading) leads to reduced yields, and the economic impact is significant.

CHT-bf and CHT-cf are the tools that allow heat treaters to simulate part heating processes inside the furnace, reducing or eliminating rule-of-thumb guesswork, increasing productivity by shortening unnecessarily long cycles, and ensuring quality at the bottom line. The following benefits are among those achieved in actual case studies:

- Cycle time was reduced by more than 20% based on system predictions.
- Alternative loads were simulated to determine an optimal load design.
- Gave a better understanding of both the fastest and the slowest heated parts for the current load pattern.

These software tools can be used in improvement/optimization of existing operations, new process design, and business quoting.

Progress in achieving the Vision 2020

This fifth and final installment in the series completes the review of work to update the 1997 Heat Treating Technology Roadmap. It focused on the Institutional Initiatives needed to achieve the Vision 2020 goals and the critical role that education — and specifically, the CHT-E virtual industry/university research center — plays in this work. These efforts will help ensure that the heat treating industry continues to grow and remain competitive in what is increasingly becoming — even for the heat treater — a more globally competitive environment.

The Heat Treating Technology Roadmap Update 2004 series of articles has included examples of research initiatives listed in the 1997 Technology Roadmap that are now implemented in production. It should give us confidence that members of the heat treating industry are actively pursuing the industry’s Vision 2020.

But much work — both technological and institutional — still needs to be done! As members of the heat treating industry it is our responsibility to understand the issues that must be resolved to achieve the Vision 2020, and to be willing to invest our own resources in achieving that vision.

Reference

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All five articles in the Heat Treating Technology Roadmap Update series, as well as the completely updated 2004 Technology Roadmap, can be accessed on the ASM Heat Treating Society’s Web page (www.asminternational.org/hts).