Electrotechnologies in Metal Heat Treating Systems—Marketing Kit

Technical Report

Electrotechnologies in Metal Heat Treating Systems—Marketing Kit

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EPRI Project Manager
L. Svendsen

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

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Taratec Corporation
1251 Dublin Road
Columbus, OH 43215

Principal Investigators
J. Wade
M. Farrell

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REPORT SUMMARY

Due to the increased demand for lighter and stronger materials and assemblies, the practice of heat treating to improve material mechanical properties is expected to expand to an even greater number of end products. This heat treating marketing kit is designed to help utility sales and marketing personnel perform a progressive analysis of electrotechnology applications in heat treating systems. The kit is designed for utility personnel who have limited knowledge of the heat treating industry and for industrial customers with limited expertise in electrotechnologies.

Background
Approximately 10,000 manufacturing facilities in the United States perform some type of heat treating process. Heat treating is an energy intensive industry, requiring approximately 500 trillion BTUs of energy per year. Electric process heating offers many advantages for efficiency and environmental improvement over more traditional gas-fired heating systems. The benefits of incorporating electrotechnologies in heat treating systems include more precise control of the heat treating process, less scale formation on heat-treated parts, lower environmental emissions, greater ability to selectively heat treat components, increased energy efficiency in the overall heat treating process, faster start up times, higher reliability and safety, and decreased labor and maintenance costs. The primary challenge lies in identifying which industries are the prime candidates for conversion to electric process heating and then employing a sales approach maximized for success.

Objective
To provide electric utility sales and marketing personnel with background information about the advantages of electrotechnology applications in heat treating systems, so they can comfortably present these opportunities to their heat treating customers.

Approach
This marketing kit is based on the accumulated heat treating knowledge within the Center for Materials Fabrication (CMF), in particular on the 15 reports the CMF has produced on this topic over the last 15 years. The marketing kit is primarily a concentration of information previously presented to member utilities, revised now to meet the needs of utility sales staff.

Results
This heat treating systems marketing kit provides

- An overview of the U.S. heat treating industry
- A description of heat treating technology and types of heat treating systems

- A method of identifying where electrotechnologies can best be applied in heat treating systems
- A complete review of the sales process, including an overview of major considerations in specifying and purchasing heat treating systems
- Suggestions for overcoming objections involving the price and availability of electricity, equipment expense, operator training, and even fear of new technology
- A reference section on heat treating technology
- A vendor list of major suppliers of electric heat treating equipment
- A glossary of basic heat treating terms

EPRI Perspective

EPRI is dedicated to helping utilities advance the use of electrotechnologies. This kit is designed to help electric utility representatives market electrotechnologies to the heat treating industry. EPRI suggests that the greatest opportunities lie in finding firms that are upgrading to higher performance specifications, replacing older equipment, or seeking to minimize environmental emissions. This kit can be used in conjunction with EPRI's Heat Treating Market Assessment (TR-111817) to provide information needed to formulate an overall marketing plan for targeting heat treating opportunities within a service territory.

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Keywords

Heat treatment
Vacuum processing
Resistance heating
Induction heating
Energy efficiency

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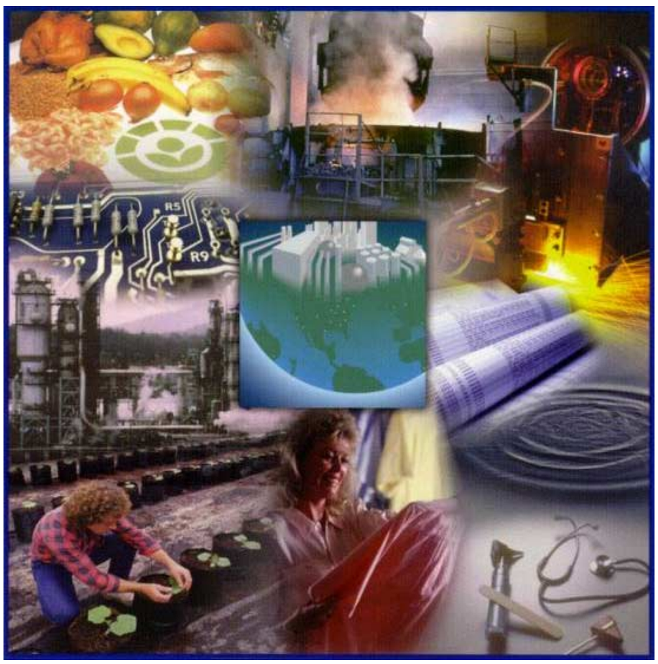


Heat treating is a major consumer of energy and a significant user of electricity. The industry is extremely diverse, both in the types of customers who heat treat and the various systems in use. The heat treating industry is an important user of electrotechnologies such as induction, resistance, vacuum processing and ancillary systems.

This section provides an overview of the U.S. heat treating industry and its potential use of electrotechnologies. It includes an analysis by commercial and captive heat treating, and a summary description of electric heating methods and technologies.

1
INTRODUCTION

How to Use This Kit

This publication is organized to aid the reader in a progressive analysis of prospects for electrotechnologies in heat treating systems. It is designed for utility personnel who have a limited knowledge of the heat treating industry.

Once a particular application for heat treating is defined, the reader is directed to follow the text through a series of inquiries that focus on that particular application. If the reader is not focusing on heat treating and is reviewing this document in order to generally become familiar with the technology, and its myriad applications, then it is best to follow the text in the sequence presented.

The kit is divided into seven major sections, briefly described below:

Introduction – provides and overview of the U.S. heat treating industry, including a description of commercial and captive heat treaters and the differences in motivation between the two segments.

Technology Description –introduces the reader to heat treating technology.

Identifying Opportunities – provides a comprehensive method of identifying situations where electrotechnologies might be used in heat treating. Beginning with a general discussion of which types of customers would be most open to electrotechnologies, it ends by presenting checklists specific to evaluating heat treating equipment purchasing decisions in both the commercial and captive heat treating segments. Along the way, it identifies SIC codes which would likely contain the more difficult to find captive heat treaters.

The Sales Process – gives an overview of the major considerations in specifying and purchasing heat treating systems. It provides a series of questionnaires and checklists that will be useful to anyone involved in purchasing a heat treating system.

References – includes useful list of books, periodicals, industry associations, and EPRI CMF publications of interest to anyone involved in heat treating. An internet web address is provided for each item listed in the section.

Vendor List – contains profiles and contact information for several major suppliers in the heat treating industry.

Appendix – heat treating is a complex subject with often confusing metallurgical and "industry" terminology used interchangeably. A glossary of common heat treating terms is provided.

Heat Treating Basics

Heat treating is a process in which metal is heated and cooled under tight controls to improve its properties, performance and durability. Heat treating may be used for a variety of purposes; it can soften metal to improve formability; it can make a part harder to improve strength; it can put a hard surface on relatively soft components to increase abrasion resistance; it can put a corrosion resistant skin on items that would otherwise corrode; and it can toughen brittle products.

Heat treated components are essential to the operation of automobiles, aircraft, spacecraft, computers, and heavy equipment of every kind. Saws, axes, cutting tools, bearings, gears, axles, fasteners, camshafts, and crankshafts all depend on heat treating to provide the properties required to perform their designed functions.

Iron and steel account for approximately 80% of heat treated materials. Alloys of aluminum, copper, magnesium, nickel and titanium are among the variety of materials that may also be heat treated.

The U.S. Heat Treating Industry

The heat treating industry is an energy intensive industry, consuming 500 trillion Btu's annually or 2.2% of total industrial energy usage in the United States. For comparison purposes, this amounts to one half of all the energy consumed nationally by the food industry. Energy accounts for approximately 20% of the cost of doing business for a heat treater. Energy efficiency and energy cost are significant concerns. Currently, the US heat treating industry employs about 140,000 people in nearly 10,000 facilities that specialize in heat treating or have heat treating capabilities as a part of their production process.

Heat treating has been perceived as a very specialized technology where metal parts enter a "black box" process and are mysteriously transformed into similar looking parts that have greatly improved mechanical properties. Although it is difficult to understand the phase transformations that occur within the part, it is not as difficult to understand the needs of the heat treating customer. What is the most efficient way to heat the part up? What can be done to minimize the environmental impact of the heat treat process? How can the customer minimize the amount of wasted energy that exhausts out the flue?

There are currently more than 50,000 heat treating furnaces and ovens in use. The overall industry growth rate has recently averaged 5 to 7 percent, however, niches exist that are currently growing in excess of 10 percent. Two high growth areas, vacuum processing and induction heat treating, are excellent electrotechnology markets. Additionally, manufacturers who are establishing their heat treating operations in-house are an especially attractive opportunity, since they are not saddled with commitments to older less efficient technologies.

Industry Importance to the Utility Industry

The opportunities for electrotechnologies within the heat treating industry are significant. Chief among the factors contributing to these opportunities is the drive for efficiencies in every area of production. Increased competition is forcing companies to rethink antiquated, inefficient processes such as those found in abundance within heat treating operations. Energy efficiencies of 15 to 40% found in fossil fired technologies are being replaced by electrotechnologies with efficiencies in the 60 to 90% range. Customers are increasingly looking to overall system costs instead of focusing solely on fuel costs.

A window of opportunity exists with customers' expectations of more favorable electric rates in the era of deregulation. Coincidentally, the heat treat industry has developed a proactive plan (ASM Heat Treating Society's Vision 2020), with ambitious goals toward reforming the industry. Electrotechnologies fit well with the plan's stated goals, and offer the highest growth potential within the heat treating field. The trends toward safety, environmental friendliness, higher quality, higher energy efficiency and more vacuum processing all favor electrotechnologies.

Though the electrotechnology market is experiencing solid growth, many sales opportunities are lost due to insufficient analysis and an aversion to change from the way it's always been done. Considerable opportunities exist for electrotechnologies in the heat treating market as customers upgrade older equipment, and look more openly to electrotechnologies in a deregulated electric utility industry.

Although many heat treaters serve the automotive sector in the Midwest, there are smaller concentrations of heat treaters within other manufacturing industries that are dispersed throughout the country. There is justification for utilities all across the country to have an interest in the heat treating industry.

General Economy

The most dominant influence on the heat treating industry is the general status of the overall economy. The heat treating industry very closely tracks the metals industry, which is a leading indicator for trends in the overall economy. Similar to most other industries, when the economy is unstable or in a recessionary lull, expansion and capital equipment purchase plans are put on hold. Capital equipment dollars are not available and any major sales effort is likely to fail. However, valuable groundwork can be laid, outlining the advantages of electric process heating and planning for potential conversion well ahead of the next economic upswing. During periods of economic growth and well being, capital dollars are available and expansion plans are being implemented. Timing is critical. If one is too late in the planning phase, it becomes extremely difficult to influence the decision to go with one heating source over another.

The recent health of the automotive sector has had a positive effect on the heat treating industry. The automotive and aerospace industries are continuously developing new materials and manufacturing processes in an effort to reduce weight and increase strength in their products. More exotic materials with requirements for higher processing temperatures and more stringent quality controls demand heating equipment capable of attaining these elevated standards. Electric process heating offers many advantages over fossil-fuel systems, including more precise temperature control and energy cost savings at higher temperatures, particularly when temperatures exceed 1800°F (982°C).

Environmental Issues

Purchasing decisions based on environmental impact are becoming increasingly common. Several pending air quality proposals, if enacted, will have a significant influence on the cost of operating fossil-fuel fired systems. The Clean Air Act of 1996 proposes the reduction of ozone, particulate matter particle size, oxides of nitrogen and volatile organic compound (VOC) emissions. Some sources suggest that the number of non-attainment zones could increase by as much as three to four times the current number. Additionally, the cost of compliance with these proposed emissions standards might reach as much as $70,000 per commercial heat treating facility.

Internal plant environmental conditions, including improved employee safety and comfort, have also moved to the forefront. Long term trends point to greater costs borne by manufacturers, particularly those in higher risk environments like those found in heat treating shops. The enforcement of OSHA regulations and other cited statutory requirements are leading to higher fines and litigation costs. These trends create significant opportunities for electric utilities. Critical work place quality issues such as safety and point-of-use emissions (air, noise, and water) are better served by electric process heating, as compared to fossil-fuel fired systems.

Commercial and Captive Heat Treaters

Commercial heat treaters are specialized establishments engaged primarily in the heat treatment of metal and metal alloys for the trade. They are also called contract heat treaters or job shops. They support manufacturers in primary metals, metals fabrication, machinery, and transportation sectors where improved mechanical properties are required. Commercial heat treaters are easily identified under SIC 3398. There are nearly 800 commercial heat treaters in the United States. A typical commercial heat treater employs an average of 30 people, has 15 to 20 heat treating furnaces or ovens at a given location, and treats a wide variety of incoming parts.

Captive heat treaters use in-house heat treating as a part of their own manufacturing process. They can be identified by knowing the metal products they produce, and understanding which of these require heat treating. Examples of captive heat treaters are manufacturers of automotive and aerospace parts, tools and dies, farm equipment, construction equipment, mining equipment, oil field equipment, medical devices and other forged and fabricated parts. There are more than 10 times the number of captive heat treaters, compared to commercial heat treaters. Estimates range from 8,000 to 10,000 captive heat treaters nationally, though manufacturers tend not to classify themselves as captive heat treaters. However, there are characteristics that define which manufacturers are likely to be captive heat treaters. Since this also means that they can be large energy consumers, their importance to energy service providers increases.

For the purposes of this report, our primary interest lies with the captive heat treater. Not only do they occupy over 85 percent of the market, they also are more likely to invest in new electrotechnologies for reasons explained later in this report.

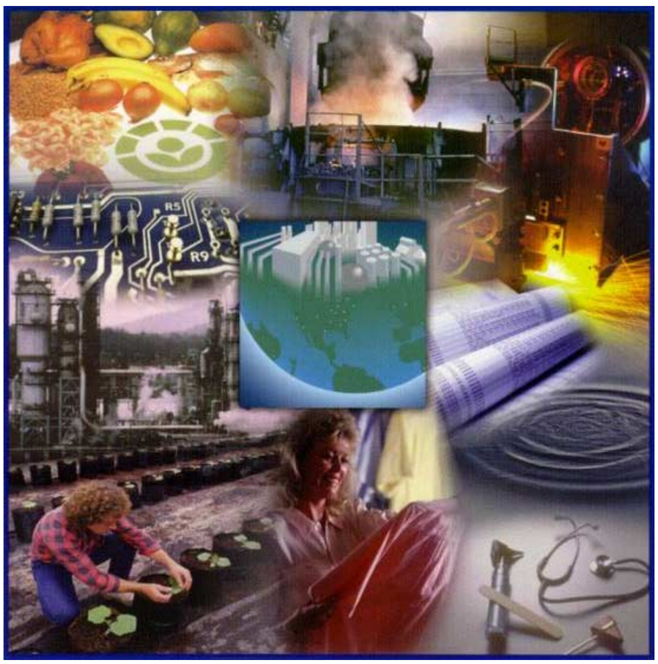
Trends

Industry sales and revenue trends are tracked by the Metal Treating Institute (MTI), a trade association representing the heat treating industry. MTI reports monthly sales figures for over 200 commercial heat treaters, which are totaled by geographic region to assure anonymity of the individual companies. The figures closely track the overall US economy, averaging 7% growth through the economic expansion of the late 1990's.

Technology trends are also affecting the heat treating industry, and are having a very positive impact on growth opportunities for electric process heating. More advanced alloys and more demanding applications are requiring more sophisticated heat treating processes. This has opened up more applications for vacuum heat treating, the highest growth segment of the heat treating industry. The application of electric process heating has dominated vacuum heat treating, specifically in direct resistance using heater elements. In fact, as the value of the finished product increases, the stronger the opportunity for electrotechnologies. Opportunities arise when the customer is demanding greater process control, higher energy efficiency, or systems that eliminate products of combustion.

The heat treating industry is a regional business. Rarely are parts shipped great distances to be heat treated. Captive heat treaters continue to streamline their operations, moving to in-line as opposed to off-site heat treating, to increase their manufacturing efficiencies. In those cases where this cannot be accomplished, parts are outsourced to commercial heat treaters. The trend toward outsourcing in the automotive industry is further complicated by labor issues. However, the net effect of outsourcing is to move the heat treating business from the captive segment to the commercial heat treat shop. Michigan’s high volume of commercial heat treaters is an indication of the significant amount of automotive heat treating business that is outsourced.

TECHNOLOGY DESCRIPTION



Electrotechnologies are very widely used in heat treating and their use is on the rise. Factors such as environmental considerations, process speed, process control and process flexibility are becoming increasingly important in equipment selection. This section details the advantages of electric systems over fossil fuel fired heat treating equipment, then discusses the considerations that are taken into account for various heat treating applications.

2
TECHNOLOGY DESCRIPTION

Heat Treating Operations Introduction

Heat treating as a technology can be very broadly defined as any process involving controlled heating and/or cooling of a work piece for the purpose of developing a given set of physical and mechanical properties. In general, this means heating the work piece to a specific temperature—well above room temperature—at which the desired metallurgical transformations occur, then holding it at that temperature for a period of time sufficient for the transformations to occur through the work piece. This is then followed by cooling at a prescribed rate to either develop additional transformed structures, or maintain the structure developed at the higher temperature. This type of heat treating process is performed when it is required that the metallurgical transformations occur completely, or nearly completely, through the entire cross section of the work piece.

Another widely used type of heat treating process is that which affects only the surface of the work piece. This generally includes hardening or some other alteration of the work piece surface while maintaining the core of the work piece in its original state. This allows the development of property combinations in one place, such as a hard, wear-resistant surface that may also be somewhat brittle with a softer, tougher body of the part. Surface treatment therefore also allows a relatively low cost base material to be upgraded into a high performance part at little additional cost.

A large number of very specific heat treatments have been developed to utilize properties in specific metals and alloys. The discussion of these process specifics requires a detailed persentation of the metallurgy of each metal/alloy system involved, i.e., low alloy steel, tool steel, stainless steel, cast iron, aluminum and the like. This is beyond the scope and intent of this report, but can be further researched using the *ASM Handbook*, Vol. 4, Heat Treating, ASM International, Metals Park, OH, 1991.

There are a number of general heat treating processes that are widely used in the commercial heat treating industry and that can be discussed in rather generic terms. These processes are performed by commercial heat treaters on a service basis, primarily for customers who do not maintain an in-house heat treating capability of their own or whose operation has reached its capacity limit. Some of the processes are quite specialized, and the commercial heat treater will serve a niche market for customers who have only occasional need for a specific process and find that it is not cost effective to maintain the capability for themselves.

For purposes of discussion, these processes can be divided into two general categories: processes that affect the entire work piece (which we will call "Heat Treatment Processes"), and processes that affect only the surface of the work piece (which we will call "Surface Treatment Processes").

Heat Treatment Processes

As stated above, the purpose of heat treating processes is to develop a desired set of mechanical properties within the work piece through the controlled heating and/or cooling of the part. Typical properties desired can be hardness, strength, toughness, ductility, reduction of area, or relief of stresses (which is not actually a "property" but a "condition"). The process usually consists of heating the work piece in a furnace or salt bath to the desired transformation temperature, holding it until the work piece comes to constant temperature and the metallurgical transformation is complete, then cooling at a controlled rate to room temperature. Different combinations of these steps are used for different metals. The most common will be described below.

Stress Relief

Many parts develop residual stresses while undergoing their various manufacturing steps. Examples are forged parts and metal castings as they are removed from the mold. These residual stresses reduce the ability of the part to perform its function to the design stress loading. The residual stresses can also contribute to, or actually cause, cracking and/or warping and distortion of the part.

These stresses can be removed by a heat treatment called "Stress Relieving", which can be defined as heating to a suitable temperature, holding long enough to reduce residual stresses, then cooling slowly to minimize the development of new residual stresses. Stress relief can be performed on any metal and is frequently used with steel parts. In steel, even rather innocuous processing steps such as repair welding and grinding can introduce significant residual stresses and stress relief is often employed subsequent to these steps.

The degree of stress relief achieved is a function of both time and temperature. For example, at a stress relief time of one hour, processing at a temperature of 752^{o}F (400^{o}C) will reduce 50 percent of the residual stresses, while processing at 1292^{o}F (700^{o}C) will reduce 90 percent of the stresses. At the same temperatures, but with a processing time of 6 hours, the reductions are 60 percent and 98 percent respectively.

Annealing

Annealing is a generic term describing a treatment that consists of heating a work piece to, and holding it at, a suitable temperature followed by cooling at an appropriate rate, primarily for the softening of metallic materials. In plain carbon steels, the metallurgical microstructure developed is known as a ferrite-pearlite structure. Steels may be annealed to facilitate cold working or machining, to improve mechnical or electrical properties, or to promote dimensional stability. The basic process is illustrated in schematic fashion in Figure 2-1. In practice, a steel work piece is first heated to a temperature, usually around 1600°F (871°C), that will transform the entire work piece to a structure called austenite, and held at this temperature until the entire piece is transformed and at uniform temperature. The precise time required can be determined by actual measurements or computer simulation. However, a widely used rule-of-thumb is a time of one hour per 1 inch (2.54 cm) of section thickness. This is usually quite conservative.

The work piece is then slowly cooled to room temperature, frequently in the furnace. The cooling rate may be controlled by a programmable control system, but the furnace is often simply shut off and allowed to cool on its own.

Annealing can be performed as either a batch process or a continuous process. The equipment used for these two different applications will be covered in later sections of this report.

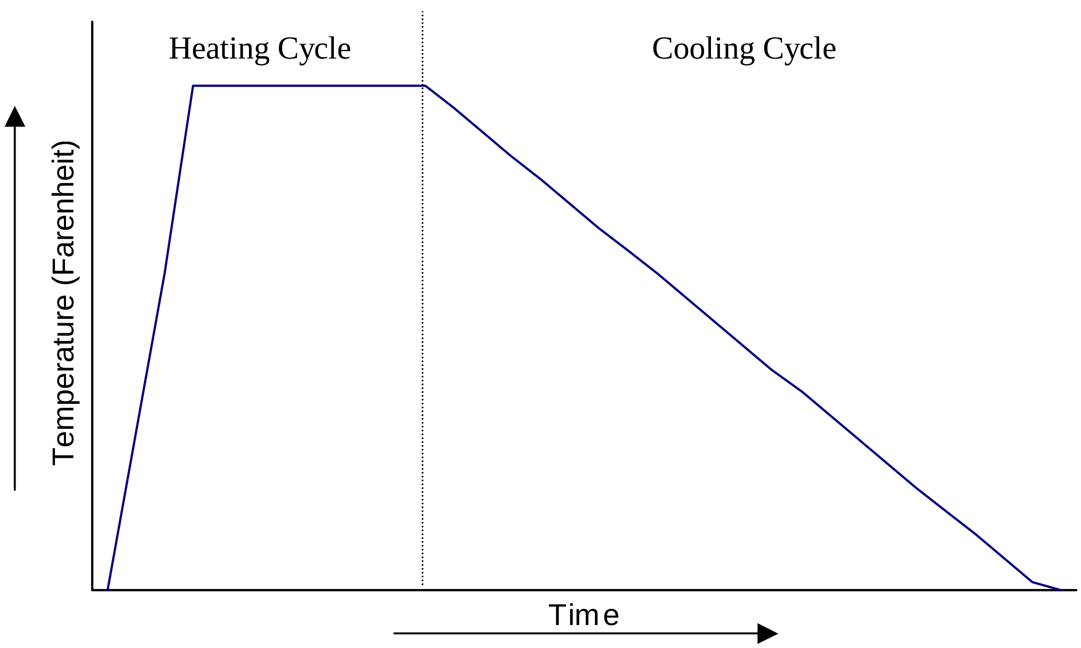


Figure 2-1
Annealing

For reasons of efficiency and productivity, it is adventageous to heat the work piece no longer or hotter than required to achieve the desired microstructure. Annealing processes can also be performed on other metals, but at different temperatures. Information on the tempertaures appropriate for each alloy system may be found in Vol.4 of the ASM Handbook.

Normalizing

Normalizing is a steel heat treating process that consists of heating the work piece to a temperature high enough to produce astenite, holding until the entire piece is transformed, then cooling in still or slightly agitated air. The difference between normalizing and annealing is in the cooling rate; air cooling is much more rapid than furnace cooling. This is illustrated schematically in Figure 2-2.

The faster cooling rate gives the resulting ferrite-pearlite structure a finer grain size, tending more toward pearlite as the alloy and carbon content increase. This in turn provides a more uniform structure that is harder, stronger and tougher than an annealed structure.

The cooling process can be quite sophisticated or very crude, depending on the operation. Often, work pieces are simply removed and allowed to stand on the shop floor, cooling by radiation and convection to the shop atmosphere. Large work pieces are often austenitized in furnaces with movable furnace bottoms resembling "cars"; the cars are moved outside and allowed to cool, again by convection and radiation, to the outside atmosphere. It is obvious that either of these approaches can produce variable results due to significant differences in atmospheric conditions. For example, outside cooling conditions in Milwaukee could range from -15^{o}F (-26^{o}C) to $+100^{o}$F (37^{o}C) during a given year—not very conducive to tight process control. The most convenient approach is to move the work pieces from the furnace to a sheltered location and cool them with forced air under controlled temperature and air flow conditions.

A specific beneficial application is the normalizing of steel castings. As the casting is removed from the mold in the as-cast state, considerable segregation of alloy elements persists, along with residual stresses. A normalizing treatment automatically reduces the stresses and also allows re-distribution of alloy by diffusion and dissolution, resulting in a more uniform structure. In the case of very complex or heavy section products, a double normalize treatment is often employed. The normalizing treatment in steel casting production can significantly reduce cracking problems in the cleaning and finishing operation, and is cost effective from this standpoint alone.

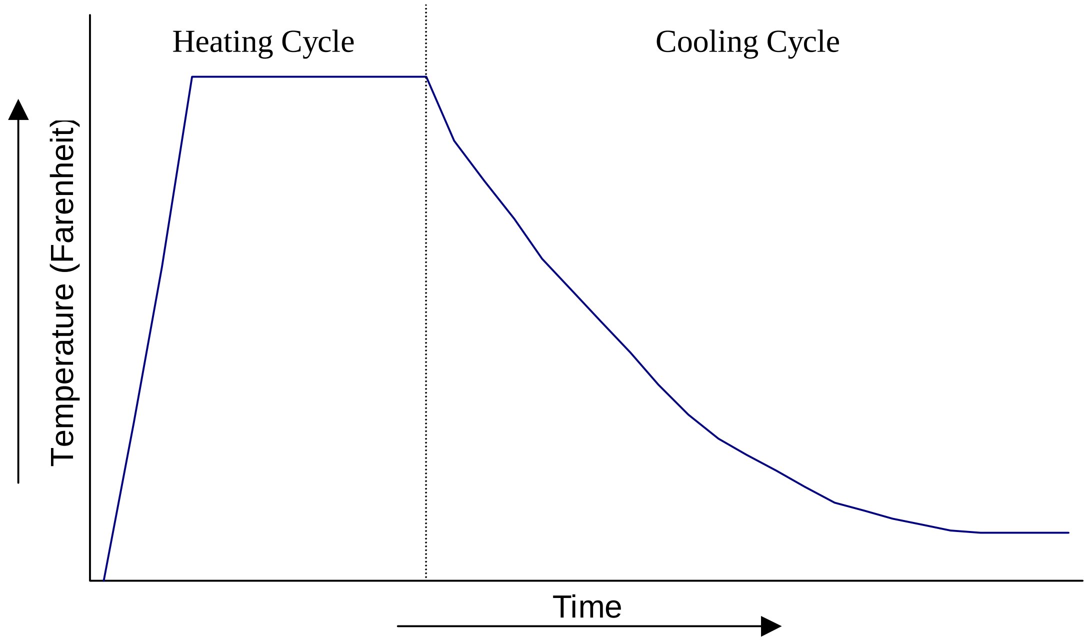


Figure 2-2
Normalizing

Quenching

Quenching is the process of rapidly cooling the work piece from the austenitizing (or, in the case of aluminum or stainless steels, solutionizing) temperature. The quenching usually takes place in a water, oil or polymer bath. Gaseous quenchants are also used.

Most carbon, low-alloy and tool steels are quenched for the purpose of producing controlled amounts of martensite, a microstructural component that hardens the workpiece. Stainless and high alloy steels may be quenched to minimize the presence of grain boundary carbides or to improve the ferrite distribution in the microstructure.

The selection of the quenching medium depends on the ability of the work piece material to be hardened (called hardenability), the section thickness and shape of the part, and the cooling rates required to develop the desired microstructure. Liquid quenchants include:

- Oil
- Water
- Aqueous polymer solutions
- Water containing salt or caustic additives

Gaseous quenchants include helium, argon and nitrogen. These are often used in conjuction with austenitizing in a vacuum.

A number of variations of the process exist. However, the basic schematic representation of the quenching process is presented in Figure 2-3. Common variations are listed below and are covered in detail in the *ASM Handbook,* Vol. 4, Heat Treating, Chapter: Quenching of Steel, ASM International, Metals Park, OH, 1991.

- Direct quenching
- Time quenching
- Selective quenching
- Spray quenching
- Fog quenching
- Interrupted quenching

The type of quenchant and the quench bath's degree of agitation are extremely important in the development of the part's desired properties.

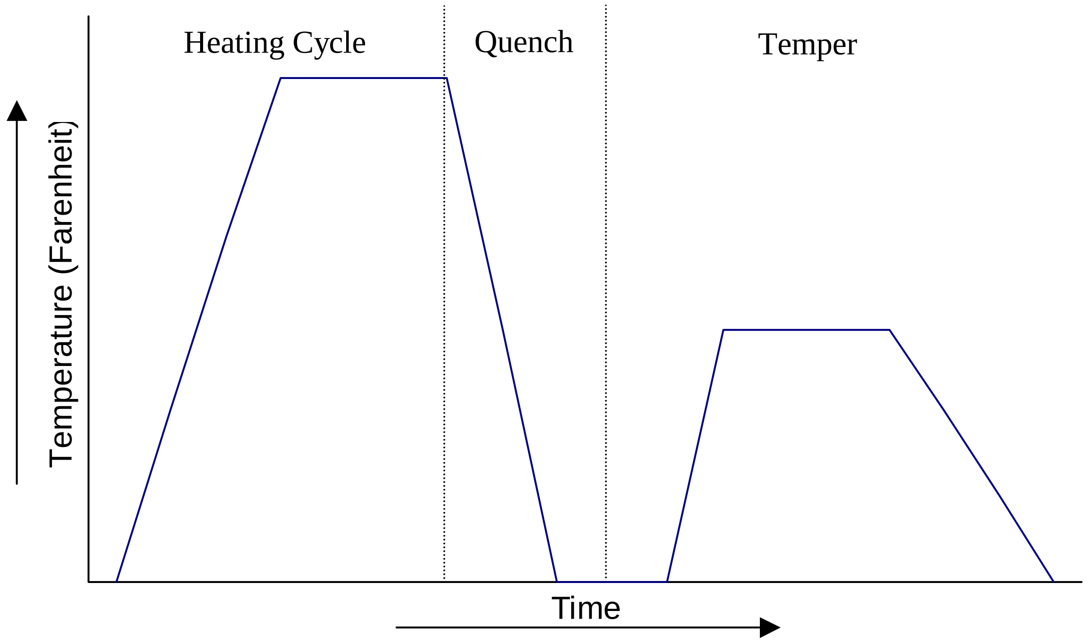


Figure 2-3
Quenching and Tempering

Tempering

Tempering is defined as a process in which a previously hardened (quenched) or normalized steel is heated to a temperature below the lower critical temperature and then cooled at a rate that will increase ductility, toughness and grain size. The process is illustrated schematically in Figure 2-3.

Principal variables that determine the microstructure and properties of the tempered part are:

- Tempering temperature
- Time at temperature
- Cooling rate from tempering temperature
- Composition of the steel, particularly the carbon and alloy content

Tempering can be performed in a wide variety of equipment, including:

- Convection furnaces
- Salt bath furnaces
- Oil bath furnaces
- Molten metal baths
- Induction equipment

Process control, particularly temperature control, is critical for proper tempering. Not only does temperature determine resulting microstructure and properties, incorrect temperatures can cause embrittling of the steel with the resultant loss of ductility in the part. This can lead to catastrophic failure in the part and must be avoided.

Martempering

Martempering is a form of heat processing that involves an interrupted quench from the austenitizing temperature with certain alloy, cast, stainless and tool steels. The purpose is to delay the cooling just above the martensitic transformation for a long enough period to achieve uniform temperature throughout the work piece. This will minimize distortion, cracking and residual stress.

The process involves quenching into a hot medium, such as hot oil or molten salt, to a temperature above the martensite range. The part is held at this temperature until the part essentially comes to a constant and uniform temperature. The part is then air cooled at a moderate rate to prevent large temperature differences between the center and surface of the part. The resulting martensitic structure is then generally tempered as described above.

Austempering

Austempering is defined as the isothermal transformation of a ferrous alloy at a temperature below that of pearlite formation and above that of martensite formation. The resulting structure is a material called Bainite, somewhat similar to extremely fine pearlite. Advantages are:

- Increased ductility, toughness and strength for a given hardness
- Reduced distortion
- Shortest overall cycle time to through-harden

Process steps are:

- Heat part to a temperature within austenite range of 1450 to 1675^{o}F (788 to 913^{o}C)
- Quench to constant temperature bath of 500 to 750^{o}F (260 to 399^{o}C)
- Allow to transform isothermally (at constant temperature) to Bainite
- Cool to room temperature

The most common quenching medium is molten salt because:

- It transfers heat rapidly.
- It eliminates vapor barrier formation (as with oil and water).
- Viscosity is uniform over a wide temperature range.
- It remains stable at operating temperature.

- It is water soluble, facilitating part cleaning.
- Salt can be recovered from the wash water by evaporation.

Surface Treatment Processes

Surface hardening refers to a group of processes used to improve a part's wear resistance without affecting its softer, tougher interior. This combination of surface hardness with a soft, tough matrix is very useful for parts such as gears, where the surface is resistant to wear during continuous operation while the tough core resists impact loading at start and stop of the device. Further, as previously mentioned, surface treatment allows the use of lower cost, less hardenable matrix material while still obtaining the desired wear characteristics.

There are two distinctly different generic methods to achieve this goal:

- Intentional addition or build-up of new wear layer
- Surface or sub-surface modification without addition of new layer

The first group includes coatings, thin films, weld overlays and the like. These are not considered heat treating processes and will not be covered in this report.

The second group will be further subdivided into two groups: diffusion methods and selective hardening methods. These will be discussed below.

Diffusion Methods

Diffusion methods of surface hardening employ techniques that modify the chemical composition of the work piece surface by the addition of some hardening species such as carbon, nitrogen or boron. Diffusion methods allow the entire surface of the work piece to be modified and are frequently used when a large number of parts are to be processed. Common diffusion methods are:

- Carburizing
- Nitriding
- Carbonitriding
- Nitrocarburizing
- Boriding
- Titanium-carbon diffusion

Carburizing

Carburizing is the addition of carbon to the surface of a low-carbon steel work piece. This is usually done when the temperature of the work piece is between 1560 and 1740^{o}F (849 and

949^{o}C), where the stable metallurgical phase is austenite (which has a high solubility for carbon). Hardening occurs when the part is subsequently quenched to form a high-carbon martensitic microstructure on the surface, combined with a tough, low carbon steel core.

Case hardness is a function of case carbon content, up to about 0.50 percent carbon. Since this is a diffusion process, case depth is a function of carburizing time and the amount of carbon present in the carburizing medium (carbon potential). The greater either or both of these parameters, the greater the case depth. The base steel usually has a carbon content of approximately 0.2 percent and the case carbon is controlled to 0.8 to 0.9 percent. Quenching is performed as described above, with considerable care taken to minimize distortion and cracking.

A number of methods for introducing the carbon into the work piece surface are used, as listed below:

- Gas carburizing
- Vacuum carburizing
- Plasma carburizing
- Salt bath carburizing
- Pack carburizing

Gas carburizing involves surrounding the parts with a carbon-containing gas atmosphere that can be continuously replenished so that a high carbon potential can be maintained. This method provides a high rate of processing, however, close control of the atmosphere is necessary to acquire reproducible results and to avoid metallurgical problems such as surface and grain boundary oxide formation. Gas carburizing has become the most effectively and widely used carburizing process for commercial heat treating establishments.

To avoid the problem of oxygen in the carburizing atmosphere, vacuum carburizing is utilized. Although the equipment is more complex, a simple one-component gas atmosphere such as methane can be used, greatly simplifying control. Further, in the absence of oxygen, higher carburization temperatures may be employed without the problem of grain boundary oxide formation. The high temperature allows higher case carbon contents to be achieved in less time.

Plasma carburizing also utilizes a simple gas atmosphere, with the energy being provided by an electrical plasma. The plasma can greatly enhance the carburization rate. For example, with the use of methane (CH_4), carbon can be absorbed by the work piece directly from the gas. Also, since the process uses an oxygen-free atmosphere, higher processing temperatures can be utilized, resulting in higher carburizing rates.

Liquid (salt bath) carburizing is a process for case hardening steel by holding the work piece above the Ac (austenitizing) temperature in a molten salt bath that can introduce carbon (or carbon and nitrogen) into the work piece surface. The carbon rich surface layer (case) is then hardened by quenching. The physics of the process are similar to gas carburizing. However, the use of the liquid salt bath results in shorter processing times due to better heat transfer characteristics between the work piece and the salt bath.

Most liquid carburizing baths contain cyanide, which introduces both carbon and nitrogen into the work piece. There is one type of bath, however, that provides only carbon when this is desired. Liquid carburizing (or cyaniding) can be performed at low temperatures of 1550 to 1650^{o}F (843 to 899^{o}C) or high temperatures of 1650 to 1750^{o}F (899 to 954^{o}C). Higher temperatures provide shorter process times and rapid carbon penetration. Typical liquid carburizing salts that are used in various combinations are:

- Sodium cyanide
- Barium chloride
- Salts of other alkaline earth metals
- Potassium chloride
- Sodium chloride
- Sodium carbonate

Because of the toxic nature of the cyanide compounds involved, special safety precautions are required for use and disposal.

Pack carburizing is a process that involves heating the work piece while it is surrounded by a solid carbon-providing material, such as carbon powder. This was the original carburizing process, but it is extremely slow and has been largely replaced by the processes listed above. The physics of the process, however, are the same.

Another process sometimes used for carburizing is the fluidized bed process, where the carbon-providing gaseous atmosphere is also used as the fluidizing gas. Again, the thermo-chemistry of the process is the same, but the intimate contact and excellent heat transfer characteristics of fluidized bed processes enhance the reaction kinetics.

A summary of processes offered by commercial heat treating establishments in North America is presented in Table 2-1.

Table 2-1
Processes Offered by Commercial Heat Treating Establishments

Processes Offered	Percent Offering
Gas atmosphere carburizing	48
Pack carburizing	19
Salt carburizing (liquid)	12
Fluid bed carburizing	5
Vacuum carburizing	2
Ion carburizing	1

Nitriding

Nitriding is a surface treatment that introduces nitrogen into the work piece surface at temperatures of 930 to 1020°F (499 to 549°C), at which point the steel is in the ferritic condition. Nitriding is therefore similar to carburizing except for two major differences:

- Nitrogen is added rather than carbon
- The steel is in the ferritic state rather than the austenitic state

Because the nitriding occurs with the steel in the ferritic condition, a quench to transform austenite to martensite is not required. This, in turn, greatly reduces distortion and the development of residual stresses in the work piece. While the mechanisms involved in hardening by nitriding are not well understood, it is generally accepted that the hardness is developed by the formation of an inter-metallic compound Fe_3N, often called "epsilon". It is also believed that some solid solution strengthening below the case is also achieved by diffusion of some of the nitrogen into the core material.

The processes used for nitriding are essentially the same as described above for carburzing. Approximately 30 percent of commercial heat treating establishments offer nitriding services. A breakdown is shown in Table 2-2, with some companies offering more than one type of nitriding service.

Table 2-2
Nitriding Services Offering

Processes Offered	Percent Offering
Gas nitriding	21
Salt bath nitriding	7
Fluidized bed nitriding	6
Plasma nitriding	5

Other Diffusion Processes

A number of other diffusion processes have been developed for specialized applications. The diffusion of both carbon and nitrogen can be accomplished, usually in a salt bath, with the steel in either the austenitic or ferritic state. These processes are carbonitriding, austenitic nitrocarburizing and ferritic nitrocarburizing. These processes have higher processing temperatures than conventional nitriding, but they offer the advantage of the ability to use cheaper, low carbon steel.

Boriding involves the diffusion of boron into the work piece surface to increase both hardness and wear resistance. This treatment is often applied to tool steels that have already been hardened by heat treatment.

Titanium-carbon diffusion is a vapor disposition/diffusion process that results in a very hard layer of titanium carbide in the work piece surface. This process is also frequently used for tool steels that have been previously hardened.

Selective Surface Hardening

Flame Hardening

Flame hardening consists of heating the surface of the work piece into the austenite range with oxy-gas or oxy-hydrogen torch equipment, then immediately quenching. The resulting structure consists of a hard surface layer of martensite over a tougher, ferrite-pearlite core. Since no carbon or nitrogen is added to the surface by this process, the carbon content of the work piece must be high enough to develop the desired hardness.

This process can be used for both general and localized surface hardening. It has become a very common process for selectively hardening areas of parts—gear teeth, for example—and can be highly automated.

Induction Hardening

Induction hardening involves heating the work piece into the austenitic range by placing the part in the magnetic field generated by high-frequency alternating current flowing through an inductor. The part is then quenched. The process is extremely versatile and can be used for uniform surface hardening, localized surface hardening, tempering and thorough hardening. The depth of heating is inversely proportional to the frequency, consequently very precise case thickness can be developed.

Laser Surface Treatment

The laser process utilizes selective heating by a laser to austenitize the localized area. This is followed by cooling by conduction to the surrounding work piece (self-quenching) to develop the hardened case. The process can also be extended to localized melting and alloying, and consequently is quite versatile with respect to properties developed.

Electron Beam (EB) Hardening

Electron beam hardening is similar to laser hardening. The EB process uses a concentrated beam of high-velocity electrons as the energy source for heating. The electron beam is generated by an integral electron gun. The beam size and energy level can be precisely controlled, giving a great deal of versatility to the process. The austenitized area is self-quenched by the remaining mass of the work piece.

Ion Implantation

Ion implantation is a specialized process where ions with very high energy, usually nitrogen, are driven into the work piece. Cases developed are very hard and shallow and applications include cutting edges of razor blades and knives, as well as tool steel working surfaces.

Heat Treating Equipment

Types of Heat Treating Furnaces

Batch Furnaces

Batch furnaces are normally loaded and unloaded manually and the work processed in discrete units called batches. Batch furnaces generally consist of an insulated furnace chamber usually supported by a steel frame, a heating system (gas, oil, electric), and one or more access doors. Batch furnaces come in various configurations such as box, bell, elevator, car bottom and pit, each named after their shape and loading arrangement.

Since these furnaces are generally loaded and unloaded manually, the high labor costs associated with this process must be taken into account when selecting a heat treating process. Consequently, these furnaces are used for low volume production. Typical applications include:

- Special parts that would be difficult to handle automatically with a conveying system
- Large parts in small quantities, such as steel castings and weldments
- Various parts that require different heat treating cycles and frequent cycle changes

The box-type furnace can be equipped with mechanized work handling systems, integral quench tanks, slow cooling chambers (for annealing) and sophisticated controls to convert it into a very versatile, semi-continuous furnace.

The "car bottom" furnace is a large box furnace in which the furnace floor is a movable car that runs in and out of the furnace for loading and unloading. This type of furnace is particularly useful for normalizing of large castings, where the entire car bottom with the casting can be quickly removed from the furnace and air cooling can be applied.

The elevator furnace is similar to the car bottom furnace except that the car runs under the furnace and is then raised into place by a motor-driven mechanism. This type of furnace is adaptable to very rapid cooling of large loads with minimum labor involvement.

Bell type furnaces are "bells" or "retorts" that can be moved into place and lowered over a stationary work piece.

Pit furnaces are just what the name implies, deep heated pits in the floor of the shop. These furnaces are particularly suited for the heat treatment of long parts that must be heat treated in a vertical orientation. Typical applications include shafts, tubes and rods. Since these furnaces are loaded from the top by overhead crane, sufficient head room must be available.

Continuous Furnaces

Continuous furnaces consist of the same components as batch furnaces: insulated chamber, heating system and access doors. However, these units are designed to operate on a continuous basis with uninterrupted heat treatment cycles as the work pieces move continuously through the furnace. Consequently, these furnaces are generally used for high volume work and are often highly automated.

Furnaces can be either of the rotary hearth or straight-chamber type. Rotary hearth type furnaces are generally of a single chamber type and are utilized where a single heat treatment is required from each furnace. These are often loaded/unloaded manually as well.

Straight chamber furnaces are of various types classified by the type of work piece movement method as follows:

- Pusher-type furnaces
- Walking-beam furnaces
- Conveyor-type furnaces
- Tumbling or inertia movement furnaces

These types of furnaces allow several separate working chambers to be included through the travel length of the work piece and allow an almost infinite combination of heating, quenching, carburizing and the like to be performed on a continuous basis. Details of operation of these types of furnaces, and combinations thereof, are beyond the scope of this report but are very well documented in the *ASM Handbook*, Vol. 4, Heat Treating, Chapter: Types of Heat-Treating Furnaces, ASM International, Metals Park, OH, 1991.

Direct Fired Furnaces

With direct fired furnaces, the work is exposed to the combustion products, usually referred to as the flue gasses. Oil, natural gas and propane are the common fuels.

In order to minimize scaling (oxide formation) of the work piece surface, the composition of the flue gasses can be controlled by adjusting the fuel/air ratio of the combustion process. Although these adjustments can be made manually (and all too frequently are), it is strongly recommended that automatic fuel/air controls be used. Not only will scaling be minimized, but the furnace will be operated in a more fuel efficient manner.

Advantages of fuel fired furnaces are:

- Lower energy cost

- Easy to adjust input fuel
- Recuperator heat-saving devices easily added
- Faster heat-up time from cold start

Disadvantages of fuel fired furnaces include:

- Extensive ventiliation system required
- Potential explosion or fire hazard
- More manpower for start-up and shut-down required
- Air/fuel adjustment difficult to maintain
- Some alloys cannot be run in fuel fired furnaces due to oxidizing atmosphere

Electrically Heated Furnaces

Electric resistance heated furnaces are widely used in the forging and heat treating industries in all temperature ranges. They can be used for low temperature tempering and stress relieving operations all the way up to heating of forge stock for subsequent forging operations. The first type utilizes resistance heating elements such as Nichrome wire or silicon-carbide elements placed on the roof and side walls of the furnace chamber. Heating takes place by both convection and radiation. The second type employs resistance elements that are encased in a protective tube to isolate them from the various furnace atmospheres that may be used. Specialized, high-temperature resistance furnaces use elements of platinum, platinum-rhodium and even graphite to achieve temperatures in the range of 3000^{o}F (1649^{o}C) and above. Detailed information on resistance heating elements can be found in the *ASM Handbook*, Vol. 2, Tenth Edition, ASM International, Metals Park, OH.

Advantages of electrically heated furnaces are:

- Systems are clean and free of pollution as in gas furnaces
- Cooler plant environment; better worker acceptance
- Quiet operation
- Uniform heating pattern
- No exhaust system required
- Does not require flame control safety system

Disadvantages of electrically heated furnaces are:

- Inflexible to changing heating capacity
- High initial equipment cost
- Demand control system necessary for multiple furnace operation
- Generally higher operating costs
- Slower heat-up and cool-down
- Nonmetallic elements become brittle with age; high replacement cost

Radiant Tube Furnaces

Radiant tube furnaces are heated by a series of heat resistant, high-alloy steel tubes that are internally heated by products of combustion or electricity. Radiant tubes are used for applications where the furnace atmosphere would not allow direct exposure to the heating elements, or where products of combustion (flue gasses) could not be tolerated.

Salt Bath Equipment

As previously described, salt baths are used for a wide variety of heat treating operation, including hardening, liquid carburizing, liquid nitriding, martempering and austempering. Heat transfer is by conduction and is very efficient, resulting in shortened heat treat processing times. For example, a one-inch (2.54 cm) diameter steel bar can be heated to a uniform temperature in a salt bath in four minutes, while it would take 20 to 30 minutes in either a conventional radiation or a convection furnace. Additionally, salt baths are extremely energy efficient with approximately 93 to 97 percent of electric power consumed in a covered salt bath unit going into the work piece. This compares to about 60 percent in atmosphere furnaces.

Externally Heated Furnaces

Externally heated salt bath furnaces are essentially metal pots that are heated from the outside with gas or oil flames, or electric resistance heating elements. Better units use a single-piece, pressed low-carbon of iron-nickel-chromium alloy steel pot. Cheaper units use welded pots. Gas fired pots range in size up to 35 inches (88.9 cm) diameter by 30 inches (76.2 cm) deep and are about 0.4 inch (1.016 cm) thick. Electrically heated pots are generally smaller.

Gas fired units are generally less expensive to both purchase and install. Self-cooling burners are generally arranged to fire tangentially around the exterior of the pot to heat the salt. As with all fuel fired processes, the products of combustion (flue gases) must be handled. Electric units do not require venting, but elements are subject to destruction if a leak in the pot occurs.

Pot service life is dependent on operating temperature, as shown in Table 2-3.

Table 2-3
Service Lives of Salt Pots

Operating Temperture (°F/°C)	Service Life (months)
1550 / 843	9-12
1600 / 871	6-9
1650 / 899	3-6
1700 / 927	1-3

Temperature of the salt is measured with a suitable thermocouple and pyrometer. All external heated units should be started slowly at low heat input until the salt begins to melt around the top. The rate of heating can then be increased. *Excessive heating rates during start-up can result in pressures great enough to expel salt from the pot, creating a severe safety hazard.* The pot should also be covered during this period.

Advantages of externally heated salt pots are:

- Can be restarted easily; good for intermittent operations
- Pots can be easily changed to vary salt composition
- Lower operating costs

Disadvantages include:

- More difficult to control temperature
- Flue gas exhaust system required
- May overheat during start-up, creating safety hazard
- Not practical for continuous operation
- High maintenance cost

Immersed-Electrode Furnaces

Immersed-electrode furnaces are essentially ceramic pots heated with water-cooled electrodes installed over the side of the pot and immersed in the salt. These units have extended the useful capacity of the process and exhibit the following advantages:

- Electrodes can be replaced without emptying furnace
- Electrodes can supply more power, increasing productivity
- Permit easy, safe start-up

A variation of this design utilized completely submerged, bottom electrodes that are even more energy efficient.

Fluidized-Bed Equipment

In recent years, fluidized-bed equipment has been applied to heat treating operations. Although fluidized-bed equipment has been used in the minerals processing industries for many years, it is only recently that the quality of refractories has been increased to allow the operation of fluidized-beds at the high temperatures required for heat treating.

In this process, a bed of dry, finely divided particles is made to behave like a liquid by a moving gas fed upward through a difusor into the bed. In heat treating applications, the bed material is typically aluminum oxide. Although the simple description accurately defines a fluidized-bed, the physics of the process are extremely complex and multi-variable in nature. For additional information, the interested reader is referred to "Controlled Fluidized Beds for the Heat Treatment of Metals", *Heat Treatment of Metals*, R.W. Reynoldson, University of Aston in Birmingham, 1976.

A very important characteristic of fluidized-bed heating is high-efficiency heat transfer. The turbulent motion and rapid circulation of bed particles provide a heating efficiency comparable to that of a salt bath. Because of the intimate contact between the work piece and gas atmosphere, very efficient controlled atmosphere processes can be carried out in this process. Processes such as carburization, decarburization, nitriding and the like are routinely performed.

Vacuum Furnaces

Vacuum heat treating involves processes where the work is heated in furnaces evacuated to partial pressures that are compatible with the material being treated. The vacuum is substituted for the more common heat treating atmospheres for all or part of the heat treating cycle. A wide variety of furnace types and configurations are commonly in use and offer the following advantages:

- Prevents surface reactions such as oxidation and decarburization, resulting in clean work piece surfaces
- Removes surface contaminants such as oxide films and residual traces of lubricants from fabricating operations
- Can add substance to surface (as in carburization)
- Removes dissolved gasses from metals (as in hydrogen from titanium)
- Removes oxygen diffused on metal surfaces
- Join metals by vacuum brazing or diffusion bonding

Vacuum heat treating furnaces are usually heated by electric resistance elements, with the ore refractory metals such as platinum and tungsten used in higher temperature furnaces. Metallic shielding of these elements is common to insure adequate element life. Vacuum furnaces can also employ gas quenching to provide a great degree of process versatility. Vacuum systems are usually of either a combination mechanical/vapor pump type or an oil vapor diffusion type. Equipment details can be found in the *ASM Handbook*, Vol. 4, Heat Treating, Chapter: Heat

Treating in Vacuum Furnaces and Auxillary Equipment, ASM International, Metals Park, OH, 1991, and in the CMF TechCommentary *Vacuum Furnaces for Heat Treating, Brazing and Sintering*, EPRI Center for Materials Fabrication, 1999, TC-113555.

Induction Heat Treating Equipment

Induction heat treating is rapidly gaining predominance for heat treating of localized areas and high production applications. The process can be used for surface hardening and termpering applications, through hardening and tempering applications, and annealing. The commercial heat treating industry particularly has accepted the process for the surface hardening and tempering of gears, shafts, valves, machine tools, and hand tools.

Induction (actually electromagnetic induction) heating relies on electrical currents that are induced internally in the work piece material. These so-called eddy currents dissipate energy and bring about heating. The basic components of an induction heat treating system are an induction coil, an alternating (ac) power supply, and the work piece itself. The coil can be configured to heat specific areas of the work piece and is connected to the power supply. The flow of current creates an alternating magnetic field that intersects the work piece, inducing eddy currents and therefore heating in the work piece. Careful selection of coil design and power supply frequency allow very precise control of heating depth.

There are several differences between induction heating and traditional heating techniques. Most important is that induction heat is generated within the work piece. In furnaces, on the other hand, heat produced by burning fuel is transported through the furnace atmosphere via convection and radiation. Because heat is generated internally, induction processes do not require a furnace enclosure or large working area.

The most important equipment parameters are coil design, power supply frequency and applied power density. Solenoidal coils are easily designed for round parts. For more complex parts, design procedures are described in textbooks and provided by suppliers.

Power supply frequency is determined by material, part size and requirement for through or surface hardening. Low frequencies provide deep penetration; high frequencies are used for surface heating. Power density must also be selected to be appropriate for part size. Design parameters are available in *Induction Tempering*, TechCommentary, EPRI Center for Materials Fabrication, 1985, TC-102573, V2-P3, and *Technology Guidebook for Electromagnetic Induction Heat Treating Processes*, EPRI Center for Materials Fabrication, 1998, CR-107876.

Quenching Equipment

Quenching equipment requirements vary widely depending on the application. A complete quenching system can include any or all of the following:

- Furnace
- Quench tank
- Facilities for handling quenched parts
- Quenching medium
- Agitation equipment
- Heaters and coolers
- Pumps with filters
- Quenchant supply tank
- Ventilation equipment and fire extinguishing equipment
- Provisions to remove scale from quench tank

Quenching medium is selected on the basis of ability to extract heat from the work piece at the proper rate. Common quenchants are:

- Water
- Aqueous brine solutions
- Aqueous caustic solutions
- Oils
- Aqueous polymer solutions

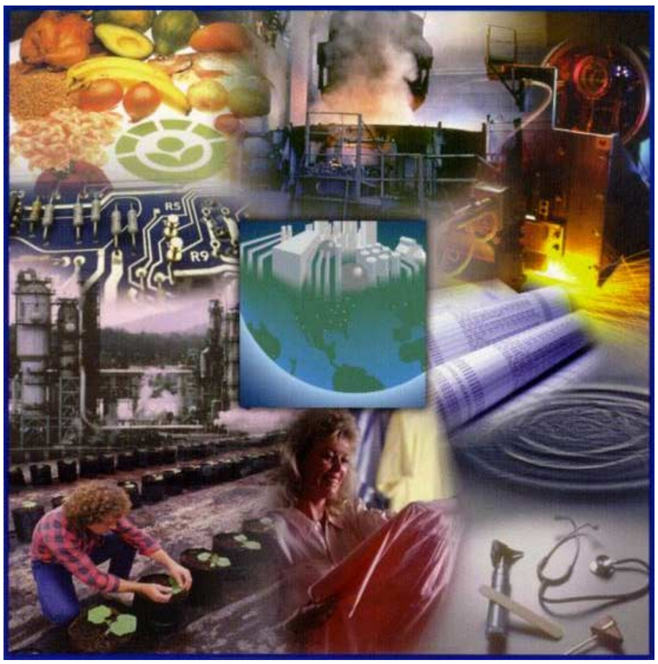
Less commonly used media include molten salts, molten metals, gases, fogs, sprays and the like.

In addtion to the properties of the quenchant, another important parameter is the degree of agitation of the quenchant. Various agitation methods are used, with the most common being:

- Pumps
- Mechanical or manual movement of work piece through quenchant
- Passage of work piece through quenchant
- Mechanical propellers

While all of the above methods can provide adequate agitation, it is important to measure degree of agitation (as flow velocity) and insure that it is adequate for the application.

IDENTIFYING OPPORTUNITIES



To identify an opportunity for using electrotechnologies in heat treating, one must first understand the nature of the business and capital investment decisions facing heat treaters. Then one must identify a specific company, qualify it as a prospect for an electrotechnology, and analyze the situation in detail. This section discusses those activities at length and provides tools for applying these methods in the real world. Proceeding from the general to the specific, it ultimately introduces the reader to a step-by-step analysis for evaluating heat treating opportunities.

3
IDENTIFYING OPPORTUNITIES

Background

For each workpiece to be heat treated, there are a variety of means to accomplish the heat treatment. Sometimes, the selection of an optimal process is not straightforward. In the case of captive heat treaters, the parts tend not to vary much, meaning that the process selection can be made with fewer compromises. Commercial heat treaters however, even though they may own a number of different types of furnaces, must always balance the variety of parts to be heat treated in the "optimal" process, with the business needs to use their furnaces most efficiently. In either case, these decisions are based primarily on the economic and performance considerations of their own equipment. Since heat treating equipment is considered a significant capital expenditure, furnace purchase decisions tend to stand for many years.

To identify an opportunity, one must first identify a need. The focus of this section is how to uncover those needs that may not be readily apparent at a commercial or captive heat treater.

Capital Investment Decisions

Adding or replacing heat heat treating equipment is a capital investment – an expenditure of hundreds of thousands of dollars on equipment that will last for many years. In addition to identifying a customer's need for a new furnace, the utility representative must also be knowledgeable about the availability of capital to that customer, the expected financial rate of return, and any other external factors such as new environmental regulations, competition and so forth. In short, the utility representative must truly know the customer, or risk the possibility of losing an electrotechnology opportunity with that particular customer.

Opportunities Defined

The suitability of a heat treating process will depend on the type of metal part, the quantities to be heat treated, the performance specifications, and external factors such as environmental emission constraints, availability of capital and a host of other factors. For example, vacuum processing first found a niche in aerospace applications, then broadened its reach to include other higher performance markets. Typical induction applications include high volume, simple geometry metal parts, and selectively hardened parts such as crankshafts and axles. The purpose of this section is to identify the strengths and weaknesses of each electrotechnology so that the reader can first understand the "best fit" applications, and then to begin to identify similar applications at other customer locations.

Applications

Vacuum Heat Treatment

Vacuum processing is really a specialized type of indirect resistance heating that incorporates a controlled atmosphere to prevent surface reactions such as oxidation and decarburization. The need for cleaner work pieces and tighter performance specifications was intially driven by aersopace and military specifications. Vacuum processing has expanded considerably to include other markets. This niche is particularly attractive to electric utilities for two reasons:

- It is the highest growth segment of the heat treating industry.
- There is almost no competition from fossil-fuel fired systems.

Advantages

Advantages of vacuum processing include:

- Ability to meet "tight" performance specifications.
- Cleaner finished parts.
- Flexibility in handling a variety of metals.
- Environmental friendliness.
- Ease of automation.
- Lower maintenance costs.
- Lower labor costs.
- More precise time/temperature control of ramp up and cool down rates.

Limitations

There is still a strong perception that vacuum processing is prohibitively expensive. Even though the vacuum furnaces are a significant capital investment, the lower scrap rates, lower emissions costs and lower labor costs allow these systems to pay for themselves more quickly than typically expected. The key is to not let this limitation close the door on a complete economic analysis.

Disadvantages include:

- High capital cost.
- Not easily adaptable to high volume production.

Typical Applications

Aerospace parts, tool steels, stainless steel food processing equipment ("Bright " processing), medical and dental instruments and prosthetics.

Induction Heat Treatment

The use of electric induction heating is commonly used both for heat treating and heating of forge stock. Within the field of heat treating, induction heating is used in surface and through-hardening, tempering, and annealing. A primary advantage is the ability to precisely control the heat input to the area that is to be heat treated. The most common induction heat treating operation (hardening), improves strength, wear, and fatigue properties of steels.

Advantages

Advantages of induction heating include the following:

- Speed –10 percent or less of the time required for conventional furnace treatment.
- Selective heating –Such treatments are not feasible with furnace processes, which are slow and heat the entire work piece.
- Energy savings – In addition to eliminating dwell periods, induction heat treating techniques put energy only where needed, improving energy efficiency.
- Increased production rates – Rapid heating often increases throughput.
- Lower labor cost.

Limitations

Induction is not a panacea for all heat treating applications. There are definite limitations with induction heating that must be considered when matching application with technology. Some of the limitations are listed below:

- Complex part geometry.
- Small production runs of varying part configurations and sizes.
- Cost and complexity of material handling systems for high volume applications.
- High cost to establish induction coil inventory.
- Operating training costs.
- Electric demand considerations.
- Shortage of experienced operators.

Typical Applications

Gears, shafts, valves, machine tools, hand tools, bearing races, spring steel, chain links, aluminum strip, steel strip,…

Direct and Encased Resistance Heating

Any electrically-conductive material can be heated by direct resistance. Basically, the work piece is clamped between two electrodes, or power connections, and current is passed between them. Current flowing through the work piece generates heat by the Joule effect. This process is commonly used to anneal wire.

Electric resistance heating offers manufacturers precise control and directed heat for applications such as preheating billets for forging, selectively producing unique hardening patterns on the metals, and selectively heating forging dies.

Another example of electric resistance heating is the use of moten salt baths. Generally, two electrodes located in the bottom of the bath provide current through the molten salt to transfer heat directly to the workpiece. The key advantages to this process are rapid and uniform heating, which lead to a consistent product with minimal distortion.

Advantages

By generating heat within the work piece rather than in a furnace, direct resistance offers a number of benefits over fuel-fired furances, including:

- Rapid heating
- Fast start up
- Energy savings
- Higher production rates
- Ease of automation
- Material saving as result of less scale
- Improved working environment
- Reduced floor space requirements
- Low maintenance costs

Limitations

- High initial price
- Integrity of clamped connections
- High operating costs
- Environmental issues (in the case of molten salt baths)

Typical Applications

Clamped electrode applications include direct resistance heating for wire and strip; molten bath applications include a wide variety of parts including gears, shafts, fasteners, automotive transmission parts and various housings.

Indirect Resistance Heating

Electric resistance furnaces offer a safe, efficient, reliable and clean method for heating in the forging and heat treating industries. Resistance heating is based on the principle that, when a current is passed through an electrical resistor, electrical energy is converted to thermal energy. The thermal energy is then transferred to the part by convection, radiation, and/or conduction.

Indirect resistance heating is gaining popularity for stock (billet) heating prior to forging, when the work pieces are of an irregular or complex shape, such as a preform. Induction and direct resistance heat faster but require a uniform work piece, such as a bar or rod. However, there are essentially no restrictions on the materials or work piece shape that can be heated in an indirect resistance furnace. Also, a single furnace can be used to heat a wide variety of parts.

Indirect resistance heating is used for annealing, austenitizing, normalizing, hardening, tempering, nitriding and carburizing a wide range of ferrous metals. It is also used for annealing, solution treating and aging nonferrous metals. These processes are carried out at temperatures from 300 to 2400^{o}F (149 to 1315^{o}C).

Indirect resistance furnaces are particularly applicable where a protective atmosphere is required, such as in the heat treating of aerospace alloys and tool steels. For example, titanium alloys, which are prone to contamination—particularly hydrogen pick-up—must be processed in a vacuum or inert atmosphere to prevent vaporization of improtant alloying elements at the surface. These special conditions are easily arranged in an indirect resistance furnace, but difficult to achieve in a gas furnace.

Advantages

Advantages of indirect electric resistance heating include:

- Flexibility – both temperature and furnace atmosphere can be varied
- Automatic temperature control – adaptable to microprocessor control
- Improved working conditions – less noise and fume
- Cost savings – considerably more energy efficient than fuel fired furnaces
- Safety – little or no explosion hazard

Limitations

- High capital cost
- High operating cost
- Electric element breakage

Typical Applications

Variety of parts can be heat treated using indirect electric resistance. Because of the higher capital and operating costs compared to gas fired systems, the most common applications occur where there is a great need for process control, environmental issues limit the use of gas, and/or there are sporadic heat treating cycles leading to idling inefficiencies for gas fired systems.

Infrared Heat Treatment

A very recent development for heat treating of aluminum alloys is the use of short-wave-length electric infrared heating. The initial application for the heat treatment of permanent molded cast aluminum automotive wheels. The preliminary results from the project indicate the process exhibits extremely rapid heating rates, resulting in increased through-put. Temperature control is also excellent, producing excellent metallurgical structures. The process, by its very design, is adaptable to sophisticated automation.

Process Optimization

Electrotechnologies are finding increased use in the forging and heat treating industry to optimize processes. Advanced instrumentation and controls are now being used to optimize process control and energy utilization. Examples are computerized energy management systems and control of equipment through the use of programmable logic controllers.

Load characteristics for forging/heat treating establishments vary greatly depending on the number of operating shifts, the extent of heat treating, and whether the production process is batch or continuous. A majority of plants, particularly forge shops, are single-shift operations with the remainder roughly split between double- and triple-shift operations. Companies will add or curtail shifts depending on work load; the nature of the product or process being used has less influence.

Process optimization is attractive opportunity for electric utilities for a variety of reasons. Forging and heat treat electrical loads are fairly flat during plant operation, except for jumps for additional furnaces coming on-line, or product die changes. Load factors during operating hours typically exceed 90 percent for continuous operations and 60 percent for batch operations. In addition to an attractive load characteristic, increases in efficiency can be used to further build solid customer relationships and to facilitate utility curtailment programs.

SIC Codes for Captive Heat Treaters

SIC codes can be a good source to identify heat treating opportunities. Even though commercial heat treaters (SIC 3398) can be easily identified in utility databases, the identification of captive heat treaters is considerably more difficult. However, there are specific industries that use significant amounts of metal parts that require heat treating. Pertinent SIC codes for identifying captive heat treaters within these industries are listed below.

Table 3-1.
Top 50 SIC Codes for Captive Heat Treaters

SIC	Description	SIC	Description
3315	Steel Wire and Related Products	3532	Mining Machinery
3317	Steel Pipes and Tubing	3533	Oil and Gas Field Machinery
3351	Copper Rolling and Drawing	3535	Conveyors and Conveying Equipment
3354	Aluminum Extruded Products	3541	Machine Tools, metal cutting type
3356	Nonferrous Rolling and Drawing	3544	Special Dies, Tools, Fixtures
3363	Aluminum Die Castings	3545	Machine Tool Accessories
3421	Cutlery	3552	Textile Machinery
3423	Hand and Edge Tools, nec	3554	Paper Industries Machinery
3425	Saw Blades and Handsaws	3556	Food Products Machinery
3429	Hardware, nec	3561	Pumps and Pumping Equipment

3441	Fabricated Structural Metal	3562	Ball and Roller Bearings
3443	Industrial Patterns	3566	Speed Changers, Drives and Gears
3451	Screw Machine Products	3567	Industrial Furnaces and Ovens
3452	Bolts, Nuts, Rivets and Washers	3568	Power Transmission Equipment
3462	Iron and Steel Forgings	3592	Carburetors, Pistons, Rings, Valves
3469	Metal Stampings, nec	3599	Industrial Machinery, nec
3479	Plating and Polishing	3612	Transformers, except electronic
3491	Industrial Valves	3621	Motors and Generators
3493	Steel Springs, except wire	3679	Electronic Components, nec
3494	Valve and Pipe Fittings	3714	Motor Vehicle Parts/Accessories
3495	Wire Springs	3724	Aircraft Engine and Engine Parts
3496	Miscellaneous Fabricated Products	3728	Aircraft Parts and Equipment
3498	Fabricated Pipe and Fittings	3823	Process Control Instruments
3523	Farm Machinery and Equipment	3841	Surgical and Medical Instruments
3531	Construction Machinery	3965	Fasteners, Buttons, Needles and Pins

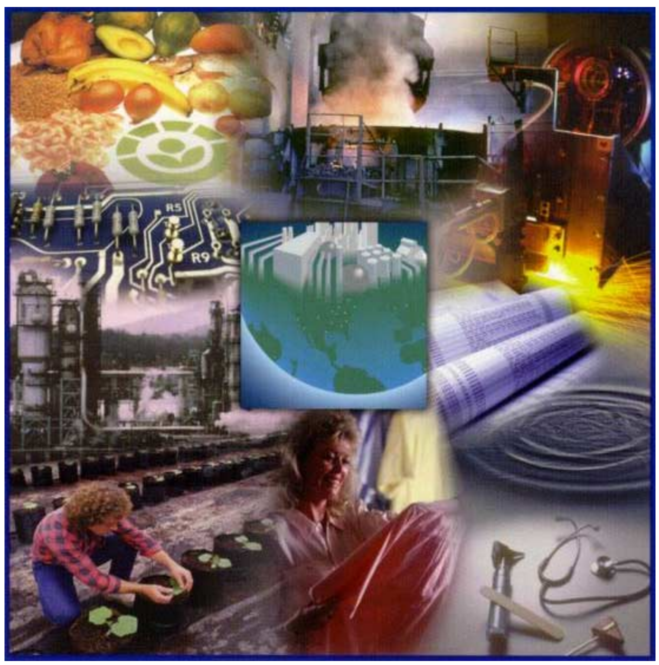
Application Opportunity Checklist

This checklist is not a substitute for a detailed analysis. Those using this guide should use it as a preliminary screening tool for assessing what are often site-specific industrial applications. If three or more of the following conditions apply to a unique potential application, further investigation of electric process heating is warranted.

- Is there a "tight" heat treating performance specification?
- Is steel material to be hardened?
- Is product production volume greater than 200,000 pieces/year?
- Are sections of the part surface to be selectively hardened?
- Is the area to be hardened a simple and uniform geometry (i.e. straight shaft)?
- Is floor space at a premium in this plant?
- Are there environmental considerations limiting the use of fuel-fired systems?

- Is the production line automated?
- Is distortion a cause for reject/scrap or is straightening a required secondary operation?
- Does the end-use service environment for the part require bending/torsion fatigue resistance?
- Does the current or proposed process require off-shift or weekend equipment idling?
- Is the current or proposed process located in a heated or cooled space?

THE SALES PROCESS



This section outlines the heat treating sales process in broad terms, then provides a series of helpful questionnaires and checklists to assist the buyer and his or her advisors.

4
THE SALES PROCESS

Introduction

The acquisition of any heat treating system is a complicated process that requires extensive information exchange between the buyer and the prospective vendor or vendors. This section outlines the process in broad terms, then provides a series of questionnaires and checklists that will be helpful to the buyer and the buyer's advisors.

Analysis and Selection

The two major steps to solve a heat treating problem are 1) an analysis of the heat treating requirements, and 2) the evaluation and final selection of the equipment to meet these requirements most effectively. In the case of a commercial heat treater, these requirements will vary depending on the type of parts to be heat treated. Though this can make the situation more complicated, the commercial heat treater can look at a range of required heat treating parameters for the more important segments of his business, and select the most appropriate equipment to meet this range of needs.

Due to the differences between commercial and captive heat treaters, this section is divided accordingly to illustrate the differences in approach between the two segments.

Commercial Heat Treaters

The general characterization of a “commercial” heat treater is typically a small business which is owner operated and very independent. The owner likely grew up with the business and is comfortable making do with aging equipment. The prospect of considering new processing methods is often met with a strong defensive posture. Because the business is typically small, a full-time engineering or technical staff is not likely to exist, and the owner must rely on his instinct for what is viable and what is not. Any attempt at being prescriptive about how they run their business may be met with an invitation to leave.

On the other hand, they enjoy talking about their business and will willingly provide information about their business and the areas in which they perceive themselves to be particularly competent. It is at this point that questions about what they do and do not do may be asked. For instance, “Do you currently use induction heat treating?” or “Are you required to use vacuum processing to meet aerospace specifications?”, “Do you get many inquiries from your customers in these areas?" The answers to these questions will give some indication whether to pursue the issue further, or suggest leaving literature about the technology and follow-up at a later date.

You need to establish trust that you, either directly or indirectly, are a credible source of information about heat treating. The nature of the commercial heat treater's business may inhibit him from being a pioneer with new processes. If, however, he believes he has a partner in investigating the viability of a new process, he will be much more likely to proceed. You will not be successful by focusing on the disadvantages of conventional heating methods. Rather, you must be prepared to overcome potential objections by highlighting the advantages of electrotechnologies in heat treating.

Note: Not all commercial heat treaters fit the small owner operated business profile. There has been a trend for mergers and acquisitions that has formed a few large nationally operated heat treat corporations. Examples would include Lindberg Heat Treating, Bodycote Hinderliter, HI TecMetal Group and Paulo Products Co. Selling heat treating equipment to these companies is very different than selling to the smaller independent heat treaters. They are quite likely already aware of the opportunities for electrotechnologies at their various plant locations, and also operate through a more sophisticated corporate organization. That is to say, identifying the decision-makers and being able to access them becomes a more difficult selling task.

Commercial heat treaters can be a valuable source of information about the types of manufacturing occurring within that geographic region. Their customers are manufacturing components that require heat treating. It is quite likely that other manufacturers (same SIC's) producing the same type of parts also require heat treating. These other manufacturers may be large enough or have other reasons, for having their own in-house heat treat departments. This can become a method for locating "captive" heat treaters.

Captive Heat Treaters

Quite unlike the typical commercial heat treater profiled above, the captive heat treater is one process or department of a much larger manufacturing process. Very likely, at one time in their history, these manufacturing companies utilized the services of a commercial heat treater and for some services, perhaps still do. Companies that operate their own "in-house" heat treat tend to be much larger organizationally than the typical commercial heat treater and are therefore more likely to maintain an engineering or technical staff. It is necessary to identify the "key" members or decision-makers within these organizations. Attempts to sell to members of an organization who do not have the authority to make the decisions regarding the selection and purchase of equipment is often a dead-end sales exercise. It will typically take some time to learn the organization, but getting to the right people within the organization is crucial for successful sales results.

The greatest opportunity to sell electrotechnogy heat treating equipment is likely to be the "captive" heat treating market. This is supported by several facts:

- First, there are a greater number (approximately ten times) of captive heat treat operations than commercial.

- Second, the advantages of electric process heating are more appropriately applied when the system can be designed to fit a particular part, as opposed to a tremendous variety of parts.
- Third, captive heat treat operations tend to be able to raise or justify the necessary capital equipment dollars if the overall product cost can be reduced.

This last issue also requires that the electric process heating equipment be more closely matched or engineered to gain the greatest cost savings. In many cases, the material handling equipment can equal or exceed the cost of the induction power supply.

Timing is still one of the most critical elements of the sale. Even though capital equipment dollars may be more readily available (compared to a commercial shop), rarely will a company replace equipment that is not fully depreciated. Therefore, it is paramount that one be in the right place at the right time. It will typically be a situation where production capacity or quality issues are the initiators for investigations into other methods or technologies, to overcome the current production issues. Being able to supply technology options or solutions for the customer’s production concerns will go a long way towards establishing credibility for being included in the planning phase for future equipment decisions.

Potential Captive Heat Treaters

It was pointed out in the previous section that companies with captive heat treat departments more than likely at one time contracted out their heat treating requirements to a commercial heat treat shop. This seems to be a natural evolution in the heat treating industry. A number of factors appear to accelerate this process. If a company repeatedly experiences delivery or quality problems with an outside heat treat source that may cause them to switch commercial shops and eventually lead to the decision to install their own heat treat equipment. Many times, it is the cost implications of doing business with an outside source rather than delivery or quality, or it may simply be a combination of all of the above factors that justify the decision to establish their own heat treat department. The point, however, is that many companies that are currently doing business with commercial heat treat shops may very well be on the verge of making the decision to install their own heat treat equipment. It is also possible that by providing literature (i.e. Tech Applications and TechCommentarys) the seed may be planted and the next time problems with outsourcing arise, the decision to install their own equipment may be the most appropriate for them.

These potential captive heat treaters can be identified by a couple of methods. Once existing captive heat treaters are located, it is more than likely that other manufacturers with the same product SIC are either also captive heat treaters or currently utilizing commercial services. Either way, there exists potential opportunities to sell electric process heating equipment. As mentioned in a prior section, commercial heat treaters are a tremendous source of information for the types of parts and the companies that manufacture those parts within a fairly local region. One must exercise caution not to compromise the confidentiality expected when visiting a commercial heat treat customers’ plants.

General Sales Approach

This document assumes that the reader is fully trained in sales or marketing, so it is not the objective of this section to instruct in those disciplines. There are as many legitimate approaches to sales as there are competent sales people. Furthermore, most sales managers have strong views about what works best in their field. The purpose of the sales approach outlined below is not to instruct in sales *per se*. It is simply to have a structure for presenting sales-related information specific to electric process heating . If the outline is useful in other ways, that is a bonus. In any case, sales personnel should follow the guidance of their own management staff.

Background Study

In order to sell electrotechnologies related to the heat treating industry, it is important that the sales person have a clear overview of this industry, such as traditional methods of heat treating and the advantages and disadvantages of utilizing electric process heating in place of more traditional methods. The material presented in this document should provide a head start in that direction.

Identifying Prospects

Sales prospects may be handed to you by your superior or by the marketing department. Otherwise, it will be necessary to identify prospects on your own. The previous section, *Identifying Opportunities,* outlined the industries that are most likely to use heat treating, many of the products that are frequently heat treated, and candidates for conversion to electrotechnologies. This information can serve as overall guidance on what to look for, leaving the question of where to look. Perhaps the best source is often overlooked: the yellow pages. Their preeminence is rapidly being displaced, however, by the Internet. If you are not looking for prospective customers in these two places, you are almost certainly missing important opportunities. Other sources include trade associations, trade shows, trade directories, trade publications, advertising, your corporate service personnel, and company client records. Current clients can also be an important source of referrals to new customers, and are frequently quite willing to provide such information.

Qualifying Leads

This is the process of estimating, for each prospective customer, the probability that you will be able to close a sale. That probability depends on the customer's need for new technology, their financial ability to purchase, where the authority for decision-making lies, and many other factors. The most likely prospects for sales of electrotechnology heat treating equipment are companies with the following attributes:

- A de facto high regard for quality
- An existing production bottleneck

- Limited floor space
- Anticipated tighter pollution control regulations
- Financial resources to purchase equipment
- Approach by a knowledgeable sales person

The absence of any one of these, except the latter, is not fatal, but their collective presence points toward a successful sale.

Collecting Information

The more one knows about the customer, the higher the chances for success. This aspect of sales is so important that a checklist for information gathering is presented at the end of this section. Prior to the first contact, one should have a clear overview of the company and its products. If possible, one should determine which products are manufactured at the site under consideration and should have reasonable cause to suspect that heat treating parts are required at that facility.

Initial Telephone Contact

The in-person “cold call” has a long tradition in American sales, but nowadays it is rarely a cost effective approach and is frowned upon by many customers. Except in cases where a salesperson was truly “in the vicinity on other business and decided to drop in for a moment” (a standard line), all sales calls should be preceded by telephone contact. In Europe and Asia, unannounced visits are considered extremely rude and are therefore out of the question. Prior telephone contact is not only a standard courtesy, but also contributes significantly to sales efficiency. Before placing the call, it is important to define for yourself the specific purpose of the call. For example, one typically might want to: determine whether heat treating is a likely requirement for parts manufactures at this facility, identify the plant manager or production foreman, and secure an appointment for a visit. Outline in writing the information you wish to gather and points you wish to make before placing the call.

The Sales Call

Preparation

Nothing reveals sales professionalism more than careful preparation for a sales call. It increases efficiency, improves confidence, and increases the probability of success. Customers interpret preparation as a sign of respect for them and their time. In preparing for the call, it is crucial that the purpose of the call be very clear. The purpose may range from simply becoming acquainted, or gathering and leaving information, to closing a sale. In addition to the generic preparation necessary for all sales calls, the person who wishes to sell electric process heating technology must do additional preparation. One should anticipate the kinds of technologies that may already be in use or may be needed at the site being visited, and review their salient points. A written list of questions should also be prepared, perhaps reviewing the checklist at the end of this section.

Finally, one should review the advantages and disadvantages of each technology that might be under consideration by the customer, as well as frequently encountered objections and your best response.

The Agenda

A written agenda is an important tool often overlooked by sales personnel. An agenda can highlight the preparedness of the sales person, place the objectives in full view, significantly reduce time spent on extraneous topics, and help to keep the visit on schedule. Hidden agendas should not exist.

Information Gathering

Perhaps the biggest mistake made by beginning sales personnel is talking too much. During the initial sales call, the sales person should generally be asking questions, listening, and taking notes. On subsequent calls, prior to the sales presentation, one should continue the process of gathering information of the types outlined in the checklist. Selling before one has collected as much pertinent information as possible, significantly reduces the probability of success. At the minimum, one must determine the volume, composition, and shape of products that are to be heat treated; when in the production process heat treating is required; conveyer types and line speeds; and the primary reasons why the company is considering or might consider new equipment. At least this information should be clear before one contacts potential equipment suppliers. Use of the CMF Electrotechnologies Application Questionnaire (EAQ) can be a valuable tool at this stage.

The Sales Presentation

Elements of presentation style, such as diction, dress, organization, voice, sequence, and gestures will not be addressed here. However, it is crucial that following elements be present:

- The credibility and competence of the supply company must be established or reinforced
- The salesperson must demonstrate an understanding of the needs and desires of the manufacturer
- The customer must be told how the supplier’s technology will meet his/her company’s needs
- The customer must be told why the recommended technology is a better choice than competing technologies
- The salesperson must explain why her/his company’s product is a better choice than competing products
- The customer must be told of similar installations where the same technology is used successfully
- The customer must be told precisely what product is being offered, including intangibles
- A proposed delivery schedule must be presented

- The customer must be shown what the payback will be for the purchase

The Closing

In the process of selling electric process heating, the utility representative will rarely have the lead role in the closing. Since the sales transaction is most likely between the customer and the equipment supplier, the supplier's personnel will probably close the sale. Because the utility representative may be present at such an event, it is wise to understand the process. The following approach is typical of a successful closing, but may vary according to personal style. The successful closing always begins with careful planning. At the closing visit, a sales presentation is made (see paragraph above), and an offer is made. Objections are raised by the customer and dealt with quickly by the salesperson. One or more "trial closings" may be performed by the salesperson, with questions of the form, "Would you buy our product if…?" These are aimed at determining whether the customer is ready to buy. When the time is right, the salesperson asks explicitly and directly for the order and becomes resolutely silent. After the customer responds, some negotiation usually ensues, and the major aspects of the deal are agreed upon. In some cases, the salesperson declares the need for consultation with the office, and some steps are repeated. If a deal cannot be closed, the salesperson always leaves the door open for a future sale.

Follow-up After the Sale

Experienced sales and marketing personnel know that it is much easier to keep an existing customer than to acquire a new one. Many professional sales people routinely contact the customer soon after the sale and emphasize what a good decision they made. The larger the purchase, the more important the call. Since the decision has already been made, your credibility is higher and the reassurance is always welcome. That, however, is just the beginning. The sales person should introduce the customer to technical support staff, check periodically to ensure that problems are being handled promptly, serve as liaison to the equipment and materials suppliers as necessary, and generally not be perceived as walking away after the sale. A very high percentage of all equipment sales are to repeat customers and to new customers referred by existing customers. It is wise to preserve the relationship.

Information Gathering Checklist

Following is a checklist of information that one might gather through telephone contacts and visits to the customer site. In some cases, such information can be found through a search of the literature, especially trade press, or through database searching, e.g. on the Internet. It is not suggested that one attempt to memorize this list or even attempt to collect all the information outlined. It is recommended, however, that the sales person read the list carefully and contemplate how the information can be helpful and to whom. Doing so will heighten sensitivity to the need for information and predispose the sales person to collect it routinely. It should also be noted that the more of these questions you can answer, the more effective potential suppliers will be.

A publication that may prove to be a valuable tool for collecting information is the Electrotechnologies Application Questionnaire (EAQ) #TB-109095. When used in conjunction with the following list of questions, significant information about the company and its heat treating process may be gathered for use during the sales process. The questions below are listed by subject.

General knowledge about customer

- What parts do you heat treat at this facility?
- What types of heat treating equipment do you have?
- Are there any areas that you would like to see improved that are causing the company to consider purchasing new equipment? (Increase production speed, reduce environmental emissions, lower operating costs, lower scrap rates, add capacity, reduce floor space, reduce noise levels, improve air quality, automate equipment?)

Electrotechnologies can increase production speed and reduce floor space

- What is the current capacity of the specific production line and of the whole plant?
  - How many parts of each type are produced each year?
  - What are the line speeds of the production lines in question?
  - How many days and how many shifts do the production lines operate?
- Does the company have plans to expand production capacity at the present site?
- Where are the current production bottlenecks?
  - Do you see ways to automate existing processes?
- What is the level of automation in the plant?
  - What is the attitude of the company toward automation?
- Are off-site heat treating services causing production interruptions or delays?
- What are the shapes and dimensions of the parts? (Simple geometries such as axles and crankshafts are strong candidates for induction)
- What are the volume requirements for each part? (Induction fits well with high volume parts)
- What is the cost of floor space in the plant under consideration?

Electrotechnologies can increase the level of quality

- What is the de facto attitude of the company toward quality?
- Do you meet aerospace specifications? (Vacuum processing has expanded beyond aerospace applications because of its high quality, flexibility, low labor cost, and high degree of automation)
- What is the current scrap rate?
- Are there any problems with the current production lines?
- Is distortion a common quality issue with heat treated parts at this facility?
  - Is straightening a common secondary operation at this facility?
- Are process variations a consistent cause for quality related rejections?
- Are off-site heat treating services causing quality related rejections?
- Are any surface pre-treatments required before heat treating operations?
  - Are there surface preparation problems?
- Are secondary parts washing required prior to subsequent processing?

- Are there post processing operations to remove scaling after heat treating?
  - How do you handle customer inquiries for "bright" finishing?
- Is a protective atmosphere gas required to prevent scale or surface condition losses?
- Could a portion of existing heat treating capacity be switched/shifted to electric process heating installation and free-up furnace capacity?

Electrotechnologies can reduce environmental emissions

- Do you or the company anticipate any regulatory changes, especially environmental?
- Does the company have or expect any regulatory compliance problems?
  - Has EPA designated this plant's location a non-attainment zone?
  - Has the company had any environmental issues with the community?
  - Are used quench oil disposal costs an increasing problem?
- Is the company looking to improve air quality in the plant or reduce outdoor emissions?

Electrotechnologies can increase energy efficiency

- At what capacity do the gas furnaces run?
  - Do the furnaces idle overnight?
  - What is the ramp up and ramp down time?
  - How often do you typically need to ramp up a furnace?
- How frequently do they or will they change parts on the production line under consideration?
- Are the time/temperature requirements changed often? (Electric process heating is flexible)
- Does part design allow for selective hardening/softening? (Induction opportunity)
- Can you eliminate any processing steps, e.g. by combining them?
- What are the annual energy costs for the company and for the processes under study?
- What are the current total energy costs and the energy cost per part?
- What types of energy sources are currently available at plant and what is their capacity?
- Is workpiece fixturing more than 25% of a batch furnace load?

Electrotechnologies can reduce costs by improving the level of worker comfort and safety

- How does the company handle worker safety or comfort issues?
- Are workman compensation premiums high?
- Does the insurance carrier at this facility require that maintenance or security personnel be on the premises during idle production (off-shift, weekends and holidays) when fuel-fired combustion systems are in operation?
- How would business interruption/continuation insurance premiums be affected if fuel fired combustion equipment installed?
- Is negative building air pressure a problem at this facility?
- Is plant appearance/clean lines a major concern at this facility?
- Is the noise level an issue of concern at the plant?
- Is the production area air conditioned? Heated?
- Is there a high turnover of production personnel?
  - What is the skill level of the current operators?
  - Are skilled combustion equipment maintenance personnel approaching retirement?

Capital Investment Issues

- Does the company have plans to buy new equipment?
- Does the company already have specifications for a new or modified line?
- How does the company make capital purchases?
  - What does the company consider the standard payback period for capital equipment?
  - Do you evaluate purchases primarily on first cost?
  - Do you also look at operating costs including energy costs, environmental costs, labor costs, scrap rates, throughput, etc.?
- Does the company have capital set aside to buy new equipment?
- Does the plant operate fairly autonomously, or is there strong control from outside?
  - Are there other similar plants in the company?
  - Does the company have plans to build new plants?
- How much influence will your contacts have in the final purchase decision?
  - Who approves capital expenditures?
- Do you need to add capacity?
  - What is the current load on existing equipment (percent of maximum capacity)?
  - What is the age of current equipment?
  - Do you have a time frame for adding equipment?

Other General Questions

- What are the major markets served by the company and by the products in question?
  - Who competes with your customer and what are their strengths?
  - What are the current trends in sales for the products in question?
- What are the projected capacity needs for the next five years?
- What are the competitive pressures? (cost, quality, product changes, foreign competition?)
- Does the customer have any prejudices regarding various forms of energy?
- Does the company have prejudices for or against any particular type of heating technology?
- How familiar are key individuals with electric process heating technology?
- Have there been an increasing number of requests for vscuum processing or induction hardening at this facility?
- Are the parts to be heat treated metallic? Magnetic? Electrically conductive?
- Are changes of any kind anticipated in the client company and how might they be relevant?
- What has been your company's previous experience with this customer?
- Is the shop union or non-union?
- What is the company's general attitude toward change?
- What is the urgency for change?

Handling Objections

In the paragraphs that follow, we look at some of the objections encountered in selling electric process heating equipment. Each sales person will develop her or his own techniques for dealing with such objections. The suggestions offered here are only examples of possible ways to handle such objections.

"Electric Power is Not Available"

Sometimes a potential customer may shy away from electric process heating due to the belief that there is insufficient power supply to the plant. One first should determine by serious calculations whether that is in fact the case. If it is not, the problem disappears. If it is true, the next step is to determine whether the potential business is worth offering price concessions or other financial support to install additional supply, e.g. a new or upgraded sub-station. In general, handling such objections should be well within the skill set of the utility sales person.

"Electricity is Too Expensive"

In many cases, electrotechnology heat treating installations are so much more efficient than their gas counterparts, that the expense for the amount of electricity needed is less than the expense for the amount of gas needed. In addition, any rational cost analysis must take into account factors other than the cost of energy. The cost of operating the electrical equipment usually can be shown to be significantly lower than comparable gas equipment. And finally, even if the cost of operating the electrical equipment was higher, it still should not be an issue if other advantages are gained. The important issue with competing technologies is the total cost per part, not the energy cost per part. A useful tool for demonstrating "process" costs versus 'energy" costs is the **High Temperature Cost Comparison Worksheet** (SW-111143). This is a user friendly software program that generates a side-by-side annual operating cost for energy cost and process cost comparisons between gas combustion, electric resistance, and induction heat treating applications.

"The Equipment is Too Expensive"

There is a frequently encountered misconception in the community that the initial purchase cost of electric heating equipment is higher than that of gas-fired equipment. This is usually not the case. The best tactic may be to avoid second guessing and assertions contradicting the misconception and focus instead on trying to gain approval to do some true cost assessments.

"I Am Really Not Interested"

This often means, "Right now I am busy and under so much pressure that I barely have time to be polite." If you sense that this is the case, the best course is the concourse, i.e., leave quickly and try to reschedule later. Other times, the meaning is literal, i.e., the person truly is not interested. Also in this case, they expect you to accept their message and leave. However, if the mood is friendly and un-rushed, it may be worthwhile to invest a bit more time. An approach that often works is to try and determine precisely what they are not interested in and why. Once that is known, other issues and techniques reign.

In questioning clients, note that they are seldom warmed by questions such as "Are you not interested in saving money?", or "Is your lack of interest based on knowledge or ignorance?". These examples may be too obvious, but the point is to pose delicate questions in such situations, not brutal, cutesy, or cynical ones, even if they are directly to the point (such as the second example above).

Technology Angst

Many users who have used gas fired ovens for many years feel they understand them, can predict how they will behave, and are generally very comfortable with them. They feel very anxious about purchasing and operating a new, powerful, sophisticated piece of equipment. Convincing them to buy a high-tech vacuum furnace or an induction furnace is like trying to convince someone who is still driving a 1966 Impala to buy and drive a new Porsche. It is a frightening thought. These people need to be handled slowly and treated gently. They worry about quality, reliability, and safety, because “They just don’t build ‘em like they used to.”

“Requires Skilled Operators”

Again the answer may be different for commercial users versus captive heat treaters. A commercial shop that wants to run as many different parts as possible, will require an operator who is knowledgeable enough to be able to change set-ups and power settings. Typically, a valued customer requests that his heat treater consider installing a vacuum furnace to run aerospace grade parts, or induction heat treating equipment to run a sizeable quantity of parts that require selective heat treating. After experience is gained, the commercial heat treater would try other customer’s parts of similar size and configuration. The captive heat treater would buy the equipment to heat treat a high volume of the same part and, therefore, require that an operator understand only one set-up.

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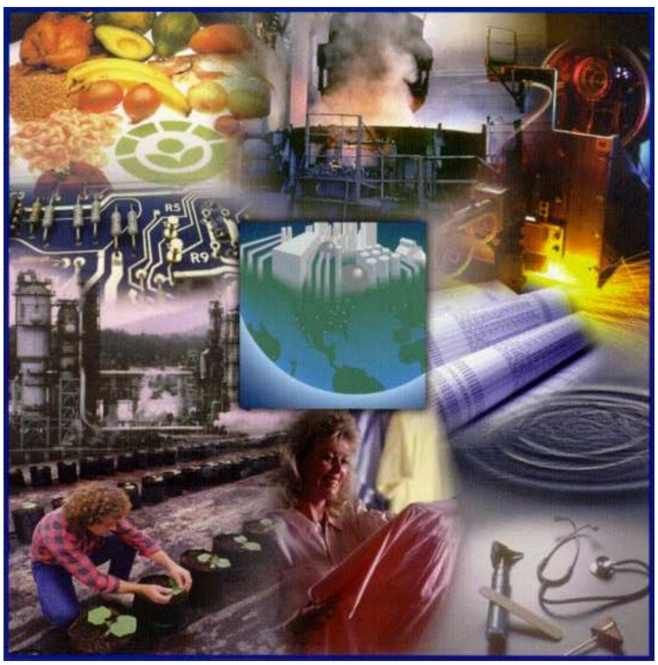

This section contains a bibliography of books and periodicals on heat treating, and a listing of industry associations whose members are involved in those fields, plus other organizations providing information about heat treating. Web addresses are included as a part of each entry.

5
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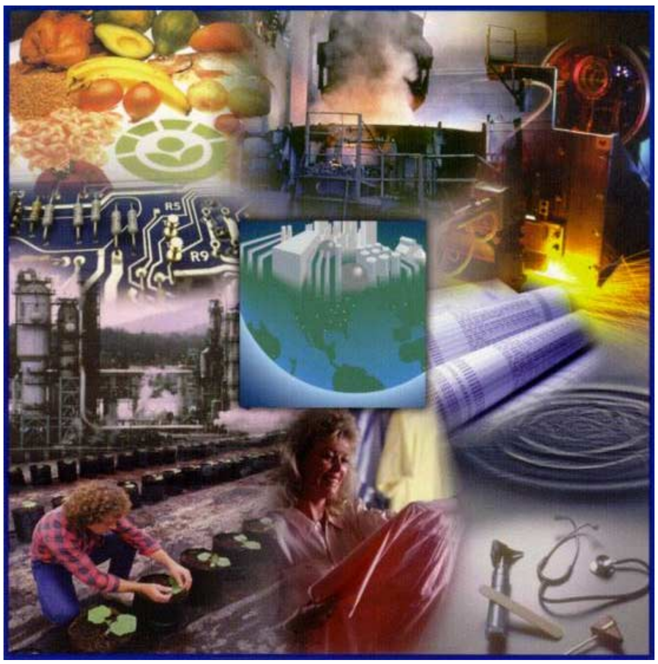
- *Induction Through Heating for Forging*, TechApplication, EPRI Center for Materials Fabrication, Vol. 1, No. 7, 1987, TA-102572-V1P7
- *Induction Heating Billets for Forging*, TechApplication, EPRI Center for Materials Fabrication, Vol. 1, No. 20, 1987, TA-102572-V1P20
- *Post-Grinding Induction Hardening*, TechApplication, EPRI Center for Materials Fabrication, Vol. 1, No. 2, 1987, TA-102572-V1P2
- *Induction Hardening with a Flux Field Concentrator*, TechApplication, EPRI Center for Materials Fabrication, Vol. 1, No. 11, 1987, TA-102572-V1P11
- *Selective Induction Heat Treatment*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 2, No. 3, 1985, TC-102573-V2P3
- *Direct and Encased Resistance Heating*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 3, No. 8, 1986, TC-102573-V3P8
- *Direct Resistance Heating Blanks for Forging*, TechApplication, EPRI Center for Materials Fabrication, Vol. 1, No. 19, 1987, TA-102572-V1P19
- *Indirect Resistance Heating*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 3, No. 7, 1986, TC-102573-V3P7
- *Infrared Heating, Drying and Curing*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 8, No. 1, 1992, TC-102573-V8P1
- *Cryogenic Processing of Metals*, TechCommentary, EPRI Center for Materials Fabrication, 1999, TC-113571

VENDOR LIST



This section provides contact information for eighty-five companies involved in the design and manufacture of electric heat treating systems. Since most of these products are custom designed for the application where they will be used, bringing one into operation usually involves the engineering of the entire project, the provision of the heat treating components, and the incorporation of the heat treating system into the customer's manufacturing process.

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VENDOR LIST

300 Below Inc., 2101 E. Olive, Decatur, IL 62526, PH: 217-423-3070, FAX: 217-423-3075, www.300below.com

ALD Vacuum Technologies, Inc., 18 Thompson Road, East Windsor, CT 06088, PH: 860-386-7227 or 800-253-8220, FAX: 860-386-7220, www.ald-vt.de

ARS Electronics & Vacuum Tubes, 7110-T De Celis Place, P.O. Box 7323, Van Nuys, CA 91409, PH: 800-422-4250

AVS Advanced Vacuum Systems, 60 Fitchburg Road, Ayer, MA 01432, PH: 978-772-0710 or 800-272-0710, FAX: 978-772-6462, www.avsinc.com

Ajax Electric Co., 60 Tomlinson, Huntingdon, PA 19006, PH: 215-947-8500, FAX: 215-947-6757, www.ajaxelectric.com

Ajax Induction Services, Division of Ajax Magnethermic Corp., 308 2nd Place S.W., Alabaster, AL 35007, PH: 205-664-0091, www.ajaxinduction.com

Ajax Magnethermic Corp., 1745 Overland Avenue at Larchmont, Warren, OH 44482, PH: 330-372-8511, FAX: 330-372-8608, www.ajaxmag.com

Alhern-Martin Industrial Furnace Co., 2155 Austin Street, Troy, MI 48083, PH: 248-689-6363, FAX: 248-689-1344, www.alhern-martin.com

Alloy Engineering Co., 844 Thacker Street, Berea, OH 44017, PH: 440-243-6800, FAX: 440-243-6489

Alnor Instrument Co., 7555 N. Linder Avenue, Skokie, IL 60077, PH: 847-677-3500, FAX: 847-677-3539, www.alnor.com

Alpha 1 Induction Service Center, 1525-T Old Alum Creek Drive, Columbus, OH 43209, PH: 614-253-8900, FAX: 614-253-8981, www.alpha1induction.com

American Cryogenics, 203 Travis Lane, Waukesha, WI 53189, PH: 414-513-0486, FAX: 414 513-0485, www.americancryogenics.com

American IR Technologies, 29 Tilton Avenue, Brocton, MA 02301-3027, PH: 508-660-0106, FAX: 508-559-8735

American Induction Heating Corp., 33842-T James J. Pompo Drive, P.O. Drawer 248, Fraser, MI 48026-1669, PH: 800-296-6309, FAX: 810-294-2293, www.americaninduction.com

Ameritherm Inc., 39 Main Street, Scottsville, NY 14546, PH: 716-889-9000 or 800-456-4328, FAX: 716-889-4030, www.ameritherm.com

BOC Gases, 575 Mountain Avenue, Murray Hill, NJ 07974, PH: 800-932-0803, ext. 1948, FAX: 908-771-1148, www.boc.com/metals

Barber-Colman Industrial Instruments, 1354 Clifford Avenue, P.O. Box 2940, Loves Park, IL 61132-2940, PH: 800-232-4343, FAX: 815-637-5341

Blasdel Enterprises, 495 W McKee Street, Greensburg, IN 47240, PH: 812-663-3213, FAX: 812-663-4968, www.blasdelent.com

Bone Frontier Company, 190 W. Southern Street, Brighton, CO 80601, PH: 800-379-BONE or 303-659-4611, FAX: 303-659-5266, www.bonefrontier.com

CM Furnaces Inc., 103 Dewey Street, Bloomfield, NJ 07003, PH: 973-338-6500, FAX: 973-338-1625, www.cmfurnaces.com

CTI-Cryogenics, 9 Hampshire Street, Mansfield, MA 02048, PH: 508-337-5000, FAX: 508-337-5180, www.helixtechnology.com

Capital Induction Inc., 6505 Diplomat, Dept. 5, Sterling Heights, MI 48314, PH: 810-254-2740, FAX: 810-254-1951, www.capitalinduction.com

Centorr/Vacuum Industries, 55 Northeastern Boulevard, Nashua, NH 03062, PH: 603-595-7233 or 800-962-8631, FAX: 603-595-9220, www.centorr.com

Chromalox, Emerson Electric Co., 701 Alpha Drive, Pittsburgh, PA 15238-2830, PH: 800-443-2640, FAX: 412-967-5148, www.chromalox.com

Cincinnati Sub-Zero, 12011 Mosterller Road, Cincinnati, OH 45241, PH: 513-772-8810, FAX: 513-772-9119, www.cszinc.com

Consarc Corp., 100 Indel Avenue, PO Box 156, Rancocas, NJ 08073-0156, PH: 609-267-8000, FAX: 609-267-1366, www.consarc.com

Coil Works, The, 18105-T Cross Avenue, Fraser, MI 48026-1669, PH: 810-296-6423

Custom Electric Manufacturing, 48941 West Road, Wixom, MI 48393-3555, PH: 248-305-7700, FAX: 248-305-7705, www.custom-electric.com

Despatch Industries, P.O. Box 1320, Minneapolis, MN 55440, PH: 612-781-5363, FAX: 612-781-5353, www.despatch.com

EFD Group, EFD USA Elva Induction, Inc., 1384 Piedmont, Troy, MI 48083, PH: 248-524-9900, FAX: 248-524-9991, www.efd-induction.com

East Coast Induction, Inc., P.O. Box 2039, Dept. P, 506 N. Warren, Brockton, MA 02305, PH: 508-587-2800, FAX: 508-587-9079, www.eastcoastind.com

Eisenmann Corp., 150 E. Dartmoor Drive, Crystal Lake, IL 60014, PH: 815-455-4100, FAX: 815-455-1018

Eldec Induction, 15511 Golfview Drive, Suite 100, Livonia, MI 48154, PH: 734-432-7955, FAX: 734-591-3340, www.eldec.de

Electric Furnace Company, 435 Wilson Avenue, Salem, OH 44460, PH: 330-332-4661, FAX: 330-332-1853, www.electricfurnace.com

Feedall Automation, 38379 Pelton Road, Willoughby, OH 44094, PH: 440-942-8100, FAX: 440-942-5710, www.feedall.com

Fluxtrol Manufacturing, 1388 Atlantic Boulevard, Auburn Hills, MI 48326, PH: 248-393-2000, FAX: 248-393-0277, www.fluxtrol.com

Hi-Temp Products Corp., 88 Taylor Street, Danbury, CT 06810, PH: 203-744-3025, www.hi-tempproducts.com

Houghton International, Madison & Van Buren, Valley Forge, PA 19482, PH: 610-666-4000, FAX: 610-666-1376, www.houghtonintl.com

I Squared R Element Co., 12600 Clarence Center Road, Akron, NY 14001, PH: 716-542-5511, FAX: 716-542-2100

Induction Tooling, 9982 York-Theta Drive, Cleveland, OH 44133, PH: 216-237-0711 , FAX: 216-237-7009

Inductoheat Inc., 32253 N. Avis Drive, Madison Heights, MI 48071, PH: 248-585-9393 or 800-257-6318, FAX: 248-589-1062, www.inductoheat.com

Inductoheat, Mass Heating Div., 15900 32 Mile Road, Romeo, MI 48065, PH: 800-257-7144, FAX: 810-752-3969, www.inductoheat.com

Inland Vacuum Industries, 35 Howard Avenue, Churchville, NY 14428, PH: 800-962-8099, FAX: 716-293-3093, www.inlandvacuum.com

Ipsen International, 984 Ipsen Road, Cherry Valley, IL 61016, PH: 815-332-4941 or 800-727-7625, FAX: 815-332-4995, www.ipsen-international.com

J.L. Becker Company, 12866 Richfield Court, Livonia, MI 48150, PH: 734-591-6036, FAX: 734-591-7858, www.jlbecker.com

Jackson Transformer Co., 4709 W. Cayuga Street, Tampa, FL 33614, PH: 813-879-5811, FAX: 873-870-6405

KVA Induction Inc., 34300 Klein, Dept. 5, Fraser, MI 48026, PH: 800-394-5488

Kanthal Corp., 119 Wooster Street, Bethel, CT 06801, PH: 203-744-1440, FAX: 203-744-2703

L. C. Miller Co., 717 Monterey Pass Road, Monterey Park, CA 91754-3699, PH: 213-268-3611, FAX: 213-264-3203

Lepel Corp., 50 Heartland Boulevard, Edgewood, NY 11717, PH: 516-586-3300, FAX: 516-586-3232

Leybold Vacuum Products, 5700 Mellon Road, Export, PA 15632, PH: 724-327-5700 or 800-433-4021, FAX: 724-325-3577, www.leyboldvacuum.com

Lindberg, A Unit of General Signal, 304 Hart Street, Watertown, WI 53094, PH: 920-261-7000, FAX: 920-262-3995, www.lindberg-bluem.com

Micropyretics Heaters International, 613 Redna Terrace, Cincinnati, OH 45215, PH: 513-772-0404 , FAX: 513-672-3333, www.mhi-inc.com

Miller Electric Mfg. Co., Dept. TR, P.O. Box 1079, Appleton, WI 54912-1079, PH: 800-426-4553

National Element Inc., 7939 Lochlin Drive, Brighton, MI 48116, PH: 248-486-1810 or 800-600-5511, FAX: 248-486-1649, www.nationalelement.com

Nemeth Engineering Associates, 5901 W. Highway 22, Crestwood, KY 40014, PH: 502-241-1502

New Castle Refractories, 915 Industrial Street, New Castle, PA 16102, PH: 724-654-7711, FAX: 724-654-6322

Nu-Bit, Inc., 1330 Fifth Avenue, New Kensington, PA 15068, PH: 724-339-3300 , FAX: 724-335-0555

Ogden Manufacturing, 64 W. Seegers Road, Arlington Heights, IL 60005, PH: 847-593-8050, FAX: 847-593-8062, www.ogden-mfg.com

PV/T Inc., 709 Fellowship Road, Mt. Laurel, NJ 08054, PH: 609-235-5400, FAX: 609-273-0303, www.pvt-vacuum-furnaces.com

Pillar Industries, 21905 Gateway Road, Brookfield, WI 53045, PH: 414-317-5300 or 800-558-7733 , FAX: 414-317-5353, www.pillar.com

Procedyne Corporation, 11 Industrial Drive, New Brunswick, NJ 08901, PH: 732-249-8347, FAX: 732-249-7220, www.procedyne.com

Quantik Industrial Corporation, 16005 S.E. River Forest Place, Portland, OR 97267-3612, PH: 503-654-4264, FAX: 503-653-6823

Radio Frequency Co., Inc., 150 Dover Road, P.O. Box 158, Millis, MA 02054, PH: 508-376-9555, FAX: 508-376-9944, www.radiofrequency.com

Radyne Corporation, 211-T W. Boden Street, Milwaukee, WI 53207-6277, PH: 414-481-8360 or 800-236-8360 , FAX: 414-481-8303, www.radyne.com

Robotron Corp., P.O. Drawer 5090, Southfield, MI 48086-5090, PH: 248-350-1444, FAX: 248-356-3989, www.robotron.com

Rolled Alloys, 125 W. Sterns Road, Temperance, MI 48182-9546, PH: 800-521-0332, FAX: 734-847-6917, www.rolledalloys.com

SBS Corporation, 81 Mill Street, Rochester, MI 48307, PH: 800-662-8776, FAX: 248-652-4303, www.sbscorporation.com

Seco/Warwick Corp., 180 Mercer Road, Meadville, PA 16335-3618, PH: 814-332-8400, FAX: 814-724-1407, www.secowarwick.com

Sheler Corp., 37885 Commerce Drive, Sterling Heights, MI 48312, PH: 810-979-8560, FAX: 810-979-8201

Spang Power Electronics, P.O. Box 457, Sandy Lake, PA 16145, PH: 724-376-7515, FAX: 724-376-2249, www.spangpower.com

Surface Combustion, Inc., 1700 Indian Wood Circle, Maumee, OH 43537, PH: 419-891-7150, FAX: 419-891-7151, www.surfacecombustion.com

T-M Vacuum Products, 630 S. Washington Street, Cinnaminson, NJ 08077, PH: 609-829-2000, FAX: 609-829-0990

TOCCO, Inc., 30100 Stephenson Highway, Madison Heights, MI 48071, PH: 248-399-8601 or 800-255-0994, FAX: 248-399-8603, www.tocco.com

TOCCO, Inc. Manufacturing, 1506 Industrial Boulevard, Boaz, AL 35957-1044, PH: 256-593-7770 or 800-255-0994, FAX: 256-593-4735, www.tocco.com

Tech Induction, 22819 Morelli Drive, Clinton Township, MI 48036, PH: 810-469-8324, FAX: 810-469-4620, www.techinduction.com

Tenaxol, Inc., 5801 W. National Avenue, Milwaukee, WI 53214, PH: 414-476-1400, FAX: 414-476-4297, www.tenaxol.com

Thermcraft Inc., P.O. Box 12037, Winston-Salem, NC 27117-2037, PH: 336-784-4800, FAX: 336-784-0634, www.thermcraftinc.com

Upton Industries, Inc., 30435 Groesbeck, Roseville, MI 48066, PH: 810-771-1200 or 800-541-1204, FAX: 810-771-8970, www.upton.thomasregister.com

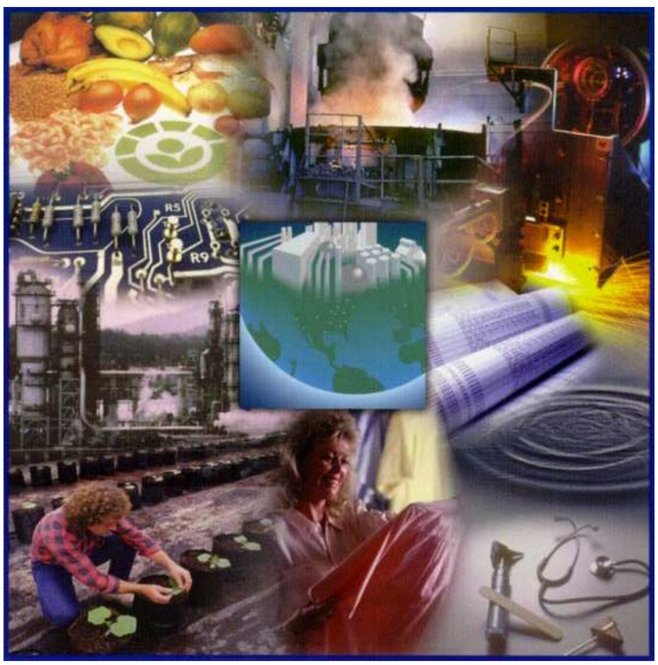
Vacuum Furnace Systems, 1983 Clearview Road, P.O. Box 480, Souderton, PA 18964-0480, PH: 215-723-8125, FAX: 215-721-4488, www.vfscorp.com

Vacuum Tube Industries, Inc., 506 N. Warren Avenue, P.O. Box 2009, Dept. J, Brockton, MA 02405-2009, PH: 800-528-5014

Watlow, 12001 Lackland Road, St. Louis, MO 63146, PH: 314-878-4600, FAX: 314-878-6814, www.watlow.com

Welduction Corp., 24492-T Indoplex Circle, Farmington Hills, MI 48335-2526, PH: 800-798-3042

APPENDIX



This section provides a glossary of terms used in this marketing kit.

A
APPENDIX

Glossary - Heat Treating Terms

Aging – a change in the properties of certain metals and alloys that occurs at ambient or moderately elevated temperatures after hot working or a heat treatment (quench aging in ferrous alloys, natural or artificial aging in ferrous or nonferrous alloys) or after a cold working operation (strain, aging). The change in properties is often, but not always, due to a phase change (precipitation), but never involves a change in chemical composition of metal or alloy.

Age Hardening – a process of aging that increases hardness and strength and ordinarily increases ductility. Age hardening usually follows rapid cooling or cold working.

Alloy Steel – steel containing significant quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, silicon, sulfur and phosphorous) added to effect changes in the mechanical or physical properties.

Annealing – a generic term denoting a treatment, consisting of heating to and holding at a suitable temperature, followed by cooling at a suitable rate, used primarily to soften metallic materials, but also to simultaneously produce desired changes in other properties or in microstructure. The purpose of such changes may be, but is not confined to: improvement of machinability, facilitation of cold work, improvement of mechanical or electrical properties, and/or increase in stability of dimensions. When applied only for the relief of stress, the process is properly called stress relieving or stress-relief annealing.

Austenite – a solid solution formed when carbon and certain alloying elements dissolve in gamma iron. Gamma iron is formed when carbon or constructional alloy steel is heated above the so-called critical range, and the ferrite (alpha iron, with a body-centered crystal structure) is transformed to a face-centered crystal structure. Austenite does not exit in most ordinary steels at room temperature.

Austenitizing – forming austenite by heating a ferrous alloy into the transformation range (partial austenitizing) or above the transformation range (complete austenitizing). When used without qualification, the term implies complete austenitizing.

Baking – (1) heating to a low temperature to remove gases, (2) curing or hardening surface coatings such as paints by exposure to heat. (3) heating to drive off moisture as in the baking of sand cores after molding.

Bainite – a decomposition product of austenite consisting of an aggregate of ferrite and carbide. In general, it forms at temperatures lower than those where very fine pearlite forms and higher than that where martensite begins to form on cooling. Its appearance is feathery if formed in the upper part of the temperature range; acicular, resembling tempered martensite, if formed in the lower part.

Blue Brittleness – brittleness occurring in plain carbon steel when heated in the temperature range of 400^0 to 650^0F, or when cold after being worked within this temperature range.

Box Annealing – a process of annealing a ferrous alloy in a suitable metal container with or without packing material in order to minimize oxidation. The charge is usually heated slowly to a temperature below the transformation range, but sometimes above or within it, and is then cooled slowly. This process is also called "close annealing" or "pot annealing."

Brazing – a group of welding processes that join solid materials together by heating them to a suitable temperature and by using a filler metal having liquidus above 450°C (840°F) and below the solidus of the base materials. The filler metal is distributed between the closely fitted surfaces of the joint capillary attraction.

Brazing Filler Metal – a nonferrous filler metal used in brazing and braze welding.

Bright Annealing – a process of annealing usually carried out in a controlled furnace atmosphere so that surface oxidation is minimum and the surface remains relatively bright.

Carbon Nitriding – a case hardening process in which suitable ferrous material is heated above the lower transformation temperature in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, create a concentration gradient. The process is completed by cooling at a rate that produces the desired properties in the workplace.

Carbon Steel – Iron alloy containing carbon up to about two percent and only residual quantities of other elements except those added for deoxidization, with silicon usually limited to 0.60 percent and manganese to 1.65 percent. Also termed plain-carbon steel.

Carburizing – absorption and diffusion of carbon into solid ferrous alloys by heating to a temperature usually above Ac3, in contact with a suitable carbonaceous material. A form of case hardening that produces a carbon gradient extending inward from the surface, enabling the surface layer to be hardened either by quenching directly from the carburizing temperature or by cooling to room temperature, then reaustenitizing and quenching.

Case Hardening – a generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two and, by diffusion, create a concentration gradient. The processes commonly used are carburizing and quench hardening; cyaniding, nitriding, and carbonitriding. The use of the applicable specific process name is preferred.

Cementite – a compound of iron and carbon frequently in steels known chemically as iron carbide and having the approximate chemical formula Fe3C.

Controlled Cooling – a process of cooling from an elevated temperature in a predetermined manner, to avoid hardening, cracking or internal damage, or to produce a desired microstructure. This cooling usually follows the final hot forming operation.

Cooling Stresses – stresses developed by uneven contraction or external constraint of metal during cooling; also those stresses resulting from localized plastic deformation during cooling, and retained.

Corrosion – gradual chemical or electrochemical attack on a metal by atmosphere, moisture or other agents.

Creep – the flow of plastic deformation of metals held for long periods of time at stresses lower than the normal yield strength. The effect is particularly important if the temperature of stressing is in the vicinity of the recrystallization temperature of the metal.

Curie Temperature – the temperature of magnetic transformation below which a metal or alloy is ferromagnetic and above which is paramagnetic (essentially nonmagnetic).

Deoxidize – in the limited sense used in metallurgy, the removal of oxygen from a batch of molten steel. Oxygen is present as iron oxide (FeO), which is dissolved in the steel, and is removed by adding a deoxidizing agent as manganese, silicon, or aluminum.

Ductility – the property that permits permanent deformation before fracture by stress in tension.

Electromagnetic Induction – inducing current flow in an electrically conducting material by means of an alternating magnetic field.

Endurance – the ability of parts to withstand repeated reversals of stress.

Endurance Limit – the maximum stress that a metal will withstand without failure during a specified large number of cycles of stress. If the term is employed without qualification, the cycles of stress are usually such as to produce complete reversal of flexural stress.

Ferrite – A solid solution of one or more elements in body-centered cubic iron; the solute is generally assumed to be carbon unless designated otherwise.

Fillet – a concave junction of two (usually perpendicular) surfaces.

Flame Annealing – a process of softening a metal by the application of heat from a high-temperature flame.

Flame Hardening – a process for hardening the surfaces of hardenable ferrous alloys in which an intense flame is used to heat the surface layers above the upper transformation temperature, whereupon the workpiece is immediately quenched.

Flux Concentrator – a magnetic material which is utilized to gather the flux field set up during induction heating and modify the resultant heating pattern. Flux concentrator are made from eight silicon iron laminations (frequencies below 10khz), ferrites, or powdered iron combinations for use at higher frequencies including those in the radio frequency (RF) range.

Forging – (1) as a noun; a metal product which has been formed by hammering or pressing, (2) as a verb; forming hot metal into the desired shape by means of hammering or pressing.

Forging Strains – differential strains that result from forging or from cooling from the forging temperature, and that are accompanied by residual stresses.

Furnace Brazing – a mass-production brazing process in which the filler metal is preplaced on the joint, then the entire assembly is heated to brazing temperature in a furnace. Usually, a protective furnace atmosphere is required, and wetting of the joint surfaces is accomplished without using a brazing flux.

Gas Cyaniding – synonymous with carbonitriding.

Grade – the term grade designates divisions within different types based on carbon content or mechanical properties; for example, "This is a high tensile grade of steel."

H-Steels – alloy steels that can be used in applications requiring different degrees of hardenability.

Hardenability – in steels, the property that determines the depth and distribution of hardness induced by austenitizing and quenching. Hardenability is a function of alloy composition and quenching medium.

Hardening – increasing the hardness by suitable treatment, usually involving heating and cooling. For steels, this typically consists of austenitizing followed by cooling to form pearlite, bainite, or martensite, or a combination of theses constituents.

Hardness – defined in terms of measurement. (1) Usually the resistance to indentation. (2) Stiffness or temper of wrought products. (3) Machinability characteristics.

Heat – (1) a form of energy which raises the temperature of bodies into which it is absorbed. (2) An individual bath of metal as it is treated in a furnace.

Hot Quenching – a process of quenching in a medium at a temperature substantially higher than atmospheric temperature.

Indentation Hardness – the resistance of a material to indentation. This is the usual type of hardness test, in which a pointed or round indenter is pressed into a surface under a substantially static load.

Induction Brazing – brazing in which the required heat is generated by subjecting the workpiece to electromagnetic induction.

Induction Hardening – a surface-hardening process in which only the surface layer of a suitable ferrous workpiece is heated by electromagnetic induction to above the upper critical temperature and immediately quenched.

Induction Heating – heating by combined electrical resistance and hysteresis losses induced by subjecting a metal to an alternating magnetic field surrounding a coil carrying alternating current.

Initial Creep – the early part of the time-elongation curve for creep, in which extension increases at a rapid rate.

Inclusions – particles of non-metallic impurities, usually oxides, sulphides, silicates, and such, which are mechanically held in steel during solidification.

Intergranular Corrosion – a type of electrochemical corrosion that progresses preferentially along the grain boudaries of an alloy, usually because the grain boundary regions contain material anodic to the central regions of the grain.

IZOD Test – a pendulum type of impact test, in which the specimen is supported at one end as a cantilever beam and the energy required to break of the free end is used as a measure of impact strength.

Jominy Test – Hardenability test performed usually on alloy steels used to determine effects.

Limited Decarburization – Restricted decarburization. Decarburization limitations may be specified in special bar quality steels.

Magnaflux Test – an inspection given to important or highly stressed parts of aircraft quality steel using alloy. It consists in suitably magnetizing the material and applying a prepared magnetic powder which has been applied to detect flaws or defects on the surface.

Magnetic Testing – or the Magnaflux method of testing for determining internal defects, which is carried out by magnetizing the bar and sprinkling it with magnetic powder which ahs been applied to detect flaws or defects on the surface.

Malleability – the property that determines the ease of deforming a metal when the metal is subjected to rolling or hammering. The more malleable metals can be hammered or rolled into thin sheet more easily than others.

Martempering – the process of quenching an austenitized ferrous alloy in a medium at a temperature in the upper portion of the temperature range of martensite formation, or slightly above that range, and holding in the medium until the temperature throughout the alloy is substantially uniform. The alloy is then allowed to cool in air through the temperature range of martensite formation.

Martensite – a metastable phase of steel formed by a transformation of austenite below the Ms temperature and composed of a body-centered tetrogonal lattice. Its microstructure is characterized by an acicular, or needlelike pattern.

McQuaid-Ehn Test – a special test for revealing grain size when the steel is heated above the critical range. The test sample is immersed in a carbonaceous medium, heated to 1700^0F for a designated period of time and then allowed to cool. The treatment causes the grains of the steel to be outlined sharply when polished, etched and viewed under a microscope. There are eight standard McQuaid-Ehn grain sizes, ranging from No.8, the finest to No.1, the coarsest.

Mechanical Properties – those properties of a material that reveal the elastic and inelastic reaction when force is applied, or that involve the relationship between stress and strain; for example, the modulus of elasticity, tensile strength and fatigue limit. These properties have often been designated as "physical properties", but the term "mechanical properties" is much to be preferred.

Microstructure – the structure of polished and etched metals as revealed by a microscope at a magnification greater than 10 diameters.

Molybdenum – a special alloying element commonly used to increase hardenability of steel. Molybdenum is sometimes added to stainless steel to enhance its corrosion resistance to certain chemicals. Molybdenum is commonly called "moly".

Notch Brittleness – Susceptibility of a material to brittleness in areas containing a groove, scratch sharp fillet or notch.

Notch Fatigue Factor – the reduction caused in fatigue strength by the presence of a sharp notch in the stressed test section.

Notch Sensitivity – the reduction caused in nominal strength, impact or static, by the presence of a stress concentration, usually expressed as the ratio of the notched to the unnotched strength.

Normalizing – heating a ferrous alloy to a suitable temperature above the transformation range and then cooling in air to a temperature substantially below the transformation range.

Oxidize – a chemical treatment which increases the positive valences of a substance. In a limited sense, adding oxygen to a substance, as in oxidizing C to CO, CO to CO_2, Si to SiO_2, Mn to MnO.

Pearlite – a lamellar aggregate of ferrite and cementite, often occurring in steel and cast iron.

Permeability – (1) magnetic permeability, the ratio of the magnetic induction to the intensity of the magnetizing field. (2) In a mold, the porosity of foundry sands and the ability of trapped gases to escape through the sand.

Physical Metallurgy – the adoption of the metal to its intended uses, a part of ferrous metallurgy dealing chiefly with physical changes produced in the properties of the metal after chemical composition has been nearly entirely fixed.

Physical Properties – those properties familiarly discussed in physics, exclusive of those described under mechanical properties; for example, density, electrical conductivity, coefficient of thermal expansion. This term has often been used to describe mechanical properties, but this usage is not recommended.

Plastic Deformation – permanent distortion of a material under the action of applied stresses.

Plasticity – the ability of a metal to be deformed extensively without rupture.

Preheating – heating before some further thermal of mechanical treatment. For tool steel, heating to an intermediate temperature immediately before final austenitizing. For some nonferrous alloys, heating to a high temperature for a long time, to homogenize the structure before working. In welding and related processes, heating to an intermediate temperature for a short time immediately before welding, brazing, soldering, cutting, or thermal spraying.

Process Annealing – in the sheet and wire industries, a process by which a ferrous alloy is heated to a temperature close to, but below, the lower limit of the transformation range and is subsequently cooled. This process is applied in order to soften the alloy for further cold working.

Quality – Refers to the suitability of the steel for the purpose or purposes for which it is intended.

Quench Hardening – Hardening a ferrous alloy, such as steel, by austenitizing and then cooling rapidly enough so that some or all of the austenite transforms to martensite.

Quench Ring – A ring typically similar in size and shape with the induction coil, used for quenching the workpiece after the heating cycle. Often additional quench rings are added to the set-up to allow for faster cycle times and to reduce the workpiece temperature for safe handling after heating.

Quenching – rapid cooling. When applicable, the following more specific terms should be used: direct quenching, for quenching, hot quenching, interrupted quenching, selective quenching, spray quenching, and time quenching.

Quenching Crack – a fracture from thermal stresses induced during rapid cooling or quenching. Frequently encountered in alloys that have been overheated and liquated and are thus "hot short".

Recuperator – a piece of equipment for recovering heat from hot, spent gases and using it for the preheating of incoming fuel or air. This is a continuous operation, in which the incoming materials pass through pipes surrounded by a chamber through which the outgoing gases pass.

Reference Depth – the effective depth of the current carrying layers. It is the depth from the surface to the depth where the induced field strength and current are reduced to 37% of their surface values (i.e., base of the natural logarithm or 2.718).

Refractory – ideally, any substance which is infusible at the highest temperature it may be required to withstand in service. A perfect refractory, which does not exist at present, would be one which: (1) would not fuse or soften, (2) would not crumble or crack, (3) its construction or expansion would be the minimum, (4) would not conduct heat, (5) would be impermeable to high temperature gases and liquids, (6) would resist mechanical abrasion, and (7) would not react chemically with substances in contact with it.

Regenerator – equipment used for recovering heat from hot, spent gases from a furnace. The regenerator differs from the recuperator in that the hot spent gases are used to heat brick checkerwork; then after the flow of the gases has been turned off, the gases to be preheated are passed through the checkerwork.

Scale – an oxide of iron forming on the surface of hot steel. Sometimes it forms in large sheets which fall off when the steel is rolled.

Scanning Method – A method of progressively heating and/or quenching where there is linear motion between the induction coil and the workpiece. This method of processing allows for the heating of very large parts (i.e. rolling mill rolls, large gears and pinions, and long shafts) with comparatively low power input relative to the mass of the workpiece. Processing by scanning can be accomplished in either the vertical or horizontal orientation.

Seam – On the surface of metal, a crack that has been closed but not welded; usually produced by some defect either in casting, or in working, such as blowholes that have been oxidized or folds and laps that have been formed during working. Seam also refers to lap joints as in seam welding.

Secondary Creep – the secondary portion of the creep curve following the initial creep stage and in which the rate of creep has reached a rather constant value.

Secondary Hardening – tempering certain alloy steels at certain temperatures so that a hardness is obtained greater than that resulting from the tempering of the same steel at some lower temperature for the same time.

Selective Heating – intentionally heating only certain portions of a workpiece.

Selective Quenching – quenching only certain portions of an object.

Self-hardening Steel – a steel containing sufficient carbon or alloying elements or both, to form martensite either through air hardening or, as in welding and induction hardening, through rapid removal of heat from a locally heated portion by conduction into the surrounding cold metal.

Shield – sheet metal devices that cancel or absorb electromagnetic flux to prevent heating where it is not intended or to prevent inter-action with adjacent coils. The sheet metals most often used are aluminum and copper and the shield thickness is not less than four times the depth of penetration of the shield material at the frequency being used.

Single-shot Method – A "static" method of processing where only one part at a time is placed in the induction coil and heated. Induction coils for this method of processing must be designated to heat the workpiece to precise heating patterns without the use of linear motion during the heating cycle.

Soaking Pit – a furnace or pit for the heating of steel to make the temperature uniform throughout.

Solution Heat Treatment – heating an alloy to a suitable temperature, holding at the temperature long enough to reduce residual stresses, and then cooling rapidly enough to hold these constituents in solution.

Special Straightness – when material is desired to closer-than-standard straightness tolerances (as set forth in the AISI manual), it may be ordered to special straightness. Such straightness is done by machinery and may result in increased surface hardness in localized areas of the steel.

Spheroidizing – any process of heating and cooling that produces a rounded or globular form of carbide in steel. Spheroidizing methods frequently used are: (1) prolonged holding at a temperature just below Ae_1, (2) heating and cooling alternately between temperatures that are just above and just below $Ae_{1,}$ (3) heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace, or holding at a temperature just below Ae_1, (4) cooling at a suitable rate from the minimum temperature at which all carbide is dissolved, and then reheating in accordance with method 1 or 2 above (applicable to hypereutectoid steel containing a carbide network.

Stabilizing Anneal – a treatment applied to austenitic stainless steels that contain titanium or columbium. This treatment consists of heating to a temperature below that of a full anneal in order to precipitate the maximum amount of carbon as titanium carbide or columbium carbide. This eliminates precipitation at lower temperatures, which might reduce the resistance of the steel to corrosion.

Stainless Steel – any steel containing four or more percent chromium is classified as stainless. However, there are many grades for specific purposes. These grades may contain nickel or molybdenum or both, but always chromium.

Strain Hardening – an increase in hardness and strength caused by plastic deformation at temperatures lower than the recrystallization range.

Stress – the load per unit if area. Ordinarily stress-strain curves do not show the true stress (load divided by area at that moment), but a fictitious value obtained by using always the original area.

Stress Relieving – heating to a suitable temperature, holding long enough to reduce residual stresses, and then cooling slowly enough to minimize the development of new residual stresses.

Susceptor – a material which is heated by the induction field and then transfers that heat to a nonconducting material by conduction, convection, or radiation.

Surface Checking – general breaking and cracking of the surface, which may result from a variety of causes, such as overrolling, overforming, or atmospheric attack at grain boundaries.

Temper – (1) in heat treatment, reheating hardened steel or hardened cast iron to some temperature below the eutectoid temperature for the purpose of decreasing hardness and increasing toughness. The process also is sometimes applied to normalized steel. (2) in tool steels, temper is sometimes used, but unadvisedly , to denote the carbon content. (3) in nonferrous alloys and in some ferrous alloys (steels that cannot be hardened by heat treatment) the hardness and strength produced by mechanical or thermal treatment, or both, and characterized by a certain structure, mechanical properties, or reduction in area during cold working.

Tempering – a process of reheating quench-hardened or normalized steel to a temperature below the transformation range, and then cooling at any rate desired.

Tensile Strength – the value obtained by dividing the maximum load observed during tensile straining until breakage occurs by the specimen cross-sectional area before straining. Also called "ultimate strength".

Thermal Stresses – stresses in metal, resulting from non-uniform distribution of temperature.

Torsion – strain created in a material by a twisting action. Correspondingly, the stress within the material resisting the twisting.

Toughness – property of absorbing considerable energy before fracture; usually represented by the area under a stress-strain curve, and therefore involving both ductility and strength.

Transformation Temperature – the temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a transformation range.

Vickers Hardness Test – an indentation hardness test employing a 136 degree diamond pyramid indenter and variable loads enabling the use of one hardness scale from very soft lead to tungsten carbide.

Viscosity – the resistance of fluid substance to flowing, quantitatively characteristic for each individual substance at a given temperature and under other definite external conditions.

Work Hardness – hardness developed in metal as a result of cold working.

Yield Point – in mild or medium-carbon steel, the stress at which a marked increase in deformation occurs without increase in load. In other steels and in nonferrous metals this phenomenon is not observed.

Yield Strength – the stress at which a material exhibits a specified limiting deviation from proportionality of stress to strain. An offset of 0.2 percent is used for many metals such as aluminum-base and magnesium-base alloys, while a 0.5 percent total elongation under load is frequently used for copper alloys.

Target:
Materials Fabrication Industry

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EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com