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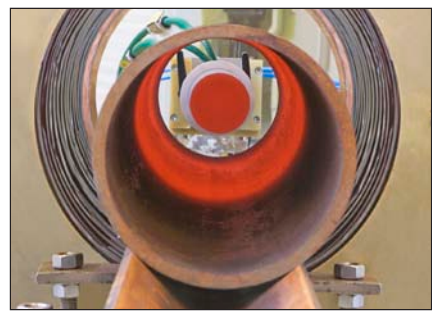
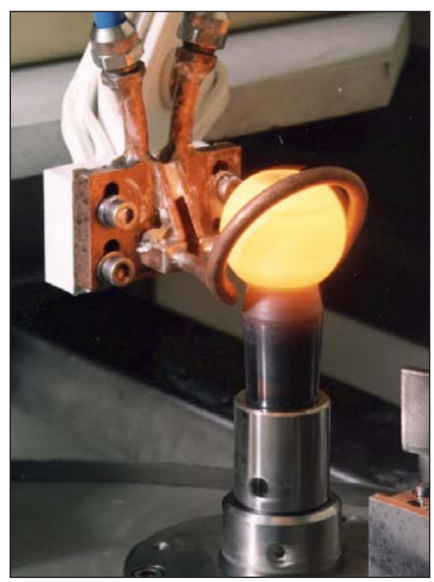
Innovative Heating Solutions

The Induction Heating Guide

What if you could heat metal parts without any physical contact, at speeds unheard off with conventional methods...with pinpoint accuracy, consistency, and up to 90% efficiency...without open flames, loud noise, or harmful fumes?

This guide will show you how all of the above can be accomplished with lean, green induction heating. If you're searching for an industrial heating alternative, we'll show you exactly how this technology works and how it can benefit your manufacturing process. No other heating method offers such an impressive combination of economy, quality, and speed for processes such as industrial hardening, brazing, annealing, tempering, soldering, and heat staking. With the proper setup, even non-metals can be efficiently heated. And this technology will easily fit on your manufacturing floor, eliminating the delay and cost of off-line processing and outsourcing. Whether your process requirements dictate a benchtop heating unit for a work cell or a fully-automated production system, there's an induction heating solution that will meet your needs.





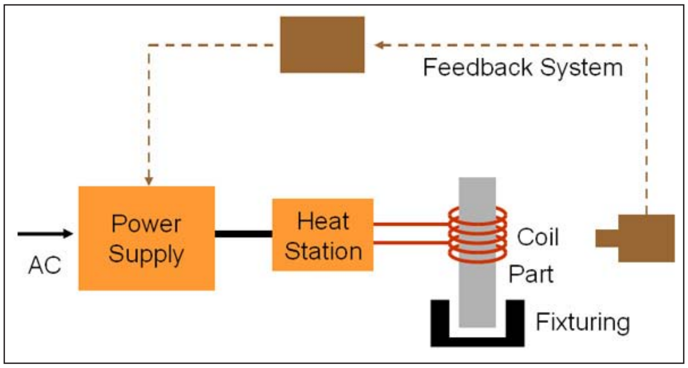
What is Induction Heating?

Induction heating is a process which is used to bond, harden or soften metals or other conductive materials. For many modern manufacturing processes, induction heating offers an attractive combination of speed, consistency and control.

The basic principles of induction heating have been understood and applied to manufacturing since the 1920s. During World War II, the technology developed rapidly to meet urgent wartime requirements for a fast, reliable process to harden metal engine parts. More recently, the focus on lean manufacturing techniques and emphasis on improved quality control have led to a rediscovery of induction technology, along with the development of precisely controlled, all solid state induction power supplies.

What makes this heating method so unique? In the most common heating methods, a torch or open flame is directly applied to the metal part. But with induction heating, heat is actually "induced" within the part itself by circulating electrical currents.

Induction heating relies on the unique characteristics of radio frequency (RF) energy - that portion of the electromagnetic spectrum below infrared and microwave energy. Since heat is transferred to the product via electromagnetic waves, the part never comes into direct contact with any flame, the inductor does not get hot, and there is no product contamination. When properly set up, the process becomes very repeatable and controllable.



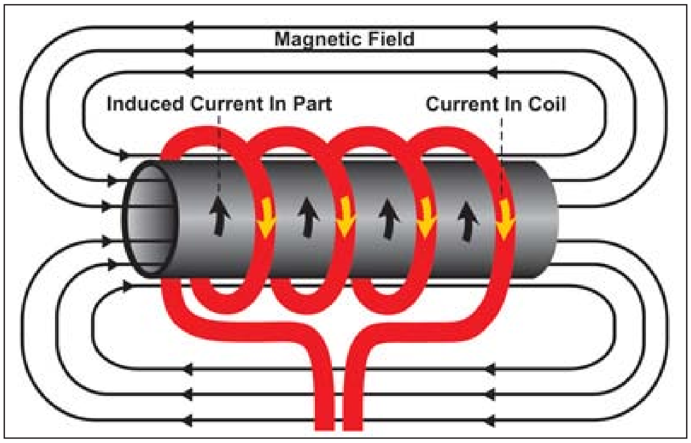
Basic induction heating setup

HOW INDUCTION HEATING WORKS

How exactly does induction heating work? It helps to have a basic understanding of the principles of electricity. When an alternating electrical current is applied to the primary of a transformer, an alternating magnetic field is created. According to Faraday's Law, if the secondary of the transformer is located within the magnetic field, an electric current will be induced.

In a basic induction heating setup shown at above right, a solid state RF power supply sends an AC current through an inductor (often a copper coil), and the part to be heated (the workpiece) is placed inside the inductor. The inductor serves as the transformer primary and the part to be heated becomes a short circuit secondary. When a metal part is placed within the inductor and enters the magnetic field, circulating eddy currents are induced within the part.

As shown in the second diagram, these eddy currents flow against the electrical resistivity of the metal, generating precise and localized heat without any direct contact between the part and the inductor. This heating occurs with both magnetic and non-magnetic parts, and is often referred to as the "Joule effect", referring to Joule's first law – a scientific formula expressing the relationship between heat produced by electrical current passed through a conductor.



How induction heating works

Secondarily, additional heat is produced within magnetic parts through hysteresis – internal friction that is created when magnetic parts pass through the inductor. Magnetic materials naturally offer electrical resistance to the rapidly changing magnetic fields within the inductor. This resistance produces internal friction which in turn produces heat.

In the process of heating the material, there is therefore no contact between the inductor and the part, and neither are there any combustion gases. The material to be heated can be located in a setting isolated from the power supply; submerged in a liquid, covered by isolated substances, in gaseous atmospheres or even in a vacuum.

IMPORTANT FACTORS TO CONSIDER

The efficiency of an induction heating machine for a specific application depends on several factors: the characteristics of the part itself, the design of the inductor, the capacity of the power supply, and the amount of temperature change required for the application.

The Characteristics of the Part

METAL OR PLASTIC

First, induction heating works directly only with conductive materials, normally metals. Plastics and other non-conductive materials can often be heated indirectly by first heating a conductive metal susceptor which transfers heat to the non-conductive material.

MAGNETIC OR NON-MAGNETIC

It is easier to heat magnetic materials. In addition to the heat induced by eddy currents, magnetic materials also produce heat through what is called the hysteresis effect (described above). This effect ceases to occur at temperatures above the "Curie" point - the temperature at which a magnetic material loses its magnetic properties. The relative resistance of magnetic materials is rated on a "permeability" scale of 100 to 500; while non-magnetics have a permeability of 1, magnetic materials can have a permeability as high as 500.

THICK OR THIN

With conductive materials, about 85% of the heating effect occurs on the surface or "skin" of the part; the heating intensity diminishes as the distance from the surface increases. So small or thin parts generally heat more quickly than large thick parts, especially if the larger parts need to be heated all the way through.

Research has shown a relationship between the frequency of the alternating current and the heating depth of penetration: the higher the frequency, the shallower the heating in the part. Frequencies of 100 to 400 kHz produce relatively high-energy heat, ideal for quickly heating small parts or the surface/skin of larger parts. For deep, penetrating heat, longer heating cycles at lower frequencies of 5 to 30 kHz have been shown to be most effective.

RESISTIVITY

If you use the exact same induction process to heat two same size pieces of steel and copper, the results will be quite different. Why? Steel – along with carbon, tin and tungsten – has high electrical resistivity. Because these metals strongly resist the current flow, heat builds up quickly. Low resistivity metals such as copper, brass and aluminum take longer to heat. Resistivity increases with temperature, so a very hot piece of steel will be more receptive to induction heating than a cold piece.

Designing the Inductor

It is within the inductor that the varying magnetic field required for induction heating is developed through the flow of alternating current.

So inductor design is one of the most important aspects of the overall system. A well-designed inductor provides the proper heating pattern for your part and maximizes the efficiency of the induction heating power supply, while still allowing easy insertion and removal of the part.

Good inductor design is one of the most important aspects of the overall machine.

Power Supply Capacity

The size of the induction power supply required for heating a particular part can be easily calculated. First, one must determine how much energy needs to be transferred to the work-piece. This depends on the mass of the material being heated, the specific heat of the material, and the rise in temperature required. Heat losses from conduction, convection and radiation should also be considered.

Degree of Temperature Change Required

Finally, the efficiency of induction heating for specific application depends on the amount of temperature change required. A wide range of temperature changes can be accommodated; as a rule of thumb, more induction heating power is generally utilized to increase the degree of temperature change.

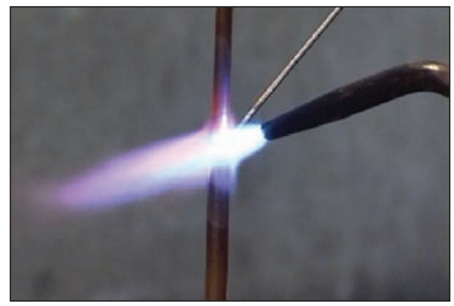
Alternative Sources of Heat

As you evaluate induction heating for your manufacturing process, it is important to understand advantages and disadvantages of alternative heating methods. All other industrial heating methods utilize one or more of three basic heat transfer methods:

- Conductive heating is the direct flow of heat through a material resulting from physical contact. The smoother the surface, the better the heat transfer.
- Convection heating systems rely on heat transfer between a surface and adjacent fluid (gas, air, liquid) and by the flow of fluid from one place to another induced by temperature.
- Radiation heating (electromagnetic radiation) does not require any transfer medium; thermal energy is transferred through matter or space by electromagnetic waves - ultraviolet, infrared, microwave, or radio frequency. So microwave ovens and infrared heaters are examples of radiant heating.

FLAME HEATING

Flame heating involves the use of gas flame to heat the part (workpiece) without melting the part or removing material. Heating torches and flame heaters are widely used for brazing, soldering, hardening, hot forming, pre-heating for welding, and many other applications.



Flame heating, an example of conductive heating, offers the advantages of relative economy and speed for one-off applications. However fumes and heat produce an unpleasant working environment, and there is the potential for burns. Other disadvantages include lack of accuracy and repeatability. Even in the hands of a skilled operator, it is difficult with flame heating to achieve consistency when working through a series of parts.

RESISTANCE HEATING

Resistance heating relies on a current being passed through a resistive material such as graphite, molybdenum, tantalum, etc. The electrical current is connected directly to the heating element. Heat from the element is then radiated towards the part to be heated. Resistance heat is used to melt metals, glass and plastics before forming; for welding, brazing, and selective surface heat treatments.

Resistance heating is very localized and works quickly. However it tends to have very poor temperature control with significant differences arising across the heating zone. Additionally, due to the fact that one piece must be done at a time, it can only be considered for low volume applications.

TRADITIONAL OVENS AND FURNACES

Ovens and furnaces are employed most often to heat batches of parts. Ovens generally operate up to 1400°F; furnaces generally heat at higher temperatures. Ovens and furnaces employe convection and radiation – either individually or in combination – to achieve the desired heating results. Ovens are often used for applications such as pre-heating and annealing, whereas furnaces are used for higher temperature processes such as brazing, heat treating, and sintering.

Ovens and furnaces require a substantial investment in valuable floor space and must be continuously operated to avoid long startup delays. Continuous operation requires relatively high operating costs. While generally effective at whole part heating, they cannot be used to heat sections of a part. Loss of heat into the factory environment is another factor to consider.

Induction Heating - The Lean Green Alternative

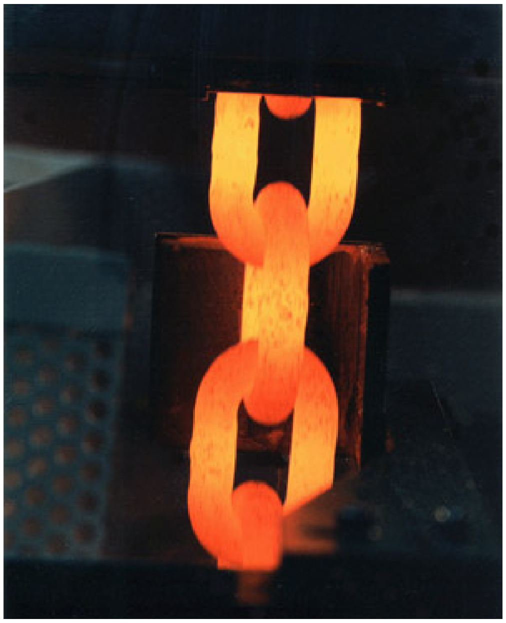
For most industrial applications, induction heating technology offers significant advantages: speed, accuracy, repeatability, cost-effectiveness, and an operator-friendly working environment. Learn more about the advantages of induction heating in our next section!

Advantages of Induction Heating

Why choose induction heating over convection, radiant, open flame or another heating method? Here's a short summary of the major advantages that modern solid state induction heating offers for lean manufacturing:

OPTIMIZED CONSISTENCY

Induction heating eliminates the inconsistencies and quality issues associated with open flame, torch heating and other methods. Once the machine is properly calibrated and set up, there is no guess work or variation; the heating pattern is repeatable and consistent. With modern solid state systems, precise temperature control provides uniform results; power can be instantly turned on or shut off. With closed loop temperature control, advanced induction heating machines have the capability to measure the temperature of each individual part. Specific ramp up, hold and ramp down rates can be established & data can be recorded for each part that is run.



Induction heating delivers consistency and quality.

MAXIMIZED PRODUCTIVITY

Production rates can be maximized because induction works so quickly; heat is developed directly and instantly (>2000º F. in < 1 second) inside the part. Startup is virtually instantaneous; no warm up or cool down cycle is required. The induction heating process can be completed on the manufacturing floor, next to the cold or hot forming machine, instead of sending batches of parts to a remote furnace area or subcontractor. For example, a brazing or soldering process which previously required a time-consuming, off-line batch heating approach can now be replaced with a continuous, one-piece flow manufacturing system.

IMPROVED PRODUCT QUALITY

With induction, the part to be heated never comes into direct contact with a flame or other heating element; the heat is induced within the part itself by alternating electrical current. As a result, product warpage, distortion and reject rates are minimized. For maximum product quality, the part can be isolated in an enclosed chamber with a vacuum, inert or reducing atmosphere to eliminate the effects of oxidation.

EXTENDED FIXTURE LIFE

Induction heating rapidly delivers site-specific heat to very small areas of your part, without heating any surrounding parts. This extends the life of the fixturing and mechanical setup.

ENVIRONMENTALLY SOUND

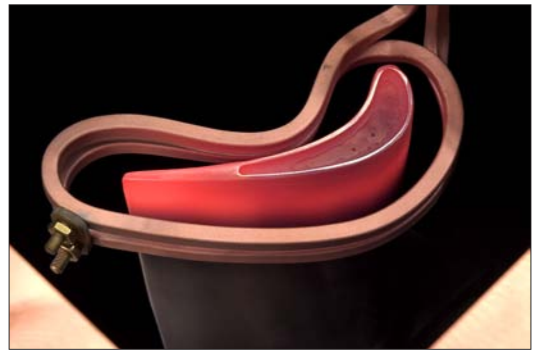
Induction heating machines do not burn traditional fossil fuels; induction is a clean, non-polluting process which will help protect the environment. An induction machine improves working conditions for your employees by eliminating smoke, waste heat, noxious emissions and loud noise. Heating is safe and efficient with no open flame to endanger the operator or obscure the process. Non-conductive materials are not affected and can be located in close proximity to the heating zone without damage.

REDUCED ENERGY CONSUMPTION

Tired of increasing utility bills? This uniquely energy-efficient process converts up to 90% of the energy expended energy into useful heat; batch furnaces are generally only 45% energy-efficient. And since induction requires no warm-up or cool-down cycle, stand-by heat losses are reduced to a bare minimum. The repeatability and consistency of the induction process make it highly compatible with energy-efficient automated systems.

Designing the Inductor

Inductor design is one of the most important aspects of the overall induction heating system. A well-designed inductor provides the proper heating pattern for your part and maximizes the efficiency of the power supply, while still allowing easy insertion and removal of the part.



It is within the inductor that the varying magnetic field required for induction heating is developed through the flow of alternating current. The heating element does not have to be shaped in a helix. With the right inductor design, it is possible to heat conductive materials of any size and form, and also possible to heat only the portion of material required.

It is even possible to heat different zones of the part at the same or different temperatures by means of a proper design of the inductor geometry. Temperature uniformity is achieved through the inductor design. The most effective uniformity can be achieved in round parts. Due to the nature of electrical current path flow, sharp edges could preferentially heat if the proper design is not used.

BASIC CONSTRUCTION

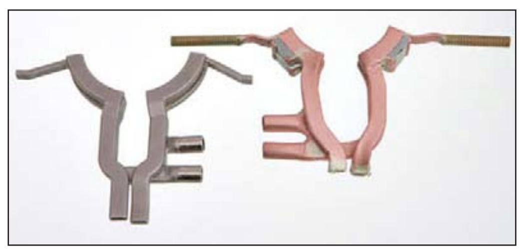
Inductors are traditionally made of copper tubing - a very good conductor of heat and electricity - with a diameter of 1/8" to 3/16"; larger copper inductor assemblies are made for applications such as strip metal heating and pipe heating. Inductors are usually cooled by circulating water, and are most often custom-made to fit the shape and size of the part to be heated. So inductors can have single or multiple turns; have a helical, round or square shape; or be designed as internal (part inside) or external (part adjacent to inductor).

COUPLING EFFICIENCY

There is a proportional relationship between the amount of current flow and distance between the inductor and part. Placing the part close to the inductor increases the flow of current and the amount of heat induced in the part. This relationship is referred to as the coupling efficiency of the inductor.

Microfusion Technology for Inductor Manufacturing

INCREASED REPEATABILITY, IMPROVED DURABILITY



GH Group has patented a revolutionary new system for inductor design using exclusive microfusion technology. Traditional inductor manufacturing is a one-off process – the copper tubing is shaped by hand to conform to engineering specifications. This makes it exceptionally difficult to manufacture absolutely identical inductors with the same performance characteristics.

With GH microfusion technology, identical inductors can be produced from the same 3D manufacturing mold. This increases repeatability and consistency when multiple induction systems are running the same process, and significantly reduces maintenance and calibration time when inductors need to changed out.

HOW THE PROCESS WORKS

The manufacture of inductors with GH microfusion technology is a three-step process:

- Obtaining a solid for this process involves two channels: design in a 3D program and 3D scanning (see Figure 1 below)
- 3D printing of the manufacturing mold (Figure 2)
- Obtaining the finished inductor by means of the microfusion process (Figure 3)

GH manufactures these inductors with a compound material that is 25% more conductive than copper. Advanced 3D design of the inside wall of the inductor improves cooling efficiency. And, the finished inductor offers improved durability with one piece construction – without any weak points from welding or braze joints.

Figure 1 Figure 2 Figure 3

Success Stories

HEAT TREATING & BRAZING TURBINE ENGINE PARTS

GE - Aviation, a leading global producer of jet engines for civil and military aircraft, previously used large batch vacuum furnaces for superalloy brazing, heat treating and chemical vapor deposition (CVD) coating. But the problems associated with the batch furnaces – large size, lack of quality control and poor efficiency – led them to search for a better way to meet lean, continuous flow manufacturing requirements.


GE - Aviation found that the VF-20 Induction Heating Vacuum Furnace provided accurate, consistent heating.

For example, the batch furnaces require significant WIP- in some cases several days worth - prior to having enough parts to justify running the large furnace. The company purchased several GH IA induction heating vacuum furnaces to replace their batch vacuum furnaces. "We're highly focused on lean manufacturing", said David Budinger, Senior Engineer for GE - Aviation. "With the VF-20 vacuum furnace as a key component of our production cell, we've been able to convert to small batch flow resulting in a 96% reduction in turn around time." "This new technology works so well the payback on the capital expense was less than two years and we are currently leveraging the technology throughout the supply chain."

GE - Aviation found that the VF-20 reaches operating temperature in minutes instead of hours. And with advanced induction heating technology, individual or small batches of engine parts can be heated with accuracy and consistency. The compact 5'x5' footprint of the GH IA system allows GE to install the units in work cells on the manufacturing floor, further improving production flow. The new furnaces have the flexibility to heat a variety of part sizes and shapes, including "orphans" from other heating processes. Additionally GH IA's furnace is over 85% energy efficient vs. about 50% for standard industrial vacuum furnaces.

BRAZING AUTOMOTIVE PARTS

Magnum Shielding of Pittsford, NY needed an alternative way to braze component parts for a new product line for its customer, Harley Davidson. Traditional bench brazing was not feasible due to the part finishing requirements.

GH IA worked with Magnum to determine if a turnkey induction heating system could perform the required brazing and meet the finishing requirements. Preliminary tests showed that the parts could be brazed in GH IA's equipment and meet Magnum's requirements. These early tests also showed that the required brazing could be performed with significant energy and cost savings over traditional batch furnace brazing methods.

Due to the large potential energy savings, Magnum and GH IA received funds from the New York State Energy Research and Development Authority (NYSERDA) to help fund the research and development of the induction heating system. After the preliminary tests were completed, GH Induction Atmospheres developed a specialized induction-based machine to Magnum's specifications, to efficiently braze the component parts. This machine yields low cycle times and consumes energy only on an as-needed basis to fulfill the downstream requirements, which is inherent to a "pull process" as part of the lean manufacturing ideology.

Using current furnace technology, brazing one set of components requires approximately 0.5 kWh. Brazing a set of components using induction heating technology only requires 0.03 kWh. By using the induction heating system, Magnum Shielding realizes energy savings of 0.47 kWh per joint.

BRAZING FUEL CELLS

Fuel cells are another area that require extensive brazing in the manufacturing process. When a manufacturer (with whom we have a confidentiality agreement) wanted to braze 200 plates in a fuel cell, GH IA was able to develop a complex brazing process using an intricate inductor design and programmable sled. Significant energy savings were recognized here as well. Using current furnace technology, soldering one set of electrodes for a fuel cell requires approximately 7 kWh. Soldering one set of electrodes using induction heating technology requires only 0.002 kWh, which results in a significant energy savings of 6.998 kWh per electrode.

Frequently Asked Questions

The founders of GH IA met recently to answer the questions they are most often asked about their heating technology.

How hot does the inductor get?
STEVE: "The inductor is cool to the touch; the heat that builds up in the inductor is constantly cooled with circulating water."

Can you use induction heating to braze steel parts in a nitrogen atmosphere?
DALE: "Yes you can, but the nitrogen has to be clean and have a low dew point."

Can diamond bits be brazed with induction heating?
DALE: "Sure, in fact induction heating is preferable for diamonds bits because it works so quickly. The longer the diamond remains at heating temperature, the faster it degrades. We recommend atmospheric brazing in a vacuum atmosphere for the best results."

How do I select a braze alloy?
STEVE: "We've added a Brazing Alloy Selection Guide to our Website to help you choose the best option. It depends on the composition of your part, how and where it will be used, and the joint strength required. Another helpful service we provide for our customers is to put them in touch with an experienced braze alloy supplier."

We've been running these old vacuum furnaces for years. How can we set up a leaner operation?
STEVE: "The best thing you can do is unplug those old furnaces and invest in a quick, clean vacuum induction system. Our new compact induction vacuum furnace will fit right into your manufacturing cell."

When is it better to use the indirect heat of an induction furnace instead of direct induction heat?
DALE: "Yeah, we get that question a lot. It depends on the geometry of your part and how you want to heat it. If you have a part with simple geometry and your process calls for heating a specific area of the part, direct induction heating will generally be preferable. However, if you need to heat the entire part, or if the part has a complex shape, then you'll achieve better results with an induction heating vacuum furnace."

Will induction heating increase my utility bills?
STEVE: "Not likely. Induction heating is a very effective, efficient means of heating. Most of our customers who are switching to induction for the first time see their utility bills go down."

What are typical utility requirements for induction?
STEVE: "Of course it depends on the system, but a typical system requires 440, 3-phase VAC at 60 Hz and 30 Amps. Also figure on 80 PSI compressed air and 40 PSI water at 4 gallons per minute for cooling."

Can you braze glass or ceramics with induction?
DALE: "If you work with glass or ceramics, a compact vacuum furnace is a great solution for brazing. You'll get quick, clean heat with very precise temperature control."

Is this joint suitable for induction brazing?
STEVE: "Our team of metallurgical and mechanical engineers will be glad to have a look at your parts and process and give you our best advice - no obligation!

Can induction be used to nickel braze in nitrogen?
DALE: "Yes, with a vacuum system. We've had some success in with foil preforms, but we've had no luck with nickel paste because the binder in the paste doesn't flow. So we suggest using a high vacuum system because it will work faster than oven heating and there is no time for nitrides to form."

Glossary of Terms

As you investigate an induction heating solution for your manufacturing process, the following definitions may be useful to you:

Annealing: A process which softens a metal by first heating and then slowly cooling it. Annealing removes stresses and improves machineability.

Bell Jar System: A relatively small protective atmosphere heating system designed for low volume production or lab use. Parts are heated in a sealed quartz "bell jar" to eliminate oxidation, scaling and carbon build-up.

Brazing: A method of joining two pieces of heated metal together with a third, molten filler metal. Brazed joints have great tensile strength – they are often stronger than the two metals being bonded together.

Capacitor: An electronic component that stores energy. Capacitors are used to smooth out or "decouple" the output of an induction heating power supply .

Conductive: An adjective describing a material that transfers heat. Inductors are usually made of copper, a highly-conductive metal.

Conduction Losses occur when heat is transferred between materials in direct physical contact. Heat loss to the fixture holding the part being heated in an inductor is a good example of conduction loss. These losses also occur in the part if only a small section is being heated.

Convection Losses are losses due to the flow of air/gasses across the surface of a heated part. Convection losses are typically smaller in magnitude and do not generally have a major impact in most applications.

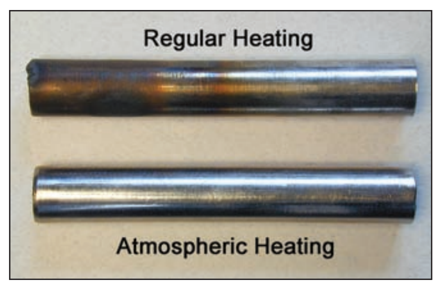
Curie temperature: The reversible point in a heating process in which a magnetic material loses its magnetic properties. For Iron (Fe) the Curie point is 770°C; for Nickel (Ni), it is 358°C; for Iron Oxide, (FE^2O^3), it is 622°C.

Capillary action: In brazing, capillary action is the pulling force that draws the melted alloy into the gap between the parts being joined .

Carburization: A process by which carbon is added t to a metal. Excess carbon can make metals brittle.

Controlled Atmosphere: A regulated atmosphere in which a heating process can be completed; usually used to ensure quality results. Brazing in a controlled atmosphere of nitrogen or argon instead of open air produces cleaner joints.

Coupling Efficiency: The proportional relationship between the amount of current flow and the distance between inductor and part. Placing the part close to the inductor increases the flow of current and the amount of heat induced in the part.



Eddy Current: Circulating movement of electrical current within an electrical conductor caused by the intersection of the conductor with a moving magnetic field.

Faraday's Law explains how a change in a magnetic field can create voltage. The law states that the amount of voltage created is equal to the change in magnetic flux divided by the change in time. The greater the change in the magnetic field, the greater amount of voltage.

Fusing: A manufacturing process which utilizes heat to melt or bond to materials together.

Glove Box: An enclosed workspace equipped with gloved openings which enable operator to allow manipulation materials inside the box. Glove boxes provide an excellent environment for controlled atmosphere brazing

Heat Station: Part of the induction heating system that incorporates the inductor. For improved flexibility, many induction heating power supplies are equipped with a remote heat station, which is connected by cabling to the main unit.

Heat Treating: A combination of controlled heating and cooling cycles applied to a metal for hardening or softening. Hardening, annealing, and stress relieving are examples of heat treating processes.

Heat Staking: The process of inserting a piece of metal into plastic. The metal is first heated, so that the plastic around the metal melts at first contact, and then cools around the metal, forming a firm bond [also known as shrink fitting].

Hysteresis: Heat produced by internal friction that is created when magnetic materials pass through the inductor. Magnetic materials naturally offer electrical resistance to the rapidly changing magnetic fields within the inductor. This resistance produces internal friction – from the process of repositioning the magnetic dipoles in the material – which in turn produces heat.

Inductor: Specially-shaped copper tubing through which alternating electrical current is passed, creating a varying magnetic field. Depending on the application, the metal parts to be heated are either positioned close to the inductor or passed through it. But the parts are heated without actually touching the inductor. Round inductors are sometimes referred to as coils.

Induction Heating: A process which is used to bond, harden or soften metals or other conductive materials, by placing the part to be heated in a copper inductor. For many modern manufacturing processes, induction heating offers an attractive combination of speed, consistency and control.

Joule Effect: A scientific formula – also known as Joule's first law – expressing the relationship between heat produced by electrical current passed through a conductor. It is expressed as "Q = I2 x R x t" where Q is the amount of heat produced, I is the current flowing through the part (conductor), R is the electrical resistance of the part, and t = time.

Pre-tinning: The process of pre-applying solder to metallic parts to improve the soldering process during the actual induction heating cycle.

Quenching: Cooling a part with water after it has been heated.

Radiation: Energy that comes from a source and travels through some material or through space in the form of rays or waves or particles. Light, heat, and sound are all examples of radiation.

Radio frequency (RF): a frequency of electromagnetic radiation in the range at which radio signals are transmitted, anywhere from 3 Hz to 300 GHz. Radio frequencies are higher than audio frequencies and lower than infrared frequencies.

Resistivity: The ability of a material to resist passage of electric current through itself or on its surface.

Shrink Fitting: The process of inserting a piece of metal into plastic. The metal is first heated, so that the plastic around the metal melts at first contact, and then cools around the metal, forming a firm bond [also known as heat staking.

Silver brazing: Joining two pieces of heated metal with a third, molten silver alloy. Silver brazing produces a very strong bond but requires very precise machining tolerances.

Soldering: the process of joining two pieces of metal by applying a third molten metal which has a lower melting point. Soldering is similar to brazing but it is done at lower temperatures and produces a less-strong bond.

Susceptor: A metal plate which is heated by the induction process and then used to transfer heat to a non-metallic material.

Tempering: A heat treatment applied to a metal after it has been hardened. The metal is first heated and then rapidly cooled to decrease hardness and increase toughness.

Vacuum Furnace: An industrial furnace which heats parts to very high temperatures in a controlled atmosphere or vacuum; frequently used for brazing to improve joint quality.

Custom-designed Vacuum Furnace

Free Parts Evaluation

HAVE YOU EVER ASKED YOURSELF:

- Isn't there a better way to heat these parts?
- Why can't I heat my parts with more precision and consistency?
- Isn't there a more energy-efficient way to run this heating process?
- Why does this process take so much time?
- How can I reduce my reject rates and improve product quality?

GH IA's free parts evaluation service for induction heating is designed to answer all these questions and more - before you commit to any investment! Simply send us samples of your parts and tell us about your process - we'll analyze your application requirements, determine the optimum combination of RF power and inductor configuration for your parts and give you our best advice!

With our free parts evaluation service, you can tap into our reservoir of induction heating experience with out any purchase obligation. The GH IA engineering staff has worked with parts of virtually every size and shape in hundreds of different applications including brazing, soldering, hardening, annealing, heat staking metal into plastic, precious metal melting, and bonding. We'll test and evaluate your parts and process requirements in our laboratory to determine the optimum heating approach.

METALLURGICAL LAB

GH IA has a complete in-house metallurgical laboratory for the evaluation of brazing and hardening applications. Our capabilities include the sectioning, metallurgical mounting, polishing, etching and metallographic examination.

We also have the capability of performing microhardness testing and standard Rockwell testing of hardened parts. Having the ability to do microhardness testing allows us to determine the exact case depth required for case hardening applications.

Our in-house metallurgical laboratory reduces our process development and machine testing time. It provides our customers with the assurance that our turnkey heating systems will meet their brazing and hardening process requirements.

HOW TO SEND US YOUR PARTS

So if you're not sure if induction heating is the right solution for you, why not send us your parts for free evaluation? There is no better way to determine how our technology will improve your manufacturing process.

The procedure is simple - start by printing a copy of our one-page parts evaluation form at http://www.gh-ia.com/pdf/IA_labform.pdf. Answer the questions as clearly as possible - the more information you provide our engineers, the better advice they can offer! Box up plenty of part samples and include the form in the package - our shipping address is at the end of this brochure and on the bottom of the form. If you have additional questions, please call, fax or e-mail us. We look forward to hearing from you!

About GH Induction Atmospheres

GH Induction Atmospheres (GH IA) is a leading American provider of innovative industrial heating solutions for automotive, aerospace, medical and energy production applications. We are an experienced industrial heating system integrator working solely with induction-based technology. We design and manufacture customized, turnkey induction heating systems for industrial brazing, welding, heat treating, hardening and general purpose heating.

THE WORLDWIDE GH GROUP

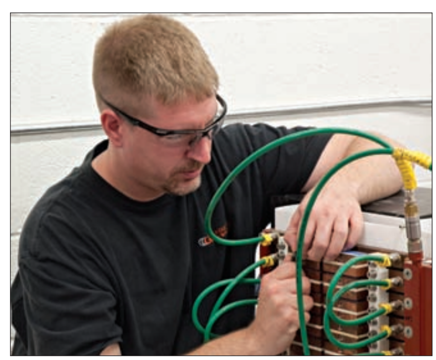
GH Induction Atmospheres is part of the worldwide GH Group. GH Group is one of the largest most experienced induction heating companies in the world with headquarters based in Valencia, Spain, and affiliated Companies in Germany, France, Mexico, Brazil, Argentina, India and China. GH has over 4000 installations in more than 50 countries serving some of the most discriminating customers for induction heating and heat treating.

INNOVATIVE HEATING SOLUTIONS

The first step of our product development process is to determine how induction heating can be integrated into your manufacturing process. In our Application Lab, we'll evaluate your part samples and determine the best heating approach. Our in-house Metallurgical Laboratory reduces our process development and machine testing time for hardening and brazing applications. Capabilities include sectioning, metallurgical mounting, polishing, etching and metallographic examination.

The process of designing the mechanics to support the induction heating machine along with the fixturing to move the customer's parts in and out of the heating zone requires an experienced, innovative engineering team. Quite simply, our mechanical engineering staff knows how to move parts, and consistently designs innovative, cost-effective machines which meet and frequently exceed our customer's process requirements.

As machine development proceeds to the manufacturing stage, periodic customer design reviews ensure that there are no surprises. Internal reviews – our entire group of mechanical/electrical engineers regularly meet to review each other's work – ensure that the evolving system design will have the benefit of the entire team's experience and input.



So if you're searching for an experienced integrator to design and build a turnkey manufacturing machine from top quality components...if your lean manufacturing initiatives dictate the replacement of outdated, energy-inefficient production equipment...if your production requirements demand higher yields with reduced downtime...then call us today at 585.368.2120 to arrange a complimentary evaluation of your parts and process requirements!

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