ENRX

Induction brazing

A GUIDE TO KEY FEATURES AND BENEFITS

Contents

Welcome

Almost everyone in manufacturing knows something about brazing. But sadly, too few fully appreciate the potential and benefits of induction brazing—a technology with many advantages over traditional flame-heating.

Many have only a hazy idea of just how versatile induction brazing can be. For example, you probably didn't know that ENRX brazing solutions range from compact, mobile systems to automated machines complete with loading robots and controlled atmospheres.

A document like this can present only a few of induction brazing's many benefits, and there's a good chance it won't discuss your specific needs and conditions. That's why we have a worldwide network of induction brazing experts. Just contact them and they'll answer any questions you may have.

ENRX is a powerhouse in induction heating, wireless inductive charging and contactless power supply for advanced manufacturing and mobility. We have a history within induction heating that goes back to the 1950s. Since then, we've grown to become one of the world's leading induction heating suppliers. To date, more than 90,000 induction systems have been installed, supported by our worldwide network of factories, laboratories, offices and agents.

Brazing basics

What is brazing?

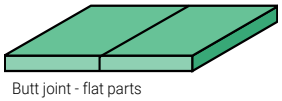
Brazing uses heat and a filler metal (alloy) to join metals. Once melted, the alloy flows between close-fitting base metals (the pieces being joined) by capillary action. This molten filler alloy interacts with a thin layer of the base metal to form a strong, leak-proof joint.

Type of braze joints

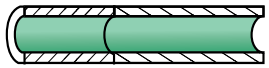
Braze joints come in many forms, but they primarily fall into two basic categories: the butt joint and the lap joint.

These fundamental joints can be modified in numerous ways to accommodate different geometries, assembly requirements, and functions of the parts involved.

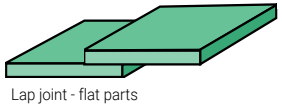
The strength of a braze joint largely depends on the bonding area, which is the overlap zone where two surfaces of the base material come into contact. Generally, a larger bonding area results in a stronger joint.



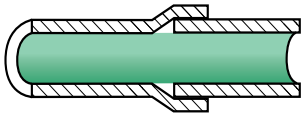
Butt joint - flat parts



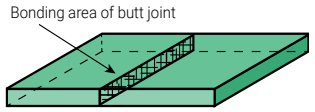
Butt joint - tubular parts (cutaway)

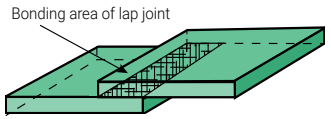


Lap joint - flat parts



Lap joint - tubular parts (cutaway)





Heat sources and brazing methods

Different heat sources can be used for brazing:

- Induction
- Resistance heaters
- Ovens and furnaces
- Torches/flame

There are three common brazing methods:

- Capillary
- Notch
- Moulding

Induction brazing is concerned solely with the capillary method.

Soldering

Induction heating is also used in soldering, a process similar in many ways to brazing. Soldering, however, uses much lower temperatures (below 450°C) than brazing (typically 450 - 1150°C). Induction soldering offers many of the same benefits as induction brazing: high heat density, short heating times, minimal heat seepage to adjacent components, no-contact heating, and controllability.

Induction brazing step by step

Before you start

Some questions should be investigated—and answered—in order to assure successful, cost-effective joining.

For instance:

- How suitable are the base metals for brazing?
- What type of braze joint should be designed?
- What coil design best meets specific time and quality requirements?
- Should the brazing process be manual or automatic?
- Is edge polishing and deburring necessary?

At ENRX, we address these critical points and more before recommending a brazing solution.

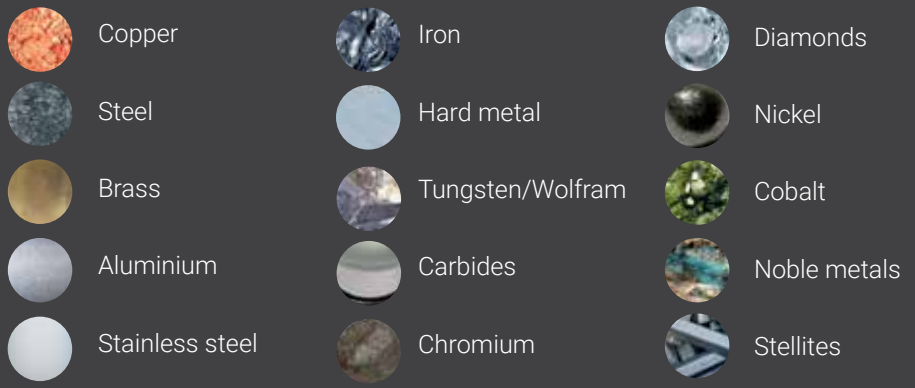
The brazing process

The induction brazing process can be divided into the following steps:

- Ensure the correct gap between the base materials.
- Clean the base materials by removing residues, oxides, etc.
- Apply flux to the joint area.
- Position and, if necessary, clamp the parts to be brazed in place.
- Apply the brazing filler alloy.
- Induce the desired heat in the joint area.
- Remove any remaining oxides or flux residue after brazing is complete.

What can we braze?

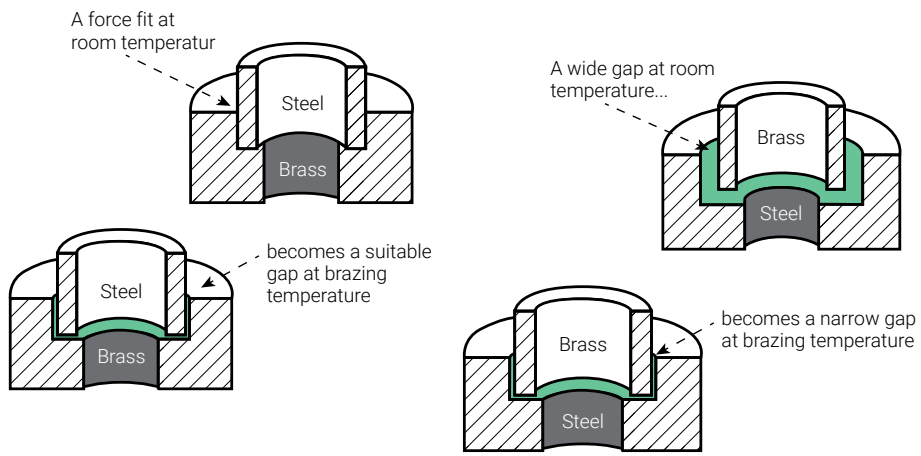
If you want to join any of these materials, chances are ENRX can devise a brazing solution tailored to your exact requirements.



Mind the gap!

Achieving the correct gap between base metals is critical. Tensile and shear strengths rely on having the appropriate clearance between the materials.

Too small a gap, and the alloy will not spread properly through the joint. Too large a gap, and the joint's strength will be concentrated in an alloy 'bridge' between the base materials, leaving the joint susceptible to failure. A too-large gap minimizes capillary force and leads to weak joints and porosity.



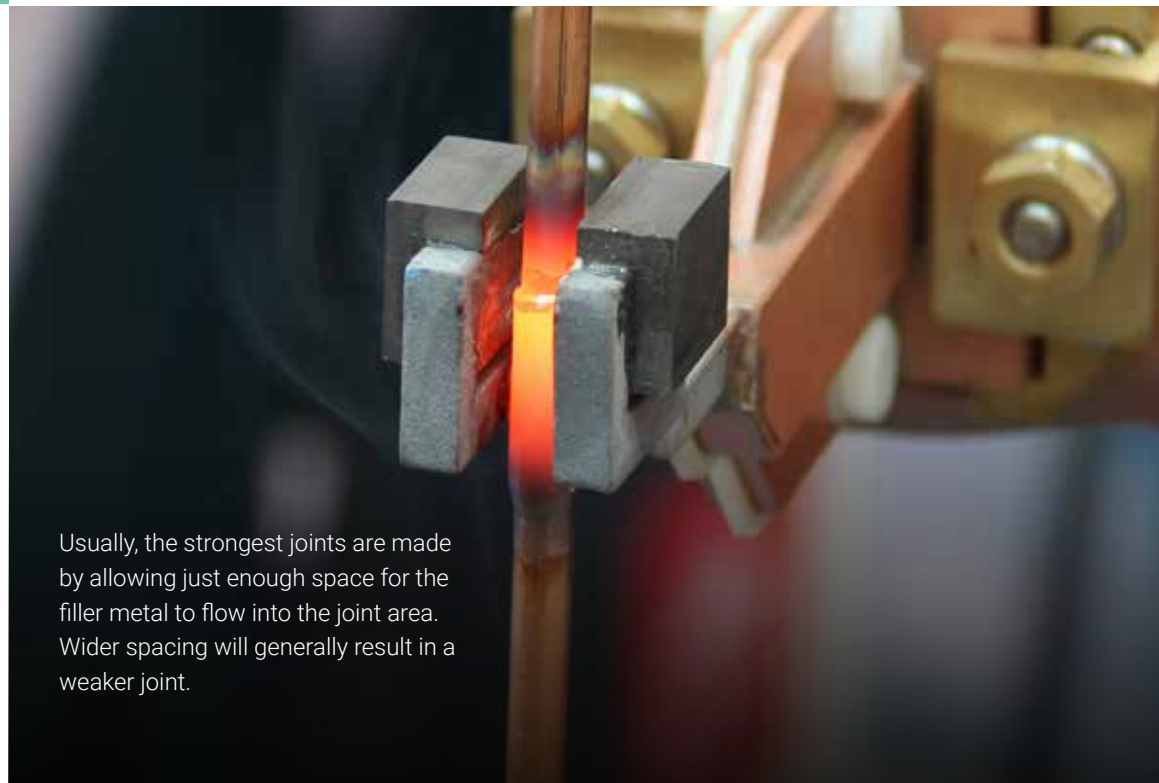
Thermal expansion

Thermal expansion means gaps have to be calculated for metals at brazing temperatures, not room temperatures.

Optimum spacing is typically 0.05 mm – 0.1 mm for materials with a high silver content.

Approx. coefficients of linear expansion at 20°C

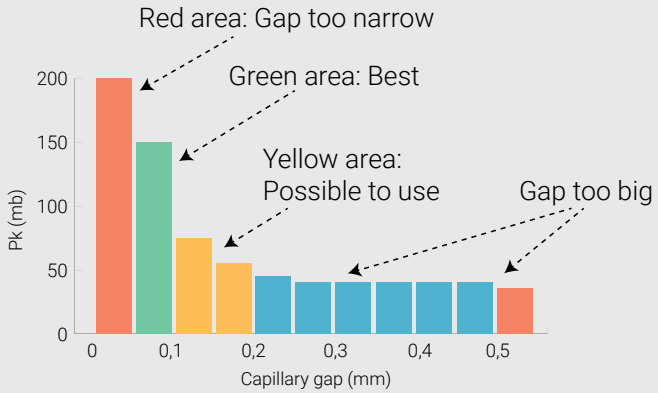
Material	10^{-6}m/°C
Copper	16.5
Brass	18.5
Steel	12.0
Tungsten	4.5
Silver	19.7
Quartz glass	0.5
Ceramic	4.0
Aluminium	23.8



Usually, the strongest joints are made by allowing just enough space for the filler metal to flow into the joint area. Wider spacing will generally result in a weaker joint.

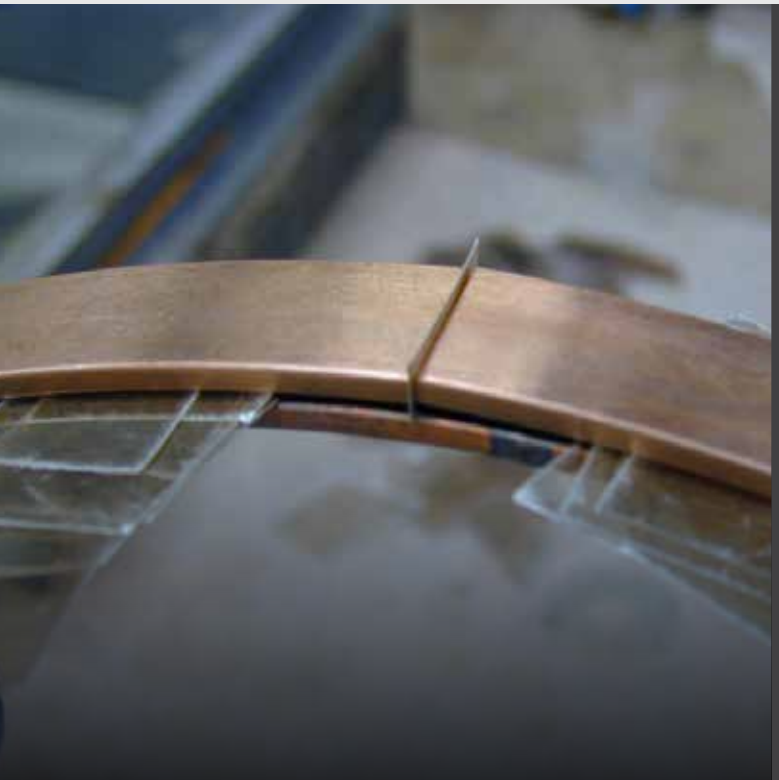
Capillary action

How to determine the optimum gap? First, we must understand the interplay between temperature, gap width, alloy viscosity and capillary pressure. Put simply, the correct temperature makes the liquid alloy 'float', enabling its distribution by capillary action throughout the joint. The rate of this capillary action depends on the gap between the parts, and the viscosity of the heated alloy.



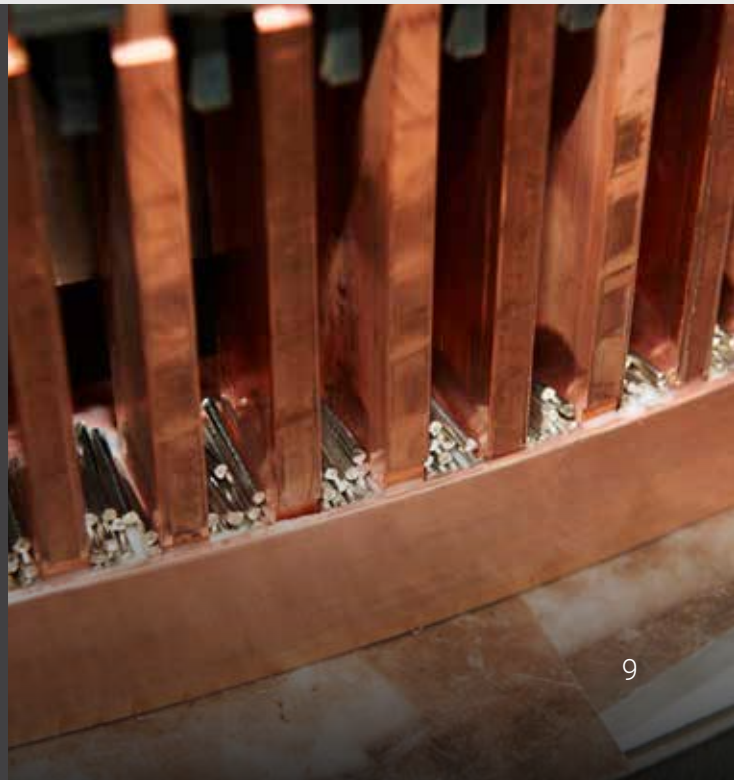
Silver content / AG%	GAP mm
>40 0,05 - 0,1	
32 - 40	0,08 - 0,15
<32 0,1 - 0,2	
Aluminium	0,08 - 0,3

Capillary pressure (Pk) as a function of the distance between the parts to be the joined. The interplay between gap width, capillary action, filler viscosity and temperature highlights the need for specialist knowledge when devising induction brazing solutions.



Left photo: Alloy viscosity influences tensile and shear strength. Silver, copper and aluminium alloys are commonly used filler metals. This photo shows brazing with phosphorous alloy without external flux.

Right photo: Bars of silver filler about to be heated for brazing bars to a short-circuit ring. Once heated to the correct temperature, the filler will appear to 'float' on the surface of the metal, before being distributed throughout the joint by capillary force.



Focus on flux

Base metals must usually be coated with a solvent known as flux before they are brazed.

A flux coating:

- cleans the base metals
- prevents new oxidation
- wets the brazing area prior to brazing
- protects the alloy and improves the flow

It is crucial to apply sufficient flux. Use too little and the flux may become saturated with oxides and lose its ability to protect the base metals.

Flux must normally be removed from the part once the filler alloy has solidified, usually below 400°C. Different removal methods are used, the most common being water quenching.

Phosphorus-bearing filler

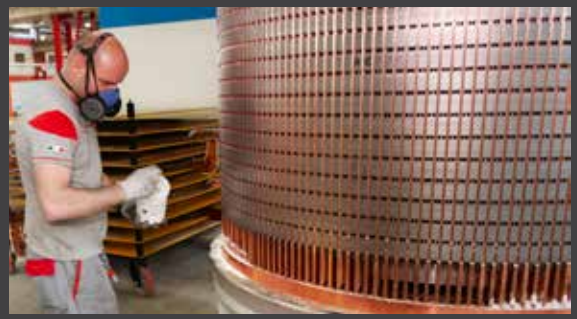
Flux is not always needed. Phosphorus-bearing filler can be used to braze copper alloys.

Controlled atmospheres

One flux-free solution being increasingly used—particularly for high-volume production of mission-critical components—combines induction brazing with some form of controlled (also known as active) atmosphere. Controlled atmosphere solutions fall into two main groups:

- Gas chamber brazing (non-furnace): The atmosphere inside the chamber is controlled by external vacuum pumps and the introduction of inert gases. This method is usually reserved for mission-critical components destined for aero-nautical, medical or other demanding fields.

- Bell jar / glove box: These involve brazing inside a sealed environment in which the atmosphere is controlled. Glove box brazing allows manual handling of the parts. Selecting the correct type of gas must take account of the type of metal filler, the base materials, brazing temperature, cost considerations.



It is crucial to apply sufficient flux. Use too little and the flux may become saturated with oxides and lose its ability to protect the base metals.

Controlled atmosphere brazing at an ENRX production facility. This method is increasingly used for large-volume production of high-quality, mission-critical components.

Why induction brazing is better

Brazing produces strong, shock-resistant and visually attractive joints. But why select induction over flame brazing? There are at least seven compelling reasons:

1. Speedier solution
Induction heating transfers more energy per square millimetre than an open flame. Induction can therefore braze more parts per hour than alternative processes. Rapid and precise heating results in less mass to be heated. Also, there is less damage to surrounding insulation.

2. Quicker throughput
Induction is ideal for in-line integration. Batches of parts no longer have to be taken aside for separate brazing or sent off site.

3. Consistent performance
Induction heating is controllable and repeatable. Enter the desired process parameters and the induction equipment will repeat the heating cycles precisely.

4. Unique controllability
Induction lets operators see the brazing process, something that is difficult with flames. This and precise heating minimize the risk of overheating.

5. More productive environment
Open flames create uncomfortable working environments. Induction is quiet and clean. It is easy to extract fumes and there is virtually no increase in ambient temperature.

6. Compact footprint
ENRX brazing equipment is designed with a small footprint, allowing induction stations to integrate seamlessly into production cells and existing layouts. Our compact, mobile systems enable easy access to hard-to-reach parts, enhancing flexibility and efficiency in your workflow.

7. No-contact process
Induction generates heat within the base metals—and nowhere else. Unlike flame heating, the base metal never comes into contact with the heat source. The homogeneous and controlled heat minimizes distortion and eliminates the risk of hydrogen embrittlement.

When and where to braze

ENRX brazing solutions are utilized across a wide range of industries globally. However, most systems fall into the following categories:

- Electricity generation and distribution
- Automotive industry
- Appliances (includes white goods and HVAC)
- Tools
- Specialist areas

The following pages take a closer look at each category.

Electricity generation and distribution

Within the power industry, our equipment is primarily used for the following components:

- Generators
- Transformers
- Turbo generators
- Switch gears
- Motors
- Short-circuit rings (squirrel cage)

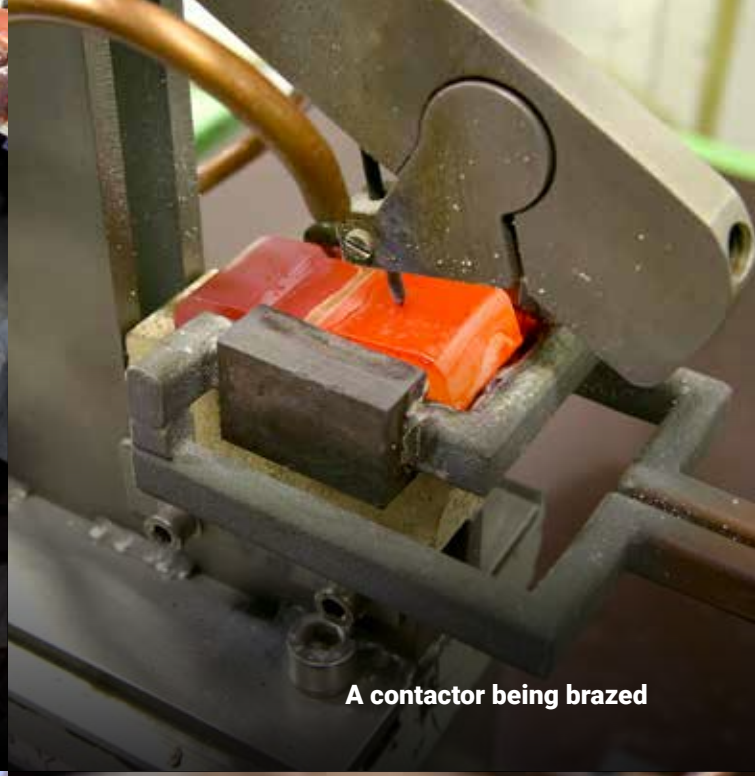
Induction brazing is ideal for these parts due to its localized heating capability, which allows for precisely defined Heat Affected Zones (HAZ) in advance.
This ensures:

- Minimal heat spread
- Minimal risk to insulation materials
- Minimal risk of deformation

When mobility is required, coils can be attached to compact handheld power units. These handheld devices are as easy to operate as regular power tools, featuring long and flexible power cables. They can be easily attached to common balancers or positioners, enhancing comfort and productivity. This portability ensures that induction brazing can be effectively utilized in various working environments, maintaining efficiency and precision in all applications.

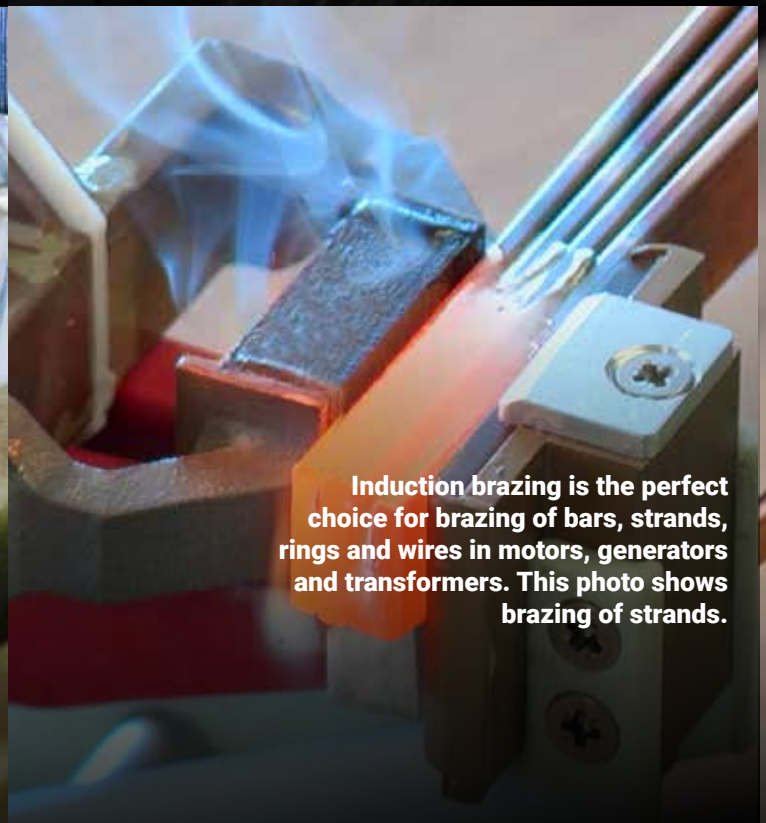
A stationary coil during brazing of a short-circuit ring

Brazing of generator windings

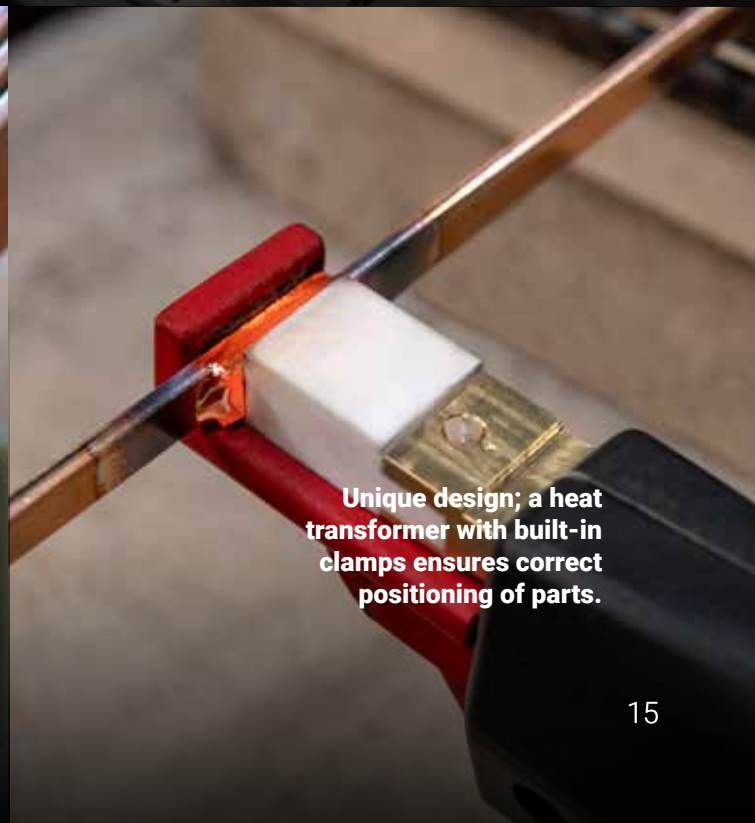


A contactor being brazed

Brazing of serial connections of stator windings



Induction brazing is the perfect choice for brazing of bars, strands, rings and wires in motors, generators and transformers. This photo shows brazing of strands.



Unique design; a heat transformer with built-in clamps ensures correct positioning of parts.

Brazing solutions for the automotive industry

Most ENRX automotive brazing solutions are used for high-volume production of fuel lines and air-conditioning. We have extensive experience in brazing solutions for:

- Aluminium parts for air-conditioning systems
- Evaporator and condenser connections (tube-to-tube, tube-to-block, tube-to-tank).
- Steel and copper components like brake linings and fuel injection pipes.
- Short-circuit rings for electric motors.

Brazing aluminum, often used in the automotive industry, is challenging due to the precise temperature control required. The gap between brazing temperature and aluminium's melting point can be as small as 20-50° C, demanding excellent coil design, fabrication skill, and stable fixtures. ENRX is the top developer of induction heating solutions for aluminium brazing, thanks to our comprehensive capabilities from initial simulation to turnkey brazing machines with automated handling systems.

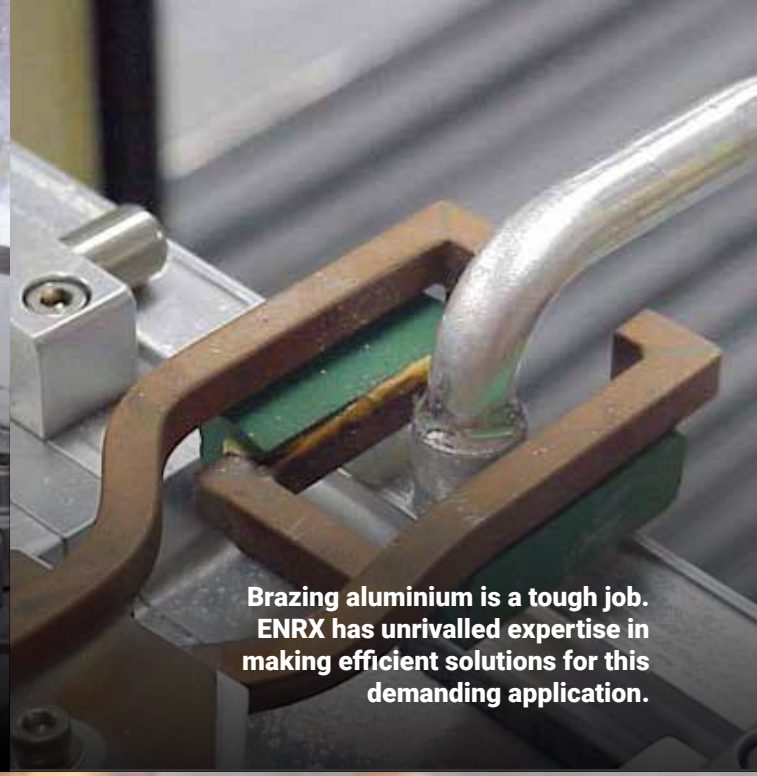
Your brazing system design depends on specific conditions but may feature:

- Integration into production lines for maximized throughput.
- Controlled atmosphere for consistent quality.
- Multi-station systems for high-volume production.
- Robotic handling and automated processes.
- Process control and record-keeping software.
- After-sales support including training, coil repair, supply, and preventive maintenance.

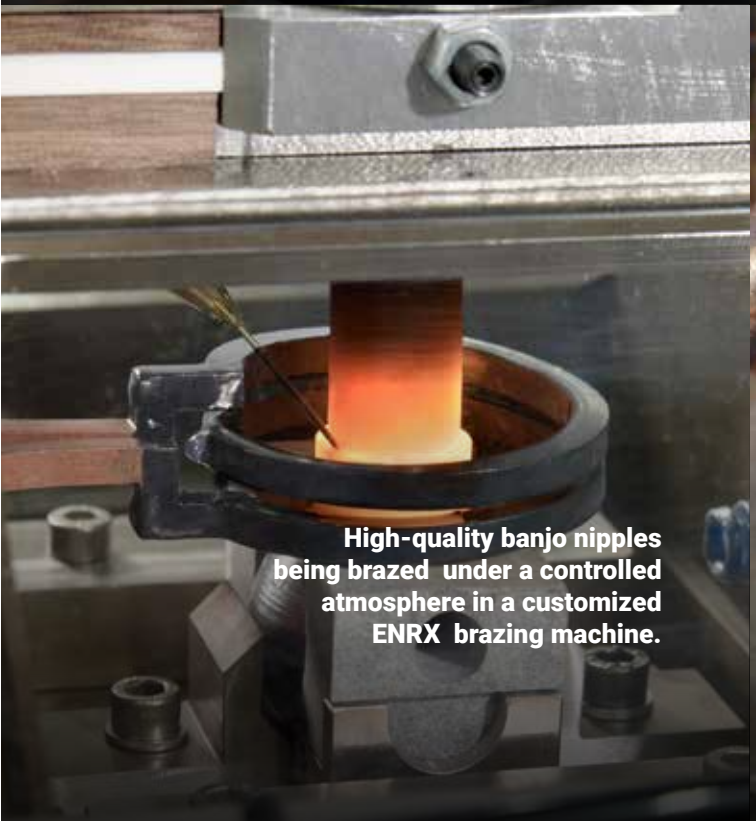
Automotive components must meet the highest standards and the industry's strict cost-control demands. ENRX is the leader in devising brazing systems that excel in productivity and reliability.

Induction heating is a perfect method for high through-put brazing of evaporator and condenser connections.

Brazing of brake linings



Brazing aluminium is a tough job. ENRX has unrivalled expertise in making efficient solutions for this demanding application.



High-quality banjo nipples being brazed under a controlled atmosphere in a customized ENRX brazing machine.

Bazing of a heat exchanger

Brazing solutions for the appliances industry

The appliances industry (includes white goods and HVAC) has for decades been a major user of ENRX brazing solutions. ENRX supplies equipment and processes to the world's leading producers of refrigerators, freezers, dishwashers and washing machines, as well as plumbing and household fixtures industries. Refrigerators and freezers contain many compressor parts that require brazing. Dishwashers and washing machines also contain numerous heating elements. ENRX brazing solutions for appliances include brazing of tube-to-tube, tube-to-block and tube-to-valve connections and involve brazing copper to copper, copper to aluminium and aluminium to aluminium.

Brazing aluminium to copper

Induction heating is ideal for brazing aluminium to copper, a key challenge in the industry. As aluminium melts at around 650°C, and copper at 1,080°C, it is essential that heat input is according to melt temperature—and as precise and as fast as possible. It is this precision and speed that is so difficult to consistently achieve with flame brazing.

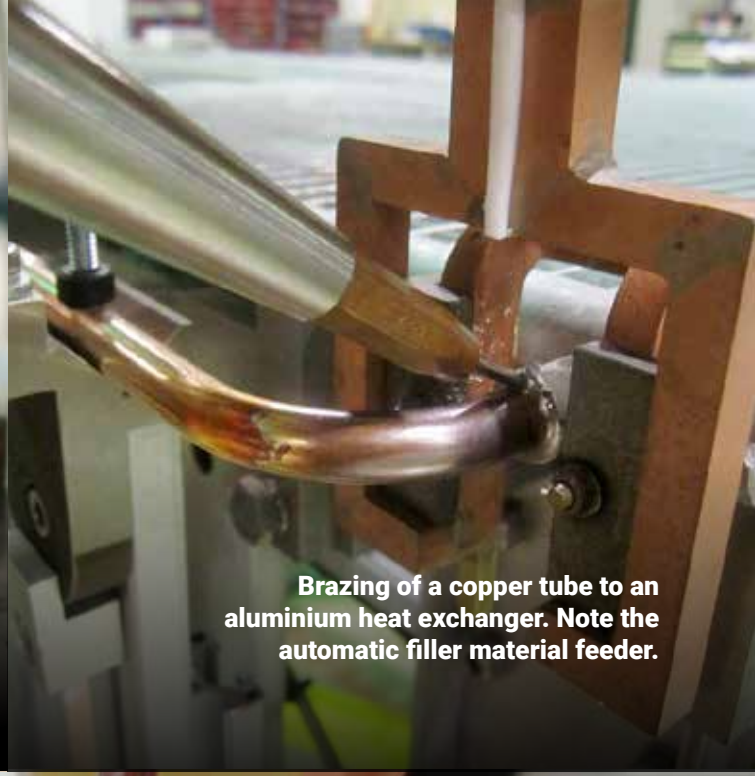
Other factors that make ENRX popular in the white goods industry include:

- Compact, mobile converters
- Handheld, easy-to-use heat output units
- Safety and comfort. The voltage at the coil of a mobile Minac unit is typically below 50 V.
- Long-life coils and coil maintenance support

Our solutions for the domestic appliances industry range from mobile, single-output Minac systems to brazing machines featuring multiple heating sources and work stations. Such machines may also feature controlled atmospheres and automated loading and unloading systems.

Brazing of heating element

Fast, precise, controllable and easy to use. Induction is perfect for faucet brazing—whether it's tube-to-socket, tube-to-tube or thread insert brazing.



Brazing of a copper tube to an aluminium heat exchanger. Note the automatic filler material feeder.

Bazing of compressor parts

Brazing of heat distributor

Brazing solutions for other specialist areas

This document provides an overview of the main areas for ENRX brazing solutions. However, our equipment is used for a vast array of other brazing solutions in industries as diverse as:

- Wire and cable
- Aviation
- Furniture
- Tube and pipe
- Shipbuilding
- Rail
- Agriculture

Many commercial service and maintenance companies use our mobile Minac units. These versatile systems can be easily transported from job to job and are not limited to brazing alone. A Minac unit can also be used for other heating tasks such as annealing, bolt removal, shrink-fitting, and more.

A single specialist system can be designed to handle a range of materials; or it can be built to only handle specific materials and components—the final design depends on your particular needs and conditions.

Manufacturing customized brazing solutions requires a range of competencies. At ENRX you'll find R&D centres and specialist workshops staffed with experts—people who have dedicated their careers to induction heating. You'll also find a worldwide network of factories and offices, and unrivalled after-sales support.

Brazing of steel support bars for sofas

Brazing of a cable shoe

Brazing of a microphone

An ENRX solution brazes parts for the aviation industry. Induction is ideal for brazing fan blades, blades for casings and numerous parts in fuel and hydraulic systems.


ENRX
SINAC
Universal
heat generators

Systems built for better brazing

ENRX brazing systems can be divided into three groups:

- Minac-powered systems
- Sinac-powered systems
- Customized brazing machines

Minac mobile converters feature output power of 10-220 kW (6-140 kW continuous) and automatic electronic matching. Highly versatile, Minacs perform practically any brazing task. Some Minacs come in Twin versions, meaning a single converter has two independent power outputs. Power outputs are also available as handheld ‘power pistols’.

Sinac stationary generators feature power outputs up to 2000 kW. Sinac is a truly comprehensive range that includes parallel and serial-compensated converters suitable for virtually any induction heating application. Twin versions with two indpendent power outputs are also available.

The ENRX Setpoint Recorder can be installed with all Minac and Sinac systems. The unique ‘teach-in’ solution lets you record and re-play your exact heating patterns.

Customized brazing machines are designed for one particular type of workpiece or closely related work-pieces. For instance, an automated pole coil brazing machine can feature loading and unloading equipment, a rotary working table, double brazing heads, and two ‘press heads’ for squeezing the brazed joints together, which eliminates the need for further finishing.

Minac-powered brazing systems

Our lower-power brazing systems are powered by a Minac–one of our compact, mobile, solid-state converters.

Minacs feature:

- Output power of 10-220 kW (6-140 kW continuous),
- Continuous automatic matching
- Supports a virtually unlimited range of coil designs
- Suitable for numerous induction heating tasks

Many Minacs are available in Twin versions, meaning a single converter has two fully independent power outputs. Minac power outputs are available as stationary units or as 'power pistols', handheld transformers connected to the Minac by long, flexible cables.

Sinac-powered brazing systems

Many ENRX brazing systems are powered by one of our Sinac stationary universal generators. Like the Minac, the Sinac range offers a wide variety of configurations, including the 'Twin' power output option.

Available in serial- and parallel-compensated versions, each Sinac features:

- A diode rectifier with a constant power factor of 85-87% from the input at the rectifier to the output at the coil
- A constant power factor of 0.95 at all power levels
- Automatic load matching

Customized brazing machines

Our customized brazing machines integrate ENRX power sources with magazines, handling mechanisms and other features as needed. Our turnkey brazing solutions are pre-assembled and ready-to-work. They come complete with induction heater, coil, braze material, flux, fixtures, cooling and temperature control. The brazing machines can be automatic, semi-automatic or manual.

Automatic brazing equipment

A fully automatic brazing machine will typically include:

- Automatic loading and unloading
- Automatic flux and brazing process
- Automatic temperature control
- Automatic coil centering device
- Customized coil design
- Complete system diagnostics
- Touch screen, menu-based and multi-language control panels
- Advanced PLC control
- Closed loop cooling system

All our brazing machines are powered by ENRX heat generators.

Induction coils

The induction coil, also known as an ‘inductor’, is essential to the induction heating process. Many factors contribute to a coil’s effectiveness: the care taken to make it, the quality of the materials used, its shape, its maintenance, its correct matching with the power source, etc. That’s why it is so important to insist on professionally made and maintained coils – preferably from the same people who made your induction system.

ENRX has perhaps the world’s most advanced coil-making and coil-care programs. We not only design and make customized coils for all materials and applications, we also have preventive maintenance and coil logistics solutions. These initiatives ensure you always use the right coils, and that their working life is maximized.

The details of every single ENRX coil are entered into a constantly updated database. This allows us to quickly and smoothly replace or repair any coil, anywhere, without compromising on quality or productivity.

27

A crash course in coils

Designing efficient induction coils is a demanding task. Take, for example, the cooling water system: in theory, it sounds simple—cooling water flows through the coil's hollow copper tubing. However, miscalculating the flow rate can be costly. High-power-density coils are especially risky, as low throughflow will result in insufficient thermal transference. Competent designers will determine if a booster pump is needed to maintain the desired flow and will specify a purity level for the cooling water in order to minimize coil corrosion.

Designing magnetic flux concentrators is another challenge. As the name suggests, their function is to concentrate current in the coil area facing the workpiece. Without concentrators, much of the flux will propagate around the coil and 'engulf' adjacent conductive components. A concentrator, however, restricts the flux to precisely defined areas of the workpiece.

Concentrators are made from laminates or from pure ferrites and ferrite or iron-based powders. While each material has its advantages, laminates have the highest flux densities and magnetic permeability. They are also less expensive than iron and ferrite-based powders. However, laminates are only produced in a relatively small range of shapes and sizes and are therefore less versatile.

Pure ferrites offer outstanding magnetic permeability but suffer from low saturation flux density, and their brittleness makes them difficult to machine. Iron powders are easy to shape and offer high flux densities, but care must be taken to avoid overheating. Due to internal losses or heat transfer, these powders have a relatively low working temperature.

Designers must achieve correct impedance matching between the coil and the power source. They also need to account of the fact that coils require five to ten times more reactive power than active power. Additionally, they must choose the appropriate insulation: should the coil be dipped in an epoxy coating, or should it be molded with high-temperature concrete? Answering these questions requires specialized equipment and expertise. Yet, too many manufacturers mistakenly view coils as simple copper tubes, which can lead to inefficient or even dangerous designs, as well as process and equipment failures.

Substandard coils can significantly impair the efficiency of a heating system. The danger lies in the temptation to opt for quick 'Do-It-Yourself' coil designs and fixes. While these may appear to save time and money in the short term, the reality is that homemade coils and makeshift repairs can ultimately raise costs and compromise quality in the long run.

Using ENRX coils ensures optimal performance with your ENRX equipment—they're designed to complement each other perfectly. However, even if you use non-ENRX power sources, we can still custom-design and manufacture new, more efficient coils for you. We also provide re-conditioning services for existing coils. Our comprehensive offerings include ensuring you always have an adequate supply of coils on hand and replacing coils proactively to prevent any disruptions to productivity.

Designing and testing coils typically represents the phase with the longest lead time in developing an induction heating solution. Furthermore, this testing necessitates the specialized equipment and personnel, that you'll find in our worldwide network of labs and coil workshops.






Get more out of your equipment. With the help from those who built it.

With ENRX, you benefit from the world's most comprehensive range of after-sales support programs. Here's a partial list of additional services available beyond what is typically covered under guarantees and warranties.

Operator training
Send us one of your operators, and we'll return a skilled, value-adding employee equipped with the knowledge to maximize output and prolong equipment lifespan.

Logistic programs
Ensure continuous availability of critical parts and consumables. We can implement a system that manages your coils in a 'stock-use-repair cycle'.

Telemetric monitoring
Remote monitoring of your key process parameters will alert us of potential issues early. We get to act pro-actively; you get more uptime.

Scheduled preventive maintenance
Lets work together to develop a tailored maintenance program that aligns with your technical and commercial requirements.

Service level agreement
A service agreement with ENRX ensures your system consistently meets expectations, minimizing the risks of unplanned, costly downtime and potential hazards for operators. This proactive approach allows you to fulfill your commitments to your customers.

Each service agreement is tailored to your specific needs and can encompass access to technical support, annual preventive maintenance, regular software upgrades, discounted service rates, reduced prices on spare parts, and prompt on-site response times. Depending on your system, remote diagnostic and support options may also be available.

An ENRX service agreement establishes a reliable foundation for optimizing equipment performance and fostering a safer and more efficient workplace.


ENRX

About ENRX

ENRX is a global green tech company driven by induction. We offer induction heating, wireless inductive charging and contactless power supply with low or no carbon footprint for virtually any application within mobility and manufacturing.

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