

# EFD Induction

The process, the products and the people.  
And how they are boosting industrial productivity  
in amazing ways.

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# Putting the smarter heat to smarter use.

Welcome to EFD Induction.

In the following pages you'll read how induction heating is superior to alternative heating technologies.

You'll read how induction heating, because it's faster than these alternatives, increases throughput.

You'll read how induction heating improves—and maintains—the quality of whatever it is you make, mend or process.

And you'll read how induction heating achieves the above while at the same time cutting costs.

Just as important, you'll read that we lead the world in finding new, exciting applications for induction heating.

We've been developing, installing and maintaining induction-heating solutions for more than 50 years. We still think they're amazing. We hope you'll think so too.

# Faster. Better. Cheaper.

The technical features of induction heating deliver three key benefits: improved throughput, better and consistent quality, reduced costs.

## **Throughput**

Integrating induction heating into the production line improves production efficiency. You cut lead times, and speed up throughput. The heating process itself is faster than with open-flame and oven alternatives. Accurate repeatability means you get to be faster because you get it right the first time.

## **Quality**

Quality improves because you can apply pre-set temperatures to pre-set parts of individual workpieces. And because induction coils are tailor-made for specific workpieces, you know, in advance, the delivered heat pattern. Also, precise heat delivery means any adjoining components and/or materials remain unharmed during the heating process.

## **Costs**

Costs go down because of shorter lead times and increased throughput. Integrated in-line induction heating means lower administration and logistics costs. Production yields go up. Swift heat cycles, precise delivery and accurate repeatability minimize waste and scrap. Energy costs go down because you heat only what you need to heat—there are no costly heat losses as with conventional ovens. (EFD Induction frequency converters are particularly effective at lowering energy costs, as they have a proven higher efficiency and power factor than competing converters.) And because induction heating lets you abandon hazardous gas and open flames, you can negotiate lower insurance premiums.

	Furnace	Flame	Induction
<b>FASTER – THROUGHPUT</b>			
Ease of integration into production line	•	••	••••
Ramp-up time	•	•••	•••••
<b>BETTER – QUALITY</b>			
Heat pattern control	•	•••	•••••
Temperature level accuracy	••••	•••	•••••
Ramp-up time control	•	•••	•••••
Dwell-time accuracy	•	••••	•••••
Repeatability	•••••	••	••••
<b>CHEAPER – COST</b>			
Yield	•••	••	•••••
Energy	••	•••	••••
Space	••	••••	••••
Safety	••	•	••••
<b>TOTAL</b>	<b>23</b>	<b>30</b>	<b>50</b>

*The scores used in this table are approximations only, designed as a general guide. The performance rating of the three heating methods can vary from case to case, depending on the application involved, workpiece characteristics, operator skills, etc.*

# 907.5°C in 3.4 seconds. Time and again. And again.

Induction heating has numerous advantages over alternative technologies:

## Quick

The produced heat from a frequency converter is instant. It takes less than one second to achieve a uniform surface temperature of 1,000°C on small metal components.

## Accurate

Just the right temperature is delivered, just where it's needed to individual workpieces. And because of the range of frequencies available, to just the right depth. Heat distribution is precise, too. We can customize induction coils to suit practically any shape or size of workpiece. Customized coils ensure optimal heat patterns with minimum energy consumption.

## Controllable

Transistorized converters and process control software give you complete control over the entire heating process. Ramp-up and dwell times can be pre-set and repeated as often as you want. Equipment can also feature in-built telemetry devices for remote diagnostics and off-site monitoring.

## Repeatable

Induction heating lets you accurately repeat your desired heating cycle. (In fact, the produced heat from a frequency converter normally varies as little as 1-2%.) You can duplicate all the key parameters: temperature, penetration depth, heat pattern, speed-of-temperature increase, etc.

## Clean, safe, compact

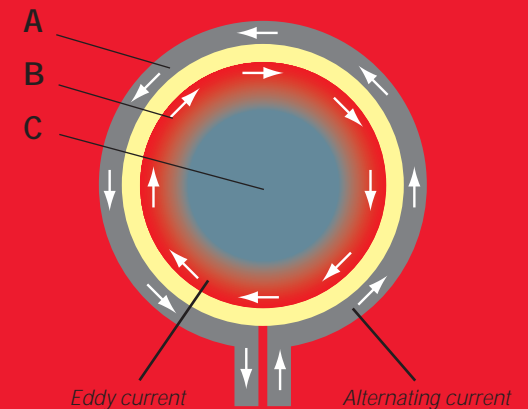
No gas. No open flames. No noticeable increase in ambient temperature. No excessive floor space occupied by ovens.

## *This is how it works.*

*Induction heating takes power from the mains, converts it into frequencies suitable for specific applications, then uses the power to create controllable heat in any electrically conductive material.*

*Power is applied to the workpiece by an induction coil. An alternating current flowing through a coil (A) generates a magnetic field (B). Placing a workpiece (C) within the field induces eddy currents in the piece. Heat is produced where—and only where—these eddy currents flow.*

*Different converters come with different power outputs and frequencies. Output power, the shape of the induction coil and the characteristics of the workpiece determine the heat pattern. The depth of heat penetration into the workpiece depends on the frequency: the lower the frequency, the deeper the penetration.*





### ***Some amazing facts about induction heating.***

- An EFD Induction frequency converter with an output power of 100 kW can harden a 60 mm diameter shaft to a depth of 2 mm (800°C at 2 mm) with a feeding speed of 1 m per minute.*
- Using one of our mobile converters, you can heat 1 kg of steel from 20°C to 800°C in five seconds flat. That's a speed-of-temperature increase of 160°C per second.*
- Induction heating is ten times more efficient than conventional ovens at curing the adhesives in automobile hoods. To cure one hood normally requires 220 kW. As induction heating uses 340 kW from the mains net, efficiency is 65%. Conventional ovens use something in the range of 4,000 kW per hood, resulting in an efficiency of only 5.5%.*

*An EFD Induction solution in action. Custom-designed induction coils harden two camshafts—both bearing and lobe are hardened in a procedure that takes only 5.4 seconds at 950°C.*

# Apart from our superior applications knowledge, equipment technology, coils capability, materials know-how and local presence, we're pretty much like any other induction heating company.

What makes EFD Induction special?

## **Applications knowledge**

To date, EFD Induction has more than 9,500 installations in 75 countries. A large number are customized heating solutions—unique installations for specific production needs. This experience has given us unrivaled knowledge of applications as diverse as annealing, bonding, brazing, curing, forging, shrink-fitting, hardening, straightening, tempering, welding, melting, plasma, optical fiber and glass.

## **Equipment technology**

EFD Induction designs, builds, installs and maintains a complete range of induction heating equipment. In fact, we pioneered—and continue to pioneer—the development of solid-state induction converters. Another key area of our expertise is CNC-controlled multiple axes machines for in-line integration. Our other equipment

areas are: tube welding systems and industrial heat processing systems such as furnaces, and billet and bar end heaters.

## **Coils capability**

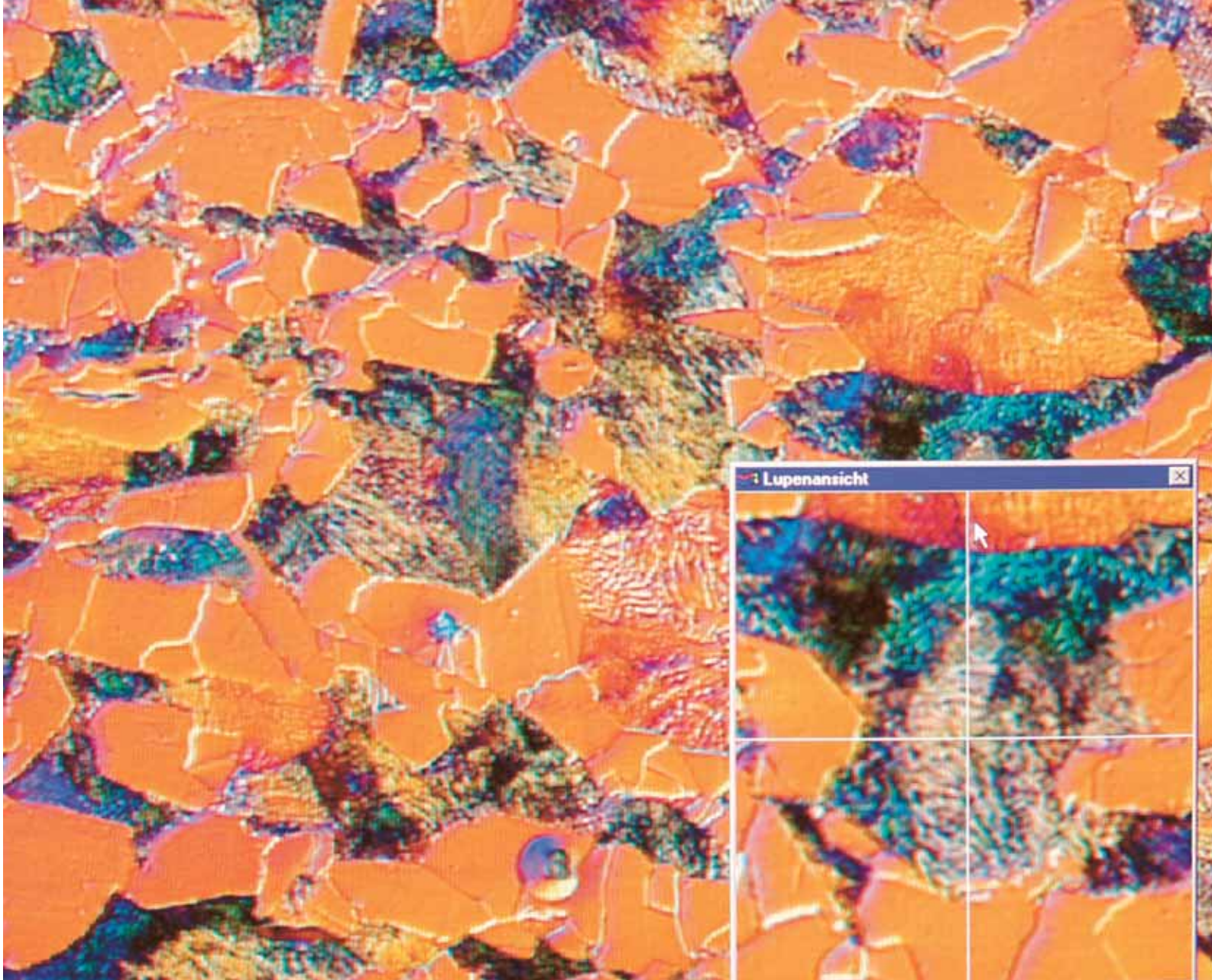
A correctly designed, made and maintained coil is crucial to the outcome of any induction heating operation. After all, it is the component that actually delivers heat to the workpiece. EFD Induction has years of experience designing and supplying customized, long-life coils for the full spectrum of applications and materials. (We offer advanced computerized coil simulation to make sure you get the optimal coil design for your specific needs.) We also have a well-proven logistics service that ensures the smooth delivery and installation of replacement coils. Maximizing coil life times is an EFD Induction specialty, resulting in coils that are prized for their longevity.

## **Materials know-how**

How will induction heating affect my metals? What happens to the adhesives? What about adjacent materials? These are just some of the questions customers ask our in-house materials experts every day. And to ensure our metallurgists and engineers give fast, accurate answers, we've built our own research labs. As a result, we not only know more about induction heating than anyone else, we know more about how the technology affects your materials.

## **Local presence**

Wherever you are, there's a good chance EFD Induction is somewhere in your neighborhood. That's because we have a worldwide network of representatives, in addition to manufacturing facilities in Germany, Norway, France, China, India and the US. We also have sales and service companies in the UK, Sweden, Spain, Italy and Austria.



*Materials analysis at an EFD Induction research lab.  
This photograph shows the microstructure of alloyed steel C35, grain size ASTM6.*

# The differences are obvious. What about the similarities?

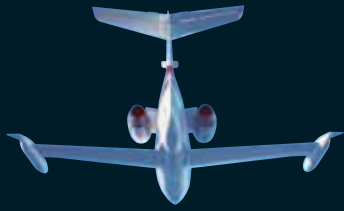
A can of peaches, a cruise liner's hull, a tub of yogurt, power station turbines, cables under the ground, pipelines under the waves, and countless trains, planes and automobiles.

What unites these different products is that induction heating is used to make them, maintain them, repair them and recycle them. (In case the yogurt tub intrigues you, induction heating attaches the foil lid to the plastic container. As for canned peaches, induction heating helps coat the tin on the can's inside so that conserved foods remain untainted.)

Simply put, our induction heating solutions can be profitably used in virtually any industrial application that requires heat.

Our hardening machines, for example, are widely used in the automotive and automotive supply industries for surface hardening and tempering of mechanical parts such as shafts, gears, axles and valves. You'll also find our converters curing the adhesives that join body panels in doors, hoods and deck lids.

Beyond the automotive and automotive supply segments, EFD Induction equipment is commonly found in the electrotechnical, metal and foundry, tube and pipe, wire and cable, aviation, shipbuilding, white goods, glass, plasma and optical fiber industries.



Heat treatment and pre/post heating.  
Bonding and joint brazing.



Brazing of compressor parts. Bonding  
of fridge bodies. Paint curing. Tube  
welding.



Hardening and tempering of transmission  
and engine parts (shafts, valves, etc.).  
Straightening during repairs.



Brazing and soldering of  
brass parts.



Hardening and tempering of engine and trans-  
mission parts. Curing of paint and brake-disc  
coatings. Bonding of body parts. Tube welding  
of exhaust pipes. Brazing of components.  
Magnet bonding in electric motors.



Disassembly and shrink-fitting of wheel  
rings and bearing rings. Brazing of copper  
components. Straightening.



Brazing of copper parts in generators. Shrink-  
fitting. Bolt expansion. Pre/post heating and  
brazing for high-pressure turbines.



Hardening and brazing  
of components. Welding  
of frame tubes.



Longitudinal tube and pipe welding. Pre-  
heating. Annealing of welds. Curing of  
coatings.



Pre/post heating when coating sheet metal.  
Re-melting of tin coatings.



Hull straightening during construction.  
Straight welding of beams in double hulls.  
Paint removal. Brazing of copper compo-  
nents. Hardening of large gears, winches  
and chains. Heat treatment of shafts.  
Pre-heating of valves prior to welding.



Pre/post heating. Curing  
of insulation around wires.  
Manufacturing of optical  
fiber cable.

# Meet the family.

Whatever your heating needs, it is almost certain EFD Induction has the equipment to meet them. And in the unlikely event we don't, we can sit down with you and devise your own customized induction heating solution.

This claim is backed by our range of equipment—and our decades of experience in the induction heating business. EFD Induction products range from standard heat sources, through customized solutions to complete manufacturing processes.

With EFD Induction you also gain the support of our experts in power electronics, metallurgy and process-control software. Not to mention the rigorous testing in our own and independent labs that ensure you get the very best solutions possible.



## **HardLine** Industrial heat treatment systems

HardLine is a complete range of stationary systems for all types of workpieces requiring hardening, tempering and annealing. HardLine offers vertical, horizontal and tailor-made machine concepts with CNC-controlled multiple axes, quality supervision and fully automatic loading systems. HardLine systems also feature serial and/or parallel compensated induction power sources with a wide range of output power and frequencies.

## **HeatLine** Industrial heat processing systems

HeatLine is a comprehensive range of heat processing systems. Included in the series are: billet heaters (for large and small billet sections); melting furnaces (tilting, double-axis tilting, roll-over, moving coil and laboratory); bar end heaters (horizontal and vertical). HeatLine systems are also used in the precious metals processing industry, and for laboratory purposes.



### **Minac**

#### Mobile heat generators

Minac mobile generators are extremely easy to install and operate. And, thanks to automatic impedance matching, are also ideal for a wide range of applications: brazing, shrink-fitting, hardening, curing, straightening, pre/post heating, annealing, etc. Available with low or medium output power, Minac can be used in workshops or in the field. All Minac systems allow fast coil changes.



### **Sinac**

#### Universal heat generators

Sinac is our range of high-efficiency stationary generators. Suitable for practically all induction heating applications, Sinac features serial and/or parallel compensated induction power sources with a wide range of frequencies and low, medium or high output power. The Sinac range includes dual-frequency models.



### **Weldac**

#### High-output solid-state welders

Weldac is our range of solid-state welders for longitudinal welding of tubes and pipes. The new generation, Weldac G2, uses EFD Induction's patented IGBT driver technology that allows rugged IGBT transistors to operate at frequencies of up to 350 kHz. Weldac G2 can handle tubes and pipes from 1/2" to 24". Weldac is suitable for both induction and contact welding.

# In the heat business, the hardest part can be to stay cool.

Induction heating should just work, delivering what you want, when you want it—leaving you free to focus on your core business.

That's why we offer services that cover everything from early-stage computer simulation to spares delivery to one-off induction heating projects and comprehensive maintenance contracts. We also offer intensive training.

More than 50 years in the induction heating business has taught us there's no such thing as a standard customer. Some aren't even sure induction heating is the right answer. In such cases, we often suggest our application engineering service. This is where we perform computer simulations to ensure induction heating is, in fact, the best choice. We also get to work on the financial spreadsheets, and examine the long-term cost implications of converting to induction heating.

Other service customers already use induction heating. Some opt for tailor-made spares delivery agreements. Some turn to us for equipment upgrades. Some take advantage of our remote diagnostics service, where advanced telemetrics prevents glitches turning into expensive problems. Others rent our equipment to deal with one-off jobs or peaks in production. The list goes on.

But there is one common denominator behind all these services: our people. Each EFD Induction service engineer is a graduate of our service boot camp. And to keep him on his toes (and abreast of the latest technical advances), each engineer must pass regular refresher courses. We also have specialized service personnel with in-depth knowledge of particular industries and applications.

Supporting our service people in the field is our network of local service centers, factories and R&D units. This global network guarantees you a swift response to any problem our service staff can't fix on the spot.



*EFD Induction services range from pre-production planning and materials analysis to full preventive and corrective maintenance contracts. Here, one of our engineers upgrades an EFD Induction Minac mobile induction heating system.*

*Rescue at sea. When a North Sea oil and gas platform needed urgent repairs in 2001, they turned to induction heating from EFD Induction.*



# “I’ll drive over right away.”

It was noon, and Rune Asdal, a technician at EFD Induction Norway, was about to leave for lunch.

Then his phone rang.

A Norwegian customer had a problem with a master pump, something to do with the roller bearing. Could Rune drop by and take a look?

“Sure,” said Rune. “I’ll drive over right away.”

“Ah, that could be a problem,” laughed the caller. “The pump is on a gas platform out in the North Sea. I hope you don’t mind helicopters.”

Within hours Rune was being whisked by chopper to the gas and condensate (light oil) ‘Sleipner A’ platform, 240 kilometers off the Norwegian coast. With him was an EFD Induction Minac 18/25 mobile induction converter.

“The problem,” explains Rune, “was pretty straightforward: the pump’s bearing was defective and had to be replaced. However, the risk of an explosion ruled out the use of gas torches and other open-flame heating. Induction heating was the only option. Well, not quite. They could have brought the pump ashore, but that would have cost a small fortune.”

Once on the 210-meter-high platform, Rune had to work quickly. Without the pump, production could be threatened—bad news when the Sleipner field’s daily production is 90,000 barrels of light oil.

“The job went without a hitch,” explains Rune. I used the Minac to heat the bearing ring prior to disassembly. Then I used Minac to treat the new bearing before re-assembly. I was back home within 24 hours. As for the pump, it’s been a couple of years since I fixed it, and last I heard it was still going strong.”

# A passion for heat.

## The EFD Induction story.

On September 3, 1950, craftsmen at a workshop in Freiburg, Germany, put the finishing touches to their first universal induction hardening machine.

The craftsmen were anxious. Their company, the family-owned firm of Fritz Düsseldorf Induktionserwärmung (FDF), had previously focused on job hardening for local Black Forest industries. But now they were entering a tough international market. Could they really make the grade?

They needn't have worried. The machine was a success. And before long FDF was exporting its equipment across Europe. (In fact, FDF soon grew to become one of Europe's leading induction surface hardening companies.)

### **The hot revolution**

While FDF was expanding in the 1970s, an induction revolution was taking place in Trondheim, Norway. The hotbed of the upheaval was the local Technical University, where a group of engineers had figured out how to transistorize frequency converters for induction heating.

The advent of transistorized frequency converters was a crucial breakthrough. Frequency converters shrank in

size as a result. Controllability was perfected. The range of frequencies—and thus the range of applications—was greatly expanded.

In 1981, three Norwegian engineers founded ELVA Induksjon. The new company had only nine employees. But it also had its Minac range of mobile converters. Workpieces no longer had to be brought at great cost to a stationary induction heater—the heater could now go to the piece.

Over the next few years, ELVA launched a whole series of transistorized induction heating products. Growth was swift; much of it driven by ELVA's ability to deliver the benefits of transistorized converter technology in customized solutions.

### **Keeping the heat on**

In May 1991, the managing directors of FDF and ELVA met by chance at a trade fair. They talked ... and speculated. FDF was strong in stationary induction hardening machines. ELVA was the agile innovator with a track record in finding new applications for induction heating. What if the two companies got together?

In January 1996, FDF and ELVA merged to create EFD Induction. (The two firms had already formed The European Induction Heating Alliance in 1993.)

Expansion was swift. One key step was the acquisition in 1998 of Grenoble-based CFEI. A veteran induction heating company, CFEI was the market leader in France. Particularly strong in devising hardening solutions for all the major French automakers, CFEI was also active



*The pioneer—FDF's first universal hardening machine awaits shipping in late 1950.*

in specialist applications such as plasma, glass and optical fiber.

EFD Induction continued to grow. British and American companies were acquired and integrated into the new group. A manufacturing facility was opened in Bangalore, India, in 1995. A greenfield manufacturing plant was set up in Shanghai in 2001.

To date, EFD Induction has delivered more than 9,500 installations in 75 countries. It's logical to attribute this growth solely to outstanding products and services. But we're convinced the really decisive factor has been something less tangible: our passion for induction heating—and what can be achieved with it.

More than half a century after that first hardening machine left the workshop in Freiburg, our enthusiasm for induction heating burns as bright as ever. If you're curious about what it might mean for the productivity of your company, give us a call. Induction heating is our passion. We'd like to share it with you.



*EFD Induction equipment has been used and trusted around the world for decades. This 1986 snap shows employees of Garden Reach Shipbuilders and Engineers Ltd. in Calcutta, India, testing their new ELVA TERAC 16 induction heating machine. The system was used for straightening ship hulls.*



*In 1981, three Norwegian engineers founded ELVA Induksjon. A year later, the Confederation of Norwegian Industry awarded them a prize for establishing "Norway's best new industrial company". Here are the three (from left, Truls Larsen, Knut Fosse Kersten and Leif Markegård) pictured at the award ceremony in Oslo.*

# Glossary.

**Annealing** is a heat treatment that alters the microstructure of a material, causing changes in its properties such as strength and hardness. It is a process that produces equilibrium conditions by heating a material and maintaining it at a suitable temperature, and then cooling it very slowly. The process is used to induce softness, relieve internal stresses, refine the structure and improve cold working properties.

**Bonding** is structurally joining parts by adhesive cured under elevated temperature.

**Brazing** or "hard soldering" is a joining process whereby a non-ferrous filler metal or alloy is heated to melting temperature above 450°C (800°F) and distributed between two or more close-fitting parts by capillary action.

**Curie point** (also called **Curie temperature**) is the temperature at which certain magnetic materials undergo a sharp change in their magnetic properties. Specification: the temperature at which there is a transition between the ferromagnetic and paramagnetic phases. Above the **Curie point**, the ferromagnetic material is purely paramagnetic.

**Eddy current** (also known as **Foucault current**) is caused by a time-varying magnetic field intersecting a conductor or vice versa.

**Electromagnetic induction** is the production of an electrical potential difference (or voltage) across a conductor situated in a changing magnetic flux.

**Flux** is used in brazing to remove oxides, prevent oxidation and wet the joining areas. Excess flux should be removed when the joint is completed. Flux left in the joint can lead to corrosion.

**Frequency converter** is the power source supplying the high-frequency alternating current. Modern frequency converters for induction are based on semi-conductor technology.

An **induction coil** is a coil carrying high- or medium- frequency

alternating current and intended to induce eddy currents to heat objects placed in the interior of the coil. The induced current also generates its own magnetic field, in opposition to the field generated by the coil, thus preventing the latter field from penetrating to the center of the heated object.

**Induction heating** is a process of heating electrically conductive material by electromagnetic induction, where eddy currents are generated within the material and its resistance leads to the heating.

**Induction surface hardening** is the process of hardening the surface of steel or cast iron objects by heating only the surface to produce martensitic microstructure in the heated zone after quenching.

**Magnetic flux** is the integral of the magnetic field times the perpendicular area that it penetrates.

**Normalizing** means to heat ferrous alloy to a suitable temperature above the transformation range and then cool it in air to a temperature substantially below the transformation range. Steel is normalized to refine grain size, make its structure more uniform, or to improve machinability.

**Penetration depth** is the distance from the surface to the depth where current density has dropped to 37%. The depth of penetration increases as the frequency decreases. It is essential that the frequency is chosen with respect to the dimensions and electrical properties of the object to be heated.

**Post heating** of weldments occurs immediately after welding, for tempering, for stress relieving, or for providing a controlled rate of cooling to prevent formation of a hard or brittle structure.

**Preheating** occurs before a heating or mechanical process is applied to the material.

**Quenching** generally means rapid cooling of metals and alloys to below the critical temperature range to harden them.

**Soft soldering** is a process of low temperature soldering using a solder with a melting point below 450 °C (800 °F).

**Stainless steel** is a common name for steel alloys that are resistant to corrosion and oxidation (rust). These normally include:

- **Austenitic steel**—the largest category of stainless steel, accounting for about 70% of all production. The austenitic class offers the most resistance to corrosion in the stainless group, due to its substantial nickel (Ni) content and higher levels of chromium (Cr). The steel is nonmagnetic and has no Curie point.
- **Ferritic steel**—the second-largest class of stainless steel, constituting approximately 25% of stainless production. Ferritic stainless steels are plain chromium (Cr) steels with no significant nickel (Ni) content; the lack of nickel results in lower corrosion resistance than the austenitic (chromium-nickel stainless steels). The steel is magnetic and has a Curie point.
- **Martensitic steel**—a small category of stainless steel characterized by the use of heat treatment for hardening and strengthening. Martensitic stainless steels are plain chromium (Cr) steels with no significant nickel (Ni) content. The steel is magnetic and has a Curie point.

**Tempering** is a reheating process that increases the ductility and impact strength of a hardened structure (martensite). The microstructure of quenched and tempered steel is referred to as tempered martensite.

**Tube welding** is in this connection a method of longitudinally welding steel and aluminum tubes, pipes and profiles by using induction coils or electrical contacts. The raw material is coiled and sheared in strips in a width and thickness that correspond to the dimensions of the final product. The strip is fed into a forming and welding line, and formed by rollers before the edges are welded together. The welding process is done without using filler metal or alloy as the edges are heated up to the forging temperature and pressed together.

