Linn High Therm

Induction Heating Devices

for High Frequency Induction Soldering, Brazing and Joining

Clean · Economical · Reliable · Suited for automation

High Frequency Induction Heating, Characteristics and Peculiarities

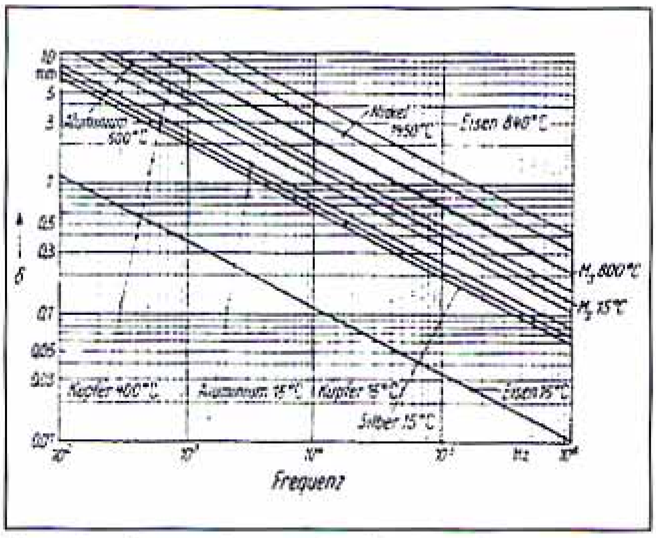
The Nature of Induction Heating.

The working principle of high frequency inductive heating, is based on an alternating current flowing through a single or multiple turn coil also called inductor. This inductor creates an alternating magnetic field, in its proximity. When electrically conductive materials are immersed in these magnetic fields, secondary currents are induced within these materials. According to Joules Law ($Q = I^2 \cdot R \cdot t$) heat is generated near the surface of the workpiece.

Viewed practically, an induction arrangement works on the principle of a transformer, where the inductor acts as the primary winding and the workpiece as a single turn secondary.

Attributes of Applications:

1. Transfer of energy, principally takes place to electrically conductive materials only.
2. Energy transfer occurs without contact.
3. Direct inductive heating occurs only in the immediate vicinity of the inductor.
4. The high frequency currents, induced in the workpiece, ($f > 10$ kHz) are largely concentrated near the surface (Skineffect).



Pict. 1a, Penetration depth of induced current as a function of the frequency of different materials.

This is the result of self induction in the core of the workpiece, which raises the electrical resistance and thereby displaces the current outward. The penetration depth of induced current as a function of the frequency of different materials is shown on picture No. 1a.

5. Flow of high frequency current takes place mainly in those parts of the workpiece, where magnetic field strength is greatest and magnetic resistance is smallest.

Factors Affecting Efficiency

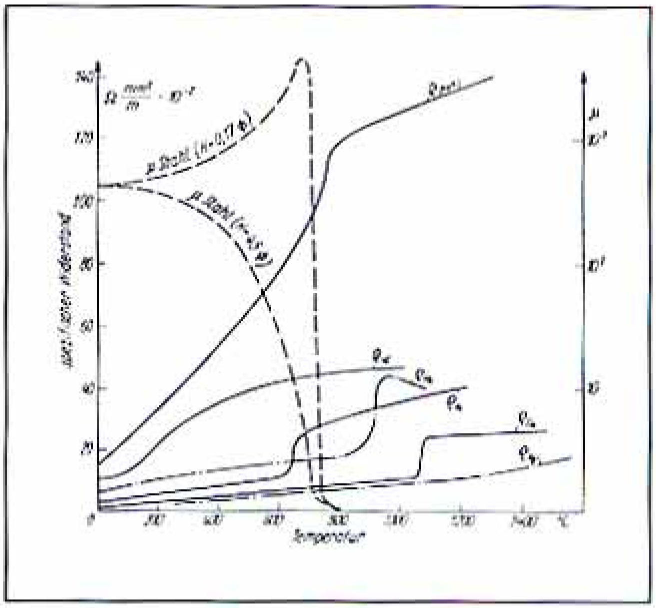
The effectiveness and therefore the efficiency of induction heating are mainly dependent on:

1. Generator dependent factors of influence.
2. Factors of influence caused by construction.
3. Factors of influence, characteristics of the workpiece.

Generator dependent factors are, operating frequency, output capacity etc. They are determined by the equipment manufacturer. They have to be optimal for a given application.

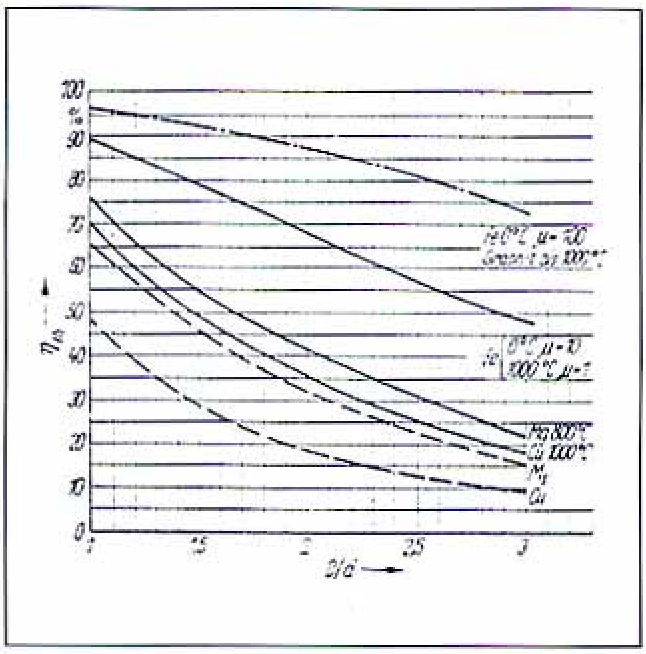
The workpieces to be heated are mostly shaped by their own requirements, rarely can they be shaped for the heating technology.

Pictorial 1c. shows the influence of the material on efficiency at given temperatures. The value of specific resistance and magnetic permeability should be large.



Pict. 1b, Specific resistance and permiability dependent on temperature for various materials as per Tripmacher.

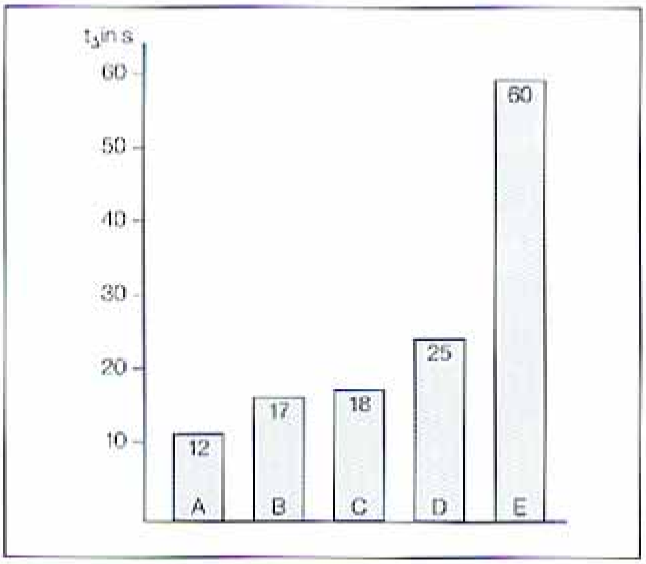
High Frequency Induction Heating offers only Advantages



Pict. 1c, Thermal efficiency as a function of diameter ratio D/d for various workpieces (D = Inductor diameter, d = Workpiece diameter).

$$\eta_{th} = \frac{1}{1 + \frac{D^2}{d^2}\left(1 + 6{,}25\ \frac{\delta^2}{d^2}\right)\sqrt{\frac{\varrho_1}{\mu \varrho_2}}}$$

Pictorial 1b, shows that steels are ideally suited for induction heating.
Pictorial 1c, shows the influence of physical attributes.



Pict. 2, Time required for heating for soldering/brazing with various methods (A...High frequency induction brazing, B...Manual flame brazing, C...Resistance soldering, D...Flame field soldering, E...Oven brazing soldering).

The following pages contain construction hints, influencing induction soldering/brazing.

The advantages of induction brazing result mainly from the physical characteristics of this process, contrary to other processes, heat is generated directly within the workpiece itself.

As a result, large amounts of energy can be transferred at relatively low losses. The power density is greater than with other heating processes, see pict #3. The heating cycles, for given workpieces are shorter with high frequency heating, when compared to other methods (see pict. #2).

These principal advantages make induction soldering/brazing particularly economical.

Heating method	P in Watt/cm²
Convection	0.5
Radiation	8.0
Contact conduction	20.0
Flame burner	1000.0
Induction	30000.0
Laser	10[illegible] to 10[illegible]

Pict. 3, Energy transfer for various heating methods as per Benkowsky.

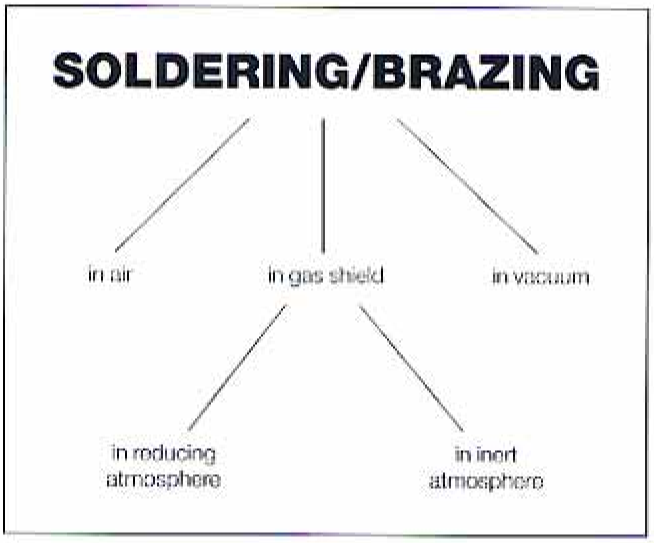
Specific Advantages of High Frequency Soldering/Brazing.

- Very economical
- Clean and non polluting (no open flame)
- Good repeatability
- Workpiece properties virtually unaffected in immediate vicinity of heating zone
- Reduced formation of oxides and dross
- Heating of inaccessible areas and shapes is mostly not a problem
- Linn high frequency installations require minimal space
- Gas or vacuum shielding is possible, special requirements of workpieces can be accommodated
- Ideally suited to automation and mechanization.

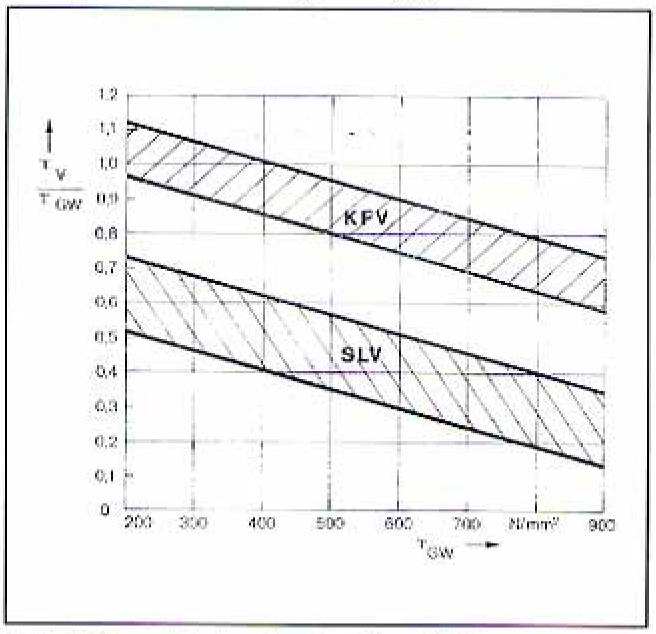
The Induction Soldering/Brazing Process

Resulting from the enumerated advantages, induction heating has become a well established sector of the industry. Having been in use for many years, it enjoys an excellent reputation.

Examples of induction heating in industrial manufacture are; annealing, soldering, brazing, welding, melting, hardening, tempering, shrinking, drying, preheating, surfacecoating, accellerated curing of adhesives.



Pict. 4, Induction soldering/brazing processes.



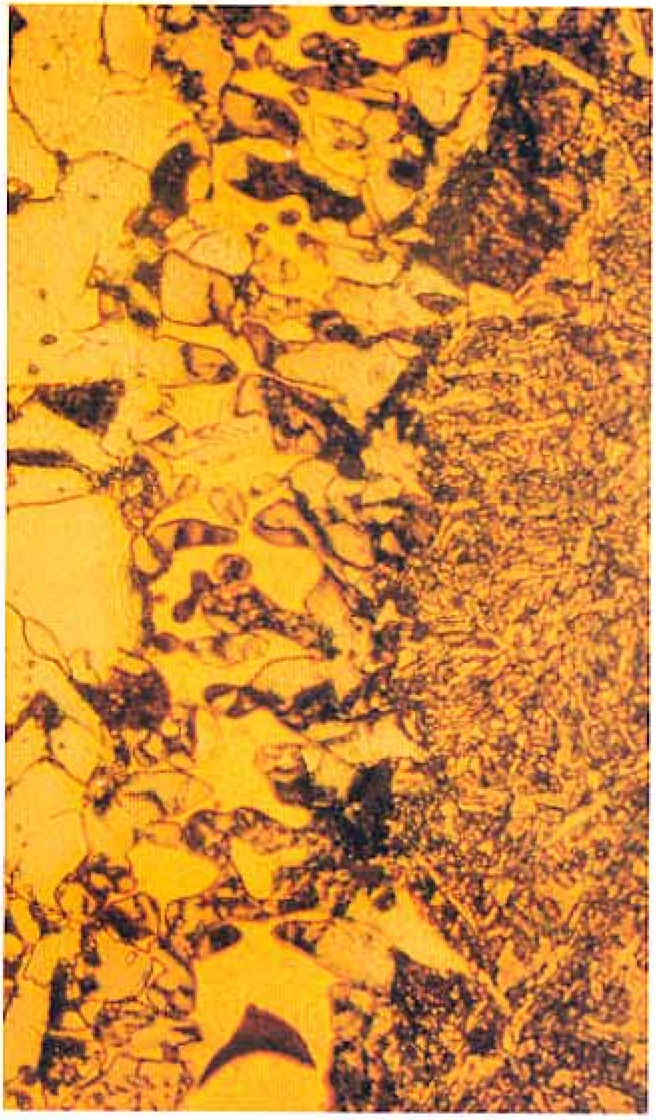
Pict. 5, Strength of meltsolder joints SLV and combination meltsolder and meltweld joints KFV.

High frequency induction heating is very successfully used for soft soldering/brazing and high temperature brazing.

Induction soldering can be applied under different processes:

- in air with or without flux,
- in reducing or inert atmospheres,
- as well as in vacuum.

For example, brazing steel with copper solder, high strength joints are obtained, under controlled conditions, special grain structure can be attained, leading to yet higher strength.



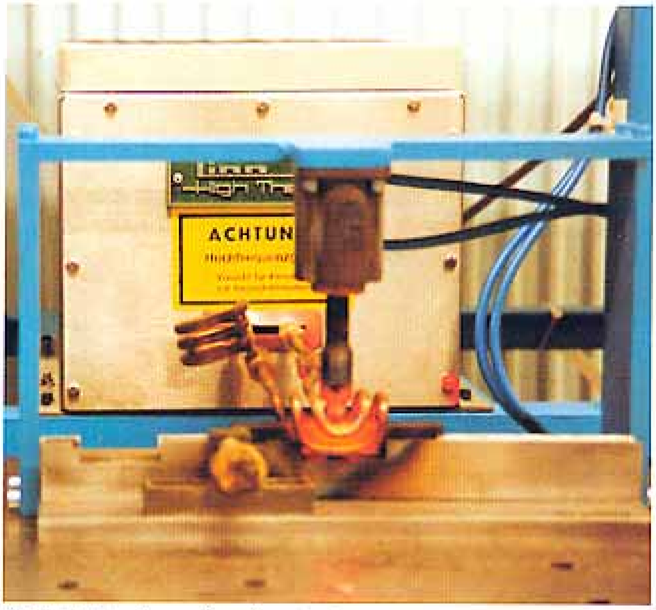
Pict. 6, Grain boundry of a high strength melt-weld joint. Average seam width 40 micro meter.

Flux Induction Soldering in Air

The most common process in practice is, soldering in air. Advantages are an uncomplicated arrangement of the soldering station resulting in a cost effective process.

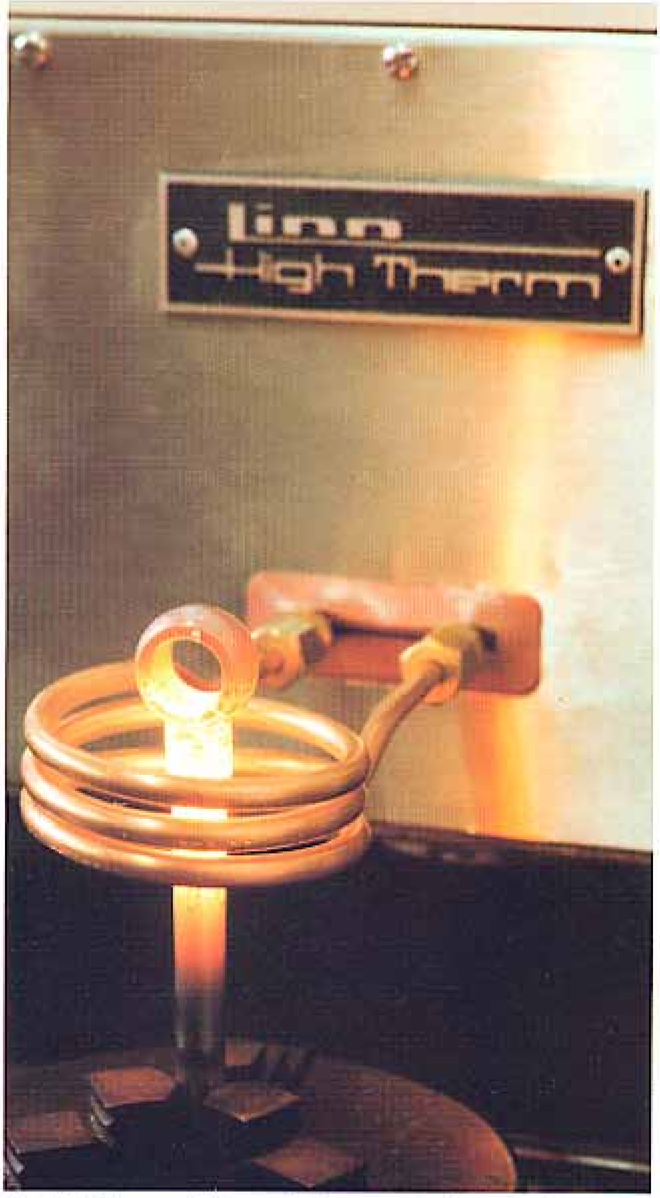
When the use of self wetting solders is not feasible, the use of fluxes is mandated. These fluxes are widely available in the trade, they are selected in accordance with the workpiece requirements and solder to be used.

One of the disadvantages occurring when using flux, is the need to chemically or mechanically remove residues.

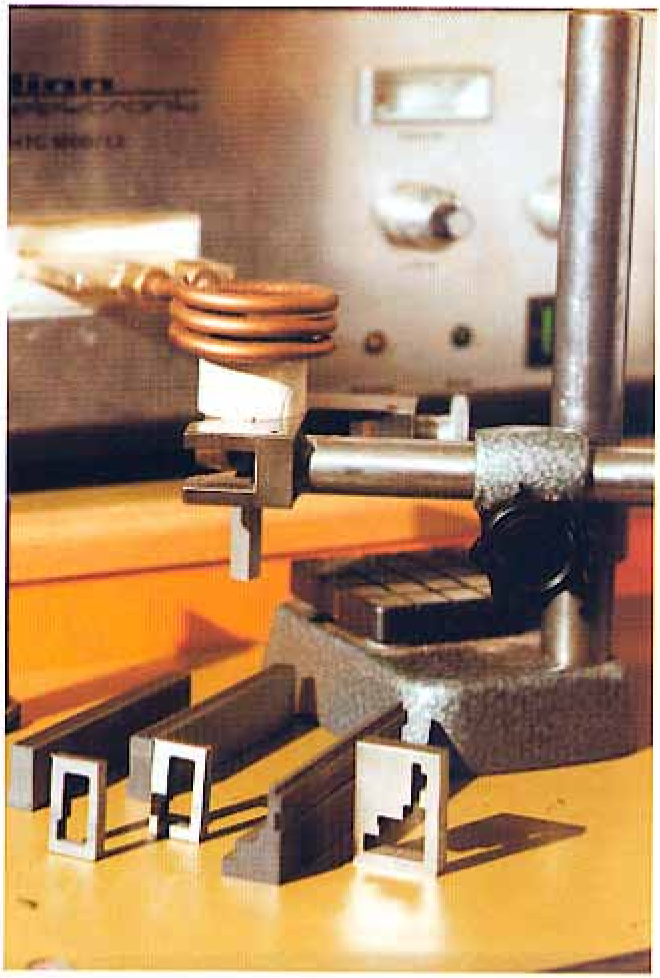


Pict. 7, Brazing of active tool parts.

Application examples:



Pict. 8, Silversoldering of pipe connections for hydraulic devices.



Pict. 9, Brazing of tools for die punches by using of a silver solder.

RF/HF Induction Soldering in Vacuum or Gas Shield

Pict. 10, Protective gas/vacuum melting chamber for melting of precious metal alloys.

Pict. 11, Coating of tool in early production stage, by RF/HF induction brazing in "Autoshielding Gas" (self generated gas).

Workpieces to be joined, often have special requirements that can only be satisfied with controlled atmospheres, during the soldering process.

The use of gas shielding or vacuum, avoids the formation of oxides or dross and actually removes the same during the heating process.

The effects are that workpieces have excellent surface quality and appearance after soldering, but place a higher demand on apparatus.

Induction soldering can be achieved in various ways:

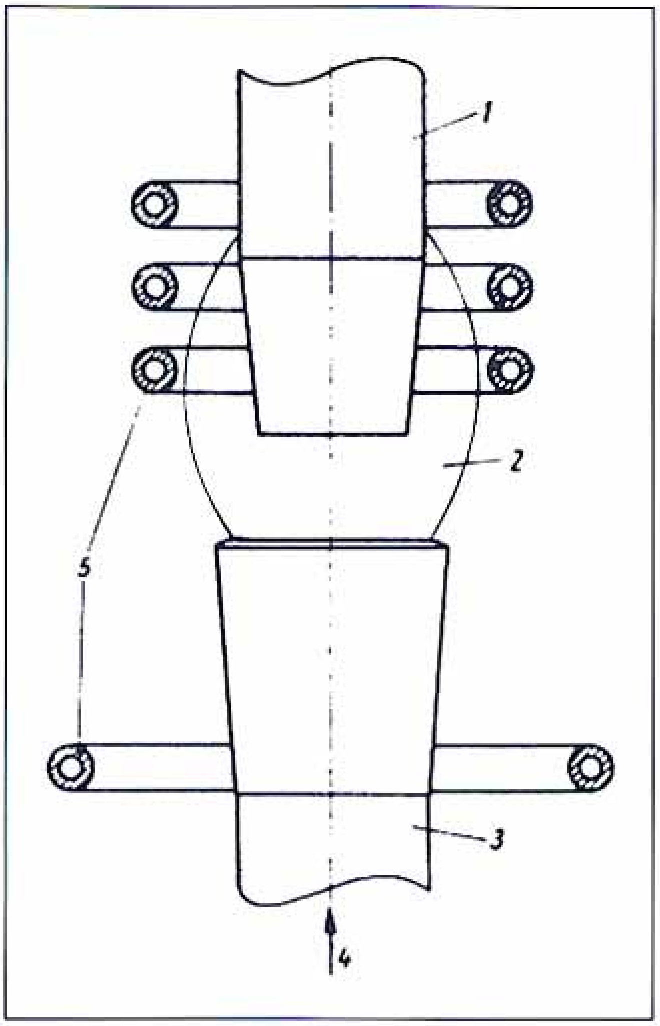
1. The inductor is within the gas shield or vacuum.
2. The inductor surrounds the gas or vacuum chamber.
3. The inductor is used as a diffuser applicator for the shielding gas.
4. The solder joint is immersed in a gas shield via a special conduit.

In the case of # 2 the gas vacuum chamber can be made of quartz (Pyrex Glass).

The workpiece is within the glass chamber, while the coil is fashioned to surround the same, heating through the glass.

An alternative to the preceding is the use of a sealed chamber, where the workpiece within creates its own reducing atmosphere.

Induction Brazing of Copper to Aluminum within a Gas Shield



Pict. 12: Principles of diffusion soldering copper to aluminum tubes as per Peter, 1 copper tube, 2 shielding gas zone, 3 aluminum tube, 4 shielding gas in, 5 inductor.

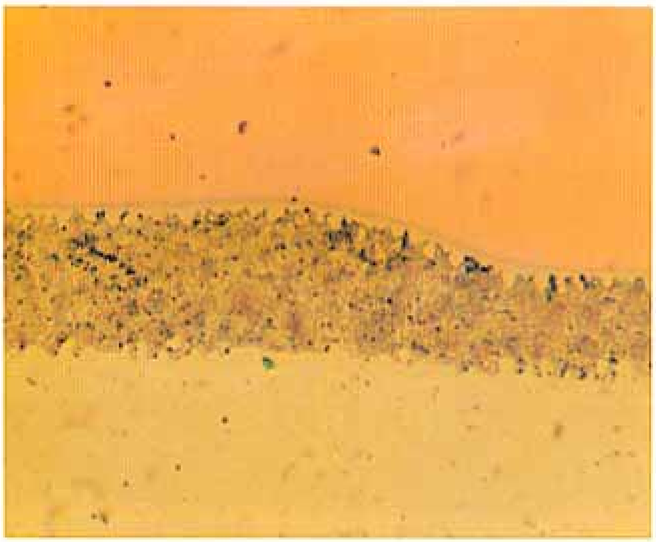
The working principle of diffusion brazing is based on the fact that during the process an eutectic alloy is formed, whose melting point is lower than that of either parent material.

Practicing diffusion soldering, of aluminum to copper, the copper end is heated to 950 deg. C, at the same time the aluminum is heated to just below the melting point.

Having attained the desired temperature, the RF/HF is turned off and the copper end is forced in to the aluminum.

By a diffusion process, an eutectic alloy is formed, at the interface having the composition of (Al-$CuAl_2$) this alloy has a melting point of 545 deg. C. The process is protected against the detrimental influence of oxygen, by immersion in a gas shield.

Pict. 13, Diffusion soldering of copper-aluminum joint made with gas shield.



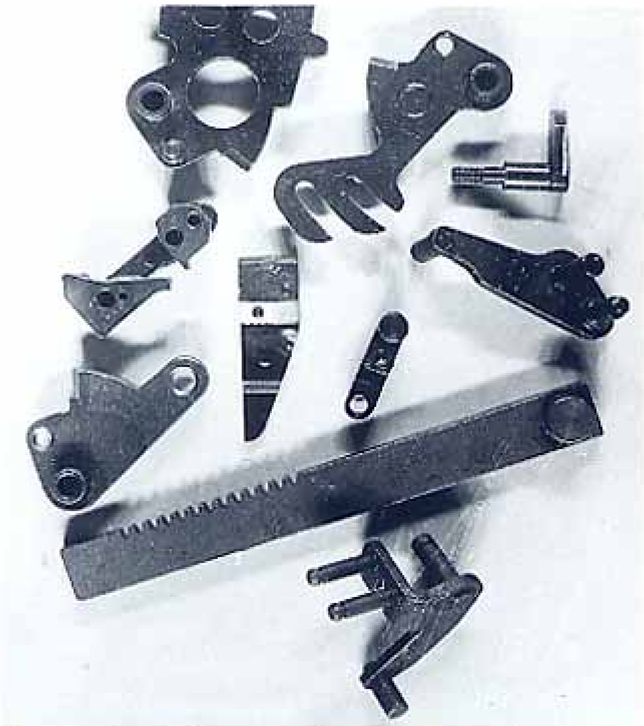
Pict. 14, Micro polished section view of a copper-aluminum connection.

Various Assemblies, Joined by Induction Brazing

Small sub-assemblies, of various kinds are often joined by induction brazing for medium production requirements in industry.

By matching the inductors to the job at hand, varying parts can be joined, economically, having single or multiple seams.

Steels, hard metals, copper, brass and aluminum can be successfully joined by the HF induction heating process.

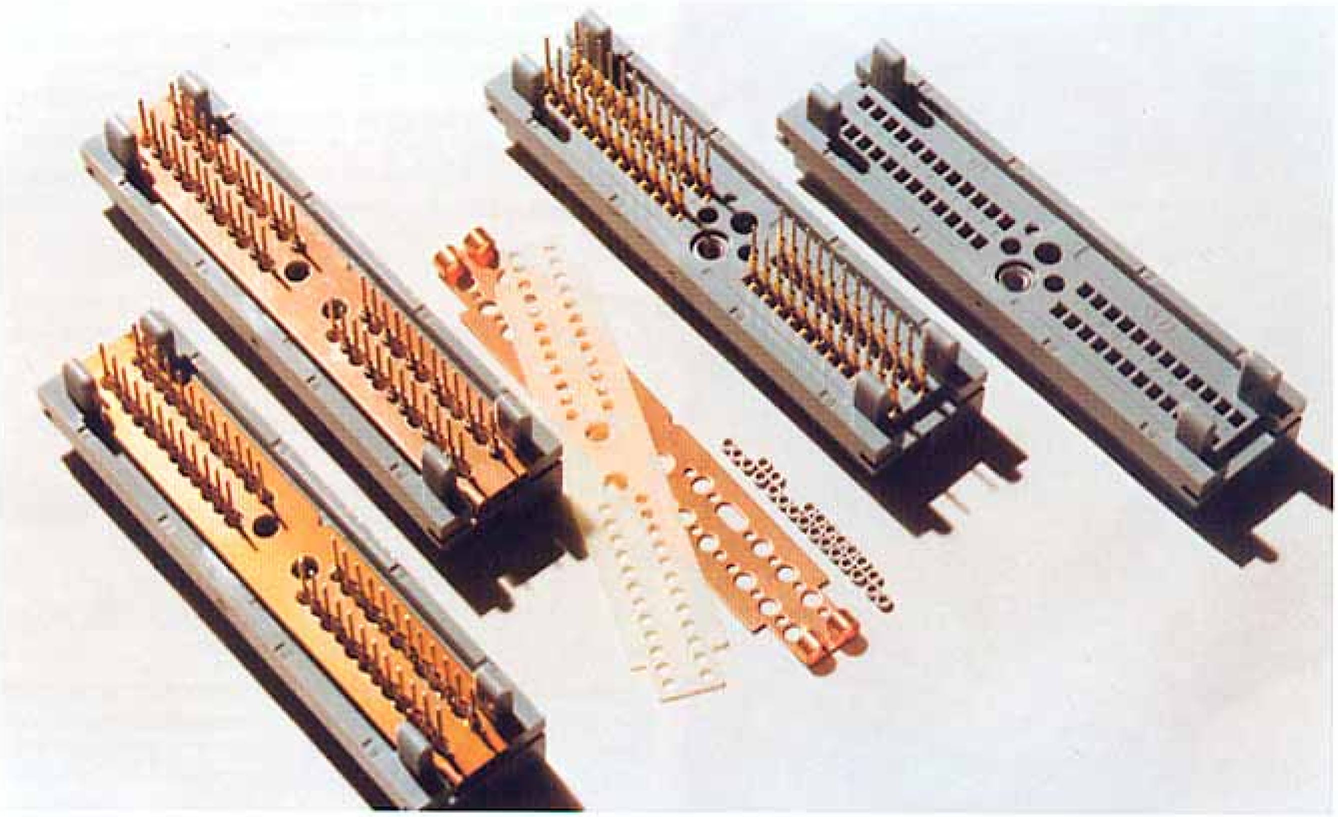


Pict. 15, Small nitting machine parts brazed in reducing atmosphere by RF/HF induction soldering. (Works Photo: Elite Diamant GmbH).

Pict. 16, Measuring probe (1.5 m lg.) 58.5 inches, RF/HF induction soldered in reducing atmosphere using a special heat resistant solder.

Pict. 17, Gas shielded induction soldered parts. Pipe nozzle – coated semy finished parts – burner jet – drills with carbide inserts – pipe connector.

High Economy by Simultaneous Induction Soldering/Brazing



Pict. 18, Construction of plug connectors for computers.

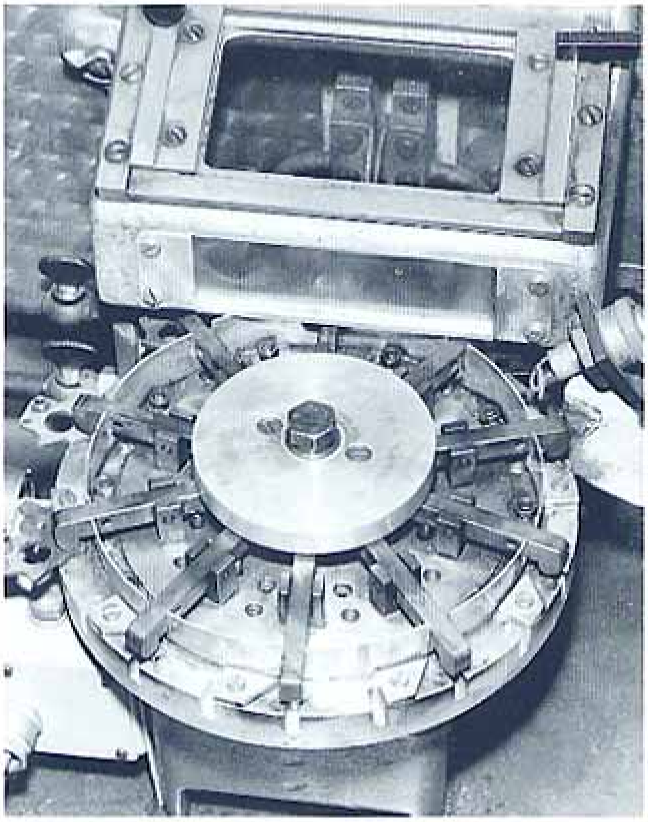
Particularly economical manufacture is possible, when special shaped inductors, adapted to the job at hand, permit the simultaneous soldering of many connections.

The use of so called needle inductors, equipped with plug in connections, for example permit the simultaneous brazing of "U" bends on heat exchangers.

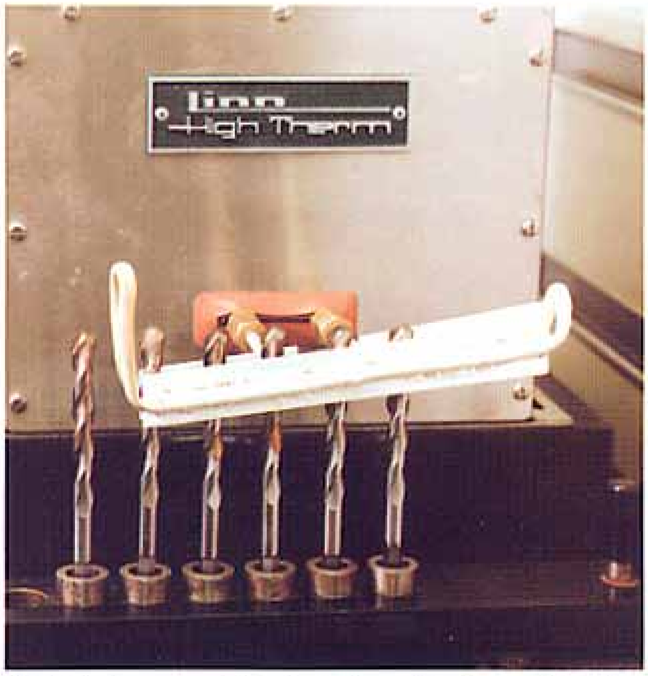
Pict. 20, RF/HF induction brazed U turns for heat exchanger.

Pict. 19, Simultaneous soldering of 24 connections, in the manufacturing of electrical connectors.

Mechanization and Automation of Induction Brazing



Pict. 21, Rotary indexing table for induction brazing (Works Photo: Elite Diamant GmbH).



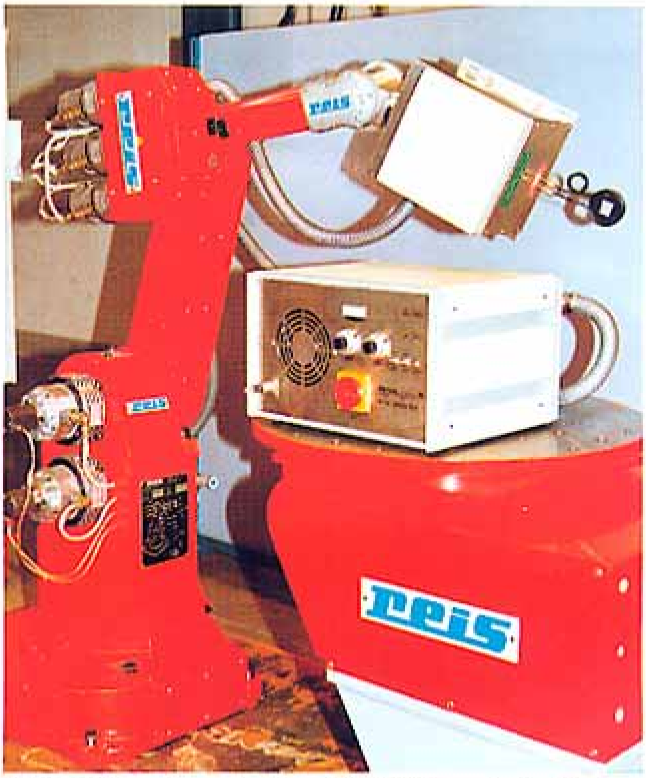
Pict. 22, Arrangment for induction soldering and simultaneous heat treating of hard metal drills with carbide inserts.

The suitability of RF/HF induction heating apparatus, for mechanization and automation arise from the following advantages:

- Immediate operational readiness,
- Short cycle times,
- Reproducible operating parameters,
- RF/HF units are adaptable to systems, integration and control,
- Simplified optical temperature measurement is feasible.

In accordance with type of parts and working parameters, as for example cycle frequency, rotary indexing tables, or incremental linear conveyors are used to hold the parts. These may be combined with lifting devices, to mechanically position parts in to more complicated inductors. Special tunnel inductors permit extended heating, bringing to brazing temperature, as well as heat treating where needed and possible.

Lightweight compact Linn RF/HF induction setups, as part of industrial robots, allow optimum use for all applications, such as brazing, annealing, hardening and accelerated curing of adhesives.



Pict. 23, Brazing robot typ RV 12/15 made by the firm Reis, 8753 Obernburg Germany for perfect tracks and super accurate positioning.

Shaping of Inductors

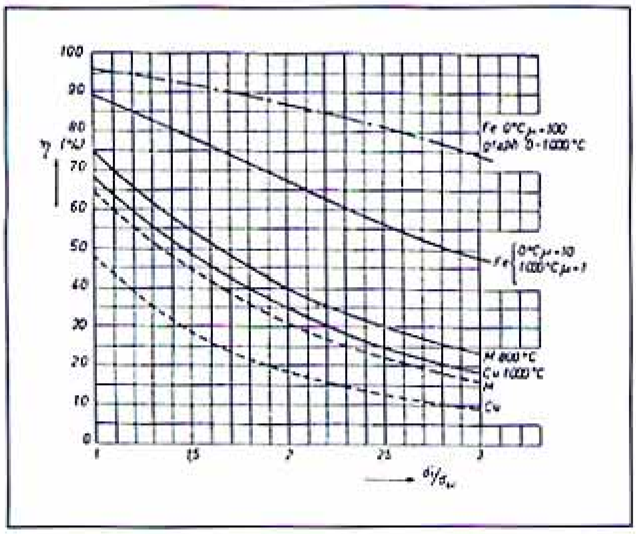
Since the parts to be brazed and the RF/HF heating equipment on hand is usually fixed in character, efficiency can only be affected by the user, matching the inductor to the workpiece.

Depending on the parts to be brazed, one differentiates between internal field inductors, (the workpiece is within the coil) and external field inductors, (the workpiece surrounds the coil) and surface inductors, these, in singles or multiples, act on the surface of the workpiece.

Inductor type	Effectivness
Int. field	0.5 to 0.9
Ext. field	0.3 to 0.5
Surface indct.	0.3 to 0.6
– Single sided surface indct.	0.15 to 0.3
– Double sided surface indct.	0.4 to 0.8

Pictorial 24, Efficiency of various inductors as per Benkowsky

Pictorial 24 shows the effectiveness of the various types. From this pictorial can be seen that the internal field types achieve the highest efficiency.



Pict. 25, Efficiency dependent on coupling distance at various temperatures as per Kretzman

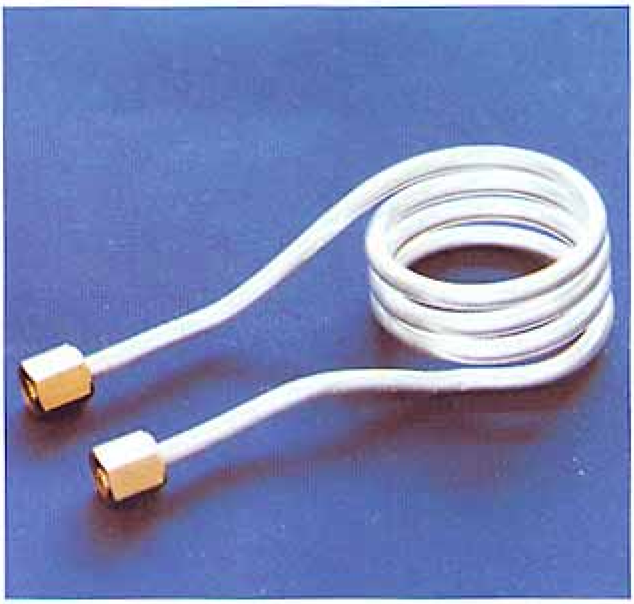
Coupling Distance

The distance between the inductor and the workpiece (coupling distance) has an important influence on the overall efficiency. Reducing the coupling distance raises the efficiency, see pict. 25.

However the coupling distance cannot be reduced toward Zero, as voltage induced flashover will occur below a certain point.

Hints for Inductor Configuration

1. The leads to the inductor, should be kept as short as possible 50 to 100 mm.
2. The leads should be an one piece construction, preferably without any intermediate connections.
3. Inductors should be made from materials having a high electrical conductivity. Copper is the usual choice. It is advantageous to silverplate the inductor, see pict. 26.



Pict. 26, Silverplated and watercooled inductor.

4. At the inductor surface current flows in the order of 300 Amp./mm² to 600 Amp./mm² are encountered. For this reason, it is necessary to cool the inductor with flowing water (Temp. in max. = 25 deg. C, Temp. out max. = 40 deg. C).
5. Inductor cross-section, round or rectangular, to be selected to minimize pressure drop, so adequate cooling media flow is assured.

Technical Description of RF/HF Generators

The Linn high frequency generators are: HTG 1500/0.5, HTG 3000/0.4, HTG 6000/0.3, HTG 12000/0.2

They are free running push/pull generators utilizing Power FET technology. Stepless output control 15 to 100 %. RFI suppression as per VDI and FTZ.

The use of transistors rather than vacuum tubes for the oscillators offers some essential advantages. Transistors do not require filament voltages. The dimensions of component parts are notably smaller than would be the case with vacuum tubes. The operating losses of the transistors are decidedly smaller, reducing cooling requirements. The overall efficiency of the facility is approx. 20 % higher than comparable vacuum tube models.

Transistor drive voltages are lower, this reduces the equipment size, as well as the weight of the power supplies.

If even smaller device dimensions are needed, separation of power supply and RF/HF section are necessary.

Frequently the retrofitting of inductive heating devices becomes impractical owing to external dimensions. Use of semiconductor type devices makes retrofitting possible in most cases, even if space availability is limited.

Vacuum tube type generators are high internal resistance devices mandating high output voltages, in the kilovolt range.

These high voltages make necessary extra guarding to prevent accidental contact with lethal voltages. Also an increased demand exists for RFI shielding.

Transistor type generators, having low internal resistance eliminate the possibility of accidentally contacting dangerous voltages. They can be safely touched.

Two types are available:

- Compact unit with integrated RF/HF section
- Control unit with separate RF/HF section max. separation distance 10 meters or 32.5 feet.
- Explosion protection model in preparation

Safety features:

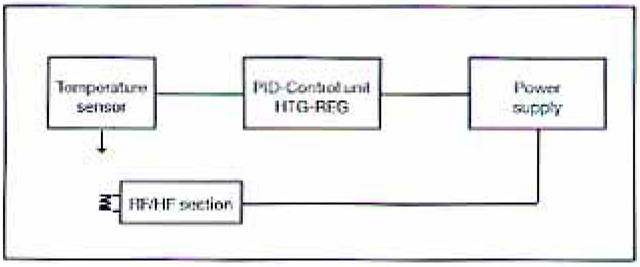
- Rapid overload disconnecting
- Control voltage monitoring
- „Drain" voltage monitoring
- Cooling water flow monitoring
- Operating temperature monitoring

LED indicators for:

- High frequency
- Overload
- Insufficient cooling water flow
- Over temperature

Options for the HTG-series

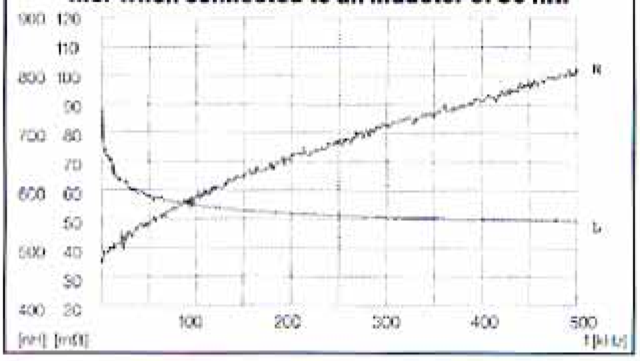
- Heat exchanger for better cooling of the RF/HF-part (at high surrounding temperatures or continuous operation)
- Potential free outlets of the control functions
- Pedal switch
- Control unit HTG-REG (also available with RS 232, see pict. 27)
- Optical pyrometer
- Adaption transformer for small inductors
  For low Ohm inductors an adapter piece (transformer) must be used between inductor and the RF/HF generator. Note the characteristic curves of the transformer in pict. 28.



Pict. 27, Control unit HTG-REG.

Device description/Type	HTG 1500/0.5	HTG 3000/0.4	HTG 6000/0.3	HTG 12000/0.2
RF/HF output	1500 W	3000 W	6000 W	12000 W
Optim. operating frequency	200-400 kHz	250-400 kHz	200-400 kHz	100-200 kHz
Reactive power at inductor	[illegible]	[illegible]	[illegible]	[illegible]
Input power and voltage	[illegible]	[illegible]	[illegible]	[illegible]
Water consumption at [illegible]	[illegible]	[illegible]	2.5 l/min	5 l/min
Dimens. RF/HF section	[illegible]	[illegible]	[illegible]	[illegible]
Dimens. control section	[illegible]	[illegible]	[illegible]	[illegible]
Dimens. compact unit	470x160x400 mm	on request	on request	on request
Weight RF/HF section/ Ctrl. sect./Compact unit in kg	[illegible]	[illegible]/on request	[illegible]/on request	[illegible]/on request

Series indutivity L_S and resistance R_S of the transformer when connected to an inductor of 50 nH.



Pict. 28, Characteristic curve of transformer.

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