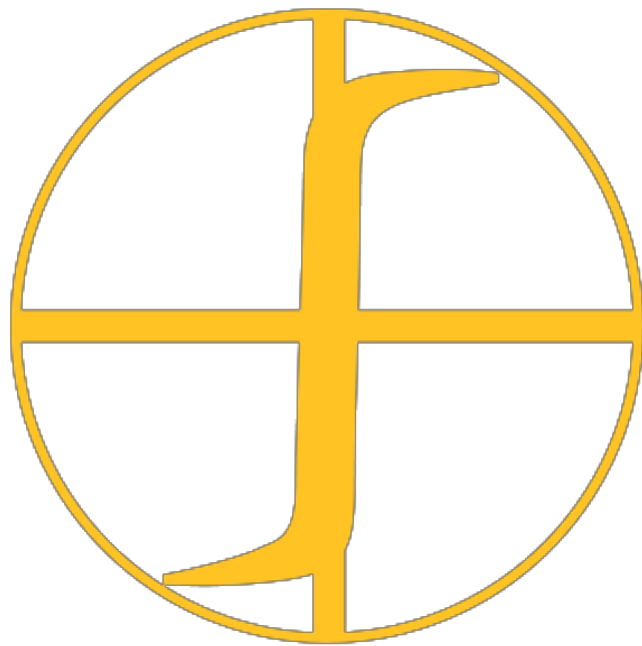




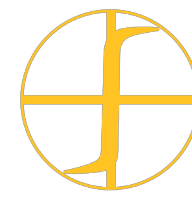
Advanced Induction Materials and Technology



O n l i n e I n d u c t i o n H e a t i n g C o u r s e

10 Case Study - Induction Brazing of Aluminum Heat Exchanger

by. Dr. Valentin Nemkov



Problem Description

Part: Aluminum heat exchanger
Operation: Brazing of a pipe to a short tube previously brazed to the heat exchanger header in a furnace

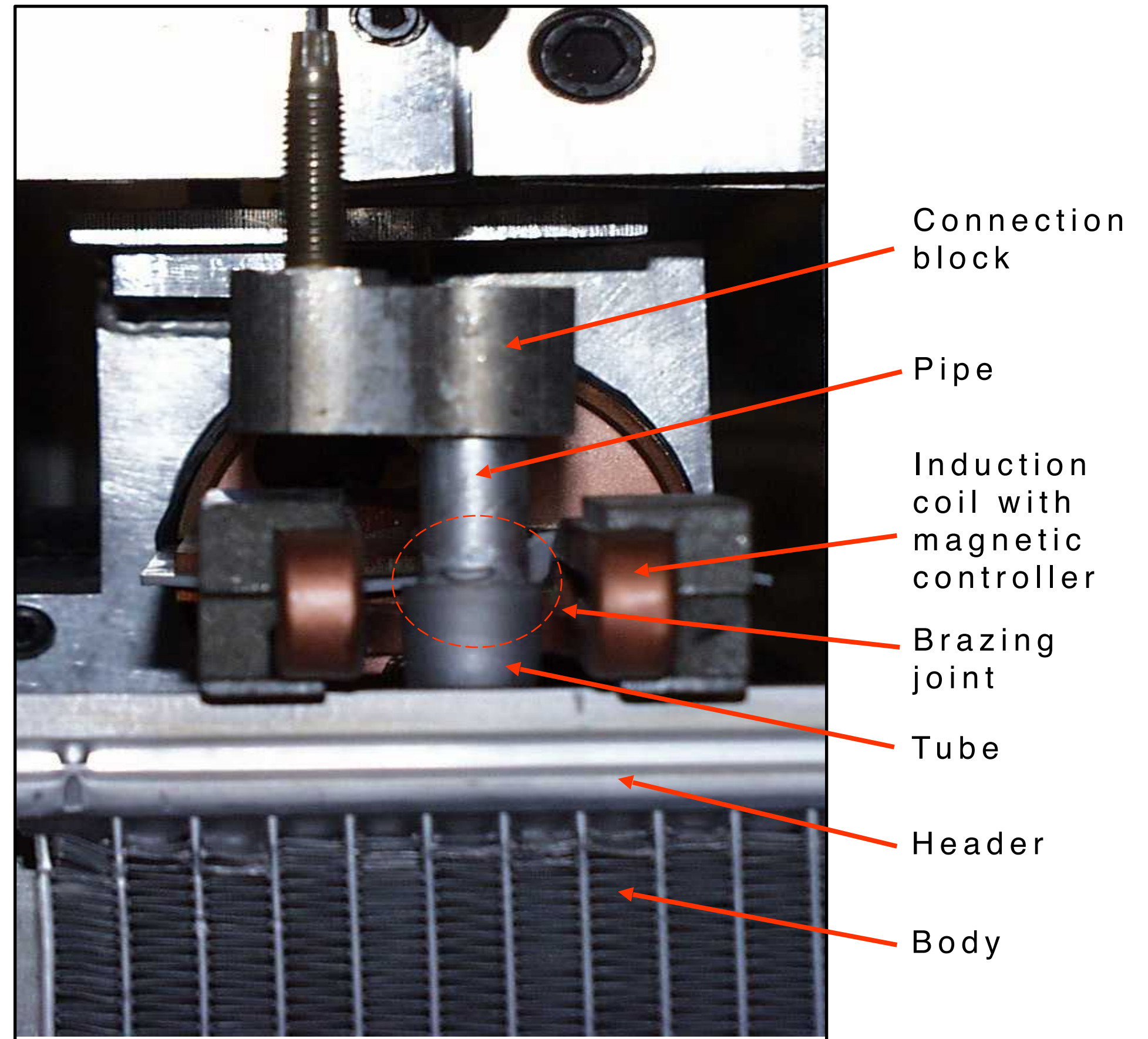
Equipment: All equipment including 60 kW, 10-30 kHz power supply, part handling system and control system with IR pyrometers already existed

Problems:

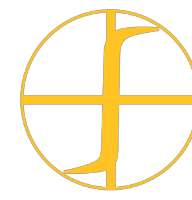
- Insufficient brazed joint depth
- Inconsistent process resulting in leakage and other defects

Variables:

- Limited coil type modification
- Coil dimensions
- Coil positioning
- Magnetic controller dimensions



Experimental brazing in
Fluxtrol laboratory

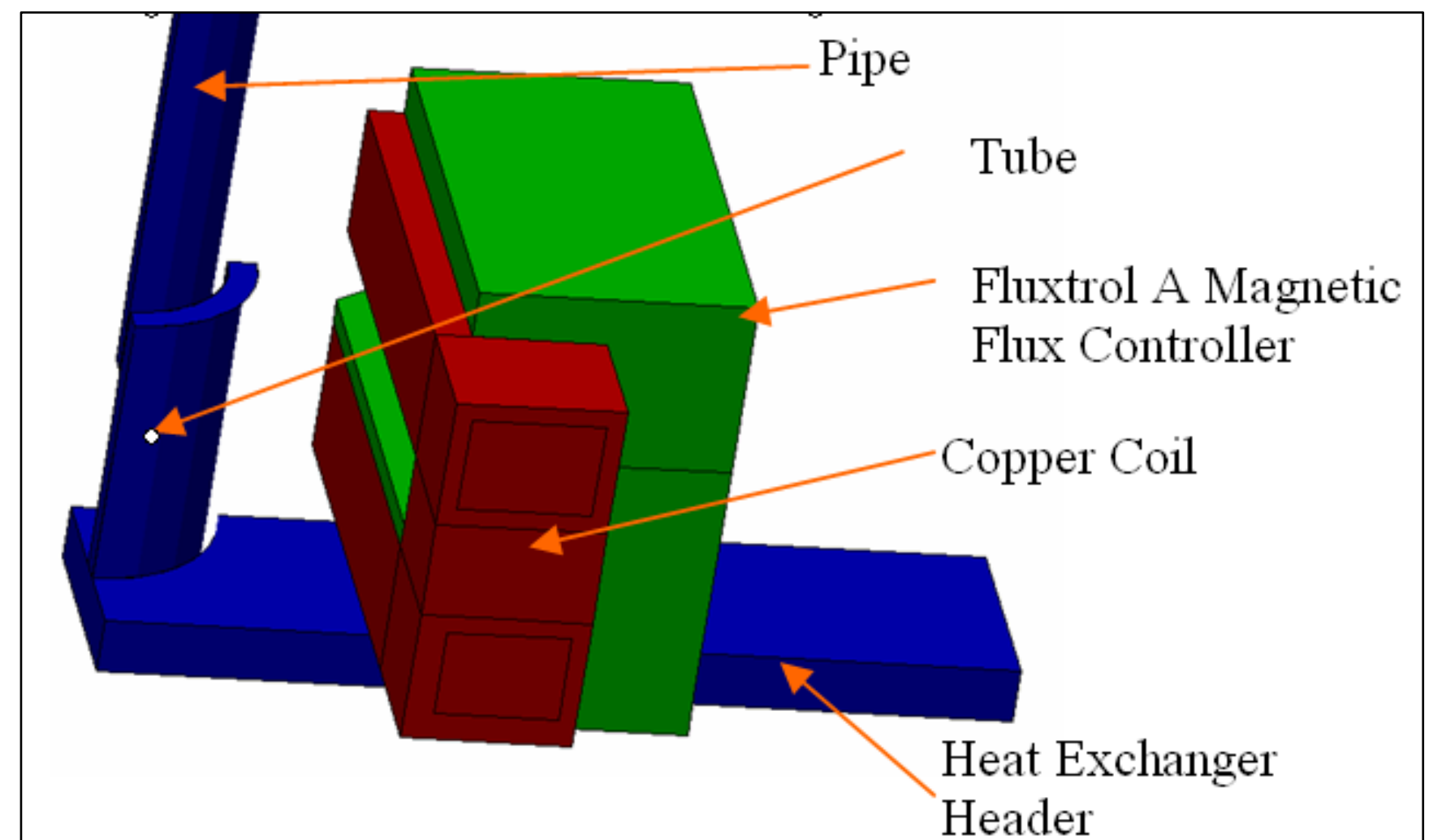


System Geometry Description

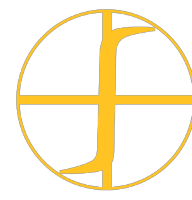
Existing inductors had a “horseshoe hairpin” shape for simple part loading. The coils consisted of two hair-pin sections connected in series with diagonal cross-over.

Geometry is clearly 3D with multiple components (pipe, tube, header, coil copper, magnetic controllers). Due to planes of symmetry it was possible to simulate only $\frac{1}{4}$ of system.

Non-symmetry due to crossovers was neglected.



Geometry prepared for simulation using Flux 3D program



Step 1: Simulation of Existing Process

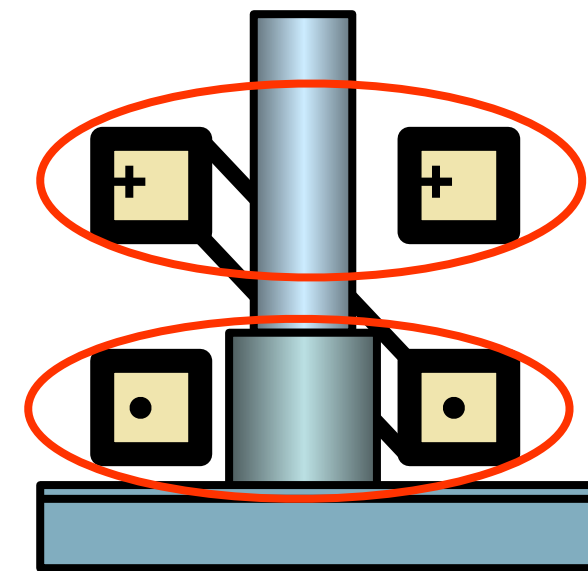
On a base of process analysis it was assumed that the main non-controlled variable was an electrical contact between pipe and tube.

These components are preliminarily coated with flux and electrical contact between them is unstable.

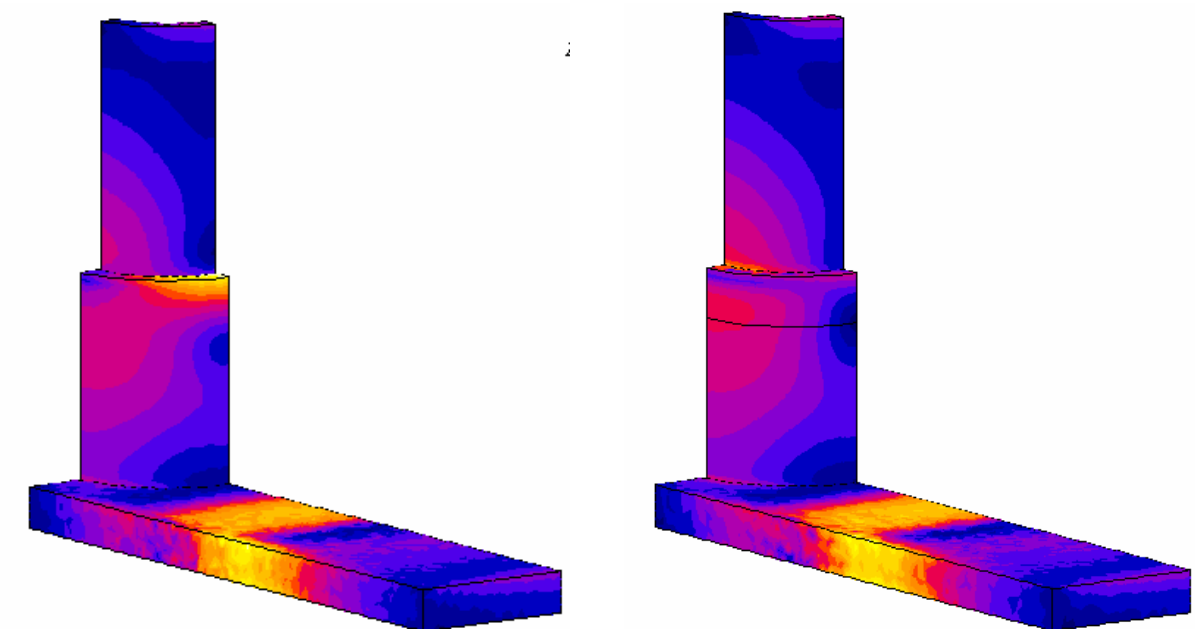
When the joint is filled with molten filler metal, contact is good.

Computer simulation confirmed this theory. With no electrical contact there is a strong heat concentration on the tube edge closest to the coil. Overheating of this area is a common defect of brazing.

With good contact current flows from tube to pipe resulting in heat pattern change. It is not possible to balance these two patterns achieving stable quality.



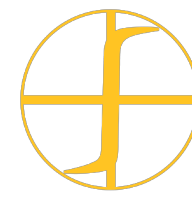
Coil currents direction and magnetic generic field lines for horseshoe coil with diagonal crossover



Current density distribution in joint area for diagonal crossover.

Left – no electrical contact

Right – good electrical contact

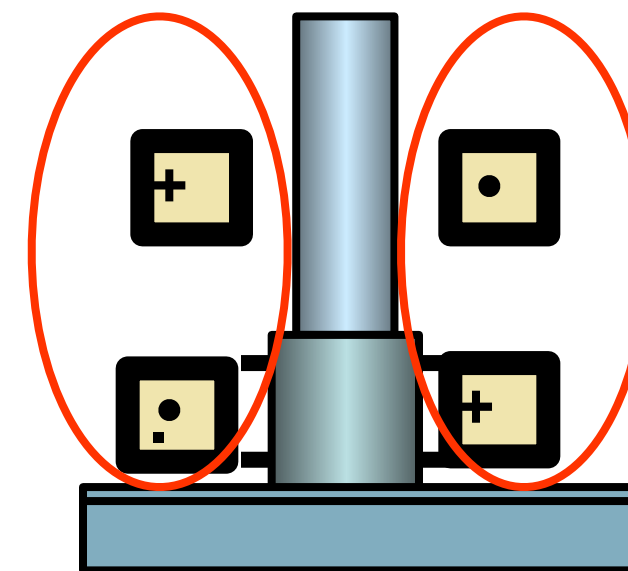


Step 2: Development of Induction Coil with Horizontal Crossover

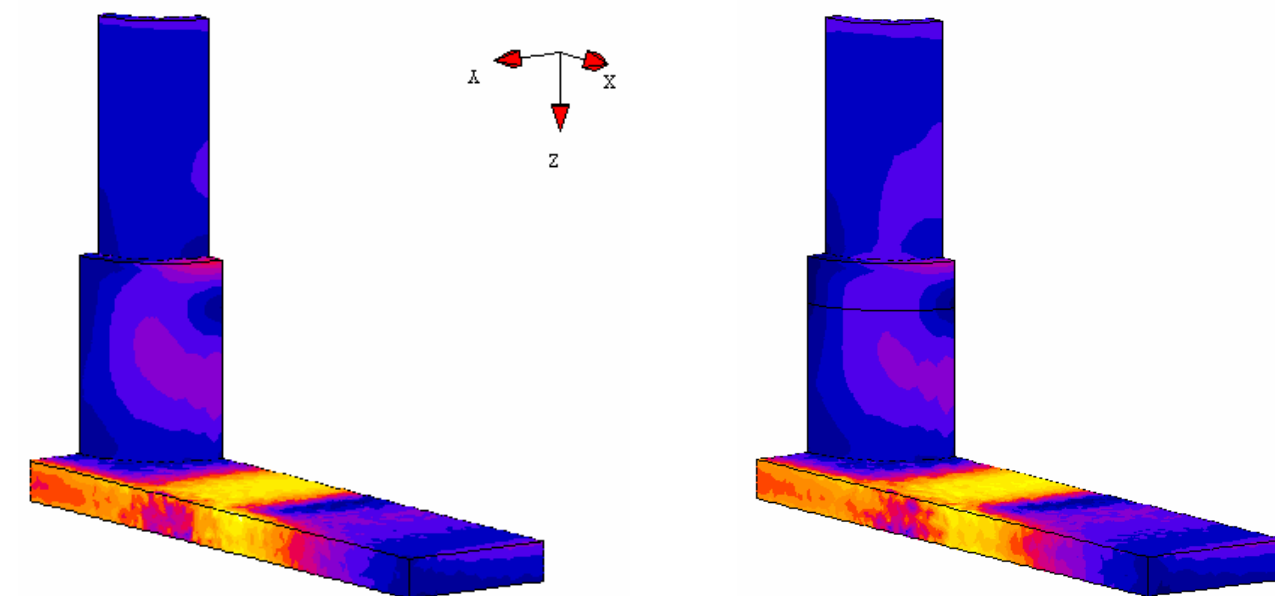
For a coil with horizontal crossover currents flow mainly inside of each component for good and no contact conditions.

However, computer simulation showed that heating of pipe and tube is very weak compared to the heat exchanger header.

Small heating of header is useful for support of temperature profile in the tube, but main power must be delivered to pipe and tube in a correct proportion.



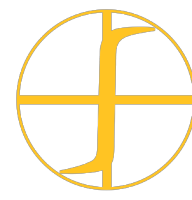
Coil currents direction and magnetic generic field lines for horseshoe coil with horizontal crossover



Current density distribution in joint area for horizontal crossover.

Left – no electrical contact

Right – good electrical contact



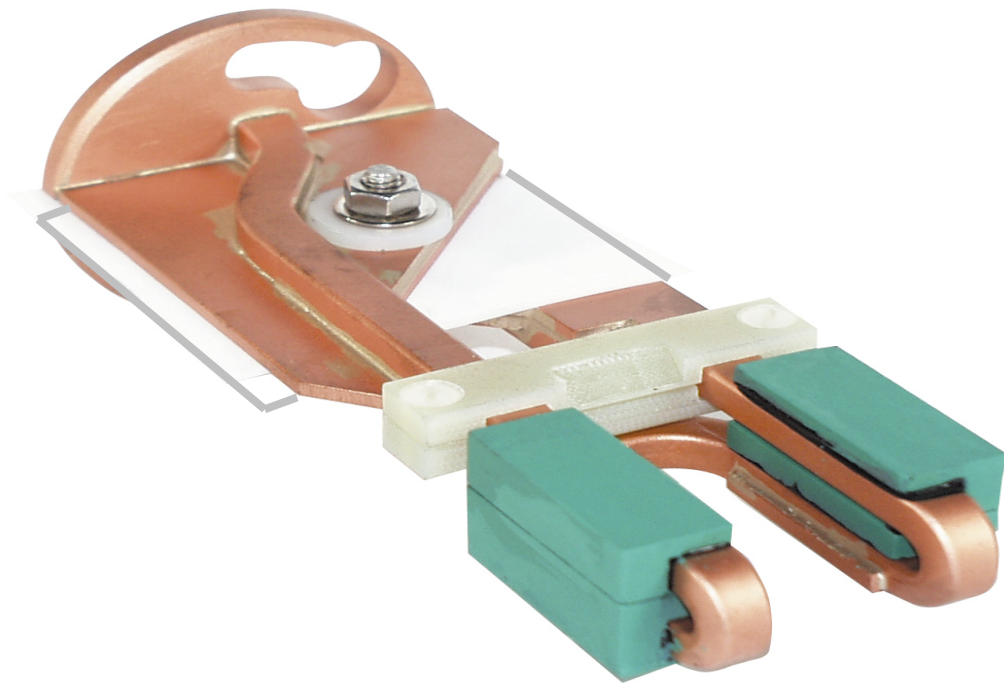
Step 3: Optimal Coil and Process Design

Additional magnetic controller was placed between the coil bottom and header surface. Variation of magnetic flux controllers made of **Fluxtrol "A"** material allowed the process to achieve optimal power distribution between all three heat exchanger components.

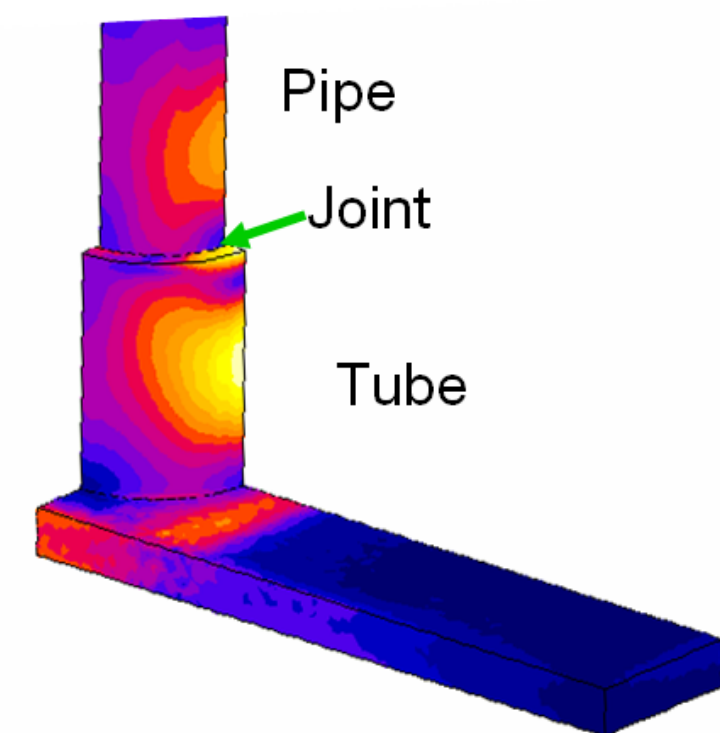
Laboratory tests confirmed stable process flow and good quality of brazed parts.

Additional consideration:

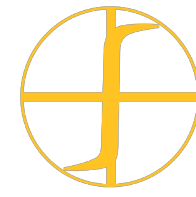
It was noticed that change of crossover resulted in much stronger electrodynamic forces. Coil tends to "open" when power is turned ON. To reduce effect of electrodynamic forces, an additional fiberglass connector was installed on the coil.



Final coil design for one of the brazing joints



Optimized power distribution in brazing joint components



Final Results

- Computer simulation helped to understand the factors causing brazing inconsistency and optimized coil design
- Combination of coil copper optimization and proper geometry of magnetic flux controllers solved a problem of brazing quality. There were no more part rejects caused by improper induction heating
- It was found that a variety of products may be brazed by the coils with the same copper by adjusting geometry of magnetic flux controllers
- Brazing cycle reduced by 15-30% when using new coils

