

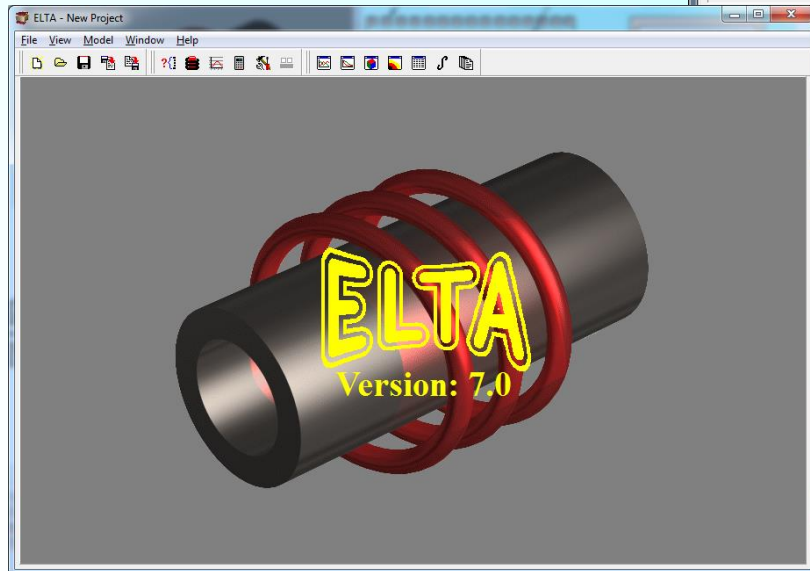
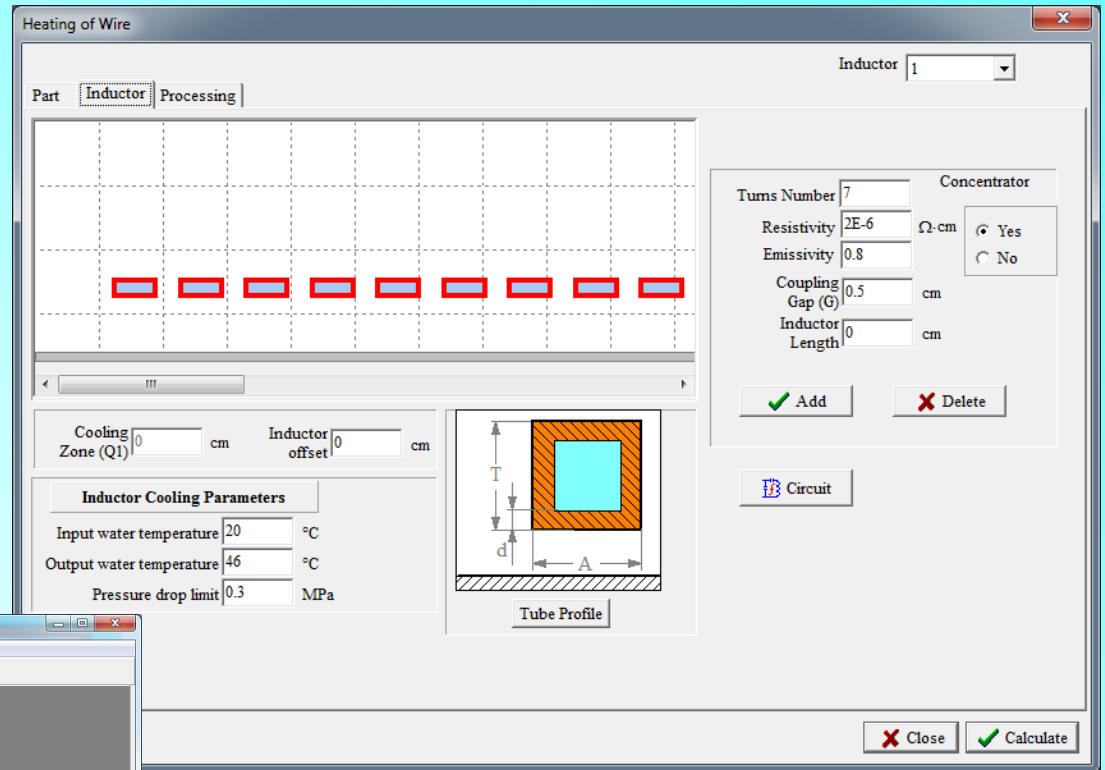
## Control System of Smart HF Power Supply Integrated with ELTA Program

Vladimir Bukanin, V. Vologdin, Vl. Vologdin Jr., A. Blagirev,  
A. Homutinnikov, A. Ivanov and A. Zenkov

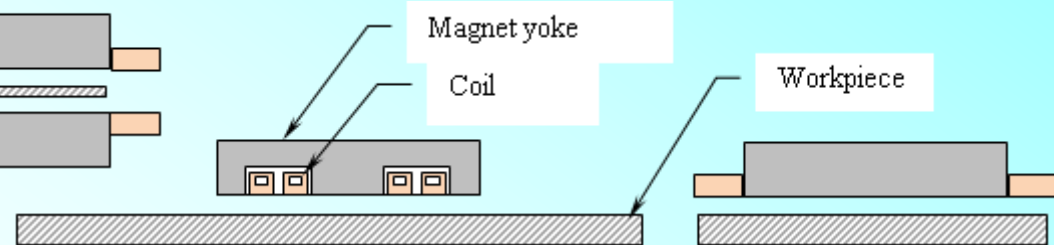
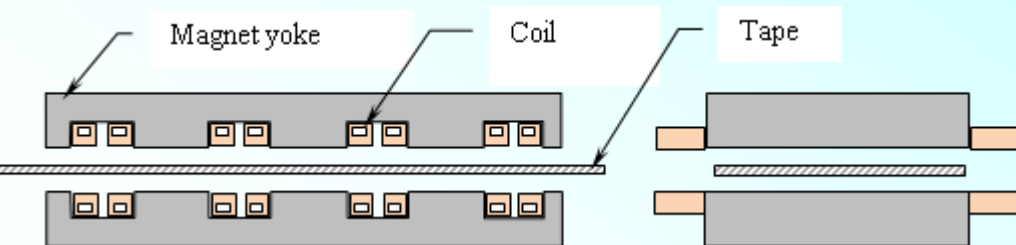
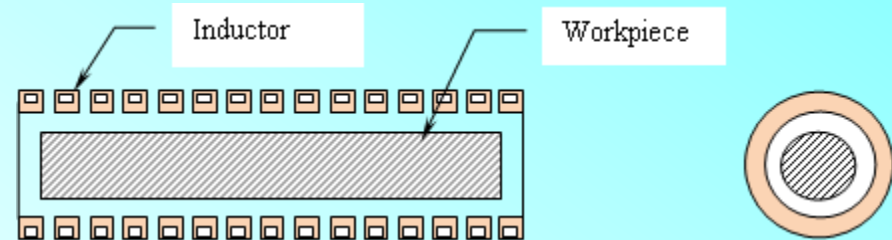
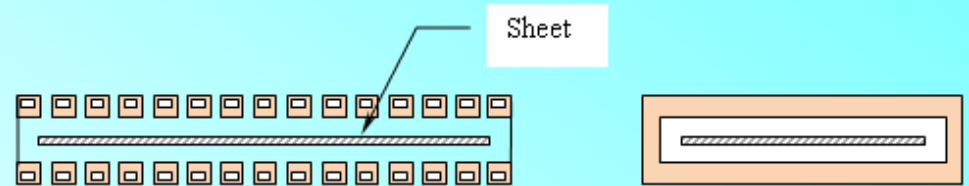
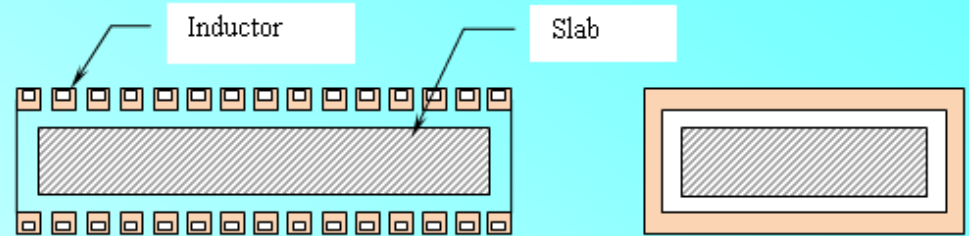
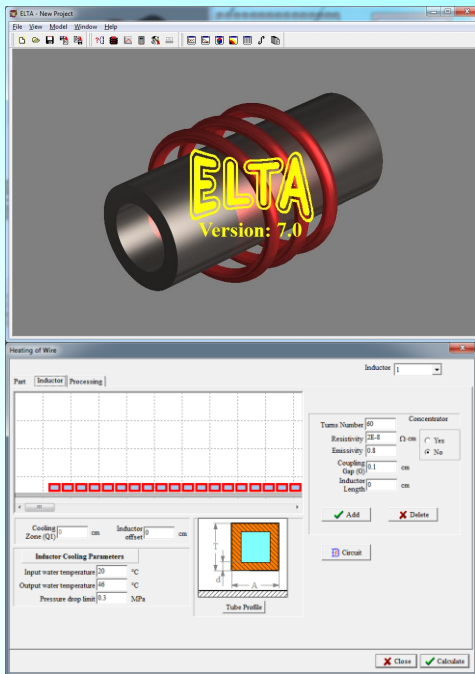


e-mail: [VABukanin@nsgsoft.com](mailto:VABukanin@nsgsoft.com),  
<http://www.etu.ru>

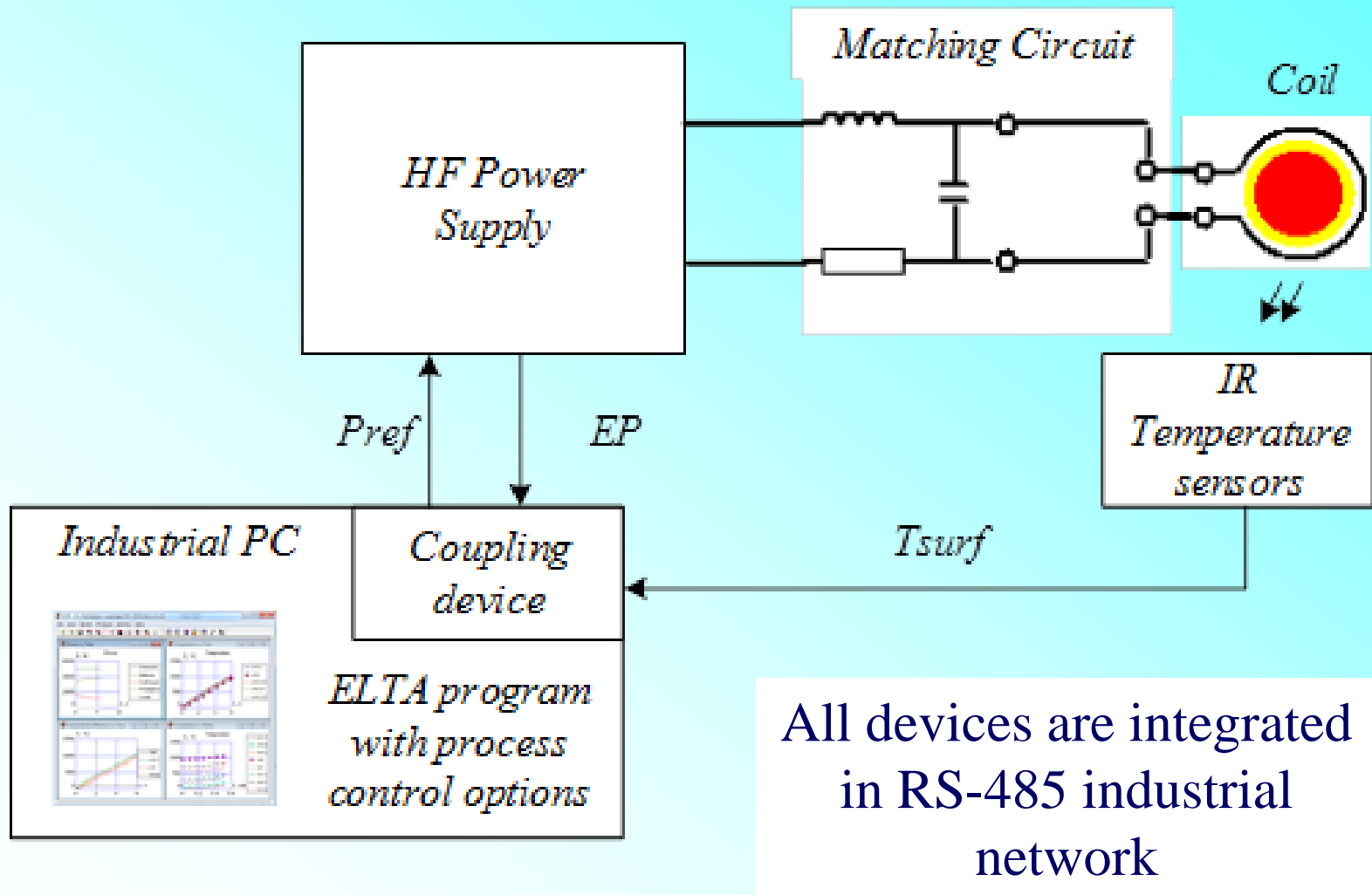
# ELTA is a love child of Valentin Nemkov



# ELTA is a powerful program for a preliminary study of processes in a wide range of applications



# STRUCTURE OF THE SMART HF POWER SUPPLY

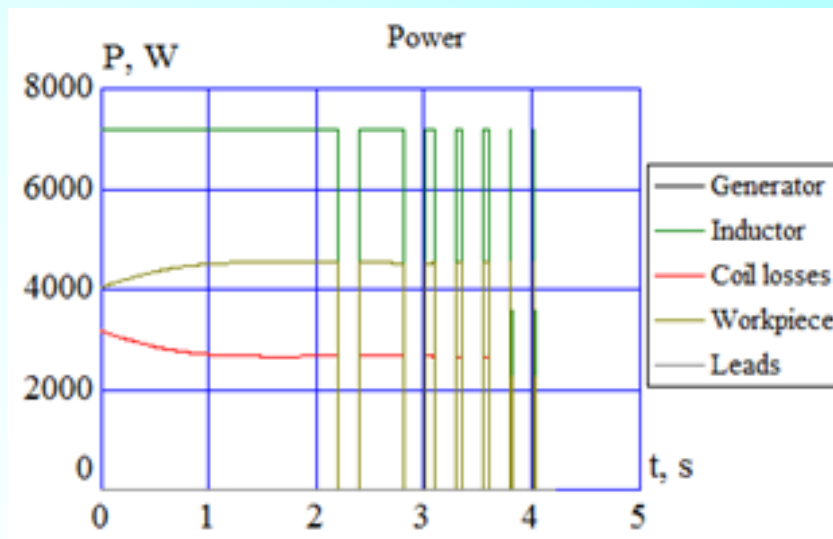


# SMART HF POWER SUPPLY OF FREAL LTD: POWER PART



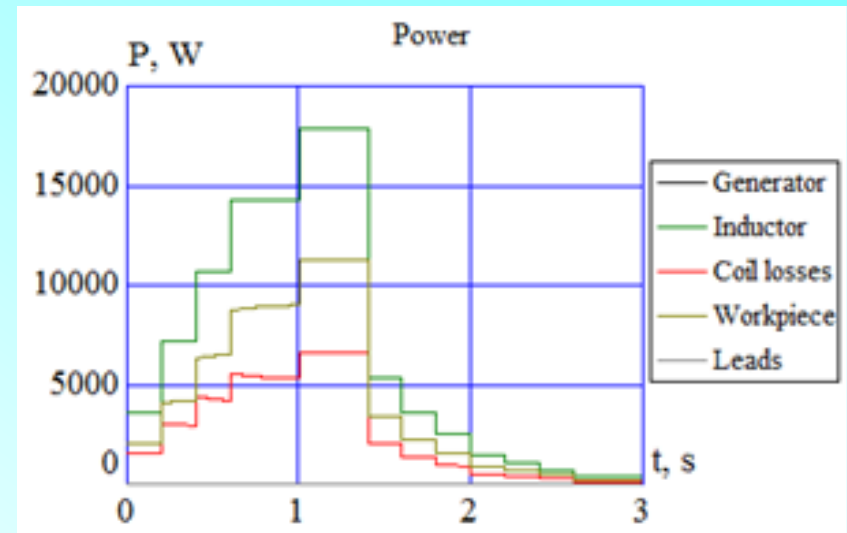
# POSSIBLE WAYS OF TEMPERATURE CONTROL IN INDUCTION HEATING SYSTEMS

Time-temperature control  
mode



PWM – pulse width  
modulation

Power temperature  
control mode



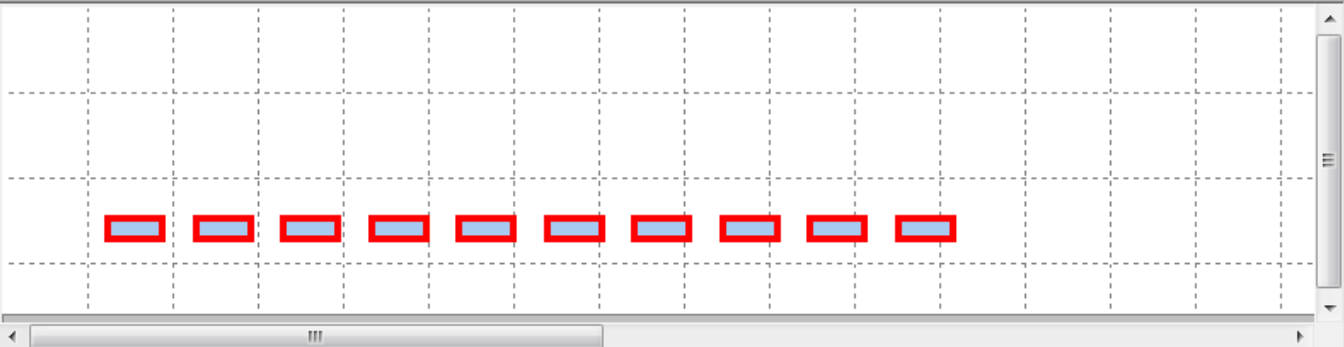
Proportional power  
control mode

# ELTA Wire Application: “Part”

Heating of Wire

Inductor 1

Part Inductor Processing



Cylindrical Heater System Configuration

T 20 °C

Material 0.4 % C Steel 2T anneal

External Radius (Re) 0.4 cm

Internal Radius (Ri) 0 cm

Close Calculate

Initial Temperature **T**; External Radius **Re**; Internal Radius **Ri**

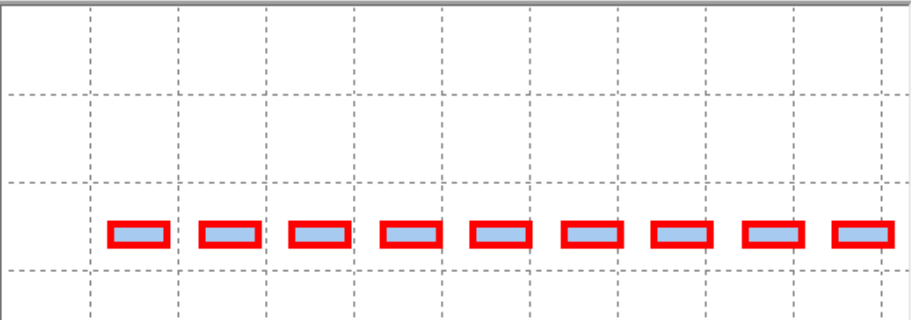


# ELTA Wire Application: “Inductor”

Heating of Wire

Inductor 1

Part Inductor Processing



Turns Number 7

Resistivity 2E-6  $\Omega$ -cm

Emissivity 0.8

Coupling Gap (G) 0.5 cm

Inductor Length 0 cm

Concentrator ☐ Yes ☒ No

✓ Add ✗ Delete

⚙ Circuit

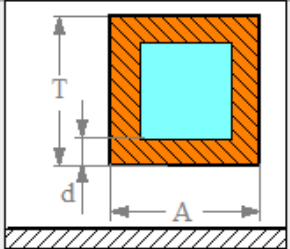
Cooling Zone (Q1) 0 cm Inductor offset 0 cm

**Inductor Cooling Parameters**

Input water temperature 20 °C

Output water temperature 46 °C

Pressure drop limit 0.3 MPa



Tube Profile

✗ Close ✓ Calculate

User interface allows to set parameters of the induction heating machine very quickly



# ELTA Wire Application: “Processing”

Heating of Wire

Inductor 1

Part Inductor Processing

Temperature Sensors

z 0 cm

Value 0 °C

dT 0 °C

☐ Activate Process Control

Processing Parameters

☒ Current Supply ☐ Inductor Power

☐ Voltage Supply ☐ Generator Power

☐ Power Supply ☐ Surface Power

Freq: 66000 Hz

Current: 100 A

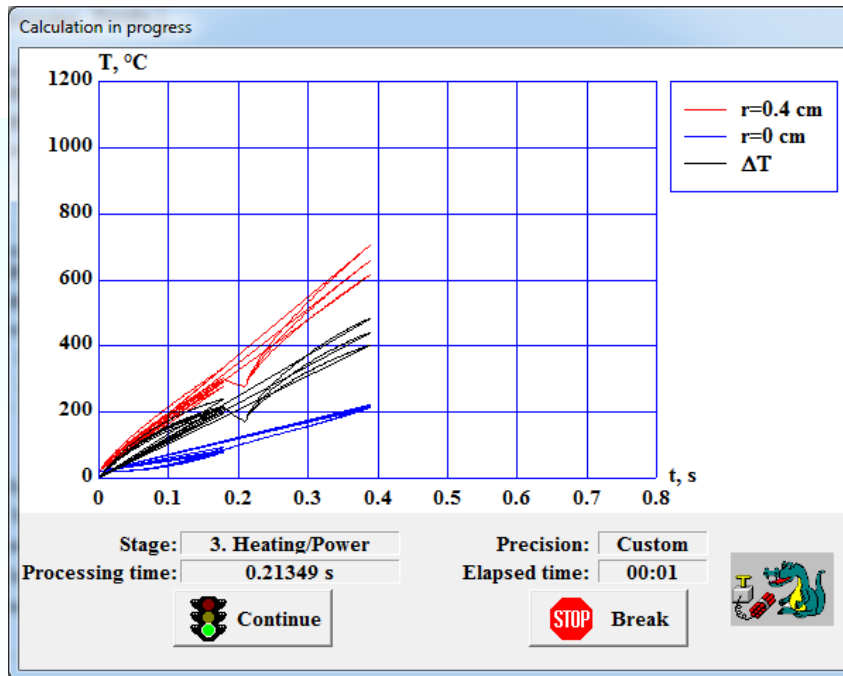
Quenching Media (Q2): Scanning Speed (V): 66.7 cm/s

Close Calculate

Temperature sensor coordinate **Z**; setpoint temperature **Value**;  
allowed temperature deviation **dT**

# Key features of smart HF power supply system

- Automatic calculation of the reference value of the output power



### Temperature Sensors

z  cm

Value  °C

dT  °C

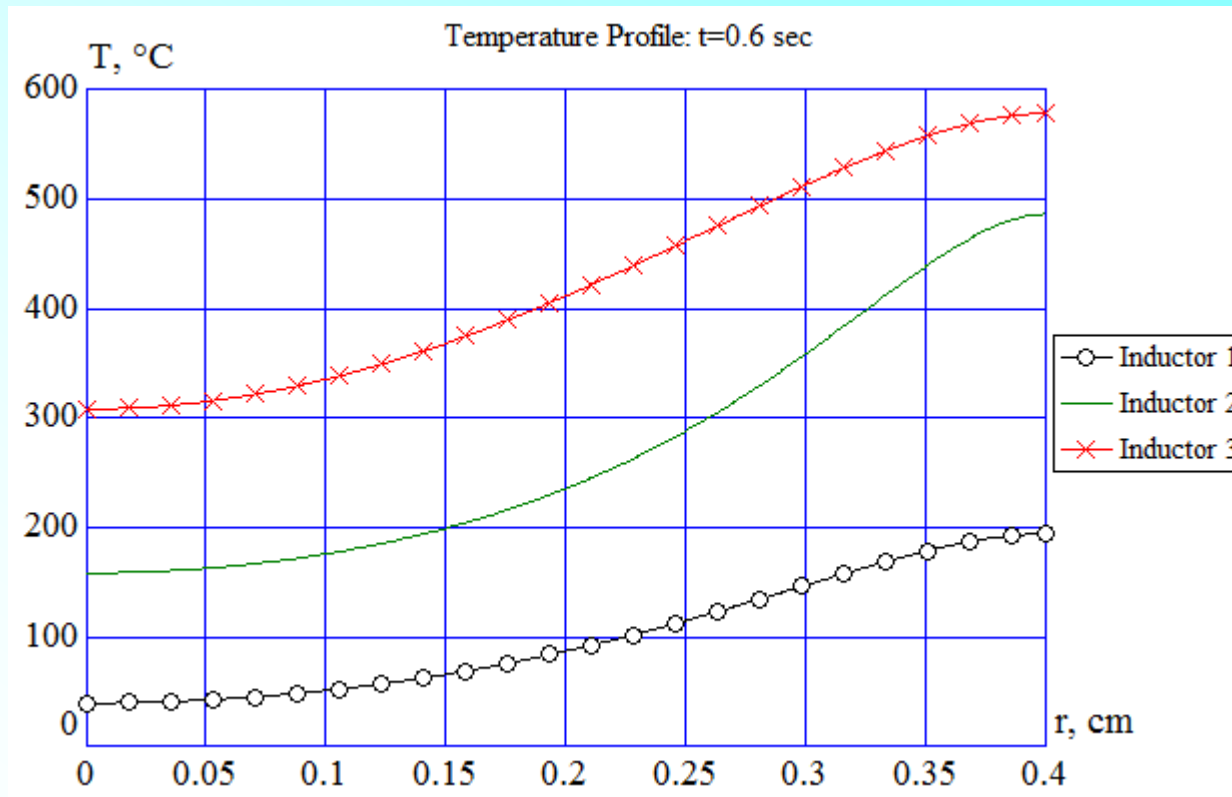
☒ **Activate Process Control**

### Process Control Parameters

Set Value	<input type="text" value="600"/>	°C
Current Value	<input type="text" value="598.403"/>	°C
Tolerance	<input type="text" value="Not calculated"/>	°C
Current Generator Power	<input type="text" value="15000"/>	W

## Key features of smart HF power supply system

- Real-time calculation and visualization of real temperature profile.



## **Example: calculation of reference power for HF power supplies for continuous heating of titanium wires**

### **Wire parameters:**

- Diameter range: 1.5 mm .. 8 mm;
- Material: titanium.

### **Processing parameters:**

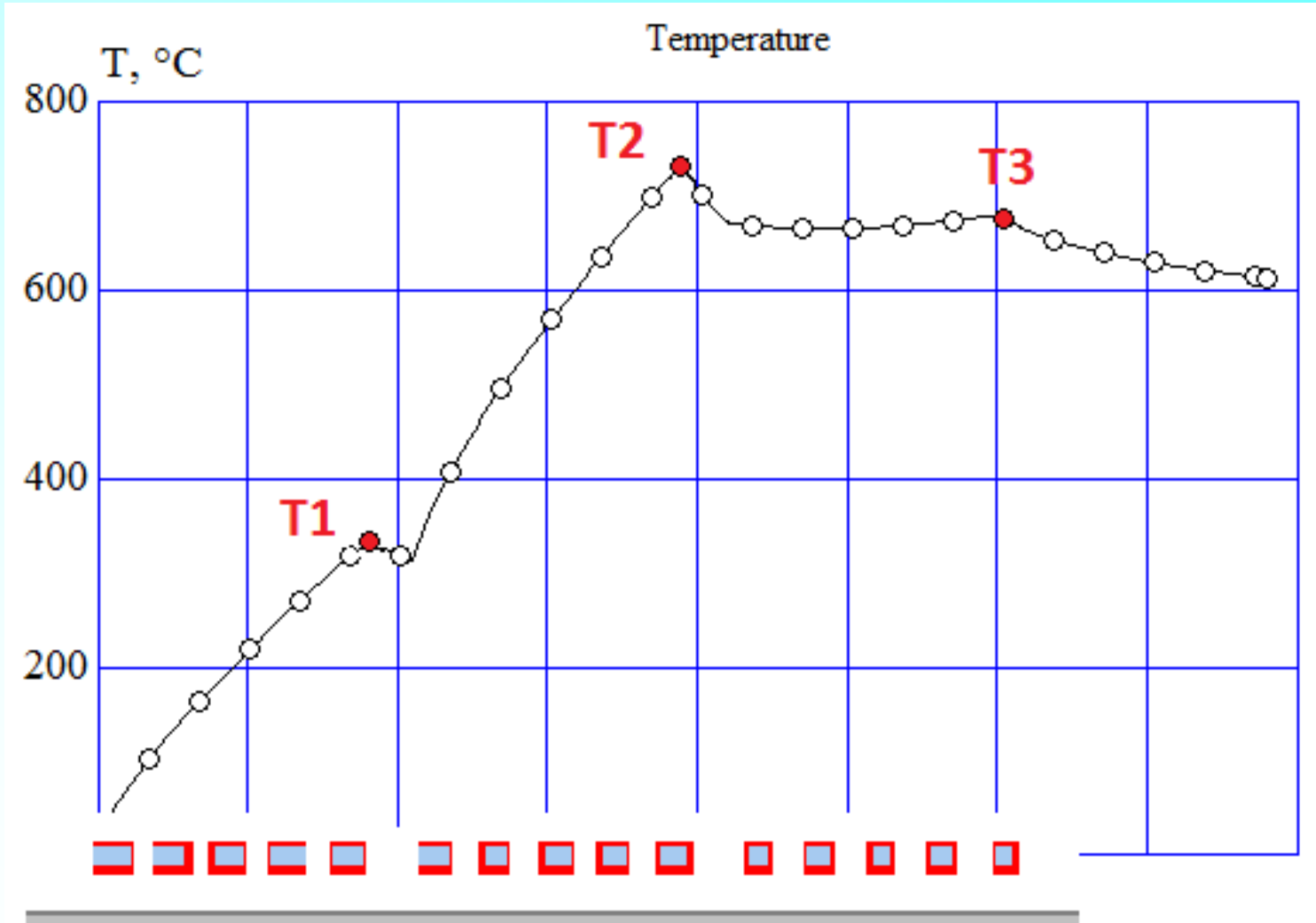
- Type: continuous;
- Speed: 40 m/min;
- Target temperature: 600 °C
- HF power supply 1: frequency is 66 kHz; max output power is 60 kW;
- HF power supply 2: frequency is 440 kHz; max output power is 60 kW;
- HF power supply 3: frequency is 440

kHz; max output power is 15 kW

### **Inductor parameters:**

- number of turns – 6,
- length is not more than 12 cm,
- internal radius 0.7 cm,
- profile and dimension of copper tube – rectangular, width 1.6 cm, height 0.8 cm, and thickness 0.2 cm.

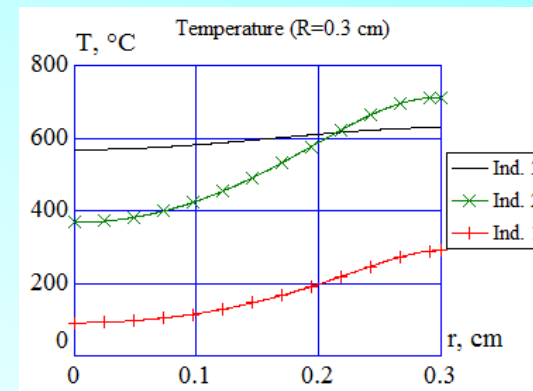
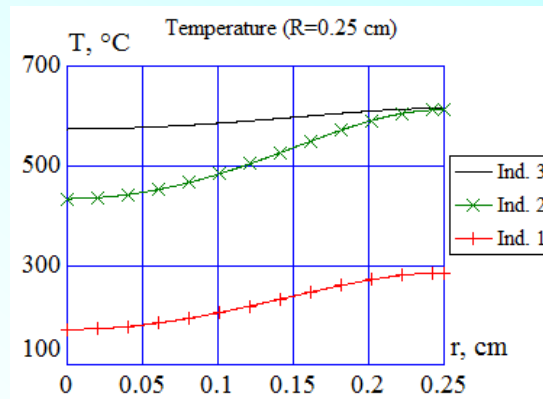
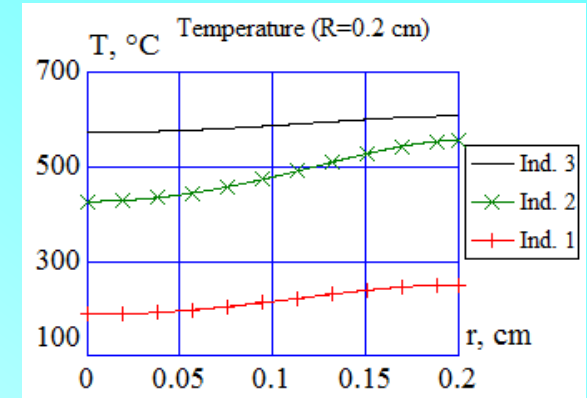
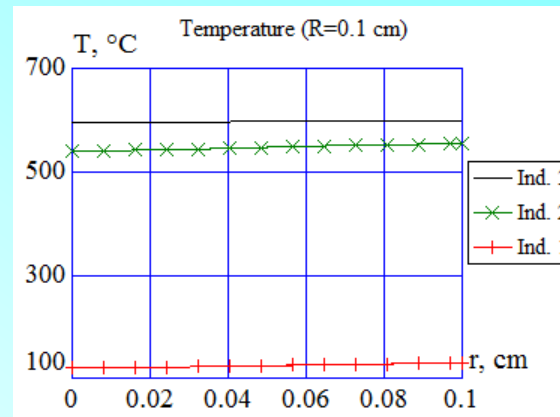
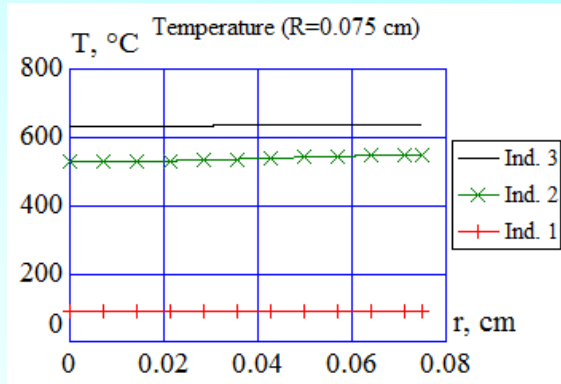
# Expected dynamics of surface temperature during heating of wire



# Results of automatic setting of smart HF power supply system

R [cm]	P <sub>1</sub> [kW]	P <sub>2</sub> [kW]	P <sub>3</sub> [kW]	T <sub>1</sub> [°C]	T <sub>2</sub> [°C]	T <sub>3</sub> [°C]
0.4	52.65	49.95	15	300	630	600
0.35	49.95	46.17	12.15	300	630	600
0.3	48.6	42.6	8.86	300	630	600
0.25	48.6	38.38	6.46	300	630	600
0.225	52.65	35.429	7.174	300	630	600
0.2	60	31.87	7.971	300	630	600
0.175	54	32.77	7.174	250	630	600
0.15	54	33.65	6.23	200	630	600
0.125	60	35.43	6.06	180	630	600
0.1	60	36.75	5.5	130	560	600
0.09	48.6	51.975	7.174	100	630	600
0.08	60	55.5	13.5	100	600	600
0.075	60	57	15	90	570	600

# Temperature profile at the end of the heating





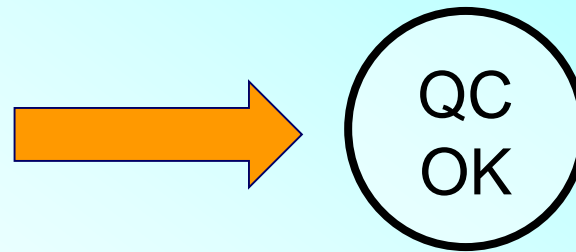
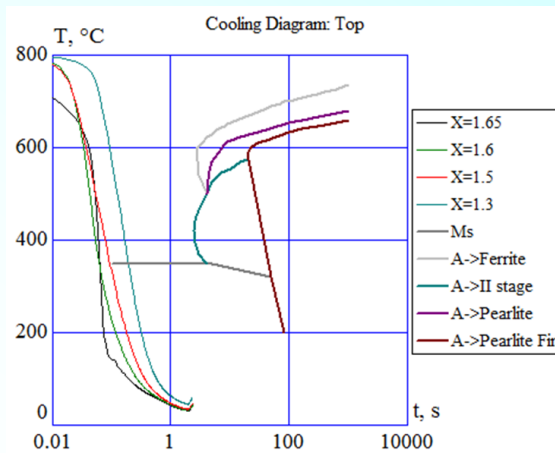
# Future development

Smart system can be used for a surface hardening of the large gear wheels



## Goals:

- Real-time calculation and visualization of real temperature profile.
- Rapid assessment of hardness values using TTT or CCT diagrams (QA tasks)



## CONCLUSIONS

Designed system includes process control functions of the FREAL HF power supplies and real-time calculation functions based on ELTA program.

Smart HF Power Supply system allows to calculate a required output power for the selected temperature profile.

Real-time simulation functions allow to control real temperature profile during the heating process.

Presented approach of integration ELTA with the Smart HF Power Supply system may be applied for other induction heating technological processes with continuous heating.

**Thank you for your kind attention!**