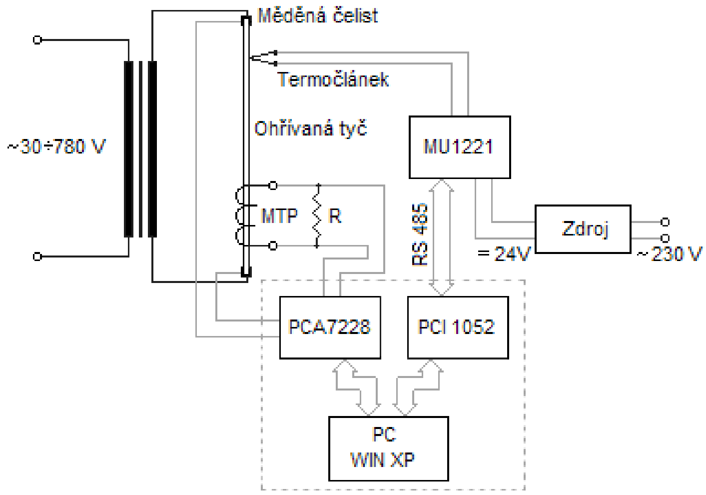
# Direct resistance heating

## Task:

1. Measure and graphically illustrate the warming curve of the rod at resistive heating $J = f(t)$.
2. Identify and graphically show the course of the heat losses $P_{los} = f(t)$.
3. Identify and graphically show the course of the dependency of heat transfer coefficient by convection $a = f(J)$ on the temperature without dependency of heat conduction.
4. Identify and graphically show dependence of the resistance rod on the temperature $R = f(J)$.
5. Determine the specific consumption of electrical energy for this heating method.

## Circuit diagram:




Měděná část – Copper part, Termočlánek – Thermocouple, Ohřívaná tyč – Heated rod, Zdroj – Power source

## Used devices:

- Device for direct heating
- Heated rod
- The thermocouple
- Measuring software
- Connection conductors
- PC + measurement cards

## Theoretical analysis:

In the equipment for direct resistance heating, heat emerges by direct passage of current through electrically conductive solid charge (burden) or electrically conductive fluid - the electrolyte surrounding the charge. The physical principle of these devices is simple (Joule’s law), but due to the nonlinear dependence of the charge properties on the temperature, the calculations and projecting of these devices is difficult.

The heat generated by passing current is divided into useful heat needed to heat of the charge and on heat losses. For uniform heating of the rod along its entire length, the length has to be at least the ten times of its diameter.

With increasing temperature of the rod the resistance increases, which makes the power consumption of the entire device decreasing and the heat loss growing. If the input power of the entire device equals the heat loss, the temperature has reached its limit value - temperature of the heating must be lower than the limit temperature.

At direct resistance heating of ferromagnetic steel rods by alternating current a very superficial phenomenon is applied - the most heat is generated approximately in the so-called penetration depth. Into loss of ferromagnetism (the Curie point for carbon steel at 768 °C) more heated is the surface of the rod(skin effect), above this point the interior of the rod is more heated (heat loss due to flow).
Neglecting the uneven rod heating and the heat dissipation from the rod into the jaws of the leading, you can write:

$$P \cdot \Delta t = m \cdot c \cdot \Delta J + a \cdot \left(J_{\mathrm{p}} - J_{\mathrm{o}}\right) \cdot S \cdot \Delta t$$

$$Q_{\mathrm{a}} = m \cdot c \cdot \Delta J$$

$$P_{\mathrm{z}} = a \cdot \left(J_{\mathrm{p}} - J_{\mathrm{o}}\right) \cdot S$$

where
$P$....... input power of heating device
$m$ ...... weight of heated rod
$c$ ....... specific heat capacity of the material rod
$\Delta t$...... evaluated time period
$\Delta J$ .... change in temperature of the rod in the evaluated time period
$a$....... coefficient of convection
$S$....... rod surface
$J_{\mathrm{p}}$ ..... temperature of the rod surface
$J_{\mathrm{o}}$ ..... the ambient temperature 20 °C

From the above mentioned formula the heat losses can be determined and the coefficient of convection can be calculated.

## Measurement procedure:

1. We make the connection according to the connection scheme.
2. We run the measuring program.
3. We enter the parameters of heated rod.
4. We set the current.
5. We run the measurement.
6. The measurement will end when the energy supplied into the charge /electrolyte is equal to the heat loss (temperature does not increase).
7. We subtract / deduct the heat accumulated in the rod during the evaluation interval from the input power - we get the value of the heat loss.
8. We calculate the coefficient $\alpha$ of heat convection.
9. At the end we calculate the specific energy consumption during the heating.

## Parameters of the heated iron rod:

| | |
|---|---|
| length $l$ | 50 cm |
| diameter $f$ | 8 mm |
| specific weight $\gamma_{Fe}$ | 7800 $kg \cdot m^{-3}$ |
| specific heat capacity $c_{Fe}$ | 450 $J \cdot kg^{-1} \cdot K^{-1}$ |