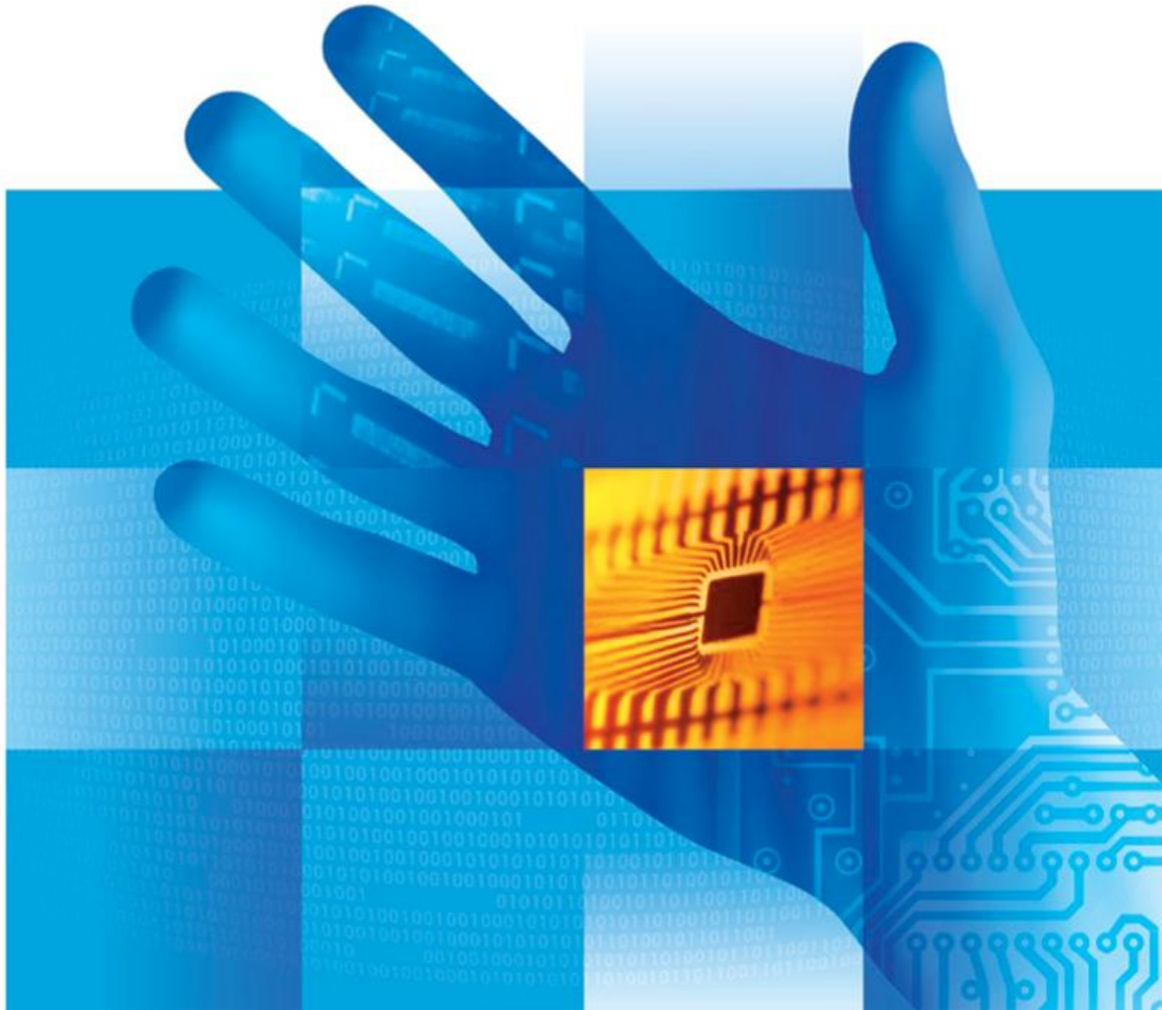
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

15. CONVERSION OF ELECTRICAL ENERGY TO HEAT ENERGY



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LECTURE PLAN

- introduction, sources of heat, advantages of electric heating
- basic principle and characteristics of resistance and arc furnace, applications
- induction and dielectric heating
- examples of electric heating in household

Introduction, sources of heat, advantages of electric heating

Introduction

- electrical energy is converted to heat energy
- metals (e.g., copper, platinum, gold, etc.) are usually good conductors of thermal energy
- Joule heating: electric current passing through a resistor converts electrical energy into heat energy

$$Q = R \cdot I^2 \cdot t$$

- Widely used in domestic sector and in industry

Introduction, sources of heat, advantages of electric heating

Sources of electric heat

- **Electrical resistance:**
  - Metal heating elements
  - Metal heating cables or conductors
- **Electrical arc:**
  - Electric arc furnaces
  - Welding
- **Electromagnetic induction:**
  - AC magnetic field
  - Dielectric losses
- **Electromagnetic radiation:**
  - Infrared, microwave and radio waves

Introduction, sources of heat, advantages of electric heating

Advantages of electric heating

- Rather high efficiency
- Low investment costs (compared to gas, oil)
- Low maintenance costs
- Small dimension (small requirements for a space)
- Ecology (no dust, waste...)
- Good adjustability
- Operation safety (absence of gas, fire)
- Quiet operation

Disadvantages of electric heating:

- well insulated against heat loss
- higher operating costs

Resistance furnaces

Basic principle

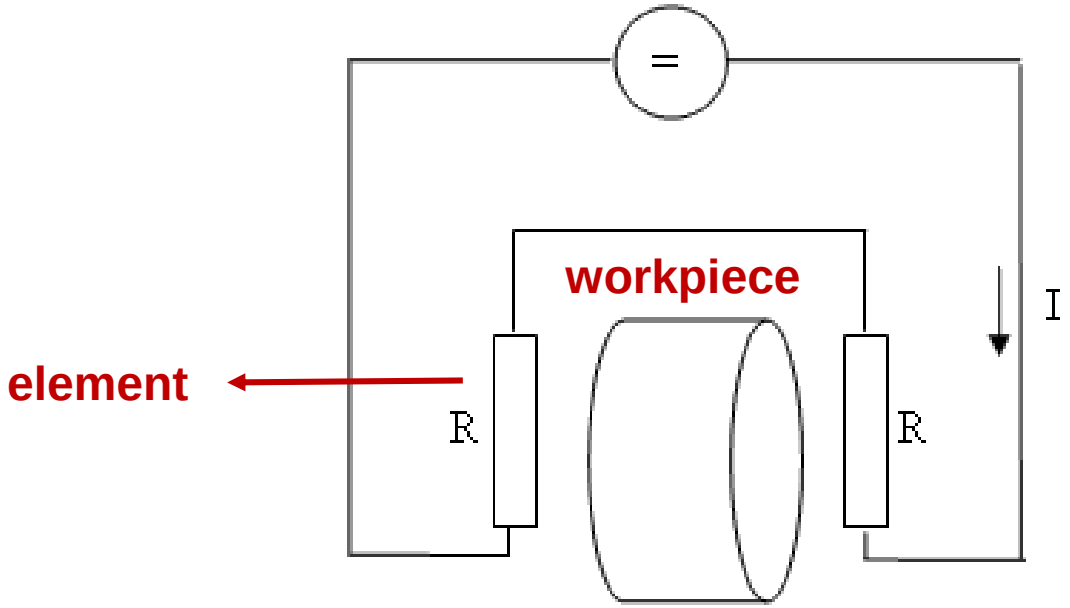
- **uses the heat generated by Joule effect in a conductive element in which an electrical current flows**

$$Q = R \cdot I^2 \cdot t$$

- **indirect resistance heating**
  - **the heat is developed in elements (resistors) located on the walls of the furnace chamber**
- **direct resistance heater**
  - **the current flows directly in the workpiece**

Resistance furnaces

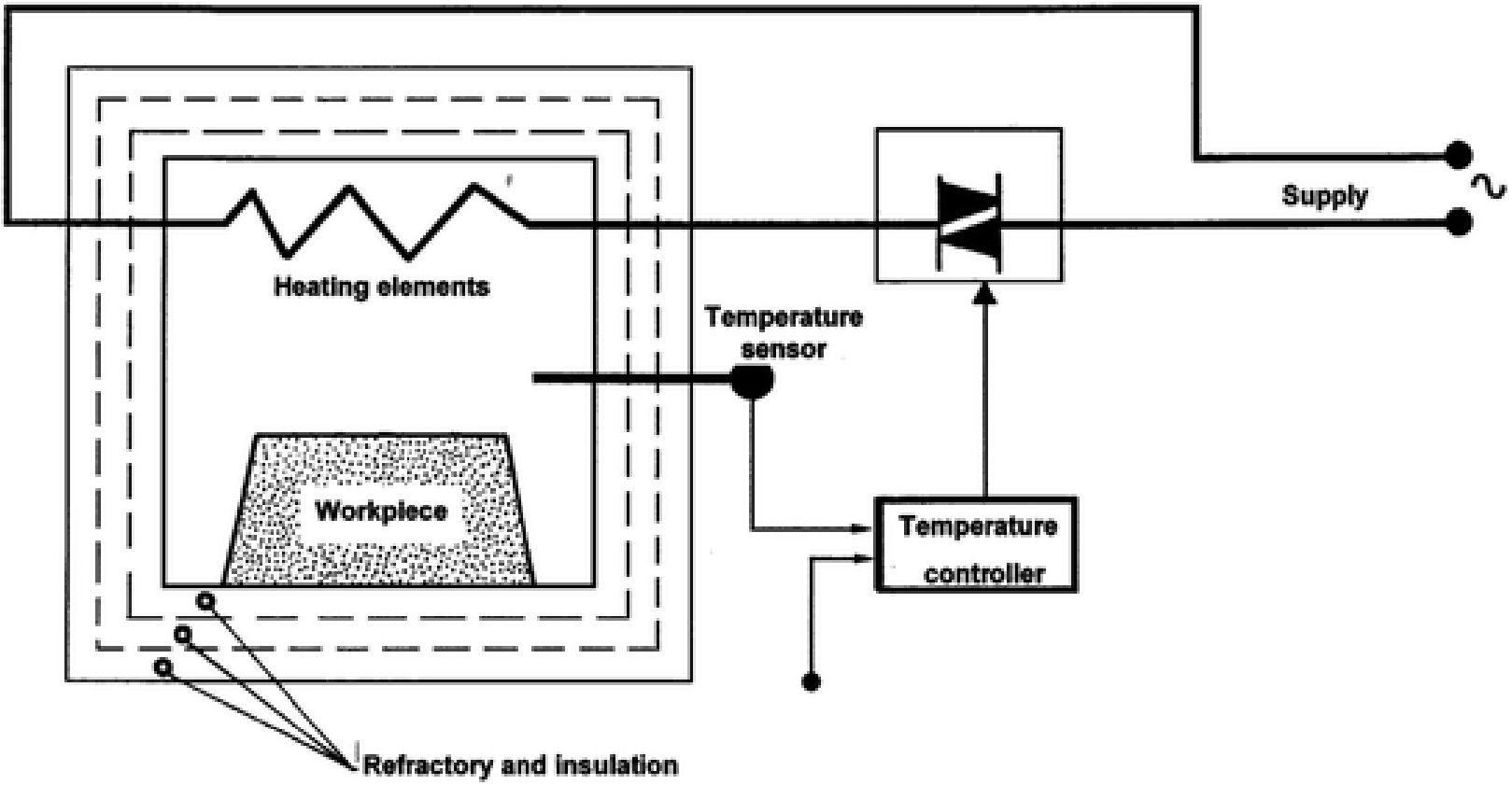
Indirect resistance heating



- operating conditions
  - non-metallic and metallic workpiece
- requirements for elements (=resistors)
  - high resistivity, low temperature resistance coefficient, size constant, high melting point, oxidation immunity, high mechanical strength, good workability

Resistance furnaces

Principle of operation of indirect resistance heating



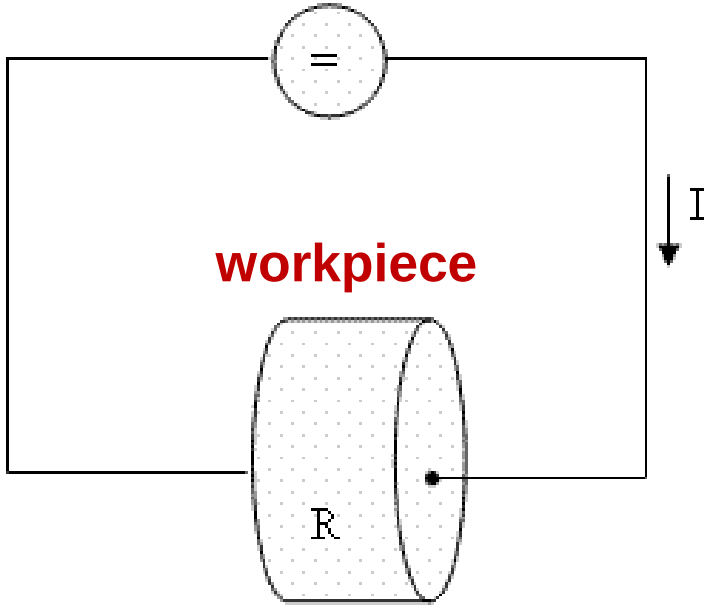
Resistance furnaces

Usage of indirect resistance heating

- **furnaces for melting or for heating liquids and solid charges**
- **metal workpiece heat treatment**
- **drying electric machines windings**
- **drying whole electric machines**
- **enameling**
- **sterilization (in health service)**

Resistance furnaces

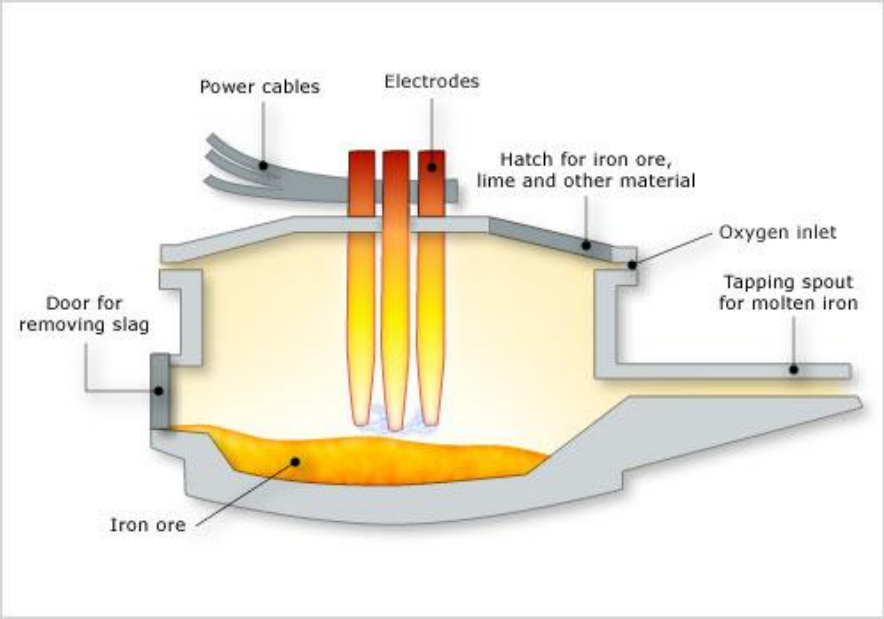
Direct resistance heating



- **operating conditions**
  - **metallic heating workpiece**
  - **large resistivity of the workpiece**
  - **supply conductors of small resistance**
  - **the voltage source of large capacity**

Electric arc furnaces

- direct current (DC) arc furnaces
  - with a single electrode
- alternating current (AC) arc furnaces
  - with three electrodes (direct arc furnace)
  - with two electrodes (indirect arc furnace)



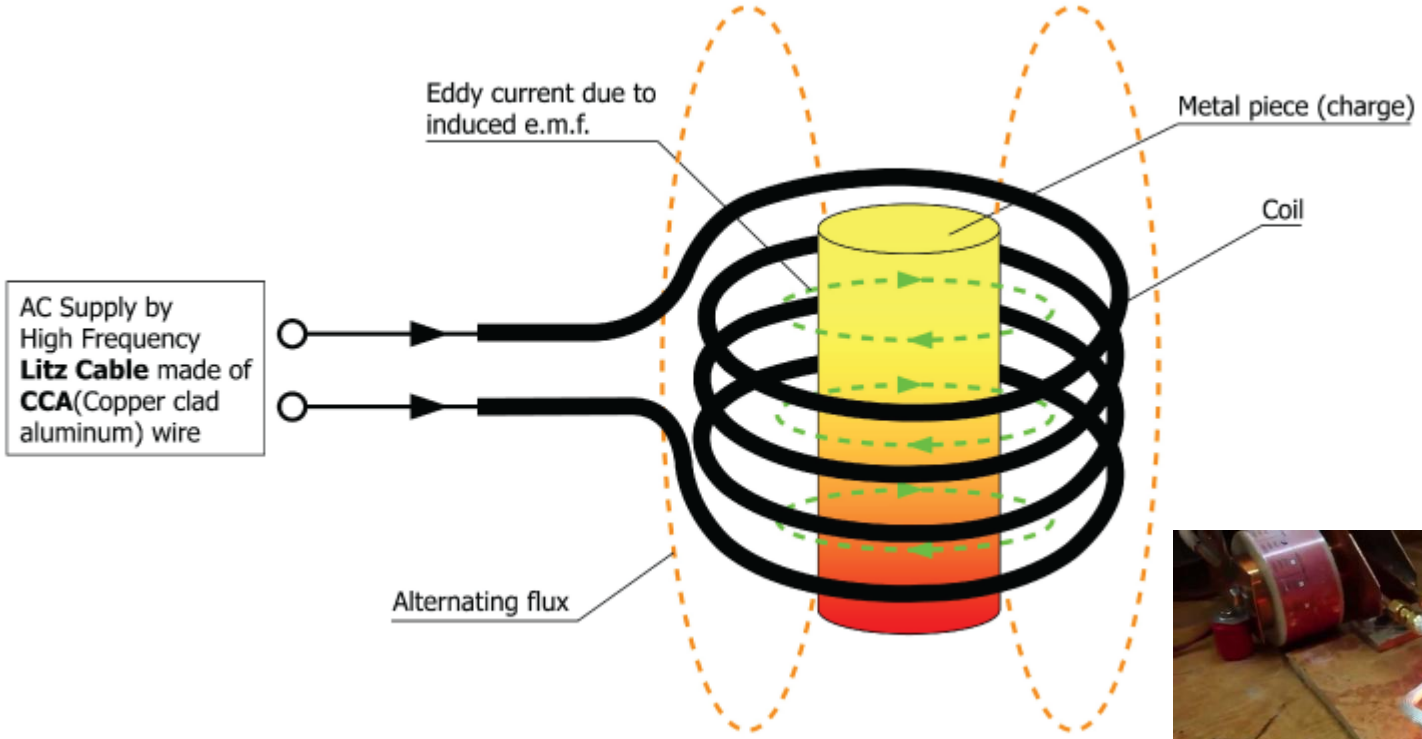


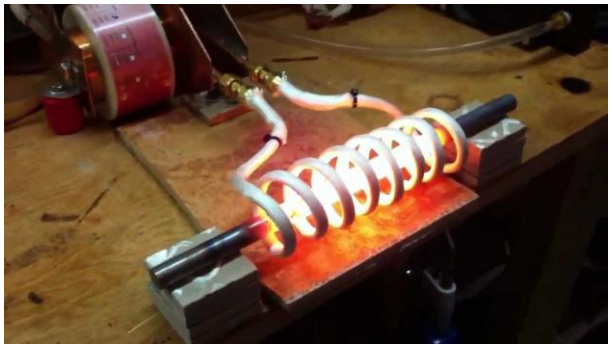
Electric arc furnaces

- usage
  - production and refining of various grade of steel, melting of non-ferrous metals
- electrodes
  - carbon or graphite
- requirements for electrodes
  - good electric conductivity
  - high mechanical strength
  - high oxidation temperature
  - low content of ash and sulfur
- Next usage of electric arc
  - arc welding
  - arc-lamp

Induction heating

- heating an electrically conducting object (usually a metal) by electromagnetic induction, through heat generated in the object by eddy currents



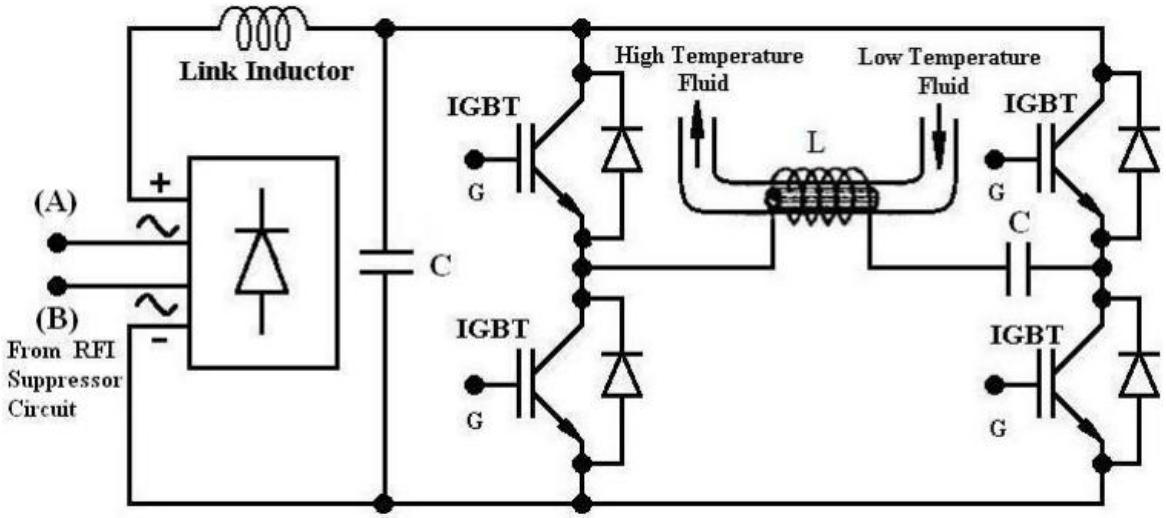


Induction heating

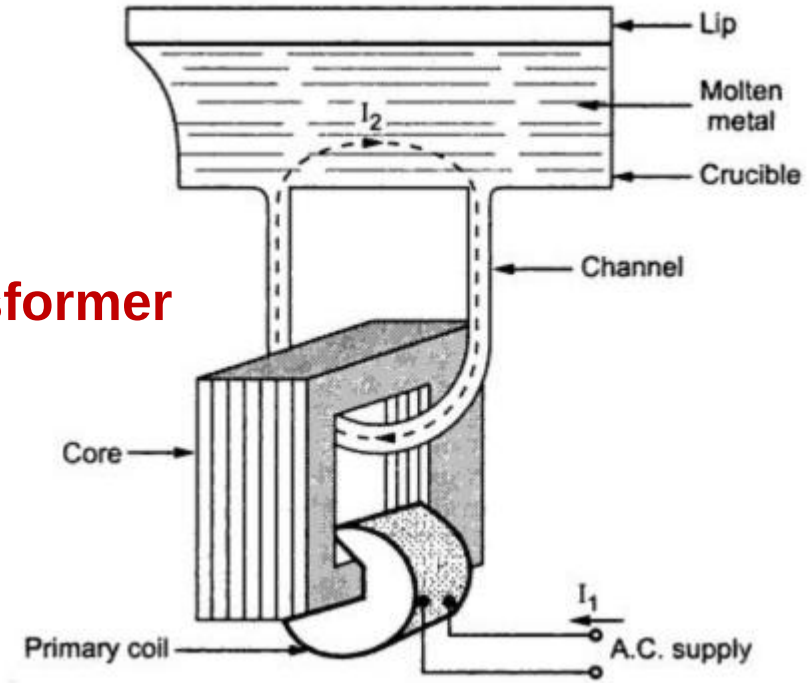
- usage
  - heat treatment in metallurgy, melting iron and other metals, heating of silicon and other semiconductors, induction cooking
- characteristics
  - alternating current (AC) through the electromagnet or coil
  - variable frequency
  - the heat is generated inside the object itself
  - clean, energy-efficient and well-controllable melting process
  - the lack of refining capacity (clean materials)

Induction heating

inverter



induction heating transformer



Dielectric heating

- radio wave or microwave electromagnetic radiation heats a dielectric material





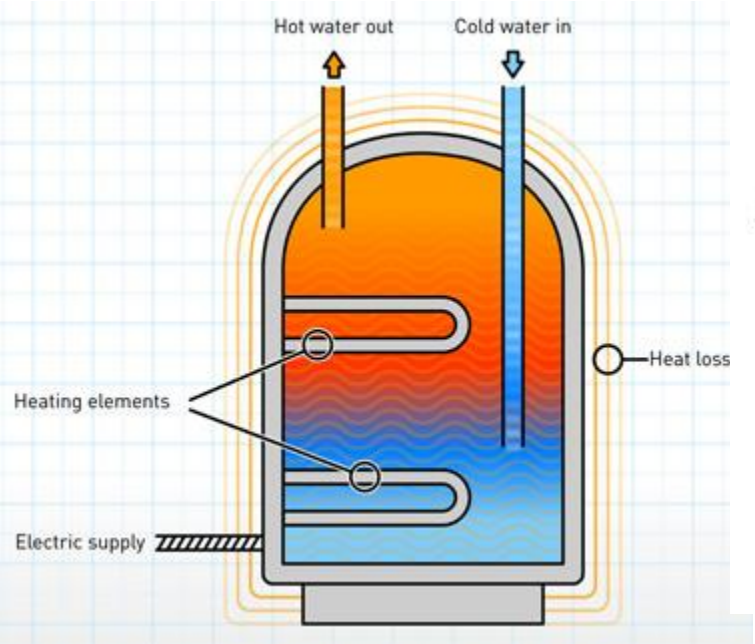
Dielectric heating

- usage
  - heating non-metallic materials, pieces…
  - drying
  - sterilization, pasteurization…
  - food preservation
  - preparing certain kinds of food
- characteristics
  - alternating electromagnetic field
  - the heat is generated inside the object itself
  - heating depends on electric field intensity, frequency, parameters of heated material
  - killing parasites and pests

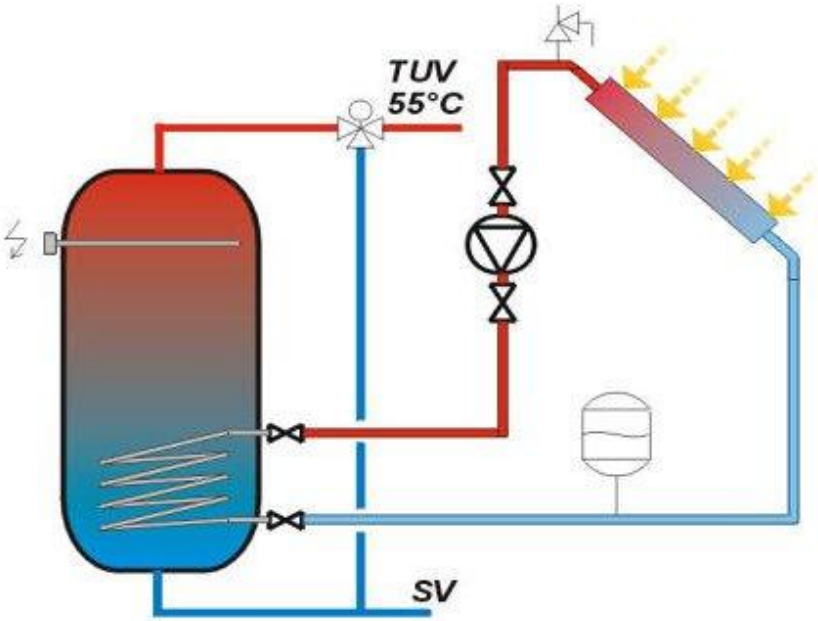
Examples of electric heating in household

- water heating
  - Storage water heaters
    - use electricity, natural gas, propane, heating oil, solar energy

electric



solar



Examples of electric heating in household

- water heating
  - tankless water heaters (instantaneous)
    - heaters instantly heat water as it flows through the device



Examples of electric heating in household

- space heating
  - Radiant heaters
    - uses heating elements that reach a high temperature
  - Fan heaters
    - electric fan to speed up the airflow
  - Storage heating
    - stores heat in clay bricks, then releases it during the day when required
  - Electric underfloor heating
    - heating cables embedded in the floor





Examples of electric heating in household

- resistance heating
  - iron, electric kitchen stove, hair dryer, washing machine, dishwasher, jug kettle
- dielectric heating
  - microwave oven
- infrared heating (radiation)
  - infra heater