Induction Heating as Efficient Heating Technology in Manufacturing

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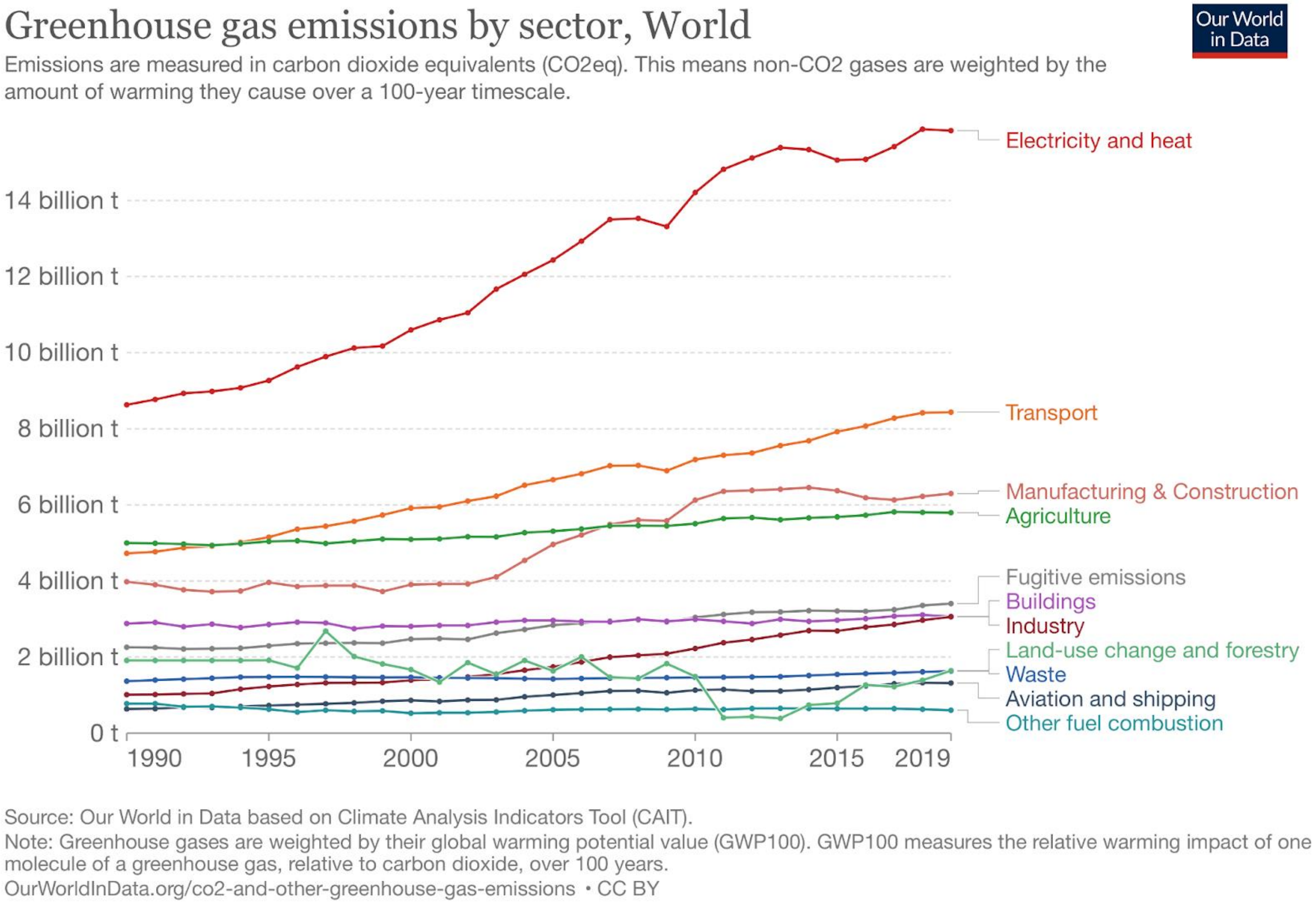
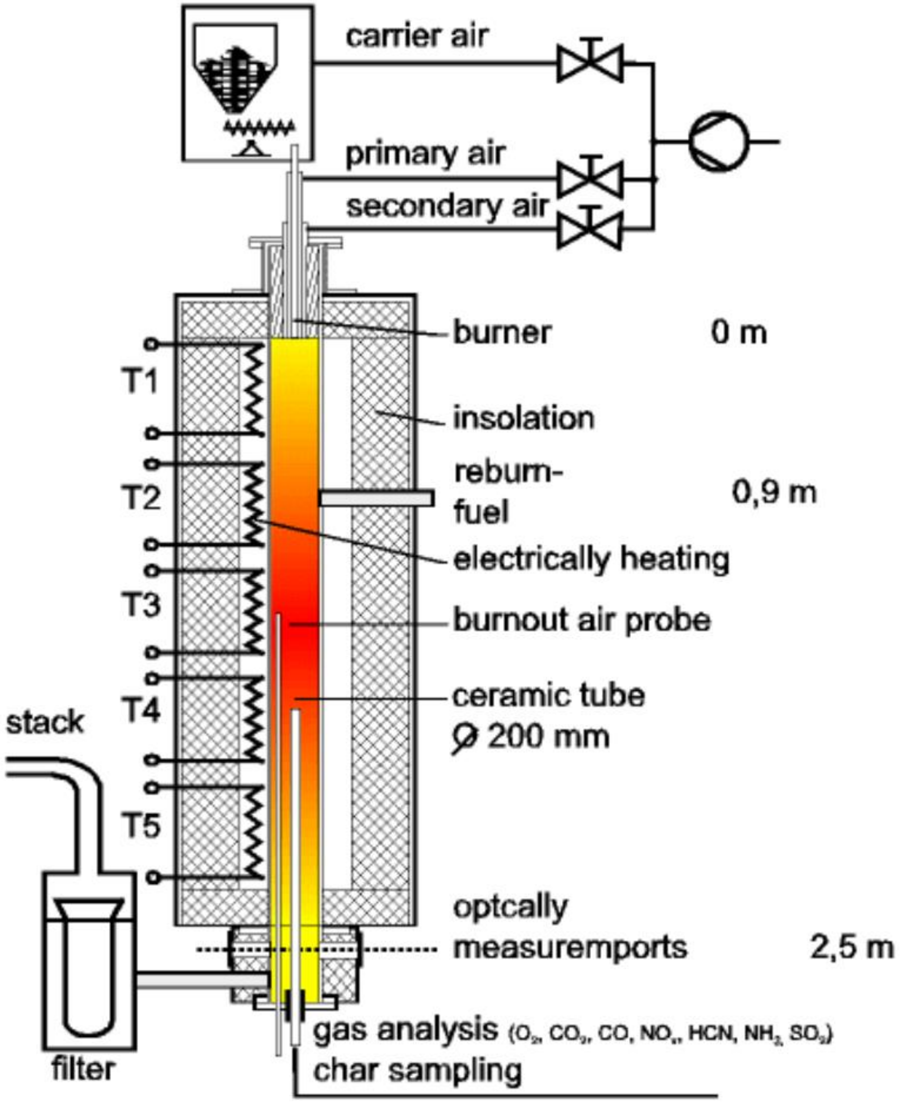
Current State



Heat Transfer Limitations

1. Slow heating/cooling rate
2. Nonuniform heating environments
3. Low energy efficiency
4. Heat losses
   - Due to the prolonged exposure of reagents and products to large temperature gradients in the reactor

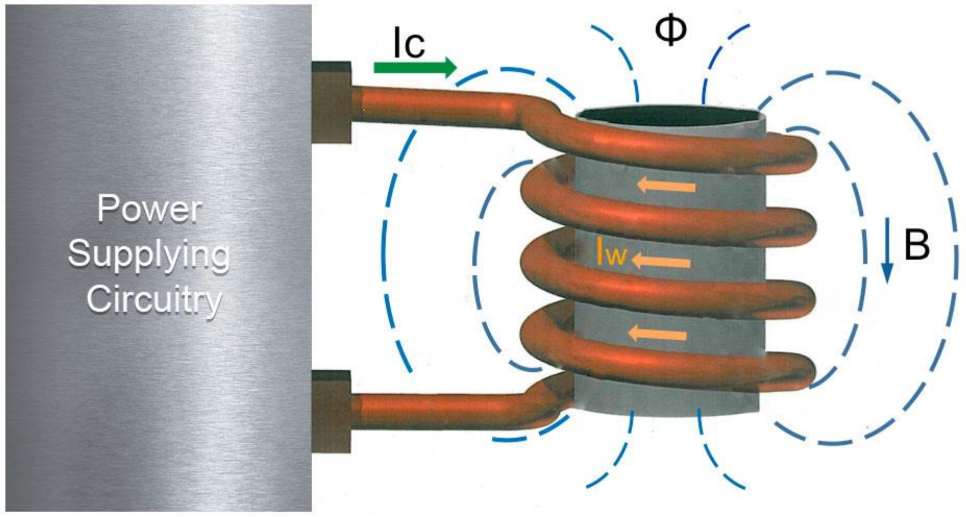


Heating Method

- Flame and resistance heating or furnaces
  - Heating scheme based on conduction/convection/radiation
  - Wall heated to conduct heat to the catalyst create large temperature gradients into the reactor → heat loss
- Induction heating
  - Reaches higher temperatures more quickly on the catalyst without heating catalyst support, liquid/gaseous carriers and reagents, or the entire reactor → save energy
  - Simple set up because it is noncontact
  - Highest power transmission because energy is transferred within the materials

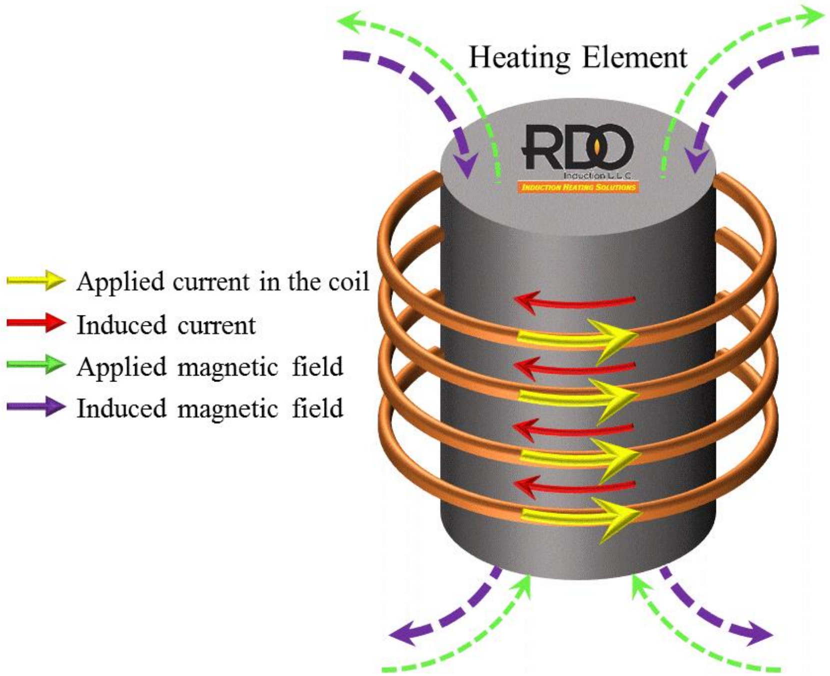
What is induction heating?

- Induction heating technology uses an AC source as a supplied power for the alternating voltage.
- The induction target is immersed in the induction coil and experiences the alternating magnetic field generated by the coil.



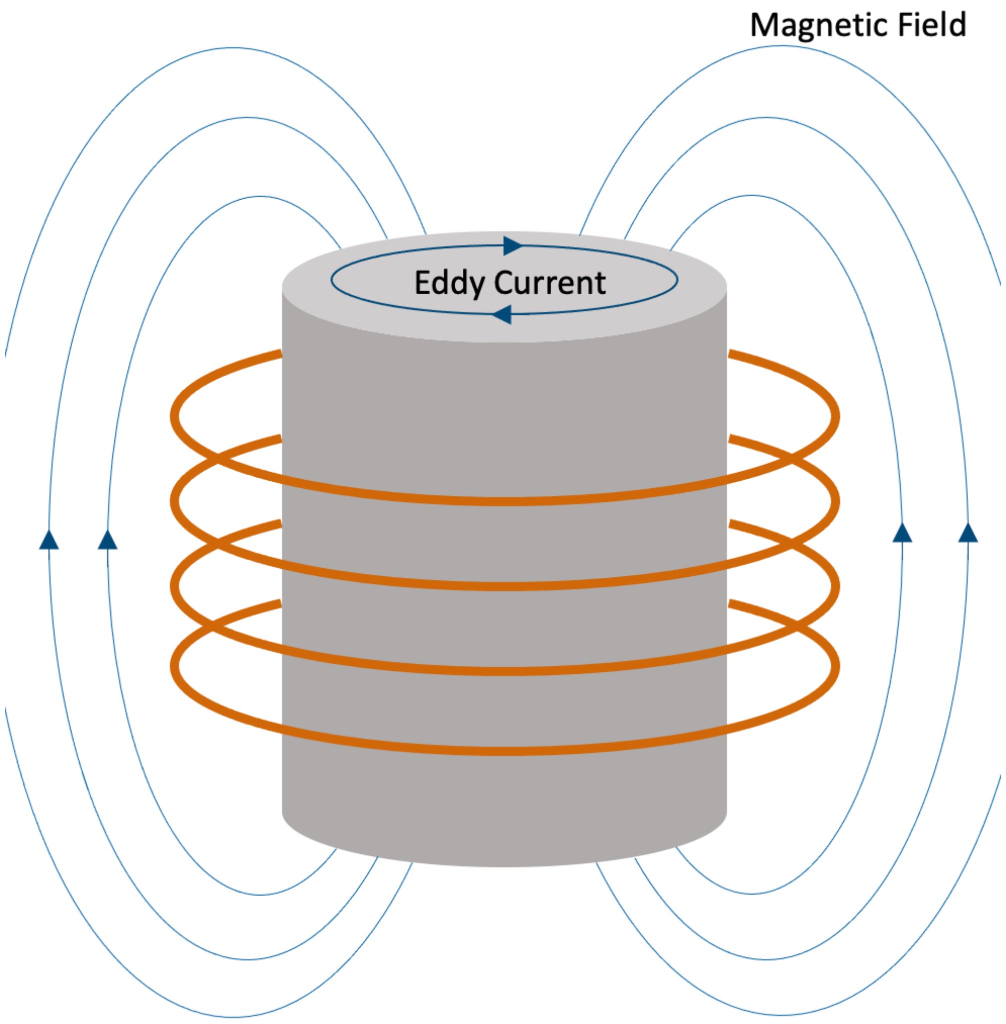
How does it work?

- Directly heats the susceptor by two physical phenomena:
  - Eddy currents
  - Magnetic hysteresis



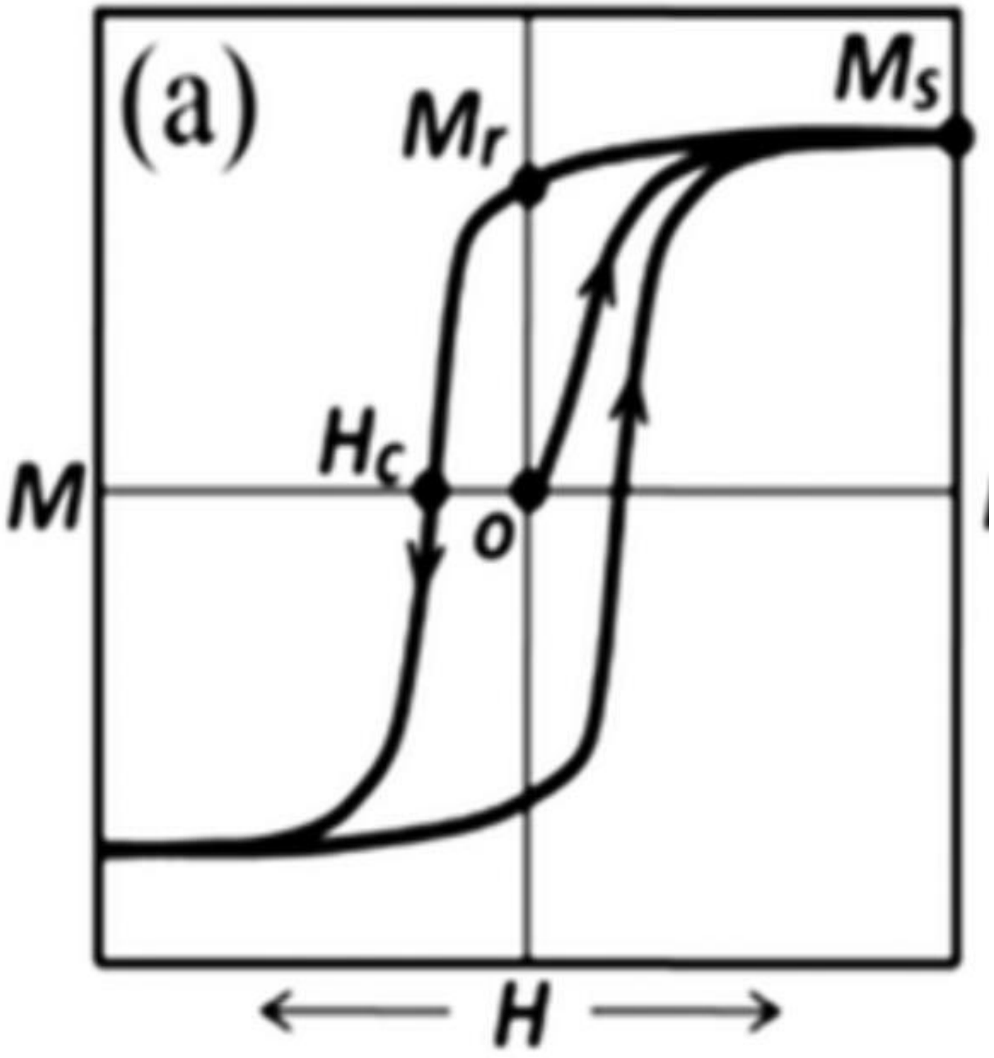
Eddy Currents

- Heat is produced by the Joule effect in which eddy current creates the resistance to the magnetic field applied to the induction target.
- Concentrate in the susceptor surface
- Large particles

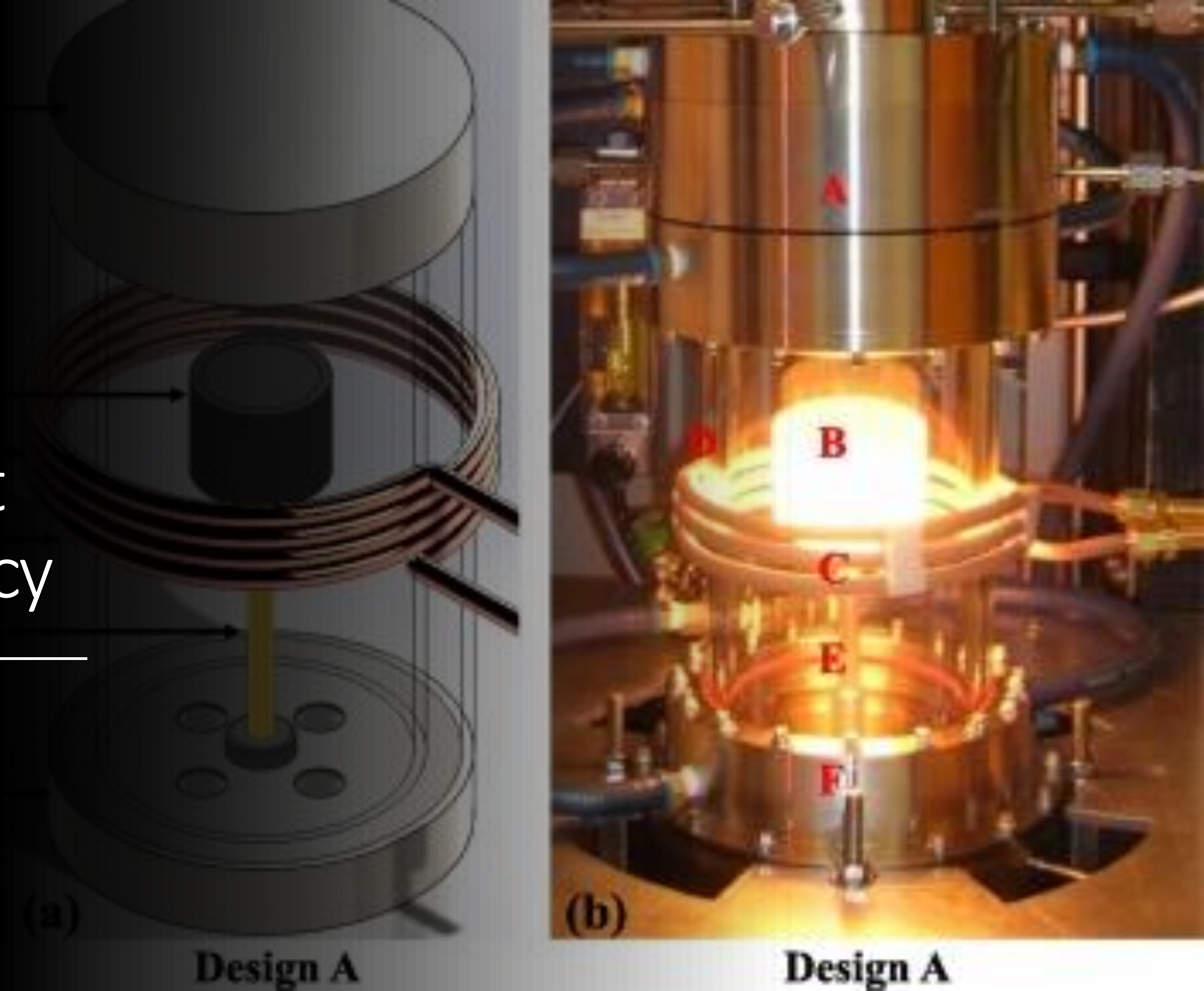


Hysteresis Loss

- As the direction of the magnetic field keeps changing and switching back and forth, the magnetic material absorbs energy during each line on the hysteresis loop and releases this energy as heat.
- Uniform
- Small particles

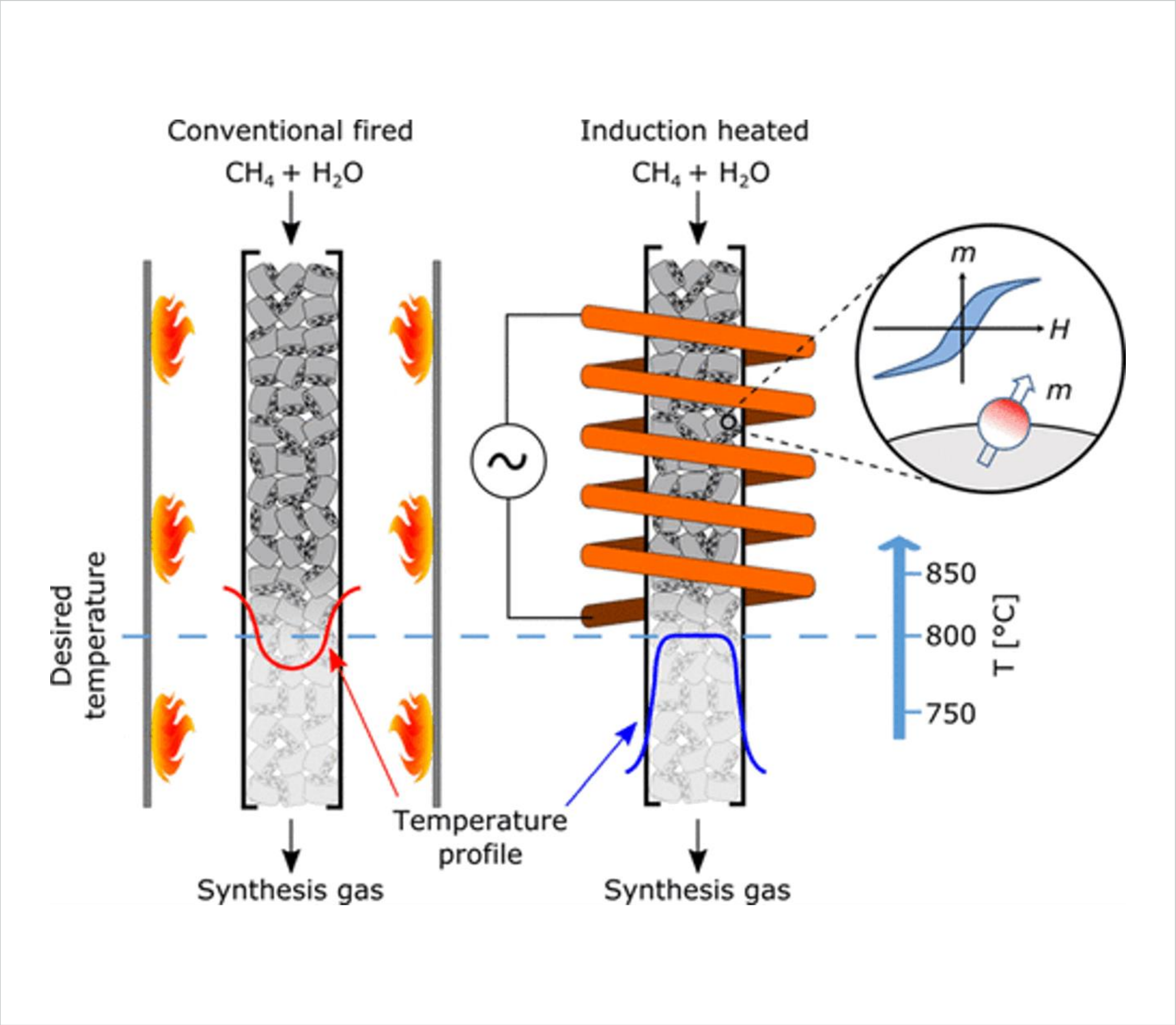


How induction heating overcomes heat transfer efficiency



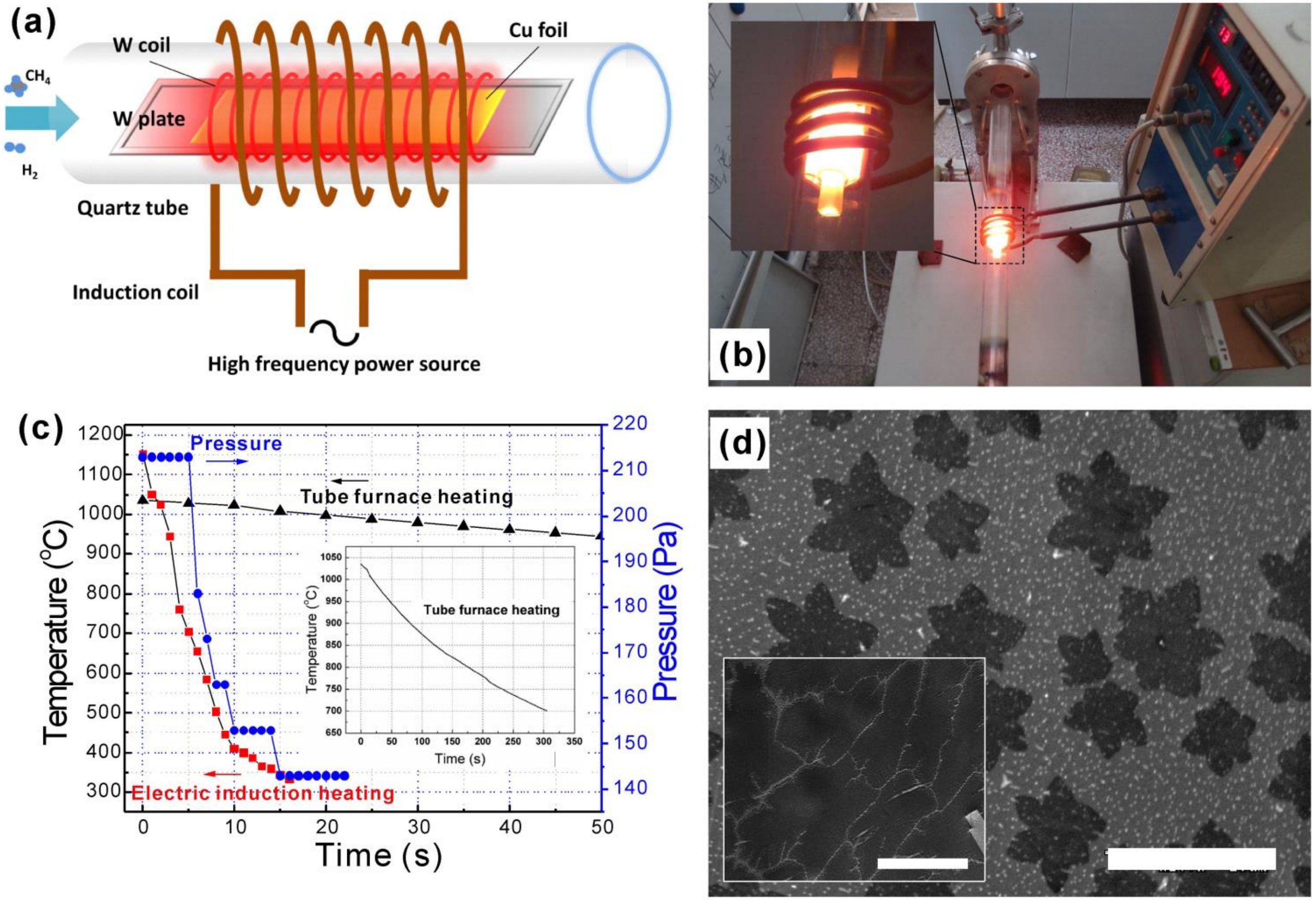
Faster heating/cooling rate

- “Cold wall” reactor
- Negligible thermal inertia
- No temperature gradients into the reactor



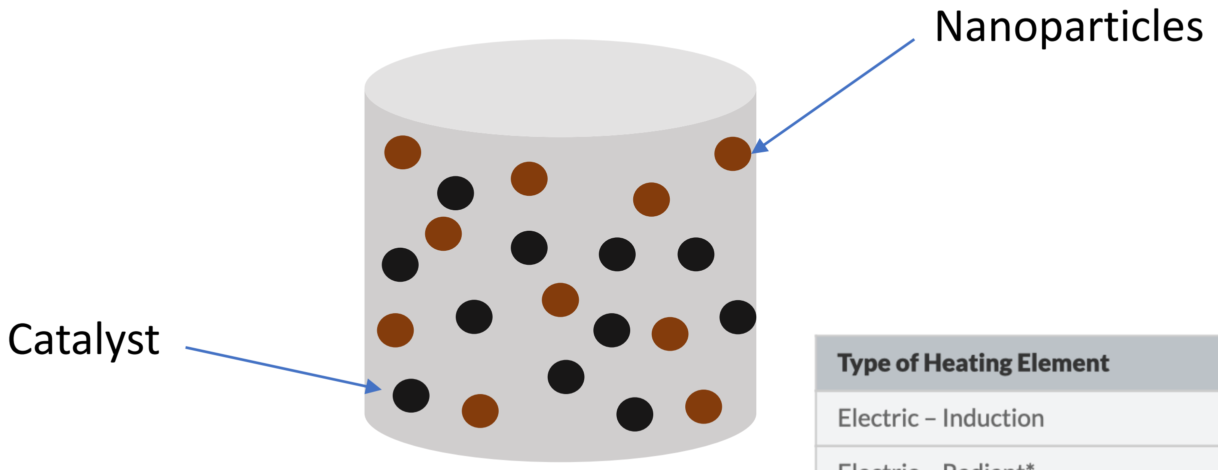
Reduce Heat Loss

- Do not waste heat on catalyst bed supports
  - Carrier gas
  - Reactor



Higher Efficiency

- Require less power to heat the catalyst bed
- Uniform temperature throughout the bed

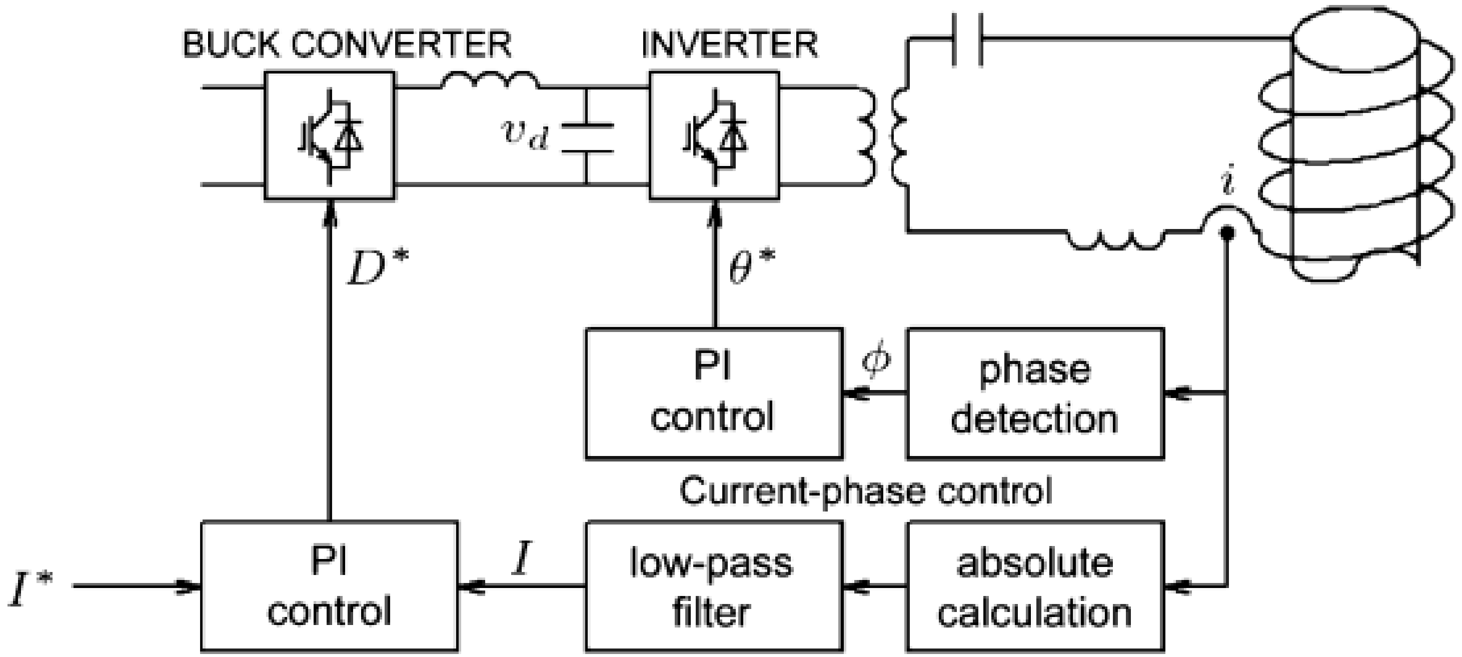


Type of Heating Element	Efficiency Factor
Electric – Induction	84.00%
Electric – Radiant*	71.00%
Gas	40.00%

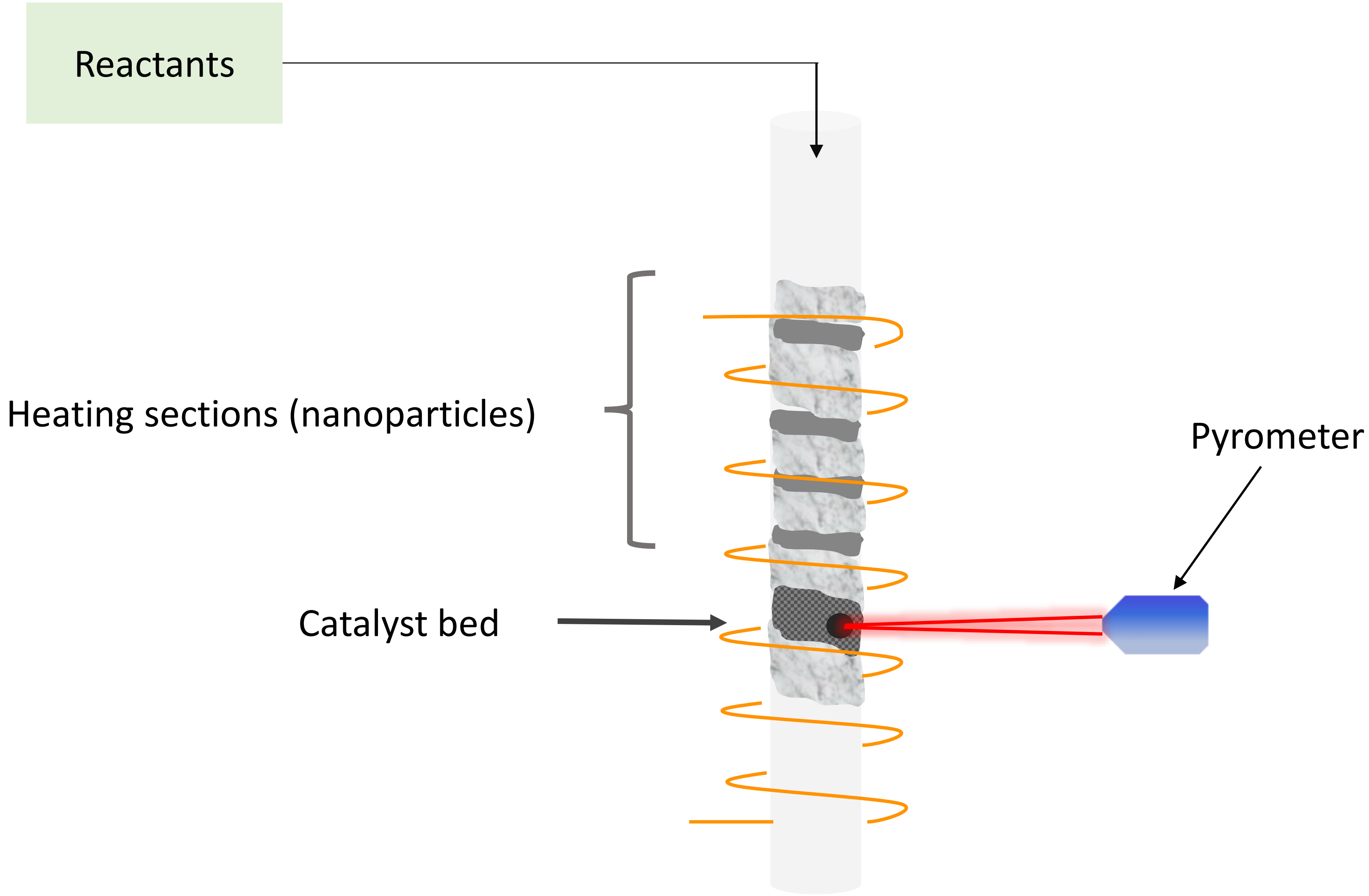
Efficiency Chart Source: US Department of Energy (1998)

Safe and Precise Control

- Predetermined temperature profiles
- PI controllers can be utilized to ensure the elimination of waste energy



Reactor Design for Experiments



Potential Projects

IMPROVE EXPERIMENTAL DESIGN THROUGH MODELING TO ACHIEVE MORE UNIFORM TEMPERATURE

FIND OPPORTUNITY TO APPLY ON LARGER-SCALE IN MANUFACTURINGNH

POTENTIAL AR FOR HEATING SYSTEM