technische universität dortmund

Fakultät Bio- und Chemieingenieurwesen

Dampfmaschine 2.0

Lehrstuhl für Anlagen- und Prozesstechnik (apt) · Lehrstuhl für Technische Chemie B · Werkstätten des bci

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Idea

Chemical reactions can elicit a wide variety of physical phenomena. Here, the idea is to exploit the heat liberated in an exothermic reaction to generate electricity to power the vehicle with the following features:

- Direct conversion of heat into electrical energy
- Utilization of the Seebeck effect

Applications of thermoelectric generators:

- Waste-heat harvesting
- Temperature measurement & control

Originality

- Major challenge: Medium remains heated after reaction terminates
  → Themal inertia makes the utilization difficult to control
- Idea: Spatial decoupling of heat generation and absorption
  → Utilization of condensible vapor phase (steam) as heat transfer medium
  → High energy density
  → Optimized heat transfer using condensing water

Energy source

Heat transfer and reaction

Cold side:

Stirred tank with ice water (0 °C):

- Good heat transfer
- Non-hazardous

Heat transfer medium: Condensing water

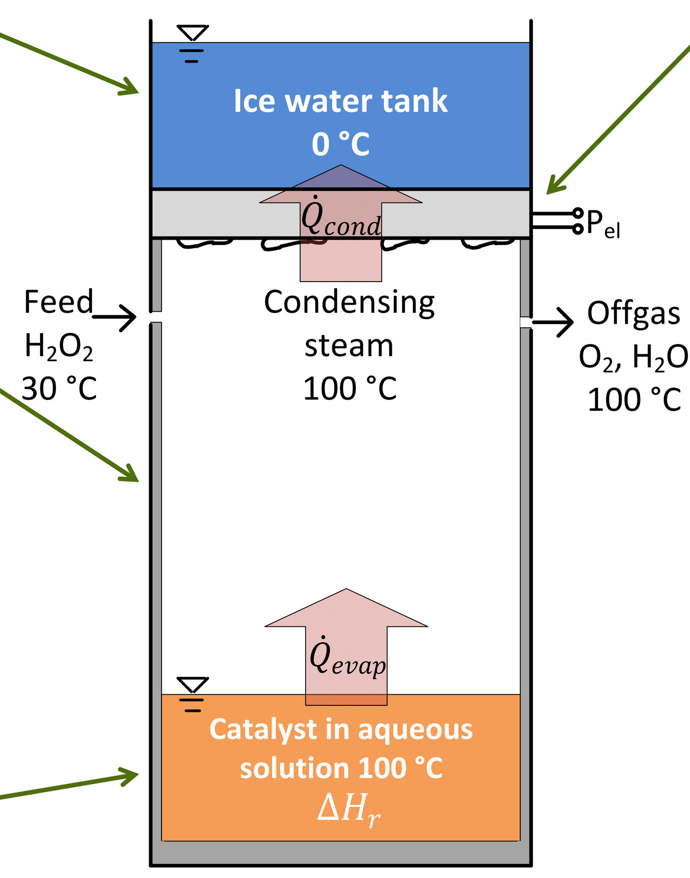
- High enthalpy of evaporation
- High boiling point
  → Provides large amounts of heat at high temperature

Reactive heat source :

Catalytic decomposition of hydrogen peroxide

$$H_2O_2 \xrightarrow{\text{Cat.}} H_2O + O_2 \qquad \Delta h^R = -98 \text{ kJ/mol}$$

- Catalyst: $Fe(NO_3)_3$
- Rapid reaction rate
  → Prompt initiation & fast heat generation



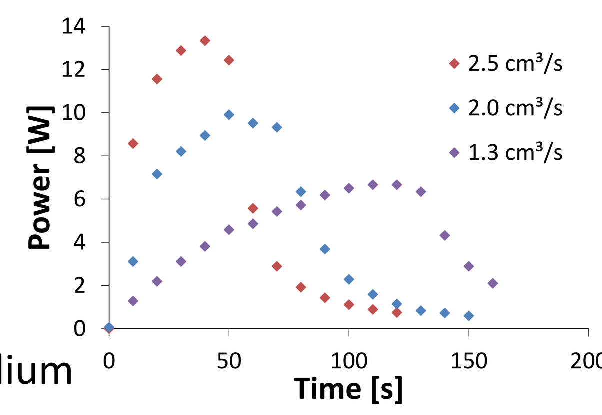
Thermoelectric generators

- Temperature gradient leads to a electrical field in semiconductor material
  → Electric current
  → Supplies power for the electric motor

Operation

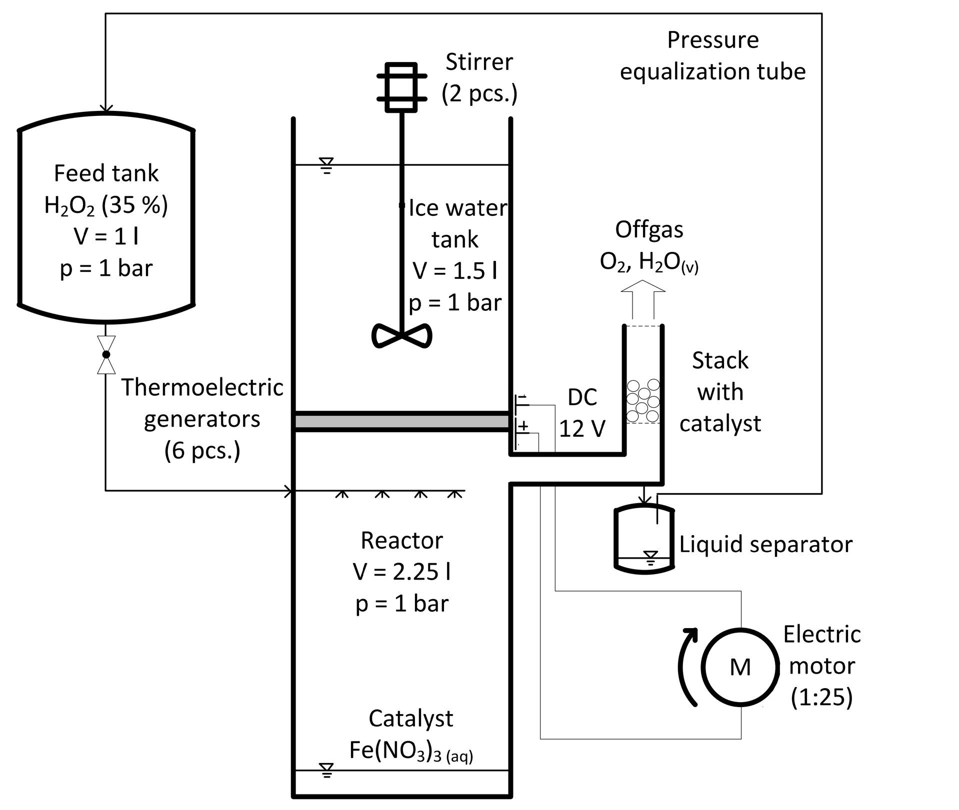
Semibatch reactor

- Catalyst is first placed in reactor
- Hydrogen peroxide is then fed continuously
  → Excellent control of the reaction, no runaway
  → Constant reaction conditions
  → Steady flow of steam generated by reaction medium
  → Uniform level of electrical power
- When feed is exhausted:
  → Reaction and evaporation stop instantaneously
  → Rapid decline in power generation
  → Regulation of distance travelled by amount of feed



Car design

Reaction flowsheet



Specifications

Weight [kg]	6.5
Size [mm]	520 x 300 x 500
Operating pressure [bar]	1
Operating temperature [°C]	100

Construction and material features

Feed tank

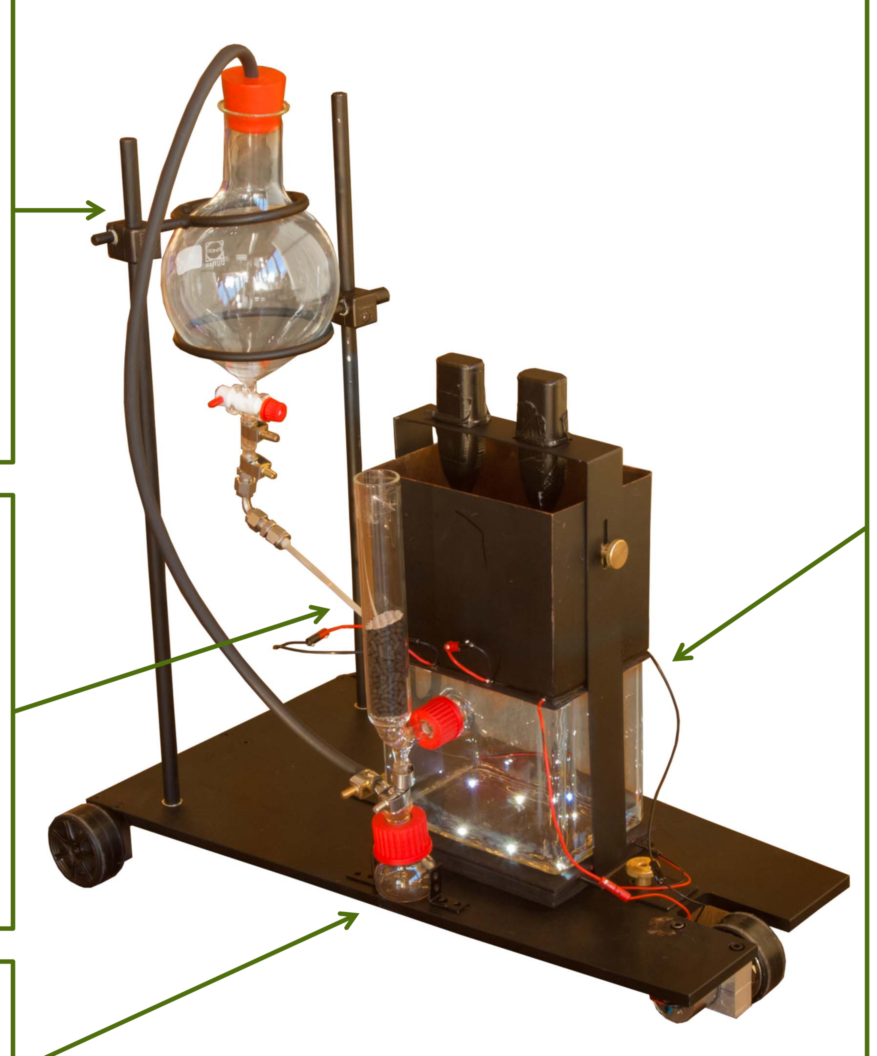
- Continuous flow due to hydrostatic head difference
- Vertical position is adjustable
- Pressure equalization with reactor

Stack

- Heterogeneous catalyst for H_2O_2 elimination
- No H_2O_2 present in waste gas
- O_2 and steam are released

Liquid separator

- Avoids liquid in the pressure equalization tube



Reactor, ice water tank & thermoelectric generators

- 6 Thermoelectric generator units located beneath ice water tank
- Constant temperature level maintained by phase change
- Low thermal capacity of reactor glas wall
- Reaction progress can be monitored visually
- High thermal conductivity of ice water tank made of copper
- Stirrers in tank provide good, reproducible heat transfer
- Special high-conductivity contact adhesive between thermoelectric generators & ice water tank

Safety

Chemicals and emissions

- Airtight system: gas escapes only through the stack
- Granular activated carbon in the stack eliminates remaining traces of H_2O_2 present in waste gas
  → Only O_2 and H_2O are released
- Potassium iodide test shows no traces of oxidizing agent in offgas

Disposal

- Disposal of catalytic solution in waste container
- No H_2O_2 remains in the system

Calibration

Operating point:

- H_2O_2 volume flow: 2 cm³/s
- Initial catalyst: 8 g, 25 w%
- H_2O_2 concentration: 35 w%