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Thermoacoustic heat pumps

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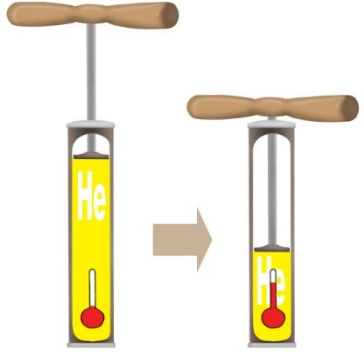
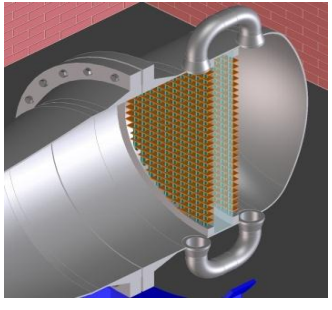
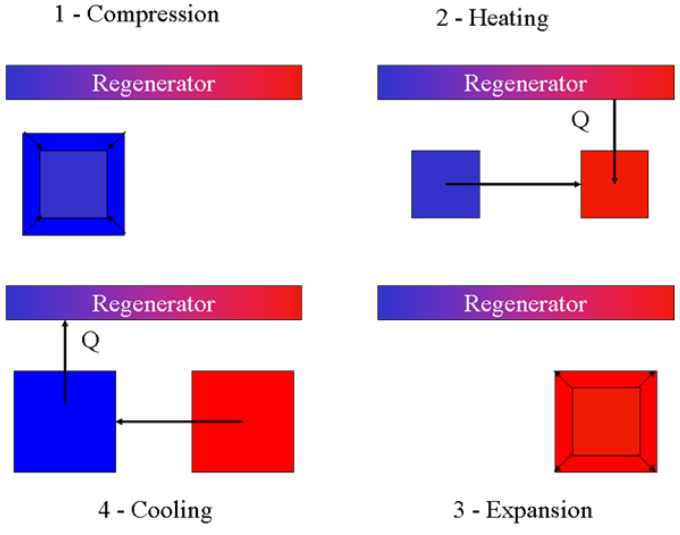
Thermoacoustics

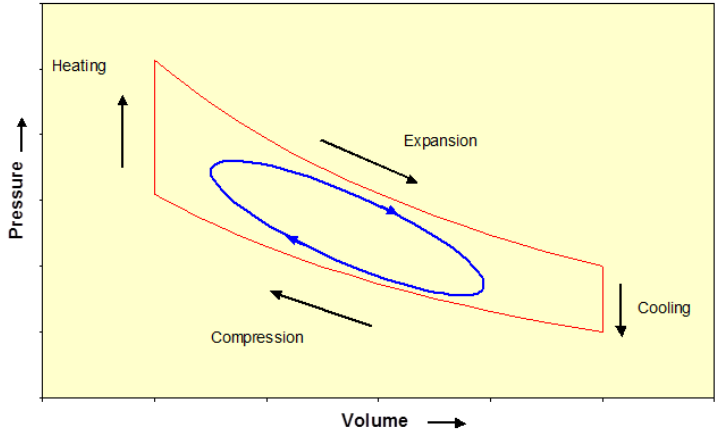
- Generate acoustic power from temperature differences (engine)
- Pump heat across temperature differences with acoustic power (heat pump)
- Thermodynamically idential to Stirling cycle but without the moving parts
- Typical operating conditions
  - 30 - 100 Hz, 40 bar Helium
  - Operating temperature -100°C till 600°C
  - Temperature lifts 10°C till 100°C





Thermodynamic cycle

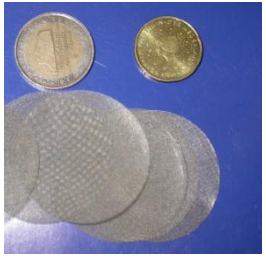


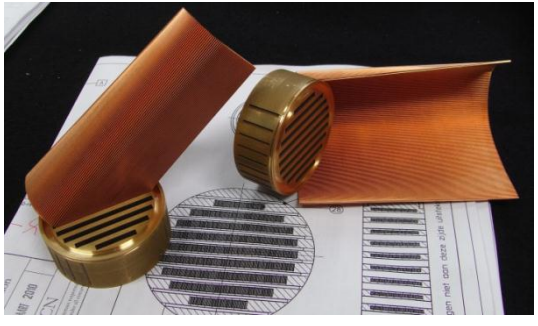


Stirling cycle $\Rightarrow$ Carnot efficiency

Thermoacoustic system components

- Regenerator
  - Porous, low conductivity, high heat exchange, low pressure drop
- Heat exchangers
  - High heat transfer, low pressure drop
- Acoustic circuit
  - Timing of process
- Resonator
  - Pressure vessel, resonance frequency
- Driver
  - Depending on application
  - Electro-acoustic transducer



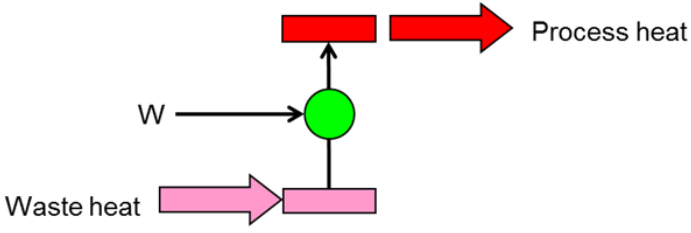


Characteristics TA-heat pump

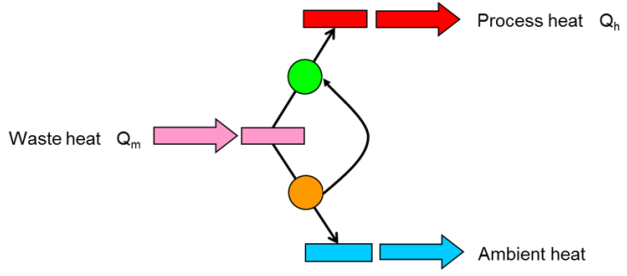
- Stirling cycle
- No phase transition of working medium
- Flexible on temperature level of heat delivery (no theoretical limit)
- Flexible on temperature lifts (up till 100°C)
- No/few moving parts (resulting in low maintenance)
- Environmentally friendly working medium (helium)
- Simple materials, no high tolerances, providing good economy
- Can be vertically placed, resulting in a small footprint.

Applications

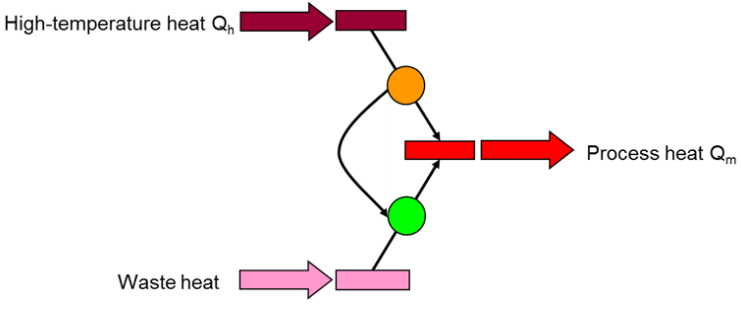
- Electrically driven heat pump



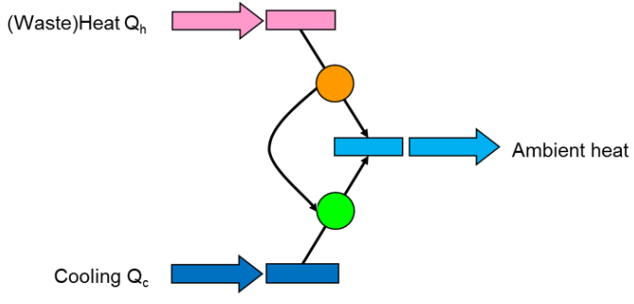
- Waste heat driven heat transformer



- High-temperature heat (burner) driven heat pump

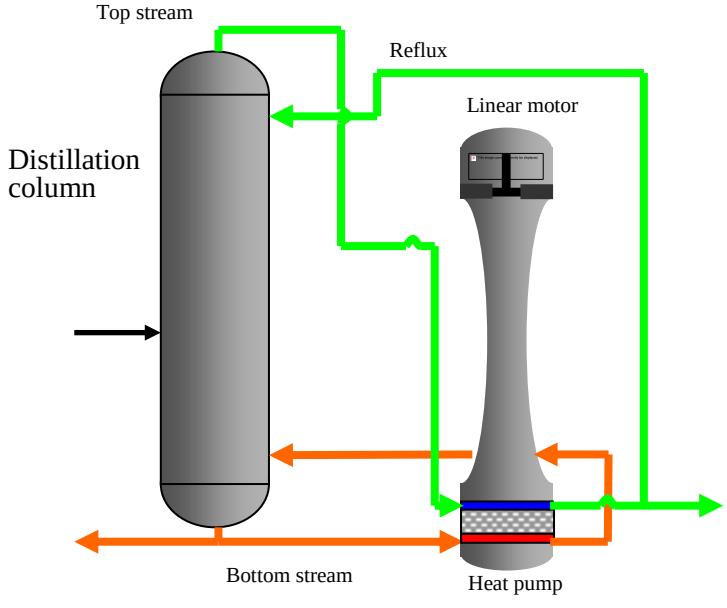


- Waste heat driven cooler



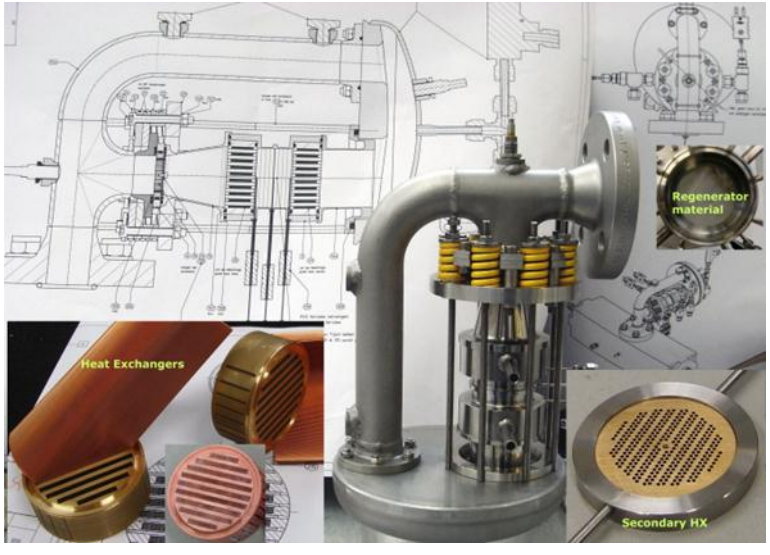
Electrically driven TA heat pump

- Suitable for wide range of waste heat temperatures
- Flexible with respect to temperature lifts
- Applicable in chemical, refining, paper and food industry
- Major components
  - Resonator
  - Regenerator
  - Heat exchangers
  - (Linear) compressor
- Example: distillation column



Testing of electrically driven TA system

Labscale



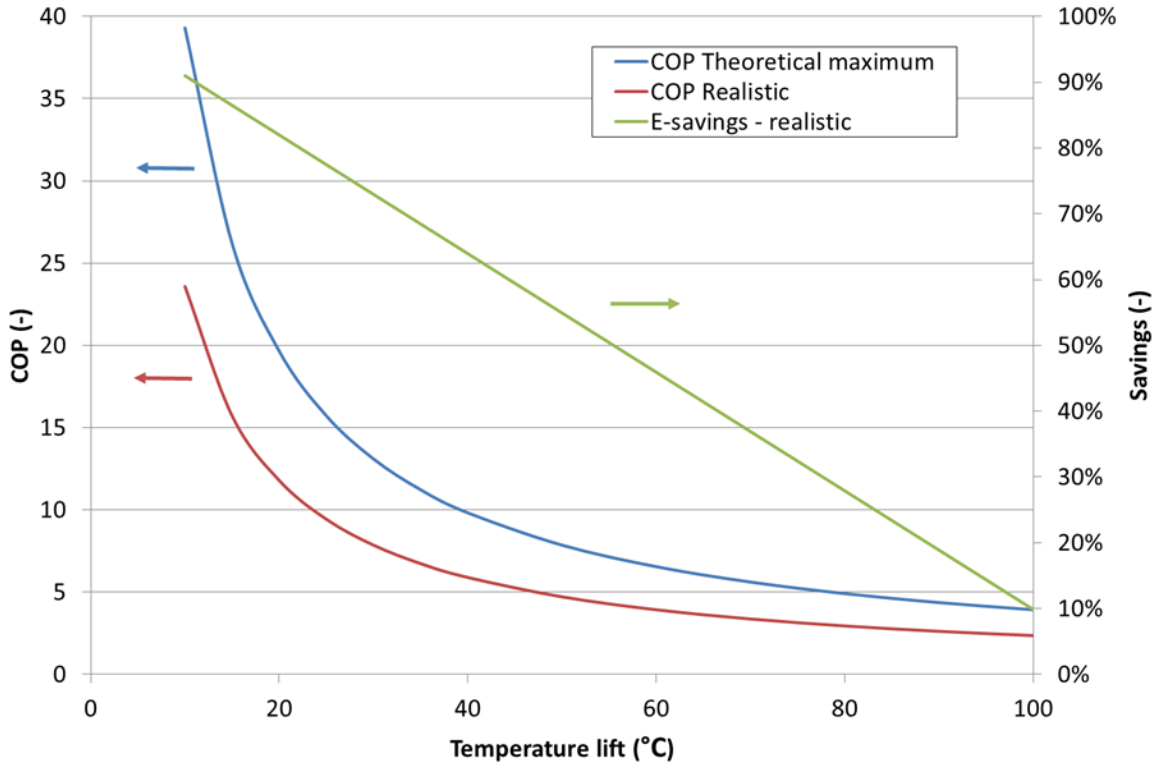
Tested for

- 10 - 80°C
- 50 - 100°C
- 80 - 140°C
- Efficiencies nearing 40% of Carnot

Benchscale

Testing currently underway

Heat pump efficiency & savings



T_h = 120°C
Boiler efficiency = 85 %
Power station efficiency = 40%

Economics – business case

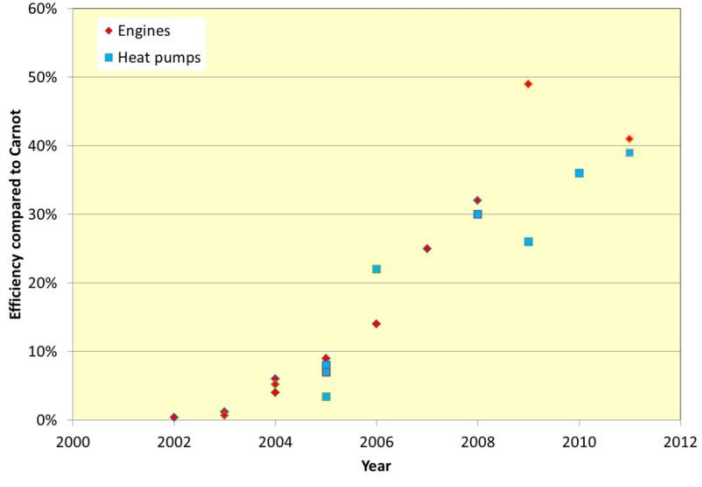
	Boiler	Heat pump
Waste heat temperature (°C)	120	
Process heat temperature (°C)	180	
Heat demand (MW)	30	
Running hours (hr/year)	8000	
Efficiency/COP (-)	0.85	4
Investment (M€)		22.5
Electricity costs (M€/year)		3.0
Insurance & Maintenance costs (M€/year)		0.9
Savings on fuel (M€/year)		8.54
Cash flow (M€/year)		4.6
Simple payback time (years)		4.9

Status and Outlook

- Further technology development (2-3 years)
  - Controllability
  - Scale effects
  - Durability tests
  - Field testing
  - Reduce cost of manufacturing

- Scaling (next)
  - 100 kW (field testing)
  - 100 kW- 1 MW (demo)
  - > 1 MW (commercial, dependent on market)

Power scale increased from 100 W to 10 kW



Thanks for your attention