Centrum výzkumu Řež s.r.o.

SUPERCRITICAL CO2 CYCLE

Václav Dostál

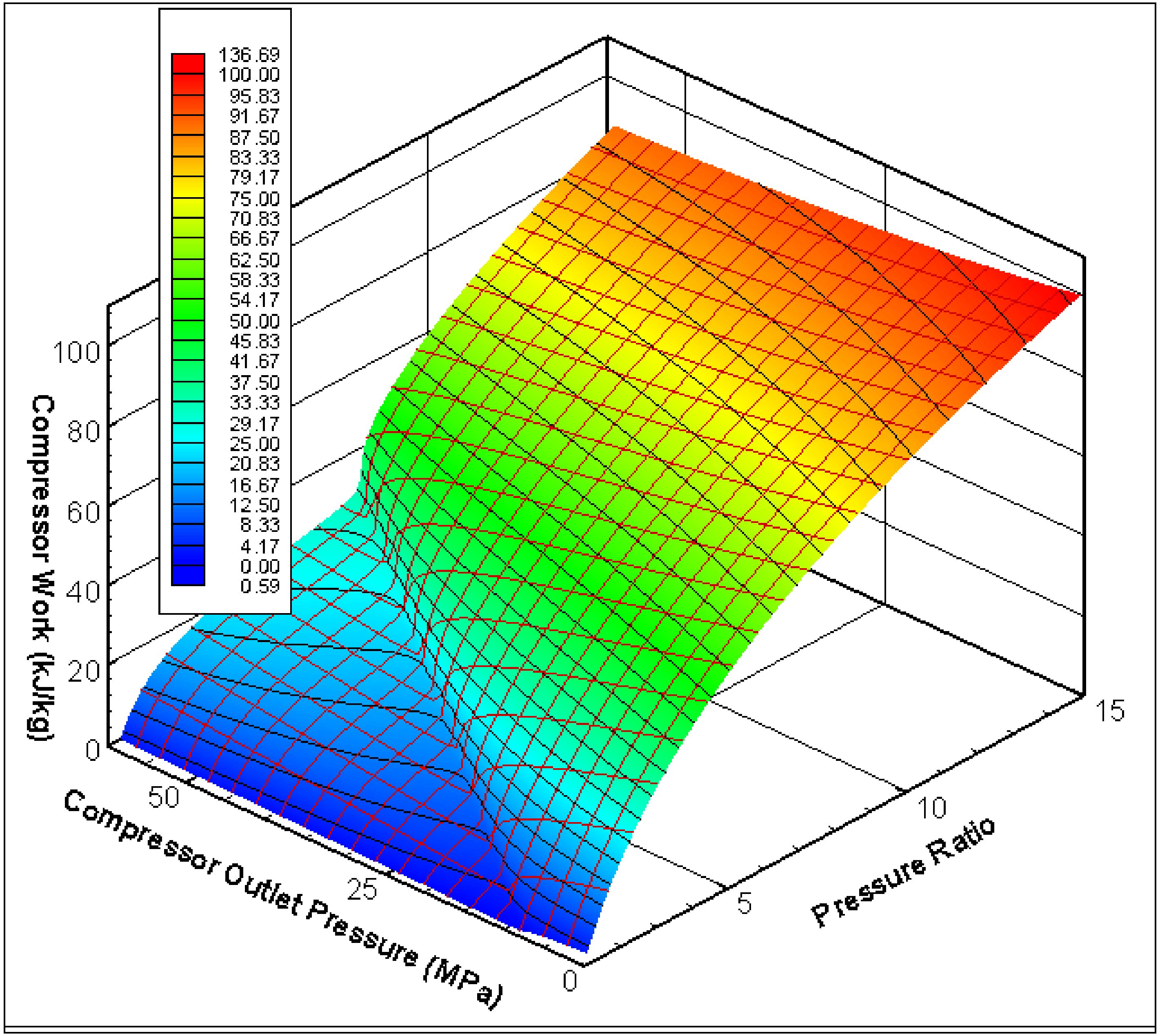
Outline

- S-CO2 cycles overview
- Aspects of S-CO2 cycles
- Applications of S-CO2 cycles
- R&D needs

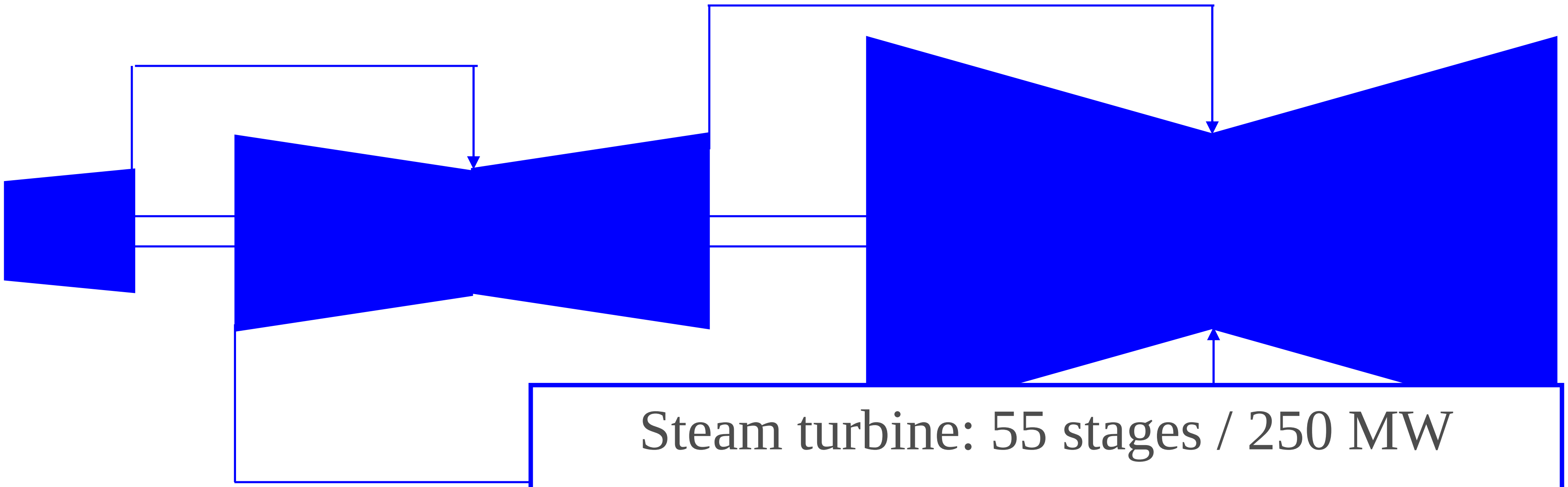
Supercritical Cycles - What are they?

- **Thermodynamic cycles that take advantage of the changes of properties around the critical point**
- **2 major types**
  - supercritical steam cycle - heating above critical pressure increases temperature of heat addition
  - supercritical CO_2 cycle - compression near the critical point reduces compressor work (i.e. reduction of temperature of heat rejection)

Reduction of Compressor Work

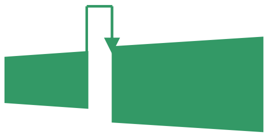


Turbine Size



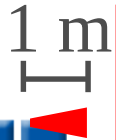
Steam turbine: 55 stages / 250 MW

Mitsubishi Heavy Industries Ltd., Japan (with casing)



Helium turbine: 17 stages / 333 MW (167 MW_e)

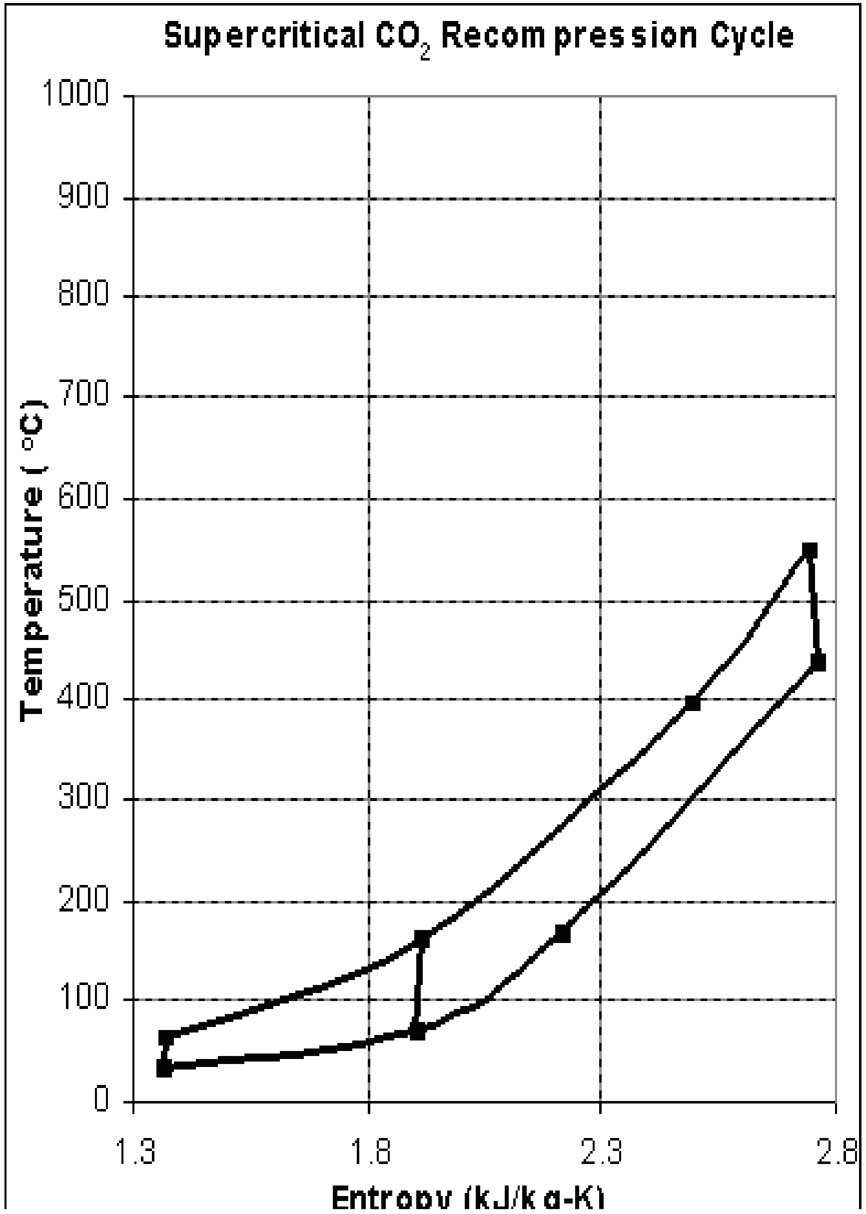
X.L.Yan, L.M. Lidsky (MIT) (without casing)

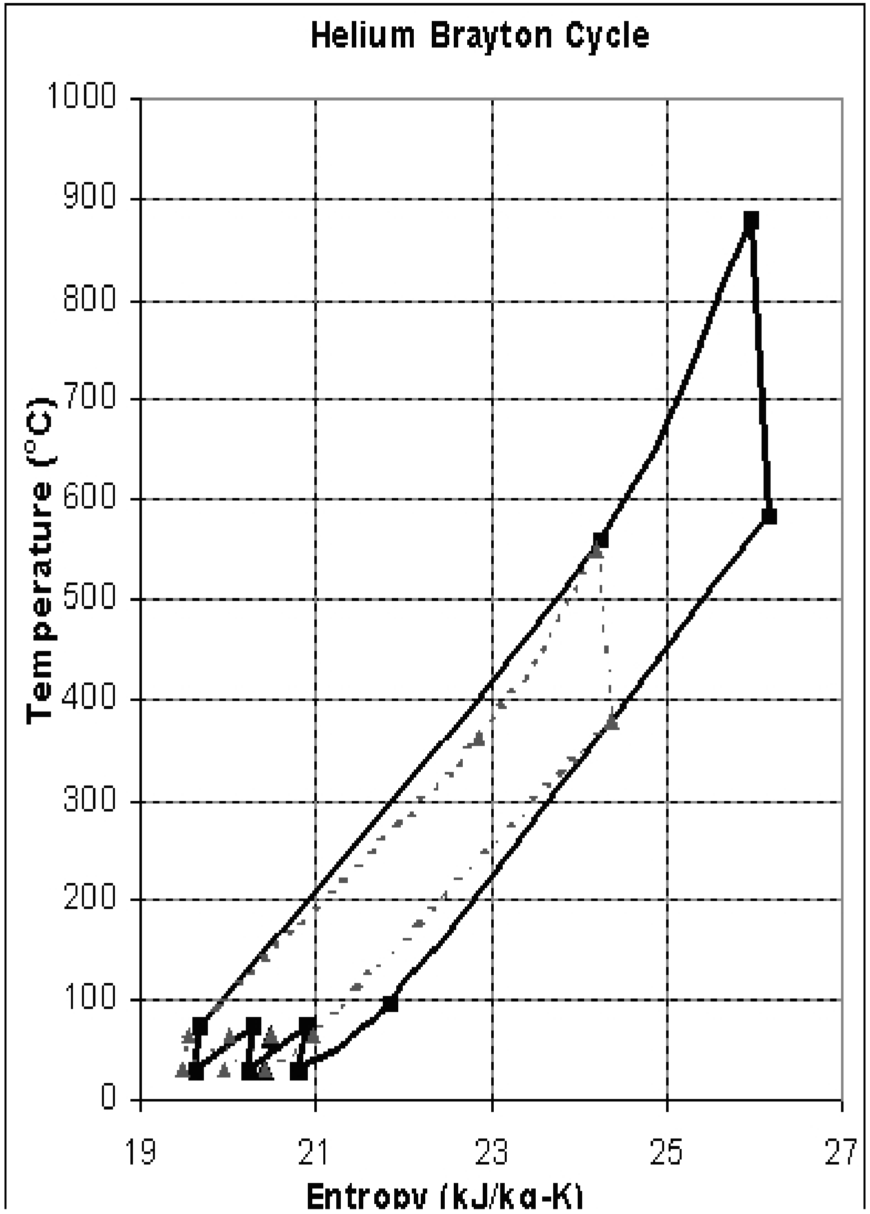


Supercritical CO_2 turbine: 4 stages / 450 MW (300 MW_e)

(without casing)

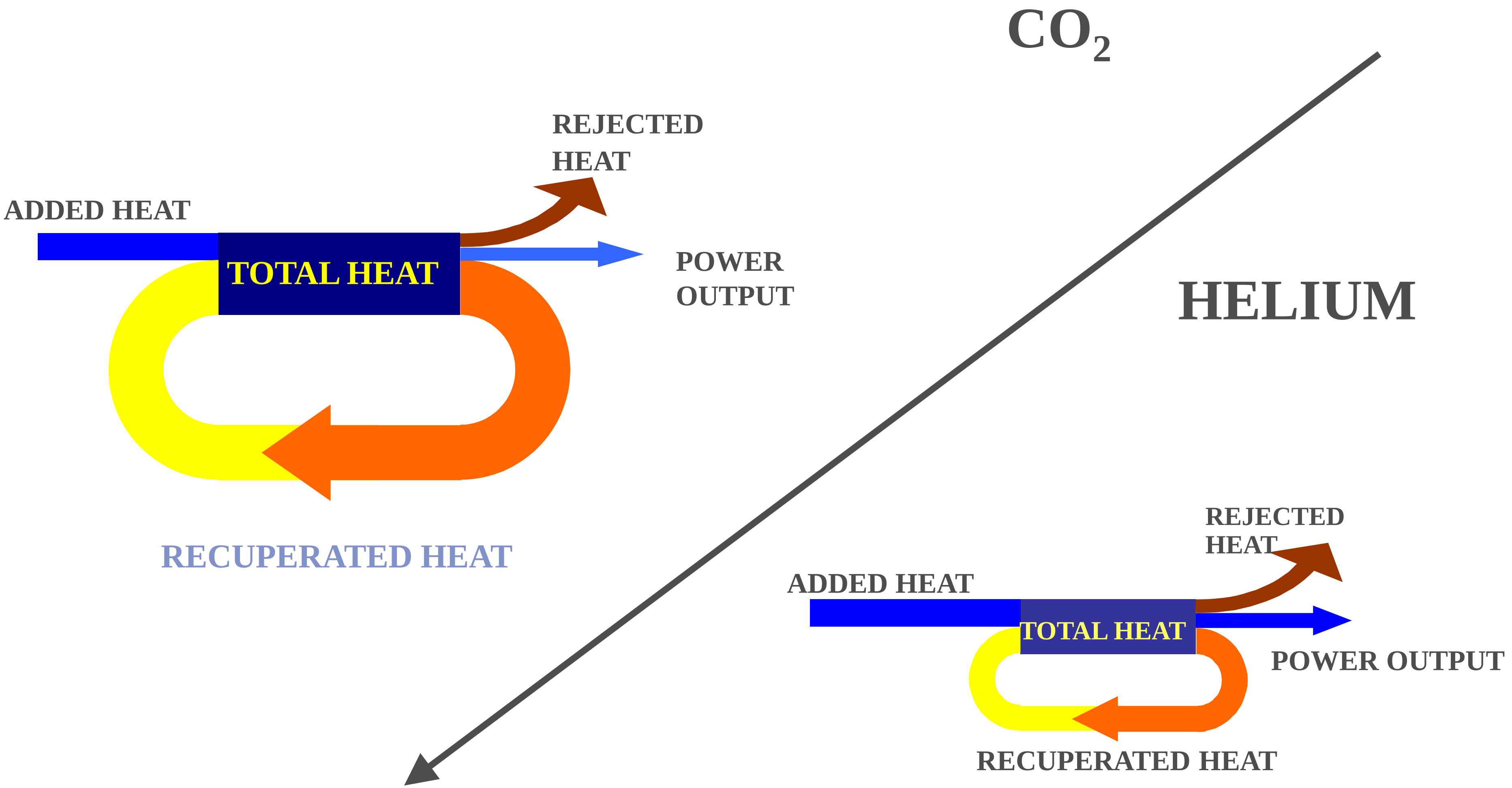
Comparison of S-CO2 and Helium Cycles





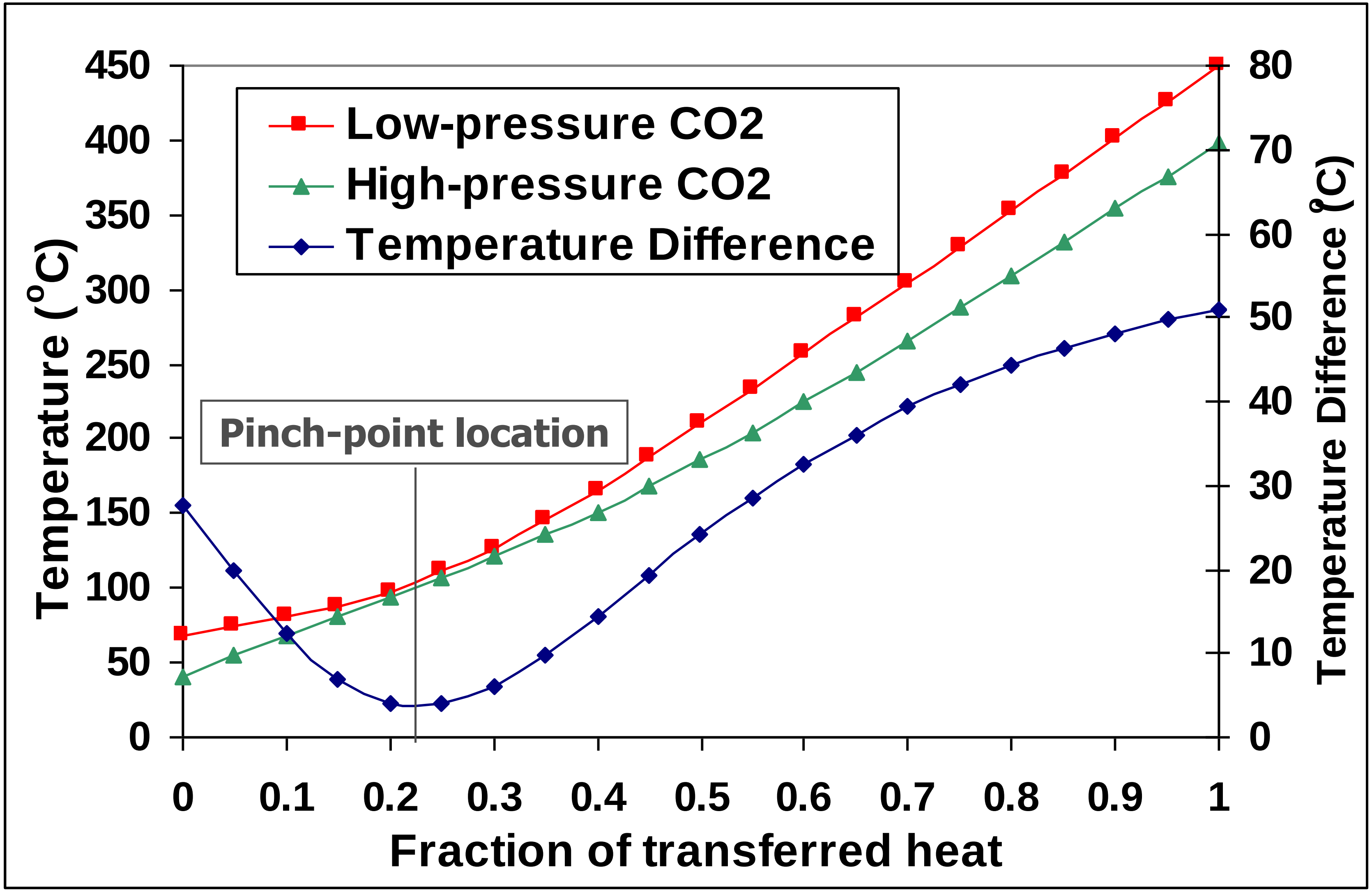
Disadvantage of Supercritical CO_2 cycle

- High Recuperation Heat

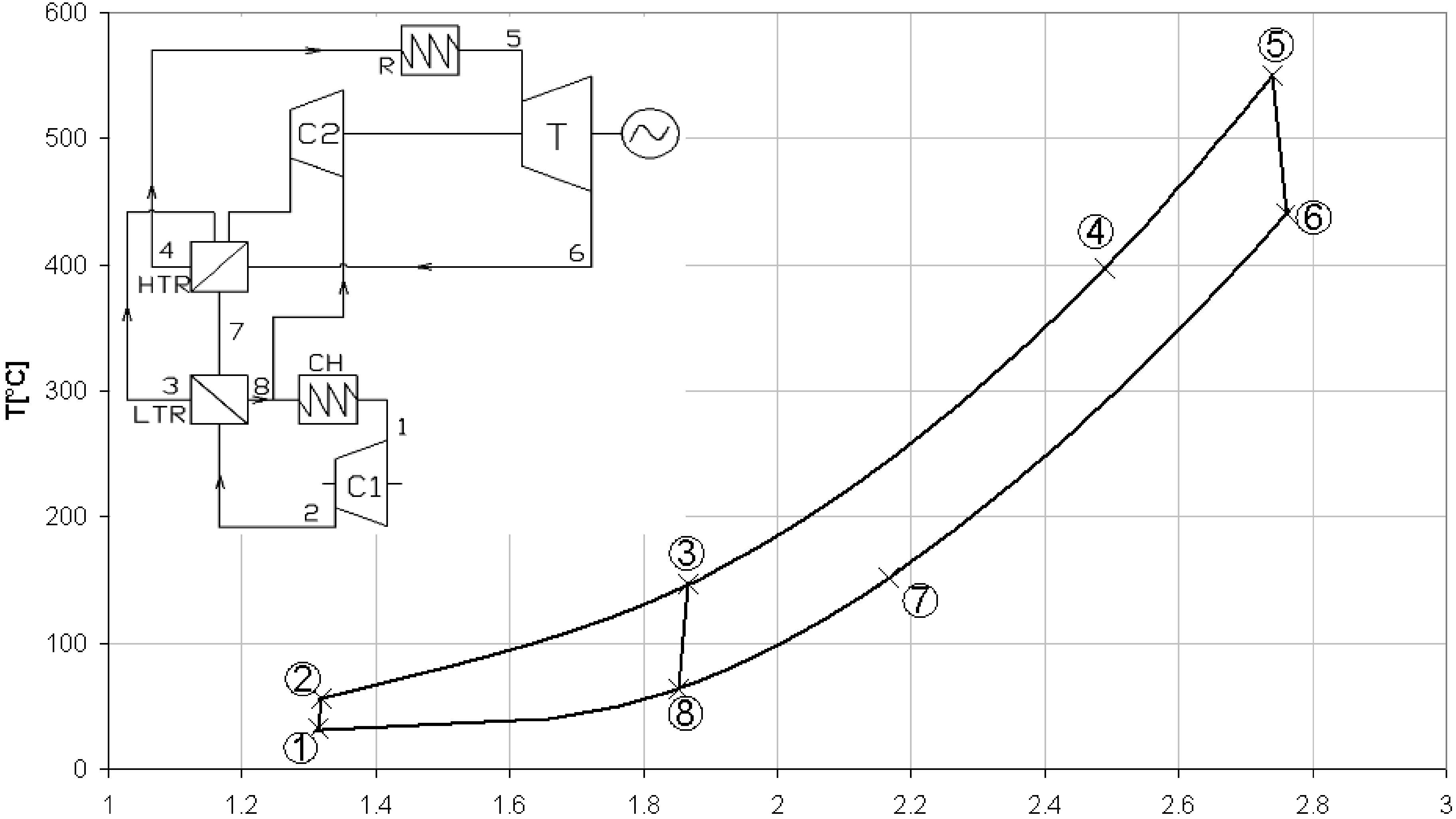


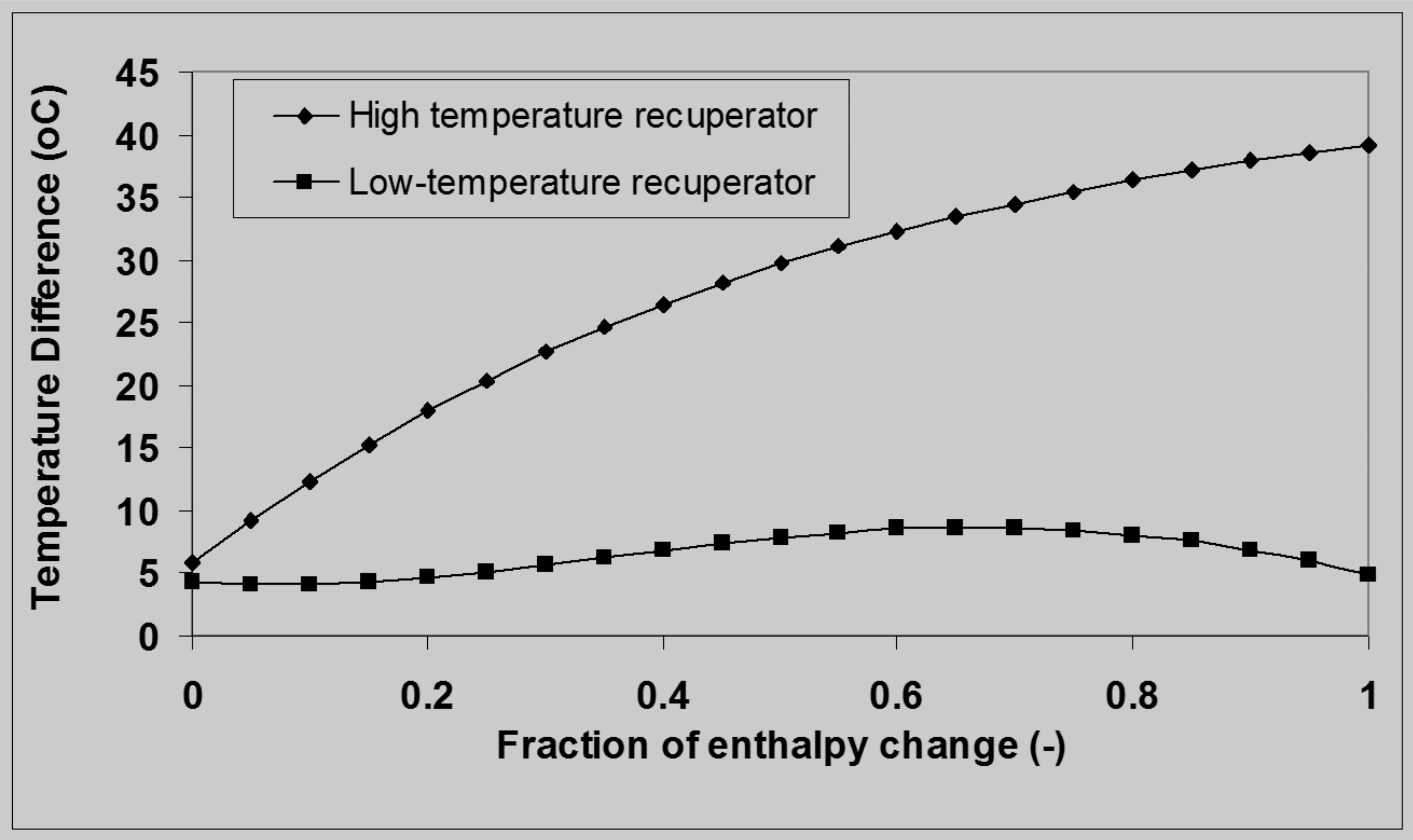
Q_{rCO2}/Q_{rHe} ~ 2-3 => ~ 4 times bigger recuperators

Pinch-point in Recuperator



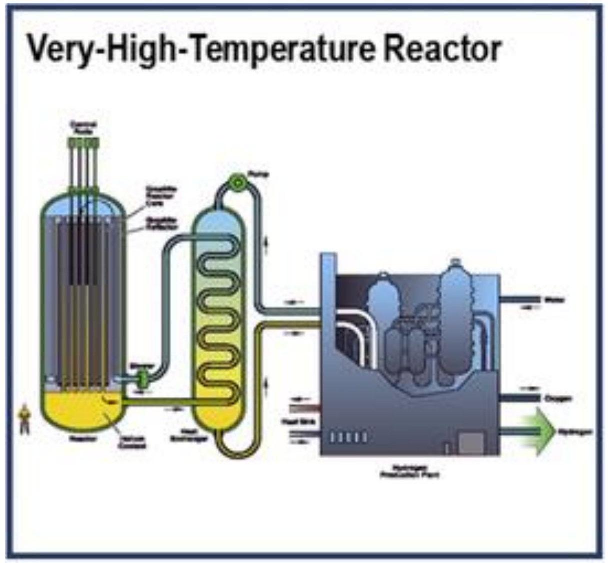
Re-Compression Cycle

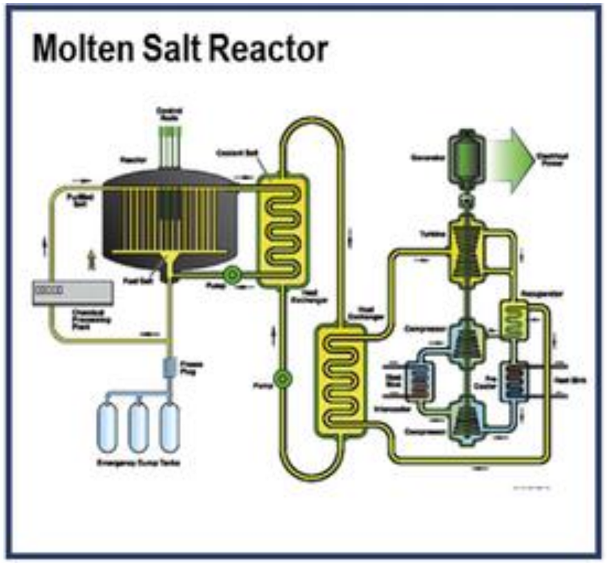


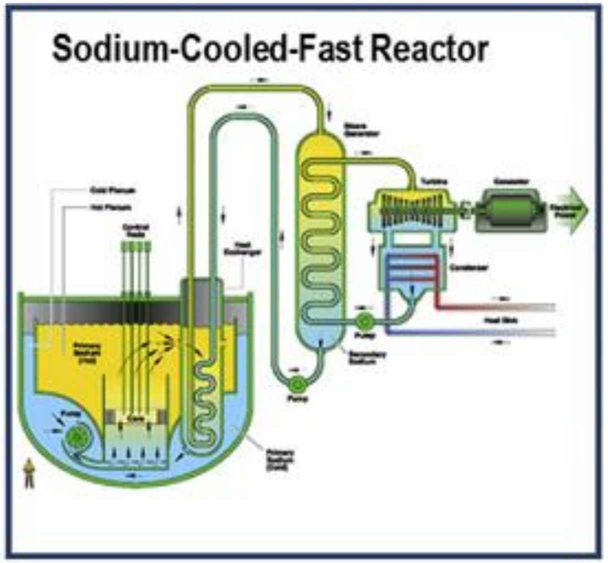


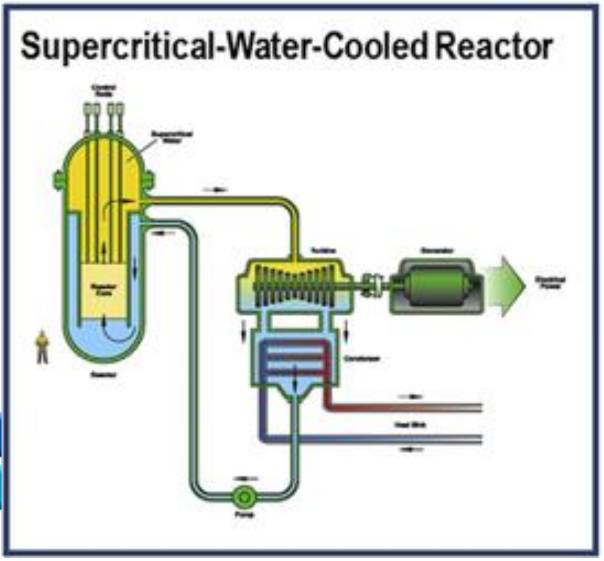
High temperature recuperator
Low-temperature recuperator
Temperature Difference (oC)
Fraction of enthalpy change (-)
0
5
10
15
20
25
30
35
40
45
0
0.2
0.4
0.6
0.8
1

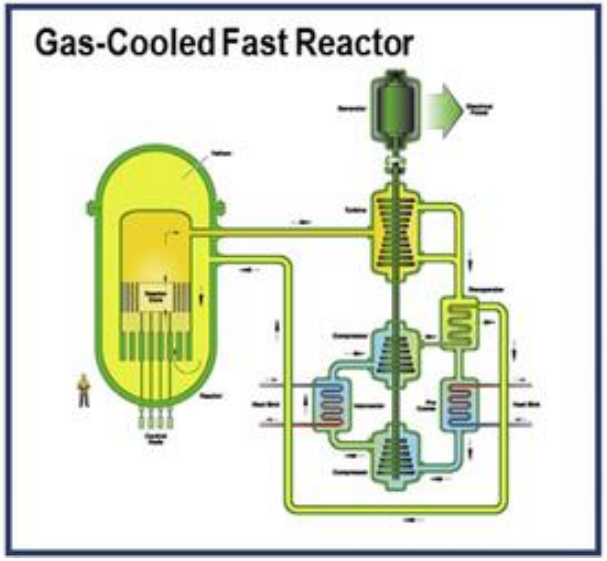
Advanced Reactors

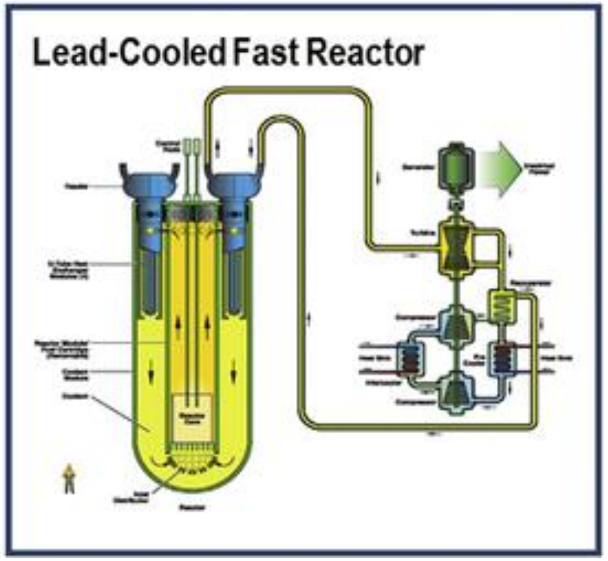




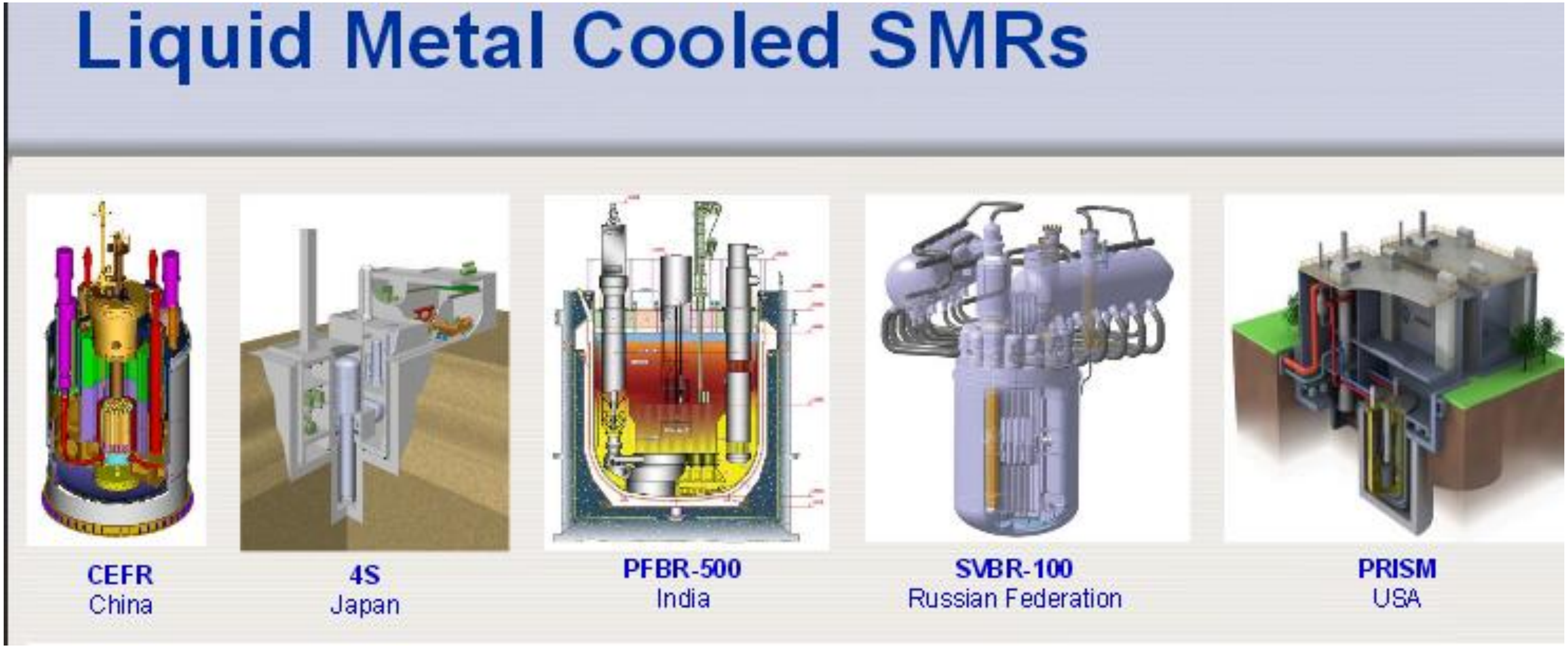






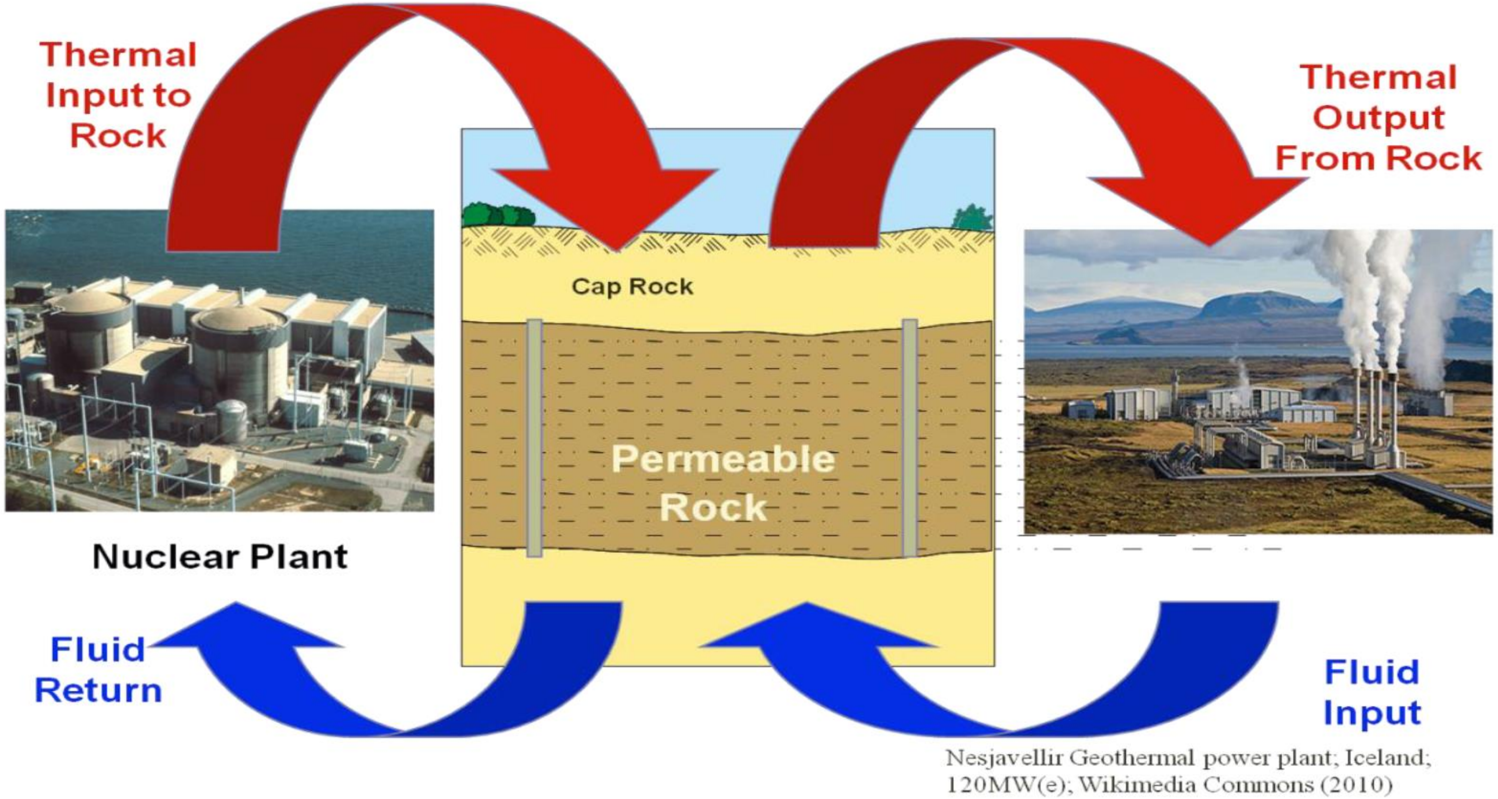


SMRs


Liquid Metal Cooled SMRs
CEFR
China
4S
Japan
PFBR-500
India
SVBR-100
Russian Federation
PRISM
USA

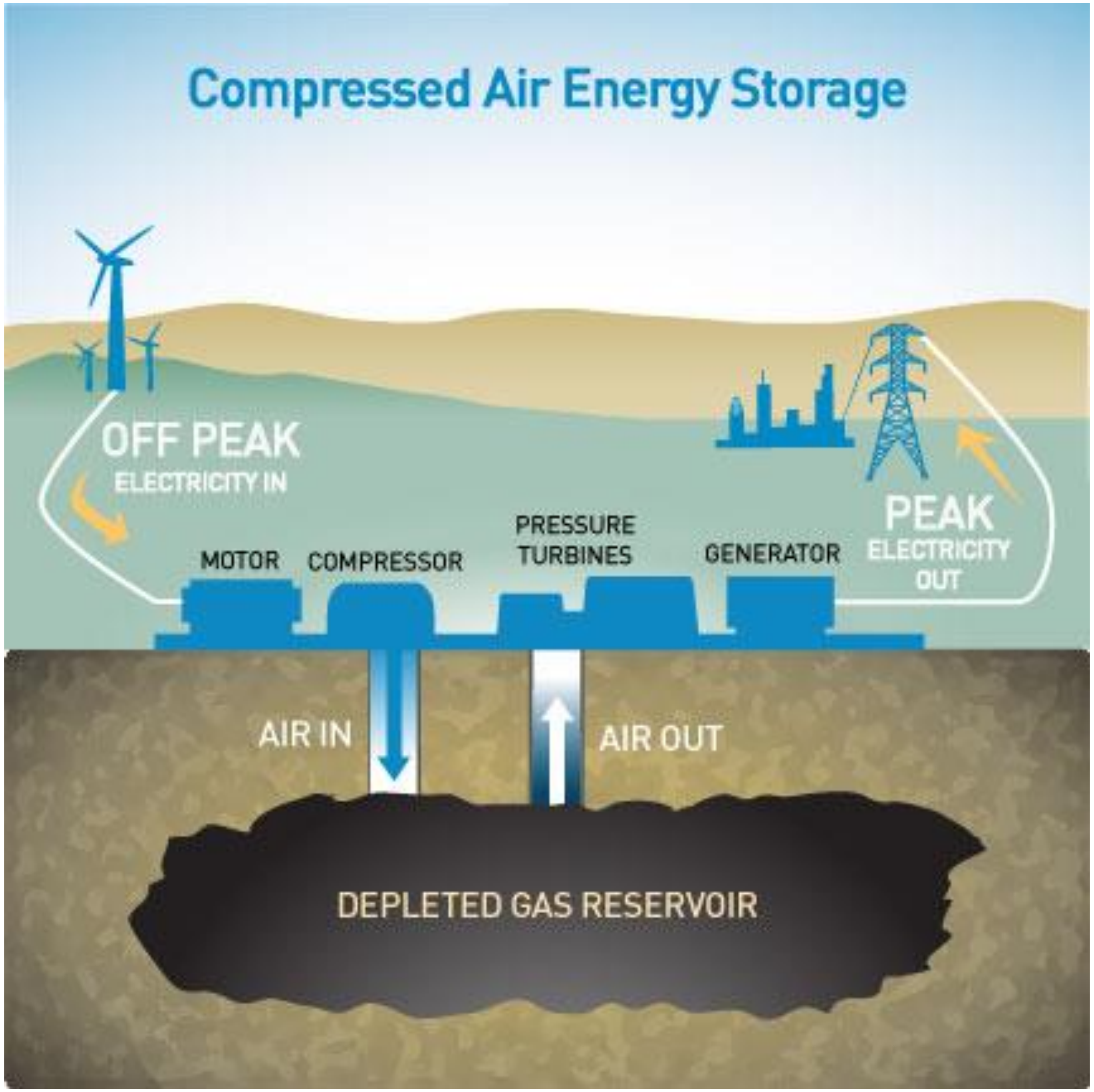
Waste Heat Recovery

Geothermal


Thermal
Input to
Rock
Thermal
Output
From Rock
Cap Rock
Permeable
Rock
Nuclear Plant
Fluid
Return
Fluid
Input
Nesjavellir Geothermal power plant; Iceland;
120MW(e); Wikimedia Commons (2010)

Solar - CSP

Storage

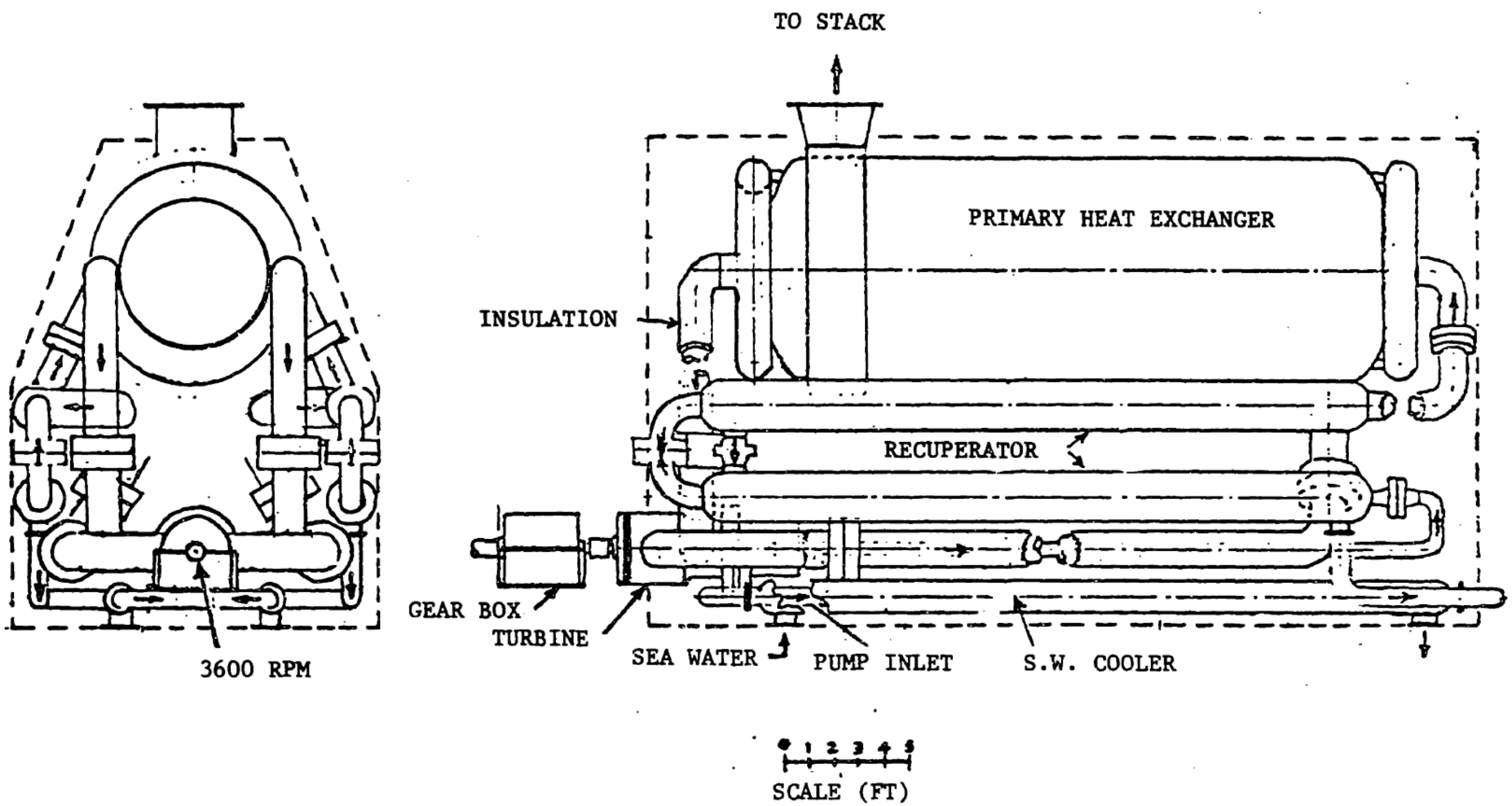


Compressed Air Energy Storage
OFF PEAK
ELECTRICITY IN
MOTOR
COMPRESSOR
PRESSURE TURBINES
GENERATOR
PEAK
ELECTRICITY OUT
AIR IN
AIR OUT
DEPLETED GAS RESERVOIR

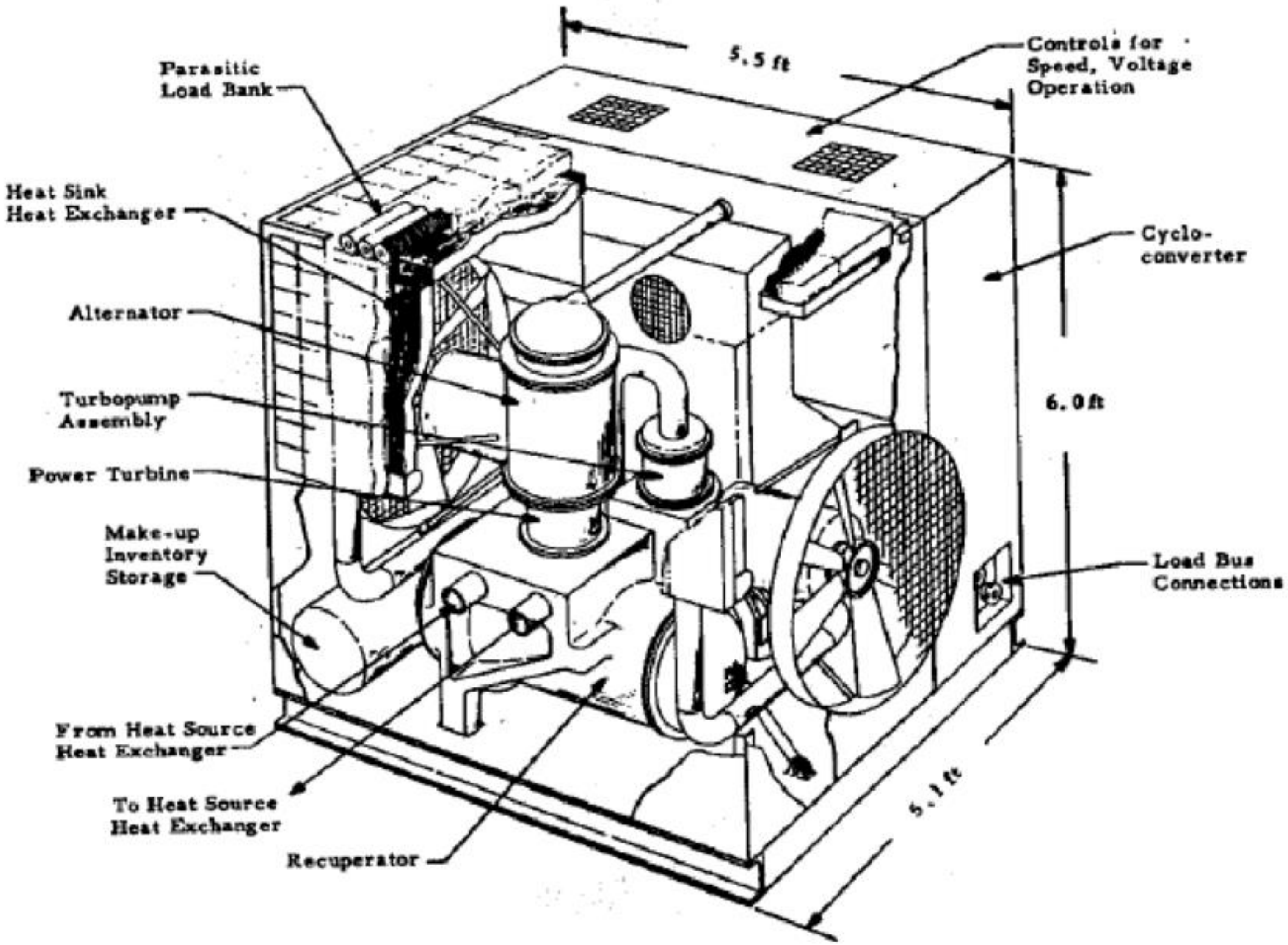
Propulsion

- An investigation of the supercritical CO2 cycle (Feher cycle) for shipboard application
- Author: Combs, Osie V

CONCEPTUAL LAYOUT OF 20,000 HP FEHER MARINE ENGINE



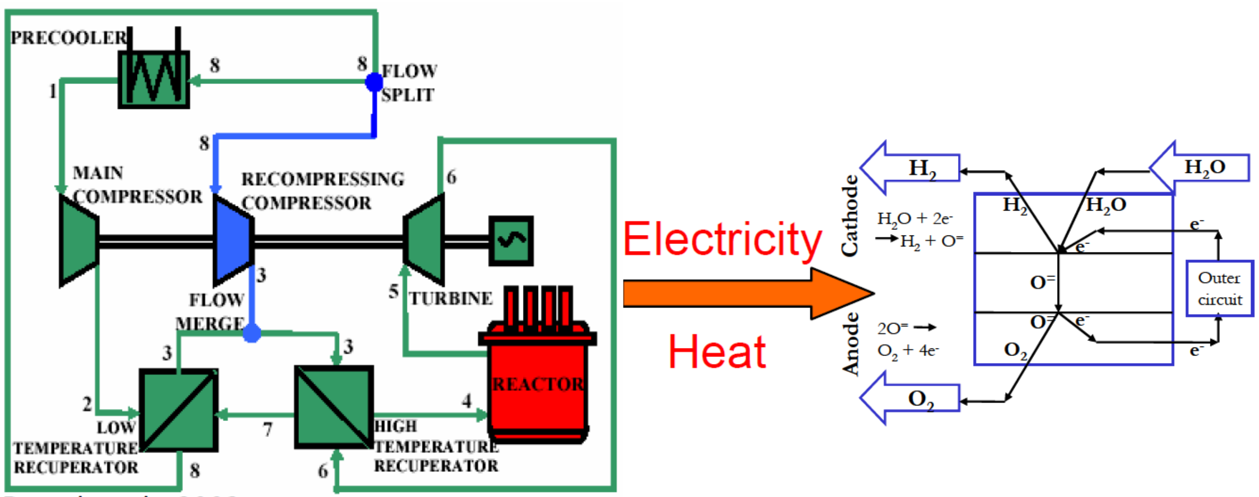
150 kWe Military Unit



Hydrogen Production

- **Nuclear Energy Options for Hydrogen Production**
- **B. Yildiz, M. S. Kazimi**

- Materials at lower temperatures
  - Compatible to CO_2 cooled reactor and the CO_2 power cycle operating temperature
  - Lower cost
  - Eliminate very high temperature related limitations



Dostal et al., 2002

Space
Mars Surface Power System

- **Sufficient power for all surface applications (i.e. ISRU, habitat etc.) Satisfy NASA DRM.**

  ~200 kW_e

- **Develop long lasting Mars surface infrastructure**
  - Lifetime of 25 EFPY

Economy

- Competitors
- Proven vs. new technology
- Mass production
- Uncertainty of power prices on the market
  - Opportunity or hurdle?
- Proper selection of markets and applications

Commercialization Path

- **New trends in power engineering**
  - Decentralization, small units
- **Power electronics/power conditioning**
- **Small units as demos for large units**
- **Turbomachinery type**
  - Radial vs. Axial
- **Compressor development**
- **Devil in details**

Further Considerations

- Maturity of technology
- Heat exchangers
- Compressors and turbines
- Cycle control
- Bearings
- Lubricants
- Seals
- Valves
  - freezing

Conclusion

- S-CO2 cycles are recently considered for many applications
- Many companies are considering its application
  - Question is in what application they can be successfully applied
- The cycle technology and components require substantial development
- For this development experimental loops are crucial
- S-CO2 loop in CVR is by its design and possibilities well suited for testing components, but also for experiments in the field of thermodynamics and heat transfer
- Projects like HeRo are very important for the cycle deployment

The COOL Application

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