Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Oxy-Combustion

OFFCET – A Novel Power Production Cycle Concept

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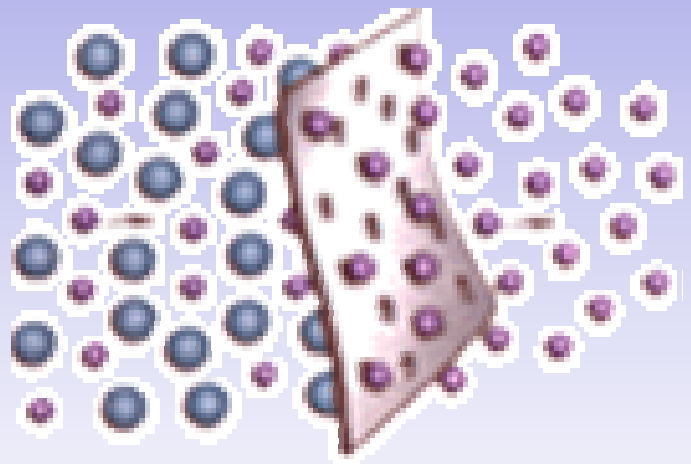
May 8-11, 2006 • Hilton Alexandria Mark Center • Alexandria, Virginia

Oxycombustion

- Burn in pure oxygen → only CO_2 and H_2O
- Condense out water
- Capture carbon dioxide
- Need to get oxygen

Oxygen production

- Oxygen Ion Transport Membranes (OTMs)
- Solid ceramic
- Conduct oxygen ions
- Developing technology



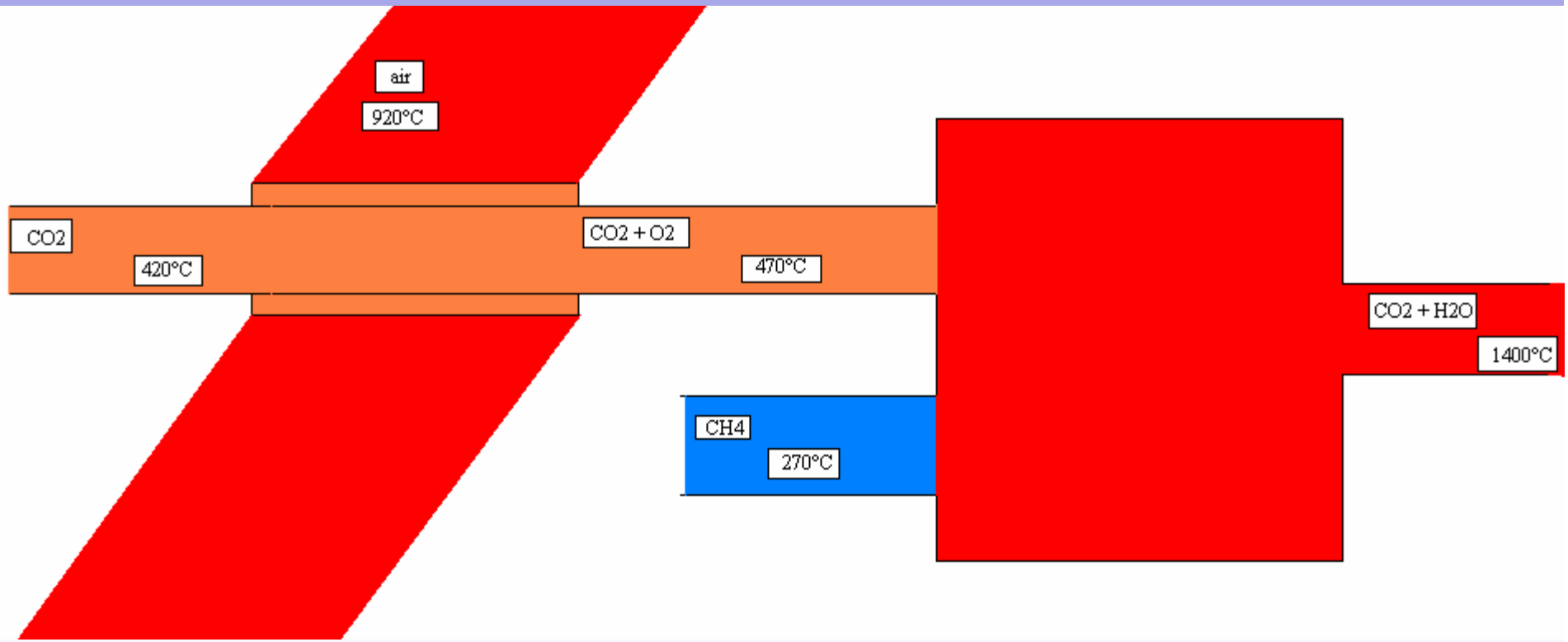
- Perovskite : high oxygen flux, < 1000°C
- Fluorite : lower oxygen flux, < 2000 °C

My research

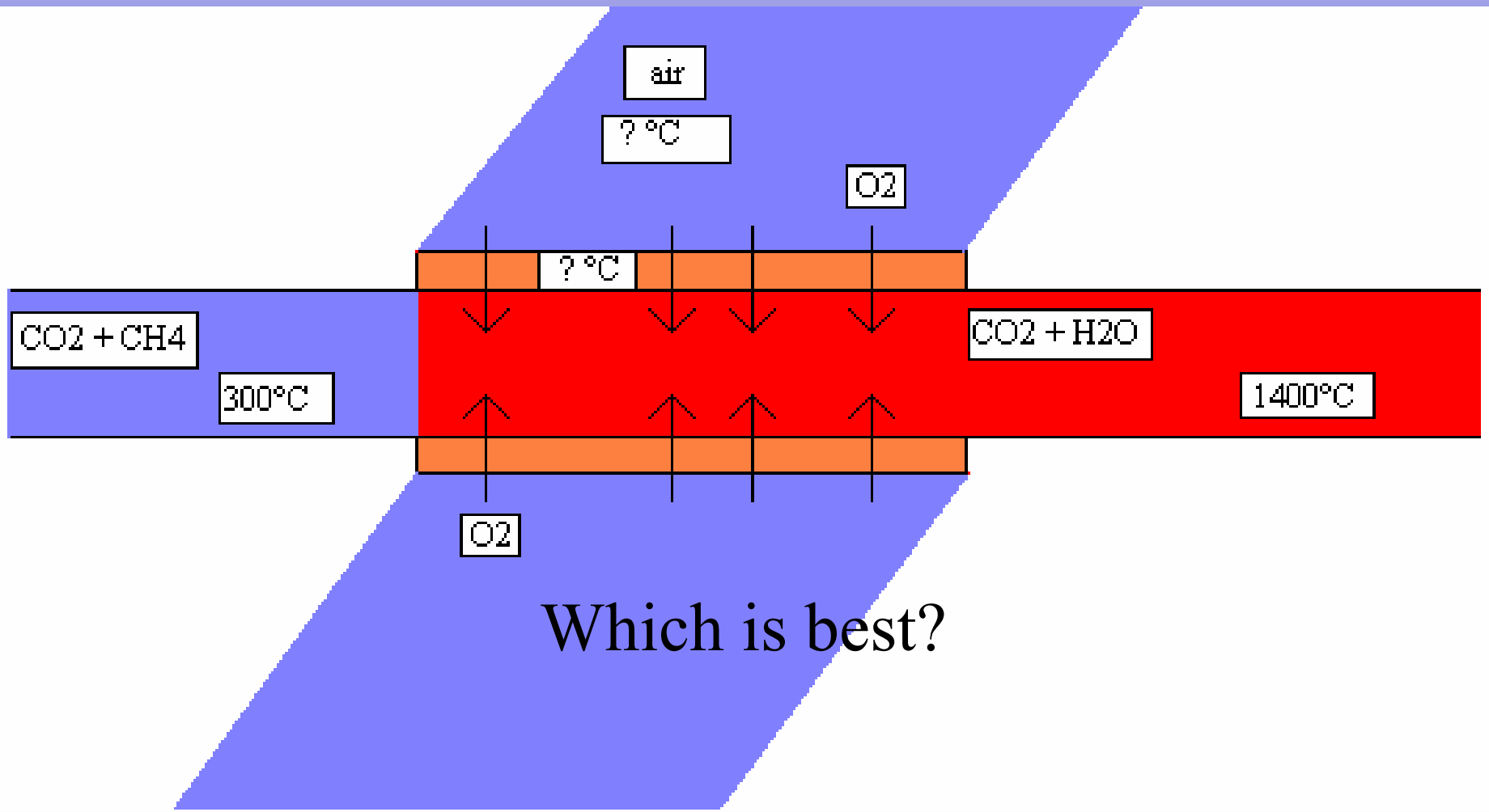
- Using OTMs in an oxycombustion plant
- 2 options:
- Separate units
  - OTM air separator
  - Combustion chamber

- Combined unit
  - OTM combustion chamber

Separate Units



Combined unit

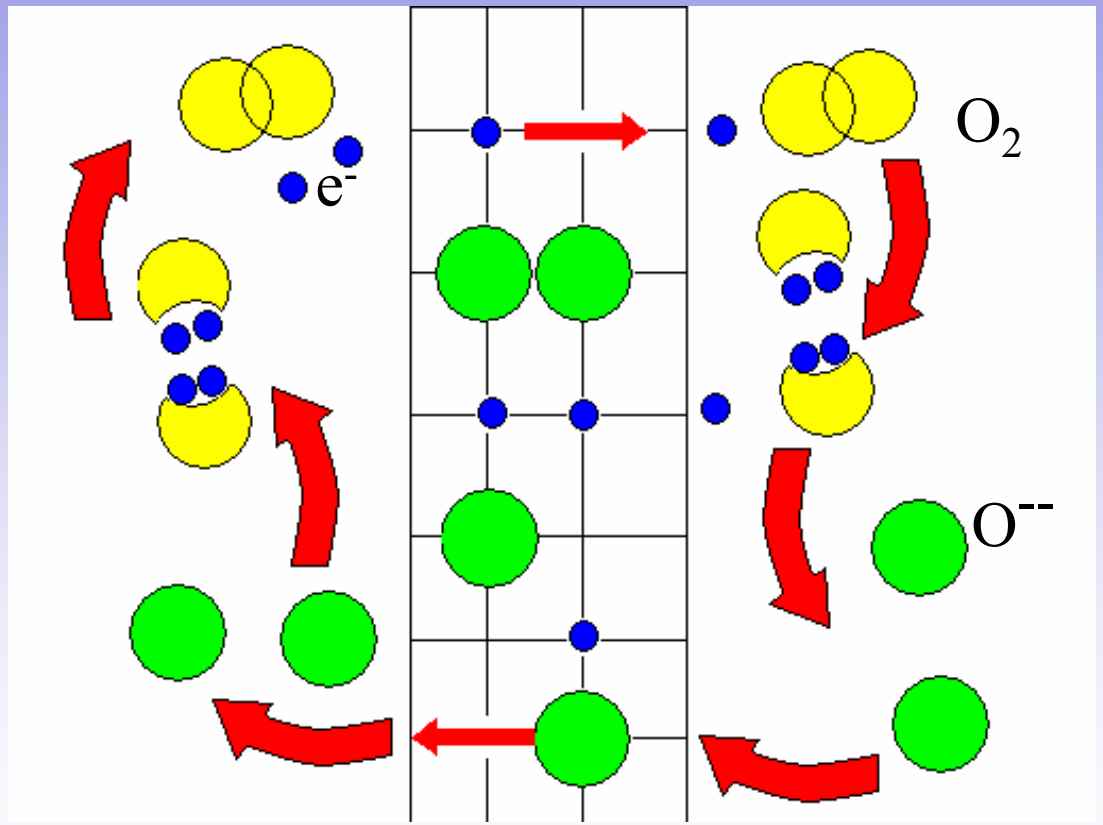


Which is best?

Experiments

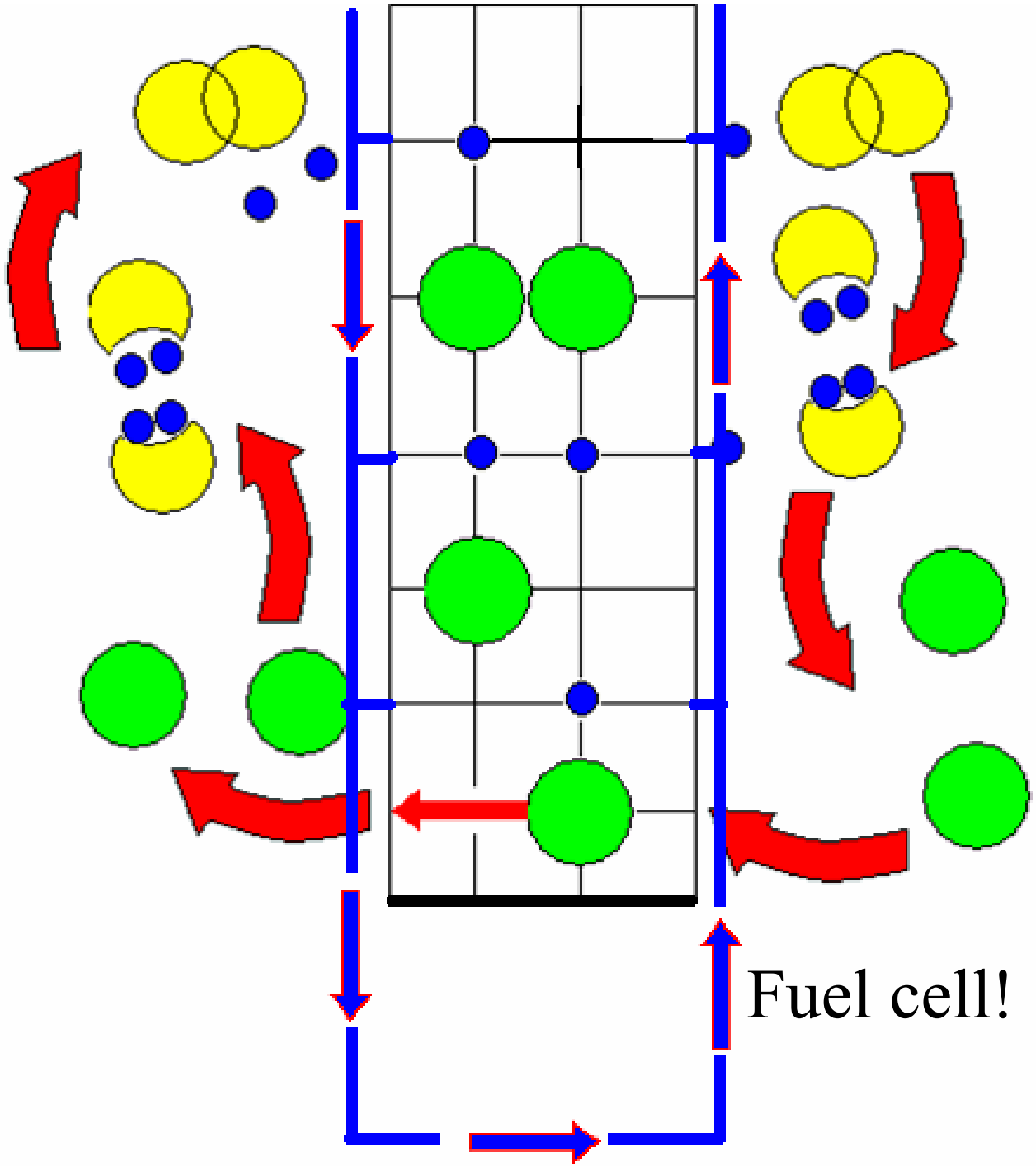
- Perovskite tubes
  - Up to 1000°C
- Fluorite tubes
  - Up to 2500°C
  - YSZ

Oxygen Ion Transport Membranes



YSZ

- Chosen for availability and high operating Temperature
- High ion transport properties
- Low electron transport properties
  - Oxygen transport is limited by electron transport
- Help electrons back to other side
  - More oxygen would pass through
- Tried to design such a rig


Fuel cell!

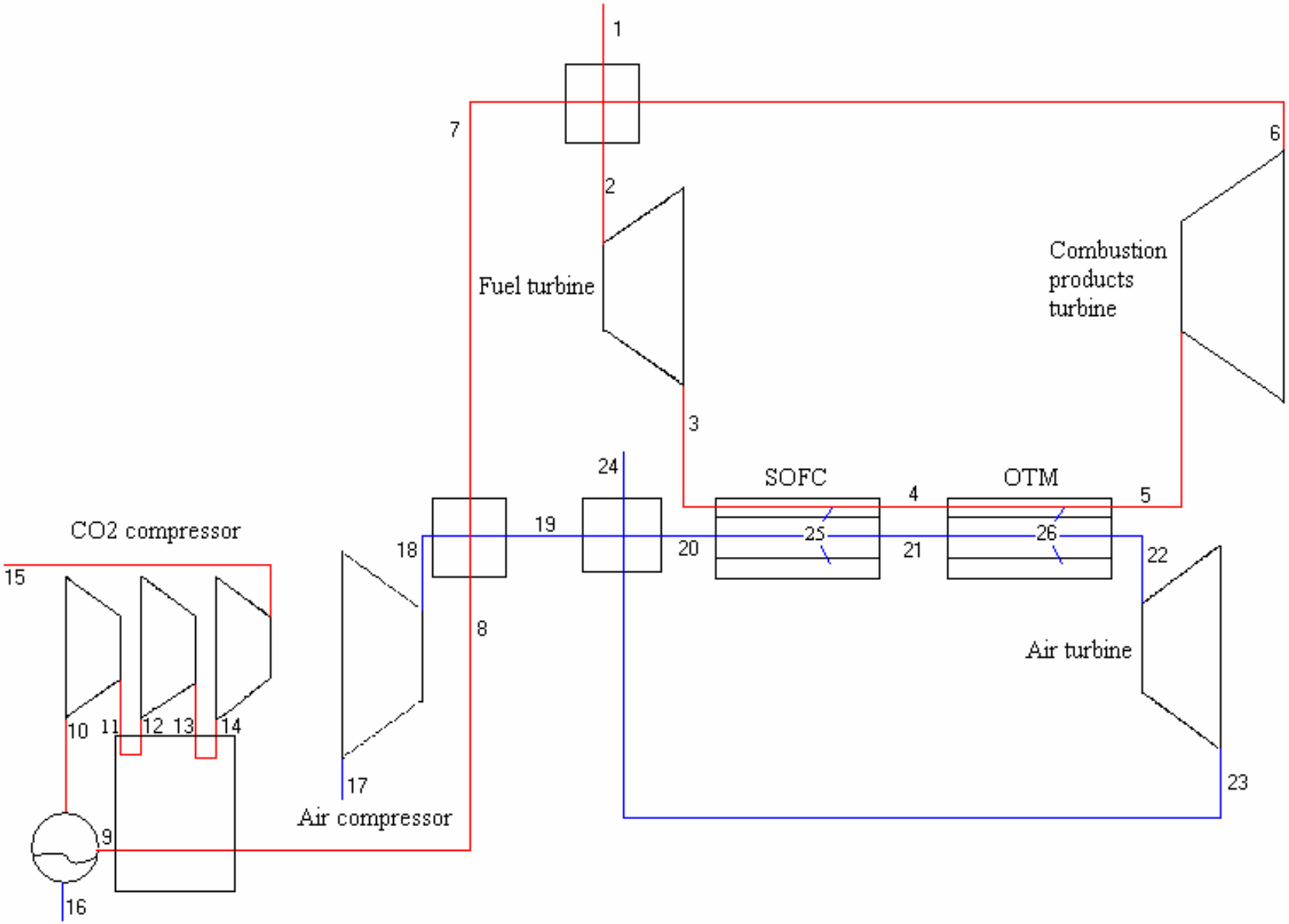
Fuel Cell!

- Obvious in retrospect
  - YSZ is a common electrolyte

- Why not use a fuel cell as the combustor in an oxycombustion plant?

OFFCET
Oxygen Fired Fuel Cell Energy Turbine

- Fuel is oxidised in fuel cell
  - Electricity is a byproduct
  - Fuel and oxidant (air) streams are heated
- Not all fuel can be used in fuel cell
  - Non-fuel cell OTM combustion after fuel cell
  - 2 options for this: combined and separate
- Exhaust gases enter gas turbine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Fuel turbine
Combustion products turbine
3
24
SOFC
OTM
4
5
CO2 compressor
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Air turbine
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Air compressor
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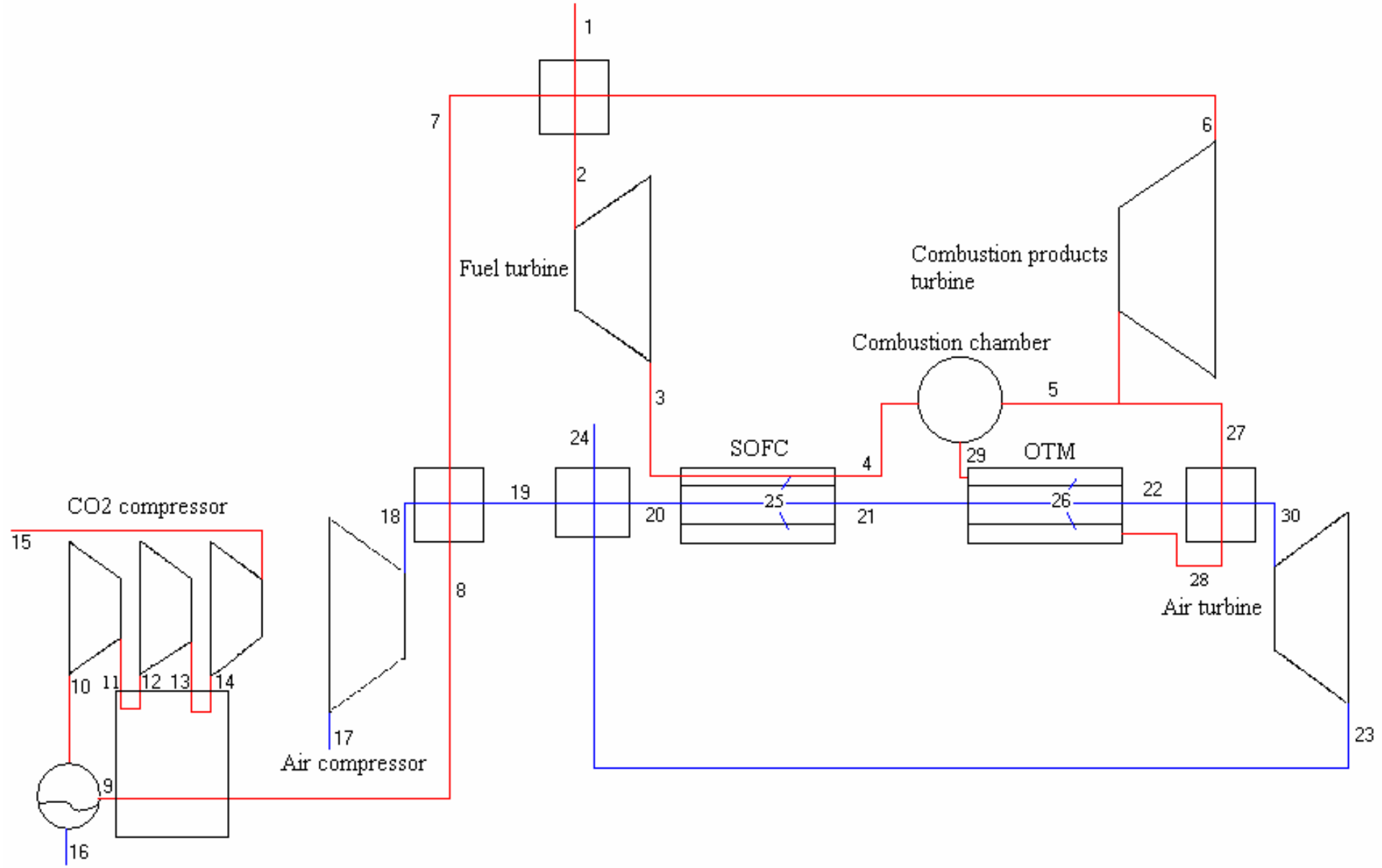
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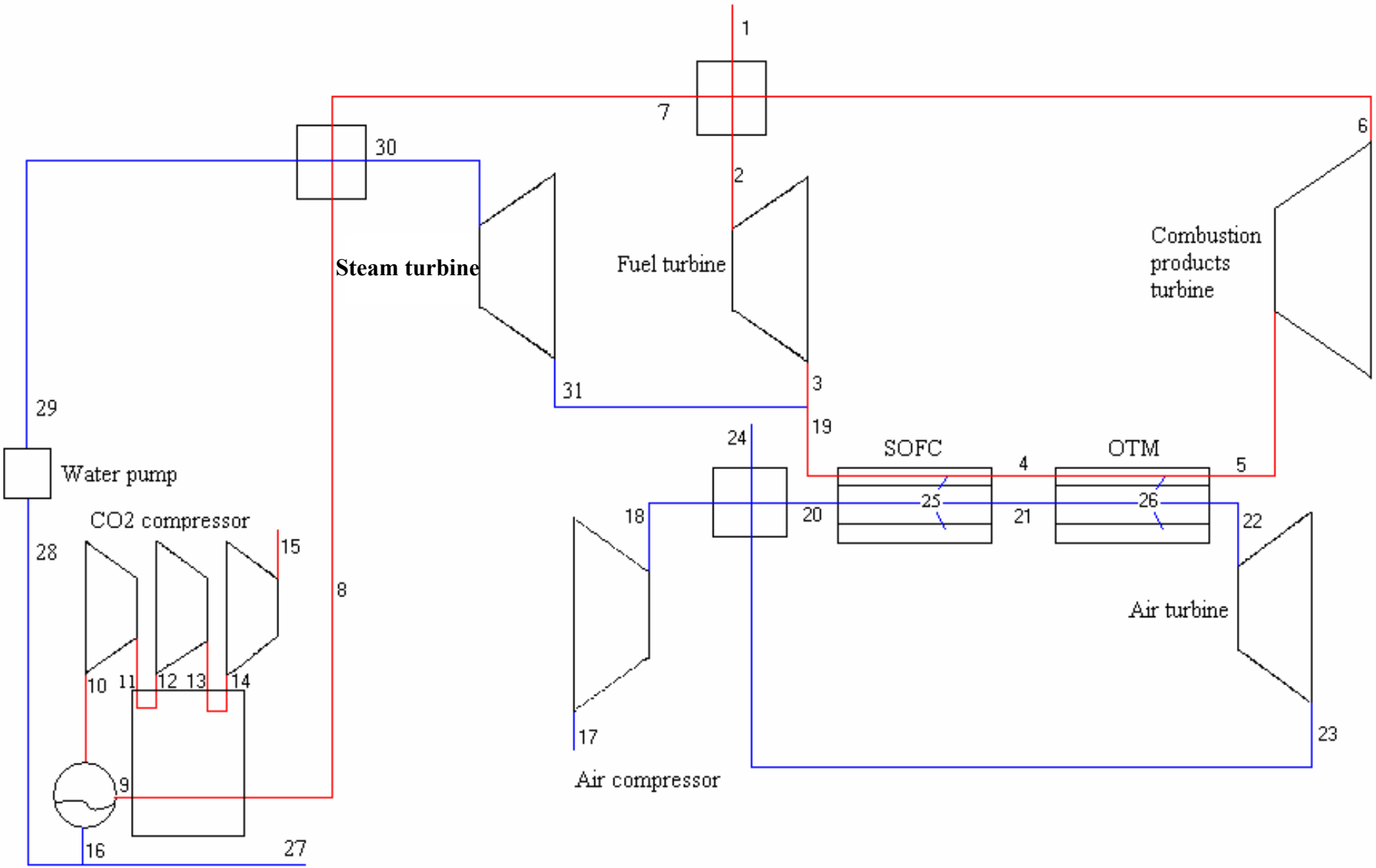
Fuel turbine
Combustion products turbine
Combustion chamber
SOFC
OTM
CO2 compressor
Air compressor
Air turbine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Steam turbine
Fuel turbine
Combustion products turbine
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SOFC
OTM
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Water pump
CO2 compressor
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Air turbine
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Air compressor
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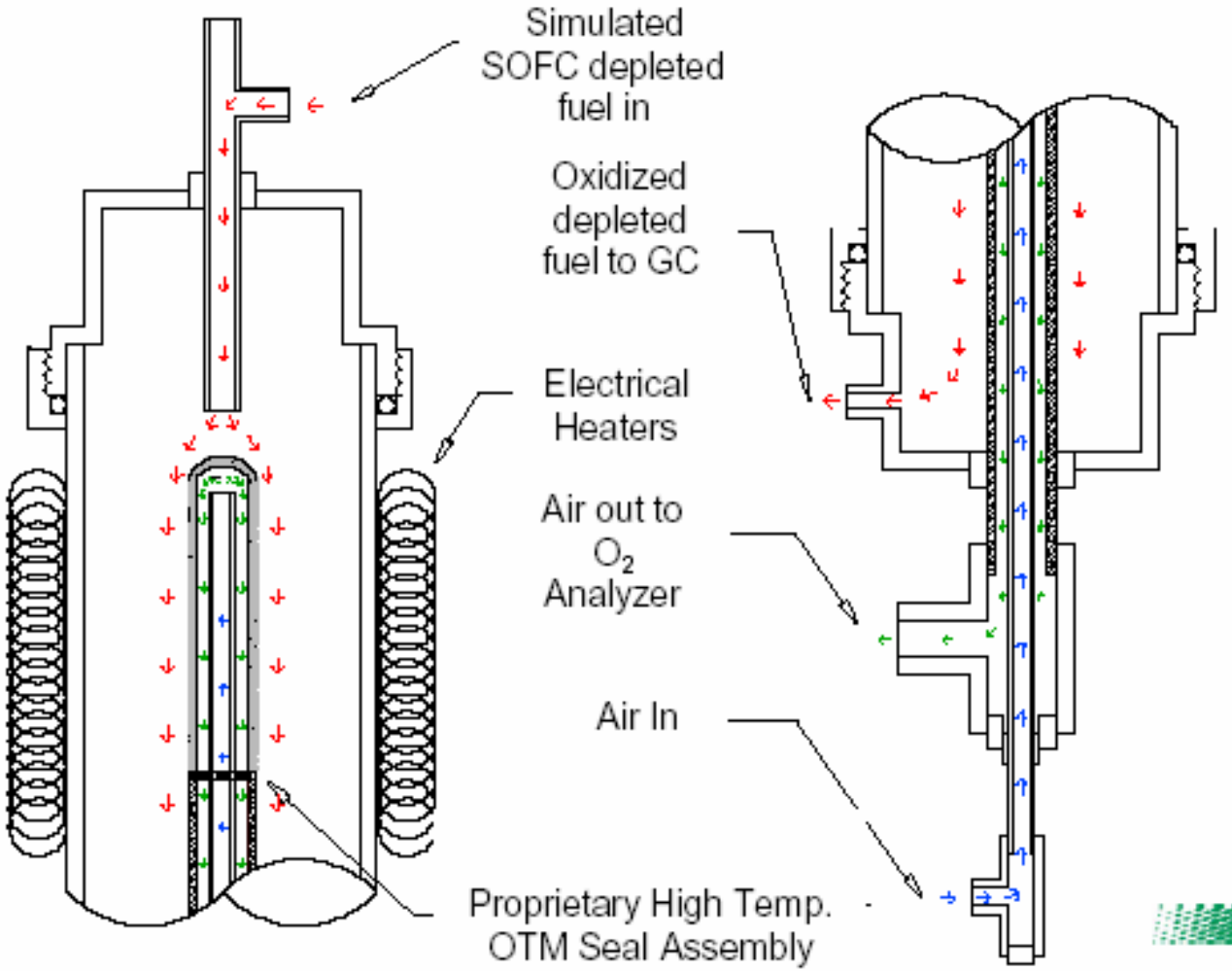
Zero Emission Power Plants with OTMs



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Good idea?

- Initial calculations

- Simplifications
  - Ideal gases
  - Adiabatic turbines/compressors
  - Constant pressure heat exchangers/fuel cell/OTM
  - SOFC and OTM are good heat exchangers
  - Complete stoichiometric combustion

SOFC model

- SOFC “block”
  - includes reformers and recirculation of fuel/air stream
  - Steady state
  - Constant voltage

- Conservation of energy:
  - All energy entering SOFC block must leave
  - Electrical power
  - Heat energy in fuel stream (anode gas)
  - Heat energy in air stream (cathode gas)
  - Unburned fuel

SOFC model

- 85% fuel utilized:

$CH_4 + 1.5725O_2 \rightarrow 0.15CH_4 + 0.765CO_2 + 1.53H_2O + 0.085CO + 0.17H_2 + 620$ kJ/mol

- Each mole of oxygen sends 4 moles of electrons through the outer circuit
  - Current directly proportional to oxygen flow
  - Electrical work is voltage times current
  - The rest of the 620kJ increases temperatures

Efficiency from simplified analysis

- ZEITMOP (initial focus of project)

  68%

- OFFCET

  66%

Conclusion

- OFFCET warrants further investigation
- Collaboration welcomed