Status of ARIES-CS Power Core Engineering

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ARIES Meeting
UW
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Major Focus of Engineering Effort During Phase II

(from last meeting)

1. **Divertor design and analysis**

2. **Detailed design and analysis of dual coolant concept with a self-cooled Pb-17Li zone and He-cooled RAFS structure:**
   - **Modular concept first (port-based maintenance)**
   - **Field-period based maintenance concept next**

3. **Coil cross-section (including insulation + structural support)**
   - **Do we need to do structural analysis?**

4. **Integration with credible details about design of different components, maintenance and ancillary equipment for both maintenance schemes.**

Action Items for Phase II (from previous meetings)

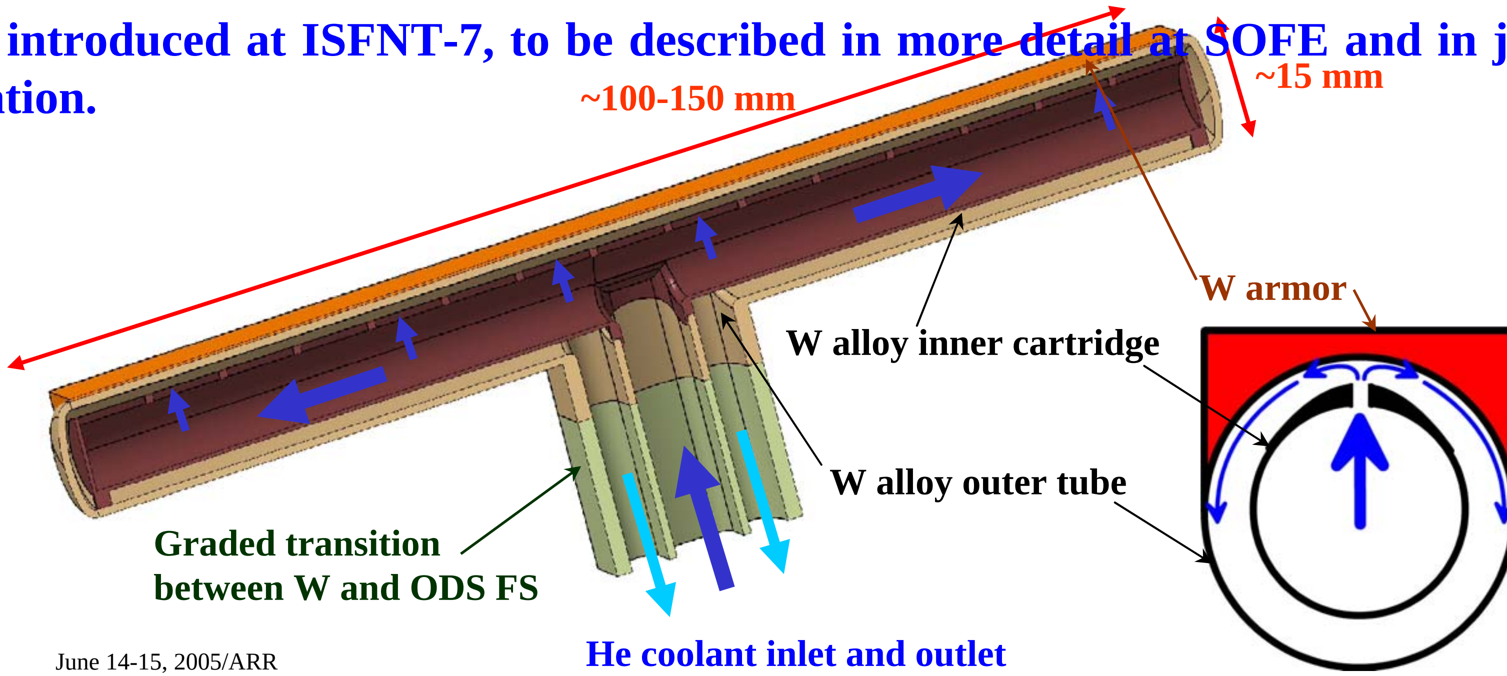
1. Run LOCA/LOFA case with low contact resistance between blanket and hot shield (UW)
2. Check effect of local radial conductance in blanket and between shield and vacuum vessel (UW)
3. Do we need to consider any other accident scenario? (INEL/UW) LOVA
4. Structural analysis of coil support to have a better definition of required thickness for cases with separate coil structure for each field period (MIT)
5. Details of module attachment and replacement (choice between "single" module maintenance or "series" module maintenance) (FNTC/UCSD)
6. Port maintenance including all pipes and lines (realistic 3-D layout including accommodation of all penetrations) (UCSD)
   Details of module design and thermal-hydraulic analysis for dual coolant design coupled to Brayton power cycle(FNTC/UCSD)
7. Coolant lines coupling to the heat exchanger (choice of HX material, e.g. W-coated FS vs. refractory alloy such as niobium alloy) (FNTC/UCSD/INEL)
8. Tritium extraction system for Pb-17Li + tritium inventories (FNTC/UCSD/INEL)
9. How high can we push the Pb-17Li/FS interface temperature based on corrosion limits? (FNTC/UCSD)
10. External vacuum vessel design (thickness and configuration) (FNTC/UCSD)
11. Divertor design and analysis (T. Ihli/UCSD)

Divertor Study

- **Major focus of ARIES Phase-II effort (Good Progress)**
  - Physics modeling to better assess divertor location and heat loads
  - Engineering effort to evolve a suitable design to accommodate a max. q'' of at least 10 MW/m^2.
  - Productive collaboration with FZK

- **Build on the W cap design and explore possibility of a new mid-size configuration with good q'' accommodation potential, reasonably simple (and credible) manufacturing and assembly procedures, and which could be well integrated in the CS reactor design.**
  - "T-tube" configuration (~10 cm)
  - Cooling with discrete or continuous jets
  - Consistent CFD analysis results from Georgia Tech. and FZK

- **Design introduced at ISFNT-7, to be described in more detail at SOFE and in journal publication.**



Coil Structural Analysis

- Need structural analysis of coil support to have a better definition of required thickness for cases with separate coil structure for each field period (MIT)
- Steady-state case (no disruption). Need force definition based on coil current and stress analysis
- Lack of progress - UCSD action item

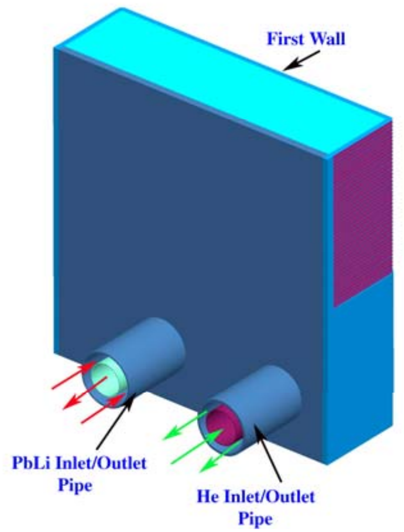
Ancillary Equipment

- **Tritium extraction and recovery method**
- **Heat exchanger design and material choice**
  - **Connection to blanket structural material**
  - **Compatibility with Pb-17Li at a temperature of up to ~700-800°C**
  - **Ni?**
- **Can benefit from effort on ITER test module, which can be updated and applied to our blanket configuration (B. Merrill)**

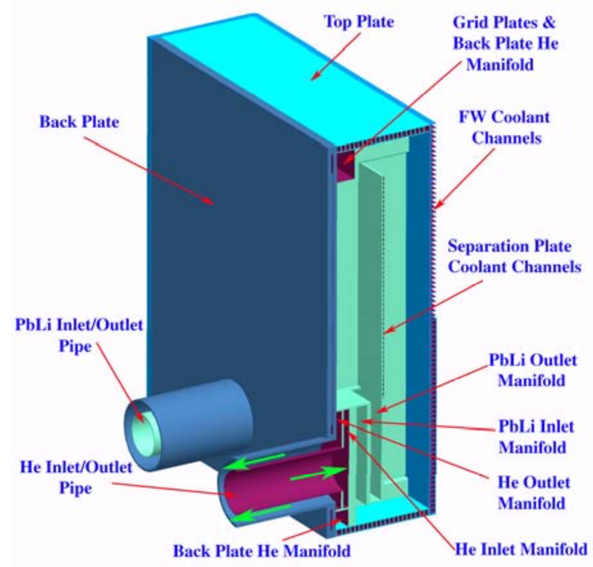
Dual Coolant Module Design

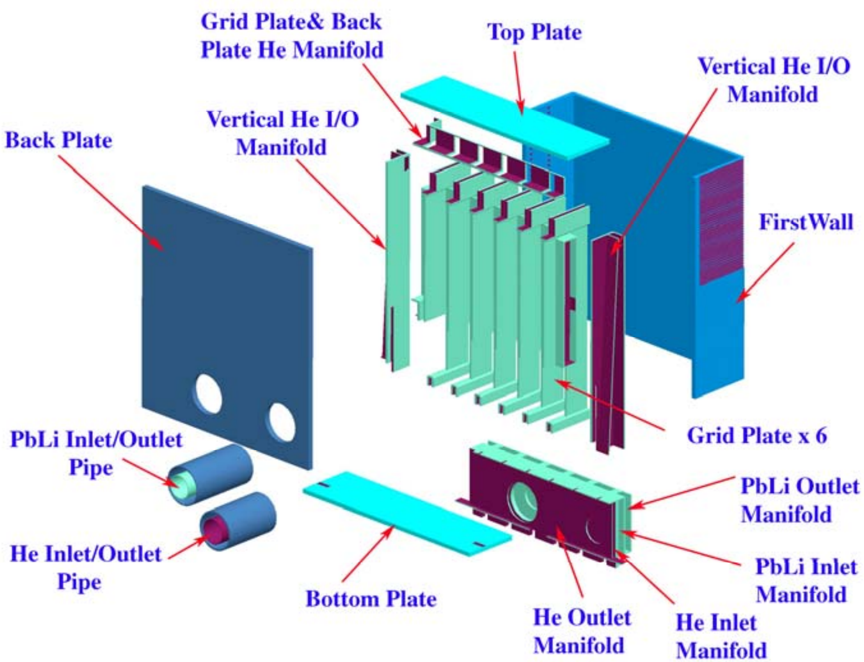
- Updated design and cooling configuration for dual-coolant blanket modular concept.
- Thermal-hydraulic analysis of blanket coupled to Brayton cycle (further optimization).
- Maintenance of DC concept requires pipe cutting behind module.
  - In-bore or outside access for pipe cutting and rewelding
  - Visit of K. Ioki and F. Elio in March (ITER JCT) for discussion
    - Pipe cutting and welding from outside commercially available
    - Some concern about space tightness in bottom of chamber for manoeuvring articulated boom.
- Latest progress summarized at ISFNT-7.

Dual Coolant Blanket Module Redesigned for Simpler More Effective Coolant Routing

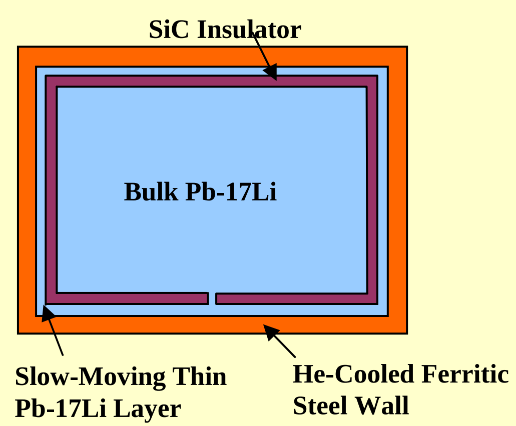


- 8 MPa He to cool FW toroidally and box
- Slow flowing (<10 cm/s) Pb-17Li in inner channels
- RAFS used (T_{max}<550°C)



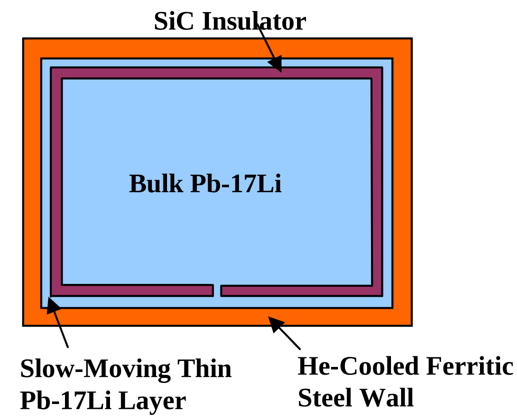


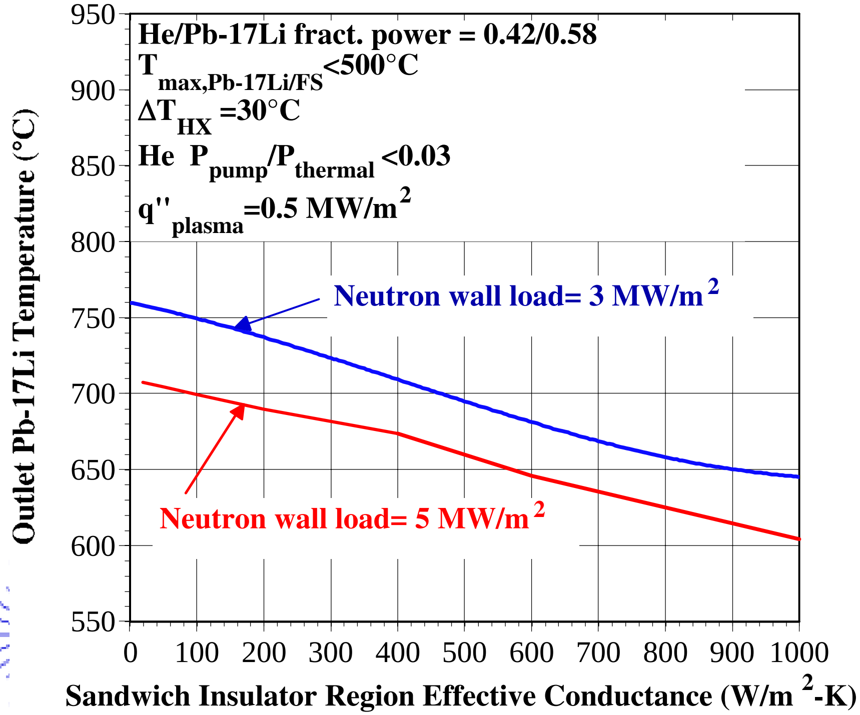
- SiC insulator lining Pb-17 Li channel for thermal and electrical insulation to maximize $T_{Pb\text{-}17\ Li}$ and minimize MHD ΔP while accommodating compatibility limit $T_{FS/Pb\text{-}17Li}$ <500°C

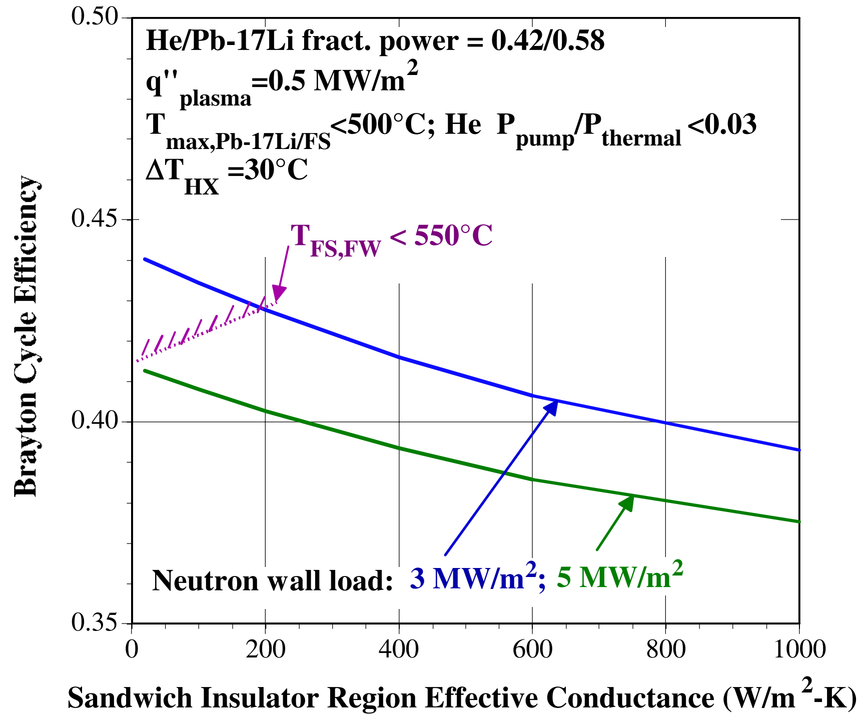


Initial Parametric Study of Pb-17Li/He DC Blanket Coupled to a Brayton Cycle through as HX

- Brayton Cycle with a single expansion stage and 3-stage compression assumed
- For an insulator conductance of 200 W/m²-K, η_{cycle} ~ 0.4 for Γ_n = 5 MW/m² and η_{cycle} ~ 0.43 for Γ_n = 3 MW/m²
- Can we do better (e.g. use ODS-FS in FW to increase the FS temp. limit; and assume a higher Pb-17Li/FS compatibility limit)?

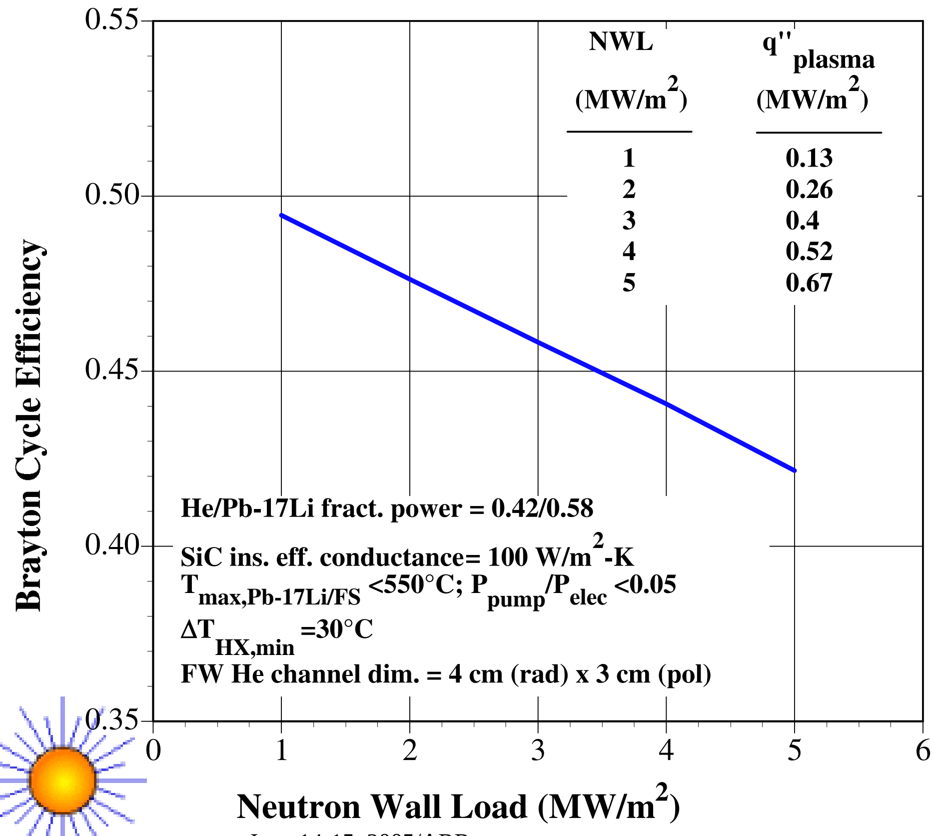


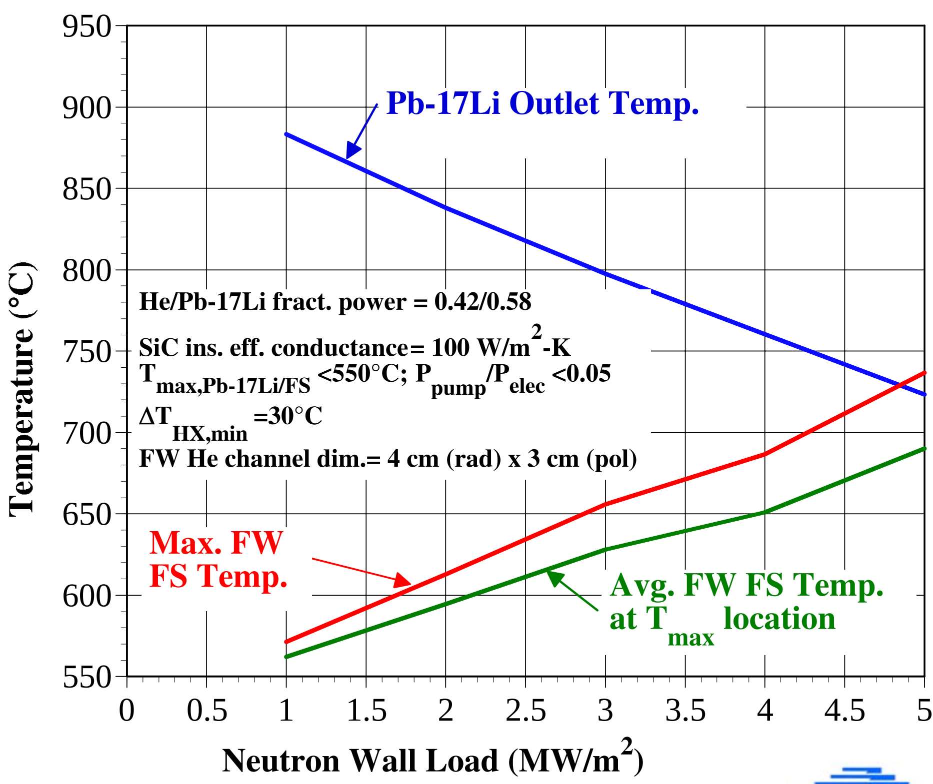




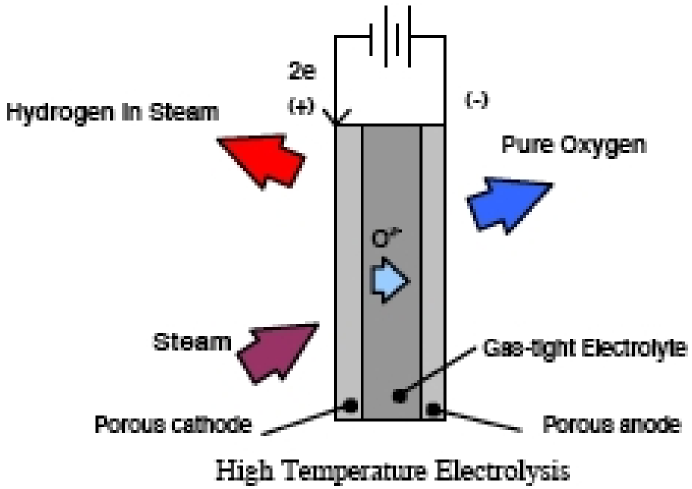
Further Optimization of DC Blanket Coupled to Brayton Cycle

- Are optimized parameter values reasonable?
- Some advantage at reducing wall load: higher cycle eff., higher Pb-17Li temp. (could be utilized for H_2 production if so desired)
- Cycle efficiency could be tweaked to exceed value corresponding to max. wall load by considering also lower wall load module (but difficult)
- Cycle eff. dependency on wall load should be considered in system study (update values previously provided to Jim)





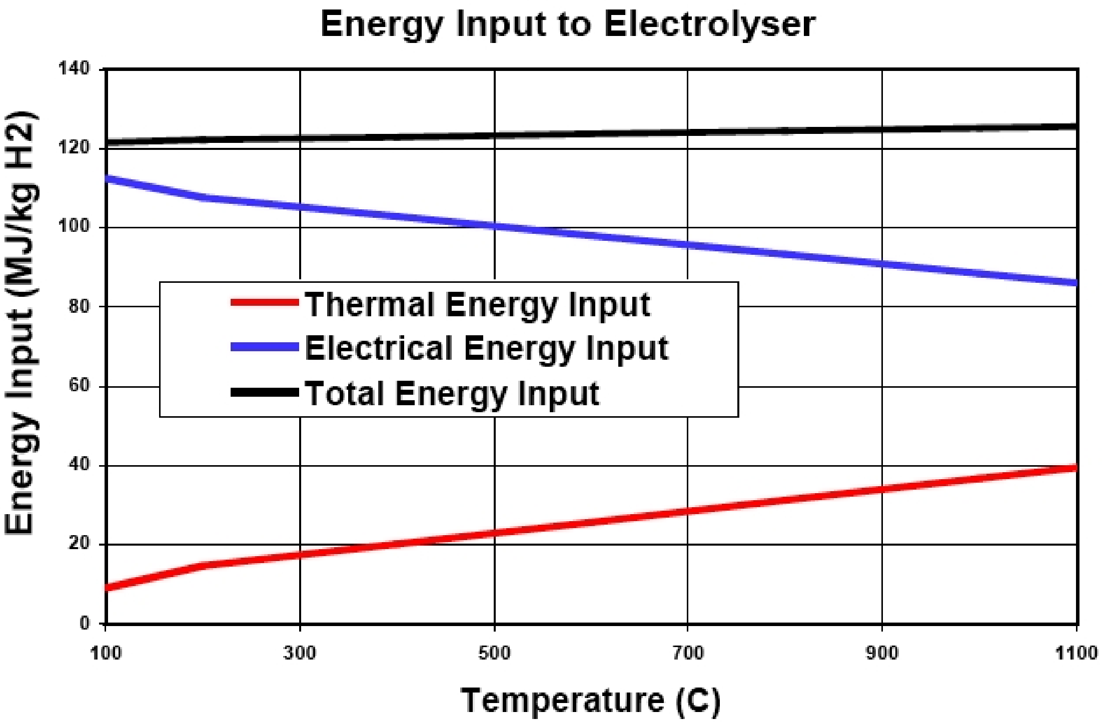
Different H_2 Production Methods Exist - High Temperature Electrolysis Used as Example Here



$H_2 (g) + 1/2\ O_2 (g) = H_2O (g)$

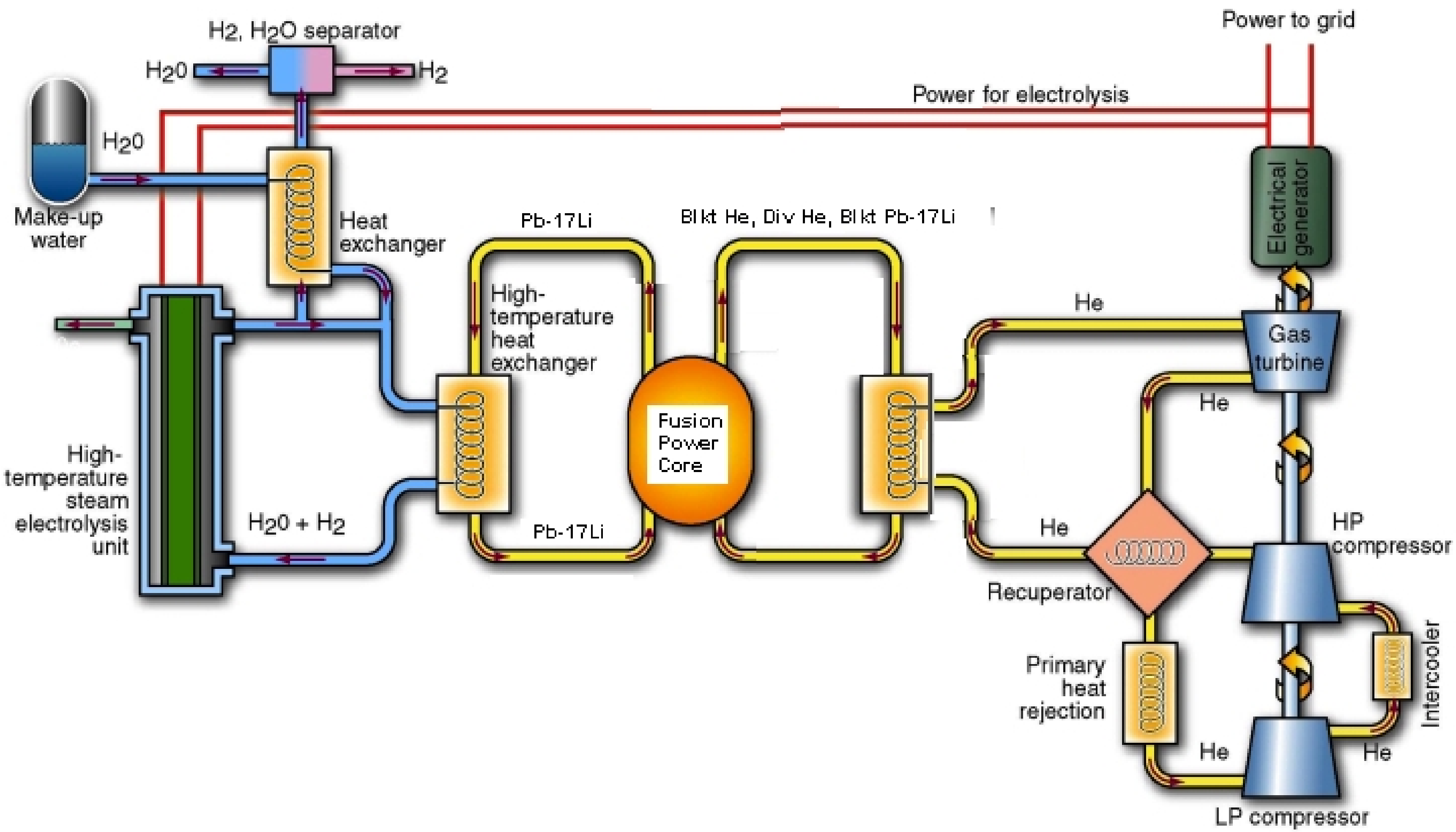
$\Delta H = -241.8$ kJ/mol

$$\eta_{H_2} = \frac{Energy_{out}(\Delta H)}{Energy_{in}(thermal)}$$



Adapted from S. Herring's May 15, 2002 presentation:"High Temperature Electrolysis Using Solid Oxide Fuel Cell Technology," INEEL

Possible Use of Dual Coolant Blanket for H_2 Production + Power Generation



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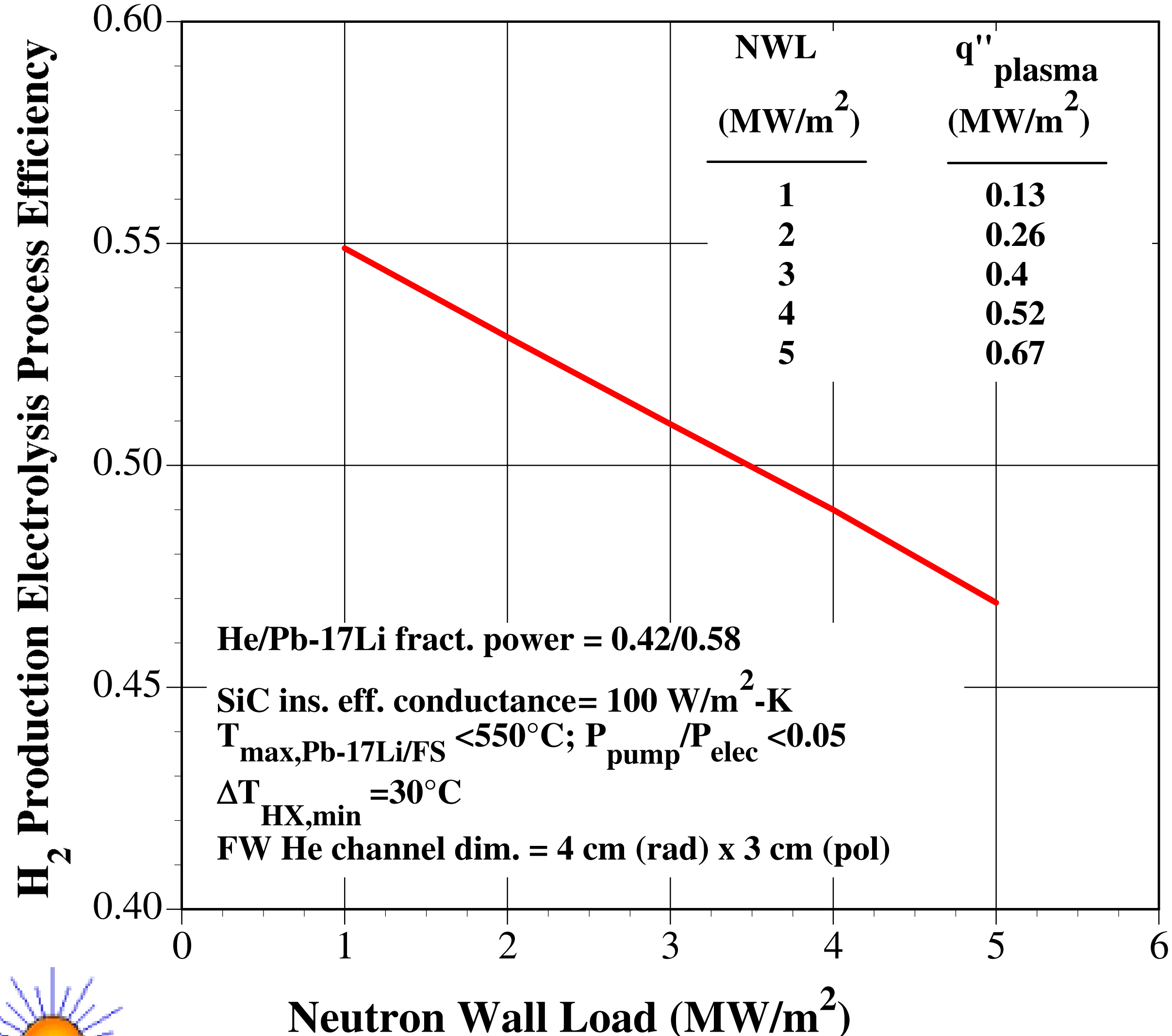
Efficiency of High Temperature Electrolysis for H_2 Production Using DC Blanket



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Interesting possibility if so desired in the future