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Heat Transfer within a Ceramic Heat Exchanger used for Sulphuric Acid Decomposition

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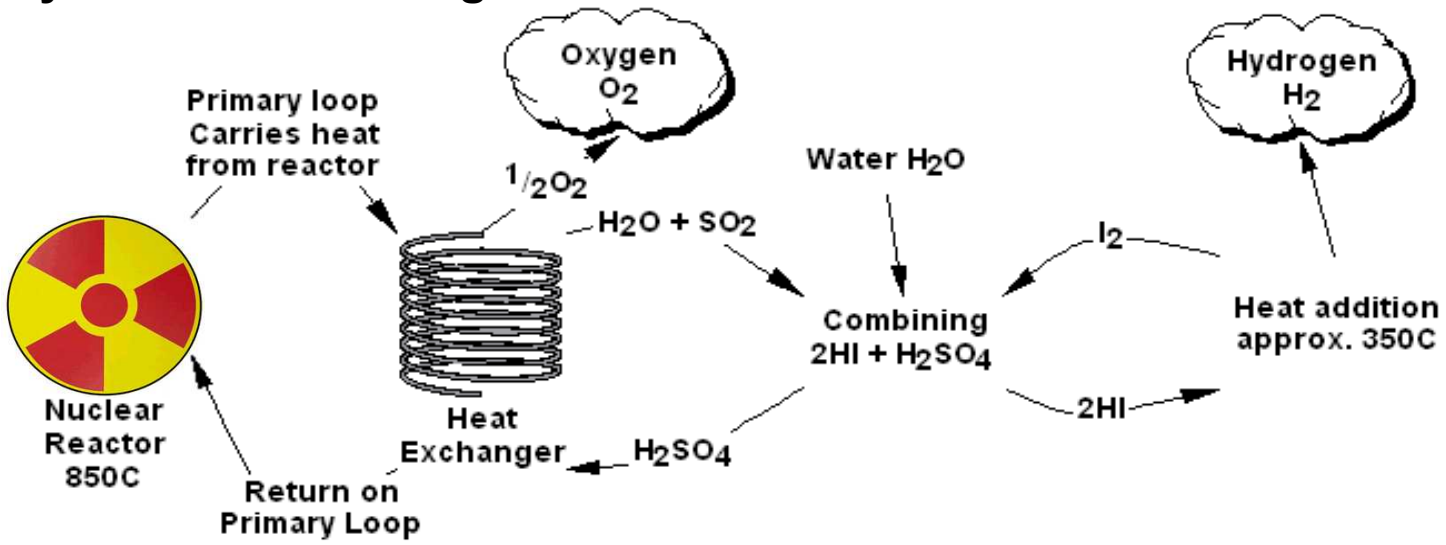
Introduction

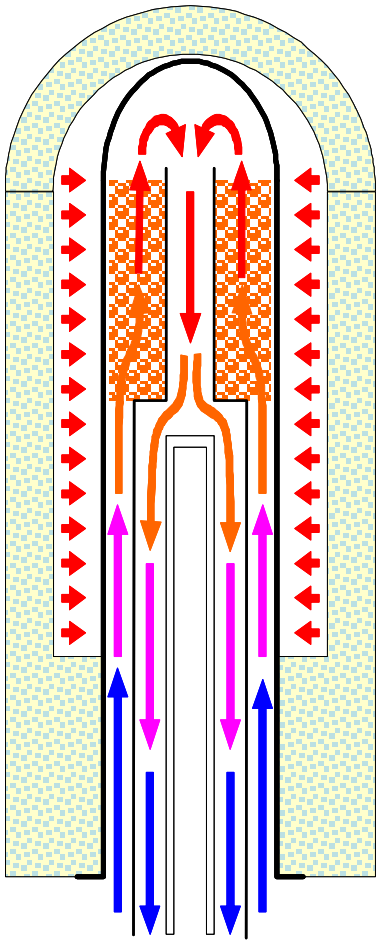
1. Materials constraints
2. Ceramic Hex
3. Initial water experiments to verify Nusselt Numbers
4. Acid experiments
5. Nodal model with acid as working fluid
6. Apply to solar and nuclear application

Materials Constraints (1)

- Previous experiments at SNL have highlighted the metallic based materials will not withstand the H2SO4 corrosive environment – Figure to Right.
- Changed approach to Ceramic (Silicon Carbide) bayonet heat exchanger.
- Bayonet design has added advantage of heat recuperation within the one device.

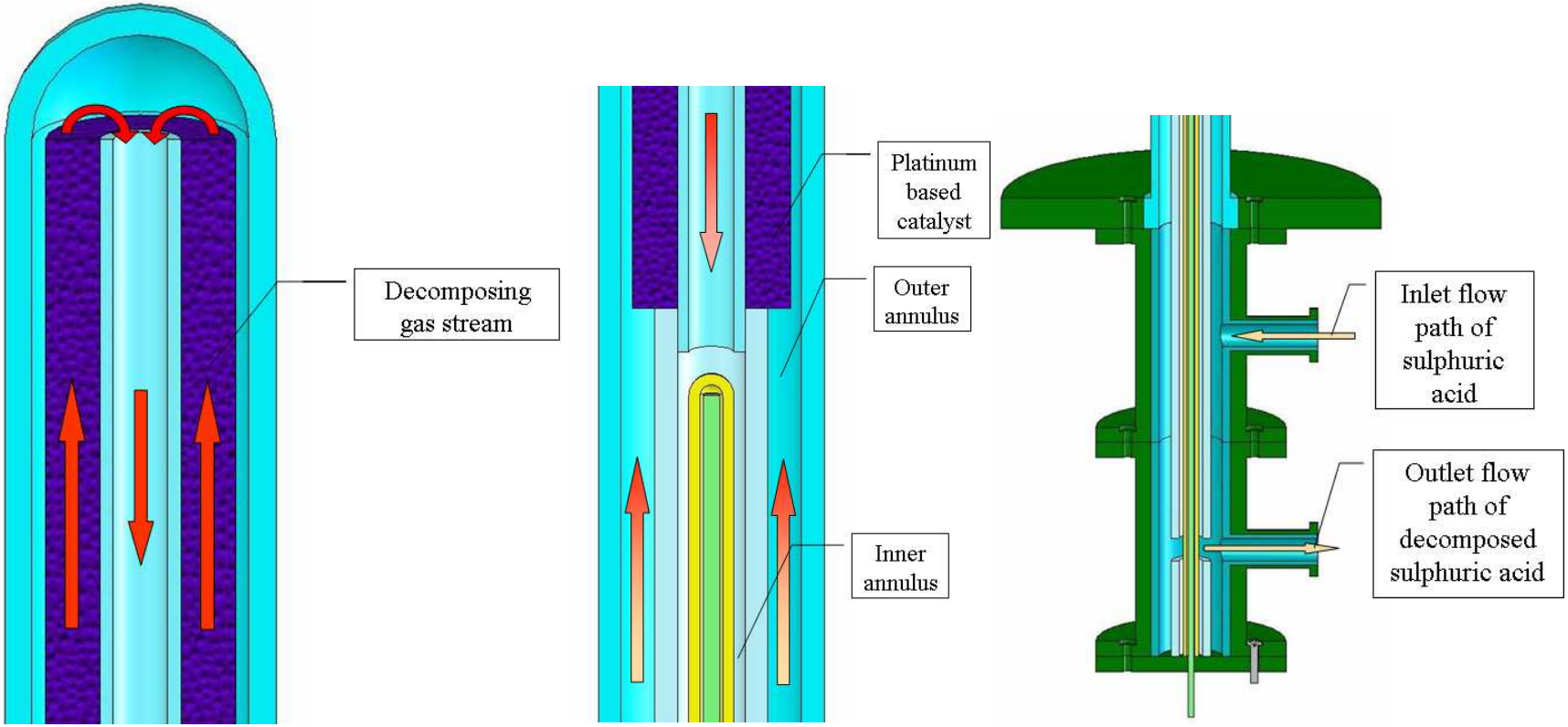


Ceramic Heat Exchanger (1)



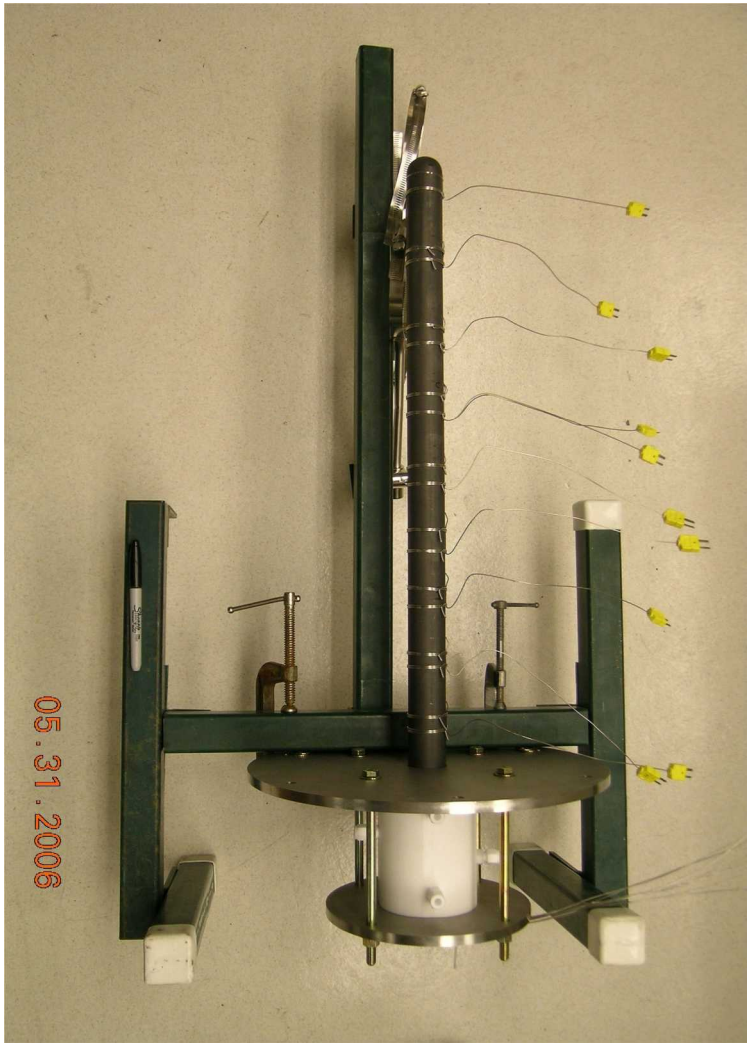
- Bayonet type heat exchanger reported in open literature in 1946 by Norman L. Hurd.
- Bayonet heat exchanger consists of one closed ended tube co-axially aligned with an open ended tube forming two annuli.
- Advantages bayonet for the S-I cycle is the internal recuperation, one connection at cool end, corrosion resistance and fabrication cost.
- Silicon Carbide Bayonets (Thermocouple tubes) are existing item.
- For instrumentation and to add recuperation additional tube is added in center.

Ceramic Heat Exchanger (2)

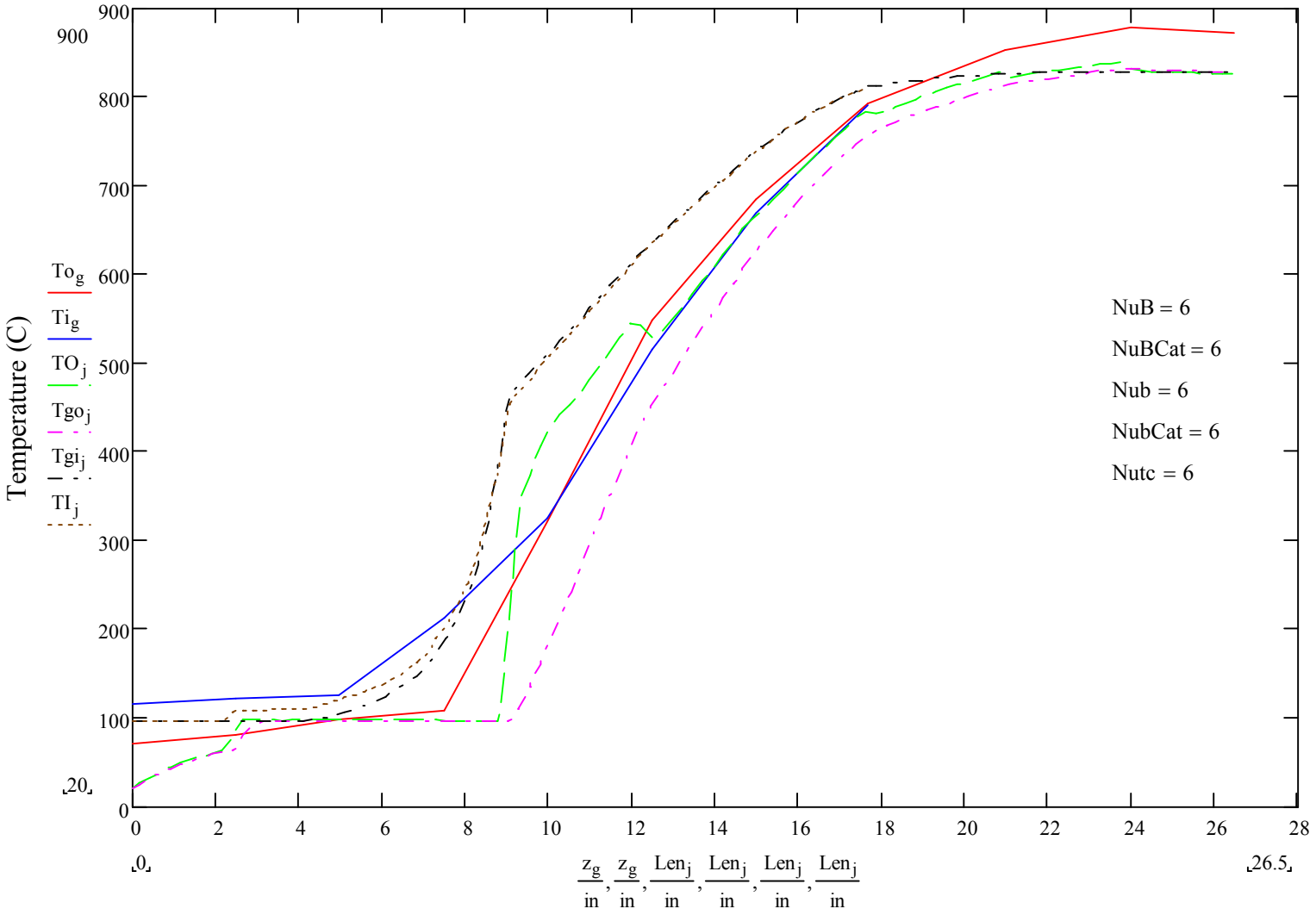


Initial water experiments (1)

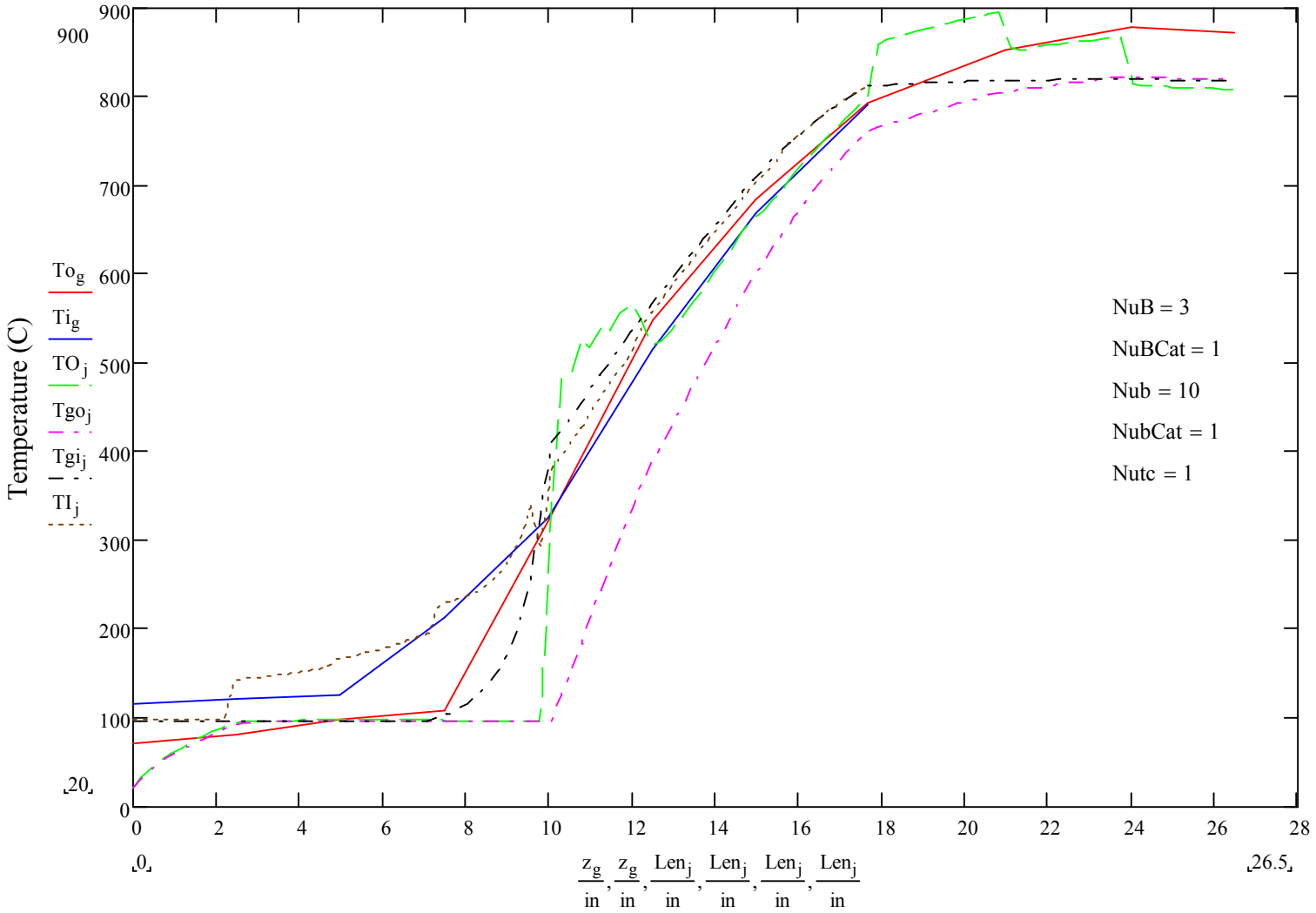
- 27 Inch Bayonet constructed ready for use with acid – Platinum catalyst added.
- Tested at flow rates of 5, 10 and 15 mL/min.
- Temperature data used to determine Nusselt numbers.
- Analyzed data with iterative nodal approach.



Initial water experiments (2)

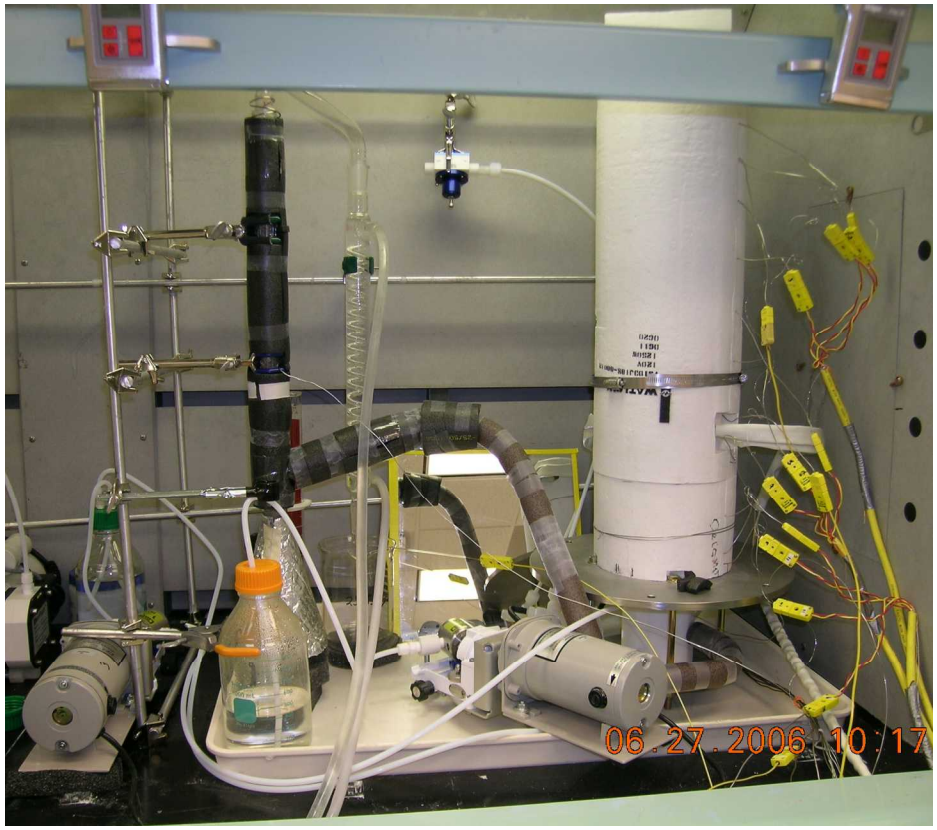


Initial water experiments (3)

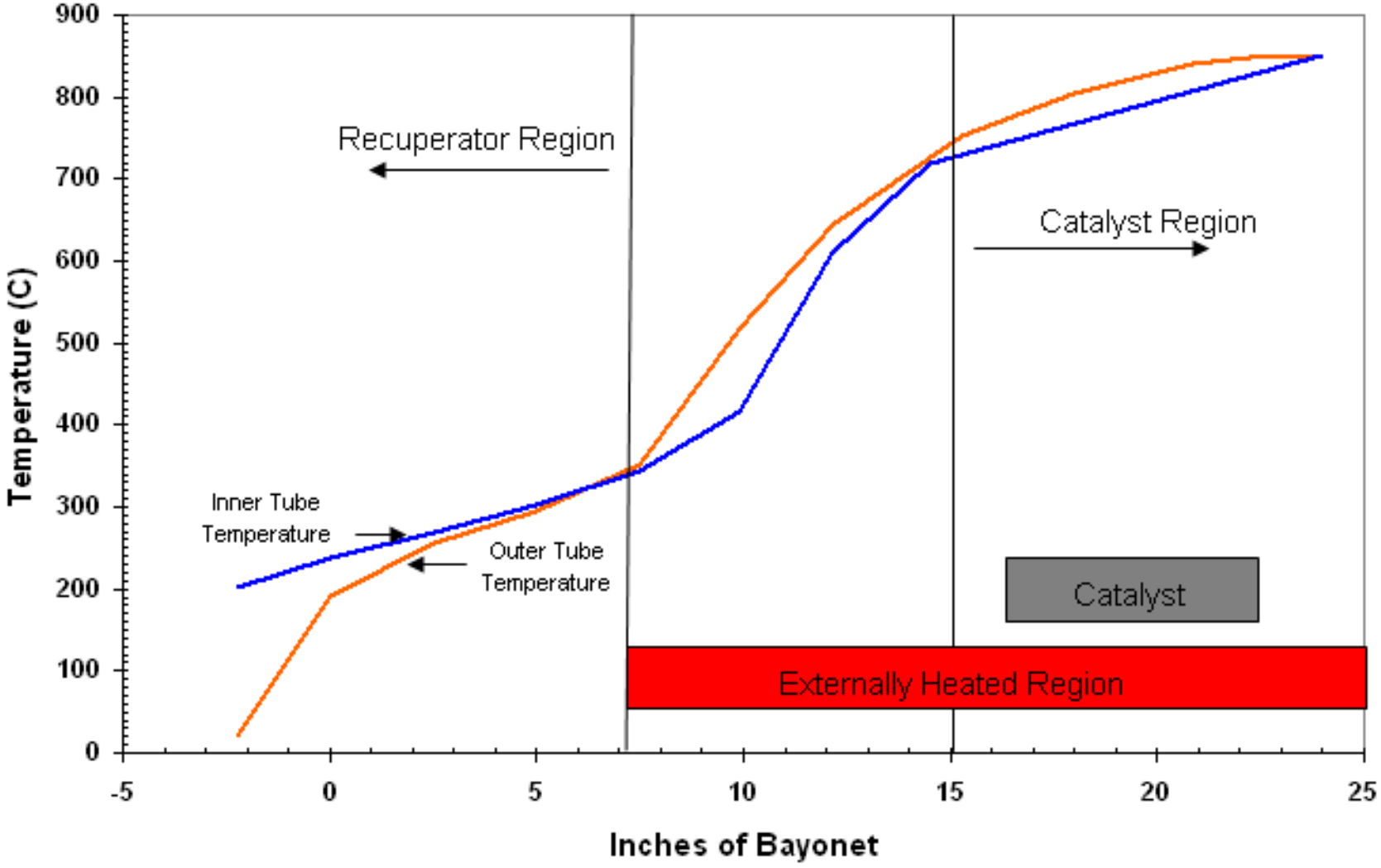


Acid Experiments (1)

- Temperature data collected at flow rates of 5, 10 and 15mL/min.
- Decomposition measured by mass balance giving a conversion ratio of 60%.



Acid experiments (2)



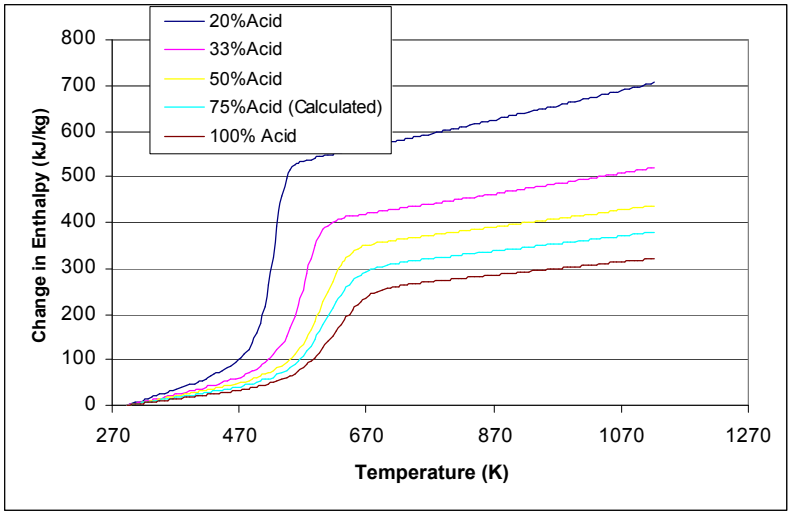
Nodal Model with Acid (1)

- Applying Nusselt numbers from water and acid bayonet tests a program will be written.
- Sulphuric acid properties (H,Cp,K).
- HSC Chemistry 5
- Constrain SO3 before catalyst
- Decompose during catalyst – 1 mole of SO2 at 850C
- Cooling constant SO2 and O2.
- Enthalpy for cooling summed.
- Thermal conductivities from equilibrium percentage at each temperature.
- Original thermal conductivities from quadratic polynomials.

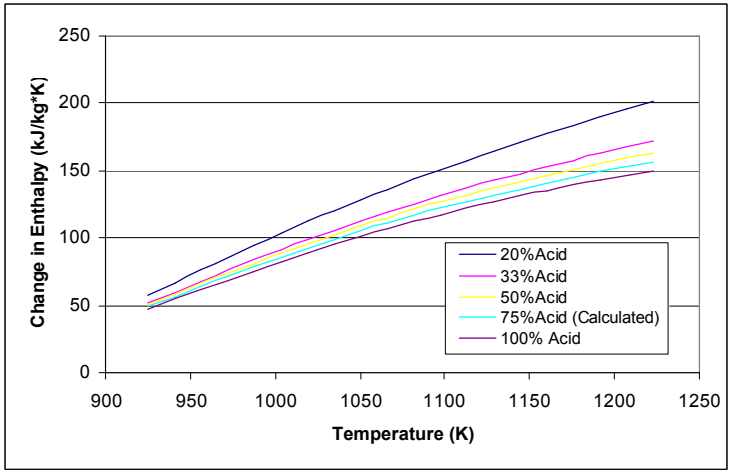
Nodal Model with Acid (2)

- **Change in enthalpy through the bayonet.**

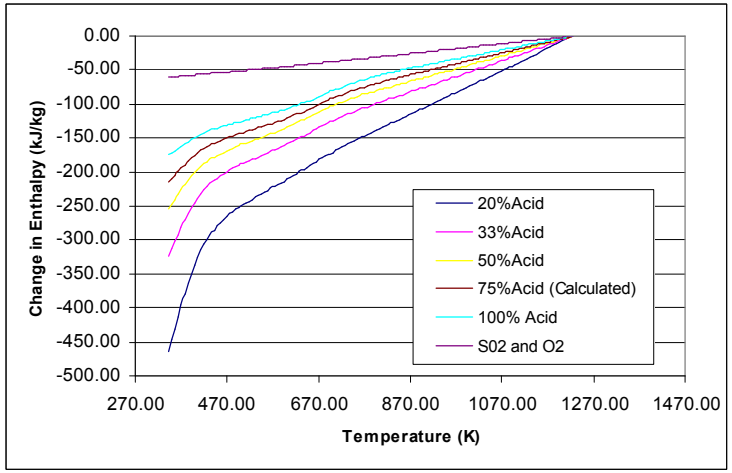
Phase change with constrained SO3



Decomposed inside of catalyst



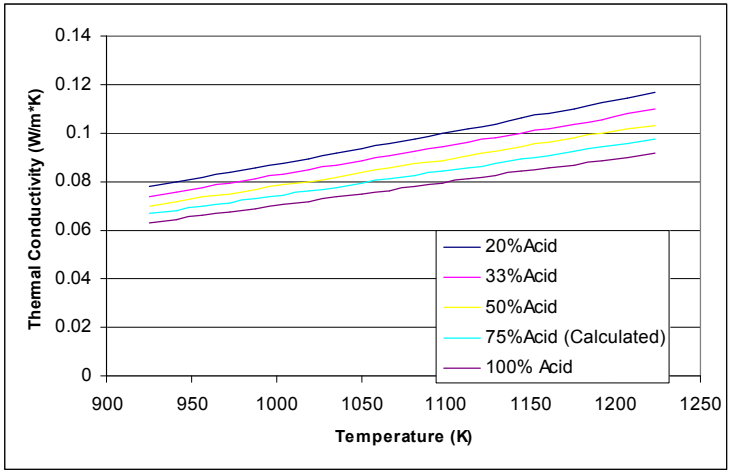
Cooling once decomposed



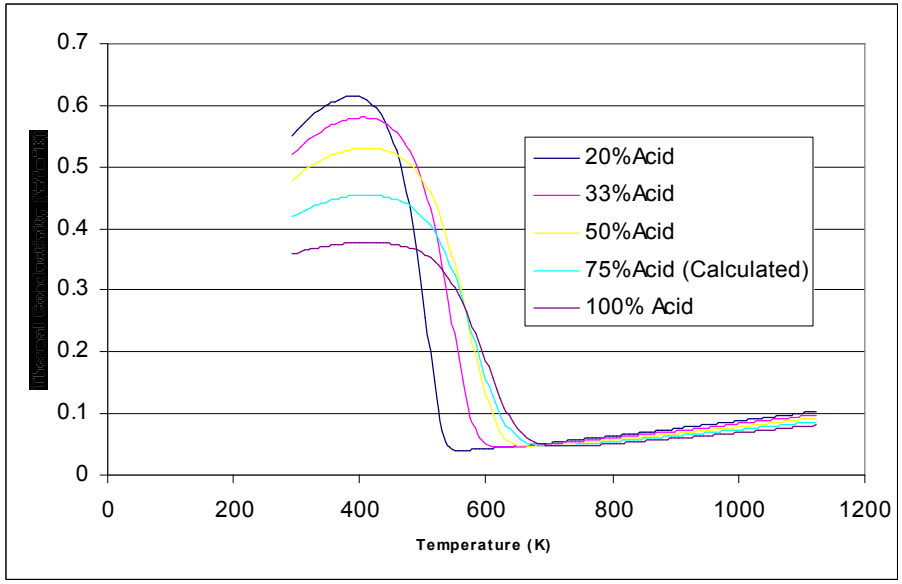
Nodal Model with Acid (3)

- **Thermal conductivity as a function of temperature**

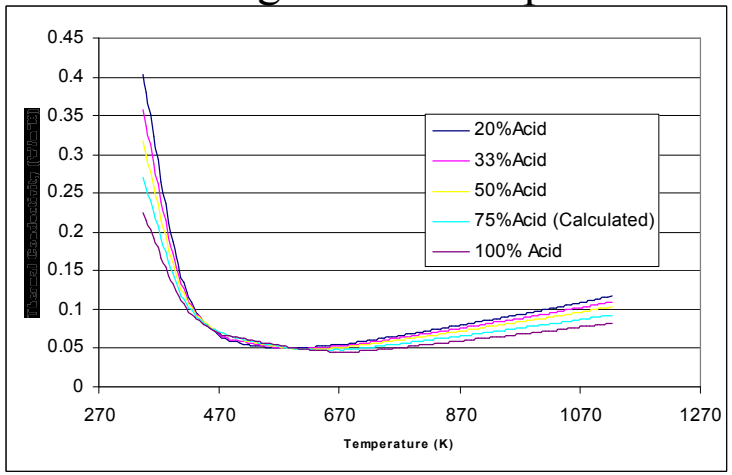
Decomposed inside of catalyst



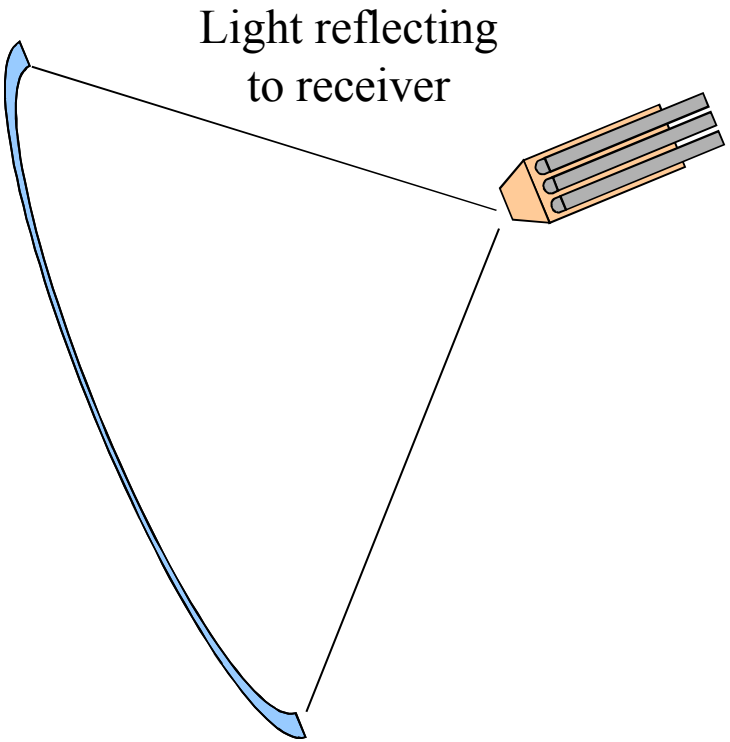
Phase change with constrained SO3



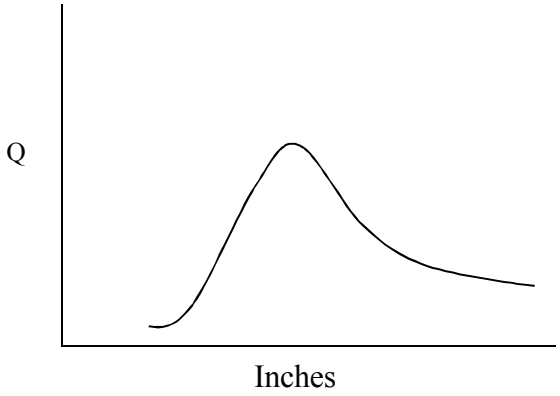
Cooling once decomposed

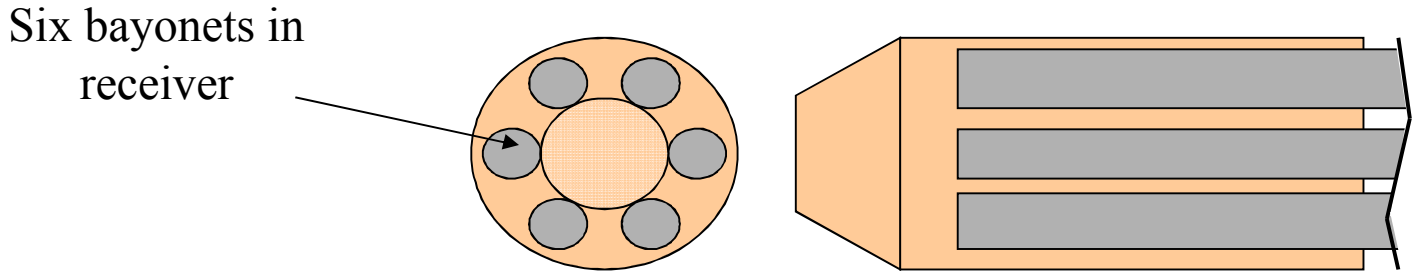


Solar/Bayonet Integration (1)



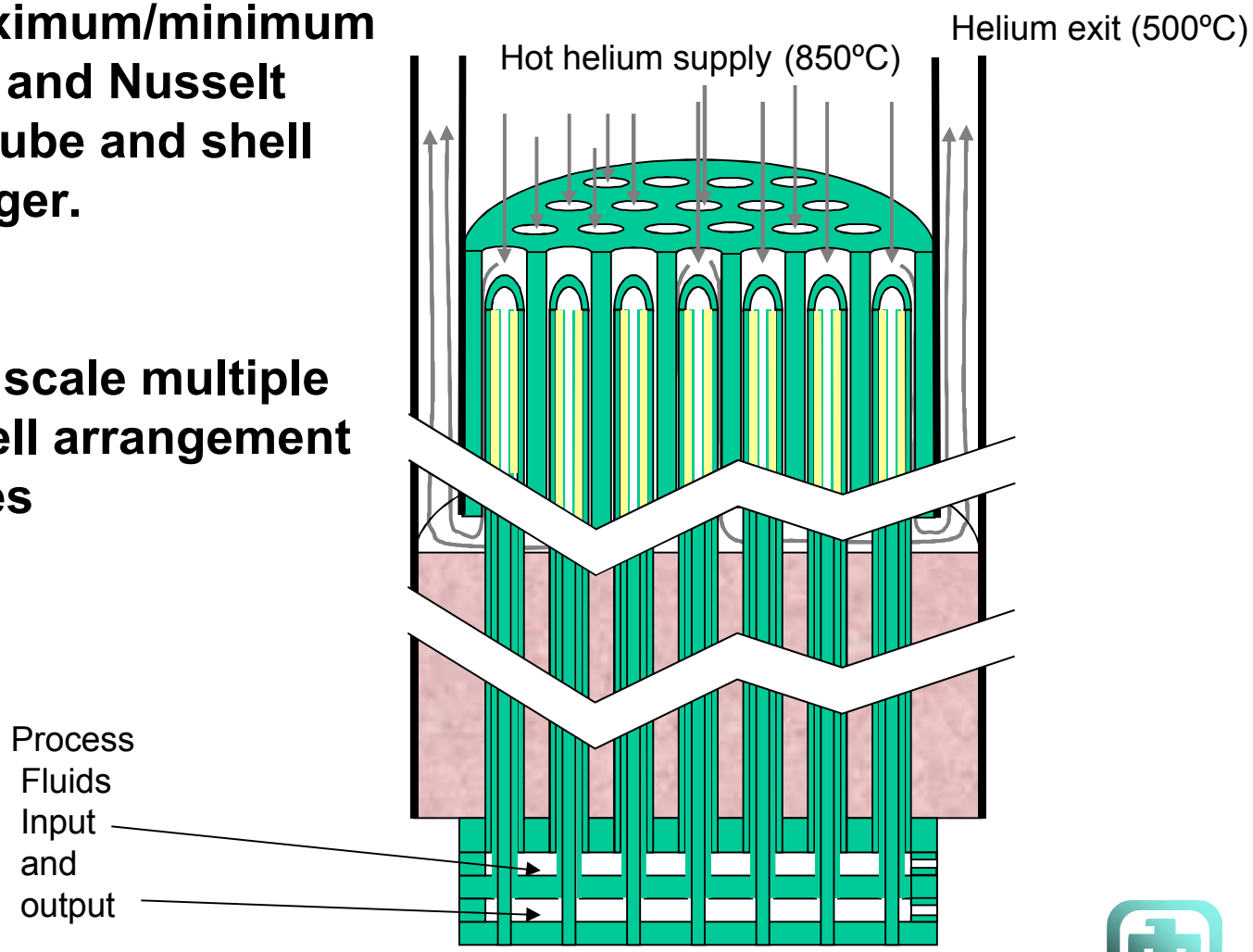
- **Thermal (Q) distribution along bayonet from solar dish/array.**
- **Currently looking into black body receiver designs.**





Nuclear/Bayonet Integration (1)

- **Assume maximum/minimum temperature and Nusselt number for tube and shell heat exchanger.**
- **HTGR**
- **Commercial scale multiple tube and shell arrangement with 14’ tubes**



Summary

Silicon Carbide bayonet heat exchanger overcomes materials issues and provides a compact decomposer capable of being used for solar and nuclear applications.

Early experiments have shown that this concept meets expectations in regard to heat exchanger performance and corrosion resistance.

Future design study will look into the integration of bayonet with solar receiver and shell-tube heat exchanger, using Sulphuric acid thermodynamic properties.

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