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Sulfur-Iodine Demonstration Project

Sandia National Laboratories

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Sulfur-Iodine Demonstration Project

- An international collaborative project between Sandia National Laboratories (SNL), General Atomics Corporation (GA) and the French Commissariat à l'Energie Atomique (CEA).
- Each participant was responsible for designing, constructing and operating a skid mounted section of the three-section Sulfur-Iodine (S-I) thermochemical cycle.
- The three sections were constructed and integrated at the GA facility in San Diego, CA.
- The project was initiated in 2004 and ended in 2009.

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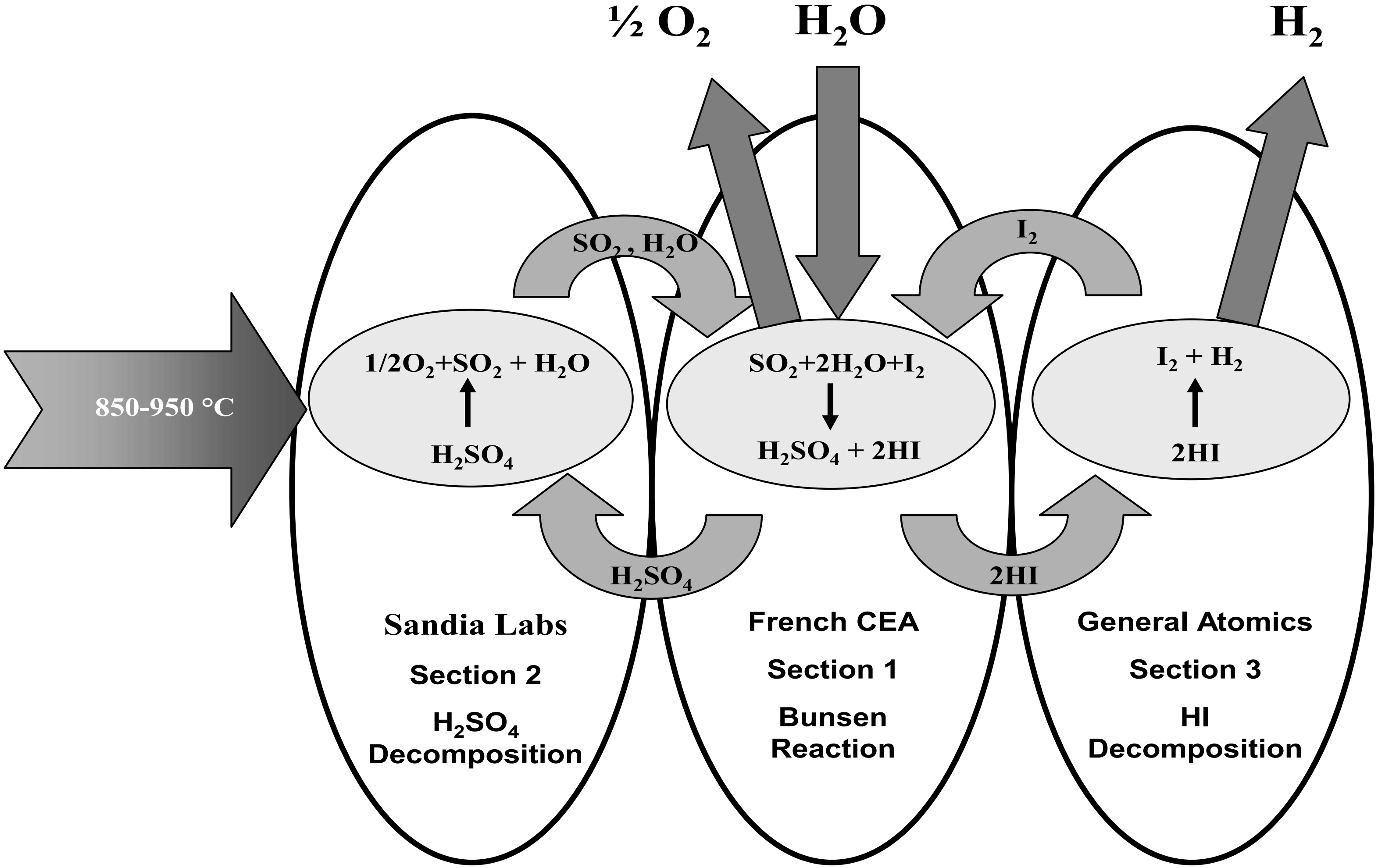
The S-I Thermochemical Cycle



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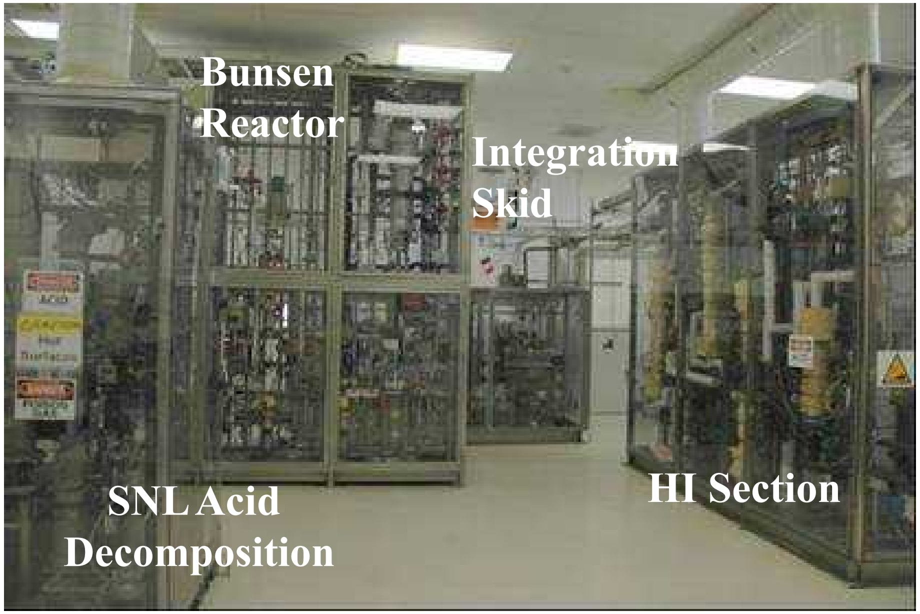
Objective

- Construct a sulfuric acid decomposition process using the following criteria:
  - Commercial off-the-shelf components where possible.
  - Minimize problems with corrosion and joining equipment for high-temperature (850ºC) operation.
  - Energy efficient with good heat recuperation where possible in this laboratory-scale process.
  - Scalable.
- Integrate and operate the SNL process with the French CEA and General Atomics process sections

Operation at the General Atomics Facility

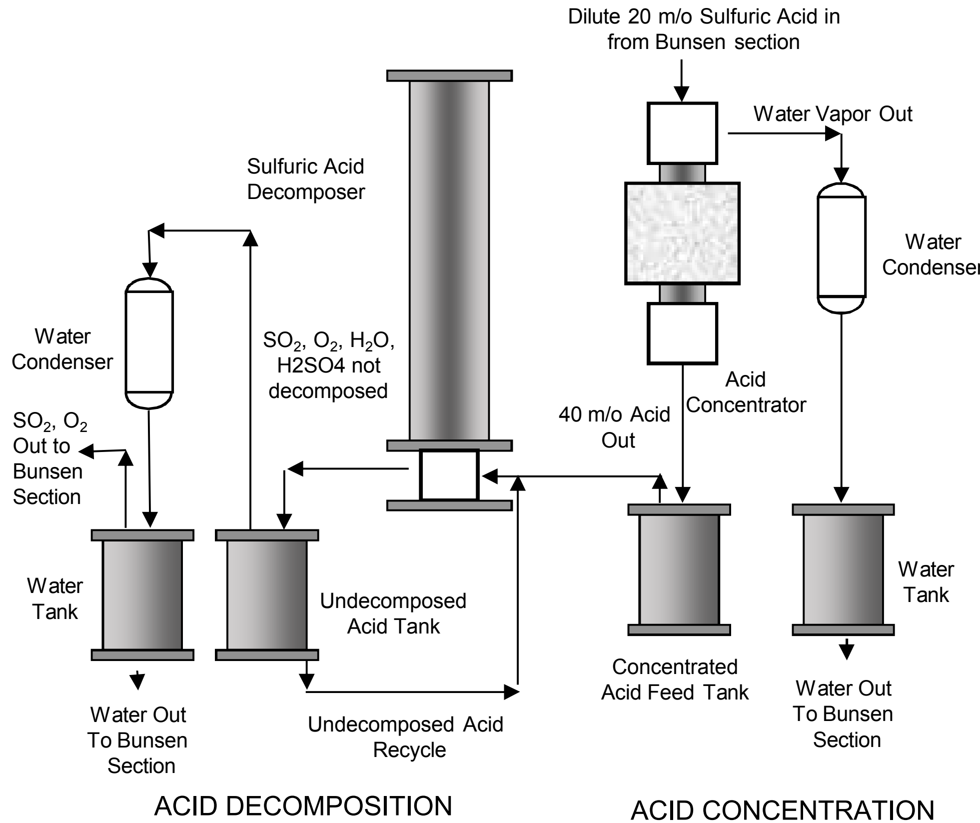
SNL Acid Decomposition Skid



Integrated S-I Process at General Atomics

Sulfuric-Acid Decomposition Process

- Dilute H_2SO_4 enters the acid concentrator at near ambient temperature
- The acid is decomposed at 800-900ºC to form SO_2, H_2O and O_2.
- Undecomposed acid is recovered and recycled back to the acid concentrator
- SO_2 and O_2 are sent to the Bunsen section for further processing.



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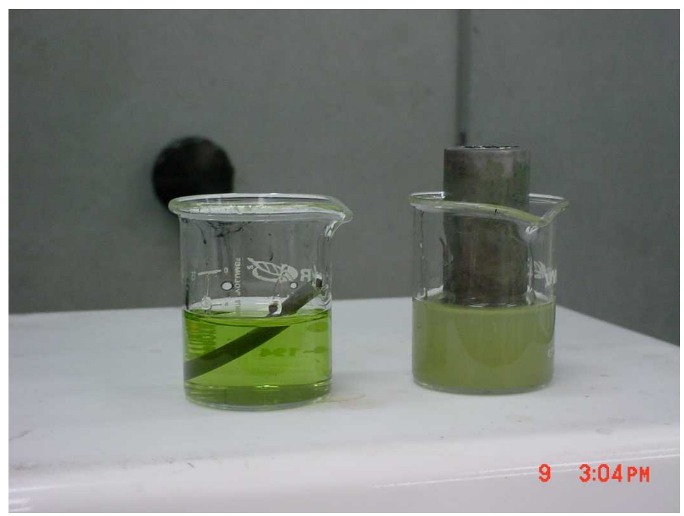
Initial Experiments at SNL

- The initial acid decomposer design used all metal components connected with flanges.
- Corrosion was extensive and no metals were identified that could survive the harsh conditions of high heat and sulfuric acid.
- Temperature cycling caused failure of flange connections.
- The results indicated an alternative using ceramic materials was needed.

Hastelloy acid decomposer after 10 min. operation



Corrosion of Hastelloy (left) and SARAMET (right) in 40% sulfuric acid at 90°C for 20 min.

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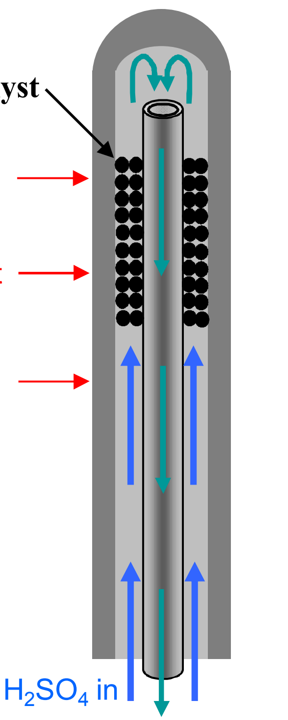
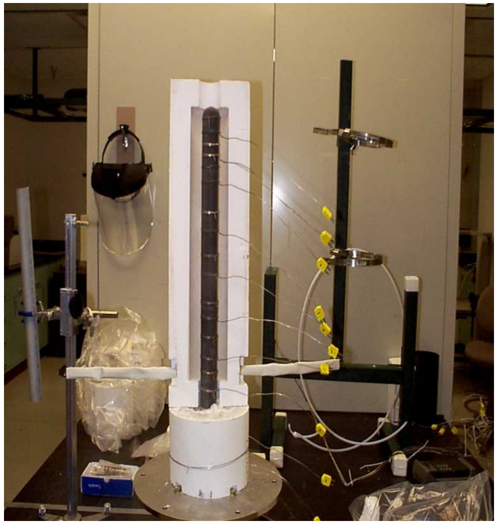
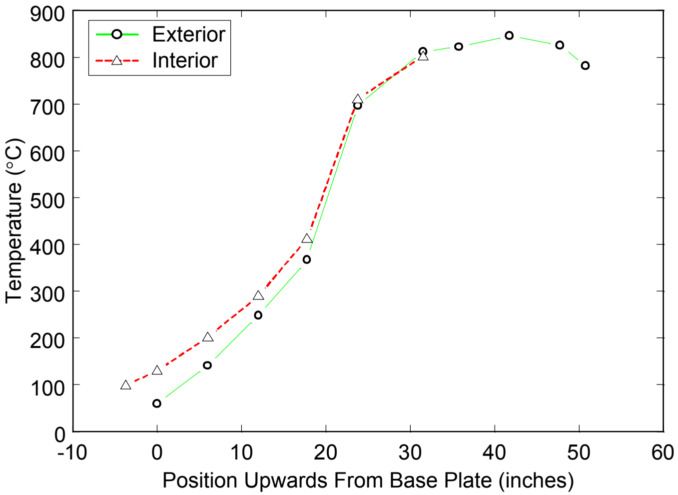
Bayonet Acid Decomposer Design

- Integrated sulfuric acid vaporizer, catalytic decomposer and heat recuperator.
- Energy efficient, economical design with very efficient heat recuperation. Inlet temperature 22ºC, outlet temperature 100ºC.
- Constructed of corrosion resistant silicon carbide.
- No high temperature seals to fail.
- Design solved many previously encountered problems







U.S. patent 7,645,437

Temperature Profile

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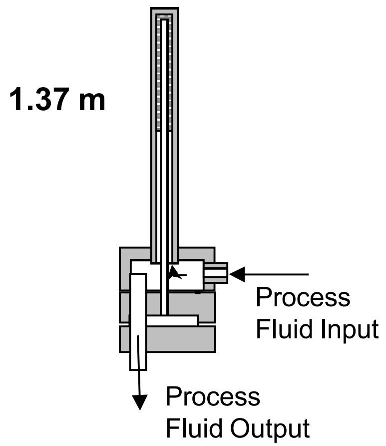
Results From Acid Decomposition

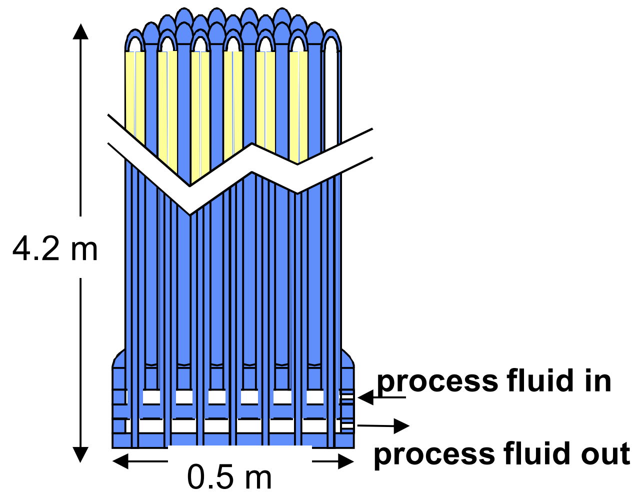
- The bayonet decomposer was successfully operated for more than 100 hours.
- SO_2 production rates of over 300 L/hr.
- Temperatures up to 950ºC.
- Pressures up to 6 bar.
- Under all conditions acid decomposition was very close to the theoretical maximum calculated from equilibrium data.

Bayonet Decomposer Scale up Approach

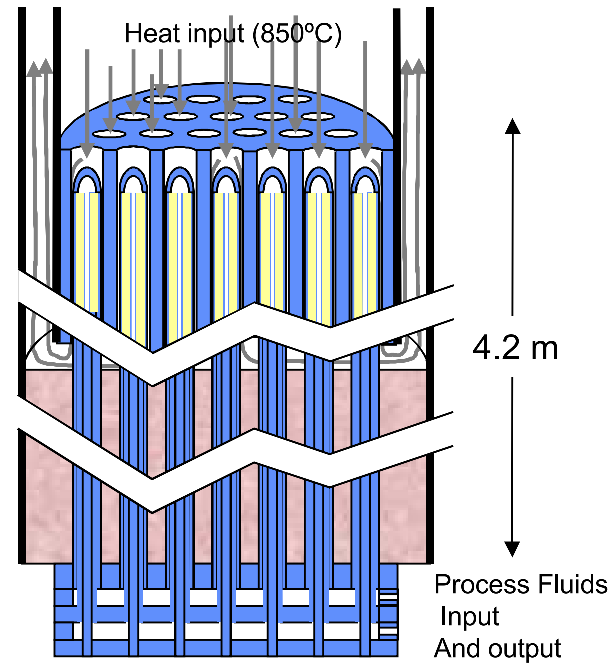
Manifold multiple bayonet units in a tube and shell HX arrangement.



Laboratory Scale (kW)
Single Tube



Pilot Scale (~MW)
Multiple (33) Tube Unit



Large Scale (>100 MW)

Increased area heat transfer model (fluted tubes), 27 kW/tube, turbulent flow

- *1 MW decomposer ~ 33 tube array, 0.5 m dia.*
- *100 MW - 3300 tube array, 5.5 m dia*

Design and Implementation Challenges

- **Remaining design challenges**
  - Reactive distillation for the HI decomposition section must be developed and incorporated into the design. Maximize cycle efficiency.
  - Effect of cross contamination needs to be examined.
- **Materials**
  - SiC proved to be very resistant to corrosion and thermal shock. No metals could be identified that could be used for H_2SO_4 decomposition.
  - Glass lined pipe steel (260ºC) performed with out any leaks or observable corrosion.
  - Tantalum lined pipe, vessels can be used but H_2 embrittlement needs is a concern. Elevated temperatures, induced currents, acid all can lead to H_2 embrittlement.
  - Eliminate H_2O from I processing units. Routine materials including Hastelloy, Inconel and certain stainless steels can be used.