Concentrated solar heat reduces metal oxide particles

Electrolysis utilizes electrical work to split water. Many have argued that one of the most promising futures for solar energy is the production of solar chemical fuels. A solar thermal reactor has been designed to experimentally investigate promising paths for reducing metal oxide particles to reduced oxidation states (e.g., Fe₂O₃ to Fe₂O). Utilizing concentrated solar energy, this reactor is windowless, able to withstand temperatures in excess of 1700 K, and has a feed system with variable particle residence time. Furthermore, this reactor utilizes a universal instrumentation system. A large-scale metal oxide reactor would serve as the first step in a metal oxide solar chemical cycle for the production of hydrogen. This hydrogen would be used in fuel cells to generate electricity or as a base material for the production of more traditional hydrocarbon fuels.

### Metal Oxide Solar Chemical Cycle
- Concentrated solar heat reduces metal oxide particles
- Electrolysis utilizes electrical work to split water
- Reduced particles reduce the required cell potential
- At the anode, the particles are oxidized to their original form
- At the cathode, gaseous hydrogen is collected as a fuel

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**Introduction**

With the current uncertainty in the future of fossil fuel energy, solar energy has risen as a competitor for large scale energy production. Many have argued that one of the most promising futures for solar energy is the production of solar chemical fuels. A solar thermal reactor has been designed to experimentally investigate promising paths for reducing metal oxide particles to reduced oxidation states (e.g., Fe₂O₃ to Fe₂O). Utilizing concentrated solar energy, this reactor is windowless, able to withstand temperatures in excess of 1700 K, and has a feed system with variable particle residence time. Furthermore, this reactor utilizes a universal instrumentation system. A large-scale metal oxide reactor would serve as the first step in a metal oxide solar chemical cycle for the production of hydrogen. This hydrogen would be used in fuel cells to generate electricity or as a base material for the production of more traditional hydrocarbon fuels.

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**Project Scope**

Design a reactor to facilitate the reduction of metal oxide particles. This reactor:
- Utilizes concentrated solar energy
- Is windowless (open to air)
- Withstands temperatures up to 1700 K (2600 °F)
- Has a quasi-continuous feed system
- Has variable particle residence times
- Is compatible with particle sizes between 325 mesh and 1 mm
- Has an instrumentation system with graphical user interface

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**Instrumentation System**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Analog Voltage</td>
</tr>
<tr>
<td>Pressure</td>
<td>0-5 V</td>
</tr>
<tr>
<td>Gas flow rate</td>
<td>0-5 V</td>
</tr>
<tr>
<td>Water flow rate</td>
<td>Digital Pulse</td>
</tr>
<tr>
<td>Solar Flux</td>
<td>Digital Signal</td>
</tr>
<tr>
<td>Feed System Motor</td>
<td>0-24 VDC</td>
</tr>
<tr>
<td>Paddlewheel Motor</td>
<td>0-24 VDC</td>
</tr>
</tbody>
</table>

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**Electrical Cabinet**

1. National Instruments CompactRIO
2. Isothermal Thermocouple Module
3. Brushed DC Servo Drive Module
4. ± 10 mA Current Input Module
5. ± 10 V Voltage Input Module
6. 24 V Digital Input Module
7. ± 10 V Voltage Output Module
8. Terminal Blocks

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**Reactor Design**

Cross Sectional View of the Solar Thermal Reactor

**Reactor Components**

1. Stainless Steel Front Plate
2. Zirconia Felt Aperture
3. Stainless Steel Shell
4. Alumina Mat Insulation
5. Stainless Steel Back Plate
6. SiC Paddlewheel
7. Mounting Bracket
8. Mounting Table
9. Feed System Base
10. Metal Oxide Particle Hopper
11. Screw Feed Auger

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**LabVIEW Graphical User Interface**

Valparaiso University