



An Energy-Efficiency Workshop and Exposition
Orlando, Florida

Regenerative Fuel Cell Storage for Alternative Energy Power Sources

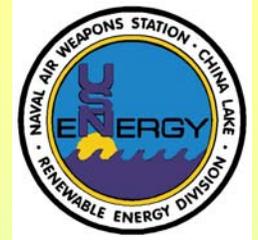
Sam Edwards

U.S. Navy, NAWS China Lake

Energy Security & Distributed Generation
Update on Emerging Technologies
Wednesday, Session 7 10:30 to 11:30 AM



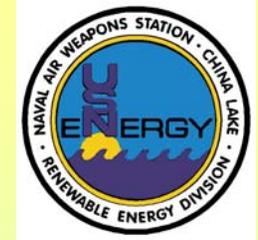
*Regenerative Fuel Cell Storage
for Alternative Energy Power Sources*



- U.S. Navy Renewable Energy Division,
Naval Air Weapons Station, China Lake, CA.
- Applying renewable energy resources to
Navy shore facilities.



Regenerative Fuel Cell Storage for Alternative Energy Power Sources



- Navy needs power in remote locations



Regenerative Fuel Cell Storage for Alternative Energy Power Sources

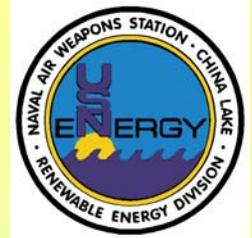


Batteries for energy storage

- Pro: Cheap
Recyclable
Available
- Con: Acid in air and on floor
 $\frac{1}{2}$ life per 15 deg F
Fires
Maintenance safety
95% of recurring cost

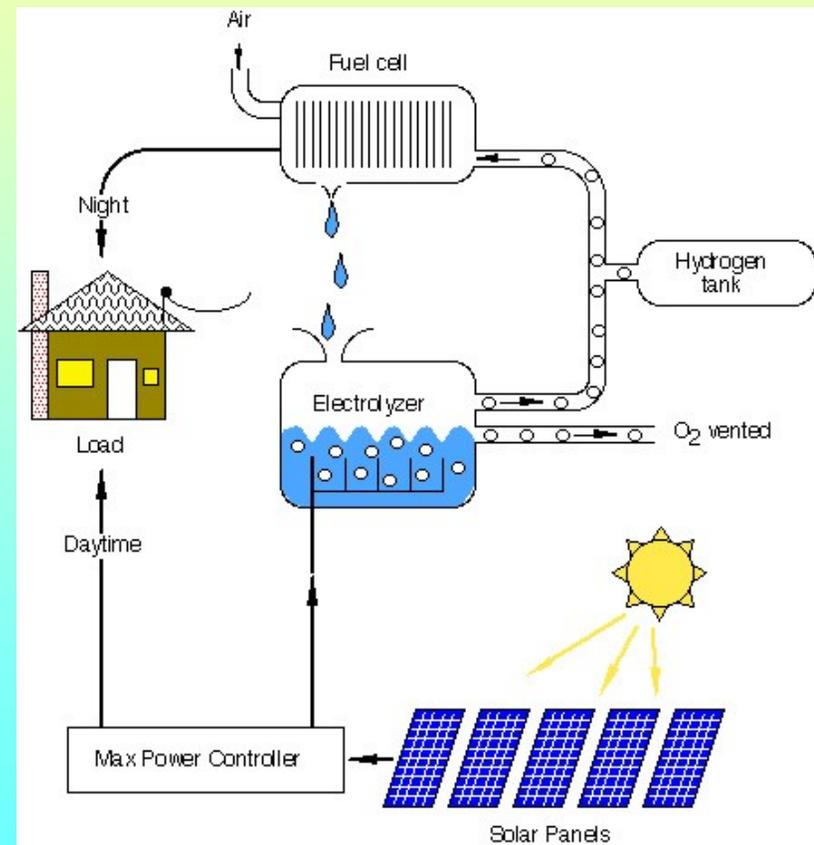


Regenerative Fuel Cell Storage for Alternative Energy Power Sources



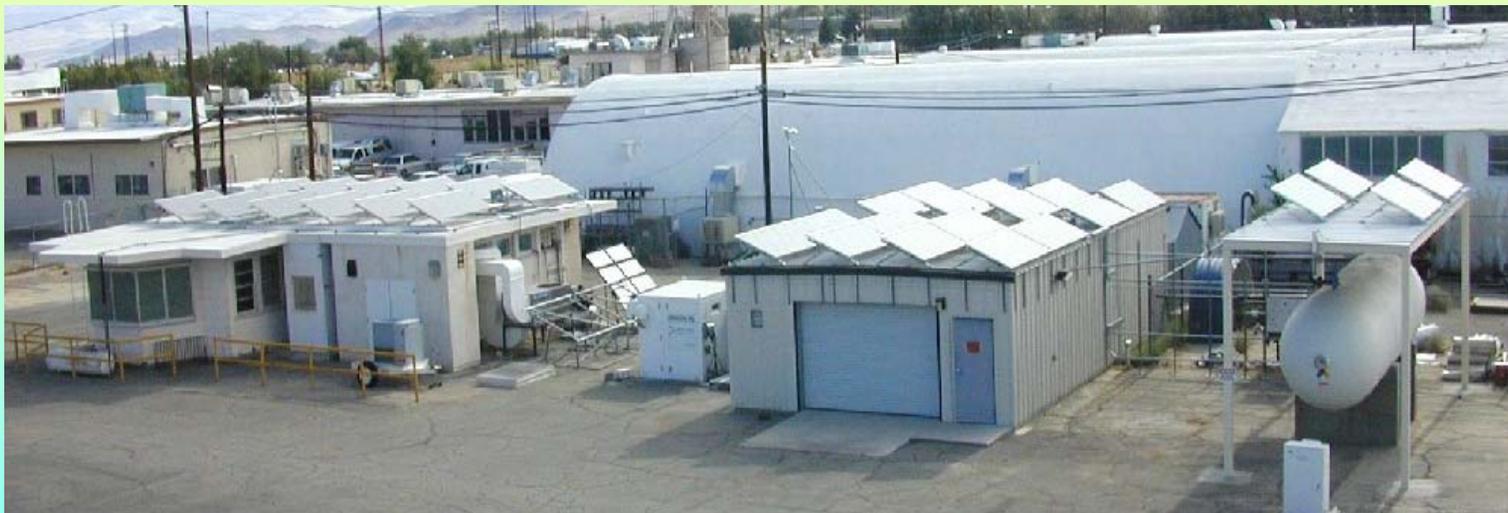
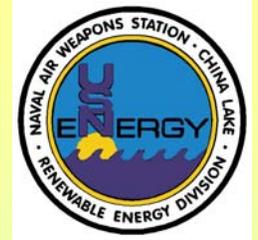
Proposed Solution

- Use solar power to produce hydrogen from water.
- Energy stored as hydrogen.
- Fuel cell produces energy at night.
- Water from fuel cell returned to electrolyzer.





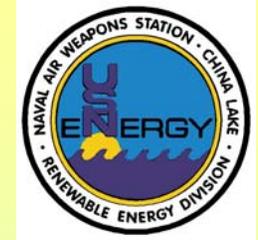
Regenerative Fuel Cell Storage for Alternative Energy Power Sources



- Navy provided the 10 kW solar array

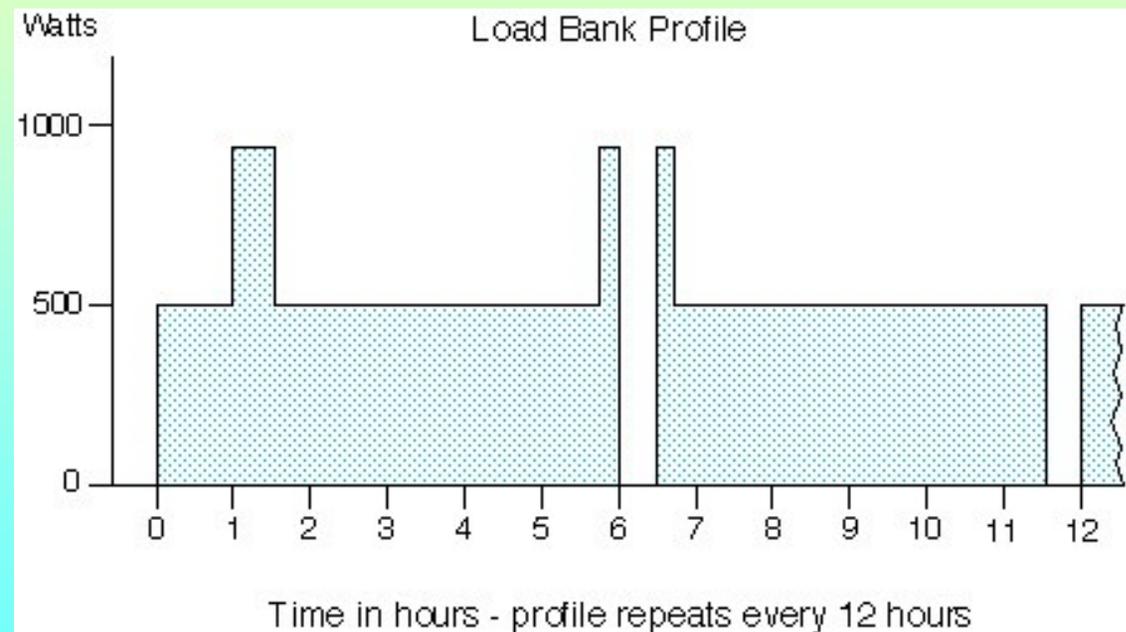


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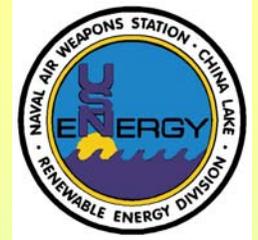
- Navy provided the test load

- Time varying profile chosen to challenge known fuel cell weaknesses
- Automatic profile or manual operation

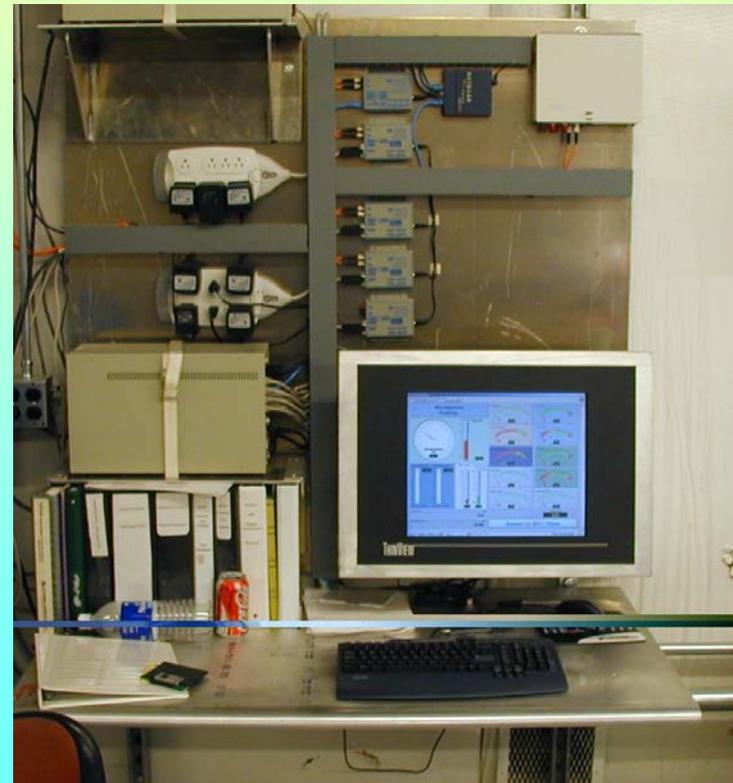




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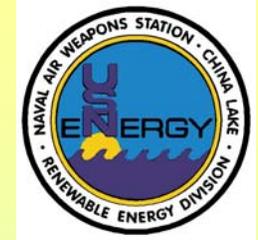


- Navy provided the data logging and display
 - Windows based
 - National Instruments Labview programming language
 - One minute records
 - One second records triggered by unusual events





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- Proton Energy Systems created the Unigen

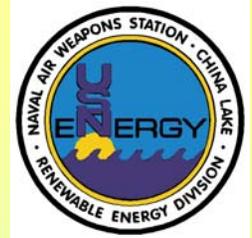


August 17-20, 2003

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Regenerative Fuel Cell Storage for Alternative Energy Power Sources



- HOGEN[®] RE electrolyzer
40 SCF of H₂/hour



- Nexa[™] fuel cells (2)
1200 Watts peak each



- Trace[™] PV inverter
1.5 kW at 120VAC

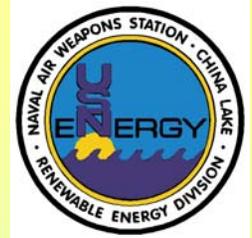
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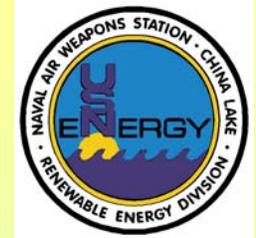


- 200 Liter water tank
 - Size of a 55 gallon barrel
- Electrolyzer draws from it
 - Continuous water circulation for cooling
 - Return water carries O₂ into tank
 - Tank vented outside of enclosure
 - Only top ¼ usable to restrict gas void area
- Tank in enclosure for thermal mass
 - Will be important in winter months.





Regenerative Fuel Cell Storage for Alternative Energy Power Sources



Hydrogen tank

- 6565 gallon steel tank
 - 7 foot diameter, 27 feet long
 - 200 PSI Working pressure
- Shade structure
 - Limits heat extremes
 - Holds additional solar panels
- 2000 PSI tank in the future
 - For reducing space requirements



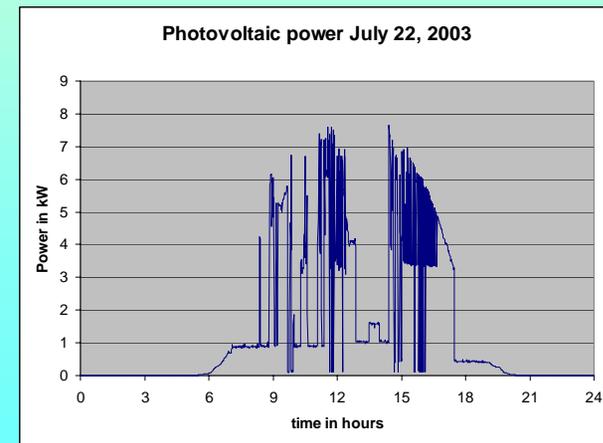
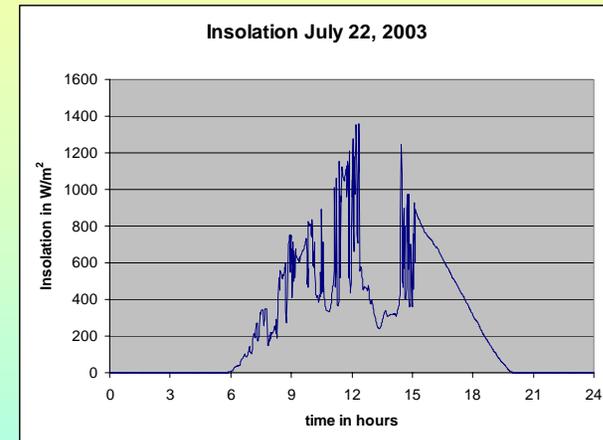


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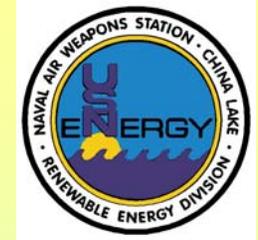
Operation

- Solar resource is large
 - 1300 Watts/meter² (peak)
- Ultra capacitor absorbs dropouts
 - No batteries in the unit
- Cloud cover robs significant energy
 - Minimum power level of electrolyzer stretches short cloud dips to 5 minutes.



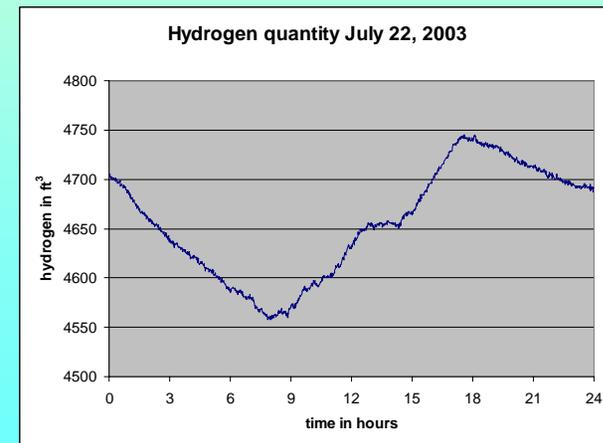
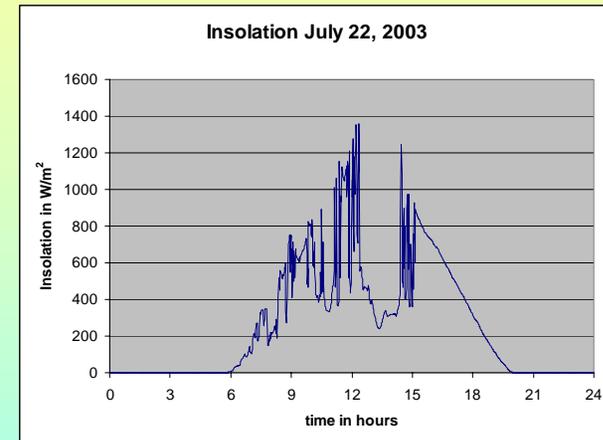


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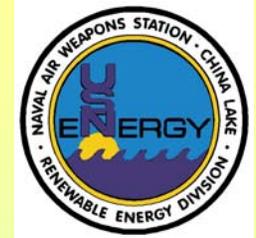
Operation

- Hydrogen production as expected
 - 30% efficient
 - Required initial hydrogen fill
 - Can be self-sustaining if matched to local solar resources
- Significant energy losses
 - Minimum power level of electrolyzer stretches short cloud dips to 5 minutes.
 - MPT derating directly affects H₂ loss



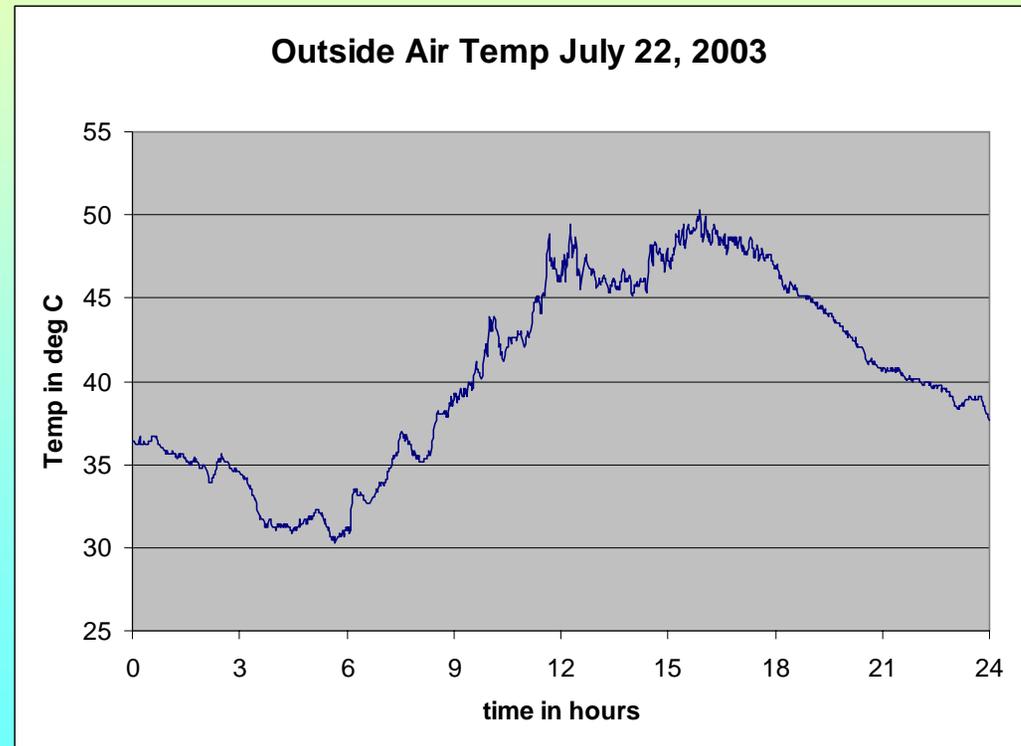


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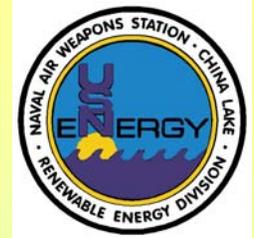
Observations

- Temperature is a big factor
 - Max power tracker derates its output to protect itself.
 - Poor air flow design
- Hydrogen safety adds heat
 - Vent fans keep interior within 4 deg of OAT.
 - Electronics run at outside temp





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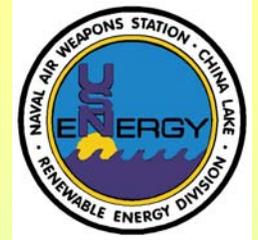
Problems

- Hydrogen tank
 - Pressure tested with Nitrogen, leaks with Hydrogen
 - Determining quantity is difficult with one temperature probe.
- No problems with permits
 - Trained the Fire Marshall before installing the system.





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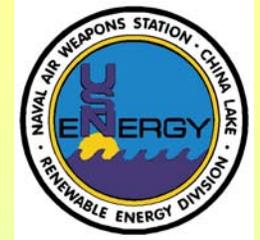


Problems

- Data Logging
Typical unexplained crashes from Windows™.
- PV panels under-performed
Brand new panels rated at 75 Watts delivered ~ 66 Watts
- Lengthy process of defining parameters in 3 interacting controllers
- MPT, electrolyzer, system controller



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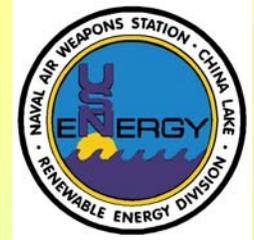


Status

- Concept works
- Ability to challenge battery systems not yet clear.
- Reliability acceptable for this phase of the project.
- Complexity of concept will require sturdy components to match the reliability of batteries.



Regenerative Fuel Cell Storage for Alternative Energy Power Sources



Future plans

- Fix the problems.
 - More heat tolerant
 - Reliable controls
- Run the system for a year.
- Install in a remote location, evaluate its performance.
- Increase power to 5 kW building blocks.
- Wait for scientists to catch up to the engineers.
Future of efforts like these directly tied to a longer fuel cell life.