RAPHAEL SCHMUECKER MEMORIAL

SOLAR-HYDROGEN SYSTEM

OUR DEMONSTRATION FARM RENEWABLE HYDROGEN AND AMMONIA GENERATION SYSTEM

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TOPICS

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- Ammonia Generation
- Energy Consumption
- Conclusion

Background

- 2009 – Project initiated as a memorial to Jay's father, an advocate for replacing fossil fuels with hydrogen, located on the Iowa farm where Raphael was raised.
- 2010 – Tractor delivered to Hydrogen Engine Center for installation of engine fueled by H2 and by H2/NH3.
- 2011 – Made hydrogen from solar power using a commercial hydrogen generator.
- 2013 – Discussed with Bill Ayres at the NH3 fuel meeting making ammonia from solar power.

Background

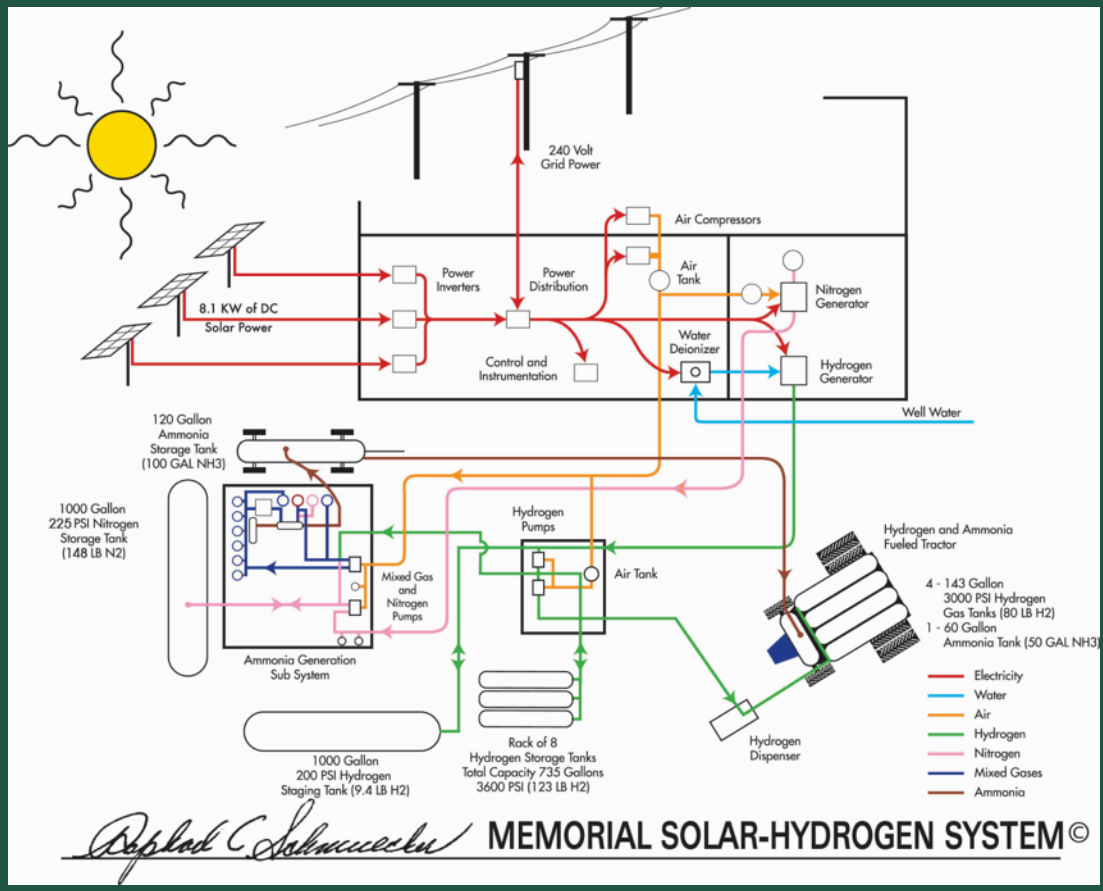
2014 – Initiated ammonia subsystem design so we could have a self-contained fuel and fertilizer demonstration system.

2014 - Tractor delivered

- 2015 – Demonstrated ammonia and hydrogen fueled tractor at NH3 fuel conference at Chicago
- 2016 – Made ammonia using a modified Haber- Bosch process. The reactor vented due overheated outer wall.
- 2017 – Designed and installed new NH3 reactor. Using Pressure Swing Absorption we generated 99.995% N2.

System Overview

- The generation & use of these on site made fuels and fertilizer are C-FREE RENEW: Carbon Emission Free and Renewable
- Use the grid instead of batteries for storage and solar shortfall.



Tractor Utilization

- The 50 gallon 200 psi ammonia tank at the front contains the energy in 2 of the 4 21” X 10’, 3000 psi hydrogen gas storage tanks.

Tractor Utilization

C-FREE RENEW™

Hydrogen Generation

- Over a year we average 5 hours/day of full solar power.
- The Proton S40 hydrogen generator uses 7 KW to make .2 lb (40 scf) of hydrogen/hr or a pound of H2 a day.

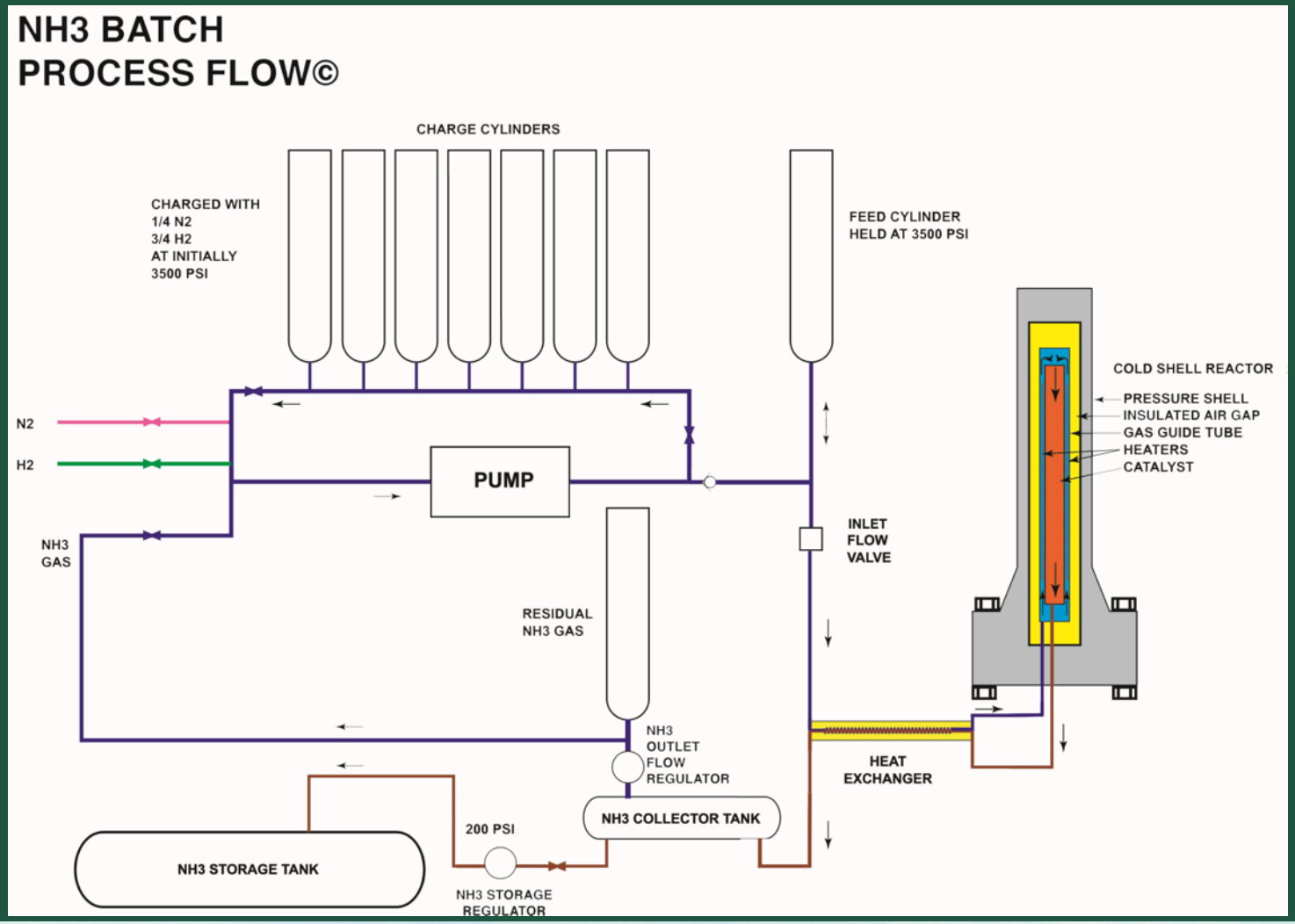
Nitrogen Generation

- A modified Parker Dual Bed, Pressure Swing Absorption unit generates high purity Nitrogen
- 2.66 lbs (36 scf) of nitrogen is generated per hour.

Ammonia Generation

- The Ammonia Shed is a 10 x 10 foot building that contains the inlet and outlet cylinders, the Reactor, and all the valves and pumps to produce NH3 stored in the mini nurse tank.

Ammonia Generation



Ammonia Generation

- The gases flow from the blue cylinders through the reactor to the red cylinder converting 3500 psi nitrogen and hydrogen gases to ammonia at a rate of 6.72 lbs/hour,
  or 1.31 gallons/hour.

Ammonia Generation

- Control valves and pumps for ammonia generation

Energy Consumption

- 50,000 Btu's (14.6 Kw) in a gallon of ammonia.
- A gallon of NH3 contains 4.22 lbs. of N2 and .93 lbs of H2.
- The energy needed to make a gallon of ammonia:
  - 32.5 Kw to make hydrogen at 200 psi.
  - 0.2 Kw to power the air compressor that drives the pump compressing the hydrogen from 200 to 3500 psi for .93 lbs (180 Scf).
  - 11.9 kw to compress the air and operate the N2 generator to make the 4.22 lbs (57 Scf) of high purity nitrogen at 225 psi.

Energy Consumption

- Energy needed to make a gallon on ammonia (cont'd):
  - 1.5 kw to pump the nitrogen from an average of 125 psi to 1200 psi for to charge the inlet cylinder with 4.22 lb of N2
  - 1.6 kw to heat the reactor catalyst (average per batch).
  - 3.8 kw to maintain the feed cylinder pressure at 3,500 psi while the reactor is functioning.
  - 1.0 kw to power the control electronics while the above activities are performed.
- 52.6 Kw Total energy required to make a gallon of ammonia containing 14.6 Kw of energy.

Conclusion

- The current ammonia generation system is 28% efficient. (Note: this is comparable to net usage for batteries)
- Nearly 2/3 of the energy goes to make the Hydrogen.
- Over 1/4 of the energy goes to making Nitrogen.
- There are no feed stock costs.
- Production can be increased by adding more solar panels, or wind turbines, to operate the subsystem longer and in parallel.
- Larger scale installations will probably improve efficiency.

Conclusion

- With this self contained system we have demonstrated that with existing technology, clean, renewable, fuel and fertilizer can be made with air, water and sun light.
- One of the reasons for building this system is to make the public, especially farmers, aware that there is technology that can be used to replace fossil fuels and to reduce carbon emissions; now, and in the future, as fossil fuels are depleted.
- See our website at: www.solarhydrogensystem.com