RAPHAEL SCHMUECKER MEMORIAL

SOLAR-HYDROGEN SYSTEM

IMPROVED METHOD OF USING HYDROGEN AND AMMONIA FUELS FOR AN INTERNAL COMBUSTION ENGINE

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FUEL CELL OR ICE POWER

- Much discussion on using ammonia in fuel cell applications
- We think that Internal Combustion Engines (ICE) are a viable alternative
  - Especially over the next several years
- There are a number of factors that need to be considered in determining how carbon emission free vehicle applications will be implemented.
  - See 2015 NH3 Fuel Conference paper: “Comparison of Hydrogen Fueled Power Sources” that compared PEM fuel cells and several Hydrogen/Ammonia ICE configurations
  - The factors are identified on the next chart:

FUEL CELL/ICE FACTORS

- Vehicle Efficiency
- Costs
- Drive Train
- Exhaust noise
- Emissions
- Carbon Emissions
- Vehicle Acceleration
- Engine Tuning
- Vehicle Personnel Space Heating
- Hydrogen Generation
- Hydrogen Purity
- Hydrogen Costs
- Hydrogen Storage
- Ammonia Generation
- Expected Life
- Maintenance Personnel
- Repair Costs
- Service Interval
- Safety

CONSIDER

- Can the world supply raw materials to make over 50 million fuel cell powered vehicles annually?
- Using ICEs will speed the transition to the use of hydrogen as a fuel.
- We have demonstrated that ammonia can be used to fuel ICE powered vehicles.
  - Ammonia powered ICEs can be easily and quickly brought to market for transportation vehicles.
  - Speed to market is important if you consider the recent UN study on global warming.

TRACTOR

C-FREE RENEW™

TRACTOR

- The 50 gallon 200 psi liquid ammonia tank at the front contains the energy in

  2 of the 4
  21” X 10’ long
  3000 psi hydrogen gas storage tanks.

DELIVERED TRACTOR ENGINE

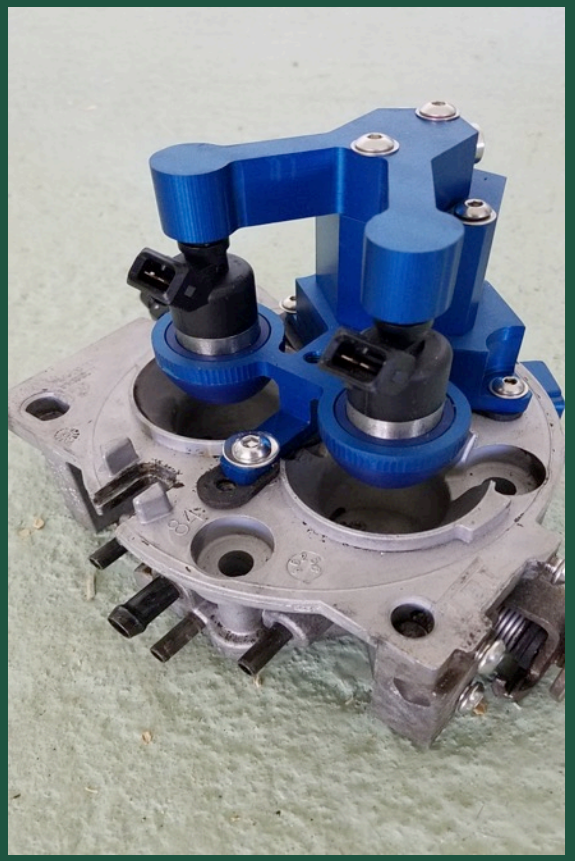
- Fairly conventional Ford 460 block engine bored out to 9.4 Liter and 13.5 to 1 compression ratio.
- Engine RPM limited to 2500 because of tractor transmission limitations.
- Start and stop engine on hydrogen, and when warm run on 85-90% ammonia and 10-15% hydrogen.

ENGINE MODIFICATIONS

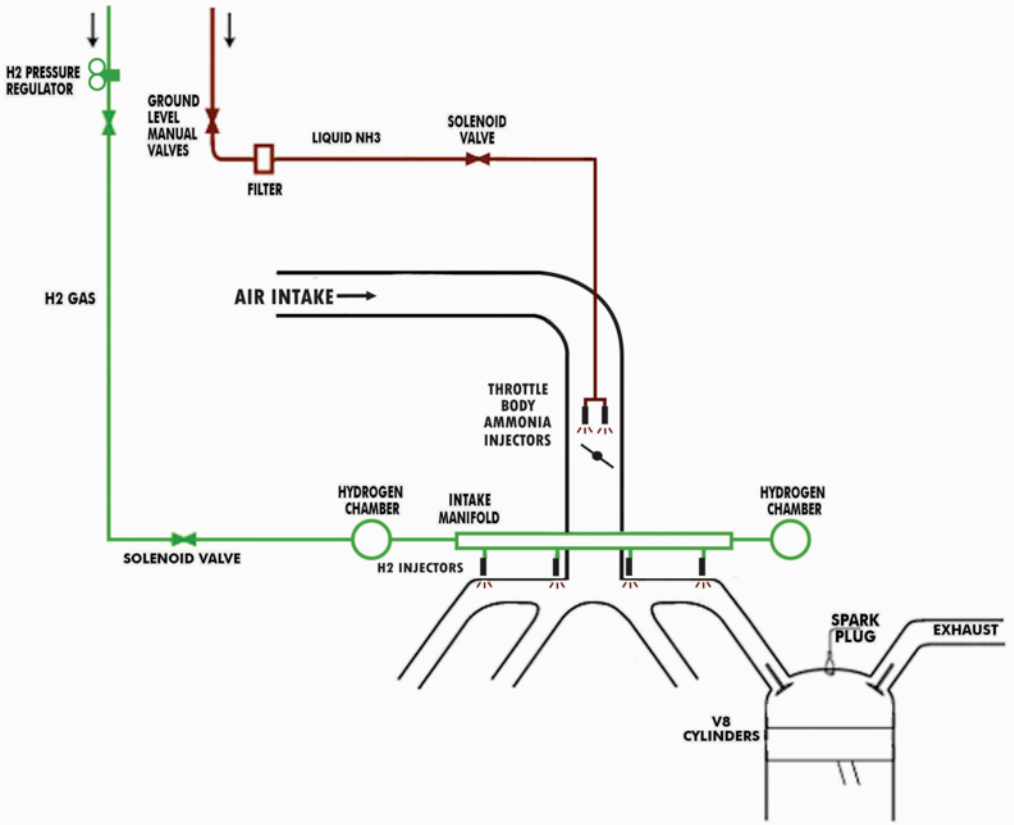
- Dual fuel Electronic Control Unit (ECU)
- Distributor replaced with 8 coils
- 8 injectors for “port injection” of hydrogen
- Two ammonia injectors in throttle body

AMMONIA INJECTION

- Two injectors are used to inject ammonia into the engine intake air.



ENGINE FUELING FLOW



CONCLUSION

- Hydrogen fueled ICEs, using ammonia as the carrier are an immediate, viable way to convert to a carbon emission free transportation vehicle fueling approach.
- The tractor performance has been significantly improved as a result of the described changes.
- More at SolarHydrogenSystem.com