Power to Gas and Back Again
Hydrogen Overview with Concentration on the Power Generation Sector

November 19, 2020
Agenda

• What is Hydrogen
• Historic Applications
• Present and Future Applications
• Green Hydrogen Sourcing
• Challenges with Hydrogen
• Engineering Future Solutions
What is Hydrogen?

- Most Abundant Element in the Universe
- Most basic Atomic Structure
- Not typically found by itself in nature
- 0.1-0.5 Nanometer Atomic Diameter
- 1 Proton, 1 Electron, 3 Isotopes

Protium

Deuterium

Tritium
Historic Hydrogen Applications

• First Hydrogen Balloon
  – 1783, by Jacques Charles of France

• First Electrolysis
  – 1800, by William Nicholson and Anthony Carlisle of UK

• First Fuel Cell Developed
  – 1842, by William Robert Grove of UK

• First Fuel Cell in Space
  – 1962, Gemini 1.0 kW Acid IEM fuel cell
Present and Future Applications

• Refineries
  – Deacidification
• Steel Annealing Furnaces
  – \( \text{O}_2 \) Poor Atmosphere
• Generator Cooling
• Renewable Fuel
• Fusion Feedstock
Green Hydrogen Sourcing

- **Electrolysis**
  - Alkaline
    - Most Mature Technology
  - PEM (Proton Exchange Membrane)
    - Extremely Responsive
  - SOFC (Solid Oxide Fuel Cell)
    - The Next Generation

- **Pyrolysis**
  - Carbon Negative Possibilities
Core Challenges with Hydrogen

- Currently Primarily Sourced From NG
- 0.1-0.5 Nanometer Atomic Diameter
- Low Energy Density in Gas Phase
- Available Storage Methods
- Flame Speed/Temperature
- 4% Lower Explosion Limit
- Embrittlement
- Public Perception
- NO$_x$ Emissions
Combustion Challenges

• Flame Temperature
  – NG = 3542 °F
  – H₂ = 3830 °F

• Flame speed
  – NG = 1.2 ft/s
  – H₂ = 9.5 ft/s

• Flow Rates
  – ~3 Times the Fuel Flow

• NOₓ Production
  – Thermal NOₓ
Storage Challenges

- Hydrogen Embrittlement
  1. Surface Embrittlement
  2. Internal Embrittlement
  3. Reaction Embrittlement

- Low Density
  - Impractical for Large Tank Storage
  - ~40% Losses from Liquification Process
Engineering Future Solutions

• Combustor Technology
• Automotive High Pressure Tanks
• Green Ammonia
  – 6.6 lbs. H₂/ft³
• Ammonia Cracking
  – 2NH₃ → N₂ + 3H₂
• Ammonia as a Fuel
  – Controlling Flame Speed & Temperature
  – Fuel NOₓ
LADWP $H_2$ IPP Project

Intermountain Power Plant

- Located in Delta Utah
- 30% $H_2$ in 2025
- 100% $H_2$ in 2045
- MHPS JAC Turbine
- Salt Dome $H_2$ Storage
- $H_2$ Fuel RFP Progressing
Hydrogen within the L.A. Basin

- NREL, LA 100 Study
- Low Carbon Research Initiative (LCRI)
- Areas of Interest
  - Hydrogen Pipelines
  - Ammonia H\textsubscript{2} Fuel Cycle
  - Combustion
    - Wet Low Emissions (WLE)
    - Dry Low NO\textsubscript{x} (DLN)
  - Other Alternative Fuels
Conclusion

• Engineering Challenges
• Hydrogen Combustion Technology
• Hydrogen Storage Techniques
• Understanding Strengths and Weaknesses
• Carbon Emissions Impact

“I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable”. Jules Verne, "The mysterious island"
Thank You