Small Scale Distributed Ammonia Production

Less than 100 tons per day

Contact:
Doug Carpenter at Sustainable Fuels, Inc.
dcarpenter21@cox.net

Presented By:
Bill Ayres at R3Sciences, LP
www.r3sciences.com
Overview

- Nitrogen Generation
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- Reaction Gas Storage
- Reaction Overview
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Nitrogen Generation

- Nitrogen from Air (79% Nitrogen)
  - Pressure Swing Adsorption (PSA)
    - Gas compression, adsorption on carbon media, depressurization, nitrogen desorption
    - Repeat until desired purity (>99.99%)
  - Cryogenic Liquefaction
    - High Cost
    - High Volume
    - Very High Purity (>99.999%)
  - LN$_2$ Delivery
Hydrogen Generation

- Traditional Catalytic Steam Reforming of Methane and Water-Gas Shift Reaction
  \[ \text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2 \]
- Capture \( \text{CO}_2 \) for Urea Production
- Chloralkali Process
  \[ 2\text{NaCl} + 2\text{H}_2\text{O} \rightarrow \text{Cl}_2 + \text{H}_2 + 2\text{NaOH} \]
- Electrolysis of Water
  \[ 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]
- Pyrolysis (Gasification) of Biomass
  \[ \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{CO} + \text{CO}_2 + \text{H}_2 \]
Hydrogen Purification

• High Purity Hydrogen Required to Prevent Catalyst Degradation
  – Low H₂O
  – Low Sulfur
  – Low CO₂ and CO
• Traditional Chemical Methods
  – Diethylene glycol water removal
  – Methyldiethanolamine for CO₂
  – ZnO, FeO remove H₂S chemically
  – N-Formylmorpholine also for H₂S
• Palladium Membrane Separation
• Pressure Swing Adsorption
Reaction Gas Blending

- Low pressure hydrogen and nitrogen are blended using mass flow controllers then compressed to 3000 psi.
Renewable Sources (Solar, Wind) Require Large Buffer Storage: for carryover when sun and wind are absent

- Fixed Tanks
- Tube Trailers
- Pressurized to 3,000 psi
Reaction Overview

- High Pressure (10,000 psi)
- No Gas Recirculation Loop (Once through)
- 95% Conversion of Hydrogen
Reactor

• Catalyst Optimized for High Pressure
  – Catalyst is pre-reduced and sealed in reactor
• Internal Heat Exchanger
• Cooled by Low Pressure Steam
• Rapid Start-up and Stabilization
• Automated Control of Operation
• Remotely Monitored
Ammonia Separation

- Internal Heat Exchanger to Reduce Temperature of Product Gases
- Let-down Turbine Further Reduces Temperature and Pressure
- Refrigeration of Product Gases
  - Cryogenic cooling using LN₂
    LN₂ → N₂ (gas)
  - Electrical Refrigeration
- Ammonia Captured
  - 97% condensed and removed to liquid storage tank
  - 3% non-condensed
N₂ + H₂ → NH₃ + N₂ + H₂

• Unreacted Hydrogen (5% of feedstock)
• Non-condensed Ammonia (3% of product)
• Residual Nitrogen
• Add Oxygen From Nitrogen Pressure Swing Adsorber
• Pressure is 200 psi
FAQ

• How Much Does It Cost?
  – For a 5 Ton Per Day (TPD) Unit; Excluding Hydrogen Generation - $500k
• How Soon Can I Get It?
  – System Delivery - 18 months
• How Long Does It Take To Get Permits?
  – If “Bugs and Bunnies Report” is required - up to 2 years
• Recent Projects
  – 5 lbs. (1 gallon) per day – completed and demonstrated
  – 5 Tons/day - under construction
  – 50 Tons/day - permitting in process (Aurora Renewable Energy)