CAPABILITIES OF HYDROGEN PEROXIDE CATALYST BEDS

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Overview

- Hydrogen Peroxide as Monopropellant
- History of Decomposition
- Proven Methods of Decomposition
  - Liquid-Liquid
  - Pellet Catalyst Beds
  - Screen Catalyst Beds
- Performance of Screen Catalyst Beds
- Conclusions
Hydrogen Peroxide as Monopropellant

- Monopropellants Decomposes and Release Energy
  - Presence of Catalyst
  - Presence of Thermal Energy
- Several Liquids are Monopropellants
  - Only a few Have Found Rocket Applications
  - Hydrazine and Hydrogen Peroxide Dominate Historical Use
  - Higher Energy Propellants are Considered to Unstable
- Specific Impulse of 90% H2O2 ~ 25% Below Hydrazine
- Density Impulse of 90% H2O2 ~ 6% Higher Than Hydrazine
- 90% H2O2 Does Not Require Sealed Handling Suits Like Hydrazine
- H2O2 Non-Toxic Decomposition Products
  - Oxygen and Water
History of Decomposition

• First Found Rocket Use in Germany WWII – 80 to 85% H2O2
  – V-1 RATO, V-2 Turbopumps, ME163
  – Submarines (with Kerosene)
• UK After WWII to Mid 1960’s
  – Gamma Engine Main Propulsion, RATO
• US After WWII to Late 1970’s
  – X-1, X-15, Scout
• Decline in Use Replaced by Hydrazine late 1960’s
  – Performance Driven
• US 1990’s Renewed Interest in Niche Markets
  – Handling, Green, Cost Driven Systems
  – Chemical Lasers, X-37 Main Propulsion
Proven Methods of Decomposition

• Many Methods Exist
  – Desire Robust, Simple, Long Life
  – All Fielded Systems Use Catalyst For Decomposition
  – Three Primary Methods
• Liquid – Liquid
  – Germany WWII
• Pellet Catalyst Beds
  – Germany WWII
  – UK - Short Experimental Period After WWII
  – US - Redstone, Jupiter
• Screen Catalyst Beds
  – UK - Until Termination of Black Arrow Program (1973)
  – US – The Method of Choice
Liquid-Liquid Systems

- Two Liquid System
  - One Liquid is Hydrogen Peroxide
  - Second Liquid is Catalyst Doped
  - Liquids Co-injected in Chamber Where Decomposition of H2O2 Occurs
- First H2O2 Decomposition System to be Fielded
  - Germany WWII
  - Typical Catalyst is Manganate Family (Ca, K, Na)
  - Example V-2 Turbo Pumps (Water – Permanganate / H2O2)
Liquid-Liquid Systems
Liquid-Liquid Systems

• Advantages
  – Injection Technology Similar to Bi-Propellant Systems
  – Catalyst Less Contamination Sensitive

• Disadvantages
  – Requires Second Fluid System
  – Catalyst is Expelled with little Specific Impulse Value
  – Exhaust is Diluted by Catalyst Carrier Liquid
  – Catalyst Must Be Soluble

• Upgrade System Uses Fuel As Carrier Liquid
  – ME163 – Hydrazine Hydrate/Methanol
Pellet Catalyst Beds

- Catalyst is a Solid in a Pressure Vessel
  - Liquid H2O2 Enters, Exists Decomposed
  - Catalyst Placed on Substrate by Dip and Bake Method
  - Vessel filled with Pieces of Catalyst/Substrate 0.5” – 2” Longest Dim
- First Used in Germany – late WWII
  - Typical Catalyst Permanganate
  - Example German Submarines
Pellet Catalyst Beds
Pellet Catalyst Beds

- **Advantages**
  - Elimination of Second Fluid System
  - Reduced Mass of Catalyst Required
  - Catalyst Does Not need to be soluble (Prefer Not – MnO2)

- **Disadvantages**
  - Life on the Order of Minutes
  - Silting, Breakup of Substrate, Catalyst
  - Increased Concentration of H2O2 Reduces Life
  - Catalyst Must be Held in Pressure Vessel
Screen Catalyst Beds

- Catalyst is Solid in Pressure Vessel
  - Liquid H2O2 Enters, Exists Decomposed
  - Catalyst is in the form of Wire Mesh
  - Plated on Catalyst or Pure Catalyst
- First Used by UK, US After WWII
  - Favored Catalyst is Silver
  - Example RCS Thruster
Screen Catalyst Beds

• Present Day Catalyst Bed
Screen Catalyst Beds

- Advantages
  - Catalyst More Robust
  - Longer Life on the Order of Hours
  - Smaller Device than Pellet Beds
- Disadvantages
  - Poisoning by Fluid Impurities
  - Silver Limited to ~ 92% H2O2
  - Catalyst Must be Held in Pressure Vessel
Performance of Screen Catalyst Beds

- Several Important Parameters of Performance
  - Life, Mass Flux, Pressure Drop, Mass
- Most Influential is Mass Flux
  - Upper Limit of Operation Not Necessarily Driven By Catalyst
  - Pressure Drop and Life Requirements are the Extremes
  - Typical Limits of Flux 0.05 to 0.4 lbm/(in^2-s)
  - Typical Pressure Drops from 20 to 200 psid
Performance of Screen Catalyst Beds
Conclusions

• Hydrogen Peroxide Monopropellant Devices Have Long History
  – Rocket Devices for Over 50 years
• Evolution of Methods of Decomposition Since WWII – Germany
  – All Methods Based Upon Use of Catalyst
  – Liquid – Liquid (WWII – Germany)
  – Pellet Beds (WWII – Germany & Short Period After WWII – UK, US)
  – Screen Beds (1950’s to Present)
• Screen Beds Have Stood the Test of Time
  – Life of Hours
  – Mass Flux Range 0.05 to 0.4 Lbm/(in^2-s)
  – Pressure Drops 20 to 200 psid