CAPABILITIES OF HYDROGEN PEROXIDE CATALYST BEDS 7/18/00

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 RATOs, V-2 Turbopumps, ME163
  - Submarines (with Kerosene)
- UK After WWII to Mid 1960's
  - Gamma Engine Main Propulsion , RATOs
- 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 H_2O_2 Occurs
- First H_2O_2 Decomposition System to be Fielded
  - Germany WWII
  - Typical Catalyst is Manganate Family (Ca, K, Na)
  - Example V-2 Turbo Pumps (Water – Permanganate / H_2O_2)

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 – MnO_2)
- Disadvantages
  - Life on the Order of Minutes
  - Silting, Breakup of Substrate, Catalyst
  - Increased Concentration of H_2O_2 Reduces Life
  - Catalyst Must be Held in Pressure Vessel

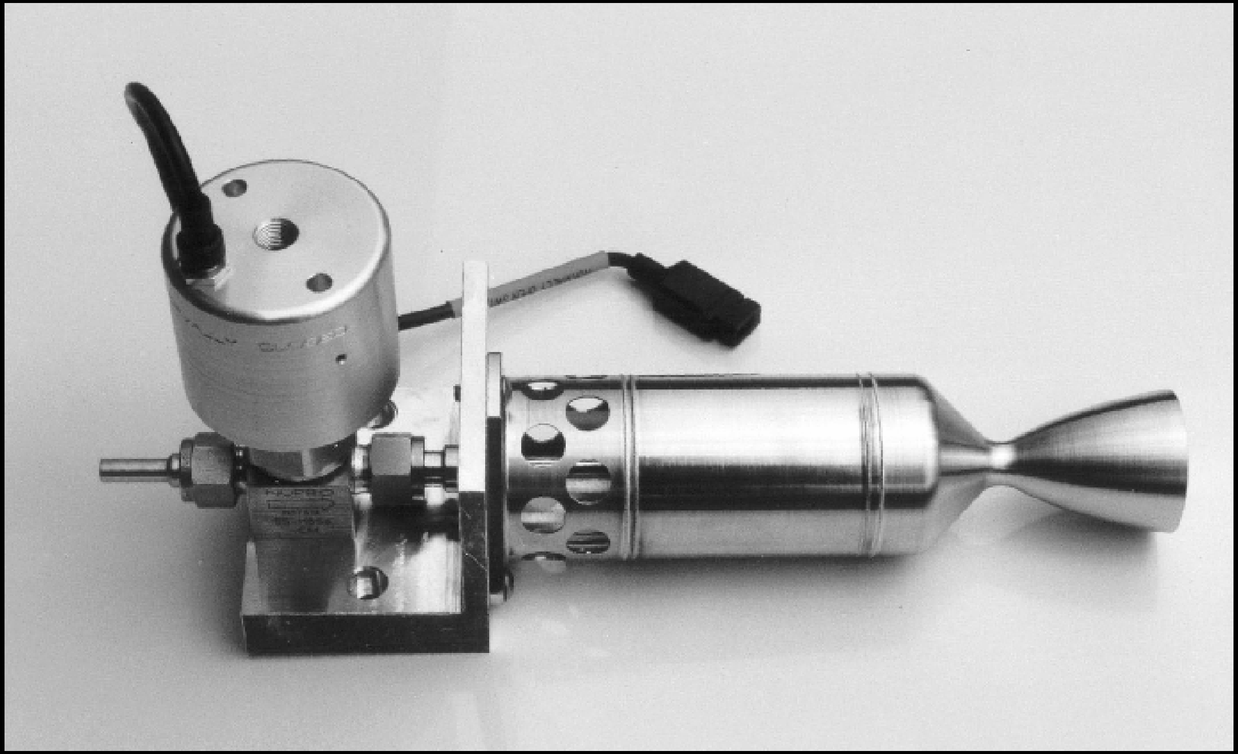
Screen Catalyst Beds

- 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

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% H_2O_2
  - Catalyst Must be Held in Pressure Vessel

Performance of Screen Catalyst Beds

- Several Important Parameter 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