AIAA-01-3250

Advancements in High Concentration Hydrogen Peroxide Catalyst Beds

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Summary

- Compare 90% and 98% H2O2
- H2O2 Catalyst Bed Requirements
- 98% H2O2 Catalyst Bed Issues
- 98% H2O2 Catalyst Bed Options
- 98% H2O2 Catalyst Beds
- 98% H2O2 Test Set-Up
- 98% H2O2 Test Data & Summary
- Conclusions
# Comparison of 90% and 98% H2O2

<table>
<thead>
<tr>
<th>Property</th>
<th>Weight % of H2O2</th>
<th>Weight % of H2O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2O2 Assay % by wt.</td>
<td>90.0 to 91.0</td>
<td>90.0 to 92.0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.5 max</td>
<td>0.2 max</td>
</tr>
<tr>
<td>Chloride</td>
<td>1.0 max</td>
<td>0.3 max</td>
</tr>
<tr>
<td>Ammonium</td>
<td>3.0 max</td>
<td>2.2 max</td>
</tr>
<tr>
<td>Nitrate</td>
<td>5.0 max</td>
<td>3.5 max</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.2 max</td>
<td>0.15 max</td>
</tr>
<tr>
<td>Sulfate</td>
<td>3.0 max</td>
<td>2.2 max</td>
</tr>
<tr>
<td>Tin</td>
<td>4.0 max</td>
<td>2.9 max</td>
</tr>
<tr>
<td>Carbon</td>
<td>200 max</td>
<td>145 max</td>
</tr>
<tr>
<td>Evaporative residue</td>
<td>20 max</td>
<td>15 max</td>
</tr>
<tr>
<td>Stability</td>
<td>2% max</td>
<td>98% min</td>
</tr>
<tr>
<td>Particulate</td>
<td>1.0 max</td>
<td>0.7 max</td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
<td>0.02 max</td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td>0.02 max</td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
<td>0.02 max</td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td>0.03 max</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td>0.02 max</td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
<td>0.02 max</td>
</tr>
</tbody>
</table>

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<th>Property</th>
<th>Weight % of H2O2</th>
<th>Weight % of H2O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>Mole fraction of H2O</td>
<td>0.7076</td>
<td>0.6748</td>
</tr>
<tr>
<td>Mole fraction of O2</td>
<td>0.2924</td>
<td>0.3252</td>
</tr>
<tr>
<td>Ave. Molecular Weight</td>
<td>22.1</td>
<td>22.57</td>
</tr>
<tr>
<td>Gamma</td>
<td>1.266</td>
<td>1.251</td>
</tr>
<tr>
<td>Temperature (deg. F)</td>
<td>1364</td>
<td>1735</td>
</tr>
</tbody>
</table>

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<th>Property</th>
<th>Weight % of H2O2</th>
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<tbody>
<tr>
<td>Density</td>
<td>(lbm/gal.)</td>
<td>11.57</td>
</tr>
<tr>
<td>Boiling point, 1 atm</td>
<td>(deg. F)</td>
<td>286.2</td>
</tr>
<tr>
<td>Freezing point, 1 atm</td>
<td>(deg. F)</td>
<td>11.3</td>
</tr>
<tr>
<td>Vapor pressure, 77 deg. F</td>
<td>mm Hg</td>
<td>3.8</td>
</tr>
<tr>
<td>Viscosity, 77 deg. F</td>
<td>centipoise</td>
<td>1.153</td>
</tr>
<tr>
<td>Surface tension, 68 deg. F</td>
<td>dynes/cm</td>
<td>79.3</td>
</tr>
<tr>
<td>Heat of Vaporization, 77 deg. F</td>
<td>Btu/lb</td>
<td>700.3</td>
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</table>
H2O2 Catalyst Bed Requirements

- **Overview**
  - Life: 1-2 hrs., > 5000 cycles
  - Mass flux: 0.1 to > 0.4 lbm/sec-sq. in
  - Fluid temperature: 40 to > 150 degrees F
  - Operating pressure: 100 to > 1000 psia
  - Environment: Vibration & shock
  - Pressure drop: < 100 to 300 psid
  - Cost, reliability, mass, transients, etc…

- Silver based screen packs are a good fit for 90% H2O2 and these requirements

- 98% H2O2 catalyst should be comparable to silver based catalysts with respect to generally meeting requirements

- *Primary challenge is higher operating temperature*
98% H2O2 Catalyst Bed Issues

- 98% H2O2 has ~ 350 degree hotter decomposition temperature
- Decomposition temperature of 90% H2O2 is ~ 360 degrees colder than melting point of silver
- 98% decomposition temperature virtually same as melting point of silver
- Decomposition temperature is a function of propellant feed temperature (1.6 degrees F/deg. F)
- Decomposition temperature is a function of operating pressure
- Actual operating temperature dependent on concentration, prop. temperature and operating pressure.
- Worst case applications are high pressure staged combustion 98% combustion devices using H2O2 regen.
98% H2O2 Catalyst Options

- Various options tested in the past
  - High melting point silver alloys (i.e. silver-palladium)
  - High temperature metallic catalysts (including alloys)
    - Platinum
    - Palladium
    - Iridium
    - Ruthenium
    - Cobalt
  - Non-metallics
    - Manganese dioxide
    - Barium oxides
- No obvious solutions that provide comparable performance as silver with 90% H2O2
- Relaxation of requirements permits some concepts
  - Stennis Space Center manganese dioxide facility catalyst bed, operated with 98% H2O2
98% H2O2 Catalyst Beds

- GK has built several functioning 98% catalyst beds in past 12 months
- Most of this work is proprietary and not currently available to the public
- An example of a flight like catalyst bed has been built and tested to reasonable operating conditions.
- Low cost manganese dioxide catalyst beds are also available
- Flight-Like Catalyst Bed
  - GK proprietary catalyst
  - Tested with X-L Space Sys 98% H2O2, 10/00
  - Demonstrated typical performance
  - Test terminated due to test stand contamination
98% H2O2 Test Set-Up

Legend
- 2-way sol. vlv
- position sensor
- press. gauge
- thermocouple
- venturi
- turbine flow meter
- 3-way sol. vlv
- ball vlv
- press. transducer
- burst disc
- 2-way manual vlv
- filter
- hose
- manual reg.
- check vlv
- dome loaded reg.
- bottle
- orifice

Note: Some instrumentation not shown for clarity.

Pressurization Panel Pneumatic Supply Interface

Pressurization Panel Pneumatic Supply

Cat Bed

Temp. #1
Temp. #2

P Inlet #1
P Inlet #2

P Exit #1
P Exit #2

Feed Panel Pneumatic Supply

Feed Panel Pneumatic Supply Interface

GN2 Gas Supply Interface

98% Catalyst Bed Test Set-Up
P/N GK-MD015-504-001, Rev. B
Originator: M. Ventura
7/2/01
98% H2O2 Test Data

- **Pressures**
  - Decomposition roughness low (Data is 1 kHz with 250 Hz low pass filter)
  - Behavior comparable in features to 90% catalyst bed
  - Pressure is high, but expected with flux and higher gas temperatures

- **Temperatures**
  - Behavior comparable in features to 90% catalyst bed
  - Lower than expected temperature due to propellant concentration being ~ 96% to 97%
98% H2O2 Test Data Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tests</td>
<td>37</td>
</tr>
<tr>
<td>Total test time</td>
<td>1112 seconds</td>
</tr>
<tr>
<td>Max. mass flux</td>
<td>0.5 lbm-sec/sq.-in</td>
</tr>
<tr>
<td>Pressure drop</td>
<td>430 psid @ G=0.5</td>
</tr>
<tr>
<td>Roughness</td>
<td>1% to 2%</td>
</tr>
<tr>
<td>Min. start temperature</td>
<td>250 degrees F</td>
</tr>
<tr>
<td>H2O2 concentration</td>
<td>96% to 97%</td>
</tr>
<tr>
<td>C-Star Efficiency</td>
<td>Approx. 100%</td>
</tr>
</tbody>
</table>
Conclusions

• 98% H2O2 catalyst beds have been built and tested under typical operating conditions

• Performance of these catalyst beds is comparable in general characteristics to 90% H2O2 catalyst beds - risk of 98% catalyst beds is low

• A 98% H2O2 catalyst bed has demonstrated typical performance with life > 1000 seconds

• 98% catalyst beds can be developed for emerging systems at diminished risk.