AIAA-01-3250
Advancements in High Concentration Hydrogen Peroxide Catalyst Beds

M. C. Ventura, E. J. Wernimont
General Kinetics LLC, Lake Forest, CA
July, 2001

Summary

- Compare 90% and 98% H_2O_2
- H_2O_2 Catalyst Bed Requirements
- 98% H_2O_2 Catalyst Bed Issues
- 98% H_2O_2 Catalyst Bed Options
- 98% H_2O_2 Catalyst Beds
- 98% H_2O_2 Test Set-Up
- 98% H_2O_2 Test Data & Summary
- Conclusions

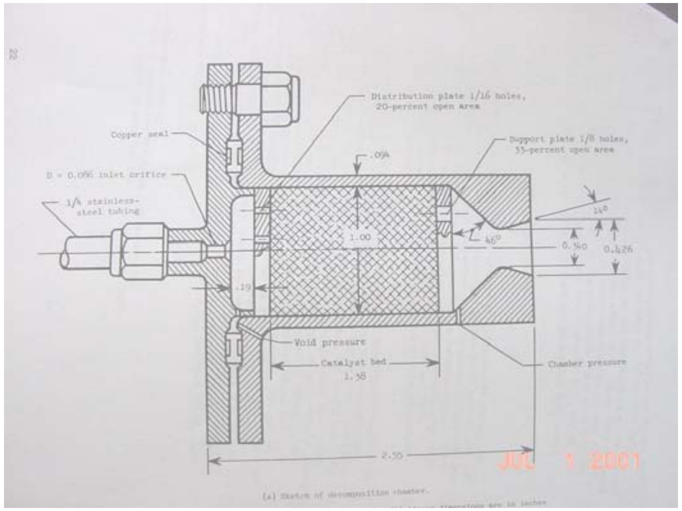
Comparison of 90% and 98% H2O2

	MIL-P-16005E (mg/l)	MIL-P-16005E (mg/kg)	FMC Type 90 (mg/kg)	FMC Type 98 (mg/kg)
H2O2 Assay % by wt.	90.0 to 91.0	90.0 to 91.0	90.0 to 92.0	98.0 to 99.0
Aluminum	0.5 max	0.35 max	0.2 max	0.25 max
Chloride	1.0 max	0.7 max	0.3 max	0.35 max
Ammonium	3.0 max	2.2 max	2.2 max	2.1 max
Nitrate	5.0 max	3.5 max	3.5 max	3.5 max
	3.0 min	2.2 min	2.2 min	2.1 min
Phosphate	0.2 max	0.15 max	0.15 max	0.14 max
Sulfate	3.0 max	2.2 max	0.3 max	0.35 max
Tin	4.0 max	2.9 max	2.9 max	2.7 max
	1.0 min	0.7 min	1.0 min	0.7 min
Carbon	200 max	145 max	30 max	30 max
Evaporative residue	20 max	15 max	15 max	14 max
Stability	2% max	98% min	98% min	98% min
Particulate	1.0 max	0.7 max	0.7 max	0.6 max
Chromium			0.02 max	0.02 max
Lead			0.02 max	0.02 max
Manganese			0.02 max	0.02 max
Iron			0.03 max	0.035 max
Copper			0.02 max	0.02 max
Nickel			0.02 max	0.02 max

	Weight % of H2O2	
Property	90	98
Mole fraction of H2O	0.7076	0.6748
Mole fraction of O2	0.2924	0.3252
Ave. Molecular Weight	22.1	22.57
Gamma	1.266	1.251
Temperature (deg. F)	1364	1735

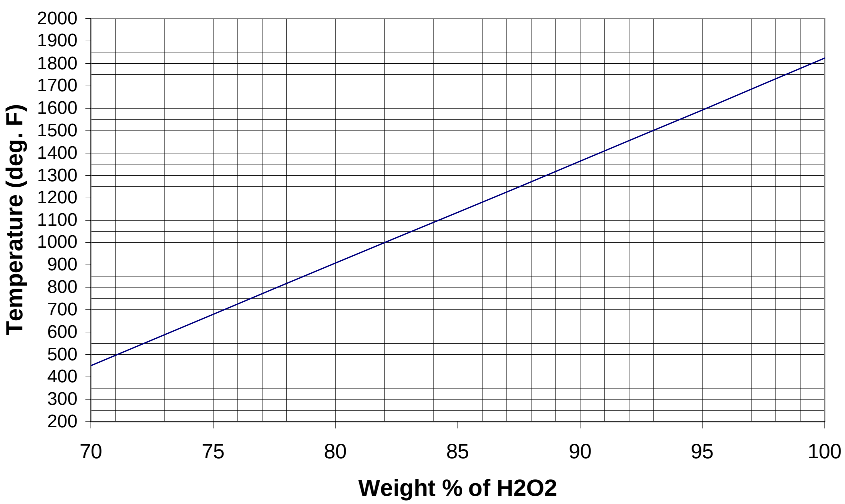
		Weight % of H2O2	
Property		90	98
Density	(lbm/gal.)	11.57	11.95
Boiling point, 1 atm	(deg. F)	286.2	299.2
Freezing point, 1atm	(deg. F)	11.3	27.5
Vapor pressure, 77 deg. F	mm Hg	3.8	2.2
Viscosity, 77 deg. F	centipoise	1.153	1.155
Surface tension, 68 deg. F	dynes/cm	79.3	80.2
Heat of Vaporization, 77 deg. F	Btu/lb	700.3	662.0

H2O2 Catalyst Bed Requirements



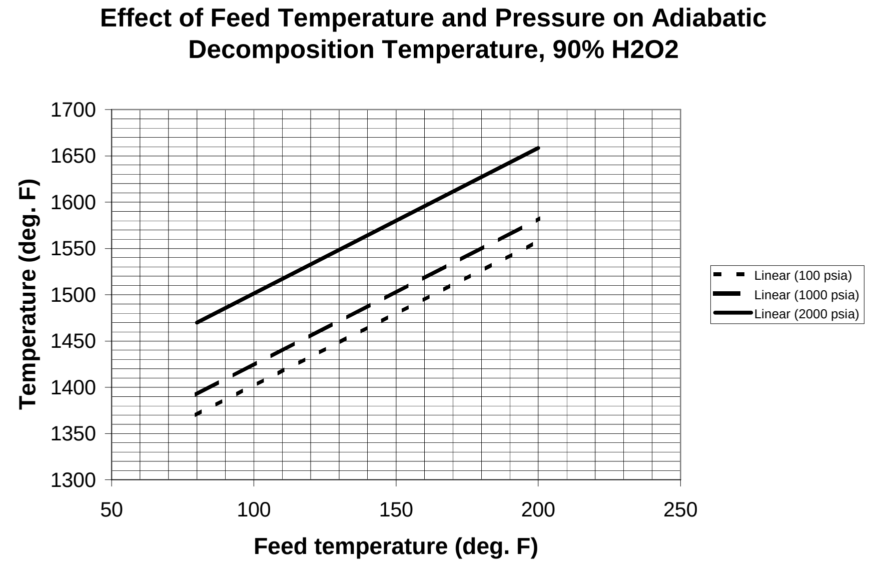
- Overview
  - Life: 1-2 hrs., > 5000 cycles
  - Mass flux: 0.1 to > 0.4 lbm/sec-sq. in
  - Fluid temperature: 40 to > 150 degrees F
  - Operating pressure: 100 to > 1000 psia
  - Environment: Vibration & shock
  - Pressure drop: < 100 to 300 psid
  - Cost, reliability, mass, transients, etc…
- Silver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

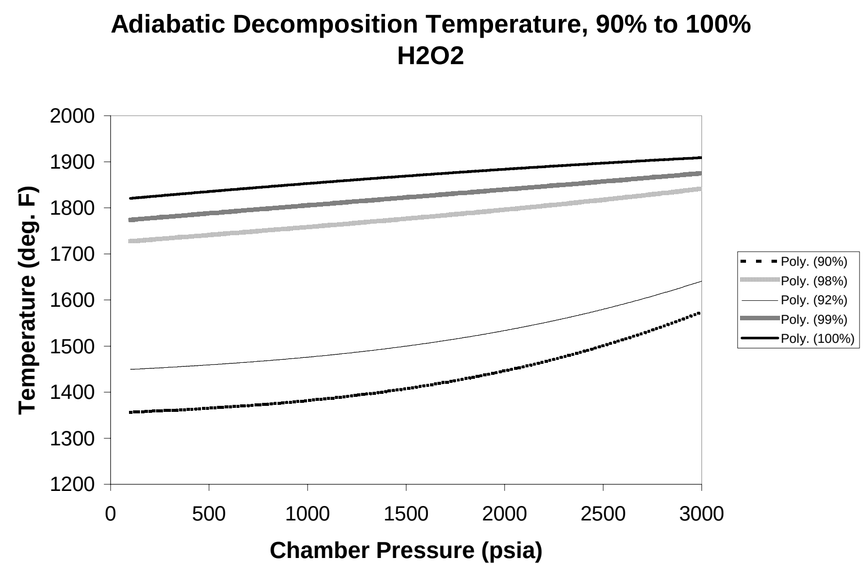
Adiabatic Decomposition Temperature of H2O2



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.





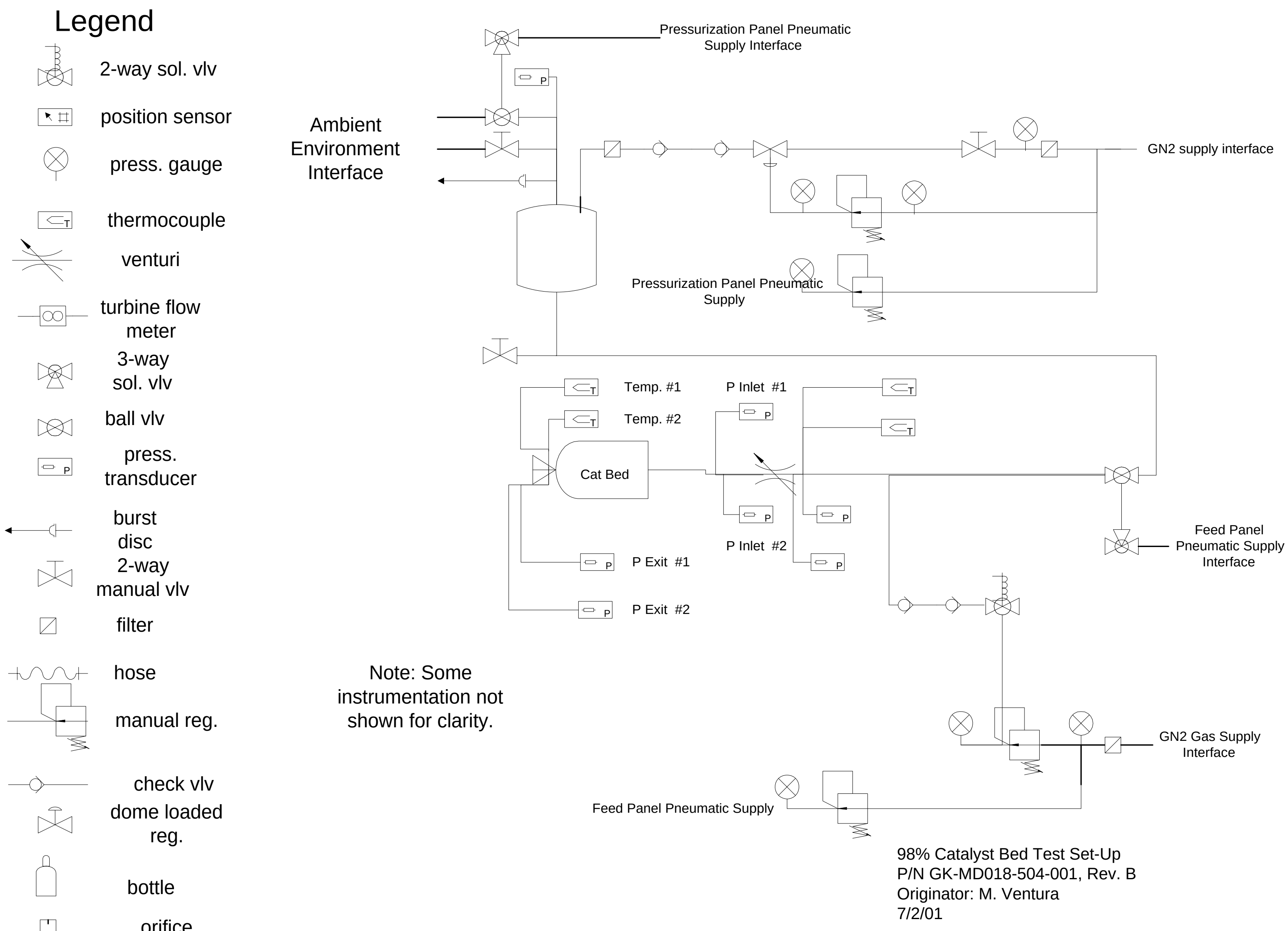
98% H2O2 Catalyst Options

- 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

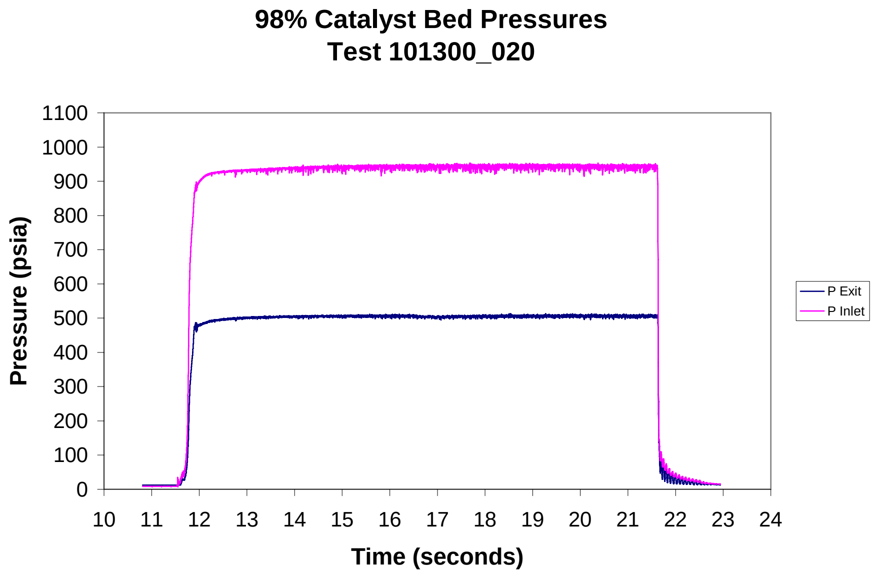
- GK has built several functioning 98% catalyst beds in past 12 months
- Most of this work is proprietary and not currently available to the public
- An example of a flight like catalyst bed has been built and tested to reasonable operating conditions.
- Low cost manganese dioxide catalyst beds are also 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

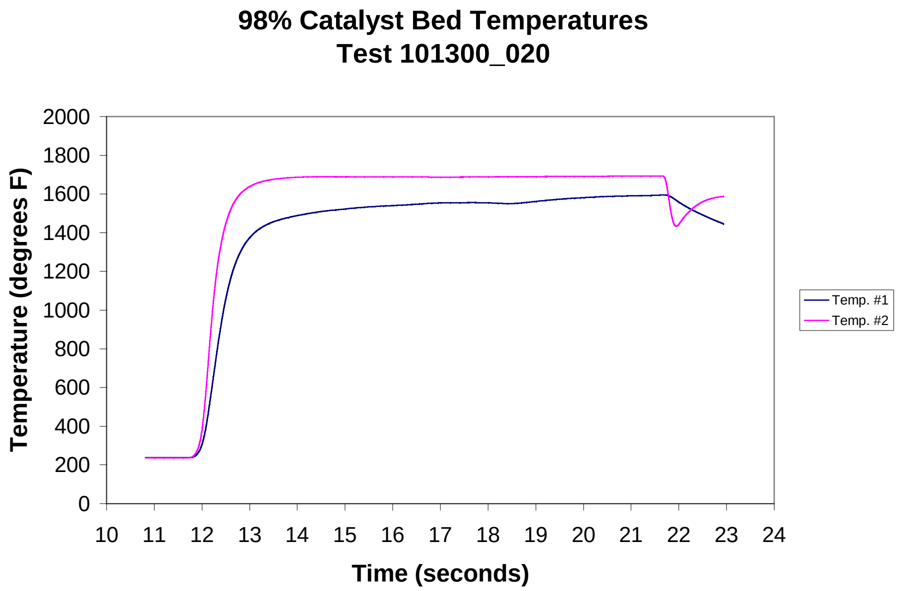
98% H2O2 Test Set-Up



GENERAL KINETICS LLC

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

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

Conclusions

- 98% H_2O_2 catalyst beds have been built and tested under typical operating conditions
- Performance of these catalyst beds is comparable in general characteristics to 90% H_2O_2 catalyst beds - risk of 98% catalyst beds is low
- A 98% H_2O_2 catalyst bed has demonstrated typical performance with life > 1000 seconds
- 98% catalyst beds can be developed for emerging systems at diminished risk.