

***AIAA 2002-3852***

***CATALYST BED TESTING FOR DEVELOPMENT OF  
A 98% HYDROGEN PEROXIDE PROCUREMENT  
SPECIFICATION***

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***Date: July 9, 2002***

# *Overview*

- Project Objectives & Motivation
- Baseline and Poisoned Tests Approach
- Baseline Test Results
- Poisoned Tests Results
  - C-Star
  - Pc Roughness
  - Pressure Drop
  - SEM Analysis
- Recommended Specification: 98% H<sub>2</sub>O<sub>2</sub>
- Cyclic Thermal Load Test
- Acknowledgements
- Conclusions

# *Project Objectives & Motivation*

- No 98% H<sub>2</sub>O<sub>2</sub> Procurement Specification Presently Exists
- Reduce Technology Risk (98% H<sub>2</sub>O<sub>2</sub> & Catalyst)
  - Push State of Art Operational Duration of catalysts to 5000 sec
  - Determine Bounds of 98% H<sub>2</sub>O<sub>2</sub> Impurity/Stabilizer limits without Performance Reduction
    - Test three impurities (SS, Al, Carbon)
    - Test three excess stabilizers (Tin, Phosphate, Nitrates)
  - Use Test Results to Formulate Future 98% H<sub>2</sub>O<sub>2</sub> Procurement Specification
  - Perform cyclic combined thermal/load tests to determine material fatigue effects
    - Test two catalysts systems to the cyclic duty cycle representative of shuttle RCS thrusters
- Catalyst Vendors: GK, RD
- Single Fluid Supplier (selected competitively): FMC

# *Baseline and Poisoned Tests Approach*

- Baseline Run with Nominal Propellant
  - Total Run Duration 5000 sec
  - $G \sim 0.27 \text{ lbm}/(\text{in}^2\text{-s})$
  - $P_c \sim 550 \text{ psia}$
  - 0.5" Diam Catalyst Bed
  - GK 2" Long, RD 4" Long Catalyst Bed
- 'Poison' Test
  - Dope Nominal Propellant
  - Total Run Duration 3000 sec
  - Use a new catalyst bed for each poison test
  - Clean test equipment between each test sequence
  - Nominal 500 sec steady state runs
- Perform SEM analysis post test



# ***Baseline Test Results***

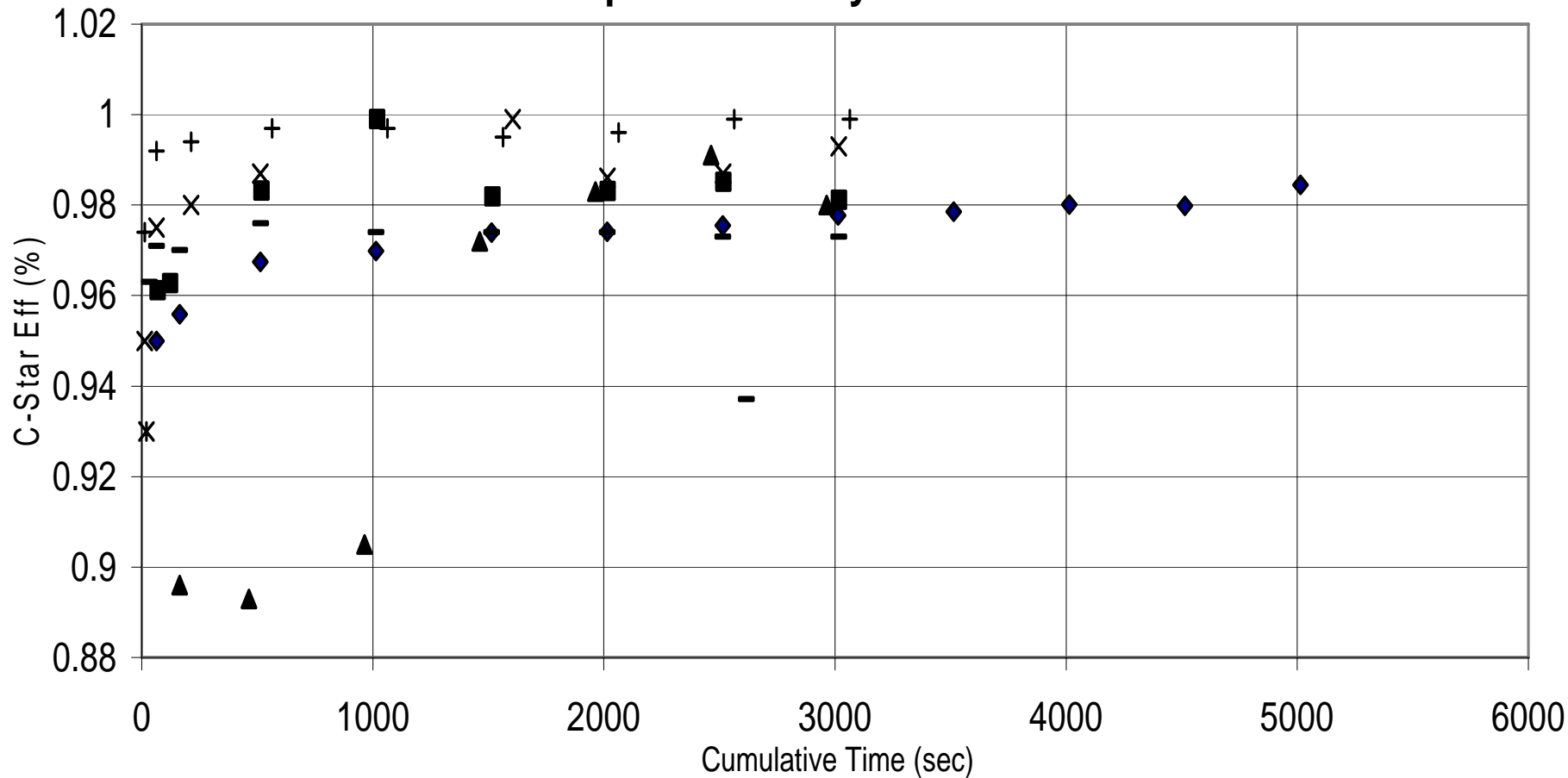
- Baseline (Nominal 98% H<sub>2</sub>O<sub>2</sub>, 5000 sec) Test Results
  - GK & RD Both Performed Well and Lasted Duration
  - C\* Greater Than 95%, (Correct RD Data for Nozzle Erosion)
  - 3-Sig Pc Roughness
    - GK < 5%
    - RD < 5% to 4000 sec, < 20% to 5000 sec (Maybe a Leak)
  - Pressure Drop: GK 30 - 50 psid, RD 100 - 325 psid

# Poison Tests Results

- Poison Test Results - Deviations From Baseline
  - NO<sub>3</sub>, TOC, SS
    - Nominal (GK & RD)
  - Sn
    - Roughness Increase to ~20% at 3000 sec (GK & RD)
    - Pressure Drop to ~Zero at 3000 sec (GK)
  - PO<sub>4</sub> on GK
    - Flooded at 10 -15 sec of Total Time (GK)
    - Mild Increase Roughness ~10-15% , Reduction C-Star ~95% (RD)
  - Al
    - Possible Memory Effect, Performance Recovery to nominal at 1500 sec (GK)
    - Nominal (RD)

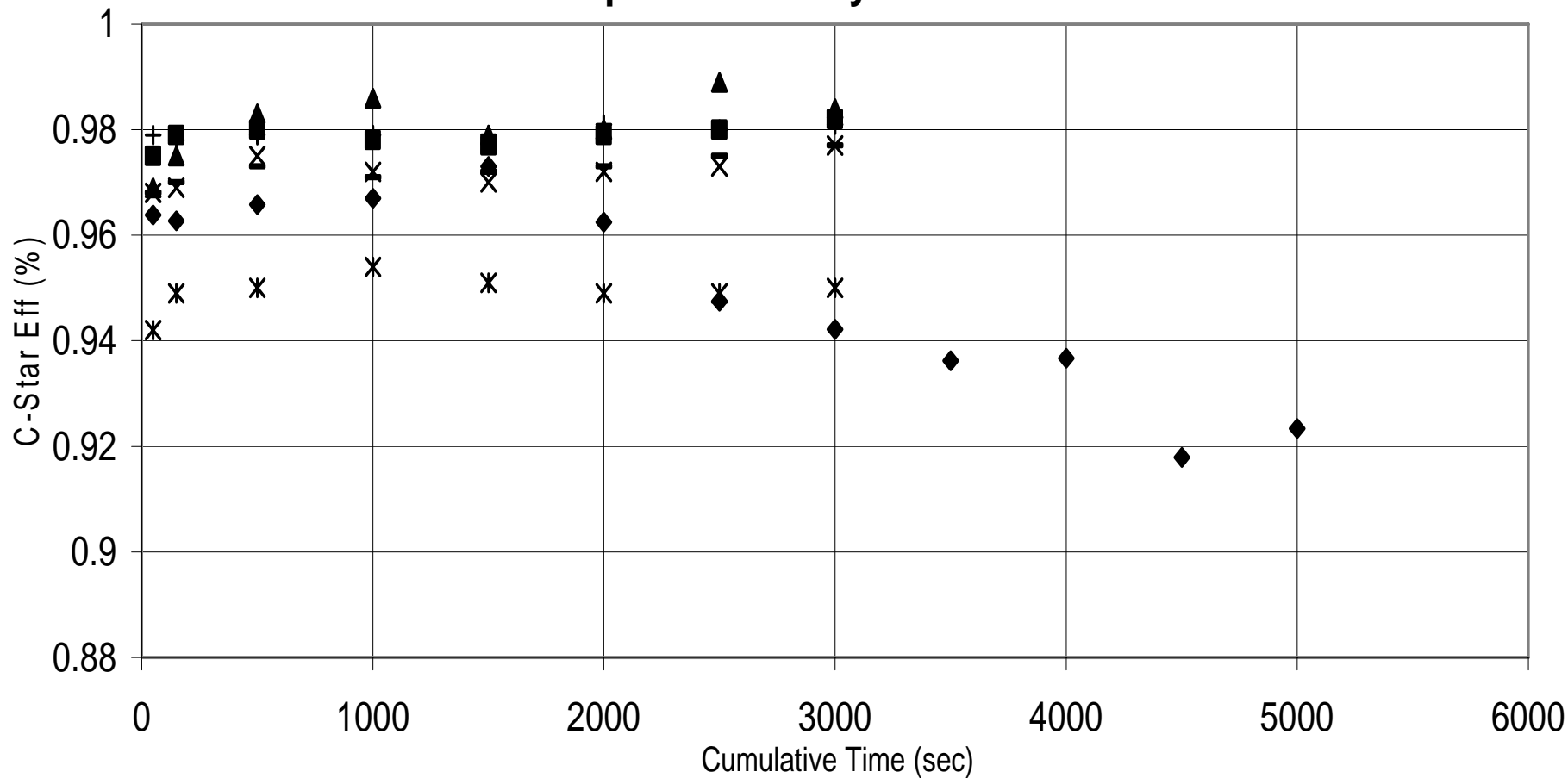


## C-Star Comparison Catalyst Tests NRA8-30



◆ GK Baseline ■ GK High NO3 × GK High Sn ✱ GK High PO4 ▲ GK High Al - GK High TOC + GK High SS

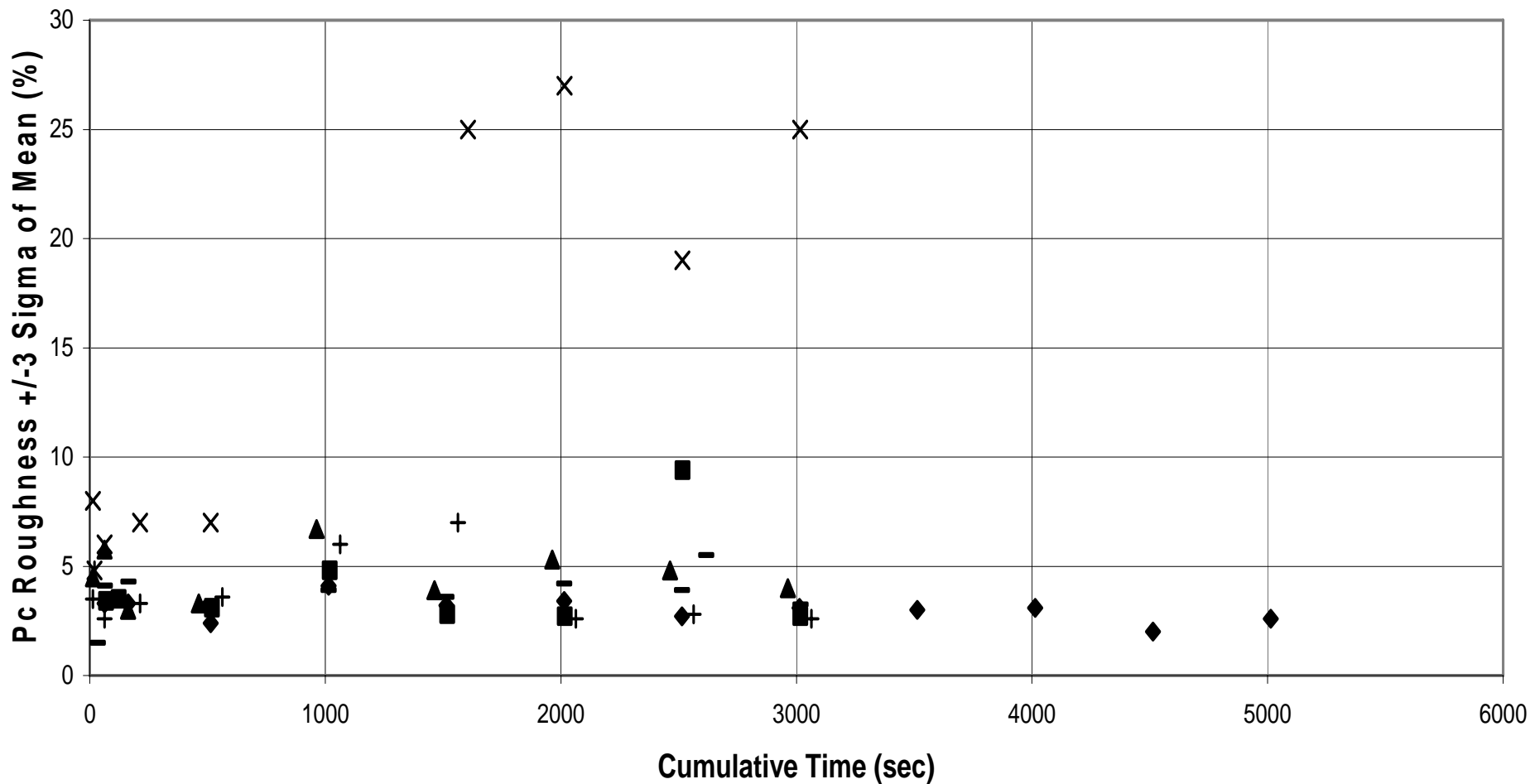
## C-Star Comparison Catalyst Tests NRA8-30



◆ BR Baseline ■ BR High NO3 ✕ BR High Sn ✕ BR High PO4 ▲ BR High Al — BR High TOC + BR High SS

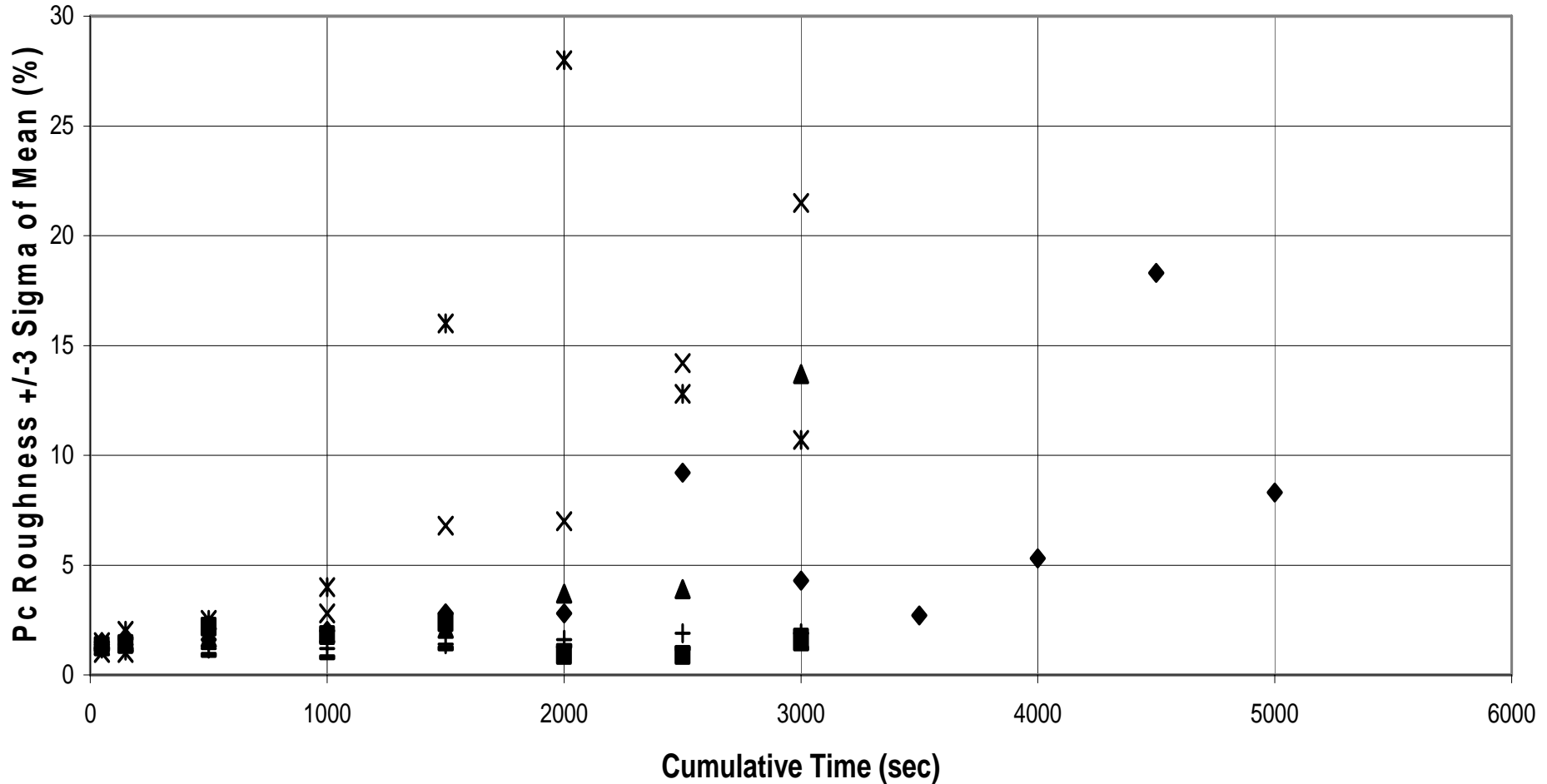


# Pc Roughness Comparison Catalyst Tests NRA8-30



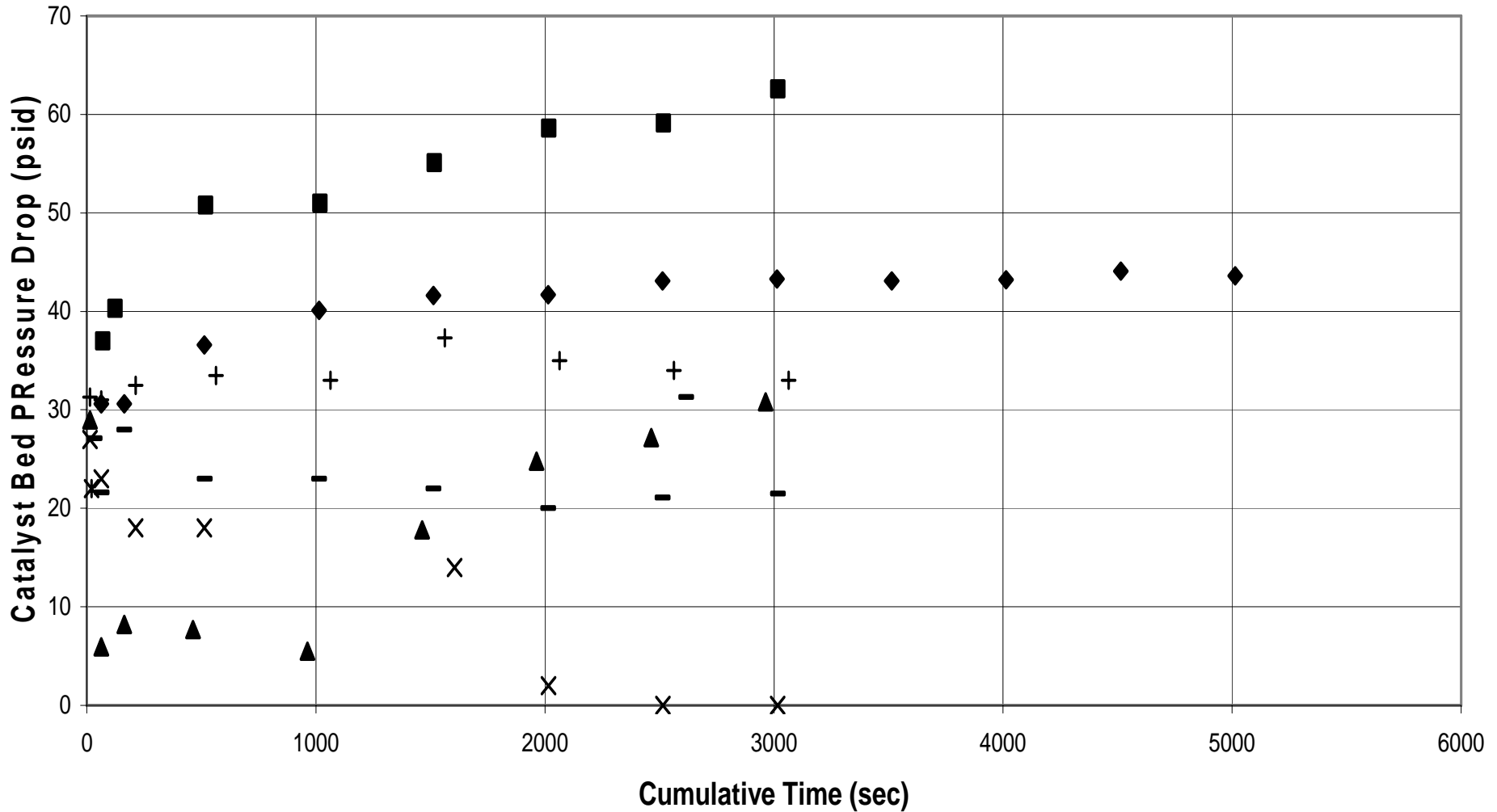
◆ GK Baseline ■ GK High NO3 X GK High Sn ✕ GK High PO4 ▲ GK High Al - GK High TOC + GK High SS

# Pc Roughness Comparison Catalyst Tests NRA8-30



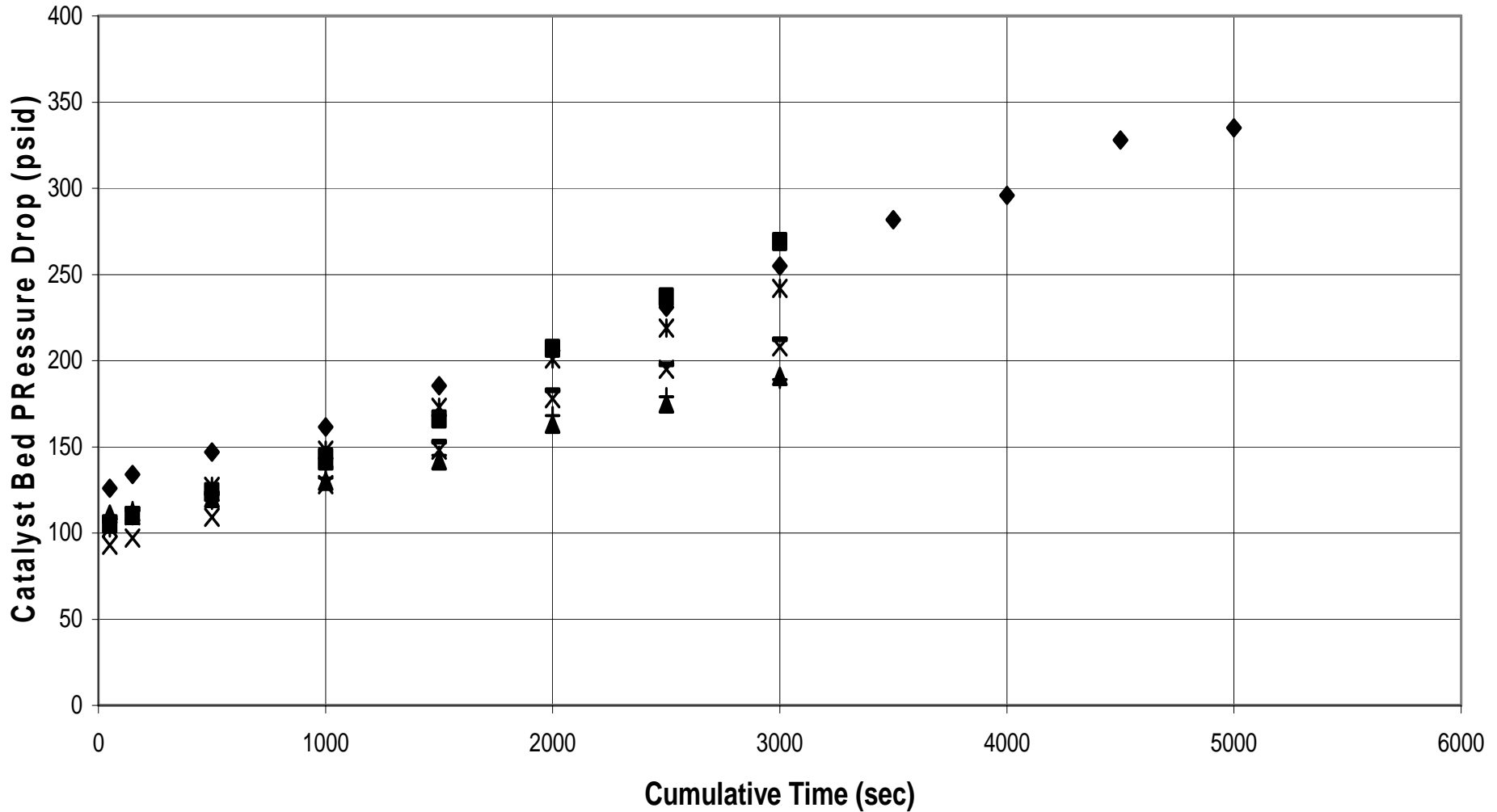
◆ BR Baseline ■ BR High NO3 × BR High Sn ✖ BR High PO4 ▲ BR High Al - BR High TOC + BR High SS

# Pressure Drop Comparison Catalyst Tests NRA8-30



◆ GK Baseline ■ GK High NO3 × GK High Sn \* GK High PO4 ▲ GK High Al - GK High TOC + GK High SS

# Pressure Drop Comparison Catalyst Tests NRA8-30



◆ BR Baseline ■ BR High NO3 ✕ BR High Sn ✖ BR High PO4 ▲ BR High Al — BR High TOC + BR High SS

# *Poison Tests Results*

- SEM Results
  - Sn, Sn, Sn Everywhere, Every Form (All poisons & Pulse Test GK, RD)
  - RD Additional Elements
    - P for PO4 Test
    - Al for Al Test
    - Traces Mg, Na, S, Fe, Ni, Cr Otherwise
  - GK Additional Elements
    - Al for Al Test
    - Traces Mg, Fe, Ni, Cr, Cu, Na, P Otherwise

# *Recommended Specification: 98% H2O2*

	<b>Expected Spec</b>	<b>Ref</b>
<b>Parameter</b>	<b>Level</b>	<b>MIL-P-16005E</b>
Assay Wt %	98-99%	98-99%
Al	0.35 mg/l max	0.5 mg/l max
Chloride (Cl-)	0.5 mg/l max	1.0 mg/l max
Ammonium (NH4+)	3.0 mg/l max	3.0 mg/l max
Nitrate (NO3-)	3 - 5 mg/l	3 - 5 mg/l
Phosphate (PO4-)	0.2 mg/l max	0.2 mg/l max
Sulfate (SO4-)	0.5 mg/l max	3.0 mg/l max
Tin (Sn)	1 - 4 mg/l	1 - 4 mg/l
TOC	40 mg/l max	200 mg/l (C) max
Evaporative Resid	20 mg/l max	20 mg/l max
Stability	2.0% max AO	2.0% max of AO
Ni	.03 mg/l max	N/A
Cr	.03 mg/l max	N/A
Fe	.05 mg/l max	N/A
Cu	.03 mg/l max	N/A
Mn	.03 mg/l max	N/A
Notes		

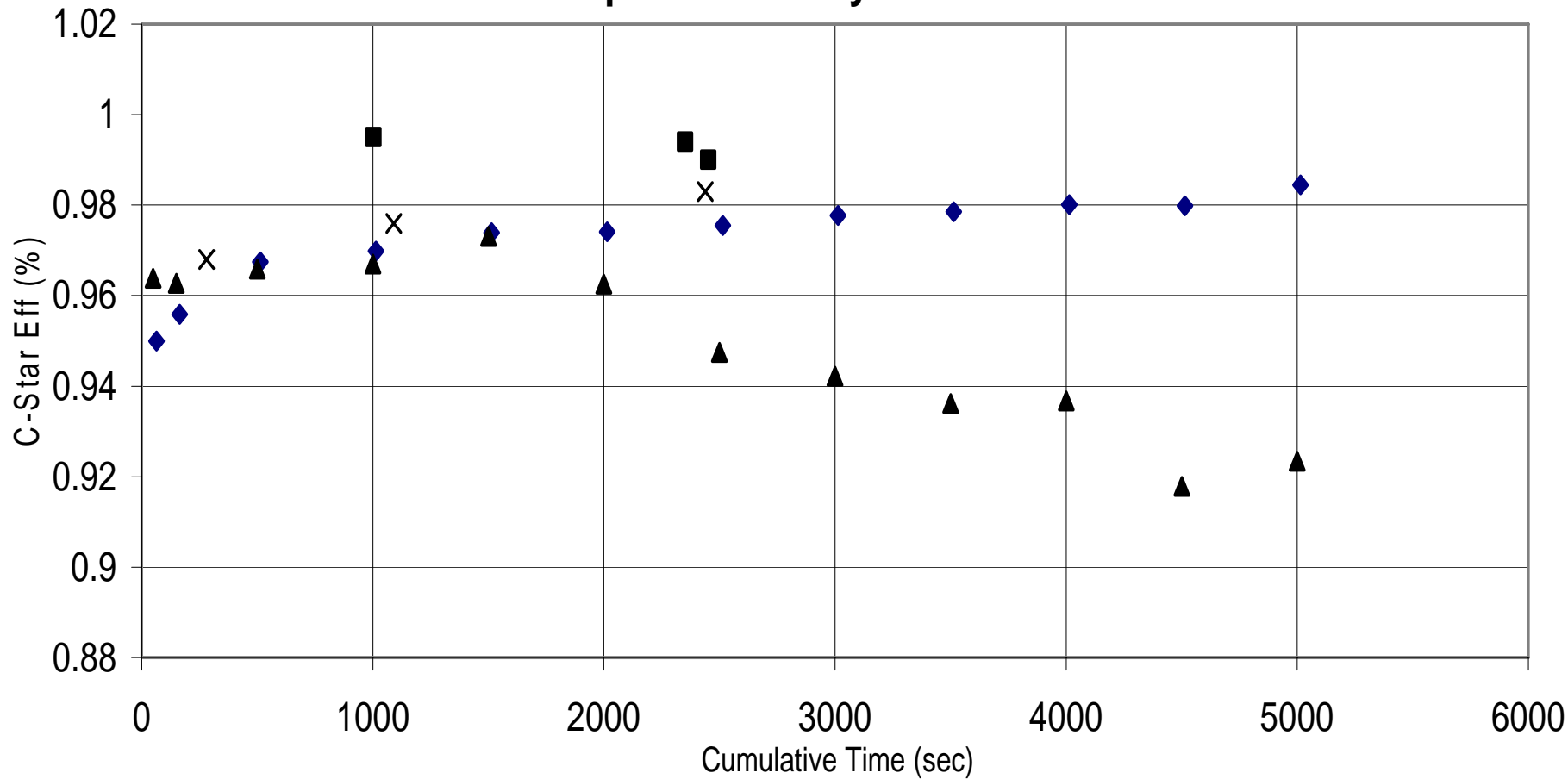
- Requires concurrence of NASA, USAF, and Suppliers

# *Cyclic Thermal Load Test*

- Replaced run valve in test stand to achieve higher computer driven valve response
- Performed test sequence A through I
- Pulse Test Results
  - Nominal (GK)
  - Slightly Different Pressure Drop Increase Behavior (RD)

	Each Cycle		Number of cycles	Total burn time Seconds	Cum Burn time	Cum cycles
	On Pulse	Off-pulse				
Sequence A	.080 sec	1.52 sec	1000	80	80	1000
Sequence B	1 sec	19 sec	100	100	180	1100
Sequence C	10 sec	190 sec	10	100	280	1110
Sequence D	.080 sec	0.42	3000	240	520	4110
Sequence E	1 sec	5.5 sec	270	270	790	4380
Sequence F	10 sec	55 sec	30	300	1090	4410
Sequence G	.080 sec	0.24	5600	448	1538	10010
Sequence H	1 sec	3 sec	450	450	1988	10460
Sequence I	10 sec	30	45	450	2438	10505

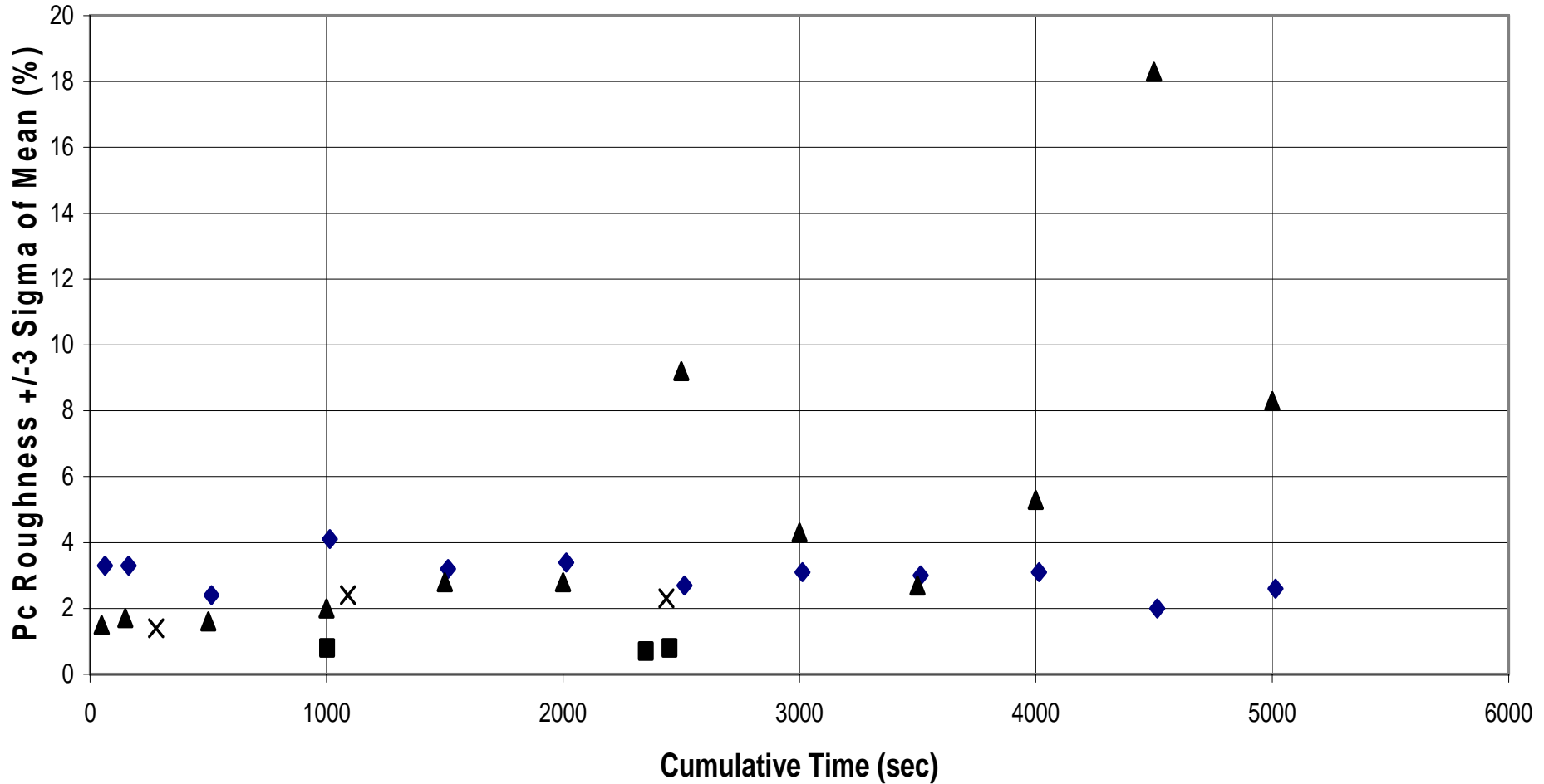
## C-Star Comparison Catalyst Tests NRA8-30



◆ GK Baseline ■ GK Pulse ▲ BR Baseline (Not Corrected) X BR Pulse

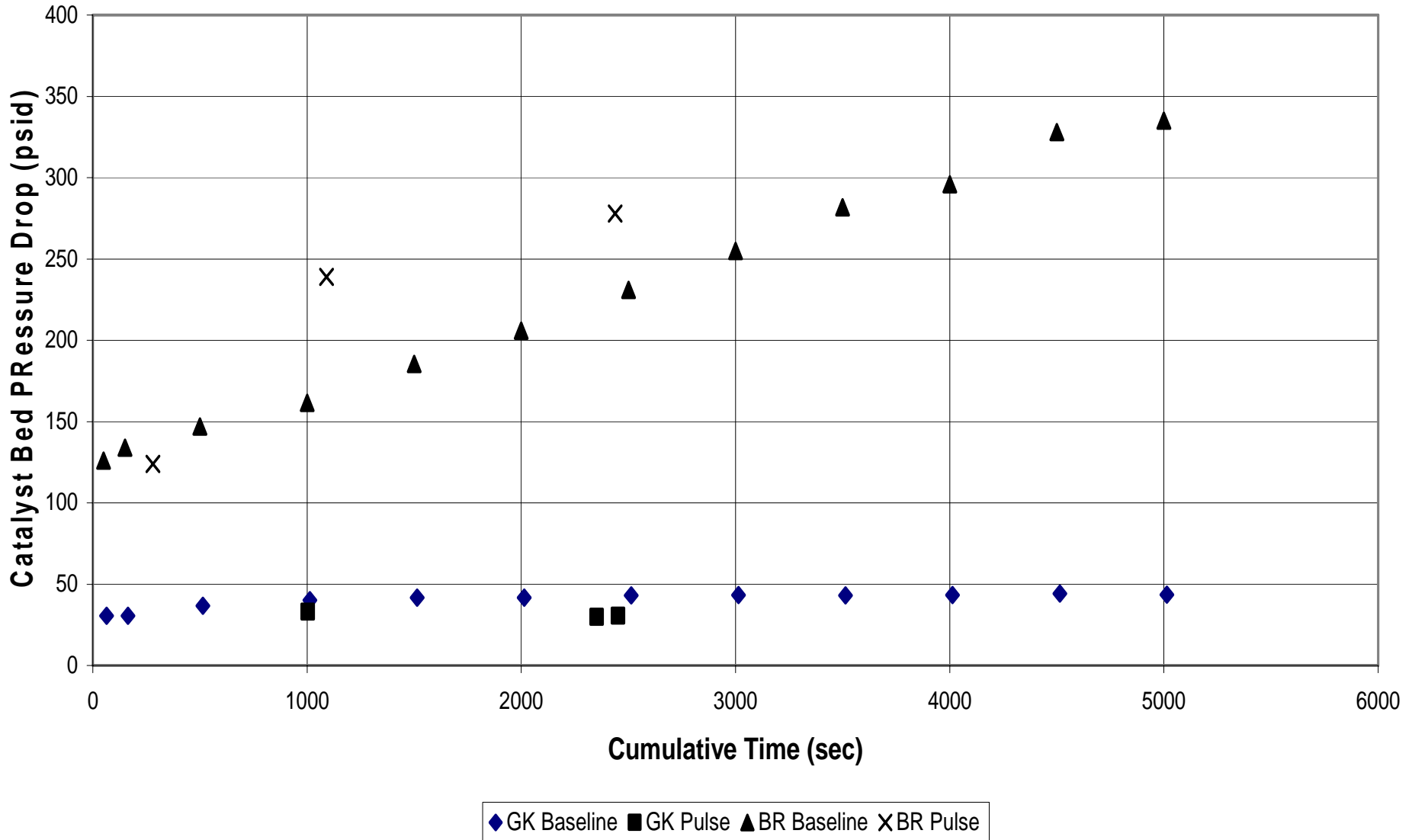


# Pc Roughness Comparison Catalyst Tests NRA8-30



◆ GK Baseline ■ GK Pulse ▲ BR Baseline X BR Pulse

# Pressure Drop Comparison Catalyst Tests NRA8-30



# *Acknowledgements*

- MSFC NRA8-30 (Space Launch Initiative)
  - Mr. Curtis McNeal & Mr. Deon Smith
- FMC
  - Mr. Steven Yuan
- Boeing Rocketdyne
  - Mr. Terry Lorrie & Kevin Lohner
- H2O2 Community

# *Conclusions*

- Completed Risk Reduction Study of 98% H<sub>2</sub>O<sub>2</sub>
  - Over 48000 Sec of Hot Fire Time on GK and RD Catalyst
  - Pulse Tested Over 10500 cycles (.08 to 1 sec pulse widths) GK & RD
  - Tested 6 Elevated stabilizers/impurities (Sn, NO<sub>3</sub>, PO<sub>4</sub>, Al, TOC, SS)
  - Both GK & RD catalyst Ran 5000 sec with Nom Propellant
    - C-star Efficiency > 95%
    - 3 Sigma Pc Roughness < 5%
    - Cat Press Drop 30-50 psid GK, 100-325 psid RD
  - Elevated Material Levels to Avoid Sn, PO<sub>4</sub>
- Greatly Increased Knowledge of Catalyst/H<sub>2</sub>O<sub>2</sub> Behavior
- Procurement Specification Data Generated With No Known Gaps