NASA

WHITE SANDS TEST FACILITY

An Improved Approach for Analyzing the Oxygen Compatibility of Solvents and other Oxygen-Flammable Materials for Use in Oxygen Systems

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History

- 1987 Montreal Protocol
  - CFC-113 phased out by 2010
  - Consumption and production of HCFCs to freeze by 2013
- 2001 CFC-113 Solvent Replacement Study
  - Ideally Solvents found “non-flammable”
    - AIT (G72) Low and High Pressure
    - Mechanical Impact (D2512/ G86)- 72 ft-lbf
  - Asahi AK225 (HCFC) selected as replacement
- 2012 AK225G Solvent Replacement Study
  - Non-ignitability not always possible
    - All Candidate Solvents found to be ignitable
    - Even previously thought non-ignitable AK-225G ignites
  - Criteria existed allowing further consideration but unclear how to make best material selection.

New Proposed Approach

- Concepts of ASTM G63 & NASA-STD-6001 used to develop new approach
  - Cannot directly apply (OCA process is application specific)
  - Solvents may see any number of applications
- Approach included
  - Ease of ignition (Low and High P AIT G72, Impact LOX & GOX G86)
    - Performance ranking vs. pass/fail results
  - Propagation and damage potential
  - Properties affecting potential results
  - Ranking of materials data against proven oxygen-compatible materials

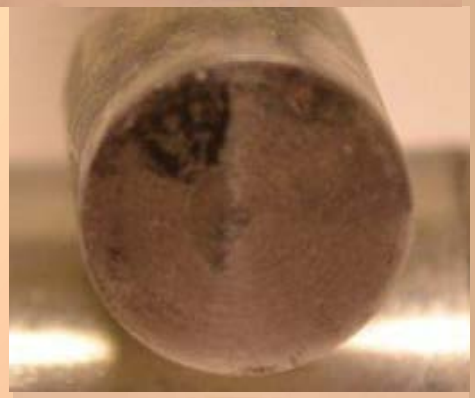
Performance Ranking Down selection

- Performance ranking used to down select
  - LOX impact energy threshold
  - GOX impact Pressure threshold
- Other down selection criteria examples
  - cleaning effectiveness, NVR, environmental regulation, etc.

G86- LOX Energy Threshold

Lowest Reaction Energy 45 ft-lbf	Lowest Reaction Energy 20 ft-lbf	Lowest Reaction Energy 10 ft-lbf (limit)	
			Sample Insert Cup
			Striker Pin
Pass Threshold 3M-L4780, 40 ft-lbf	Pass Threshold Solstice, 15 ft-lbf	Pass Threshold Solvokane, None	1 piece LOX Cup

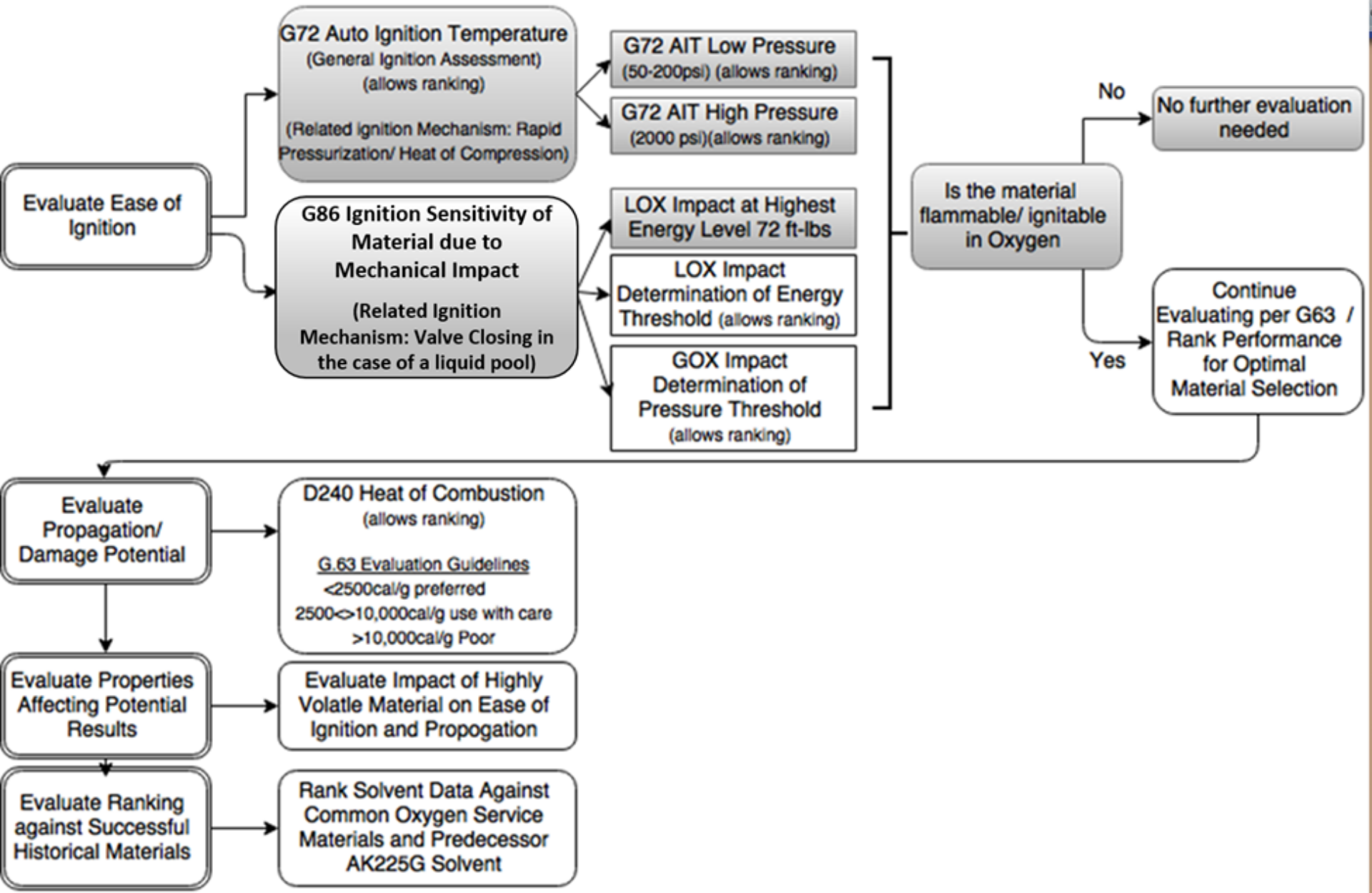
G86 GOX P Threshold 72 ft-lbs

Lowest Reaction Pressure 8000 psi	Lowest Reaction Pressure 8000 psi	Lowest Reaction Pressure 500 psi (limit)	
			Sample Insert Cup
			Striker Pin
			1 piece LOX Cup
Pass Threshold 3M-L4780, 7500 psi	Pass Threshold Solstice, 7500 psi	Pass Threshold Solvokane, None	

Final Candidates for Full Selection Testing

- Four solvents tested
  - 2 candidate solvents Solstice PF, L-14780
  - AK-225G as a baseline comparison
  - Vertrel MCA due to current use
- Final Selection Required Tests
  - Propagation Damage Potential (ASTM HOC D240)
  - Ignition Resistance (AIT G72)

Application of G63 Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service Concepts to Solvent and other Material Evaluation and Selection



Comparison to Proven Materials / Final Selection

- 1st Damage potential (HOC D240)
  - Primary ranking driver against common O_2 system materials (Direct Comparison possible)
    - Solstice PF, L-14780, & Vertrel MCA within proven range
- 2nd Ignition Resistance (AIT G72)
  - Solvents exhibit lower AITs than common O_2 softgoods
    - Increased severity of 2,000psi vs. 1,500psi
  - Volatility affords higher ignition resistance
    - Evaporation & dissipation (ignition, sustained combustion, propagation)(AK-225G history of use)
  - All Solvent AITs within family
    - Solstice PF (161 °C), L-14780 (167 °C), & Vertrel MCA (182 °C), AK225G (230 °C)

Comparison to Proven Materials / Final Selection

- Damage potential (HOC D240) ranking driver
- Ignition Resistance (AIT G72)- Within family

MORE COMPATIBLE

	Material	D240 HOC (Cal/g)	D240 J/g	G72 AIT (°C)
Common O_2 system Materials	Fluorogreen	2402	10,057	479
	TFE Teflon	1701	7,122	434
	Kel-F/ Neoflon	2558	10,710	377
	Vespel SP-21	7603	31,832	321
O_2 K-bottle use	Viton A	3995	16,726	155
	Nylon 6/6	7905	33,097	178
	Buna-N	9909	41,487	142
	IPA	7165	29,998	425 (in air)
	Polypropylene	11107	46,503	174

LESS COMPATIBLE

Solvents Ranking with HOC as Primary Driver**

Solvent	D240 HOC	D240 J/g	G72 AIT (°C)
AK-225G	1153	4,827	230*
3M L-14780	1925	8,060	161*
Vertrel MCA	2034	8,516	167*
Solstice	2448	10,249	182*

In same realm of O_2 compatibility

* AIT method performed at 13,800 kPa (2000 psi) Oxygen (Standard method performed at 10,300 kPa (1500 psi)

**Volatile solvents are ranked with HOC as a primary driver. Due to their high volatility, ignition resistance performance of solvents is in fact higher than their AIT would suggest.

Back-up Slides

Solvent	ASTM G86 GOX Impact Pressure Threshold @ 97.6 J (72 ft-lbf) MPa	psi	ASTM G86 Ambient LOX Impact Energy Thresh Modified Method / Standard Method J	ft-lbf	ASTM G86 Past LOX Impact Results @ 97.6 J (72 ft-lbf)	ASTM G72 AIT @ 345-1379 kPa (50-200 psi) Modified Method / Standard Method °F (SD)	°C (SD)	ASTM G72 AIT @ 13.79 MPa @2000psi Modified Method / Standard Method @ 1500psi °F (SD)	°C (SD)	ASTM D240 HOC cal/g (SD)	J/g (SD)
FlrGr	30.44	>4415[a]	--	--	--	--		479[b]	248[b]	2400[b]	10,048
PTFE	51.02	7400[c]	--	--	(1/60)	--		434[b]	223[b]	1700[b]	7118
PCTFE	45.61	6615[d]	--	--	--	--		377[b]	192[b]	2557[b]	10,706
IPA	--	--	--	--	--	--		--	--	7165[b]	29,998
Solstice PF	52[e]	7500[e]	97.6[e] (0/20)(1/61)	72[e]	--	464 (29)[e] @ 345 kPa (50 psi) 477 (13)[e] @ 480 kPa (70 psi)	240 (16)[e] 247 (7)[e]	360 (9)[e]	182 (5)[e]	2448 (22)[e]	10,249 (12)
L-14780	52[e]	7500[e]	97.6[e] (0/20)(0/70)	72[e]	--	454 *[e] @ 1.38 MPa (200 psi)	234 *[e]	322 (27)[e]	161 (15)[e]	1925 (20)[e]	8060 (11)
AK-225G	--	--	97.6[e] (0/20)	72[e]	9-0/20[f] 1-2/43[g] 1-6/60[h] 1-3/60[h] 2-0/60[i]	528*[e] @ 480 kPa (70 psi)	276*[e]	446[e]	230[e]	1153 (11)[e]	4827 (6)
Vertrel MCA	--	--	--	--	0/20[j] 5/20[k] 0/20[l]@15ft-lb	--	--	333[m]	167[m]	2034 (6)[n]	8516 (3)

Solvent	ASTM G86 GOX Impact Pressure Threshold @ 97.6 J (72 ft-lbf) MPa	psi	ASTM G86 Ambient LOX Impact Energy Thresh Modified Method / Standard Method J	ft-lbf	ASTM G86 Past LOX Impact Results @ 97.6 J (72 ft-lbf)	ASTM G72 AIT @ 345-1379 kPa (50-200 psi) Modified Method / Standard Method °F (SD)	°C (SD)	ASTM G72 AIT @ 13.79 MPa @2000psi Modified Method / Standard Method @ 1500psi °F (SD)	°C (SD)	ASTM D240 HOC cal/g (SD)	J/g (SD)
Solvay Solvokane®[o]	NT @ 3.45[e]	NT @ 500[e]	NT @ 14[e]	NT @ 10[e]	--	496[e] @ 345 kPa (50 psi) 489[e] @ 480 kPa (70 psi)	258[e] 254[e]	305[e]	151[e]	--	--

Table 3. AIT Results for Solvents Tested

Solvent	AIT @50 psi (°C)	AIT @2000 psi (°C)	LOX Impact[1]
CFC 113	NI	NI	NO
Tetrachloroethylene	136	161	NO
Trichloroethylene	108	77	NO
HFE 71DE	NI	157	YES
Vertrel MCA	NI	167	NO
HFE 7100	NI	NI	NO
Vertrel XF	NI	241	NO
HCFC 141b[2]	NI	NI	NO
HFE 7200	NI	262	NO
OS-10	125	224	Yes
ABZOL VG & EnSolve	102	185	Yes
HCFC 225	NI	NI	NO

NI = No Ignition (did not ignite at maximum test temperature of 450 °C)

[1] Reactions in Mechanical Impact at 72 ft lbs

[2] Nonvolatile residue of solvent was less than 17 ppm.