



Solstice® Performance Fluid in Oxygen Line Cleaning

By Ryan Hulse (Global Solvent and Aerosol Application Leader) and Jon Herdlein (Senior Research and Development Engineer) – Honeywell

Introduction

Solstice® Performance Fluid (Solstice PF) is a new fluorinated solvent that offers exceptional cleaning power while satisfying your long-term environmental and safety requirements. In 2015, NASA announced it had tested Solstice PF, stating it is a “preferred replacement for cleaning and non-volatile residue (NVR) verification sampling of NASA propulsion oxygen systems hardware, ground support equipment (GSE), and associated test systems. Solstice PF is recommended for cleaning and NVR sampling in applications at NASA propulsion test facilities where AK-225G is currently used”¹. Solstice PF is non-flammable per ASTM E681, has a global warming potential (GWP) of 1, and an occupational exposure limit (OEL) of 800 ppm established by Workplace Environmental Exposure Levels (WEEL). It is also volatile organic compound (VOC) exempt as

determined by the U.S. Environmental Protection Agency (EPA), and is listed under its Significant New Alternatives Policy (SNAP).

Solstice PF is a pure component solvent that contains no stabilizers or additives. As a pure compound, Solstice PF is able to effectively remove common residues while not leaving behind any new contamination, which is generally observed with stabilized solvents.

Compatibility

Metals commonly used in the aerospace industry were tested for compatibility with Solstice PF. The solvent was shown to be compatible with all the metals listed below when tested according to the ARP 1755B method.

Table 1: Compatibility of Solstice PF According to SAE Aerospace Recommended Practices (ARP) 1755B

Uncoated Panels		
AMS 4037 Aluminium	AMS 5040 Steel	AMS 5537 Cobalt
AMS 4375 Magnesium	AMS 5382 Cobalt	AMS 5596 Nickel
AMS 4442 Magnesium	AMS 5504 Corrosion Resistant Steel	AMS 5661 Nickel
AMS 4507 Copper	AMS 5508 Corrosion Resistant Steel	AMS 6431 Steel
AMS 4544 Nickel	AMS 5524 Corrosion Resistant Steel	AMS 4434 (AZ92) Magnesium
AMS 4640 Aluminum Bronze	AMS 5525 Corrosion Resistant Steel	MAR-M-002
AMS 4911 Titanium	AMS 5536 Nickel	IMI 685

Table 1 Continued:

Electroplated Panels		
AMS 4037/AMS 2470 Anodic Treatment	AMS 5504/AMS 2410 Silver Plating	AMS 5504/AMS 2424 Nickel Plating
AMS 5504/AMS 2400 Cadmium Plated	AMS 5504/AMS 2416 Ni – Cad Plating	
AMS 5504/AMS 2406 Chromium Plating	AMS 5504/AMS 2418 Copper Plating	
Plasma Coated Panels		
AMS 4911/AMS 2437-3	AMS 5504/AMS 2437-3	AMS 5504/AMS 2437-6
AMS 5504/AMS 2437-2	AMS 5504/AMS 2437-5	AMS 5504/AMS 2437-7
Uncoated Panels (Intergranular End Grain Pitting/ASTM F2111 Testing)		
AMS 4037 Aluminum	AMS 4911 Titanium	AMS 5504 Corrosion Resistant Steel
AMS 4375 Magnesium	AMS 5382 Cobalt	AMS 5536 Nickel

NASA also ran metal compatibility with Solstice PF using the metals listed below, and the solvent showed good compatibility with each of them¹.

Table 2: Metal Compatibility Completed at NASA¹ with Solstice PF at 72°F for 168 Hours

Ferrous-Based Coupons	Vapor Coupon Wt Change	Liquid Coupon Wt Change	Control Coupon Wt Change	Sample vs. Control Appearance
A286 SST	-0.1 mg	-0.3 mg	0.0 mg	No Change
304L	-0.1 mg	-0.1 mg	-0.1 mg	No Change
440C SST	0.2 mg	0.0 mg	0.1 mg	No Change
17-4PH	0.2 mg	0.1 mg	0.0 mg	No Change
AISI 4140	0.2 mg	-0.5 mg	-0.4 mg	No Change
Elgiloy	0.0 mg	0.0 mg	0.0 mg	No Change
Inconel 718	0.0 mg	0.0 mg	0.1 mg	No Change
Monel 400	0.0 mg	-0.1 mg	-0.1 mg	No Change
Naval Brass	-0.1 mg	-0.1 mg	0.0 mg	No Change
Tin Bronze 510	-0.2 mg	-0.2 mg	-0.2 mg	No Change
6061 T6 Al	0.0 mg	-0.1 mg	0.0 mg	No Change
2219 T6 Al	0.0 mg	0.0 mg	0.1 mg	No Change
2195 T8 (Al Li)	0.1 mg	0.0 mg	0.1 mg	No Change

Flammability

Solstice PF does not exhibit any flashpoint or vapor flame limits – it has been determined that it has no vapor flame limits at temperatures up to 100°C in ASTM E 681 testing. The reactivity of Solstice PF in an oxygen rich environment was further characterized by NASA, with the heat of combustion, autogenous ignition temperature (AIT) and liquid oxygen (LOX) testing of the solvent reported by NASA, as shown in Table 3.

Table 3: Flammability Properties of Solstice PF¹

Properties	Method	Value
Heat of Combustion at 500 psia	ASTM 63-99	2448 cal/g
AIT 50 psia (JSC-WSTF)	ASTM G72	464°F
AIT 50 psia (MSFC)		510°F
AIT 2000 psia (JSC-WSTF)	ASTM G72	360°F
AIT 2000 psia (MSFC)		411°F
LOX (JSC-WSTF)	ASTM G86-98	0/20 Reaction - Pass 15 ft.-lb. (JSC-WSTF)
LOX (MSFC)		0/20 Reaction - Pass 72 ft.-lb. (MSFC)

NVR Testing

Two SST braided, 6' x .25" Teflon-lined hoses were doped with mineral oil (mixed aliphatics) as the representative NVR. Hose 1 and Hose 2 were doped with 2.4 mg and 4 mg of mineral oil respectively. The demonstration was performed in the clean line area near an open high bay door. At the time of the test, the temperature was 86°F and the relative humidity was 72%. Honeywell also demonstrated rough cleaning of the exterior surface of an A/N fitting that was heavily contaminated with a fluorocarbon grease.

Table 4: NVR Testing with Solstice PF¹

NVR Testing at Stennis Space Center (SSC)	
Sample 1: Flexhose Doped with 2.4 mg of NVR (Mineral Oil)	Sample 2: Flexhose Doped with 4 mg of NVR (Mineral Oil)
First Solstice Sample: NVR, 2.27 mg	First Solstice Sample: 2.6 mg
Second Solstice Flush: (Catch Pan – No NVR Sample)	Second Solstice Flush: (Catch Pan – No NVR Sample)
Third Solstice Sample Flush: NVR 0.46 mg	Third Solstice Sample Flush: 0.5 mg
Background (Solvent) NVR/200 ml: 0.4 mg	Background (Solvent) NVR/200 ml: 0.4 mg
Final AK225G Flush: 0.01mg	Final AK225G Flush: 0.2 mg
Solstice PF Removal Efficiency: >99.9%	Solstice PF Removal Efficiency: 95% (3.8 mg)

Table 5: Part Cleaning with Solstice PF¹

Cleaning of an A/N Fitting Heavily Coated with Christo Lube MCG111 Grease (Similar to Krytox 240 AC)	
Before	After
	

Summary

Solstice PF is a safe and effective choice for cleaning parts which will be used in oxygen service. NASA has recently designated the solvent as the preferred alternative to AK-225G in oxygen system cleaning. Solstice PF has an ideal combination of non-flammability, low toxicity, low volatility, and high cleaning performance, which allows it to be used to clean tight spaces and then be removed to leave a pristine surface.

Reference

1. Replacement of Hydrochlorofluorocarbon-225 Solvent for Cleaning and Verification Sampling of NASA Propulsion Oxygen Systems Hardware, Ground Support Equipment, and Associated Test Systems; H.D. Burns, M.A. Mitchell, J. H. McMillian, B.R. Farner, S.A. Harper, S.F. Peralta, N.M. Lowery, H.R. Ross, A. Juarez; NASA/TP—2015–218207

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Honeywell Fluorine Products
101 Columbia Road
Morristown, NJ 07962-1053
Phone: 1-800-631-8138
www.honeywell-solvents.com



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