



**Solstice[®] Performance Fluid
High Performance (PF-HP)
in Oxygen Line Cleaning**

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Honeywell's Solstice® PF-HP (High Performance) is an ultra clean (very low non-volatile residue content), highly-effective, nonflammable cleaning solution, with a favorable toxicity profile and low environmental impact. In 2015, NASA announced it had tested Solstice Performance Fluid (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-HP is recommended for cleaning and NVR sampling in applications at NASA propulsion test facilities where AK-225G is currently used".¹ The tests performed by NASA were designed to determine the compatibility of Solstice PF with commonly-used metals and other materials used in its systems. Solstice PF demonstrated good cleaning efficiency (>97 %) and had the most favorable safety, health and environmental profile compared to other cleaning solutions investigated.

High Performance; Critical Cleaning

It is critical that oxygen lines and parts used in oxygen service are completely clean and free of debris. Solstice PF-HP is compatible and well suited for oxygen line cleaning due to its ability to effectively remove contamination from the desired lines or parts and then be completely dried. The oxygen-enriched autoignition temperature of Solstice PF-HP was determined to be 210 °C (410 °F) by ASTM G 72 at 1500 psig.

Solstice PF-HP is manufactured and specially packaged to deliver product with a NVR specification of less than 2 parts per million (ppm).

Solstice PF-HP is a pure component solvent that contains no stabilizers or additives.

After comparison testing, NASA has stated that "Stabilizer additives, although < 1% of the solvent, can affect NVR residues and must be considered and controlled for oxygen system cleaning applications".²

Designed with critical cleaning in mind, it can be used in vapor degreasing equipment, cold cleaning, NVR verification and tube flushing.

Fluid Properties

Select physical properties of Solstice PF-HP are given in Table 1. The vapor pressure of Solstice PF-HP will facilitate quick evaporation and drying of cleaned materials.

Table 1. Physical Properties of Solstice PF

Property	Solstice PF
Chemical Name	trans-1-chloro-3,3,3-trifluoropropene
Molecular Formula	CF ₃ -CH=CClH
Molecular Weight	130
Boiling Point	66°F 19°C
Latent Heat of Vaporization at Boiling Point	83.4 BTU/lb 194 kJ/kg
Freezing Point	-161°F -107°C
Vapor Pressure at 77°F (25°C)	18.6 psia 126 kPa
Liquid Density at 77°F (25°C)	10.5 lb/gal 1.26 gm/mL
Surface Tension at 77°F (25°C)	12.7 dyne/cm
Liquid Viscosity at 77°F (25°C)	0.446 cP
Solubility of Water in Solvent at 25°C	460 ppm
KB Value	25
NVR (non-volatile residue) Content	<2 ppm

Environmental and Safety Profile

It is extremely important to consider the effect on the surrounding area and the safety of individuals who works and come in contact with a cleaning solution. The environmental impact of Solstice PF-HP has been studied and is shown to have negligible ozone depletion and a very low global warming potential (GWP). The MIR also indicates that Solstice PF-HP will create less ground level ozone or smog than ethane. Designated as VOC exempt by the United States EPA and California's South Coast Air Quality Management District (SCAQMD). Solstice PF-HP does not

Table 2. Environmental and Safety Properties of Solstice PF

Property	Solstice PF
Flash Point	None
Lower Flame Limit, vol %	None
OEL (PPM)	800
GWP (100-year)	1
VOC (U.S.)	Exempt
AIT O ₂ Enriched ASTM G72 @ 1500 psig	210 °C (410 °F)

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. Table 2 lists a few of the important environmental and safety properties of Solstice PF-HP.

Cleaning Capabilities

Solstice PF-HP is able to dissolve a number of typical soils that are encountered in military and aerospace cleaning. Table 3 lists a selection of the soils that have been tested and can be easily dissolved by Solstice PF-HP. The solubility characteristics allow for Solstice PF-HP to be used in a wide variety of military and aerospace cleaning operations.

Table 3. Example of soils that can be readily cleaned with Solstice PF

Soils that can be cleaned with Solstice PF	
Mineral Oils	Heavy Grease
Silicone Oils	Vacuum Oils
Silicone Grease	Refrigerant Oils
Cutting Oils	Fluorinated Oils

Wetting Index

Solstice PF-HP has a very high wetting index value as compared with many other products available today as well as phased out legacy fluids. The wetting index is a numerical indicator of how well a fluid will effectively wet the surface of the parts being cleaned and facilitates the rapid cleaning of intricate pieces and parts containing small channels. The wetting index is determined by the following equation: $(1000 \cdot \text{density}) \div (\text{surface tension} \cdot \text{viscosity})$.

Table 4: Wetting Index of Solstice PF-HP

	Solstice PF-HP	HFE-7100	HCFC-225	CFC-113	nPB	TCE
Wetting Index	221	183	162	140	106	102
Surface Tension (dynes/cm)	12.7	13.6	16.2	17.3	25.9	26.4
Viscosity (cp)	0.45	0.61	0.59	0.65	0.49	0.54
Density (g/cm ³)	1.26	1.52	1.55	1.57	1.35	1.46

Conformance

There are a wide variety of tests and specifications that a solvent must conform to in order to be acceptable for use in military and aerospace applications.

Solstice PF-HP has been tested and found to conform to many of the solvent specifications typically used in military and aerospace applications. Table 1 lists the specifications, ASTM method and the result in testing Solstice PF-HP.

As shown in Table 5, Solstice PF-HP conforms to all standards tested with the exception of the stress crazing test on acrylic plastics.

Table 5. Results of Solstice PF Testing

Name	ASTM	Result	Comments
Effect on Painted Surfaces	ASTM F 502	Conforms	
Residue	ASTM F 485	Conforms	
Sandwich Corrosion	ASTM F 1110	Conforms	2024-T3 Bare/Anodized per MIL-C-5541 2024-T3 Bare/Anodized per MIL-C-865 2024-T3 Clad/Anodized per MIL-C-5541 2024-T3 Clad/Anodized per MIL-C-8625 7075-T6 Clad/Anodized per MIL-C-5541 2075-T6 Clad/Anodized per MIL-A-8625 7075-T6 Bare/Anodized per BAC 5019
Stress Crazing Test on Acrylic Plastics	ASTM F 484	Does not Conform	
Immersion, Corrosion, Aluminum	ASTM F 483	Conforms	Aluminum 7075-T6
Cadmium Removal	ASTM F 483	Conforms	4130 Steel Panels
Hydrogen, Embrittlement	ASTM F 519	Conforms	Cadmium plated per MIL-STD-870
Paint Softening	ASTM F 502	Conforms	Type II and III primer
Titanium Stress Corrosion	ASTM F 945	Conforms	

Compatibility

Metals commonly used in the aerospace industry were tested for compatibility with Solstice PF-HP. The solvent was shown to be compatible with all the metals listed (see Table 6) when tested according to the ARP 1755B method.

NASA also ran metal compatibility with Solstice PF-HP using the metals listed (see Table 7), and the solvent showed good compatibility with each of them.¹

Table 6. 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
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

Table 7. 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
Non-Ferrous				
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

Summary

Solstice PF-HP 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-HP has an ideal combination of high cleaning performance, non-flammability, low toxicity, and low volatility, which allows it to be used to clean tight spaces and then be removed to leave a pristine surface.

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/ GPO1502015-218207.
2. HCFC-225 Solvent Replacement Project -Cleaning and Verifying MSFC/SSC Propulsion Oxygen Systems; Nikki M. Lowrey/Jacobs ESSSA Group, Mark A. Mitchell/NASA-MSFC, George C. Marshall Space Flight Center. Presented at ASTM G04 Education Session ASTM Committee, Week April 28-30, 2015.

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