A FRESH PERSPECTIVE

Rethink the possibilities for personal care products using Earth-friendly Solstice® Propellant

SOLSTICE® PROPELLANT FOR PERSONAL CARE

It's time for a fresh perspective about how we can all help preserve our planet without compromising on product performance. Solstice Propellant (HFO-1234ze(E)) is a groundbreaking Earth-friendly[1] advancement for aerosol-based face, body, hair, and sun care products.

Not only does **Solstice Propellant** help keep your products ahead of changing environmental regulations, it provides exceptional formulating benefits such as:

- Nonflammable (ASTM E-681, EU A11) – a proven alternative to flammable propellants or to help reduce formulation flammability[2]
- Create creamy, shiny, and easy to spread foam
- Can be used in combination with **Solstice® Enhance** and other ingredients to create novel formulations
- Excellent compatibility with plastics enables packaging design flexibility
- Similar vapor pressure to that of A-46 propellant

Based on our breakthrough hydrofluoro-olefin (HFO) technology, Solstice Propellant can help reduce climate impact. With an ultra-low global warming potential (GWP) of less than one, it is an environmentally-preferred alternative to high GWP hydrofluorocarbons (HFCs) such as HFC-152a, HFC-134a, HFC-227ea, and others.

Additional environmental benefits include:

- Ultra-low GWP < 1 – reduces carbon dioxide equivalent emissions by 99.9% compared to hydrofluorocarbons (HFCs)
- Non-ozone-depleting
- VOC-exempt (per U.S. EPA and CARB)
- Negligible contribution to smog formation

This brochure provides technical information about Solstice Propellant including its physical properties, environmental attributes, exposure guidelines, and other important features. The information provided is but some of a mosaic of properties that must be evaluated in assessing candidate ingredients.

EARTH-FRIENDLY FACT

If every can of hairspray sold in the U.S. used Solstice Propellant, it would be equivalent to the amount of carbon dioxide emissions removed annually by approx. 6,500 square miles of trees.[3]

Table 1. Physical Property Summary

PROPERTIES	VALUES
Chemical Family	HFO-1234ze (E), 1234ze(E), trans-1234ze
INCI	Tetrafluoropropene
Formula	$CF_3CH{=}CHF$
Molecular Weight	114.0 g/mol
Vapor Pressure at 21.1°C (70°F) at 37.8°C (100°F) at 54.4°C (130°F)	 3.4 bar g (49.5 psig) 6.2 bar g (89.9 psig) 10.1 bar g (147 psig)
Boiling Point	-19.0°C (-2.2°F)
Specific Gravity of Gas at 15.6°C (60°F)	3.958
Liquid Density at 15.6°C (60°F) at 21.1°C (70°F)	 1.19 g/cc (74.5 lb/ft³) 1.17 g/cc (73.4 lb/ft³)
Volume of Vapor Per liter of liquid at 15.6°C Per gal. of liquid at 60°F	 0.25 m³ 33.02 ft³
Expansion Ratio (Liquid to Gas) at 15.6°C (60°F)	247
Specific Heat of Gas, Cp at 15.6°C (60°F)	0.224 cal/g-°K (0.224 BTU/lb-°R)
Specific Heat of Liquid, Cp at 15.6°C (60°F)	0.324 cal/g-°K (0.324 BTU/lb-°R)
Heat of Vaporization at Boiling	195 kJ/kg (84 BTU/lb
Theoretical (Net) Heat of Combustion of Liquid at 21.1°C (70°F)	10,100 kJ/kg (4,340 BTU/lb)
Viscosity of Liquid, Centipoises at 37.8°C (100°F)	0.171
Solubility in Water, % by Weight at 21.1°C (70°F)	0.037
Solubility of Water, % by Weight at 21.1°C (70°F)	0.022
Surface Tension, dynes/cm at 21.1°C (70°F)	10.1
Kb (Kauri-butanol) **Value**	12.5
Stable pH Range[4] 10 days at 40°C (104°F)	≤ 12

Table 2. Vapor Pressure and Liquid Density (English Units)

°F	PSIG	LB/FT³	°F	PSIG	LB/FT³	°F	PSIG	LB/FT³
0	0.8	80.6	45	26.0	76.1	90	74.8	71.1
5	2.7	80.1	50	30.0	75.6	95	82.1	70.5
10	4.4	79.7	55	34.4	75.0	100	89.9	69.9
15	7.2	79.1	60	39.1	74.5	105	98.2	69.3
20	10.0	78.6	65	44.1	73.9	110	106.9	68.6
25	12.5	78.1	70	49.5	73.4	115	116.1	68.0
30	15.4	77.6	75	55.2	72.8	120	125.9	67.3
35	18.7	77.1	80	61.4	72.3	125	136.2	66.6
40	22.2	76.6	85	67.9	71.7	130	147.0	65.9

Figure 1. Vapor Pressure vs. Temperature (English Units)

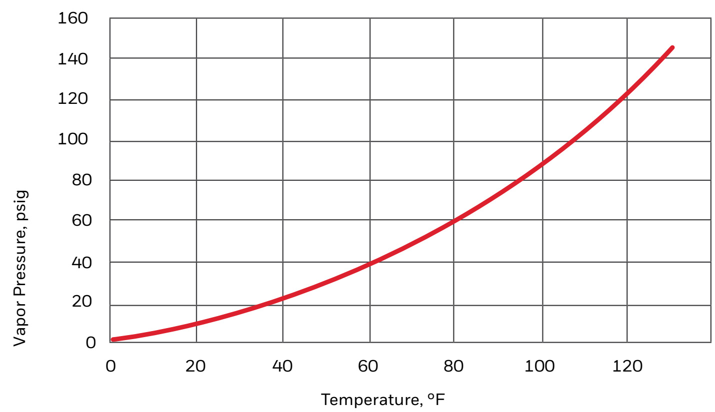
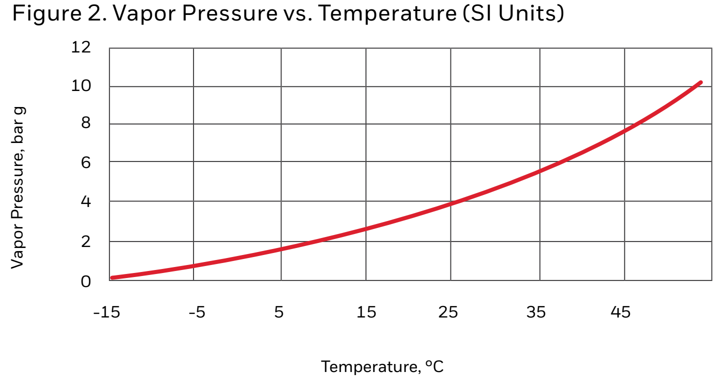


Table 3. Vapor Pressure and Liquid Density (SI Units)

°C	BAR G	KG/M³	°C	BAR G	KG/M³	°C	BAR G	KG/M³
-15	0.20	1280	9	1.98	1210	33	5.31	1140
-12	0.36	1270	12	2.30	1200	36	5.86	1130
-9	0.53	1270	15	2.64	1200	39	6.46	1120
-6	0.73	1260	18	3.01	1190	42	7.09	1100
-3	0.94	1250	21	3.41	1180	45	7.76	1090
0	1.17	1240	24	3.84	1170	48	8.47	1080
3	1.42	1230	27	4.29	1160	51	9.23	1070
6	1.69	1220	30	4.78	1150	54	10.03	1060

Figure 2. Vapor Pressure vs. Temperature (SI Units)



FORMULATING ADVANTAGES WITH SOLSTICE PROPELLANT

Solstice Propellant is miscible with commonly-used propellants, including hydrocarbons, fluorocarbons, and dimethyl ether (DME) (Tables 4 and 5). Also, Solstice Propellant offers excellent solubility across a wide range of personal care ingredients. It also works well in formulations with zinc oxide and other inorganics. Thus, Solstice Propellant is a preferred choice for formulators seeking flexibility when developing products such as hair sprays, dry shampoos, sunscreen, make-up, barrier creams, body oils, etc.

CREATING A SINGLE-PHASE FORMULATION WITH WATER

As regulations continue to drive VOC levels down in aerosol products, water plays an important role to reduce VOC content in the formulations. With increased use of water, it

Table 4. Vapor Pressure (psig) of Propellant Blends - English Units

VAPOR PRESSURE, PSIG								
	70 °F				130 °F			
Weight % Solstice Propellant	20	40	60	80	20	40	60	80
Solstice Propellant /134a	68	65	61	56	192	184	174	162
Solstice Propellant / 152a	62	62	60	57	176	175	171	163
Solstice Propellant / DME	61	59	57	55	168	165	162	156
Solstice Propellant / butane	28	39	47	52	91	114	134	149
Solstice Propellant / isobutane	37	46	52	55	115	131	145	154
Solstice Propellant / propane	114	116	113	102	269	273	269	244

Table 5. Vapor Pressure (bar g) of Propellant Blends – SI Units

VAPOR PRESSURE, BAR G								
	21 °C				54 °C			
Weight % Solstice Propellant	20	40	60	80	20	40	60	80
Solstice Propellant /134a	4.7	4.5	4.2	3.8	13.1	12.5	11.8	11.0
Solstice Propellant / 152a	4.3	4.3	4.2	3.9	12	11.9	11.7	11.1
Solstice Propellant / DME	4.2	4.1	4.0	3.8	11.5	11.3	11.0	10.7
Solstice Propellant / butane	2.0	2.7	3.2	3.6	6.2	7.8	9.2	10.2
Solstice Propellant / isobutane	2.7	3.2	3.6	3.8	7.8	9.0	9.9	10.5
Solstice Propellant / propane	7.9	8.0	7.8	7.0	18.3	18.7	18.4	16.7

is important in certain formulations to have single-phase propellant/base systems.

Solstice Propellant (HFO-1234ze) has a limited solubility in water. By using ethanol or DME, Solstice Propellant can achieve single-phase propellant/ base systems in a certain composition as show in Figures 3 and 4.

Figure 3 shows a ternary solubility phase diagram of ethanol, water, and Solstice Propellant. Figure 4 shows a ternary solubility phase diagram of ethanol, water, and Solstice Propellant/DME at 3 different ratios (7:1, 3:1, 5:3). Comparing the two diagrams, note how the single-phase region is increased when DME is introduced. This synergistic effect of Solstice Propellant with DME can be used to improve the miscibility of Solstice Propellant with water, while achieving lower VOC content to meet environmental regulations.

EXCELLENT MATERIALS COMPATIBILITY

Solstice Propellant is compatible with most materials commonly used in the personal care industry. Preferred gasket materials for use with Solstice Propellant are polytetrafluoroethylene (PTFE) and PTFE-encapsulated Viton®[5]. Solstice Propellant has been found to be generally compatible with grades of buna, butyl rubbers, and neoprene. Tests show that Solstice Propellant is also compatible with most plastics, except acrylics.

It is important to recognize that results may vary with different grades and manufacturers of the same polymer. Therefore, when evaluating a material for compatibility with Solstice Propellant, it is recommended that the manufacturer be consulted, or further independent testing be completed. Results shown in Table 6 should be used only as a guide.

Figure 3. Single-phase area of three ingredients

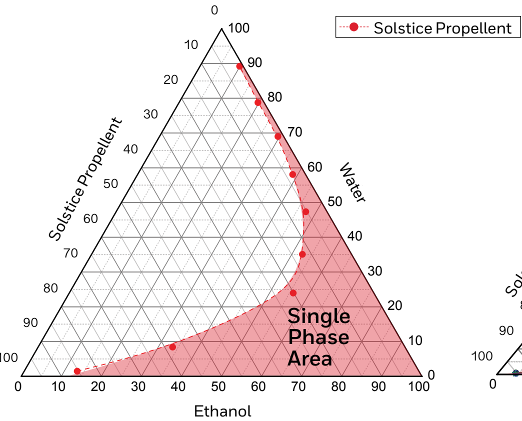


Figure 4. Single-phase area of three components

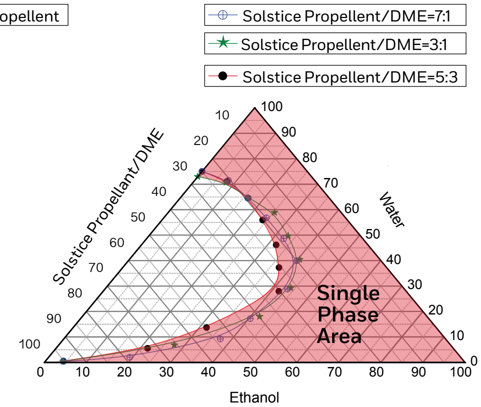


Table 6. Compatible with Commonly Used Plastics and Elastomers

SUBSTRATE	AVG. % CHANGE IN WEIGHT	AVG. % CHANGE IN VOLUME
ABS	0.21	-0.6
Acrylic	Extremely Distorted Substrate	
Buna-Nitrile	-4.95	-7.18
Butyl Rubber	1.27	0.88
Delrin® Aceta[6]	0.18	-0.48
EPDM	-2.0	-2.49
Epichlorohydrin	0.73	1.51
HDPE	0.82	-3.74
HIPS	0.26	-0.45
Kalrez® 6375[7]	5.22	33.0
Kynar® PVDF[8]	0.21	0.0
Natural Rubber (Gum)	-0.64	-0.75
Neoprene	-7.7	-11.47
Nylon 66	-0.26	0.0
PEEK	-0.02	-0.14
Polycarbonate	1.1	0.77
Polyethylene terephthalate (PET)	-0.01	0.0
Polypropylene	0.83	0.0
PVC-Type 1	0.002	-0.44
SBR/CR/NBR	2.0	-4.31
Silicone	-1.57	-1.96
Teflon®PTFE[9]	2.03	2.43
Texin® (Thermoplastic)[10] Polyurethane 390	5.14	4.41
Ultem® Polyetherimide[11]	-0.04	0.0
Viton® B Comm. Grade[5]	4.43	5.71

Materials compatibility data resulting from tests performed by Honeywell in which samples were immersed for 2 weeks in liquid Solstice Propellant at room temperature.

COMPATIBLE WITH MOST METALS

Honeywell has tested the compatibility of Solstice Propellant with commonly-used metals, including carbon steel, stainless steel, copper, brass, and aluminum. The test results showed no measurable impact on Solstice Propellant purity. Further, Honeywell and third-party tests[12] shows Solstice Propellant to be stable when combined with various common refrigeration lubricants and coupons of the above metals in the presence of up to 500 ppm moisture and 2,000 ppm air in sealed glass tubes at 175°C (347°F) for 14 days. Although Solstice Propellant has been shown to be compatible with aluminum in thermal stability tests, exposure to finely divided aluminum or freshly abraded aluminum surfaces should be avoided.

HIGH THERMAL AND HYDROLYTIC STABILITY

Honeywell has studied the thermal and hydrolytic stability of pure Solstice Propellant up to 110°C (230°F) in the presence of common materials of construction, including steel (carbon and stainless), copper, and aluminum. It was found to be stable. Further, Honeywell and third-party tests[12] show Solstice Propellant to be thermally and hydrolytically stable using the same test parameters noted in the compatibility testing of metals.

COMPATIBLE WITH COMMON AEROSOL PACKAGING MATERIALS

Aerosol Cans:

Honeywell tests show Solstice Propellant to be compatible with common types of aerosol cans. Sample cans were stored at 40°C (104°F) to simulate an accelerated aging process. After aging for 12 months, the cans were visually inspected for signs of corrosion or liner degradation, and the propellant was analyzed for evidence of chemical breakdown (Table 7). In long-term storage tests, no visual liner changes were observed in tinplated steel, PET-lined aluminum, polyacrylamide (PAM)-lined aluminum, or epoxy-lined aluminum cans filled with Solstice Propellant. The unchanging non-volatile residues confirm that Solstice Propellant did not extract plasticizers or other liner components.

Table 7. Compatibility with Aerosol Cans

CAN DESCRIPTION	STORAGE TEMPERATURE	EXPOSURE TIME, MONTHS	OBSERVATIONS
Tinplated Steel, Unlined	40°C / 104°F	12	- No visual liner changes - No propellant breakdown
Tinplated Steel, PET Liner	40°C / 104°F	19	- No visual liner changes - No increase in non-volatile residue - No propellant breakdown
Aluminum, PAM Liner	40°C / 104°F	12	- No visual liner changes - No increase in non-volatile residue - No propellant breakdown
Aluminum, Epoxy Liner	40°C / 104°F	12	- No visual liner changes - No increase in non-volatile residue - No propellant breakdown

Honeywell test results for sample aerosol cans stored at 40°C (104°F) and aged for 12 months.

Plastic Aerosol Bottles:

Due to its nonflammability and moderate vapor pressure, Solstice Propellant is currently the only liquefied gas propellant which may be used in plastic aerosol bottles. In addition, Solstice Propellant diffuses much more slowly through PET bottles than compressed gases. In Honeywell tests, the diffusion rate of Solstice Propellant was 29 times slower than carbon dioxide.[13] A slower diffusion rate may equal longer shelf life. Honeywell tests also showed excellent compatibility of Solstice Propellant with PET bottles from several manufacturers (Table 8).

Table 8. PET Bottle Compatibility with Solstice Propellant

MANUFACTURER	GRAHAM PACKAGING	RCP PROMENS	ALPLA	ALPLA
Bottle Contents	Solstice Propellant + water	Solstice Propellant	Solstice Propellant + water	Solstice Propellant
Storage Time	13 months	2 years	3 months	3 months
Visual changes to PET	None	None	None	None
Increasing Non-Volatile Residue	No	No	No	No
Solstice Propellant Reactivity	Stable	Stable	Stable	Stable

PET bottles stored at 40°C / 104°F during the entire storage time.

Aerosol Valves:

Solstice Propellant valve compatibility studies were performed by Precision Global[14] and Summit Packaging Systems.[15] Good compatibility was seen with grades of buna, butyl rubbers, and neoprene. In addition, an Aptar Pharma study of Solstice Propellant with its metered-dose inhaler valves concluded that the compatibility of Solstice Propellant was equivalent to that of HFC-134a and HFC-227ea.[16]

Bag-On-Valve (BOV):

The compatibility of Solstice Propellant with laminated BOV pouches was tested by Summit Packaging Systems.[15] BOV pouches containing water as the surrogate product were pressurized with Solstice Propellant. Periodic testing included vapor pressure measurements and examination of the bags for signs of delamination. After 12 months at room temperature, 4-ply polyethylene and 4-ply polypropylene laminated BOV pouches showed the best results for long-term stability, with minimal vapor pressure loss and no delamination of the pouch. For assistance with valve selection, consultation with a supplier is recommended.

ENVIRONMENTAL, HEALTH, AND SAFETY

Solstice Propellant is nonflammable (ASTM E-681, EU A11), non-ozone-depleting (ODP ~ 0), and has an ultra-low global warming potential (GWP<1). Solstice Propellant exhibits no vapor flame limits below 30°C (86°F) (Table 9).

The results of extensive toxicity tests support the conclusion that Solstice Propellant exhibits a very low order of toxicity. Accordingly, the American Industrial Hygiene Association (AIHA) has assigned a Workplace Environmental Exposure Limit (WEEL) of 800 ppm (8-hour time-weighted average).[19]

Solstice Propellant has a low environmental half-life (16.4 days atmospheric lifetime vs 1.5 years for HFC-152a). The final decomposition products are not new and at levels much lower than naturally present. These decomposition products are then rained out and mineralized with no additional effect on ozone or on climate.[20] During decomposition, no trifluoroacetic acid (TFA) is formed.

Solstice Propellant has not been tested for use in every personal care formulation, and it is the customer's responsibility to determine whether it is appropriate for use in its specific formulation and to conduct required tests. Additional information is available upon request.

Table 9. Environmental and Safety Aspects

ASPECT	VALUE
Vapor Flame Limits [17] (ASTM E-681)	No flame propagation below 30°C (86°F)
Auto Ignition Temp. (AIT)[18]	368°C (694°F)
Min. Ignition Energy (MIE)[18] at 20°C (68°F) at 54-55°C (129-131°F)	No ignition Between 61,400 and 64,200 mJ
VOC (U.S. EPA and CARB)	Carbon Exempt
REACH	Registered
WEEL	800 ppm
ODP	~ 0
GWP (100 yr.)[1]	<1.0

SAFE USE AND HANDLING

Before handling or using Solstice Propellant, Honeywell recommends carefully reviewing the information in the Safety Data Sheet (SDS). The SDS may be viewed online at the Honeywell SDS Resource Center: www.honeywellmsds.com. Copies of the SDS may also be obtained by contacting Honeywell at **1-800-631-8138** within the U.S. and Canada, or by contacting the local Honeywell sales office.

Solstice Propellant is supplied in cylinders that meet U.S. Department of Transportation (DOT) requirements and comply with all applicable codes and regulations for the regions in which they are transported. Store Solstice Propellant packaged cylinders in a dry, ventilated, enclosed area away from heat, flame, corrosive chemicals or fumes, and explosives. Avoid direct sunlight, particularly in warm weather.

The Solstice Propellant 10-lb. sample returnable cylinder outlet has a CGA 165 fitting which accepts a standard 1/4" S.A.E. 45° flare connector. This is a common refrigeration fitting. Other packaging options are also available. For additional information on safe use and handling of Solstice Propellant, please consult a Honeywell Technical Service Representative.

REFERENCES:

1. Ultra-low Global Warming Potential<1: Intergovernmental Panel on Climate Change (IPCC), Appendix 8A, pg.732: http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf
2. Your specific formulation incorporating Solstice Propellant would require flash point or other flammability testing to confirm it is nonflammable
3. Assumes a 10 oz. can with 40% Solstice Propellant vs. HFC-152a. Source using EPA website
4. Solstice Propellant solutions ranging from pH = 2.9 – 12.5 were aged for 10 days at 40°C (104°F). Fluoride ion concentrations reaching levels of 150-200 ppm can indicate HFO breakdown, which would warrant further investigation. Solstice Propellant fluoride ion concentrations stayed below this range up to a pH level of 12
5. Viton: Registered trademark of The Chemours Company
6. Delrin: Registered trademark of DuPont
7. Kalrez: Registered trademark of DuPont
8. Kynar: Registered trademark of Arkema Inc
9. Teflon: Registered trademark of The Chemours Company
10. Texin: Registered trademark of Covestro LLC
11. Ultem: Registered trademark of The General Electric Company
12. Stability study conducted by the Air Conditioning, Heating, and Refrigeration Technology Institute (AHRTI): Solstice Propellant (HFO-1234ze) and lubricants (ISO 32 branched acid POE, ISO 32 mixed acid POE, ISO 32 PVE) at 175°C / 347°F for 14 days. The fluoride ion concentration was less than 65 ppm in all cases except for the Solstice Propellant/ISO 32 branched acid mixture at 48 ppm moisture and 2,000 ppm air when it was 142 ppm. Air appears to play a role in decomposition
13. Honeywell testing demonstrated that Solstice Propellant has a slower diffusion rate through PET than CO_2. Time to lose 0.5 grams of propellant: CO_2 = 7 months; Solstice Propellant = 17 years (or 29 times slower)
14. Details of study methodology are available from Precision Global
15. Details of study methodology are available from Summit Packaging Systems
16. Details of study methodology are available from Aptar Pharma
17. ASTM E-681 Test Conditions: 23°C (73.4°F) and 100°C (212°F), 50% Relative Humidity, ~1 atmosphere: No flame propagation was noted below 30°C (86°F)
18. ISO 10156, EC Test Method A11: Flammability of Gases (section 1), Minimum Ignition Energy and Auto Ignition Temperature (section 2) were conducted by Chilworth Technology Ltd. Copies of the test reports can be made available upon request
19. The American Industrial Hygiene Association (AIHA): https://www.honeywell-solstice-propellants.com/wp-content/uploads/2016/06/HFO-1234ze-_WEEL_2011.pdf
20. "We conclude that the products of the atmospheric oxidation of trans-$CF_3CH{=}CHF$ will have negligible environmental impact", M.S. Javadiet. al. ; Atmospheric Chemistry of Trans-$CF_3CH{=}CHF$ in Atmospheric Chemistry & Physics Discussions,Vol 8, pp 1069-1088, 200

For more information

Visit: http://hwll.co/PersonalCare
Call: 1-800-631-8138 (U.S. and Canada) or your local sales office

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