# SOLSTICE® AIR
# HFO-1234ze(E), cGMP

Technical Bulletin

Honeywell

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**Solstice Air is a non-flammable aerosol propellant that has an ultra-low global warming potential (GWP) and very low photochemical reactivity. Its full chemical name is trans-1,3,3,3-tetrafluoroprop-1-ene, also known as HFO-1234ze(E). Its INCI name is tetrafluoropropene.**

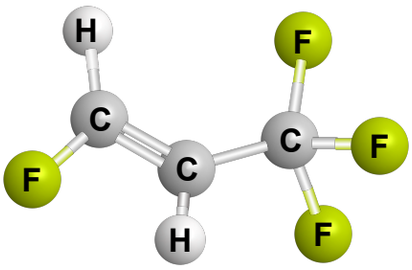


*Figure 1: Chemical structure of Solstice Air*

## PROPELLANT PROPERTIES

Some of the physical properties of Solstice Air are shown in Table 1. Tables 2 and 3 show vapor pressures and liquid density as a function of temperature (in SI and English units).

**TABLE 1.** Physical Properties of Solstice Air*

| SOLSTICE AIR | | |
|---|---|---|
| Molecular Formula | $CHF{=}CHCF_3$ | |
| Molecular Weight | 114 g/mol | |
| Boiling Point | -2.2°F | -19°C |
| Vapor Pressure at 70°F/21°C<br>at 130°F/54°C | 64.2 psia<br>161.7 psia | 4.4 bar<br>11 bar |
| Liquid Density at 70°F/21°C | 1.17 g/mL | |
| Vapor Flame Limits (Vol.% in Air) Measured at 70°F | NONE | |
| Solubility of Water in 1234ze at 68°F/20°C | 225 ppm | |
| Solubility of 1234ze in Water at 68°F/20°C | 373 ppm | |
| Dipole Moment | 1.44 debye | |

**TABLE 2.** Vapor Pressures of Solstice Air*

| °C | bar | kg/m³ | °C | bar | kg/m³ | °C | bar | kg/m³ |
|---|---|---|---|---|---|---|---|---|
| -15 | 1.20 | 1283 | 9 | 2.98 | 1214 | 33 | 6.31 | 1136 |
| -12 | 1.36 | 1274 | 12 | 3.30 | 1204 | 36 | 6.87 | 1126 |
| -9 | 1.53 | 1266 | 15 | 3.64 | 1195 | 39 | 7.46 | 1115 |
| -6 | 1.73 | 1258 | 18 | 4.01 | 1186 | 42 | 8.09 | 1104 |
| -3 | 1.94 | 1249 | 21 | 4.41 | 1176 | 45 | 8.76 | 1093 |
| 0 | 2.17 | 1240 | 24 | 4.84 | 1166 | 48 | 9.48 | 1082 |
| 3 | 2.41 | 1231 | 27 | 5.30 | 1156 | 51 | 10.2 | 1070 |
| 6 | 2.69 | 1223 | 30 | 5.78 | 1146 | 54 | 11.0 | 1058 |

**TABLE 3.** Vapor Pressures of Solstice Air*

| °F | PSIA | lbs/ft³ | °F | PSIA | lbs/ft³ | °F | PSIA | lbs/ft³ |
|---|---|---|---|---|---|---|---|---|
| 0 | 15.5 | 80.6 | 45 | 40.6 | 76.1 | 90 | 89.5 | 71.1 |
| 5 | 17.4 | 80.1 | 50 | 44.7 | 75.6 | 95 | 96.8 | 70.5 |
| 10 | 19.5 | 79.6 | 55 | 49.1 | 75.0 | 100 | 105 | 69.9 |
| 15 | 21.8 | 79.1 | 60 | 53.8 | 74.5 | 105 | 113 | 69.3 |
| 20 | 24.4 | 78.6 | 65 | 58.8 | 74.0 | 110 | 122 | 68.6 |
| 25 | 27.1 | 78.1 | 70 | 64.2 | 73.4 | 115 | 131 | 68.0 |
| 30 | 30.1 | 77.6 | 75 | 69.9 | 72.8 | 120 | 141 | 67.3 |
| 35 | 33.4 | 77.1 | 80 | 76.0 | 72.3 | 125 | 151 | 66.6 |
| 40 | 36.9 | 76.6 | 85 | 82.5 | 71.68 | 130 | 161.7 | 65.9 |

## FLAMMABILITY

Solstice Air does not exhibit vapor flame limits under standard test conditions. It is therefore classified as non-flammable according to EC Testing Method A11: Flammability of Gases, as well as by the U.S. Department of Transportation (DOT) standard (tested according to ASTM E681). HFO-1234ze(E) is non-flammable in the ASTM flame projection test. HFO-1234ze(E) has also been tested and found to be non-flammable in the ignition distance test and the enclosed space ignition test (closed drum test).[1]

## MISCIBILITY

Solstice Air is miscible with other liquefied gas propellants such as HFA-134a and HFA-152a. It is also miscible with commonly used solvents such as lower alcohols, ketones, chlorinated solvents and hydrocarbons.

Vapor pressure data for blends of HFO-1234ze(E) with other propellants are shown in tables 4-5.

**TABLE 4.** Vapor Pressures of 1234ze/HFA Mixtures*

| | 1234ze/134a | | 1234ze/152a | |
|---|---|---|---|---|
| Weight % 1234ze | 70°F | 130°F | 70°F | 130°F |
| 80 | 71 | 177 | 70 | 175 |
| 60 | 76 | 189 | 73 | 182 |
| 40 | 80 | 199 | 75 | 186 |
| 20 | 83 | 207 | 76 | 189 |

**TABLE 5.** Vapor Pressures of 1234ze/HFA Mixtures*

| | 1234ze/134a | | 1234ze/152a | |
|---|---|---|---|---|
| Weight % 1234ze | 21°C | 54°C | 21°C | 54°C |
| 80 | 4.9 | 12.2 | 4.8 | 12.0 |
| 60 | 5.2 | 13.0 | 5.0 | 12.5 |
| 40 | 5.5 | 13.7 | 5.2 | 12.8 |
| 20 | 5.7 | 14.3 | 5.3 | 13.0 |

## ENVIRONMENTAL PROPERTIES

In work done at the University of Copenhagen, the atmospheric lifetime of HFO-1234ze(E) was determined to be approximately two weeks. The GWP, which is largely a function of atmospheric lifetime, was determined to be <1 versus CO2 on a 100-year integrated time horizon[2]. In a companion study, also at the University of Copenhagen, it was determined that the atmospheric degradation products of HFO-1234ze(E) have negligible impact on the environment[3]. Compounds with short atmospheric lifetimes often contribute to the generation of tropospheric, or ground-level, ozone which is one of the components of photochemical smog. That is not the case with HFO-1234ze(E). The MIR (maximum incremental reactivity) and POCP (photochemical ozone creation potential) values for HFO-1234ze(E) have been determined to be 0.09[4] and 6.4[5], respectively. These very low values indicate that HFO-1234ze(E) has very low photochemical reactivity and does not contribute in any significant way to tropospheric ozone generation. The U.S. EPA has recommended that HFO-1234ze(E) be classified as a non-VOC.

Table 6 shows the environmental properties of HFO-1234ze(E) compared to those of some commonly used propellants.

**TABLE 6.** Environmental Properties of MDI Propellants*

| | HFO-1234ze(E) | HFA-152a | HFA-134A | HFA-227ea |
|---|---|---|---|---|
| GWP (versus CO2, 100 year ITH) | <1 | 138 | 1300 | 3350 |
| Atmospheric Lifetime (years) | 0.04 | 1.4 | 13.8 | 33 |
| VOC Status | Exempt | Exempt | Exempt | Exempt |

## COMPATIBILITY

Solstice Air exhibits good compatibility with plastics, elastomers and metals. In storage tests, it has been shown to be compatible with aluminum aerosol cans, tinplate cans and PET-lined cans.

Solstice Air has also been tested with aerosol valves and found to be compatible with common gasket materials including grades of butyl rubber, buna and neoprene. Since results may vary, it is always recommended that testing be done to confirm compatibility with specific package components and materials of construction. Metered Dose Inhaler (MDI) valve compatibility tests have been run by Aptar Pharma. Test information is available upon request.

## STABILITY

HFO-1234ze(E) has been shown to be thermally and hydrolytically stable. In one experiment, samples of HFO-1234ze(E), in the presence of water and metals, were stored at 392°F (200°C) for two weeks. There was no observed effect on the metals and analysis showed no indication of breakdown of the HFO-1234ze(E). Also, samples stored in steel cylinders for several years have been analyzed and found to be within the specification.

## TOXICITY

Solstice Air has an extensive battery of toxicity studies that have been used to support FDA Investigational New Drug (IND) filings. Pre-clinical toxicity studies used to enable the IND included: acute inhalation exposure, repeated dose inhalation exposure, genotoxicity, and reproductive and developmental toxicity in multiple species. Additional long-term repeated dose studies are ongoing in multiple species. In a human clinical study, Solstice Air was not found to be a human skin sensitizer. The results of those studies concluded that Solstice Air exhibited a good safety profile for its use in Metered Dose Inhalers as well as other drug delivery systems.

## STORAGE AND HANDLING

Solstice Air should be handled in a manner consistent with materials categorized as "liquefied gases under pressure." As illustrated by the vapor pressure data, HFO-1234ze(E) is a moderate pressure gas and containers (bulk storage tanks or packages) should be rated for the pressure of HFO-1234ze(E).

Solstice Air, in approved containers, should be stored in a cool, well-ventilated area. HFO-1234ze(E) containers should neither be punctured or dropped, nor exposed to open flames, excessive heat or direct sunlight.

Container valves should be tightly closed after use and when the container is empty.

As with other fluorinated materials, HFO-1234ze(E) should not be mixed with oxygen at elevated pressures. Applications necessitating pressurization – exceeding the vapor pressure of HFO-1234ze(E) – should use dry nitrogen.

The Honeywell safety data sheet (SDS) contains the most current and comprehensive information on the health, safety and environmental aspects of HFO-1234ze(E).

*These are just some of a mosaic of properties that must be considered in identifying a suitable propellant.


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3. Javadi, M.S., Sondergaard, R., Nielsen, O.J., Hurley, M.D. and Wallington, T.J.: Atmospheric chemistry of trans-CF3CH=CHF: products and mechanisms of hydroxyl radical and chlorine atom-initiated oxidation, Atmospheric Chemistry and Physics Discussions, 8, 1069-1088, 2008.
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**For more information**
sustainability.honeywell.com


**Honeywell Advanced Materials**
115 Tabor Road
Morris Plains, NJ 07950
USA
1-800-631-8138 (U.S and Canada)


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