

SOLSTICE[®] ZE **REFRIGERANT** **(HFO-1234ZE)**

Ultra-Low GWP Hydrofluoroolefins (HFO)
Alternative to Hydrofluorocarbons

Refrigerants



Honeywell

FOURTH GENERATION REFRIGERANTS FOR THE 21ST CENTURY

Honeywell has been at the forefront of every major development of fluorocarbon refrigerants technology. As the world seeks new, lower-global-warming-potential solutions, Honeywell delivers again, with its Solstice® brand of hydrofluoroolefins (HFOs), a

family of unique products that offer comparable performance to today's most widely-used stationary and mobile refrigerants, blowing agents, propellants, and solvents. However, unlike their more common counterparts, the molecular structure of Solstice products causes

them to have short atmospheric lifetimes, which means they have very low global warming potential (GWP).

Honeywell's Solstice brand reflects the products' breakthrough environmental properties.



HYDROFLUOROOLEFINS (HFOs): WHO IS WHO

The chemical structure of pure fluids such as Solstice® ze, Solstice® yf and Solstice® zd contains a carbon-carbon double bond which is a key feature facilitating the low global warming characteristic. These molecules also have low atmospheric lifetimes.

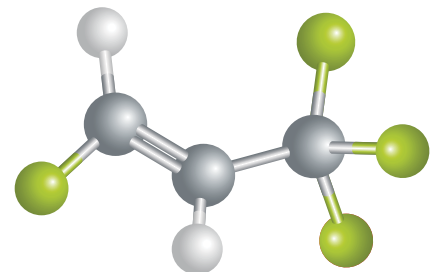
SOLSTICE® ze (HFO-1234ze)

Chemical Name	Trans-1,3,3,3-Tetrafluoroprop-1-ene
Molecular Formula	CF ₃ CH=CHF
Appearance	Colourless
Ozone Depletion Potential (ODP-R11=1)	0
Global Warming Potential rev 5th IPCC (GWP CO ₂ =1)	1
ASHRAE Std. 34 Safety Classification	A2L
Flammability Limits – ASTM E681-04 @ 69.8°F	Nonflammable
Flammability Limits – ASHRAE 34 @ 212°F	7% – 12% (by volume)

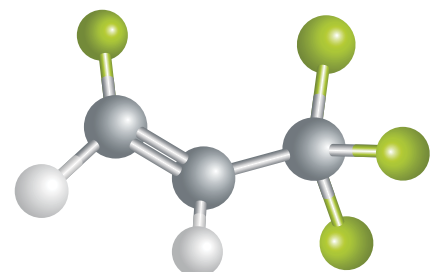
	FLUID	R1234ZEE
Property		refprop result
molecular weight	114.0	lbm/lb-mol
boiling temperature @ 0 psig	-2.2	F
critical temperature	228.9	F
critical pressure	527.2	psia
critical volume	0.03274	ft ³ /lbm
critical density	30.5	lbm/ft ³
saturated liquid pressure @ 77°F	96.5	psia
saturated vapor pressure @ 77°F	72.3	psia
vapor density @ 0 psig boiling point	0.356	lbm/ft ³
vapor density @ 77°F	1.643	lbm/ft ³
vapor pressure @ 77°F	72.304	psia
liquid density @ 32°F	77.42	lbm/ft ³
liquid density @ 77°F	72.61	lbm/ft ³
liquid heat capacity @ 77°F	0.331	Btu/lbm-R
vapor heat capacity @ 77°F	0.233	Btu/lbm-R
liquid thermal conductivity @ 77°F	0.0429	Btu/(h-ft-R)
vapor thermal conductivity @ 77°F	0.0079	Btu/h-ft-F
liquid viscosity @ 77°F	1.28E-04	lbm/ft-sec
vapor viscosity @ 77°F	8.22E-06	lbm/ft-sec
	Scientific notation should write as 10 ^x	
	ie, 5.5E-04 = 5.5x10 ⁻⁴	
	5.5E04 = 5.5x10 ⁺⁴	

HFO-1234ze Isomers

HFO-1234ze(E)



HFO-1234ze(Z)



PHYSICAL PROPERTIES

Solstice® ze is trans-1,3,3,3-tetrafluoroprop-1-ene to which ASHRAE Standard 34 has assigned the nomenclature of R-1234ze(E). The suffix (E) indicates that it is an isomer. The other isomer (suffix (Z)) is cis-1,3,3,3-tetrafluoroprop-1-ene. The physical properties of the (E) and (Z) isomers are different: both are ultra-low GWP molecules with GWP<1, but R-1234ze(Z) has a high boiling point (49.6°F) associated with a higher critical temperature (308.66°F) and a volumetric capacity roughly 50% lower than R-1234ze(E), which means it is not a good candidate to replace R-134a. Even if the properties of R-1234ze(Z) could be utilised in specific applications like high-temperature heat pumps, R-1234ze(E) will show operating conditions and applied costs much more in line with R-134a according to system and compressor sizes.

LEAKS

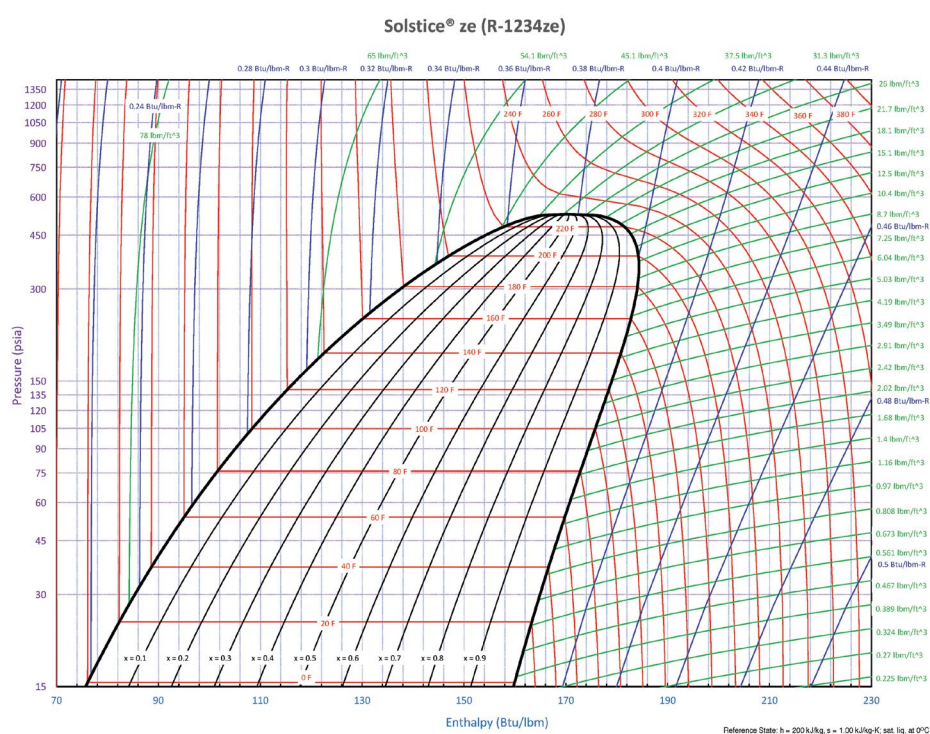
If a large release of Solstice® ze vapour occurs, take the same measures as with R-134a.

Leak detection

Hand-held leak detectors can be used for pinpointing leaks. For monitoring an entire room on a continual basis, leak monitors are available. Leak detection is important for protection of those in proximity of the system, refrigerant conservation, equipment protection and performance, and reduction of emissions. Customers should consult the equipment manufacturer for appropriate detectors.

Pressure (psig)	Temperature (F)
0	-2,2
5	10,3
10	20,6
15	29,3
20	36,9
22	39,7
24	42,4
26	45,0
28	47,6
30	50,0
32	52,3
34	54,6
36	56,7
38	58,9
40	60,9
42	62,9
44	64,9
46	66,8
48	68,7
50	70,5
55	74,8
60	78,9
70	86,6
80	93,6
90	100,1
100	106,1
105	108,9
110	111,7

Pressure (psig)	Temperature (F)
115	114,4
120	117,0
125	119,6
130	122,0
135	124,4
140	126,8
145	129,1
150	131,3
155	133,5
160	135,7
165	137,8
170	139,8
175	141,8
180	143,8
185	145,7
190	147,6
195	149,5
200	151,3
205	153,1
210	154,9
215	156,6
220	158,4
230	161,7
240	164,9
250	168,1
260	171,1
270	174,1
280	177,0



PRESSURE AND ENTHALPY



MATERIALS COMPATIBILITY

Honeywell does not recommend the use of chlorinated solvents to clean refrigeration systems or components.

PLASTICS AND ELASTOMERS

Solstice® ze is compatible with most common materials. Since there are many different grades and formulations of these materials, we recommend that compatibility testing be performed on the specific grade of materials under consideration and at the conditions of use when designing new systems.

The table below contains materials compatibility data resulting from tests performed by Honeywell (testing conditions: two weeks liquid immersion at room temperature). This data should be used only as a guide to the compatibility of materials with Solstice® ze. The rankings in the table should be used with caution since they are judgments based on limited samplings. Customers should consult the manufacturer or conduct further independent testing.

DESICCANTS

Desiccant driers compatible with Solstice® ze are commercially available. Individual drier manufacturers should be contacted for specific recommendations.

LUBRICANTS

POE (polyol ester) oil is recommended for using Solstice® ze. As with most ultra-low GWP refrigerants, Solstice® ze is more miscible and more soluble in oil than traditional HFCs or HCFCs. When a higher miscibility is very favourable in systems for returning oil to compressors from the liquid side of the circuit, a higher solubility means that more refrigerant will be trapped in gaseous phase in the oil sump. A direct consequence is the reduction

in working viscosity of the lubricating mixture (combination of lubricant and refrigerant) to the compressor bearings. The minimum viscosity criterion to operate under the highest bearing loads varies depending on compressor and bearing technology, so there could be a need for certain technologies and at certain conditions to increase the viscosity of the lubricant for compressors used with Solstice® ze to maintain reliable bearing lubrication.

Compressor manufacturers typically qualify specific lubricants for use with their products. Users should check with the equipment manufacturer for the recommended lubricants for their system.

SUBSTRATE	AVG. % CHANGE IN HARDNESS	AVG. % CHANGE IN WEIGHT	AVG. % CHANGE IN VOLUME	COMMENTS
ABS		0.21	-0.6	
Delrin® Acetal		0.18	0.48	
Acrylic	Extremely distorted			Pitted after 1 week. Expands
HDPE		0.82	-3.74	
NYLON 66		-0.26	0	
Polycarbonate*		1.1	0.77	Turbid fluid after 1 week. Residue
ULTEM® Polyetherimide		-0.04	0	
Kynar® PVDF*		0.21	0	Fluid discoloration
Teflon®		2.03	2.43	
Polypropylene*		0.83	0	Turbid fluid. Residue
HIPS		0.26	-0.45	
PVC-TYPE 1		0.002	-0.44	
PET		-0.01	0	
SBR/CR/NBR	7.28	2	-4.31	
Viton® B COMM. GRADE	-11.29	4.43	5.71	
Buna-Nitrile	8.91	-4.95	-7.18	
EPDM	-1.5	-2	-2.49	
Epichlorohydrin	-3.5	0.73	1.51	
Silicone*	-0.71	-1.57	-1.96	Slight fluid discoloration. Residue
Natural Rubber (Gum)	2	-0.64	-0.75	
Texin® (Thermoplastic) Polyurethane 390	-4.35	5.14	4.41	
Butyl Rubber	-1.13	1.27	0.88	
Neoprene	7.32	-7.7	-11.47	
Kalrez® 6375	-10.36	5.22	33	

 Suitable

 Suitable under certain conditions

 Unsuitable

* Although changes in weight, volume and hardness are minimal, fluid discoloration and/or residue suggest the material may not be suitable for some applications.



SAFETY AND STORAGE

Honeywell recommends reading the Safety Data Sheet (SDS) before using the product.

Refrigerant Solstice® ze or trans-1,3,3,3- tetrafluoroprop-1-ene is registered under the European Union's REACH program (Registration, Evaluation, Authorisation and Restriction of Chemicals).

TOXICITY

Solstice® ze has undergone extensive toxicity testing and when used in accordance with applicable guidelines and standards, is considered safe for its intended refrigeration and air-conditioning applications.

The Occupational Alliance for Risk Science (OARS) WEEL value for R-1234ze(E) is 800ppm (8-hour time-weighted average). HFC-134a, with a 1,000ppm WEEL value is currently used in centrifugal and screw chillers. The Solstice® ze refrigerant SDS contains the following toxicity information: the 4-hr acute inhalation LC50 (rat) was >207000ppm; no skin

irritation was observed in rabbits; no cardiac sensitisation was observed in dogs with exposures up to 120,000 ppm; repeated dose toxicity in rats (13-wk) found mild effects on the heart (NOEL 5,000ppm); in vitro genotoxicity findings include negative Ames Test and negative human lymphocyte chromosome aberration test; in vivo genotoxicity findings in the mouse micronucleus test were negative (inhalation, mammalian bone-marrow cytogenic test with chromosomal analysis).

FLAMMABILITY

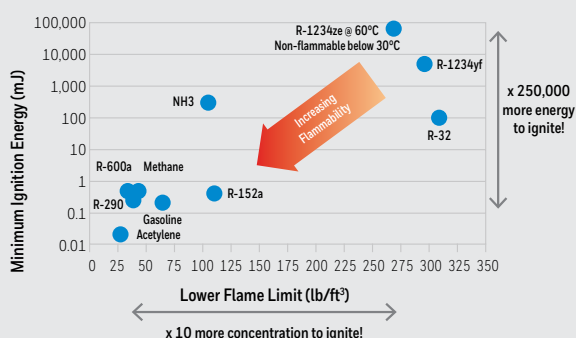
According to ASHRAE Standard-2010, Solstice® ze, R-1234ze(E) is classified

in safety group A2L, i.e., it is in the lower segment of the mildly flammable refrigerants.

A unique characteristic of this refrigerant is the absence of flammable mixture with air under 86°F of ambience. That's why it is nonflammable for handling and storage.

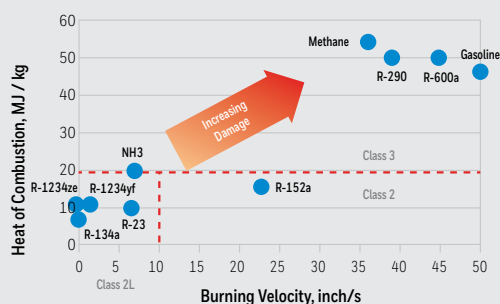
When utilised in a system, R-1234ze(E) could become flammable with air. In case of leakage, the following chart gives a graphical positioning of R-1234ze(E) versus other refrigerants in the 'chance of flame occurring' ranking: R-1234ze(E) needs 10 times more concentration and 250,000 times more energy than hydrocarbons to become flammable, only above 30°C. In case of a flame occurring with Solstice® ze, the effect of this flame would be extremely mild, as its very low heat of combustion (5 times less than propane) associated to a ultra low burning velocity wouldn't be enough to propagate a fire.

Flammability is evaluated by 'Chance of Flame occurring' and 'Effect of Flame occurring'



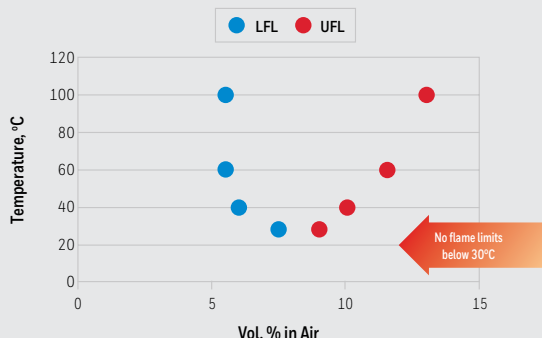
PROBABILITY OF IGNITION

Chance of Flame occurring → Lower Flame Limit, Minimum Ignition Energy



DAMAGE POTENTIAL

Effect of Flame occurring → Burning Velocity, Heat of Combustion



R-1234ZE FLAME LIMIT: US DOT & ASHRAE

FLAMMABILITY CHARACTERISTICS

Upper Flammability Limit, Vol. % in air (69.8°F, ASTM E681-01)	None
Lower Flammability Limit, Vol. % in air (69.8°F, ASTM E681-01)	None
Upper Flammability Limit, Vol. % in air (140°F, ASTM E681-01)	5.7
Lower Flammability Limit, Vol. % in air (140°F, ASTM E681-01)	11.3
Minimum Ignition Energy, mJ at 68°F and 1 atm (Chilworth Technology)	No ignition
Minimum Ignition Energy, mJ at 129.2°F and 1 atm (Chilworth Technology)	>61,000 <64,000
Autoignition Temperature, °F (EC Physico/Chemical Test A15, Measured by Chilworth Technology, UK)	368
Heat of Combustion, btu/lb per ASHRAE Standard 34 (Stoichiometric composition 7.73% in air)	4600
Fundamental burning velocity, cm/s (per ISO 817, Measured by AIST, Japan)	0 (no flame propagation)

PED

PED is a European directive and not an industry standard like ISO5149 or EN378. When refrigerant classification for industry standards refers to ISO817 or ASHRAE 34, it is based on EU definition for PED (or any European directive classification).

PED has two fluid groups, hazardous and not hazardous. Flammable are in the hazardous group and the PED define flammability according to A11 method from European Regulation EC 440/2008. This flammability test is done at 21°C so under EU A11, Solstice® ze is not flammable and does not flash, therefore it is group 2. Honeywell duly registered R-1234ze under REACH at the highest tonnage tier and the classification, as submitted to the European Chemicals Agency (ECHA) is reported in the Producer's Safety Data Sheet (SDS): therefore R-1234ze (trans- 1,3,3,3-Tetrafluoroprop-1-ene) properties correspond to that of PED group 2.



APPLICATIONS

Honeywell Solstice® ze refrigerant (HFO-1234ze) is the best medium pressure, low GWP refrigerant on the market when considering the balance of all properties. It is an energy-efficient alternative to traditional refrigerants in different medium temperature uses and has been selected by a number of equipment manufacturers for applications with a capacity range from several kW to 20MW and charges varying from 300g to 13mT:

- Air-cooled and water-cooled chillers
- District heating and cooling
- Heat pumps
- Refrigerators
- Vending machines
- Beverage dispensers
- Air dryers
- CO2 cascade systems, etc.

Multi-awarded by the industry, Solstice® ze meets the criteria that are most important to refrigerants users: Performance, Cost Effectiveness, Environmental Impact and Safety.

STORAGE AND HANDLING IN BULK AND CYLINDER

Solstice® ze has similar storage and handling requirements to R-134a, since according to the compressed gas classification it is nonflammable.

Solstice® ze cylinders must be clearly marked and kept in a cool, dry and properly ventilated storage area away from heat, flames, corrosive chemicals, fumes, explosives – and be otherwise protected from damage.

Under no circumstances should an empty cylinder be refilled with anything other than virgin product. Once empty, properly close the cylinder valve and replace the valve cap. Return empty cylinders to your Honeywell distributor. Cylinders of Solstice® ze should be kept out of direct sunlight, especially in warm weather.

Liquid Solstice® ze expands significantly when heated, reducing the amount of vapour space left in the cylinder. Once the cylinder becomes liquid-full,

any further rise in temperature can cause it to burst, potentially resulting in severe personal injury. Never allow a cylinder to get warmer than 52°C.

Vessels, containers, transfer lines, pumps and other equipment used with Solstice® ze should not be exposed to high-temperature sources (such as welding, brazing and open flames) until they have been thoroughly purged and confirmed free of vapours or liquid. Cylinders must never be exposed to welding, brazing or open flames. When possible, maintenance or cleaning of equipment should be performed without entering the vessel. If a tank or any confined space must be entered, then formal confined space entry procedures must be followed. These procedures require that a fully qualified work team be used and that applicable confined space entry documentation be completed.

PERFORMANCE

Field tests of air-cooled chillers in similar systems comparing Solstice® ze with propane (R-290) show significantly lower energy consumption. In addition, compared to traditional refrigerants, the properties and operating characteristics of Solstice® ze are a very good match, but without the environmental penalty of high GWP HFCs.

Once the design of the application has been optimised to match capacity of R-134a, the advantage of Solstice® ze is higher energy efficiency or Coefficient of Performance (CoP) than R-134a across a range of applications and conditions. According to compressors experts, performance with HFOs can be further improved with optimisation of compressor design. Reciprocating, scroll, screw and centrifugal compressors can be used.

OTHER FEATURES OF SOLSTICE® ZE:

- As Solstice® ze is a pure molecule it can be used in flooded systems
- The thermodynamic properties of Solstice® ze may benefit from a liquid-line/suction-line heat exchanger or other cycle modifications

COST-EFFECTIVENESS

Fast Implementation

Solstice® ze exhibits similar performance to medium-pressure refrigerants like R-134a, so only minor considerations are required to use Solstice® ze.

Longer life of compressors

Solstice® ze refrigerant's lower discharge pressure results in less mechanical stress, thus extending the life of the compressor.

Energy Efficiency

Solstice® ze is more energy efficient in hot regions than competitive LGWP alternatives for this type of equipment.

Global Solution

Solstice® ze refrigerant provides efficient cooling in all global climate zones and is commercially available.

ENVIRONMENTAL IMPACT

Solstice® ze has a GWP of <1, exceeding existing climate protection goals.

- Helps with eco-design directives
- Reduces direct CO₂ emissions by 99.6 percent
- Reduces indirect CO₂ emissions due to the lower energy consumption
- Atmospheric life is only 18 days, much lower than the 13 years of 134a.

SAFETY

Solstice® ze Refrigerant is significantly safer in use than alternatives such as hydrocarbons and ammonia, which are either extremely flammable or highly toxic.

ATMOSPHERIC DECOMPOSITION OF SOLSTICE 1234ZE

HFO-1234ze(E) breaks down into the same by-products of other commonly used fluorinated compounds at levels much lower than naturally present. F atoms degrade into HF which is then rained out and mineralised with no additional effect on Ozone or on Climate*.

*“We conclude that the products of the atmospheric oxidation of trans-CF₃CH=CHF will have negligible environmental impact”, M.S. Javadiet. al. ; Atmospheric Chemistry of Trans-CF₃CH=CHF" in Atmospheric Chemistry & Physics Discussions, Vol8, pp 1069-1088, 2008

PACKAGE SIZES

Solstice® ze refrigerant is available in 1962.11 lb rolldrum and ISO bulk. For other packing sizes please contact Honeywell distribution network.



A COMPARISON OF R-134A ALTERNATIVES

	134a	1234ze	CO ₂	R-600	R-290
ASHRAE class	A1	A2L	A1	A3	A3
GWP (rev 5th IPCC)	1300	<1	1	3	3
LFL (vol% in air)*	N/A	7% **	N/A	1.80%	2.10%
UFL (vol% in air)*	N/A	12% **	N/A	8.40%	9.50%
Heat of Combustion (btu/lb)	1806	4600	N/A	19604	19905
Burning Velocity (in/s)	N/A	N/A	N/A	16.1	15.2
Minimum Ignition Energy (MBtu)	N/A	57800 to 60660***	N/A	~0.24	0.24
PED (97/23/EC) class	2	2	2	1	1
Flammability for handling and storage	No	No	No	Yes	Yes
Commercial availability	Yes	Yes	Yes	Yes	Yes
Ease of adoption	Baseline	Moderate – Easy when systems can be designed	Difficult – Very sophisticated systems	Difficult – Flammability issues limit charge amounts	Difficult – Flammability issues limit charge amounts
Cost of adoption	Baseline	Moderate	High	High	High

*Flame limits- ASTM E681-04 at 21°C; **(at 100°C); *** (at 54°C)

DEGRADATION PRODUCTS OF VARIOUS FLUORINATED COMPOUNDS

FLUORINATED COMPOUND	IN USE	IN ATMOSPHERE
134a	None known (hypothetically CF ₂ = CHF)	TFA, CO ₂ , Acid gases (HF) → Minerals like CaF ₂
1234ze	None known (hypothetically CF ₃ -C = CH)	CO ₂ , Acid gases (HF) → Minerals like CaF ₂



AVAILABLE TOOLS

SIMULATION SOFTWARE

Honeywell Refrigerants simulation software is a free download that eliminates the guesswork involved in selecting a refrigerant by allowing refrigeration engineers to run simulations based on actual data. The tool runs property calculations of refrigerants, conducts thermodynamic evaluations of air conditioning and refrigeration cycles, and provides a first principle thermodynamic comparison of new alternative refrigerants for retrofit applications or new system designs.

The software models systems from simplified basic cycles to large, complex refrigeration systems. The results can be exported to Microsoft Excel, where the data can be manipulated in a variety of ways. The software also creates typical Mollier diagrams (Pressure-Enthalpy, Temperature-Entropy). You can download the Genetron Refrigerants Modelling Software at www.honeywell-refrigerants.com

MOBILE APPS

Download **Honeywell PT calculation** applications for **iOS** and **Android** free



LITERATURE

Honeywell has a wide range of literature available on Solstice® ze including case studies, customers references, etc.

References

- IPCC WG AR – Chapter 8: Anthropogenic and Natural Radiative Forcing, February 2014
- Danfoss Turbocor Mostra presentation: The TG310 compressor with ultra-low GWP refrigerant HFO-1234ze, March 2014
- IOR (Institute of Refrigeration: R-1234ze for variable speed centrifugal chillers, April 2013
- 'Atmospheric Chemistry of Trans-CF3CH=CHF' in Atmospheric Chemistry & Physics Discussions, Vol8, pp 1069-1088, 2008

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Our commitments:

The safety of our employees

The quality of our products

Being responsible stewards for the protection of the environment, the communities in which we operate and our customers

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IS
WHAT
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