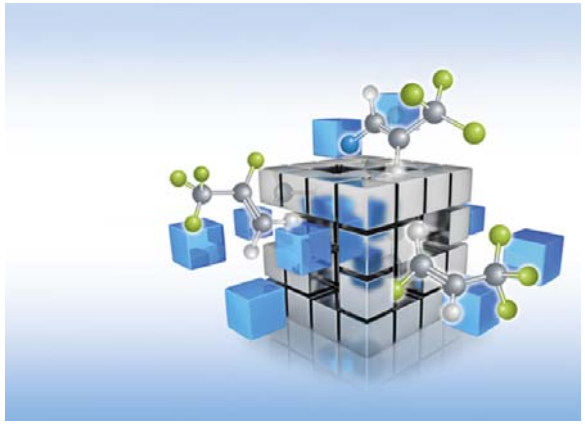


Sébastien Casterman
14th April 2016

SOLSTICE HFO REFRIGERANTS

ATIC 2016

Honeywell

Honeywell: history of innovation

$40.3B
in sales **2014**

55%
sales outside U.S.

- 1,250 sites, 70 countries
- 127,000 employees
- Morristown, NJ (HQ)
- Fortune 100, NYSE:HON

Aerospace

Performance Materials and Technologies

Automation and Control Solutions

Energy efficiency + Environmental compliance + Safety + Cost-affordable

Montreal Protocol

Kyoto Protocol

F-gas

CFCs	HCFCs	HFCs	HFOs
Very high ODP&GWP	High ODP and GWP	ODP=0, but high GWP	ODP=0, GWP low or ultra low
R12	R123 R22	404A, 410A, 407C, 134a, Performax (407F)	

Genetron Performax® LT F-Gas Ready Honeywell

Solstice® Refrigerants F-Gas Ready Honeywell

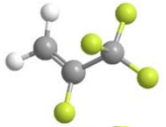

Stationary RAC


Blowing Agents

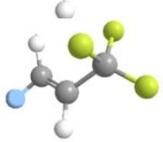

Aerosols / Solvents

MAC

Solstice® family


Solstice® **yf**


Solstice® **ze**


Solstice® **zd**

Honeywell

Technology And Innovation

21,600
technologists worldwide

116
research & engineering facilities

34,000
patents granted or pending

Developing solutions for the world's toughest challenges

Honeywell

Fluorine Products Profile

Pioneers in developing Low Global Warming Potential (LGWP) solutions

Honeywell Fluorine Products has innovated new low-global-warming-potential refrigerants, blowing agents, solvents and aerosols that have **99.9% lower global warming impact** than previous generation of materials.

Markets

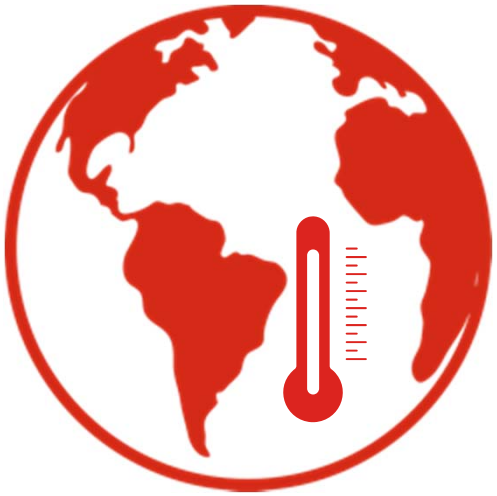
- Air conditioning and refrigeration
- Building and construction
- Oil refining
- Appliance and containers insulation
- Aerosols and solvents

Products / Services

- Solstice ® refrigerants, blowing agents, aerosols and cleaning solvents
- Enovate® blowing agents
- Genetron® and Perfromax™ LT refrigerants
- Hydrofluoric acid, Boron Trifluoride, industrial gases

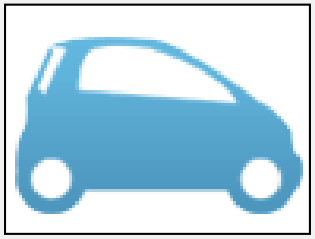
Honeywell

Impact of Solstice® to Date



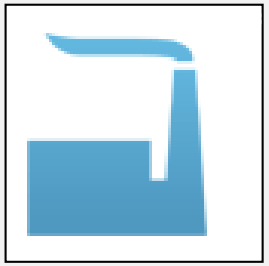
- **Solstice® products are making a significant impact*:**
  - Solstice® YF: 7.5 Million kg CO_2e
  - Solstice® ZE: 6.0 Million kg CO_2e
  - Solstice® ZD: 8.5 Million kg CO_2e
- **That's the same as eliminating**:**

4.5 M passenger vehicles not driven for a year



OR

5 coal power plants not used for a year



OR

50 M barrels of oil not consumed

*Based direct emissions of the lifetime sales of Solstice products vs what replaced. **Source: http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

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Solstice® family for today and tomorrow

Solstice® Low GWP Refrigerants:
Winner of the Low Carbon Achievement of the Year

Solstice® HFO molecules
Low and medium pressure applications

	Nonflammable (ASHRAE A1)	Mildly flammable (ASHRAE A2L)	Examples of potential applications
R-134a GWP=1430		**Solstice® yf** GWP* < 1	Auto A/C, Vending, Refrigerators
		Solstice® ze GWP* < 1	Chillers, CO_2 cascades Refrigerators
R-123 GWP= 77	**Solstice® zd** GWP* =1		Centrifugal Chillers High t^a heat pumps

Today

Solstice® Blends

	Non Flammable (ASHRAE A1)	Mildly Flammab (ASHRAE A2L	Examples of potential lications
R-134a GWP=1430	**Solstice® N13 (R-450A)** GWP* = 547		rs, Med-temp efrigeration
R-404A GWP=3922	**Solstice® N40 (R-448A)** GWP* = 1273	**Solstice® L40X (R-455A)** GWP* = 148	Low-Temp Refrigeration
R-22 GWP=1810	**Solstice® N20** GWP* = 891	**Solstice® L20 (R-444B)** GWP* = 295	Stationary A/C, Refrigeration
R-410A GWP=2088		**Solstice® L41 (R-447A)** GWP* = 572	Stationary A/C Applications

Coming soon

*IPPC5

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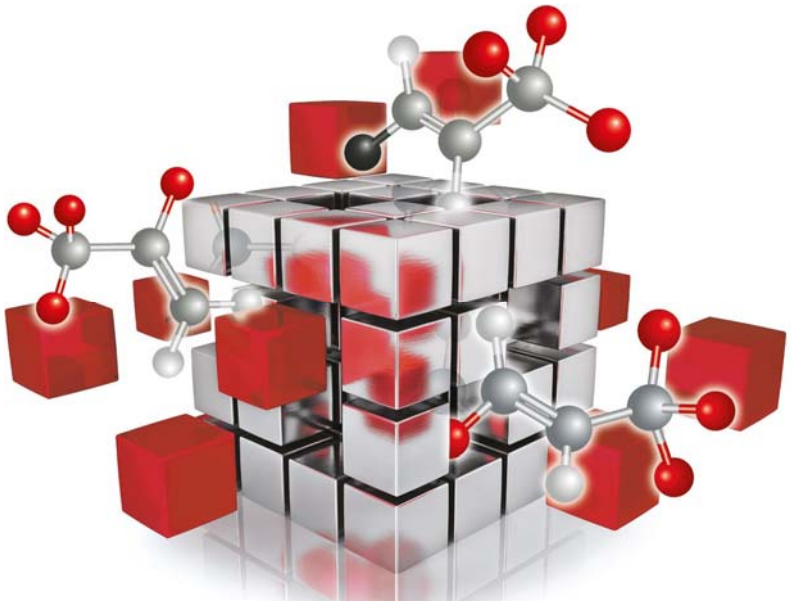

Air Conditioning & Heat Pumps
Solstice ze, Solstice zd

Solstice® ze

Physical properties

Solstice® ze (HFO-1234ze)	
Chemical Name	trans-1,3,3,3-Tetrafluoroprop-1-ene
Molecular Formula	$CF_3CH=CHF$
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 @ 21°C	Non Flammable
Flammability Limits – ASHRAE 34 @ 100°C	7% – 12% (by volume)

Applications

- Air-cooled and water-cooled chillers
- District heating and cooling
- Heat pumps
- Refrigerators
- Vending machines
- Beverage dispensers
- Air dryers
- CO_2 cascade systems, etc.

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Recent Low GWP Chiller Launches

R-1233zd Chillers

- Trane Introduced New Line of High Efficiency Chillers
- Mitsubishi Heavy Electric

R-1234ze Chillers

- Carrier Aqua Force screw chillers
- Danfoss Turbocor compressor for 1234ze
- Friotherm district heating&cooling
- Geoclima screw and centrifugal
- Star Refrigeration high efficiency Turbocor
- Airedale chillers with free cooling
- Cofely Turbocor chiller
- Multistack screw chiller
- Cooltherm chillers
- Smardt chillers
- Blue Box
- RC high efficiency screw chiller, wáter- and air-cooled chillers

Industry converting, regular announcements of new launches

Carrier screw chiller

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Solstice ze can open high temperature market

District heating & cooling (16.4 MW)

Waste heat HP (280 kW)

Food processing (200 kW)

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Solstice® ze in HP for district heating & cooling

- Rolfbuskta: heating & cooling
- Heat source sea water, indirect
- End user: large Scandinavian energy company
- Operating for 2 years
- World largest combined heating & cooling plant with refrigerant with GWP<1

Cooling mode

- Cooling capacity = 20.1 MW
- COP=5.0

Heating mode

- Heating capacity = 16.4 MW
- LWT= 78ºC (COP=4.83)
- LWT 98ºC possible

98°C

FRIOTHERM

Honeywell

Solstice® zd

Solstice® zd: Compliant with key EU and U.S. regulations

- Solstice zd is not listed in either the EU F-Gas or the EU ODS regulations
- Not considered to be an ozone depleting substance
- Not considered a fluorinated greenhouse gas
- Not subject to use controls
- Not subject to cap & phase down
- Not subject to de-listing by U.S. EPA
- Not subject to separate waste stream treatment under the EU WEEE Directive
- Solstice zd is not listed in the RoHS directive

Non Flammable

Non-flammable refrigerants are easier to handle safely

GWP of 1

Non-ozone-depleting Solstice zd refrigerant has a global warming potential (GWP) of 1 – existing alternative low-pressure refrigerants have GWPs between 850 and 1,300

Solstice zd can provide a lower GWP and higher efficiency when compared to R-245fa in the renewable heat recovery market and in the waste recovery market in both mobile and stationary applications

ORC Organic Rankine Cycle

WHEN

Solstice zd is commercially available today.

Solstice zd, due to its higher capacity with efficiency similar to R-123, is a good replacement in centrifugal chillers and other low-pressure applications

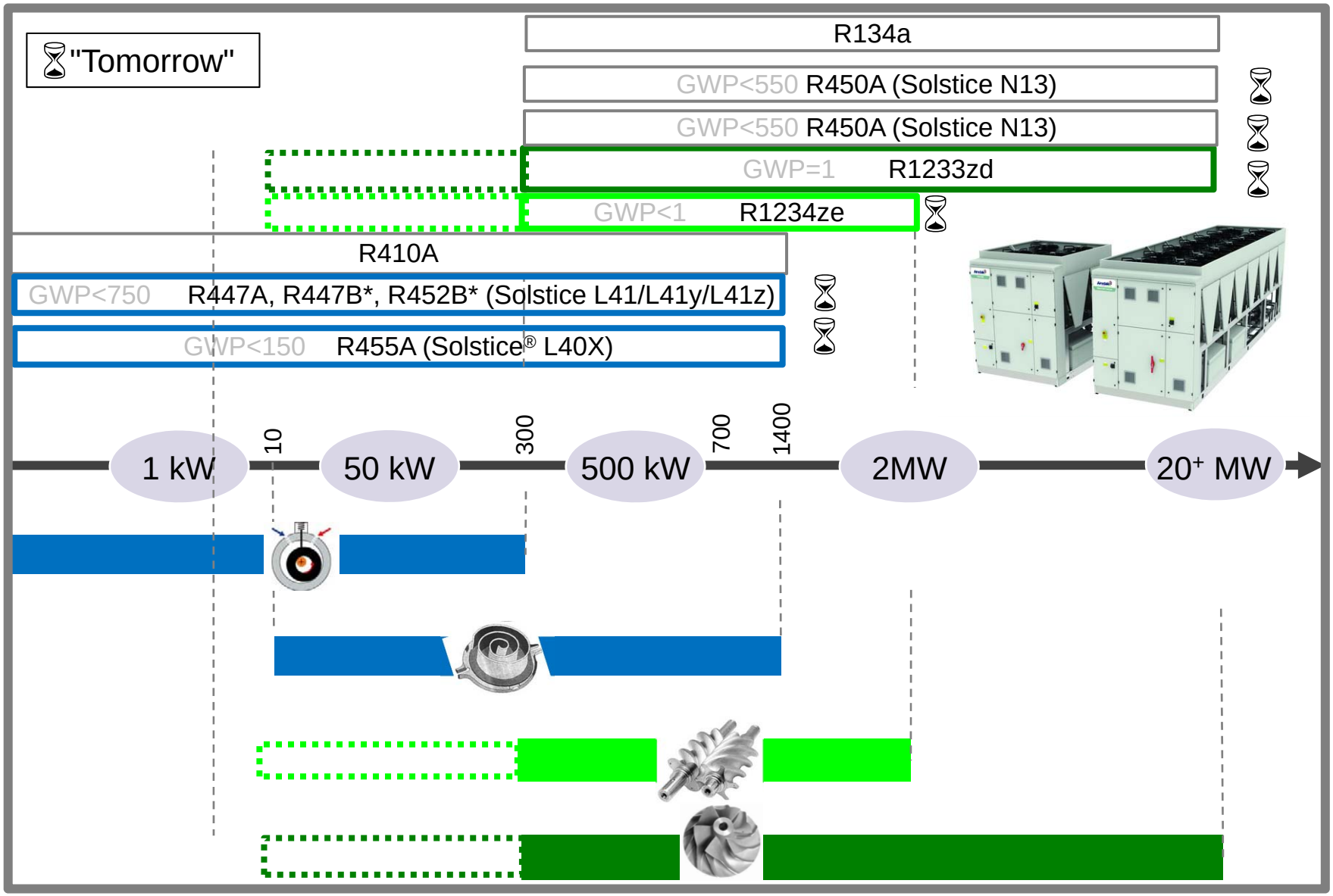
Centrifugal Chillers

Industrial applications can potentially benefit from energy savings when using Solstice zd

High temp. Heat Pumps

Honeywell

Comfort AC with GWP<150: technology projection



* Provisional Ashrae number

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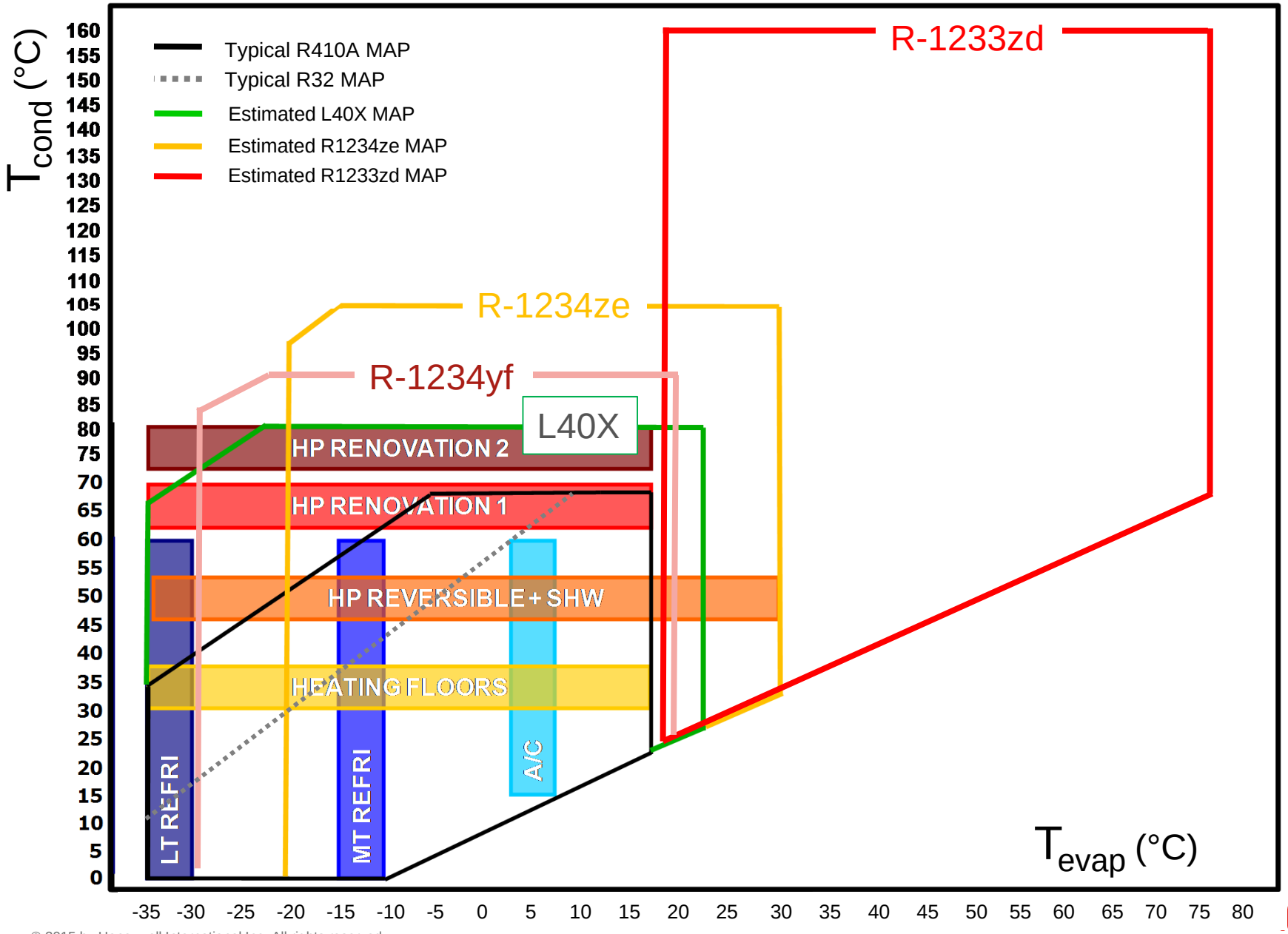
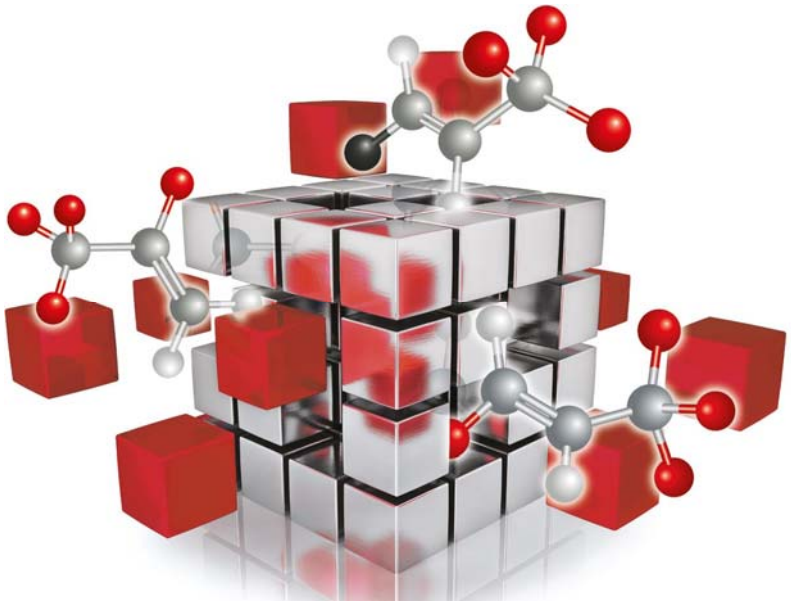
HFOs MAP analysis



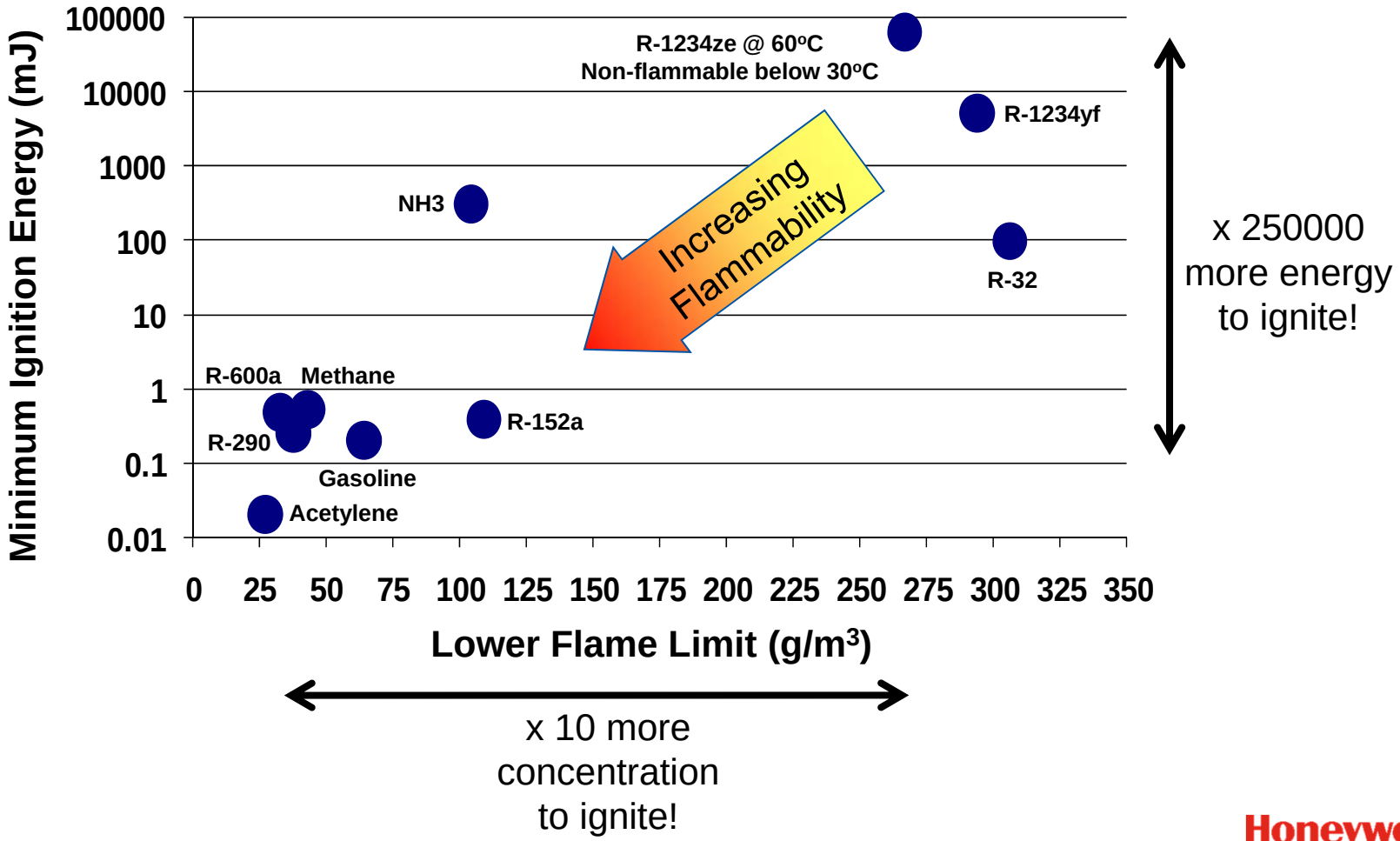


Flammability

Probability of Ignition

Flammability is evaluated by ‘Chance of Flame occurring’ and ‘Effect of Flame occurring’

- Chance of Flame occurring -> Lower Flame Limit, Minimum Ignition Energy



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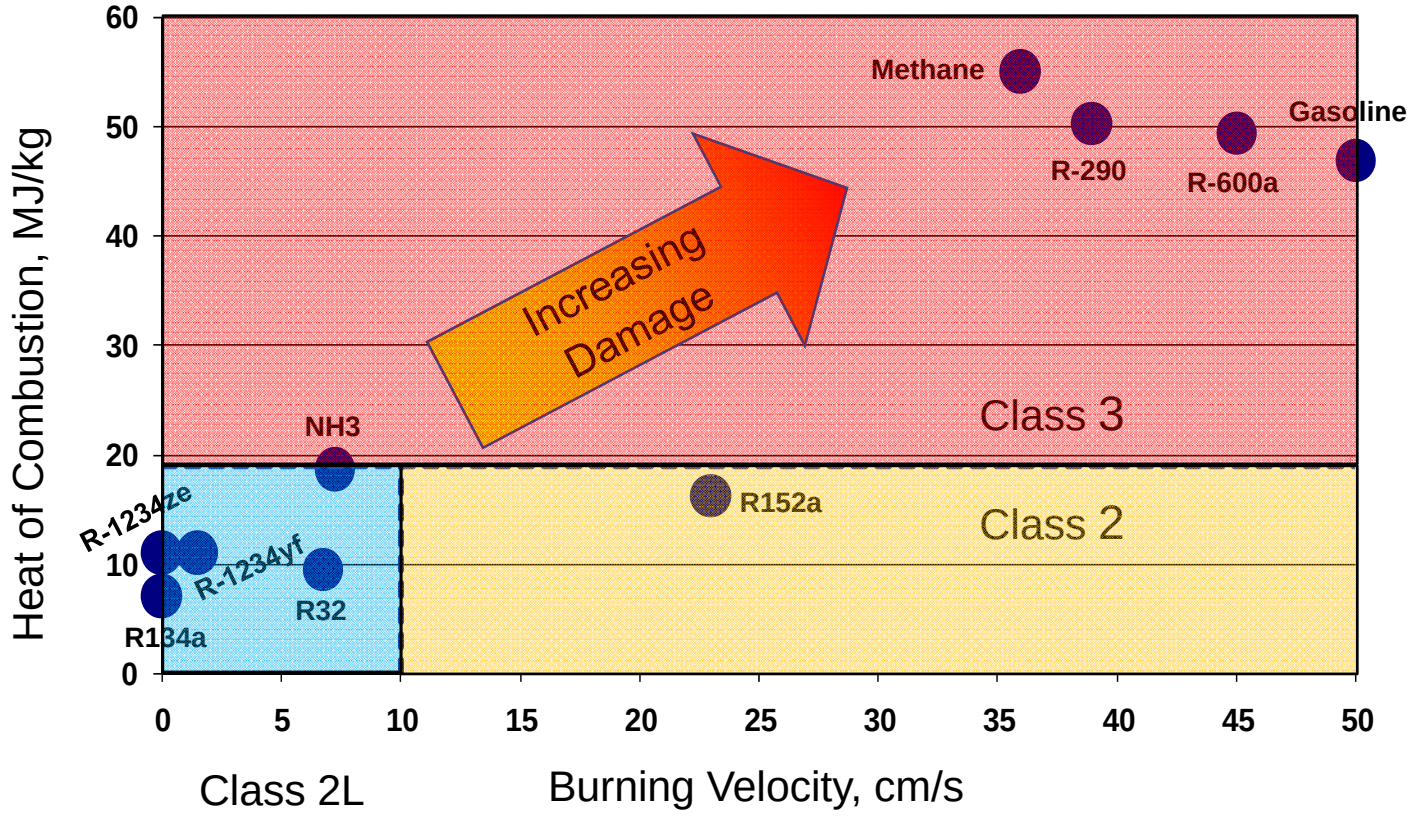
Damage Potential

- Effect of Flame occurring -> Burning Velocity, Heat of Combustion



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R1234yf and R1234ze Flame Limit: US DOT & ASHRAE

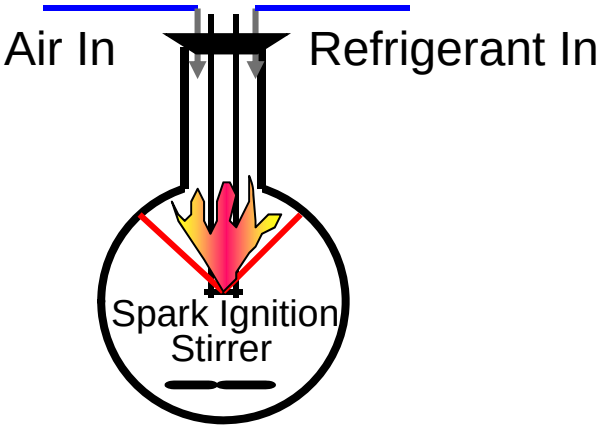
Honeywell Results For 1234yf

- T = 23°C : 6.5 to 12.3 vol.%
- T = 60°C : 5.7 to 12.3 vol.%
- T = 100°C : 5.3 to 12.3 vol.%

Independent U.S. Test Lab Results

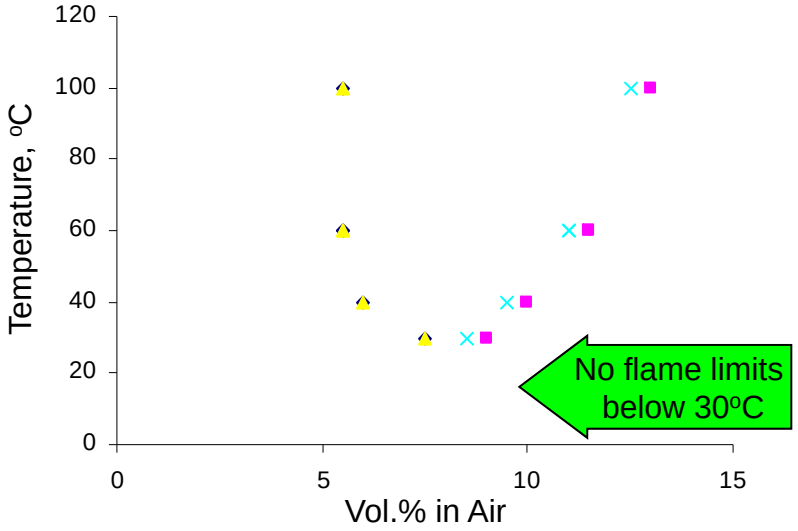
- T = 23°C : 6.2 to 12.3 vol.%

ASTM E681 Apparatus



Honeywell Results For 1234ze(E)

- T = 21°C : No Flame Limits
- T = 60°C : 5.7 vol.% to 11.3 vol.%
- T = 100°C : 5.7 vol.% to 12.7 vol.%



Independent U.S. Test Lab Results

- T = 23°C : No Flame Limits
- T = 100°C : 7 vol.% to 12 vol.%

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Thank you! Questions?

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