R744 compressors for MAC and light commercial refrigeration

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- Milestones of ixetic's compressor development
- Overview of belt driven compressors, customer feedback
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Milestones of ixetic's R744 compressor development

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in 1994: Start of R744 compressor project, together with German OEM's

in 1995: First delivery of prototypes for initial tests

from 1996 up to 1999: Basic design work to optimise efficiency, controllability and durability of compressor

from 2000 up to 2005: development of mass production design

in 2005: start of industrialisation, readiness for production in 2009

in 2008: ixetic gained a contract for serial production of the first CO_2 compressor for MAC worldwide

mid of 2009: belt driven compressor projects stopped due to refrigerant decision of OEM's
electric compressor development continued

in 2011: presentation of a Heating/Cooling-Unit with R744 for thermal management of EV's and batteries

in 2012: presentation of a compressor family for light commercial refrigeration

Overview of ixetic's R744 belt driven compressors

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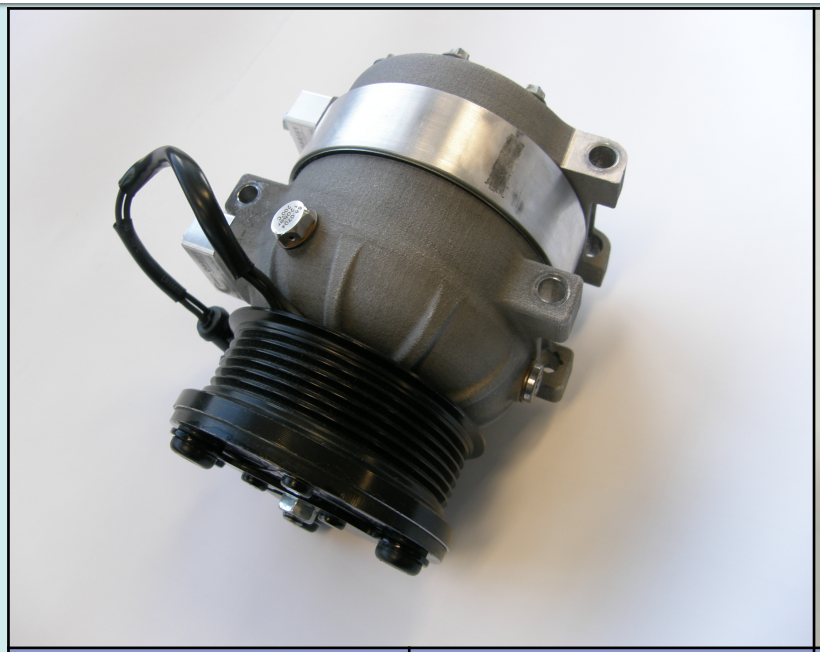

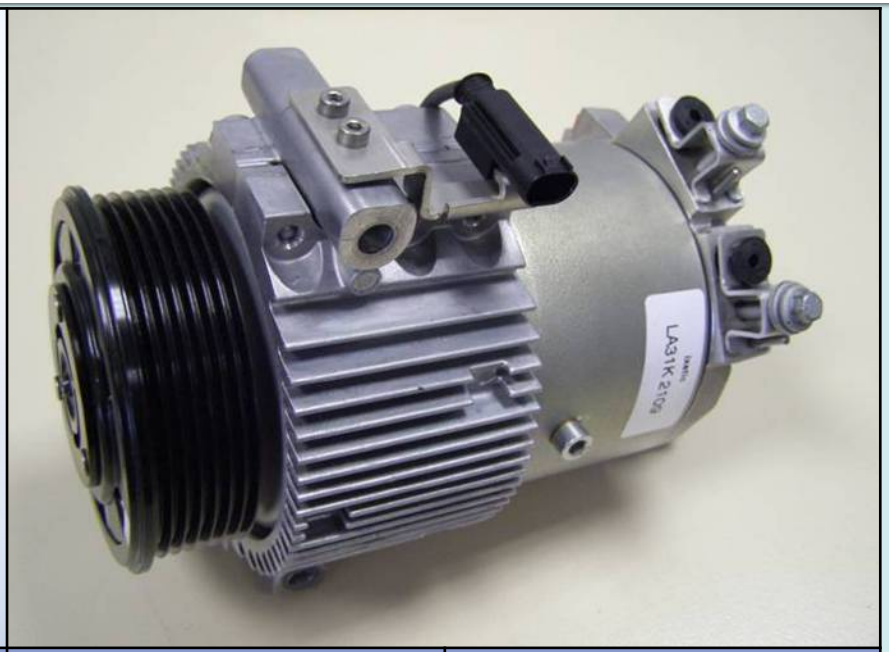

LR15K	LR23K	LA25K	LA31K
• 15ccm³ fix	• 23ccm³ fix	• 0-25ccm³	• 0-31ccm³
• Radial-Piston	• Radial-Piston	• Swash-Ring	• Swash-Ring
• Suction throttle	• Suction throttle	• Displacement control	• Displacement control
• Compact cars	• Medium class	• All classes	• SUV/luxury class
• Europe/Asia	• USA/Asia	• Europe	• Worldwide

Customer feedback about ixetic's R744-compressors (belt driven)

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- steel housing, steel piston, high temperature PAG-oil for high operating temperatures R744 ✓
- very low parasitic horse power consumption ✓
- OCR-rate below 1% ✓
- integrated contamination absorber for high demands of R744 systems. ✓
- modular design for all mounting requirements ✓
- swash ring drive mechanism enables innovative torque - management concept ✓
- reliability proven during 2 fleet tests with major VDA OEM, 1 Mio. km, including extreme tests ✓

Conclusions:

1. ixetic can reactivate development of belt driven compressors
2. a time of 3 up to 4 years will be required to start mass production

Heating/Cooling-Unit, 3D view

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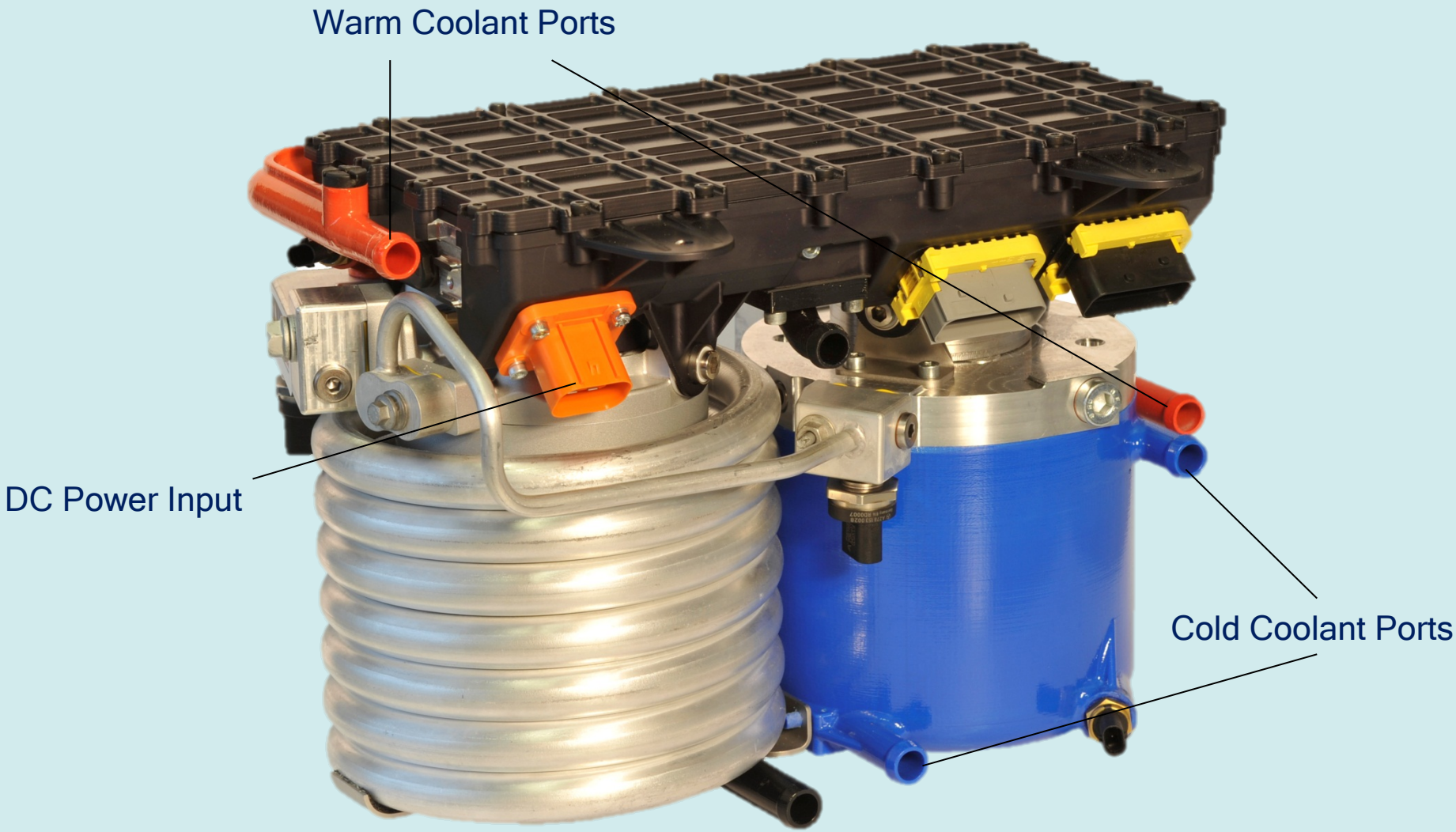

Application examples
Performance and efficiency

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	Heat Pump	Battery Chilling	Air Conditioning
ambient temperature [°C]	**-15**	**+30**	**+30**
warm or cold water (output line) temperature [°C]	**+60**	**+15**	**+5**
heating or cooling (typical stationary demand) performance [kW]	**4**	**3**	**4**
COP [-]*	**3,0…3,4**	**2,3…2,7**	**1,7…2,0**

* simulation based on component test results; pessimistic up to optimistic boundary conditions

R744 compressor for light commercial refrigeration

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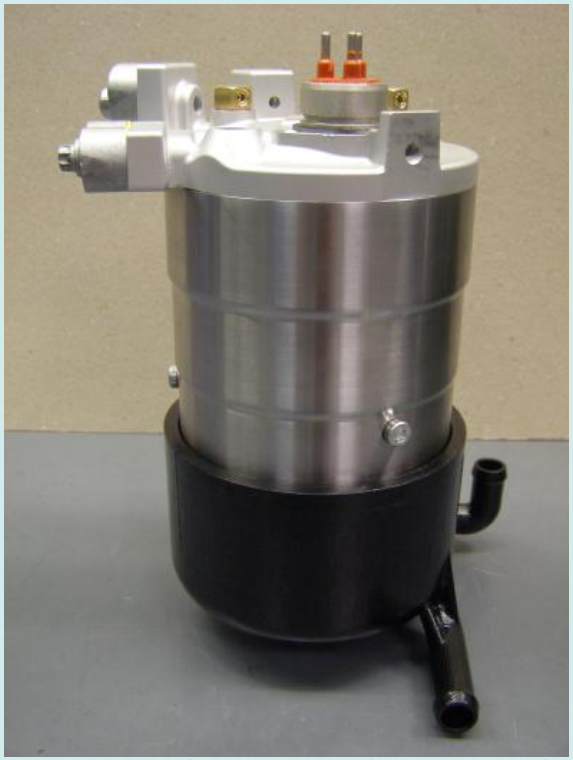

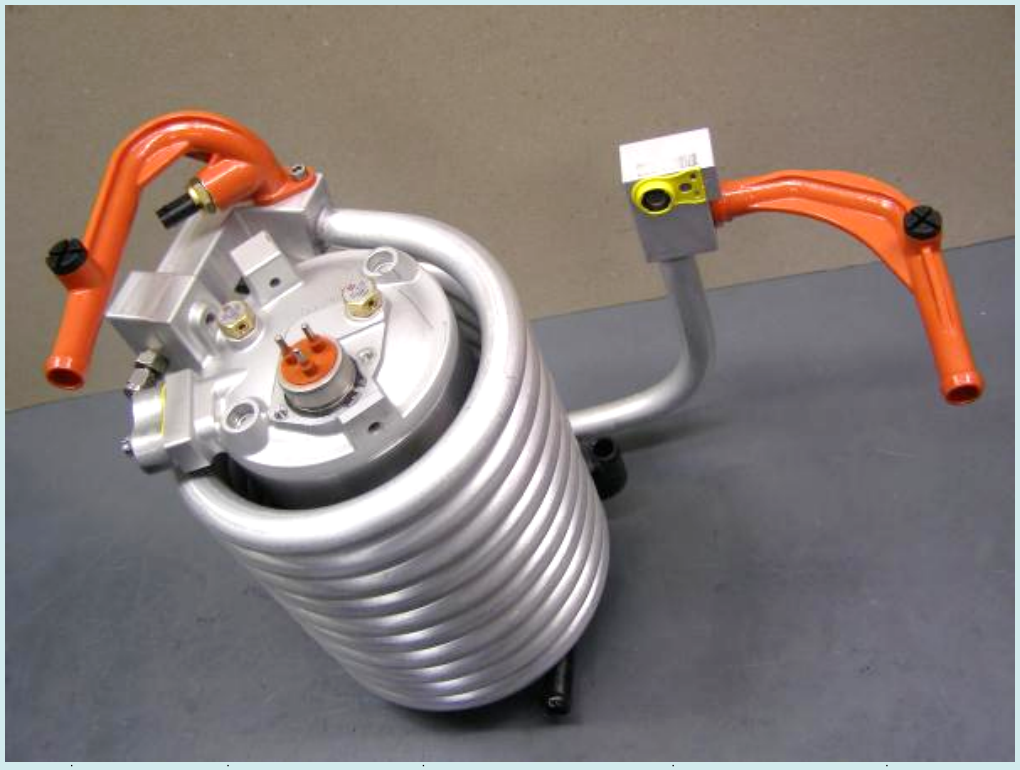

Refrigerant Evaporation Temp.	Refrigerant Suction Pressure	Gas Cooler Water Inlet Temp.	Gas Cooler Water Outlet Temp.	Discharge Pressure	Compressor Speed	Heating Performance	Electric Power-Consumption	COP Heat
[°C]	[bar]	[°C]	[°C]	[bar]	[1/min]	[kW]	[kW]	[-]
-15	23	10	65	85	3600	**4,0**	1,4	**2,8**
15	51	10	65	110	1550	**4,0**	0,9	**4,6**

Based on single component measurements of Compressor and Gas Cooler Heating Performance

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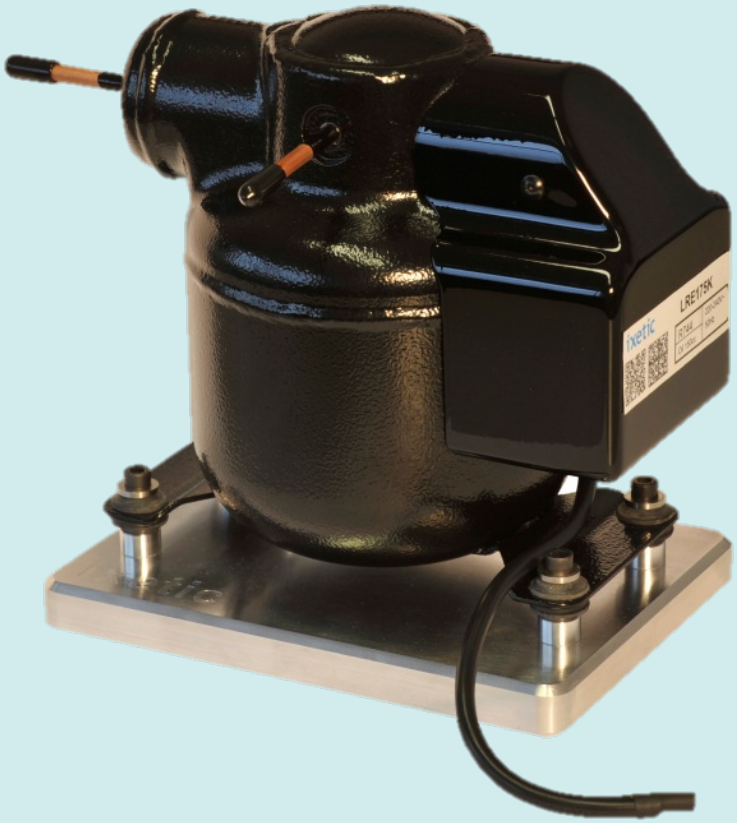

- available AC-Motor with constant speed for 230V / 50 or 60Hz and 115V / 60Hz
- compressor with variable speed under investigation

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Compressor model	LRE175K			LRE315K**			LRE455K**			LRE600K***		
Drive	1 phase, fixed speed (230V / 50Hz) *			1 phase, fixed speed (230V / 50Hz) *			1 phase, fixed speed (230V / 50Hz) *			3 phase, variable speed		
Test conditions	Discharge pressure: 92bar Suction temperature 32°C / Exp. valve inlet temperature: 32°C											
Evaporating temperature [°C]	-10	-5	0	-10	-5	0	-10	-5	0	-10	-5	0
Cooling capacity [W] ± 5%	656	761	879	1181	1370	1581	1705	1980	2284	3217	3972	4849
Power consumption [W] ± 5%	370	374	372	666	674	670	962	975	968	1875	2018	2124
COP [W/W] ± 5%	1,77	2,03	2,36	1,77	2,03	2,36	1,77	2,03	2,36	1,72	1,97	2,28

* Also available with 230V / 60Hz, 115V / 60Hz.
** Calculated values based on LRE175K
*** Measured values including Inverter. Motor speed 5000rpm

Energy savings

	COP
Competitor A	1,5
Competitor B	1,7
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Cooling capacity 600W →

Pel [W]
400
345
296

Operating time: 14h per day →

Energy consumption per year [kWh]
2044
1763
1513

Reduction 531 kWh

Savings EU27 countries →
based on an European average electricity rate of 0,13 €/kWh

69 € per year

or 362 kg CO2 per system and year

based on the German electricity mix of 682g/kWh

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Thank you for your Attention