REPORT · REFRIGERANT BENCHMARK

Low & Ultra-Low GWP Refrigerants

for EV Heat Pumps

Laboratory benchmark · 1D simulation · in-vehicle drop-in test

Green, low-flammability refrigerant alternatives tested 1-to-1 under controlled laboratory conditions and as a drop-in solution in a serial electric vehicle.

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WHAT'S INSIDE

Three test domains — *one refrigerant verdict.*

A comprehensive benchmark of two novel low- and ultra-low-GWP refrigerant blends in a compact indirect heat-pump unit — from controlled laboratory testing to a calibrated simulation model and a real-vehicle drop-in test.

01

Laboratory Test

Direct 1-to-1 comparison of the novel blends against today's standard automotive refrigerant and a natural alternative (propane), in a compact indirect heat-pump unit. Test matrix based on the SAE cycle.

02

Virtual Analysis

A calibrated 1D system model extends the measured data to non-tested operating points and quantifies optimisation potential — e.g. internal-heat-exchanger integration.

03

Drop-In Vehicle Test

Climate-chamber and open-road field testing in a serial EV — heat-up at −7 °C and cool-down at +40 °C — mapping real-world potential and limitations.

2 novel blends · 4 refrigerants benchmarked · 3 test domains

INSIDE THE FULL REPORT

What the *measured data* covers.

Every operating point is instrumented and compared — capacity, efficiency, pressures, power and energy. A selection of what the full report details:

01

Performance & Efficiency

Chiller and condenser capacity, compressor speed and power consumption per SAE test point; COP comparison across all four refrigerants; capacity and efficiency deltas vs. the incumbent.

02

System & Instrumentation

Compact indirect refrigerant system with glycol-side chiller and liquid-cooled condenser; full CAN instrumentation — loop pressures & temperatures, PTC power, blower speed, surface sensors.

03

Vehicle Behaviour & Tuning

Cabin pull-down and heat-up dynamics, pressure-level and safety-limit behaviour, energy consumption; control and expansion-valve adaptation to leverage the novel refrigerant.

- Novel A2L blend performs on par with propane — above the standard HFO refrigerant.
- Drop-in feasibility validated for heating (−7 °C) and cooling (+40 °C).

From lab bench *to open road.*

WHAT YOU RECEIVE

— Full PDF report — lab, simulation & vehicle results

— Measured data per SAE operating point

— Calibrated 1D-model insights & optimisation potential

— Q&A session with a SATTELO refrigerant & thermal-management expert

Examples shown in the full report:

PROJECT OVERVIEW – TESTED REFRIGERANT BLENDS

Two KPIs matching candidates investigated for potential EV heat-pump utilization. Refrigerants by Daikin Chemicals, recognized by ASHRAE.

- Ultra-low GWP variant for smooth transition from R-1234yf → **R-474B**
- **PFAS compliant** and low GWP as a predecessor of R-290 → **R-491A**

Conditions: Te=5degC, Tc=60degC, SH=5K, SC=5K, Comp. efficiency =70%

R-474B
Ultra-low GWP
- A2L flammability
- Blend of R-1234yf and R-1132(E)

R-491A
Low GWP
- A2 flammability
- Blend of R-152a and R-1132(E)
- PFAS compliant

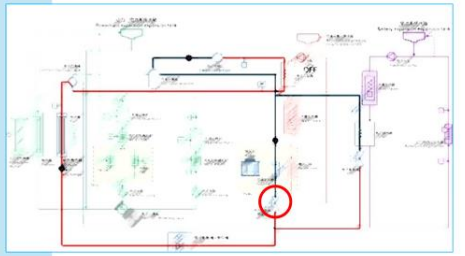
Refrigerant	GWP (AR4)	Safety	Saturation Pressure 20°C	40°C [MPa]	60°C	Discharge Temperature [°C]
R-474B	<4	A2L	0.86	1.48	2.38	84
R-491A	81	A2	0.69	1.21	1.98	100
R-134a	1430	A1	0.57	1.02	1.68	82
R-1234yf	4	A2L	0.59	1.02	1.64	70
R-290	3	A3	0.84	1.37	2.12	81

*Te = Temperature Evaporator, Tc = Temperature Condenser, SH= superheat, SC = sub-cooling

VEHICLE - Setup

Target:
Validate the R-474B drop in solution in real world system:
Climate chamber test (heating and cooling case)
Field test
B2B comparison (Daikin R-474B vs R-1234yf)

1. Compact Heat Pump (Proace II) Laboratory Test
2. 1D System Simulation Calibration and Calculation
3. Refrigerants Comparison
4. Vehicle Drop-In Test



BENCH TEST - Setup

SETUP:
SATTELO own heat pump module (PROACE), developed specifically for R-290 and indirect systems

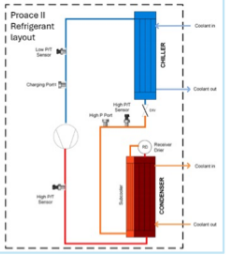
9k W cooling capacity (base)

Optimized inner volume, validation completed and simulation models available /1D model ready

TEST CONDITION:
*Test matrix / target based on SAE J2765 matrix
*Test cases adapted to indirect system
*Maximum performance cases specified
*Test performed on two accuracy levels:
-PROACE unit – compact automotive heat pump
-Test bench – identical components with detailed instrumentation for 1D calibration
*Pure drop in => same components
*Same control (only adaptation of refrigerant properties) operating conditions target performance, lab and team

Test ID	Evaporator coolant inlet temperature	Condenser coolant inlet temperature	Compressor speed	Evap Coolant flow	Cond Coolant flow	SH
[#]	[°C]	[°C]	[RPM]	[LPM]	[LPM]	[K]
1_max	10	40	8500	25	25	5
2_max	10	50	8500	25	25	5
3_max	10	60	8500	25	25	5
4_max	-5	40	8500	25	25	5
5_max	-5	50	8500	25	25	5
6_max	-5	60	8500	25	25	5
7_max	-10	40	8500	25	25	5
8_max	-20	50	8500	25	25	5
9_max	-20	60	8500	25	25	5

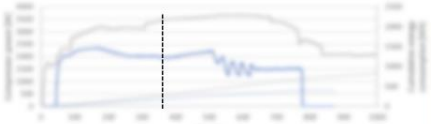
R-290 Heat pump module



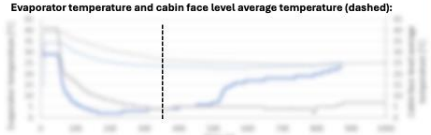
VEHICLE- Results 40°C Pulldown

Compressor suction and discharge (dashed) pressure:

Compressor power and cumulative energy consumption (dashed):



Evaporator temperature and cabin face level average temperature (dashed):



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Remarks:
- R-474B shifted to higher pressure level, hitting the system safety limit →compressor speed reduced
- Compressor power consumption of 2kW for R-474B vs. 3 – 3.4kW using R-1234yf at the same cabin cooling
- R-474B - Initial temperature pull down on evaporator outlet and in cabin is slightly more effective in first minutes of the run, until the compressor is ramping down due to system limits
- The vehicle was operated in "standard" mode = no control adjustment. This gives us a lot of space for working with system control to optimize the performance withing the pressure limits.

GET THE FULL REPORT

Purchase the report — *talk to an expert.*

The full report includes the complete laboratory dataset, the calibrated 1D-model insights and the in-vehicle drop-in results — plus a Q&A session with one of our refrigerant and thermal-management experts.

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