Testing of novel refrigerants in an indirect automotive heat pump module

- Drop in comparison of R-1234yf, R-474B, R-491A, and R-290 -

Miloš Fojtlín [1)] **Ján Tuhovčák** [1)] **Tomáš Mrkvica** [1)]

1) SATTELO s.r.o., Stojanova 1334, Uherské Hradiště, Chzechia (E-mail: tomas@sattelo.com)

KEY WORDS:**heat fluid, refrigerant,** drop-in test, low GWP, heat pump, R-474B, R-491A, R-1234yf, R-290 (D1)

The study addresses the ongoing transition toward refrigerants with very low global warming potential in automotive thermal management systems. In response to regulatory pressure and the growing importance of efficient electrically driven heat pumps in electrified vehicles, the work compares two novel blends based on R-1132(E) with the established baseline R-1234yf and the high-performance reference R-290. The objective was to determine whether these refrigerants can be applied in a drop-in manner within current indirect automotive heat pump architectures while preserving acceptable performance and remaining within prevailing safety limits.

Experimental testing was performed using a compact indirect refrigerant system with a plate-type chiller, liquid-cooled condenser, and electrically driven automotive scroll compressor. All refrigerants were tested on the same hardware platform under the same discharge pressure and discharge temperature limits. Representative operating points covering summer cooling, winter heating, and re-heat conditions were defined from the SAE matrix and translated into coolant-loop boundary conditions suitable for an indirect system. Performance was evaluated from coolant-side calorimetry, with COP used for heating mode and EER for cooling mode.

The results showed that under moderate cooling conditions all refrigerants were able to achieve the prescribed targets, although R-290 delivered the highest EER and R-1234yf required the highest compressor speed. At elevated ambient temperatures, the differences became more pronounced. R-474B and R-491A both outperformed R-1234yf in high-temperature cooling cases, while R-290 remained the strongest performer overall. In the most demanding operating conditions, R-474B approached the required cooling capacity but was limited by discharge pressure, whereas R-491A was more strongly constrained by discharge temperature. By contrast, R-1234yf was not directly limited by safety boundaries in the same way, but lacked sufficient capacity to meet the highest cooling targets.

In heating and re-heat operation, all investigated refrigerants were capable of meeting the required heating demand. At low ambient temperature, COP values were similar across the tested refrigerants, while at milder winter conditions R-1234yf and R-290 retained an efficiency advantage. The novel blends performed acceptably, but their operation revealed distinct system-level constraint tendencies: R-474B shifted toward higher condensing pressures and R-491A toward higher discharge temperatures. This behavior suggests that the main barriers to further performance gains are related to the present system design and control envelope rather than to the intrinsic suitability of the refrigerants. The paper identifies several pathways for improvement, including increased heat exchanger effectiveness, more thermally robust lubricants, and refined control strategies such as adaptive superheat or subcooling management.

A supplementary vehicle-level assessment with R-474B demonstrated that the refrigerant can operate in an existing battery electric vehicle heat pump system without hardware redesign, particularly in heat-up mode. Compared with R-1234yf, operation with R-474B showed lower compressor speed under steady conditions, indicating potential for improved acoustic behavior, compressor downsizing, and energy savings. At the same time, the vehicle tests also confirmed the importance of dedicated control calibration, especially under high ambient conditions and during transient events such as defrost.

In conclusion, the study demonstrates that both R-474B and R-491A are technically viable low and ultra-low-GWP candidates for automotive heat pump applications. Among the synthetic alternatives, R-474B showed the most promising balance of cooling capability and practical applicability in the current system architecture. The overall findings support the view that targeted system optimization would be sufficient to unlock the performance potential of these novel refrigerants in future automotive thermal management systems.

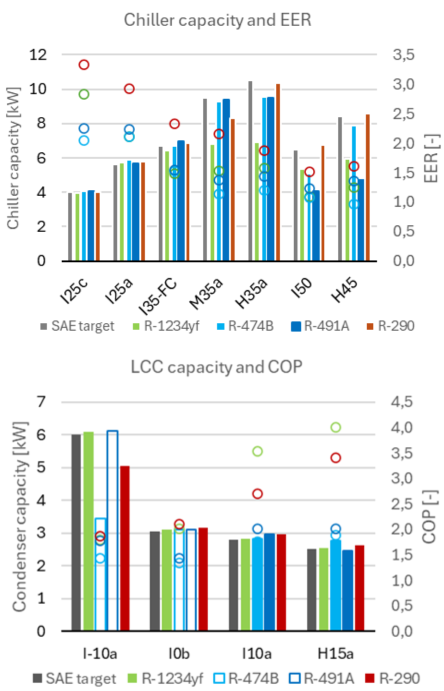

Fig. 1 Cooling and heating performance, COP. NOTE: columns without a fill are simulated values.