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Experimental study and simulation on the performance of a heat pump system with novel low-GWP R474A for new energy vehicles

Yunlong Zhang [1] Nie Hao [2] NEGISHI YASUTAKA [3] AJIOKA SHOHEI [3] BUNNO ASUKA [3] YAMAMOTO KEI [2] Jiangping Chen [1] Binbin Yu [1]

1)School of Mechanical Engineering, Shanghai Jiao Tong University.
Room 420, M&E building A, No. 800, Shanghai 200240, China (E-mail: ybbedc@sjtu.edu.cn)
2)Daikin Fluorochemicals (China), Co. , Ltd.
37th Floor, Zhongxin Tower, No. 1468 West Nanjing Road, Jing'an District, Shanghai, 200040, China
3) Daikin Industries, Ltd.
34th Floor, Osaka Umeda Twin Towers South, 1-13-1 Umeda, Kita-ku, Osaka, 530-0001, Japan

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The increasing stringency of global environmental regulations has accelerated the search for next-generation low-GWP refrigerants suitable for new energy vehicle (NEV) heat pump systems. This study evaluates the thermophysical properties, cycle performance, and system behavior of R474A, a novel A2L-classified Hydro-Fluoro-Olefin (HFO) mixture with a global warming potential (GWP) of less than 1. This study employs an integrated approach combining thermodynamic analysis, system simulation, and experimental validation to evaluate the performance of R474A in a heat pump system, with comparisons made against R290 and R134a, as well as an investigation of its temperature uniformity. The results indicate that the optimal refrigerant charge for R474A in this heat pump system is 1250 g. In cooling mode, R474A achieves a COP exceeding 2.2 under low-load conditions and provides a cooling capacity of over 7000 W under high-load extreme conditions. Notably, in battery cooling mode, the cooling capacity exceeds 10 kW with a COP above 3.6. R474A demonstrates superior cooling performance compared to both R134a and R290 across both low and high-load scenarios, while its COP is generally higher than that of the R290 secondary loop system. In heating mode, R474A maintains a COP above 2.1 under low-load conditions and delivers a heating capacity exceeding 4500 W under high-load extreme conditions. Its heating performance surpasses that of both R134a and R290 across all conditions, with consistently higher COP than the R290 secondary loop. Moreover, R474A overcame the operational limitations of R134a at extreme low temperatures. These findings highlight R474A's significant potential as a sustainable alternative refrigerant for NEV heat pump applications.

The comparative analysis of R474A, R134a, and R290 shows that R474A outperforms both R134a and R290 in terms of cooling and heating capacity under both conventional and extreme conditions. The improvement compared to R134a reaches 15% to 25%, and in some conditions, it shows approximately a 10% improvement over R290. Notably, under extreme low-temperature heating conditions, R474A overcomes the operational limitations of R134a. Additionally, the COP of R474A is higher than that of R290 across all conditions, with an improvement of up to approximately 25%.

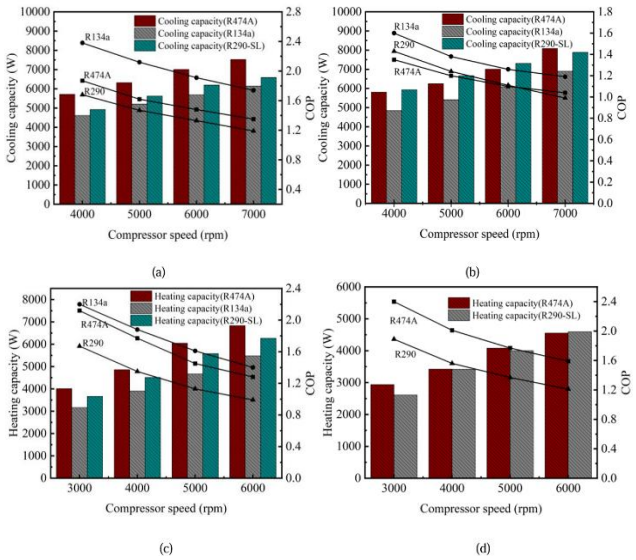

Fig. 1 Performance comparison of R474A, R290, and R134a. (a) 35℃/27℃. (b) 50℃/40℃. (c) -7℃/-7℃. (d) -20℃/-10℃.