From R134a to R1234yf: A Case Study in Overcoming Performance, Safety, and Cost Barriers for Sustainable Refrigeration in EV/Alt. Power Thermal Management Applications

Author: Sumbal Zaman

In our recent white papers, we discussed the need to adopt alternatives to R134a due to its High GWP and search for a potential "drop in" replacement. Considering the thermodynamic properties of both Refrigerants, as shown in Figure 1, R1234yf serves as a viable low-GWP alternative to R134a, especially in applications where environmental considerations are paramount. While it may not match R134a's performance in all aspects, strategic system modifications can bridge the gap, making R1234yf a compelling choice for sustainable refrigeration solutions.

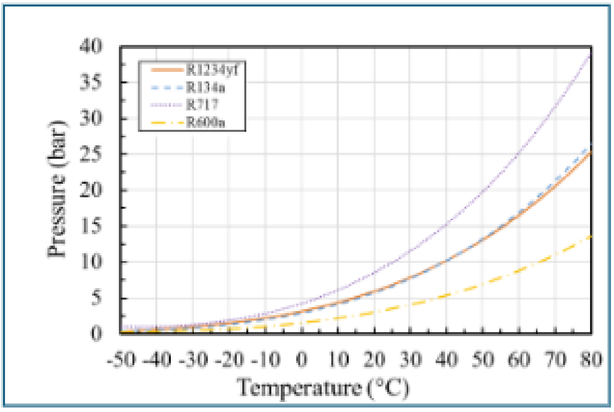

Figure 3: Saturation Pressure vs. temperature of R1234yf, R134a, R717 and R600a [3]

Industries that utilize refrigerants must adapt to the impending phase-out of R134a. This may involve investing in new equipment that uses alternatives or retrofitting existing systems to be compatible with environmentally friendly refrigerants. These adjustments can require significant financial investment and present logistical challenges.[1]

A number of studies have been conducted by researchers to investigate the drop-in performance of R1234yf in R134a vapor compression refrigeration (VCR) systems. In this paper we highlight some of the key challenges that are under consideration at AKG – as we prepare to convert our systems from R134a and R1234yf.

- **Safety**: Is and should always be the top priority for all. While R1234yf is mildly flammable (classified as A2L), blending it with a small percentage of R134a (e.g., 11%) can render the mixture virtually non-flammable, enhancing safety without substantial performance loss.[2] R1234yf tends to result in a lower compressor discharge temperature, which can be beneficial for system longevity and safety.

- **Cooling Capacity and COP**: R1234yf could not perform as effectively as R134a – with cooling capacity 17.1% and COP 12.4% lower than R134a. Adding an IHX enhanced the cooling performance of the system by 10%.[3] Another research listed that cooling effect of R134a is 25% higher than R1234yf and COP by 12.6%.[2] R1234yf typically exhibits a 9% lower cooling capacity, and a 19% lower COP compared to R134a under similar operating conditions. In oil-free systems, the COP of R1234yf was found to be 20% lower, with volumetric efficiency reduced by 5% relative to R134a.[1]

- **Cost**: R1234yf is 6X more expensive than R134a (as of May 2025, at the time of publishing this article) since it's a newer refrigerant and has higher production costs. Additionally, the process of leak checks, charging, recycling and retro filling requires specialized equipment and training. This adds an extra layer of complexity and cost to the process.

- **System Modifications:** To optimize R1234yf performance, some adjustments might be needed, such as:
    - **The compressor** must be approved for R1234yf use. Older compressors may overheat or wear faster due to different lubrication or pressure/enthalpy profiles. In some cases, compressor replacement is recommended.
    - Tuning the thermal expansion valve (**TXV**) - These may not meter refrigerant properly due to different pressures and superheat characteristics.[4]
    - Enhancing **heat exchanger** designs may be necessary. Adding an **IHX** helped recover system losses.[3] To compensate for lower heat transfer performance of R1234yf, in high-performance systems, consider upgrading to high-efficiency models.
    - R1234yf may permeate **seals**, **O-Rings**, and **Hoses** or degrade **older rubber materials**. Consider replacing HFO-compatible elastomers, such as HNBR (hydrogenated nitrile) O-rings and barrier hoses. R1234yf uses unique **connectors** to prevent accidental mixing with R134a.
    - Add a high-efficiency **condenser** or increase fan speed to offset any capacity reduction.
    - **Pressure sensors** and **control logic** may be calibrated for R134a. Verify compatibility or recalibrate if the system uses electronic expansion valves (EEVs) or advanced control modules.
    - **Charge** and **oil** determination must be re-performed as both refrigerants have different thermal properties. POE oil (polyol ester) or specific PAG oil compatible with R1234yf must be used. R1234yf has different solubility and miscibility characteristics, so oil designed for R134a may not suffice. Clean the system thoroughly or flush it to remove residual incompatible oil.
    - **Drier** or **Accumulator** desiccants are rated for both / or refrigerant.

In conclusion, while R1234yf presents a viable low-GWP alternative to R134a, its adoption requires careful consideration of performance trade-offs, safety measures, and financial implications. With appropriate system modifications and safety protocols, R1234yf can serve as a compelling choice for sustainable refrigeration solutions.

At AKG, we are proactively addressing the challenges associated with transitioning from R134a to R1234yf. Our approach encompasses a comprehensive evaluation of system design and components, excessive prototype testing, and continuous process improvements. Additionally, we are investing in specialized training for our technicians to ensure safe handling and servicing of R1234yf systems. By taking these proactive steps, AKG aims to lead the industry in adopting environmentally friendly refrigerants while maintaining system reliability and performance.

Please reach out to Sumbal Zaman/Vykram Vijayasekaran if you have any questions on this topic or inquiries related to EV/Alt.Power for your applications at sales@akg-america.com or 919-563-4286.

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