

R454C and the next generation of data center air conditioning

Sebastian Maron, senior product manager at STULZ, explains the advantages of using R454C refrigerant in recirculating air conditioning units and outlines the engineering considerations, operational benefits and long-term prospects for sustainable cooling in data center environments.

As the world intensifies its efforts to mitigate the ongoing climate crisis, R454C refrigerant in recirculating air conditioning units has emerged as an effective way to help data center operators reduce their environmental impact. Offering lower global warming potential (GWP), improved energy efficiency and regulatory compliance with F-Gas Regulation 2024 / 573, R454C adoption also supports reliable operation and long-term sustainable cooling strategies.

Latest and greatest

First introduced in 2006, F-Gas Regulation 2024 / 573 is the latest version of the European Union (EU) law that controls fluorinated greenhouse gases (F-gases), such as hydrofluorocarbons (HFCs), which are used in refrigeration, air conditioning, heat pumps and aerosols. HFCs have a high GWP and F-Gas Regulation 2024 / 573 aims to reduce overall emissions by banning certain products, improving leak prevention and mandating proper recovery and recycling.

As part of their F-Gas Regulation 2024 / 573 compliance, data center operators must convert any air conditioning units in new installations to refrigerants with a GWP of less than 150 by 2027, otherwise they risk having their operating licence revoked. This can result in high costs due to corresponding penalties, while also having a negative impact on business development, as many customers only want to work with companies that can demonstrate a strong corporate social responsibility (CSR) strategy.



Meeting the challenge

Almost all available refrigerants with a GWP below 150 are classified as safety class A2L (low flammability) or A3 (high flammability), according to ISO 817. In environments such as data centers and server rooms, where high availability requirements and strict safety standards apply, any potential flammability hazard, however slight, must be prevented.

The solution to this dilemma lies in A2L refrigerant R454C. Classified under ASHRAE safety standards, A2L refrigerants are non-toxic, flame resistant, highly energy efficient and feature significantly reduced GWP. In fact, as a zeotropic mixture of R1234yf and R32, R454C has a GWP of only 148 and meets the requirements of F-Gas Regulation 2024 / 573, while at the same time offering a balance between thermodynamic efficiency and safety controllability.

When compared to A3 refrigerants, R454C requires significantly fewer structural and technical protective measures, which facilitates integration into existing systems. In addition, A2L refrigerants can only produce a flammable gas-air mixture at four times the concentration of refrigerant. With a maximum condensation temperature of 65 °C, R454C is ideal for the precise climate control of IT infrastructures and can be used in recirculating air conditioning units with a closed refrigeration circuit and an output of up to 50 kW until at least 2040.

Safety first

The safe operation of recirculating air conditioning units with R454C requires a holistic safety approach that considers the normative requirements outlined DIN EN 378. Gas detectors with a preset trigger value of 25 per cent lower explosive limit (LEL) for R454C, in accordance with EN378-3, are required for the early detection of refrigerant leaks. As such, sensors must be installed in locations where refrigerant can accumulate and a level of redundancy is also recommended as an additional safety measure.

Monitoring is important and integration into a building management system (BMS) allows centralized supervision and fast intervention if faults occur. When a leak is detected, an automatic safety shutdown immediately deactivates the system and this must include emergency logic that remains operational even during power outages or control system failures. A robust ventilation strategy is also required to ensure refrigerant concentrations in indoor air remain below the lower flammability limit (LFL). This includes forced ventilation with specified air change rates, optimized duct design and automatically triggered emergency ventilation in high-risk areas.

Although R454C offers extensive advantages over other commonly used refrigerants, it does have some technical limitations. Due to its lower volumetric cooling capacity compared to refrigerants such as R410A, slightly larger compressor volumes are required. In addition, both the refrigerant itself and the necessary components and safety systems are currently more expensive than conventional solutions. That said, the production process for these systems is very similar to that for devices with conventional refrigerants, which greatly simplifies production, allowing them to remain cost effective despite the slightly higher material costs.

Sealing the deal

An air conditioning unit using an A2L refrigerant must be permanently sealed. This requires the use of high quality, non-detachable pipe connections, a thorough pressure test and regular leak checks. Furthermore, all materials used must be approved for use with R454C to prevent corrosion and material deterioration.

To minimize the risk of fire, explosion proof electronic components should be used where possible and potential ignition sources should be shielded structurally. This can be achieved, for example, by extending the sealing of the electrical box or by limiting the maximum surface temperature of the electric heater. The surface temperature of the heater should always be 100 K lower than the ignition temperature of the refrigerant, while comprehensive equipotential bonding is required to prevent electrostatic discharges.

Regardless of room volume and safety measures, there are limits for the R454C filling quantity per cooling circuit. These limits depend on the category of the installation site and the type of access area:

Site categorie	I		II			III	IV
	a, b & c	^c (number of person < 1 / 10m ²)	a	b & c	^c (number of person < 1 / 10m ²)	all	all
Maximum R-454C filling quantity per circle regardless of room volume	~11 kg	50 kg	~11 kg	25 kg	unlimited	unlimited	~57 kg

Category of the installation site

- I - Mechanical equipment in areas where people are present
- II - Compressor in the machine room or outdoors
- III - Complete refrigeration machine in the machine room or outdoors
- IV - Ventilated enclosure

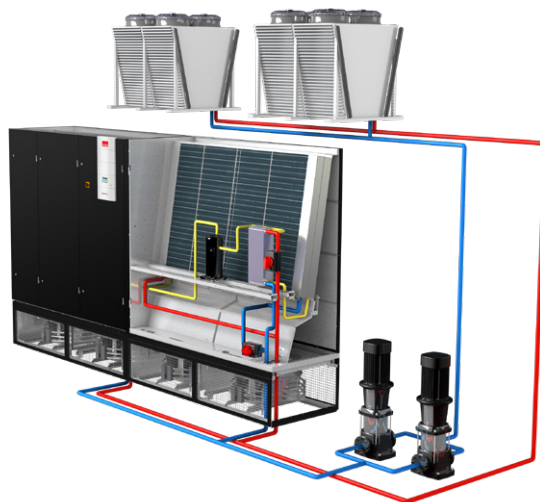
Type of access area

- a - General access area
- b - Monitored access area
- c - Access area for authorised personnel

Leading the way

In accordance with DIN EN 378, and as part of its commitment to ongoing research and development in sustainable air conditioning solutions, STULZ has already developed cutting edge closed refrigeration circuits for use in its CyberAir Mini DX and CyberAir 3PRO GE4 / GE4S series – both of which use R454C refrigerant. These innovative air conditioning units feature integrated gas detection, automatic safety shutdown, optimised airflow and a compact design with adapted compressor volume.

The refrigeration circuit deployed in these units is certified and tested to ensure permanent leakproof performance, while its optimized design prevents refrigerant accumulation. Additionally, two explosion proof gas sensors, installed in the housing and control cabinet, continuously monitor refrigerant levels and this data can be integrated into a BMS.



As soon as one of the sensors detects a gas concentration of 10 per cent of the LFL, the fan speed is increased to the maximum to distribute the refrigerant while, at the same time, all other components are switched off. In addition, an acoustic and visual alarm is triggered and forwarded to the BMS. If the gas concentration rises to 20 per cent of the LFL, the entire unit is automatically shut down.

To make planning easier, and in accordance with DIN EN 378, STULZ lists the minimum room volume required for operation without on-site personal protection measures in its data sheets for all CyberAir Mini DX and CyberAir 3PRO GE4 / GE4S units. The required room volume depends on the refrigerant charge. For example, the smallest CyberAir Mini DX GE unit (8 kW) requires a minimum room volume of 15 m³, while the largest CyberAir 3PRO GE4 unit (71 kW) requires 109 m³.

A step in the right direction

The aim of F-Gas Regulation 2024 / 573 is to tighten the phase down schedule for HFCs and promote the use of climate friendly and future proof A2L alternatives like R454C. Although some data centre operators will be concerned about switching to a refrigerant that is flammable, R454C-based air conditioning units like the CyberAir Mini DX and CyberAir 3PRO GE4 / GE4S series are designed to be as safe as conventional units that use non-flammable refrigerants. By supporting the use of R454C refrigerant, STULZ is continuing its mission to help data center operators strengthen their environmental credentials, and the company's air conditioning experts are always available to help to develop a customized migration strategy.

