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Samuele Da Ros, product manager of advanced refrigeration systems for EPTA Group examines the advantages of carbon dioxide and its use in modern systems

A commercial break for CO_2

IT IS ten years since EPTA began developing its CO_2-based systems, coinciding with the phase out of environmentally impacting refrigerants. At that time no transcritical equipment was available and the natural move was to start installing small cascade units to cool frozen food cabinets. They were derived (especially the compressors) from R404A units with the necessary modifications.

At present there are a number of options available to replace fluorocarbon refrigerants with CO_2. However, owing to its very high pressures (up to and above 100bar) different solutions have been developed to cope with different applications. There are currently four main options: two for high temperature applications and two for lower temperature applications.

In the first category are transcritical systems and pumped CO_2 systems, in the latter there are cascade and booster systems (only possible in combination with a transcritical system). In the HT systems, it has to be acknowledged that each of the above-mentioned systems carries both advantages and disadvantages.

High pressures

Due to the high working pressures and the thermodynamic properties of the refrigerant, transcritical systems mean higher capital costs.

In recent developments pressure regulations have been introduced to limit the pressure level into the liquid receiver and hence into the liquid runs. This is not the only piece of legislation in this instance, nor does any sort of standard apply to the set pressure level. The most likely value seems to converge toward 45bar which allows the use of copper pipework in most installations. All other systems need liquid lines made with steel. The higher complexity and costs of the compressor packs are traded off by lower total system installation costs.

The efficiency of transcritical CO_2 is not as good as R404A systems at higher ambients. On the other hand, transcritical CO_2 systems can be operated with extremely low condensing temperatures (these systems go transcritical only when the external temperature exceeds 20°C). As a result, seasonal efficiency in such countries as the UK, is comparable to that of HFC-based installations. In truth it is very likely a system installed in the UK will run subcritical more than 90% of the time.

Pumped CO_2 technology overcomes the constraints of cool climate conditions of the installation site to achieve high efficiency performances. CO_2 used as a secondary coolant requires very low pumping energy compared to the cooling capacity of the plant. Even if this technology enables a dramatic reduction of the total amount of HFC refrigerant in a store, it has to be said that the refrigerant flowing back from the cabinets has to be condensed before being pumped again to the sales area.

As a matter of fact, in most cases, this cooling effect is carried out by an HFC system (unless ammonia or hydrocarbons are used). In terms of operating costs this is a good solution because the losses related to the internal heat exchange (between CO_2 and the primary refrigerant) and to the pumps is offset by the increased efficiency of the flooded evaporators compared to the standard dry expansion ones.

CO_2 pumps and condensers are required but the pipework can be reduced and only basic cabinet controls are needed. Even for this technology there is not an established standard but most of the installations seem to be designed for maximum working pressure of 40bar and copper pipes.

Low temperature applications have proven to be the most successful for CO_2. Hundreds of cascade systems have been installed over the last few years and is seen as a fast growing niche market.

As pumped CO_2, cascade systems need a primary coolant, analysis of costs and benefits must include both the HT and the LT systems.

Experience from real installations shows efficiency can be improved by up to 10% and the carbon footprint of the store, measured through the TEWI index, can be lowered by up to 30%. Capital costs are comparable to a standard, all-HFC, installation. The complete plant has to be considered as, for instance, the HT pack capacity has to be increased to include the heat extraction rate needed to condense the CO_2 on the LT circuit.

Booster systems represent the latest development in the field of all-CO_2 systems. Previously, mainly cascade packs (in combination with a transcritical HT one) or double stage CO_2 compressors packs were used.

Discharge from low temperature compressors is directly connected to the suction line of the HT ones. There is a common liquid receiver and no need for internal heat exchangers as in cascade systems. The installation is made up of a unique circuit and some care has to be paid to oil management as well as the temperature at the HT compressor inlet. At present this arrangement provides the best option in terms of efficiency and capital cost optimisation of a complete CO_2 system.

Cascade and booster systems are typically designed for 25bar maximum operating pressure into the suction line and 40-45bar into the discharge line. Pipework is usually made with copper.

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