CO₂ HIGH TEMPERATURE HEAT PUMPS
SUSTAINABLE & EFFICIENT

THE REFRIGERATION MAGAZINE FROM ENGIE REFRIGERATION GMBH

REFLECT #01 2018
IMPULSE by ENGIE REFRIGERATION
An intelligent use of heat pumps makes it possible to raise the generation of cold and heat to new levels of efficiency for all kinds of applications.

In June 2018, ENGIE Refrigeration added heat pumps with CO₂ technology to the existing heat pumps in its portfolio. This natural refrigerant is powerful, especially climate-friendly and non-critical to use.
Heat pumps are an especially intelligent and sustainable way of generating heat out of energy from renewable sources. These machines are equally suitable for all kinds of commercial and industrial buildings and facilities, including swimming pools, for example. And heat pumps are more than just an energy-saving and environmentally friendly way of heating. Intelligent concepts make it possible to use just one system to provide heat in the winter and cooling in the summer. In the same way, it is possible to simultaneously generate heat and cold – for example, in offices and food storage spaces.

Exploiting unused potential

The fundamental principle of heat pumps is to absorb heat at low temperature levels and dispense it as useful heat at a higher temperature. Jörn Stiegelmeier, head of technology and development at ENGIE Refrigeration, explains the benefits of the technology: “A heat pump uses heat sources that are normally technically not usable. For instance, a heat pump can increase the temperature of geothermal energy from 10 °C to 40 °C. In addition to geothermal energy, it can utilise surface water and seasonal heat stores as heat sources. But a heat pump only lives up to its full potential in terms of performance and sustainability when it converts waste heat from industrial production, exhaust air from air-conditioning systems, or waste heat from chillers and has already been successfully used for this purpose by various industrial customers – often for combined heating and cooling.

In June 2018, our portfolio was expanded to include high-temperature heat pumps and drying technology with CO₂ technology. With the help of this natural refrigerant – whose technical name is R-744 – it is possible to achieve effective temperatures of up to 110 °C. This opens up applications in the fields of heating, heat provision in communal and industrial heating networks, and drying technology, for instance in automotive paint shops. The device series is on the market under the name of “thermeco₂”.

Standard heat pumps are usually inadequate for heating drinking water. When drinking water is heated, heat carrier temperatures of 60 to 70 °C need to be achieved in order to kill off legionella. These high temperatures are usually generated by means of an additional electrical heating element. However, this is not very energy-efficient, as electric power is used for the heating process. High-temperature heat pumps like the thermeco₂ can handle both the heating process and the heating of drinking water in full, so that no electrical additional heating is required. CO₂ stands out because it is harmless to use (classified as A1), cheap to procure, and, with a GWP of 1, has no harmful effects on the earth’s atmosphere (see Q&A). CO₂ (in subcritical mode) has become standard for use in refrigeration – for instance, in the cooling and storage of food. At higher temperatures (supercritical mode), it is possible to implement heat pump applications that are highly efficient in their respective temperature ranges. Supercritical applications are a relatively new field of application for CO₂ as a refrigerant. It can make a lot of sense to use CO₂. What is important is the expertise to identify applications where CO₂ is the perfect refrigerant, and applications for which it is less suitable,” says Stiegelmeier. “CO₂ is predestined for all applications that require colder temperatures and a lot of heat at the same time, such as an air-conditioned hotel with a swimming pool and sauna, for example.

New: CO₂ as a refrigerant

Chillers from ENGIE Refrigeration are especially known as highly efficient cooling generators. However, they are also excellently suited as heat pumps, and have already been successfully used for this purpose by various industrial customers – often for combined heating and cooling.

In June 2018, our portfolio was expanded to include high-temperature heat pumps and drying technology with CO₂ technology. With the help of this natural refrigerant – whose technical name is R-744 – it is possible to achieve effective temperatures of up to 110 °C. This opens up applications in the fields of heating, heat provision in communal and industrial heating networks, and drying technology, for instance in automotive paint shops. The device series is on the market under the name of “thermeco₂”.

Standard heat pumps are usually inadequate for heating drinking water. When drinking water is heated, heat carrier temperatures of 60 to 70 °C need to be achieved in order to kill off legionella. These high temperatures are usually generated by means of an additional electrical heating element. However, this is not very energy-efficient, as electric power is used for the heating process.

High-temperature heat pumps like the thermeco₂ can handle both the heating process and the heating of drinking water in full, so that no electrical additional heating is required. CO₂ stands out because it is harmless to use (classified as A1), cheap to procure, and, with a GWP of 1, has no harmful effects on the earth’s atmosphere (see Q&A). CO₂ (in subcritical mode) has become standard for use in refrigeration – for instance, in the cooling and storage of food. At higher temperatures (supercritical mode), it is possible to implement heat pump applications that are highly efficient in their respective temperature ranges. Supercritical applications are a relatively new field of application for CO₂ as a refrigerant. It can make a lot of sense to use CO₂. What is important is the expertise to identify applications where CO₂ is the perfect refrigerant, and applications for which it is less suitable,” says Stiegelmeier. “CO₂ is predestined for all applications that require colder temperatures and a lot of heat at the same time, such as an air-conditioned hotel with a swimming pool and sauna, for example.

Long-term trend towards natural refrigerants

In general, major changes are happening at the moment in the field of refrigerants: “Environmentally harmful HFC refrigerants are being replaced by HFO refrigerants, and increasingly by natural refrigerants as well,” says Stiegelmeier. “In the long term, a trend towards natural refrigerants seems likely, due to the F-gas Regulation, which is currently leading to restrictions on volumes of halogenated refrigerants.” Cold and heat pump technology is a key technology of the future. If we stop generating power from fossil fuels and instead generate it from renewable energy sources whose availability is permanently shifting, we will need storage facilities to provide load balance. Thermal storage can provide this load balance. CO₂ is a highly suitable refrigerant for efficient thermal energy storage. In case of excess power in the grid, hot and/or cold thermal energy storage units can be charged with a CO₂ heat pump and discharged again when power becomes scarce.

F-gas Regulation

The F-gas Regulation published by the European Parliament and European Council came into effect on 1 January 2015. Since that date, refrigerant filling capacities have been weighted according to their global warming potential. The F-gas Regulation is intended to reduce the volumes of fluorinated greenhouse gases (F-gases) put into circulation in the EU by 79% from 2015 levels down to 35 million tons of CO₂ equivalent by 2030. This objective is to be achieved by three measures in particular.

1. A step-by-step restriction of the F-gases available on the market; by 2030, they should be down to 21 per cent of the amounts generated in the reference years of 2013 to 2015 (phase-down scenario, see figure)

2. Prohibiting the sale of refrigerants with high GWP values

3. Extending existing regulations on leak tests, certification, disposal and labelling

In general, major changes are happening at the moment in the field of refrigerants: “Environmentally harmful HFC refrigerants are being replaced by HFO refrigerants, and increasingly by natural refrigerants as well,” says Stiegelmeier. “In the long term, a trend towards natural refrigerants seems likely, due to the F-gas Regulation, which is currently leading to restrictions on volumes of halogenated refrigerants.” Cold and heat pump technology is a key technology of the future. If we stop generating power from fossil fuels and instead generate it from renewable energy sources whose availability is permanently shifting, we will need storage facilities to provide load balance. Thermal storage can provide this load balance. CO₂ is a highly suitable refrigerant for efficient thermal energy storage. In case of excess power in the grid, hot and/or cold thermal energy storage units can be charged with a CO₂ heat pump and discharged again when power becomes scarce.
**GWP – global warming potential of refrigerants**

The GWP value (global warming potential) is a CO₂ equivalent that determines the relative greenhouse potential of a chemical compound. This measure describes the average warming effect on the earth’s atmosphere over a specific period (usually 100 years). It thereby specifies how much a defined mass of a specific greenhouse gas contributes towards global warming when compared to the same mass of CO₂. For example, the GWP for the refrigerant R-134a for a period of 100 years is 1430. This means that one kilogramme of R-134a will contribute 1430 times as strongly to the greenhouse effect within the first 100 years of being released as one kilogramme of CO₂.

There are other commonly used natural refrigerants apart from CO₂, for instance ammonia (NH₃) and propane. However, due to the dimensions of chillers and their correspondingly large refrigerant filling capacities, propane is a problematic and explosive substance when it comes to leaks and maintenance. It is suitable and manageable when used in chillers containing less than one gram of refrigerant, such as those used in supermarkets. “Consequently we have been working with ammonia and CO₂ for many years and developing chillers and heat pumps for these natural refrigerants,” says Stiegelmeier.

**AMONUM in container format**

Chillers with a natural refrigerant are not new territory for ENGIE Refrigeration: the AMONUM series was launched in 2013. The AMONUM stands out because it has a compact design for a new territory for ENGIE Refrigeration: the AMONUM series was launched in 2013. The AMONUM in container format

The experts at ENGIE Refrigeration are currently examining whether the market requires machines with an even higher performance. “Reasons of redundancy suggest that multiple powerful machines are a more sensible choice than one extremely large heat pump,” says Stiegelmeier. “Market and customer demands will determine the right path in future.”

**Know-how in the team**

The thermeco machines add high-temperature applications to the ENGIE Refrigeration portfolio. QUANTUM reaches approximately 55 °C; SPECTRUM with screw technology reaches approximately 60 °C; AMONUM with ammonia as a natural refrigerant reaches approximately 60 °C; and thermeco with CO₂ reaches approximately 110 °C.

The thermeco series machines that have already shipped around the world will be looked after by the international ENGIE Refrigeration service network. “Our entire organisation, from sales and consultation to service, is adjusting to the new portfolio,” says Jörn Stiegelmeier. “At ENGIE Refrigeration, we view ourselves as a team that takes care of all technologies and customers, using its extensive know-how.”

**What are the advantages of CO₂ as a refrigerant?**

- Future-proof: a natural substance, so no usage prohibitions or restrictions are to be expected.
- Very good availability
- Climate neutral and environmentally friendly
- No additional contribution to the greenhouse effect (GWP = 1)
- No contribution to the destruction of the ozone layer
- Non-toxic, non-flammable, thermally stable, suitable for materials
- Safety group A1
- Low running costs when compared to other natural refrigerants

**Why is CO₂ non-harmful as a refrigerant even though it is such a big problem as exhaust gas from combustion engines?**

- CO₂ refrigerant operates in a cycle process and is not released or emitted as it would be during a combustion process. It can only escape in the form of a leak. Leaks of a refrigerant with a GWP value of 1 are non-critical.
- No environmentally harmful contribution to the overall CO₂ balance: all the CO₂ involved existed beforehand; no newly generated CO₂ is released.
- CO₂ refrigerant is a by-product generated by plants, contrary to the chemicals industry.

**What are the technical challenges posed by systems that use CO₂ as their refrigerant?**

- High efficiency during supercritical operation in the interior heat exchanger
- Greater control required during supercritical operation
- For maximum efficiency, the required temperature regime needs to match the way the CO₂ heat pump is operated.
- Pressurisation up to 120 bar calls for suitable pipe dimensions, but is easily manageable in technical terms. In vehicle manufacturing, for example, much higher pressures of up to 2,000 bar are customary for common rail injectors.

**CO₂ heat pumps for SWR**

The buildings of the Südwestrundfunk (SWR) broadcaster in Baden-Baden require a lot of energy to run. Until 2012, SWR generated its own cold and heat centrally with a water-cooled liquid cooler and large boilers. In order to improve the efficiency of the systems, the SWR technology department decided to find a new, efficient and ecological solution to cover the basic heating load. Engineers achieved their aim with the help of a CO₂ high-temperature heat pump from the thermeco, series, which became part of the ENGIE Refrigeration portfolio in mid-2018.

The HHR 360 high-temperature heat pump combines the generation of heat and cold. For the SWR building, it generates thermal heat of 40/80 °C in parallel to the new large boilers and uses the waste heat directly from the network of chilled water for climate application to do so. In addition, the HHR 360 reduces waste heat losses from refrigeration and relieves the existing chillers and recovers. SWR chose a heat pump with an eco-friendly refrigerant because its use will not be restricted in future, e.g. by the F-gas Regulation. In addition, the new heat pump lowers CO₂ emissions when compared to a heating system based only on fossil fuels.

By running the CO₂ heat pump, SWR has lowered heating costs by a third. In addition to the annual heating capacity of the heat pump, the cooling capacity and avoided re-cooling work also flow into the efficiency analysis. Because of these positive results, SWR ordered another HHR 520 thermeco, High-temperature heat pump in September 2013 to supply a different part of the building with heat and cold.

**Reference**