LYOAIR®

A Natural Gas Combination for Improved Freeze Dryer Cooling.

Engineering for a better world.

GEA.com

THE EARTH IS GETTING HOTTER!

By 2050, we'll need 350% more refrigeration capacity than we do today, making how we think about cooling technology increasingly important.

Natural refrigerants could contribute to a better future and GEA has the equipment and expertise to capitalize on this growing trend.

INDUSTRIAL FREEZE DRYING.

Freeze drying is a dehydration process that's typically used to preserve a perishable material or make the material more convenient for transport or storage.

In the past, industrial refrigerants were improved to avoid ozone depletion, but they still have a high potential to contribute to global warming (thousands of times greater than carbon dioxide [CO_2]). At the end of the 1980s, for example, environmental pressure and regulation resulted in a ban being placed on any refrigerants with an ozone depletion effect (ODP). As such, the replacement of CFC (chlorofluorocarbon) and HCFC (hydrochlorofluorocarbon) refrigerants by hydrofluorocarbon (HFC) and PFC (fluorocarbon) alternatives is more or less completed and state-of-the-art. Now, climate change is the driving force.

To control emissions from fluorinated greenhouse gases (F-gases), including HFCs, the European Union has adopted two legislative acts: the F-gas Regulation and the MAC Directive. The F-gas Regulations came into force on 1 January 2015. These regulations are concerned with the phase down of F-gases and preventing their release into the atmosphere. More specifically, one of the objectives of the EU legislation is to cut greenhouse gas emissions by 80–95% of 1990 levels by 2050.

In 2018, the first major reduction step of 37% of the CO_2 equivalent came into force. That means that a distributor can only sell refrigerants with a CO_2 equivalent of 63% of 2014 levels. And, as of January 2020, the use of refrigerants with a global warming potential (GWP) of ≥2500 to service or maintain refrigeration equipment (charge size ≥40 t CO_2-equivalent) — except for machinery running at temperatures of less than –50 °C — will be prohibited. This, of course, has a profound effect on the design, production and operation of industrial freeze dryers.

Industrial Freeze Drying

From its earliest applications in the stabilization of blood plasma, freeze drying has been in use in the life science industries for more than 50 years. During this period, the freeze dryer — or lyophilizer — has evolved from a simple device for vacuum drying at low temperature to an extremely sophisticated integrated system that combines a number of processes to ensure that a product is consistently delivered to technical and biological specifications while also considering economic, safety and environmental issues.

Freeze drying is a dehydration process that's typically used to preserve a perishable material or make the material more convenient for transport or storage. Freeze drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase. The use of refrigerants is fundamental to the entire procedure.

GEA offers a variety of options for the implementation of a freeze dryer refrigeration system, either mechanical or cryogenic, which can be specifically adapted to individual process and product requirements. The two main considerations when selecting a suitable refrigeration solution are refrigeration temperature and cooling capacity.

Currently, GEA refrigeration units can operate with either natural or synthetic refrigerants, depending on process and product needs. However, as conventional synthetic refrigerants are becoming less common and increasingly more restrictive laws prohibit the use of chemicals with a high GWP (according to the Montreal and Kyoto Protocols), investing in a compressor cascade that use natural refrigerants will become increasingly pragmatic.

Compared with single-stage applications, different refrigerants are used in a cascade (multi-stage thermodynamic cycle) cooling system in two distinct and separate refrigerating circuits. Given that the availability of currently used refrigerants is already running low and may well have disappeared from the market in 2030, significant changes are afoot for the pharmaceutical freeze-drying sector. For low temperature applications (below –50 °C), it's still acceptable to use HFC refrigerants; but, every year, sourcing them becomes increasingly difficult and the price continues to rise. Soon, it will become impossible to obtain like-for-like replacements for low temperature (below –70 °C) refrigerants.

SEEKING ALTERNATIVES.

In the last few years, GEA has been looking for alternative low temperature cooling solutions that use natural refrigerants.

One of the few usable compounds is ethane (C2H6). Owing to its very low boiling point (–88.5 °C), ethane — like the HFC R23 — is compatible with cascade cooling systems. In an indirect silicone oil-cooled ice condenser, for example, temperatures of less –80 °C can be achieved.

There is a downside; some natural refrigerants, including ethane, are explosive and need to be handled correctly. However, companies such as GEA have the experience and expertise to make these systems as safe as possible. To ensure the protection of both product and operator, GEA incorporates a containment facility around every cascade working with explosive refrigerants — including all the required safety measures to ensure that such a system is ready for the use in a standard pharmaceutical environment. The system can be operated without special ATEX-equipment and installed in a non-ATEX equipped room. The first systems were delivered to customers as early as 2015 and have demonstrated high levels of throughput and reliability.

A Mirai air cycling unit.

THE GEA SOLUTION.

In 2019, MIRAI INTEX, a company that specializes in the design and production of turbo compression equipment, introduced a new Air Cycle Technology machine. The technology is based on the heating capability of air during compression and subsequent cooling during the expansion process. Repeating the compression and expansion cycles allows users to reach and maintain ultra-low temperatures down to –160 °C.

Despite being a well-established technology — the first air cycle machines were developed in the 19th century and the process is known as the reverse Brayton or Bell Coleman cycle — because this thermodynamic cycle is based on the compression and expansion of a constant air volume, the fundamental method of operation — unlike all other cooling systems — is no not based on evaporation or phase change.

Air cycle systems do, however, confer certain advantages: by using air as a refrigerant, it is environmentally neutral; air cycle equipment is extremely reliable and durable, which helps to reduce maintenance costs and ensures a long lifecycle with no loss of performance (unlike vapor compression equipment).

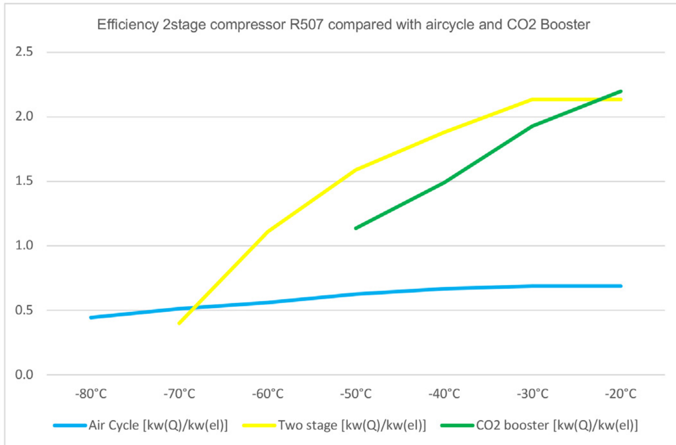
Furthermore, as the compressor makes use of the energy generated by the electric motor and the expander, the unit is highly efficient and able to generate the low temperatures required to operate a freeze-drying condenser can be achieved with ease. And, as the air cycle process is not based on evaporation, the temperature-to-power use gradient is relatively linear (Figure 1).

When comparing relative refrigerating capacity efficiencies with a conventional compressor, for example, the graphs only show similar profiles at temperatures below -70 °C. For lyophilization applications, this is significant: to freeze product in a specific temperature range — 20 °C to –45 °C — the highest possible refrigerating capacities are required.

One way to compensate for the reduced cooling capacity of the air cycle process at higher temperatures is the use of storage tanks with pre-cooled silicone oil. Given that the air cycle machines run non-stop and continuously refill the reservoirs, the replenished cold oil can then be used as required — even at higher cooling capacities. Unfortunately, however, this cooling capacity requires up to three times more energy, even without considering storage losses.

To overcome these shortfalls, GEA has now developed an innovative air cycle system for freeze dryers that also incorporates CO_2 cooling. GEA CO_2 booster systems can reach temperatures down to –50 °C and are suitable for a wide range of product freezing applications. The cooling system uses natural refrigerants and has a GWP of 1 (equivalent to CO_2). The corresponding air cycle cooler, for optimal energy utilization, is used to chill the condenser and as a booster during the freezing process. Although having a slightly higher energy consumption requirement compared with high GWP refrigerants, no silicone oil storage is needed.

A contained ethane/propane cascade cooling system.



(Figure 1). Energy use versus temperature.

SUMMARY

The GEA cooling system employs natural refrigerants that comply with the 2015 F-gas regulation and benefits from the integration of highly efficient and economic GEA compressors. The combination of an air cycle system with a CO_2 booster offers a not negligible lower energy consumption for freeze dryers compared with a regular air cycle system. Notable benefits also include the elimination of explosive or toxic natural gases and no GWP.

In Closing

Worldwide, 15% of all electricity is used for refrigeration and air conditioning; therefore, the way we handle cooling will become increasingly important in the years to come. GEA has the equipment and expertise to deliver the best engineered solution for any industrial cooling process. We all have a vested interest in improving our world and GEA firmly believes the use of natural refrigerants is an important part of achieving this goal.

Below, an integrated GEA CO_2 booster system ensures that the lyophilizer shelves are cooled to the correct temperature (–50 °C).

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