

We are Refolution, the engineering company for sustainable industrial refrigeration. We offer consulting, planning and product development in our core competences refrigeration, process engineering and special plant engineering.

Our vision is that in the near future every refrigeration task will be solved with natural refrigerants only. In combination with innovative technology, the systems will be more efficient, more durable and more environmentally friendly than the industry standard.

Customer needs are the top priority in our new developments.

We analyze complex tasks, processes and then develop a tailor-made solution for our end customer. Our main focus is on energy efficiency, functionality, safety and economy.

### **Our published product developments:**

#### **Ultra low temperature rooms:**



Abbildung 1 Schleuse der ULT-Anlage



Abbildung 2 Lagerraum der ULT-Anlage

For Wasserburger Arzneimittelwerk GmbH (Recipharm) we realized a turnkey cryogenic storage system in October 2021. In 5 months after initial contact we, as planner and project manager, achieved the acceptance. The warehouse consists of two storage rooms, each with 187 m<sup>3</sup> and 85m<sup>2</sup> storage area, and an active cooled sluice, which reduces the heat input into the chambers. Each room is cooled by a total of 3 (n+1 redundancy) Mirai Intex MC10 O/W machines using air as refrigerant. The technology used allows the chambers to be continuously tempered between -90 °C and -20 °C, with a control accuracy of +/- 0.5 K and a temperature homogeneity of less than 1 Kelvin.

The airlock is tempered to -20 °C with the help of a cold brine set from Secon. The cooling water systems are self-sufficient via two redundant R290 chillers. Thus, the plant operates purely with natural refrigerants and is the most efficient, safest and environmentally friendly solution on the market at operating temperatures of -80 °C.



**ULT-Container:**



*Abbildung 3 ULT-Container der Firma KTI*

The CSC certified 40" container consists of two insulated cold rooms and a machine compartment. The ULT storage is enclosed with an air shield to increase the efficiency and insulating effect (box-in Box). The airlock is tempered to -20 °C by a water-cooled subcritical CO<sub>2</sub> refrigeration system with ceiling air cooler. Two additional radial blowers installed in the airlock distribute the cooled air in the intermediate walls and the intermediate ceiling. The cold air chiller from Mirai Intex is used to cool the storage room to temperatures ranging from -30 °C to -110 °C. Thanks to the speed-controlled oil-free compressor-expander unit, this machine has a high control accuracy over the entire temperature range. A chilled water ceiling air cooler is used for temperature control of the machine compartment. This means that only a cold water supply and power supply need to be provided for operation.

This solution can be rented or purchased.

### Coldtruck:



Abbildung 4 Zum Kältetruck umfunktionierter LKW

In our current project, we are installing a cold storage room with cold air refrigeration technology in a 40-ton tractor-trailer. This allows vaccines or other temperature-sensitive materials to be transported over long distances. It is fail-safe with two redundant diesel units and can also be used flexibly with the tractor unit connected for stationary use. The first truck was completed in March 2022.

### Storagroom Teledoor



Abbildung 5 transportabler Tieftemperaturlagerraum

For the preservation of sensitive substances such as drugs, enzymes, hormones, biomaterials and intermediates, low temperatures are required for storage. Together with our partner companies Teledoor, Mirai Intex and Secon we have developed a standardized storage room with cold air refrigeration technology. This can keep any temperature stable from  $-40^{\circ}\text{C}$  to  $-90^{\circ}\text{C}$ , is transportable, efficient, safe and environmentally friendly. This will be available from the end of 2020.

## Pharmazeutische Prozesse:

Gefriertrocknung:



Abbildung 6 Gefriertrockner "CryoBlizzard" der Firma HOF Sonderanlagenbau GmbH

A large proportion of medicines worldwide are freeze-dried for shelf life and certain product properties. With this process, also known as lyophilization, different temperatures of mostly  $-40^{\circ}\text{C}$  and  $-80^{\circ}\text{C}$  are required. We have developed a new process for this temperature generation for HOF Sonderanlagenbau GmbH and GEA, which can master this task much more fail-safe and efficiently using only air as refrigerant. The first plant went into operation in 2019.



Abbildung 7 HOF Freeze-Thaw-Unit (FTU), Einfriergerät für Beutelsysteme

Plasma freezers are used for rapid cooling to low temperatures of up to  $-70^{\circ}\text{C}$  of blood plasma to preserve certain substances for further processing. With Firma HOF, we upgraded the process so that the plant runs on air as a refrigerant. The first plant went into operation in 2020.



Gasreinigung / Teilkondensation:



*Abbildung 8 Schema der Lösungsmittelverflüssigungs-  
anlage*

For a customer in the pharmaceutical sector, we have developed a new process for recycling environmentally harmful solvents from exhaust gas. Exhaust gas limits are regulated in Germany by the TA-Luft. With our process, the customer is able to recover 99% of the solvent and reuse it in his process. The first plant went into operation in March 2021.

Kältesauna COOLINN:



Abbildung 9 Eingang zur Kältesauna des COOLINNs

The healing effect of short physical stimuli has been known for generations. Cryotherapy is successfully used in many areas such as regeneration, pain therapy and in the therapy of mental illnesses. We have developed a cold sauna that can generate  $-115^{\circ}\text{C}$  using only air, thus providing a unique experience for the user due to its even temperature distribution, high dryness and real temperatures. It is also the most efficient, safe and environmentally friendly cold sauna. The first cold sauna was put into operation in October 2019.

#### **Material processing :**

In addition to pharmaceutical, medical or logistical applications, cryogenic temperatures are also required for material processing. This is particularly the case in the processing of plastics, such as cold deburring and cryogenic grinding. But metals can also be hardened at very low temperatures using refrigeration technology. We are currently developing new processes for material processing with cold air refrigeration technology.

#### **Job Report:**

##### **Refolution of the freeze dryer with the help of cold air technology**

Current refrigeration technologies are regulated worldwide (e.g. Kigali Protocol) due to the use of environmentally harmful refrigerants. In Europe this is mainly the F-Gas regulation.

Our partner HOF Sonderanlagenbau GmbH is a renowned company in the field of pharmaceutical freeze dryers and freezers. Together with them we have developed a new process for freeze drying to replace conventional with sustainable refrigeration technology and to make the whole process future-proof. A process and equipment analysis crystallized clues for optimizing the refrigeration technology. Freeze-drying or lyophilization is a process that

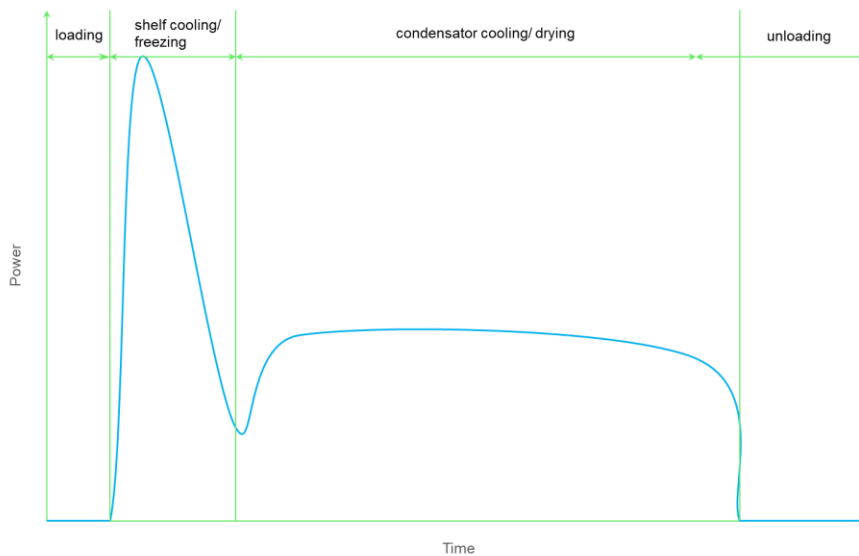


Abbildung 10 Prozesskette beim Gefriertrocknen

Batch process and thus has several steps with different requirements on the refrigeration technology. Figure 6 "Process chain in freeze drying" illustrates the individual steps and their required performance in freeze drying.

The process steps of loading and unloading the freeze dryer do not require any refrigeration applications in the current state of the art. Therefore, the focus is placed on the further steps.

In the second step of freeze drying, the freezing process,  $-40^{\circ}\text{C}$  is required in a short time. This results in a power peak that is very high compared to the rest of the process. The "drying" process step is carried out at lower temperatures and for a longer duration. In total, this process requires significantly more energy than freezing. We have therefore focused on the drying process when optimizing the refrigeration technology. In diagram 1, "Energy consumption per

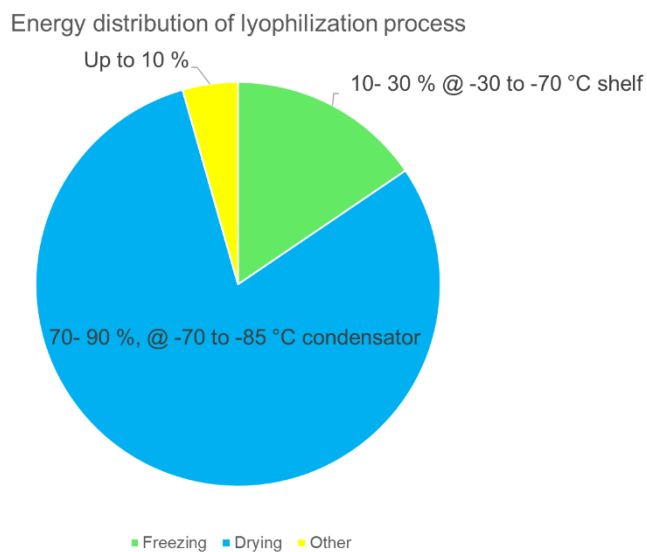


Diagramm 1 Energieaufwand je Prozessschritt

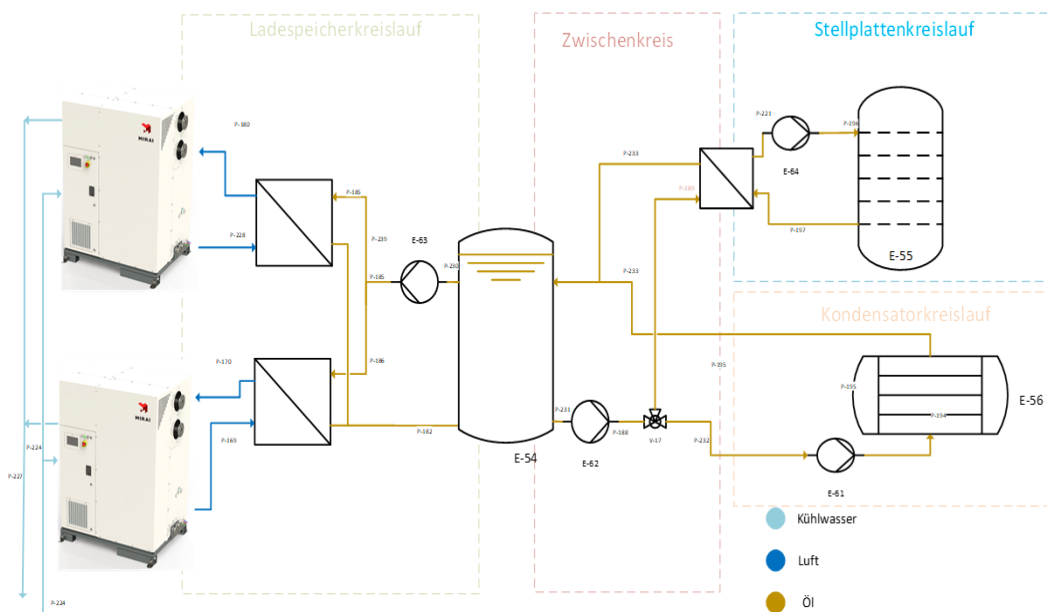




process step", it becomes clear why this process step is crucial for the energy efficiency of the plant.

The existing refrigeration solution focused on the power peak at the start of the freezing process, which accounts for only 10 - 30% of the energy consumption. Conversely, this means that the existing refrigeration solutions are run in partial load mode during the drying process, which is inefficient for most refrigeration solutions.

The initial power peak and a homogeneous temperature distribution on the actuating plates is realized by using a charging accumulator, which can be seen in Figure 8 "Simplified process diagram HOF Sonderanlagenbau freeze dryer". During the loading process of the freeze dryer, the cold air chillers charge the load accumulator with cryogenic silicone oil, which can be used to absorb the power peak at the start of the drying process. This also eliminates the load peaks in electricity and cooling water consumption.





## GEA Lyophilisation

In cooperation with the company GEA, we have developed another concept for freeze drying. GEA approached us with the specific customer request of reduced oil management and more energy efficient freezing. We designed a process in which we combined an industry standard CO<sub>2</sub> refrigeration system with cold air technology. The CO<sub>2</sub> system supplies the freeze dryer plates (-40°C to -60°C) and the cold air technology supplies the ice condenser (-80°C).

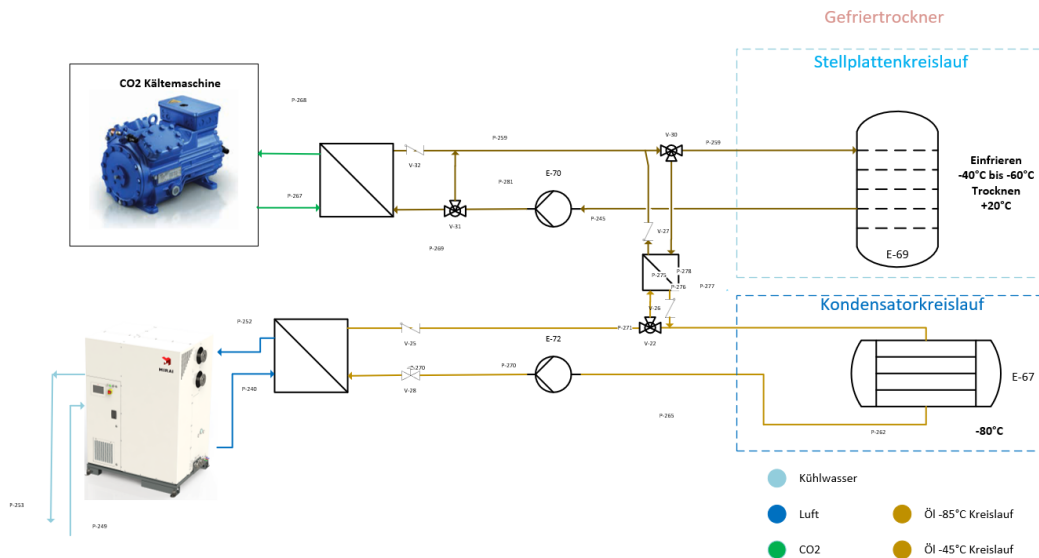


Abbildung 12 Vereinfachtes Anlagenschaubild GEA Lyophilisation Gefriertrockner