

Future of Refrigeration Technology in Freeze Drying

Martin Christ Gefriertrocknungsanlagen GmbH

H. Spütz

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Agenda

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 3. Natural refrigerants
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 2. Refrigeration with flammable refrigerants

1. Refrigerant regulation







1.1 Global warming potential (GWP)

- GWP is an index to measure the impact of fluids on the global warming
- CO₂ is defined as reference material to rate different fluids (GWP = 1)
- Hydrofluorocarbons (HFCs) conventionally are used for low temperature refrigeration
- HFCs have a high GWP
 - R-410A → GWP = 2088
 - Isceon 89 → GWP = 3805
- Alle over the world governments decided to minimize greenhouse gas emissions
- Increasing regulations e.g. EU F-gas regulation

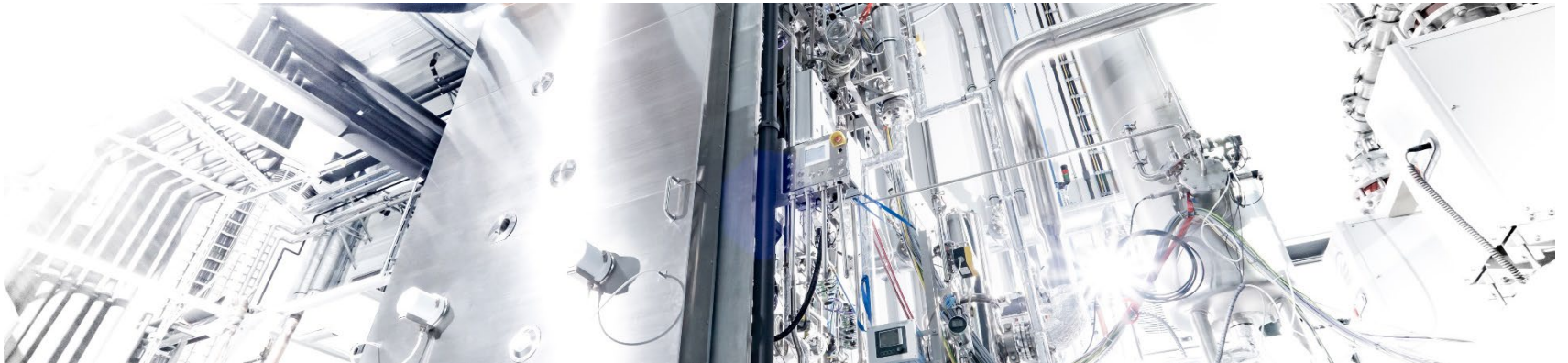
1.2 Conventional refrigerant: R-410A

- Well-established refrigerant in low temperature refrigeration and heat-pumps
- Until 2024 → exceptional EU-regulation for temperatures $< -50^{\circ}\text{C}$
- In 2030 → R-410A is not allowed in new refrigeration systems with direct evaporation
- In 2032 → R-410A will be prohibited for maintenance
 - Exception for refrigeration systems with temperature $< -50^{\circ}\text{C}$
 - Use of recycled refrigerant is still possible
 - Many manufacturers
- R-410A will be available for maintenance after 2032
 - Rising costs are expected

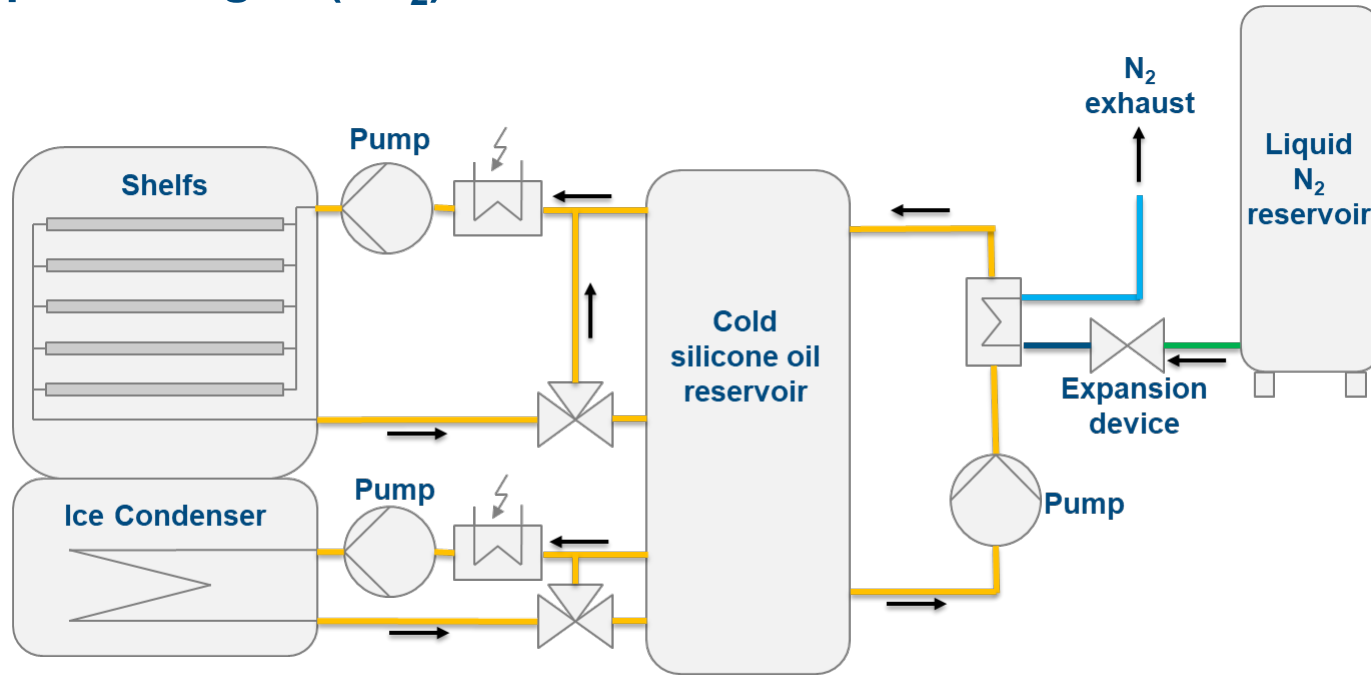
1.3 Natural refrigerants

	Pros	Cons	
Hydrocarbons (Propylene, Ethane, Ethylene)	<ul style="list-style-type: none"> + Well established technology + Moderate investment costs + Moderate operational costs + Moderate footprint 	<ul style="list-style-type: none"> - High safety precautions - Flammable refrigerant (A3) 	
Liquid Nitrogen (LN ₂)	<ul style="list-style-type: none"> + Well established technology + Low maintenance costs + Fast cooling rates possible + No flammability 	<ul style="list-style-type: none"> - High investment costs - High operational costs - Large Footprint 	
Air	<ul style="list-style-type: none"> + Moderate operational costs + Low maintenance + No flammability + No refrigerant necessary 	<ul style="list-style-type: none"> - High investment costs - Large Footprint 	
Air / CO ₂	<ul style="list-style-type: none"> + Moderate operational costs + No flammability + High efficiency 	<ul style="list-style-type: none"> - High investment costs - Large Footprint 	

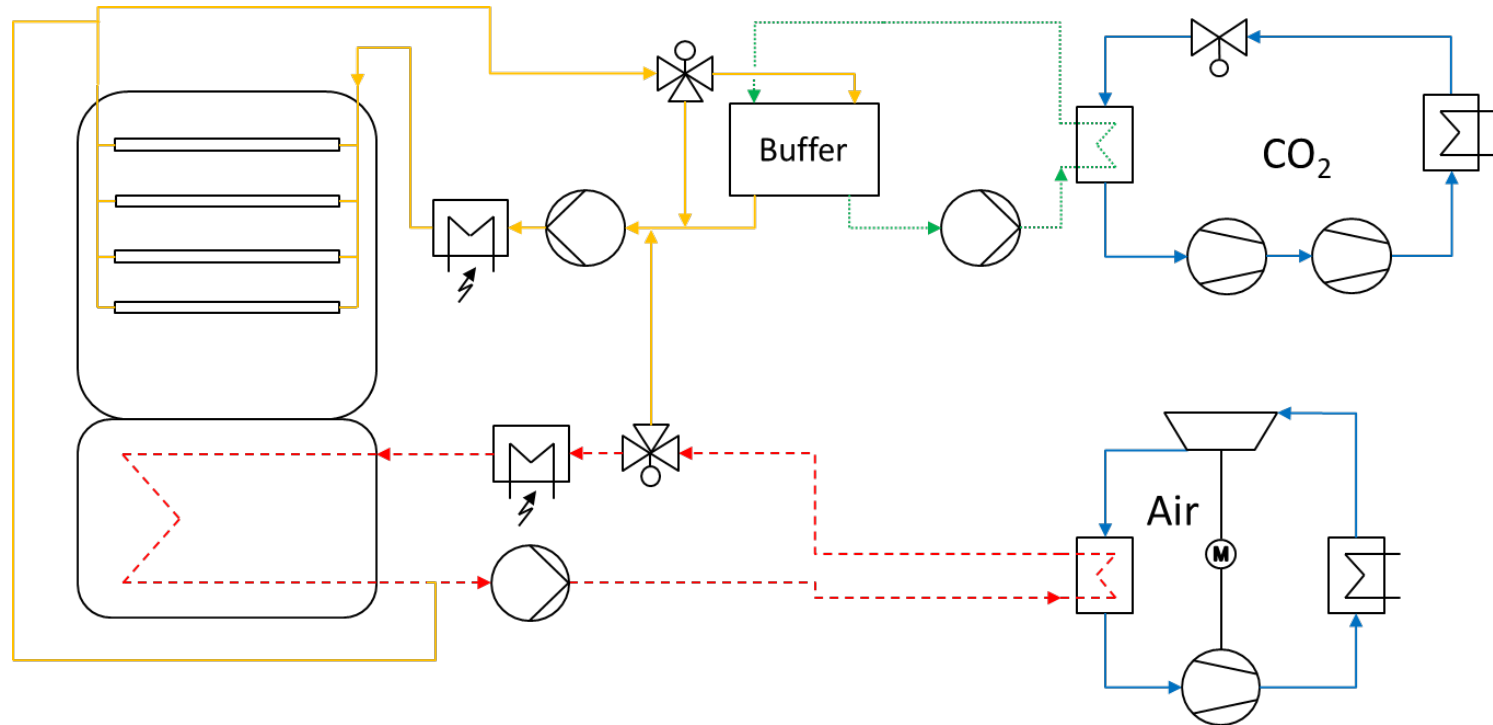
2. Available Christ solutions



2.1 Liquid nitrogen (LN₂)



2.2 Air-CO₂ system



2.2 Air-CO₂ system

- Two staged compression
- High cooling capacity
- Limited evaporation temperature
- Quite operation
- High pressure levels



2.2 Air-CO₂ system

- No condensation and evaporation
- No refrigerant must be filled
- Very low temperatures (< -100°C)
- Quite operation
- Low maintenance efforts



Source: Mirai Intex

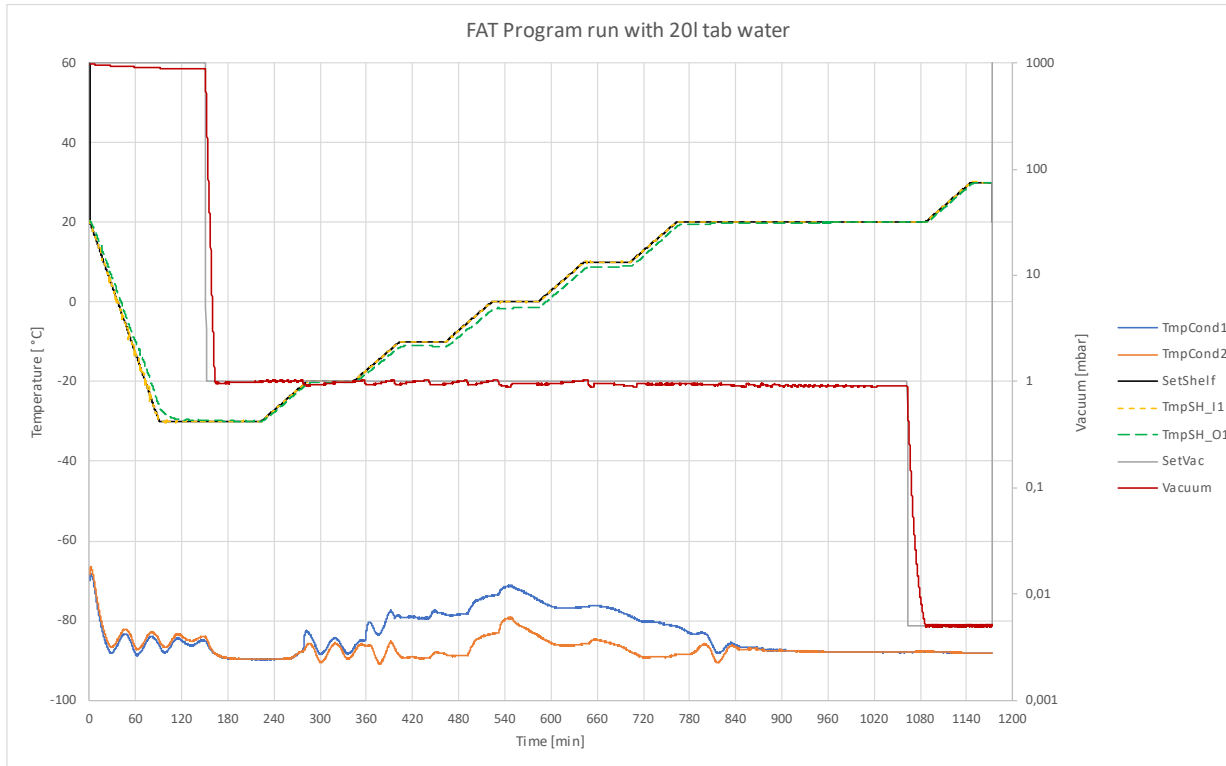


Source: <https://mirai-intex.com/de/products/mirai-cold-10-t/p5>

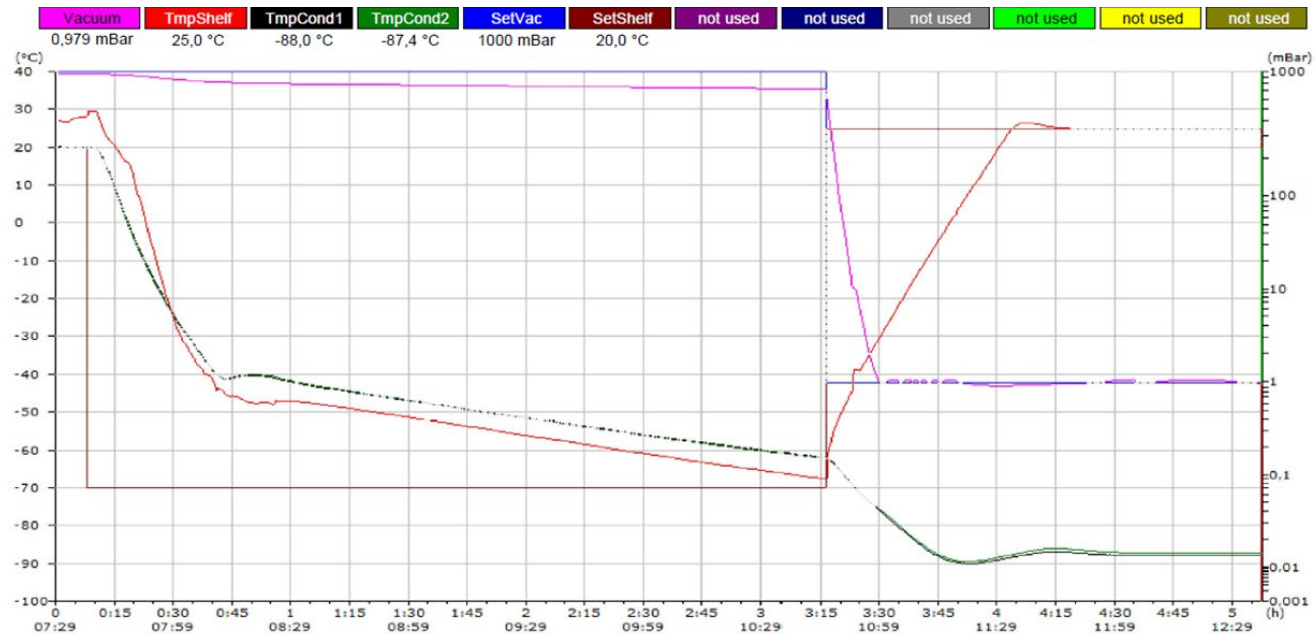
2.2 Air-CO₂ system



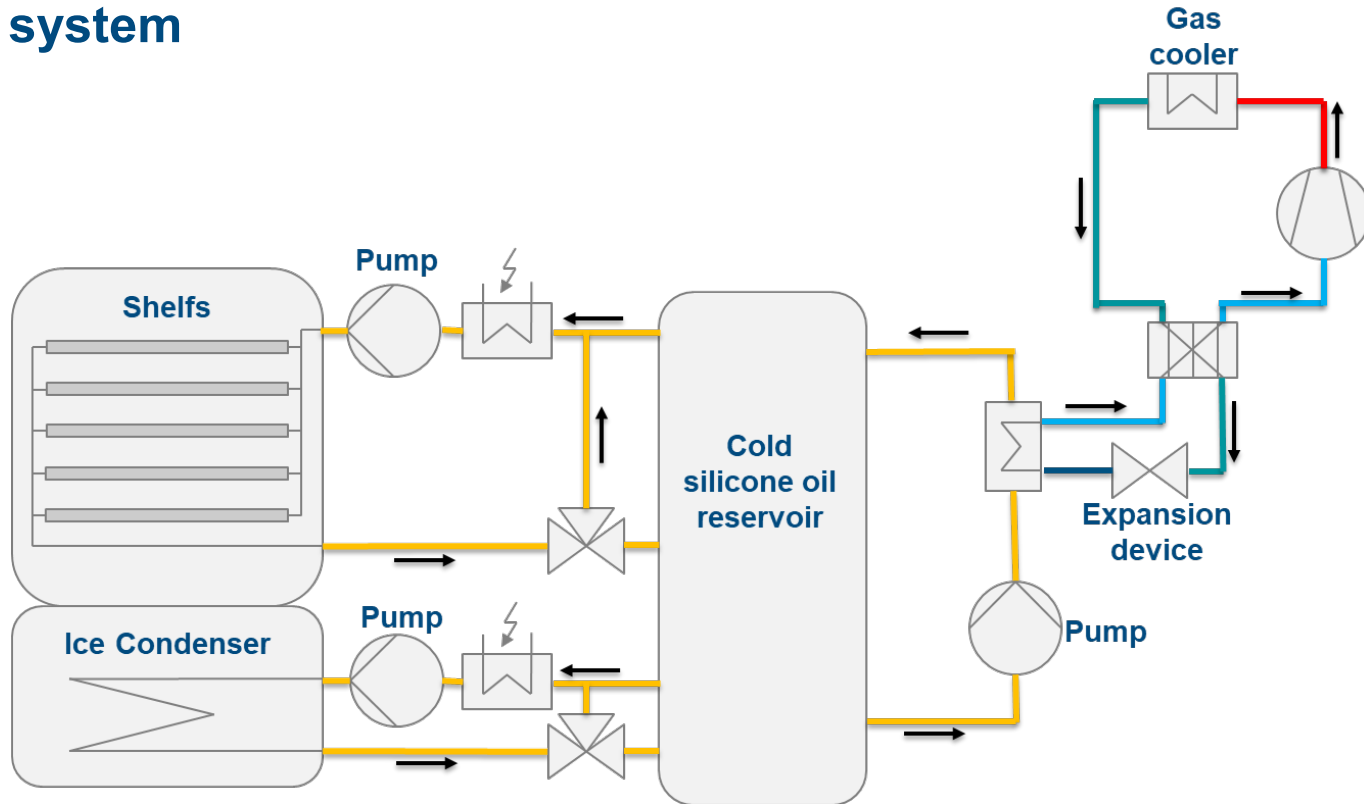
2.2 Air-CO₂ system



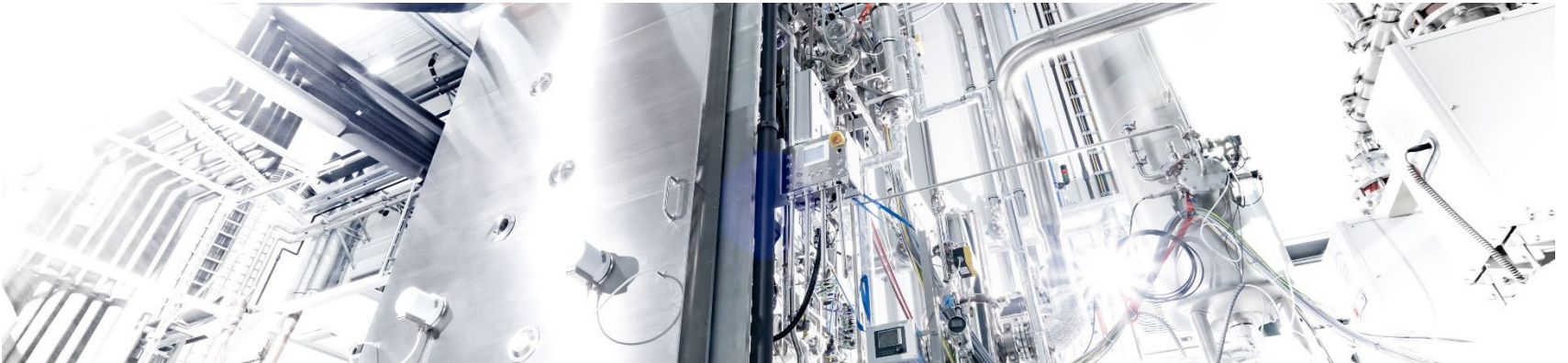
2.2 Air-CO₂ system



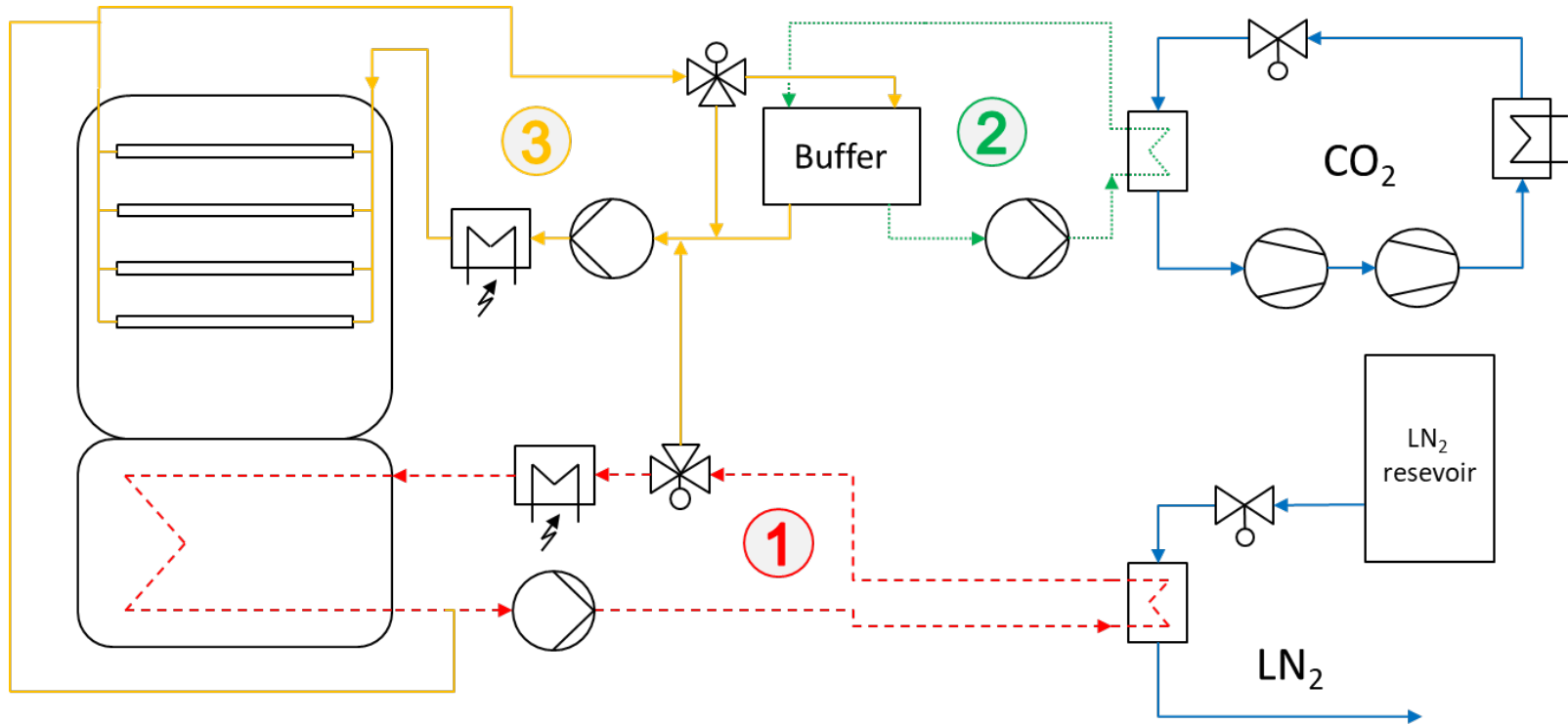
2.2 Air system



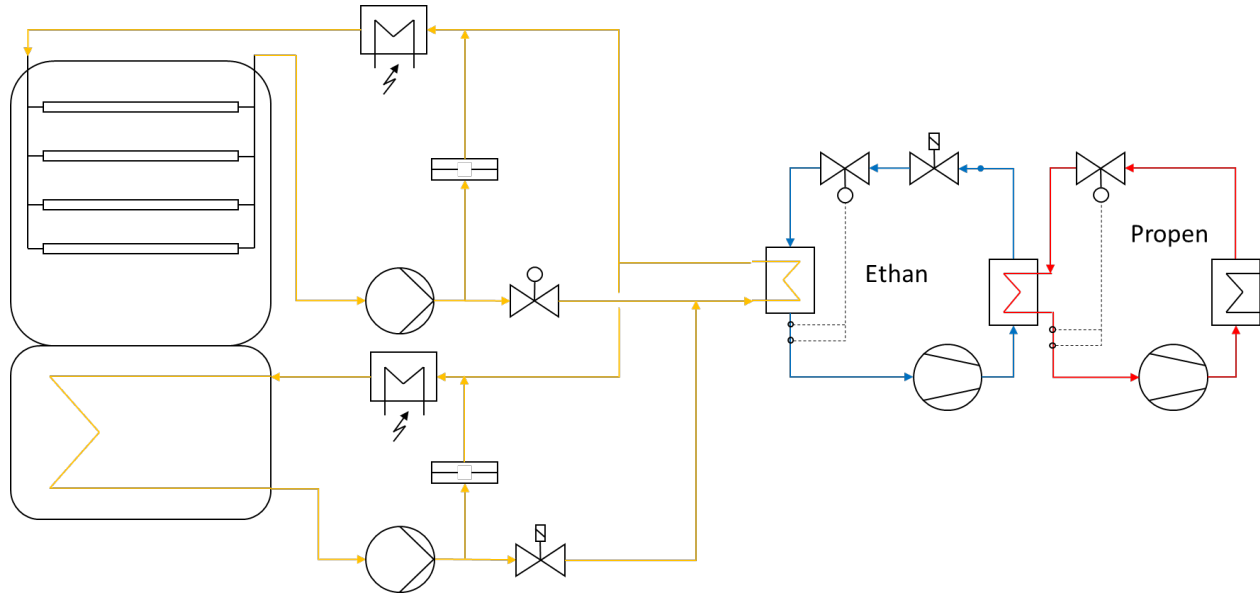
3. Solutions under development



3.1 LN₂-CO₂ system



3.1 Refrigeration with flammable refrigerants



Thank you for your attention