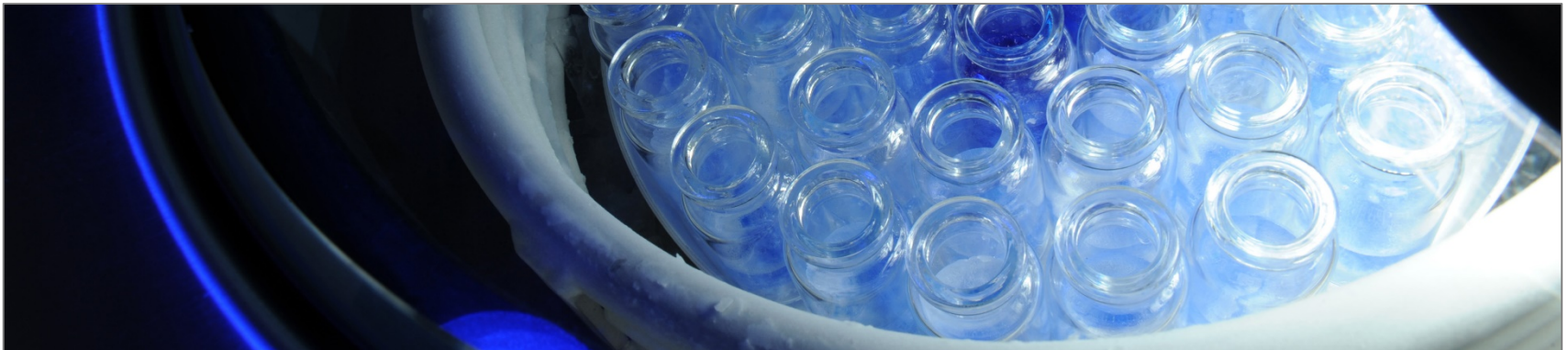


# Refrigeration in freeze dryers

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## Content

- Requirements for the cooling system
- Types of cooling systems in freeze dryers
  - One stage
  - Two stage cascade
  - Two stage compression
  - LN<sub>2</sub> expansion
  - Air cycle refrigeration
- Future refrigeration technology in freeze dryers

# Requirements for the cooling system

## Laboratory freeze dryers

- Ice condenser cooling

### Shelves

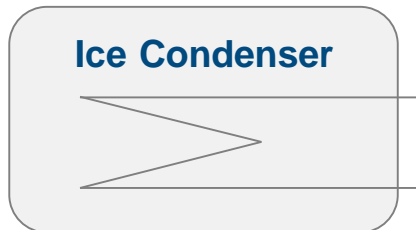
-55...+60°C

- Heating
- Cooling

### Ice Condenser

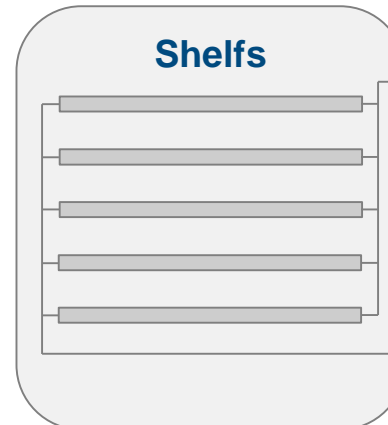
- 55...-85°C

- Cooling

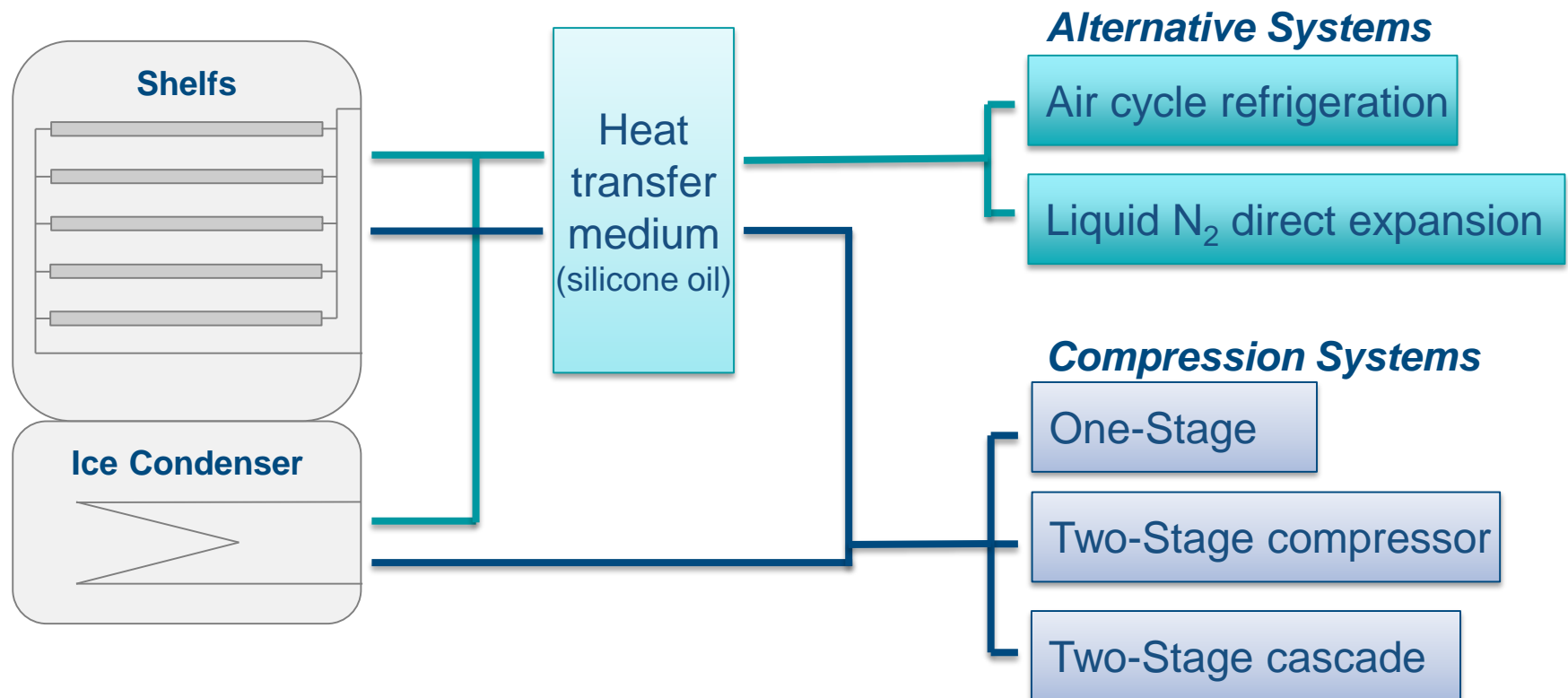


## Pilot- and Production freeze dryers

- Ice condenser cooling
- Shelf cooling and heating

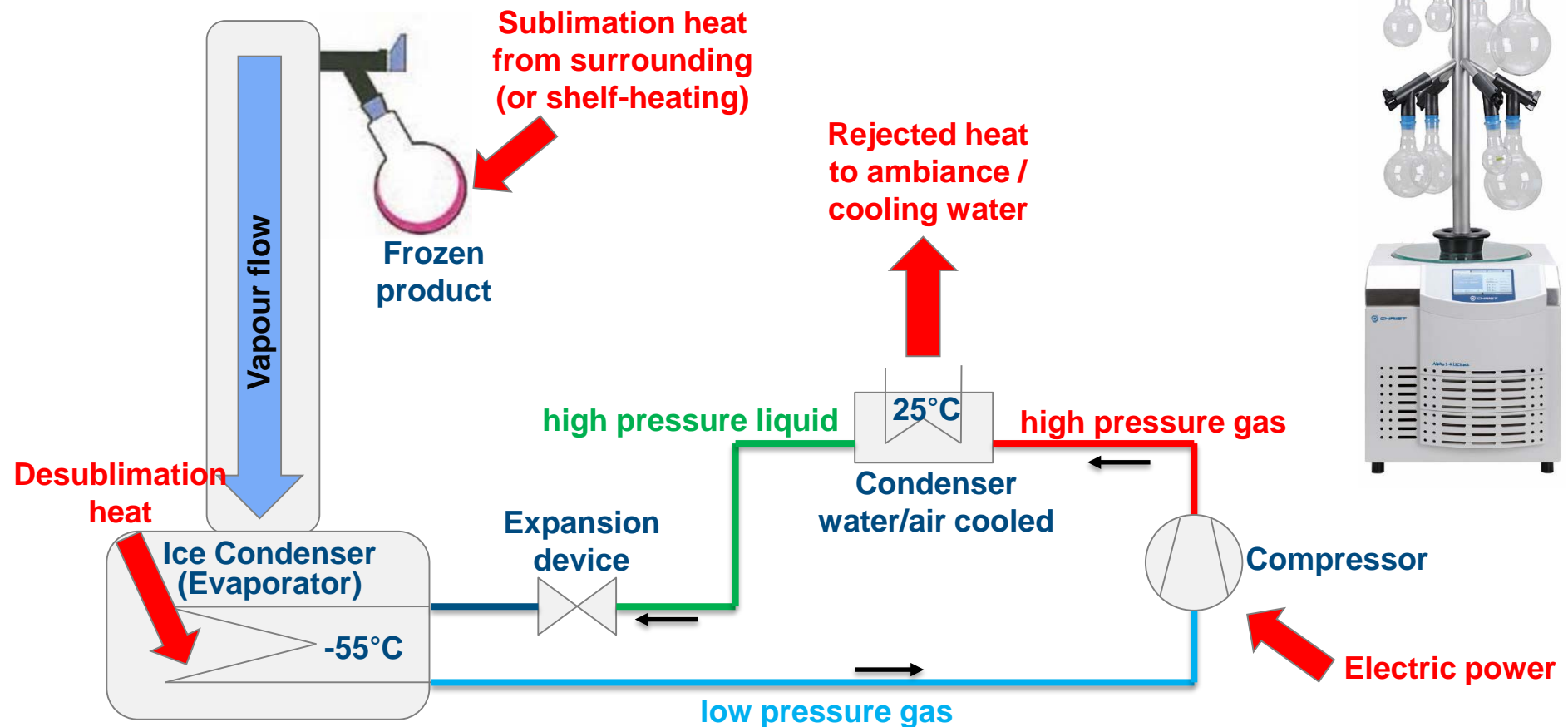


# Types of cooling systems



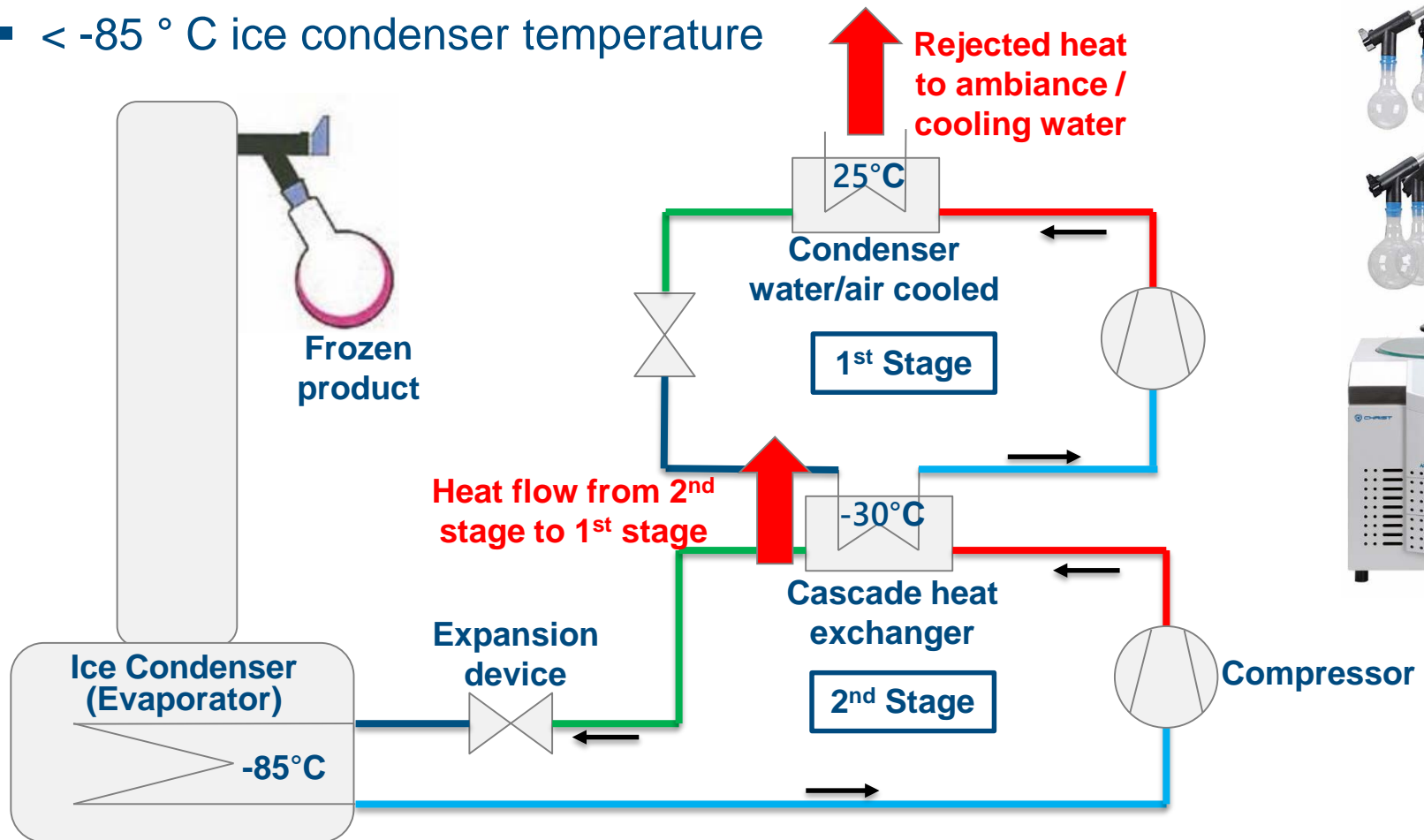
# One-Stage refrigeration system / function

- $< -55\text{ }^{\circ}\text{C}$  ice condenser temperature



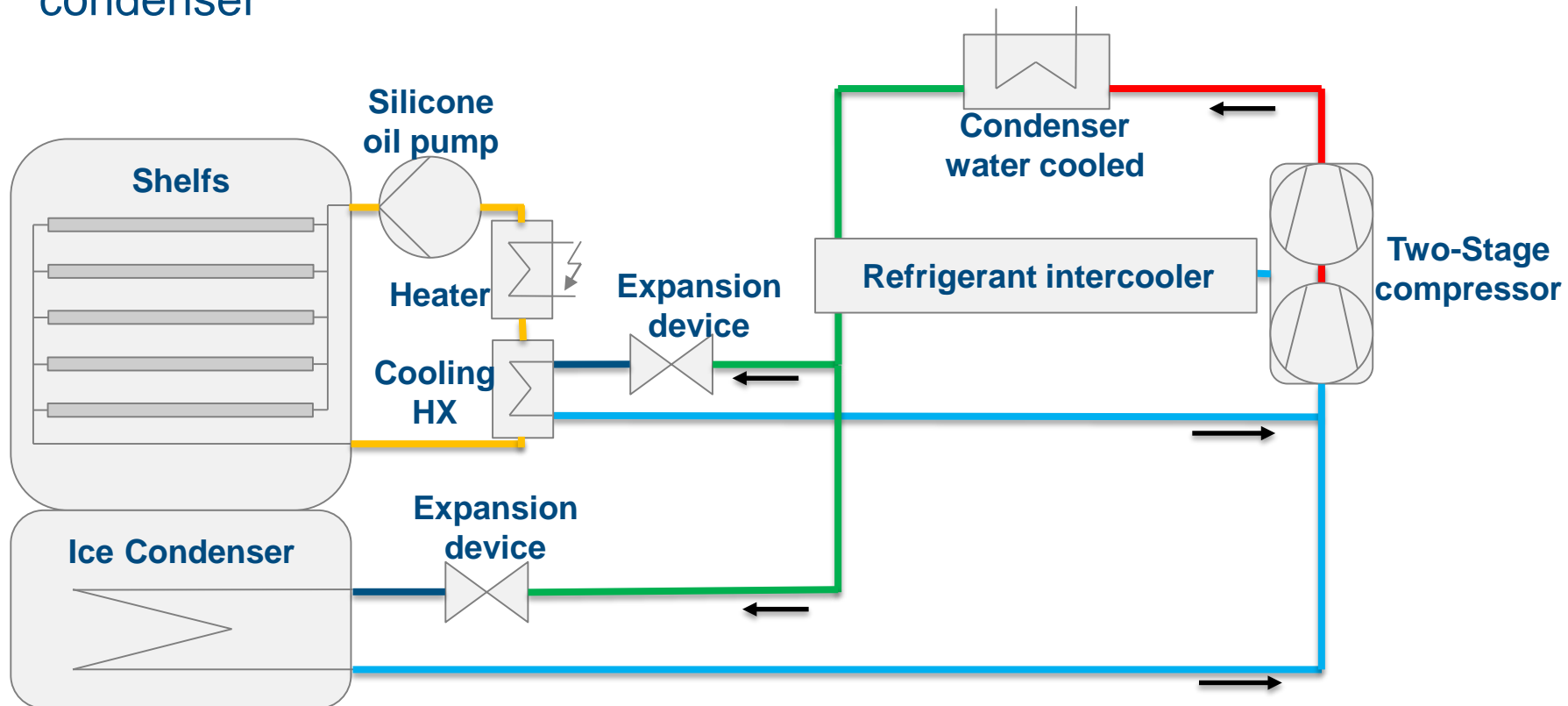
# Two-Stage cascade refrigeration system

- $< -85\text{ }^{\circ}\text{C}$  ice condenser temperature



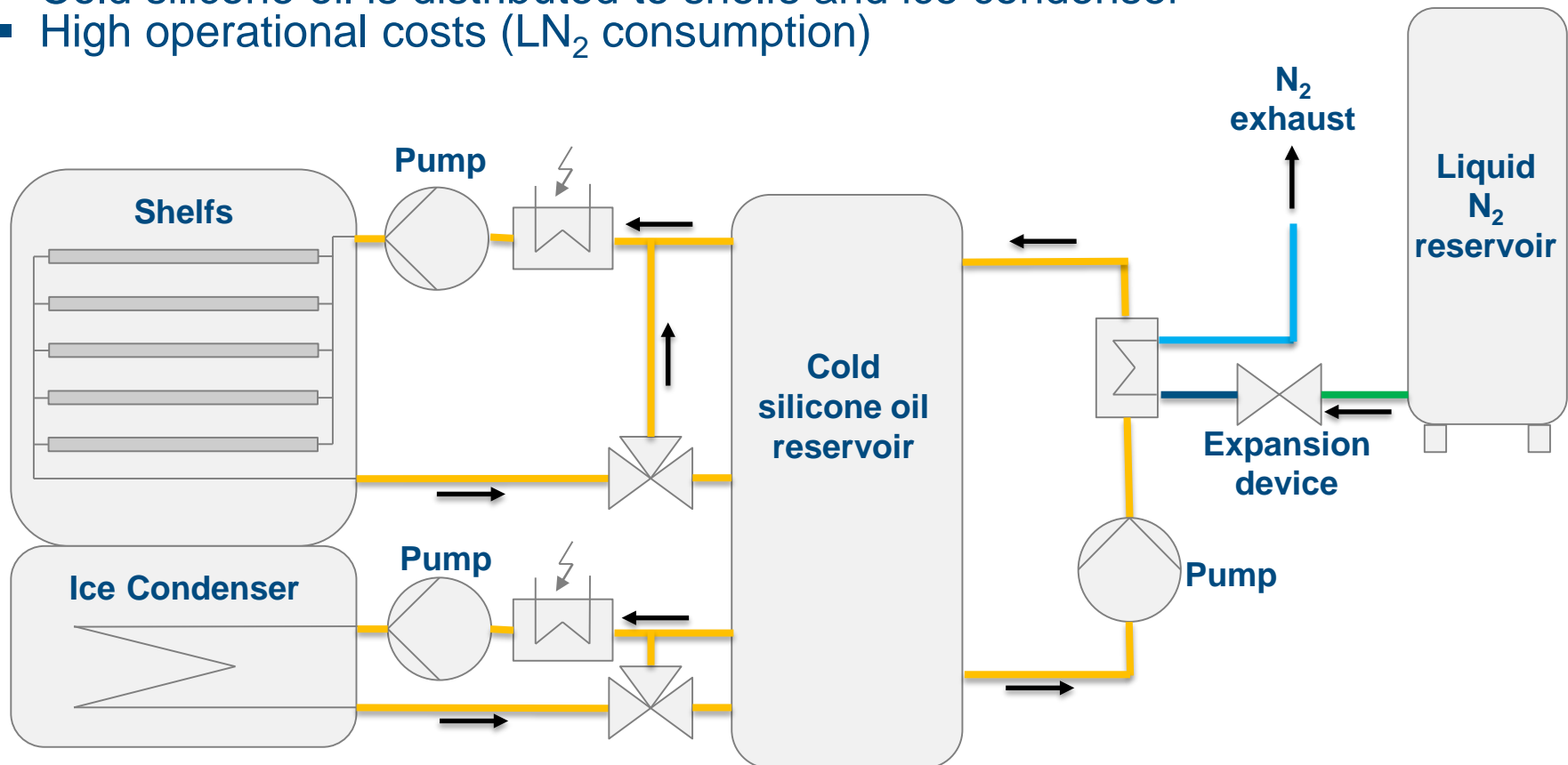
## Two-Stage compression refrigeration system

- Silicone oil circuit for shelf temperature control
- Liquid refrigerant is distributed to shelves and ice condenser



## Liquid nitrogen direct expansion

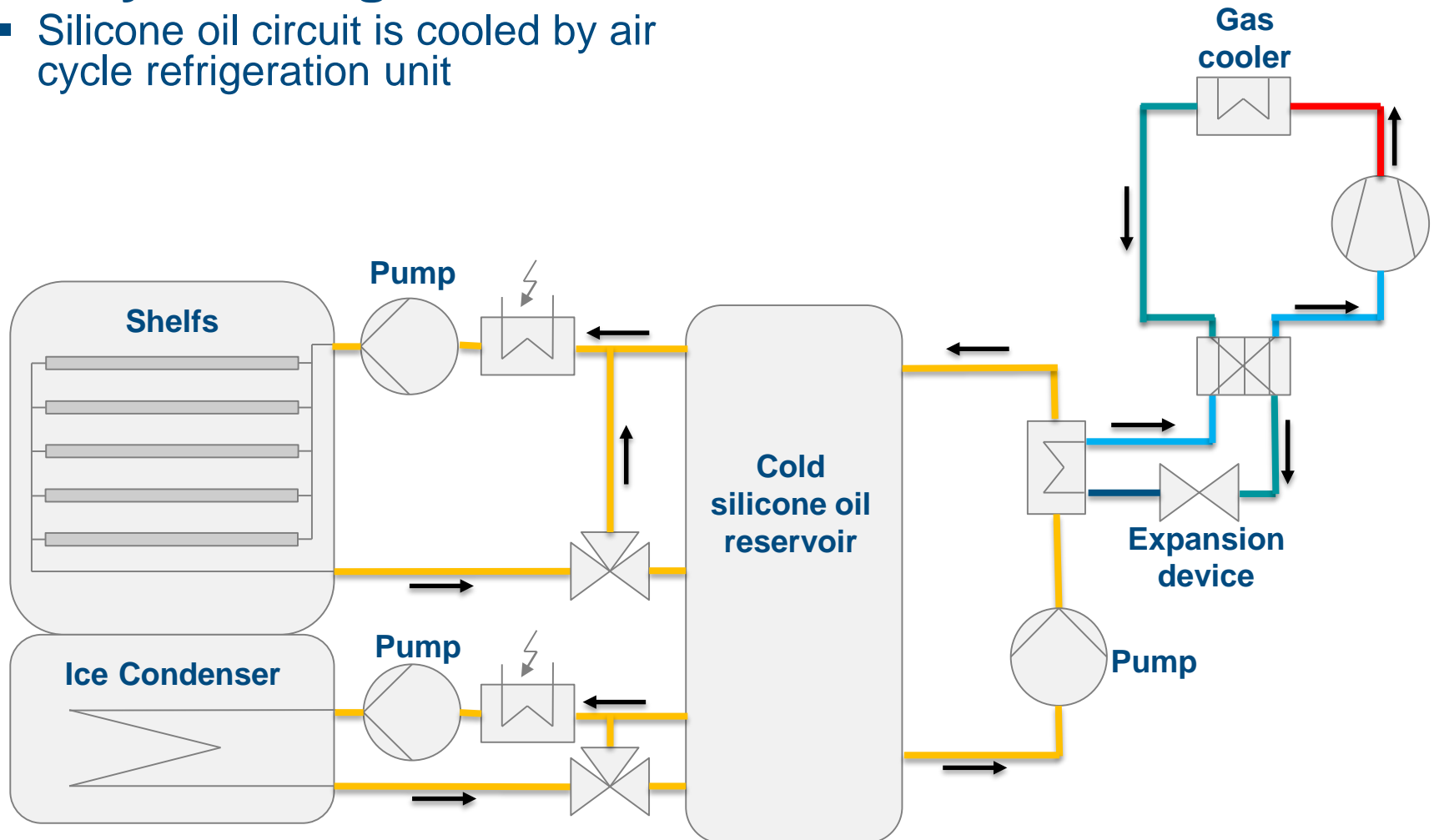
- Evaporating  $N_2$  cools silicone oil
- Vessel is charged with cold silicone oil
- Cold silicone oil is distributed to shelves and ice condenser
- High operational costs ( $LN_2$  consumption)





## Air cycle refrigeration

- Silicone oil circuit is cooled by air cycle refrigeration unit



## Future refrigeration technology in freeze dryers

- F-gas regulation influence on refrigerants:
  - Phase down of HFCs with GWP>2500 (global warming potential)
  - F-gas regulation does not affect freeze drying applications (temperatures below -50 °C)
  - Influences on price and availability of currently used fluorinated refrigerants
    - R-404A (3920)
    - R410-A (2090)
    - R-508A (13240)
    - Isceon89 (3805)
  
- Demand to use natural refrigerants with low GWPs
  - R-290 (Propane) (3)
  - R-1270 (Propylene) (2)
  - R-170 (Ethane) (6)
  - R-1150 (Ethylene) (4)
  - R-744 (CO<sub>2</sub>) (1)

## Future refrigeration technology in freeze dryers

### Laboratory systems with small amount of refrigerant (<150g)

→ flammable refrigerants



**One-stage system (-55 °C)**  
Propane / Propylene / (Ethane)

**Two-stage cascade (-85 °C)**  
Propane / Propylene / Ethane / Ethylene

## Future refrigeration technology in freeze dryers

### Systems with bigger amount of refrigerant (>150g)



Two-stage compressor system  
R-410A (GWP=2090)

LN2 direct expansion  
(with silicone oil circuit)

Air cycle refrigeration system  
(with silicone oil circuit)

Two stage cascade system  
CO<sub>2</sub>(?) / N<sub>2</sub>O (laughing gas)

Two stage cascade system  
Flammable refrigerants >150 g  
(high safety requirements)

**Thanks for your attention!**

