Heat and Mass Transfer in Cryogenic Condensers

F. Herzog and T. Kutz

Cryogenic Heat and Mass Transfer

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http://www.utwente.nl/chmt

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Dr.- Ing. Friedhelm Herzog

- Studium: Maschinenbau, RWTH Aachen (D)

- Messer Griesheim: seit 1990
  (Messer Group: seit 2004)

- Kryoprozesstechnik:
  z.B. Supraleitung, Kryokondensation, …
  (Entwicklung, Anwendung, Vertrieb)

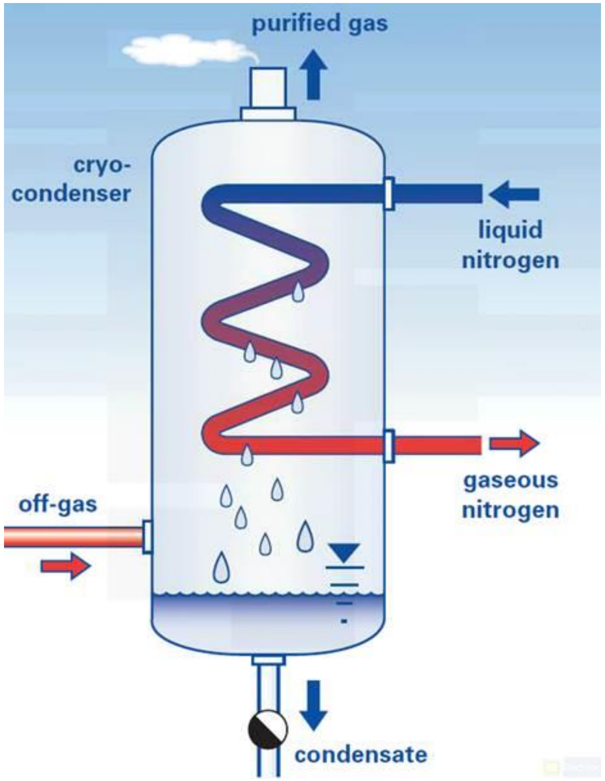
- Abteilungsleiter (international agierende Ingenieure)

- Job Title: Senior Manager
  Application Technology
  Industry

Introduction

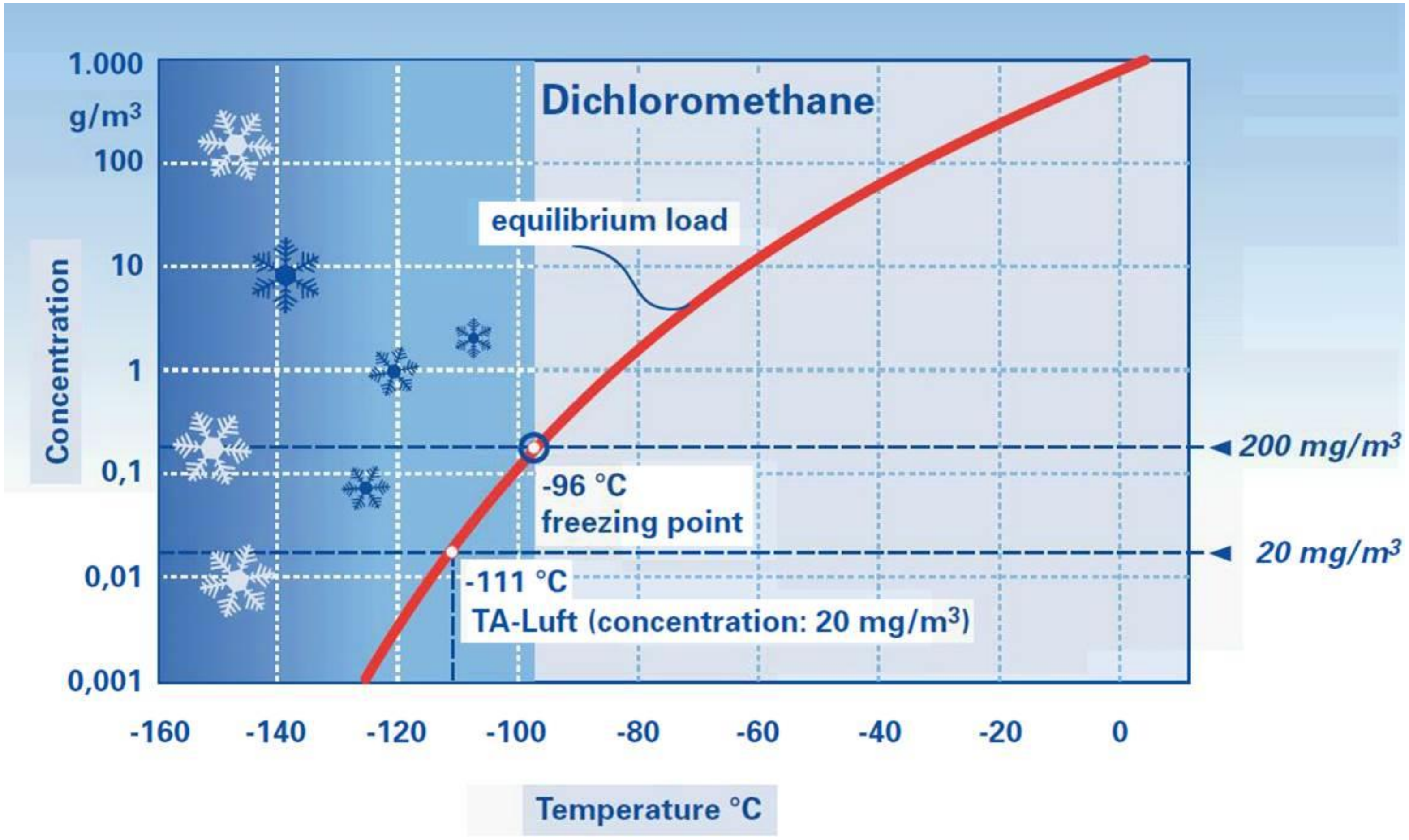
What is « cryogenic condensation » ?

Cooling of solvent loaded off gas streams with liquid nitrogen

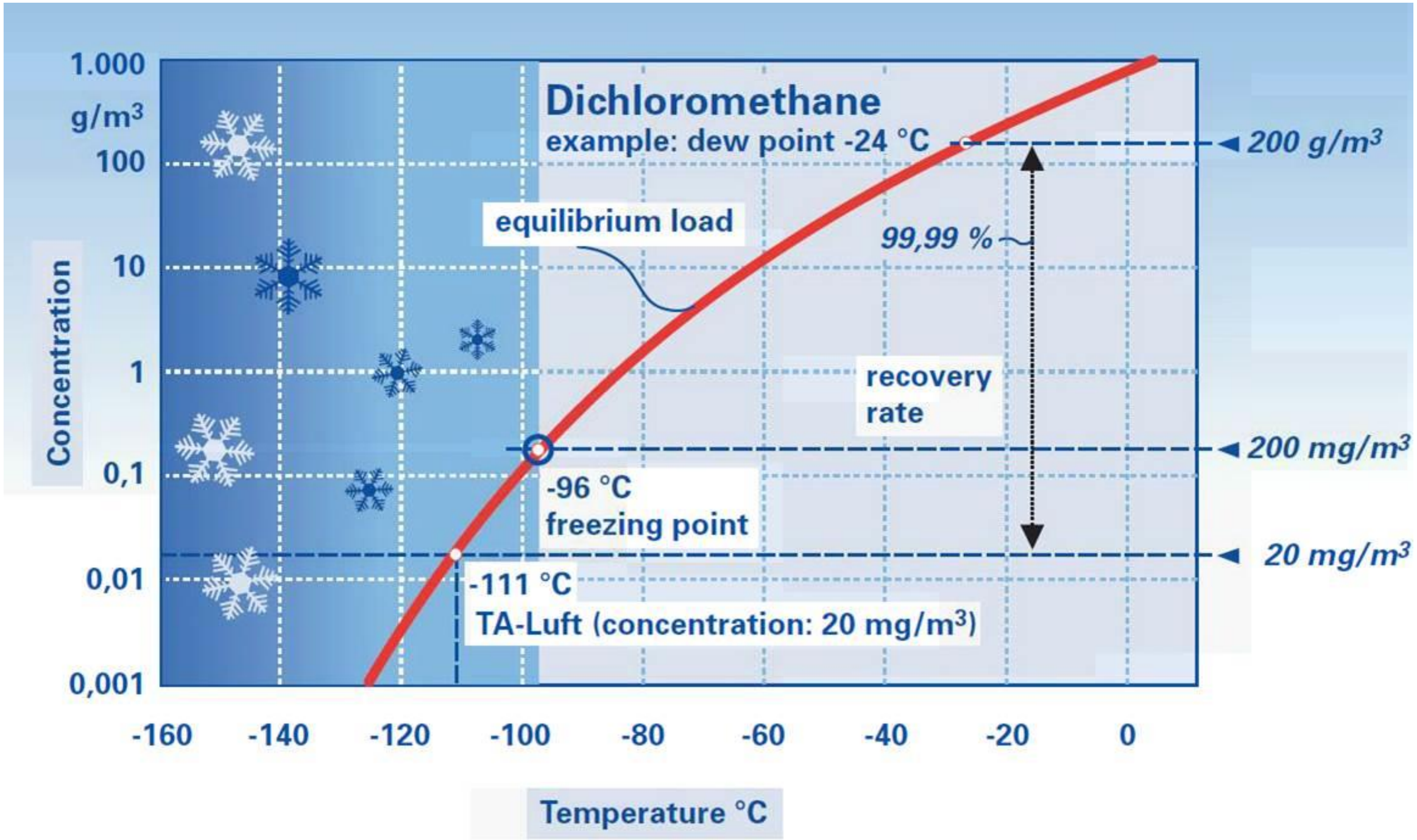


- ➔ solvent vapours become liquid
- ➔ liquid solvents can be recovered
- ➔ off gas streams are purified

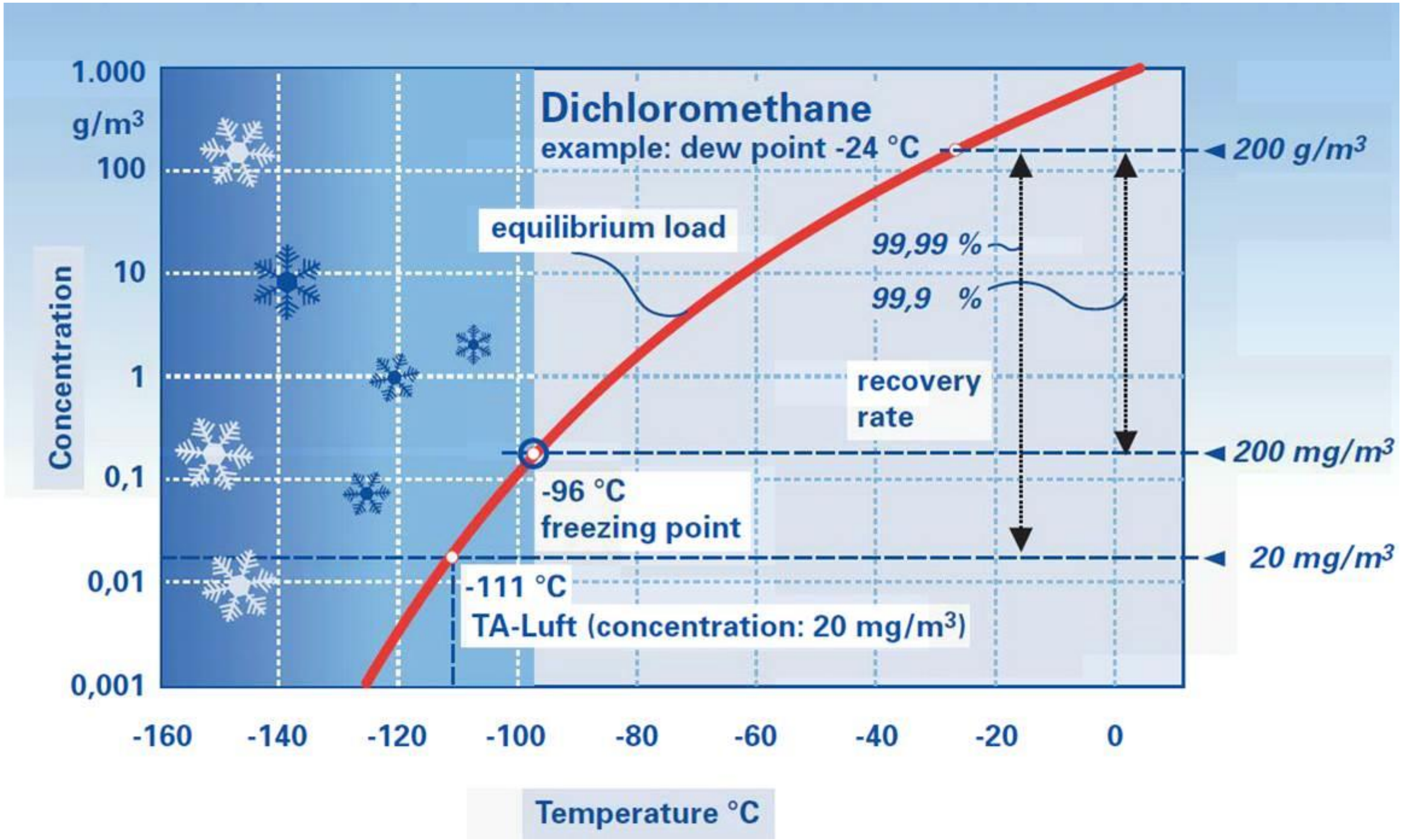
physical background (1)



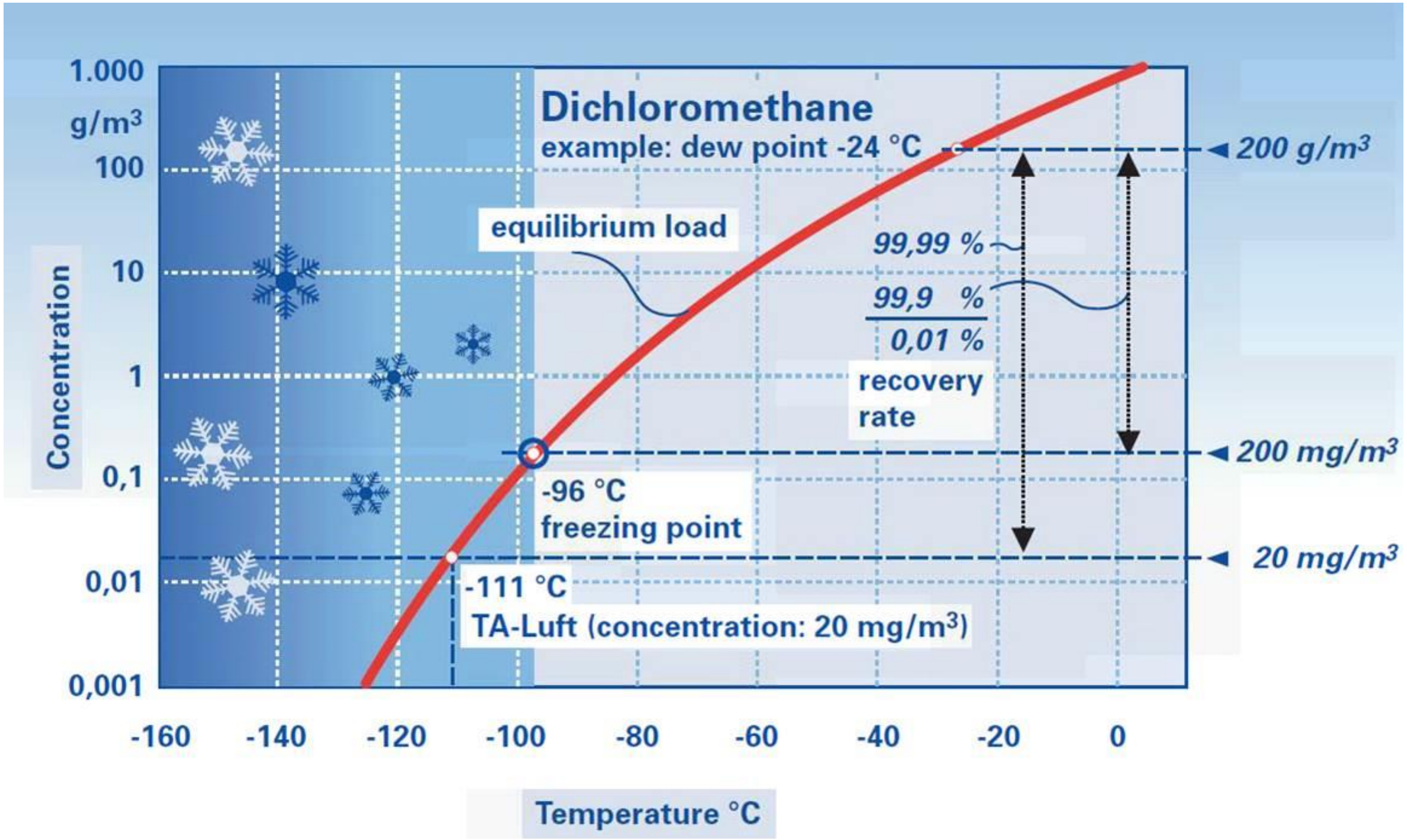
physical background (2)



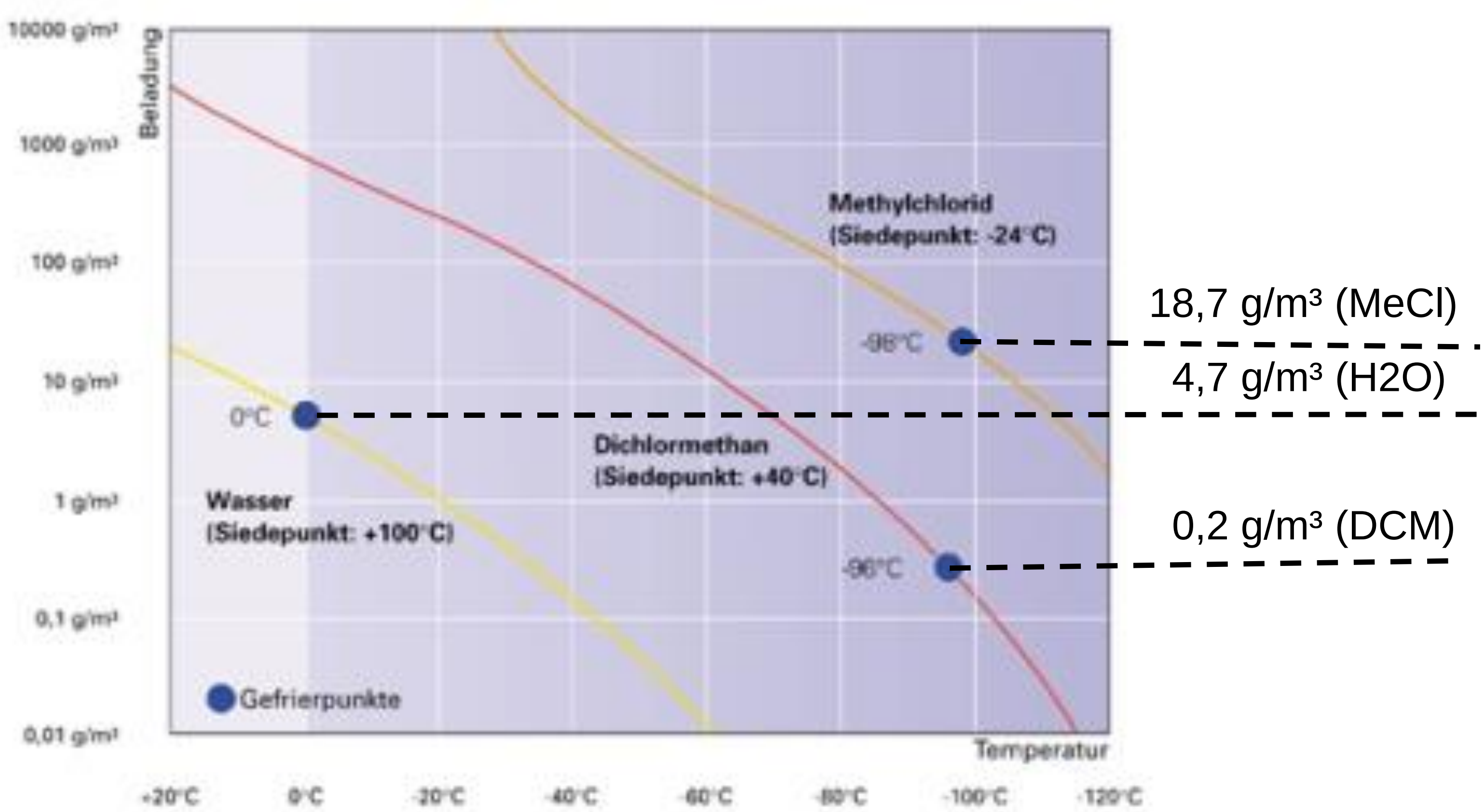
physical background (3)



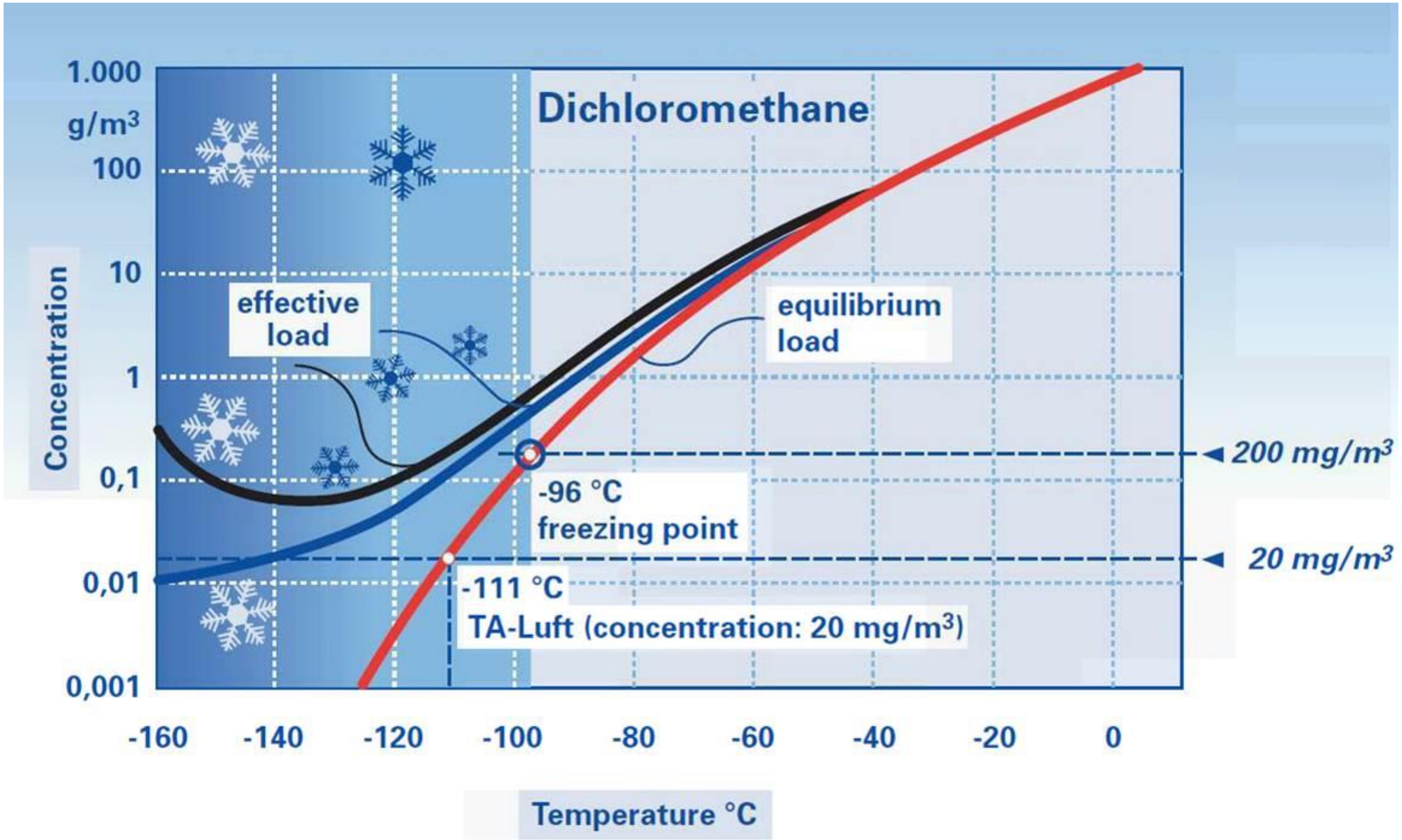
physical background (4)



Vapor load at melting point



effective load / equilibrium load

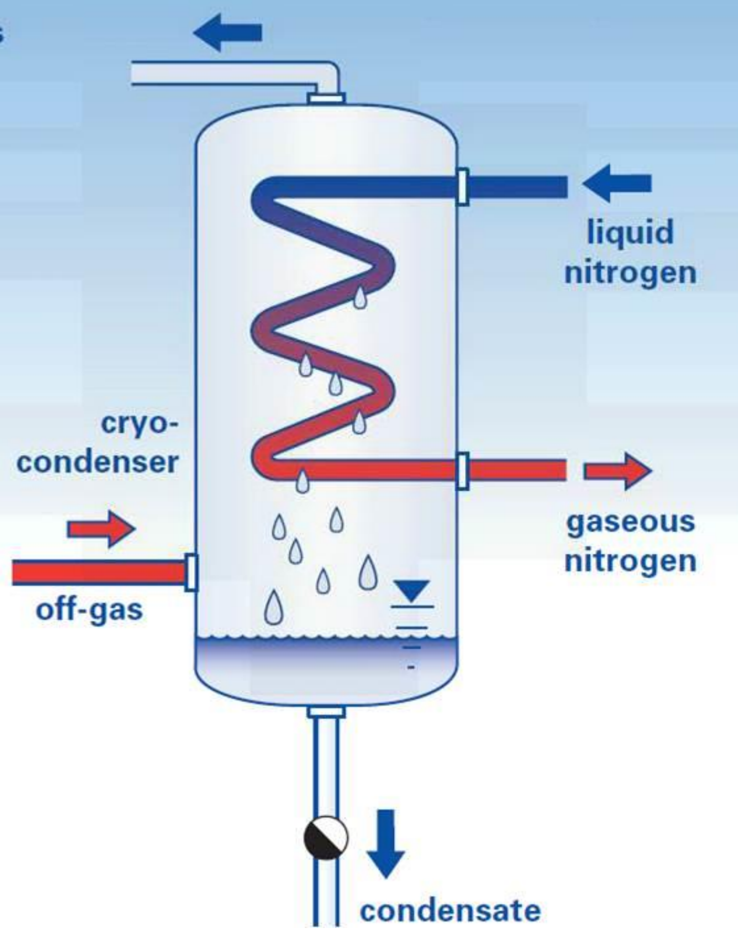


Technical Solutions (1)

simple cryogenic condenser:

➔ off gas gets cold

➔ but not pure



Avoiding Ice and Aerosols

What happens inside of a « cryogenic condenser » ?

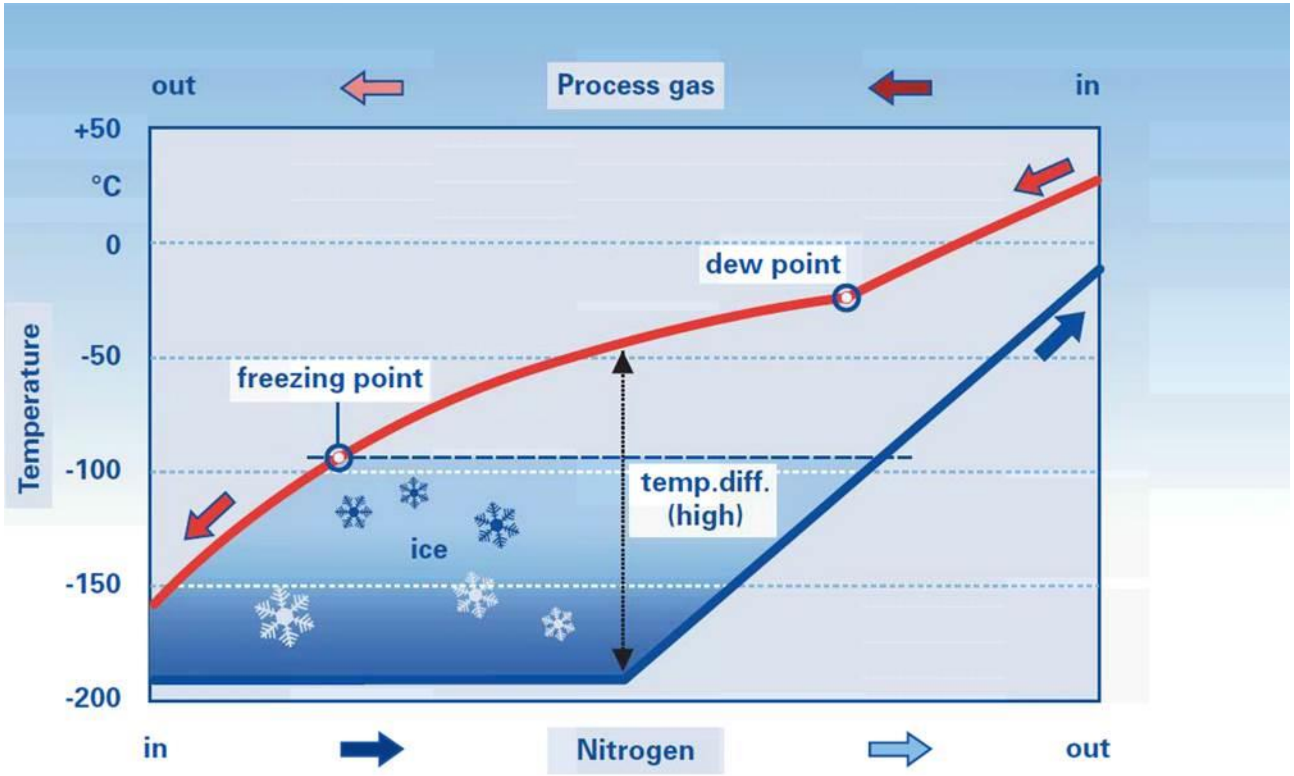
A) cooling with <u>liquid</u> nitrogen

B) cooling with cold <u>gaseous</u> nitrogen (DuoCondex and Cryosolv)

Temperature profile (A)

Temperature profile in a cryogenic condenser:

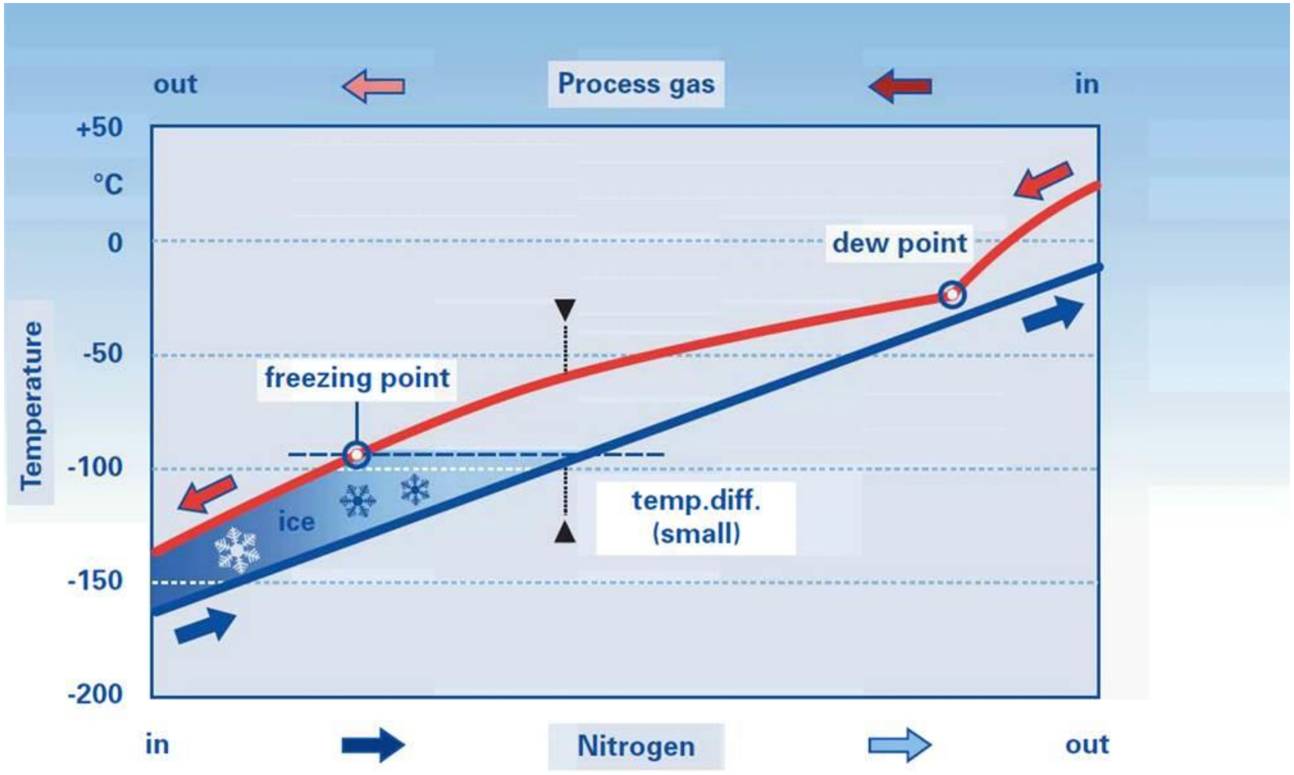
A)
cooling with <u>liquid</u> nitrogen



Temperature profile (B)

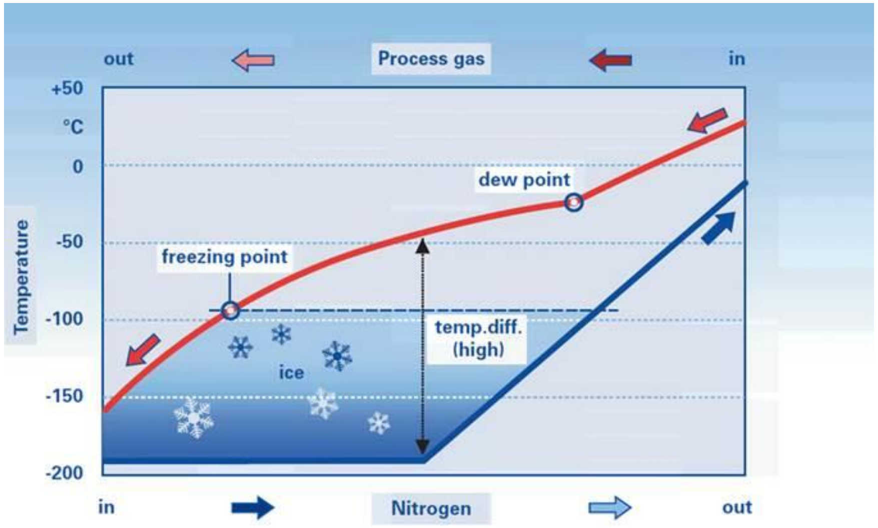
Temperature profile in a cryogenic condenser:

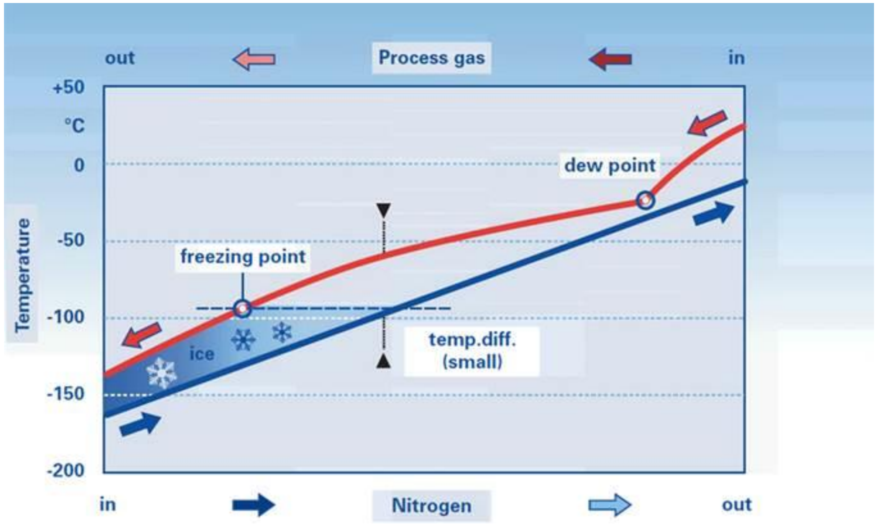
B) cooling with cold <u>gaseous</u> nitrogen



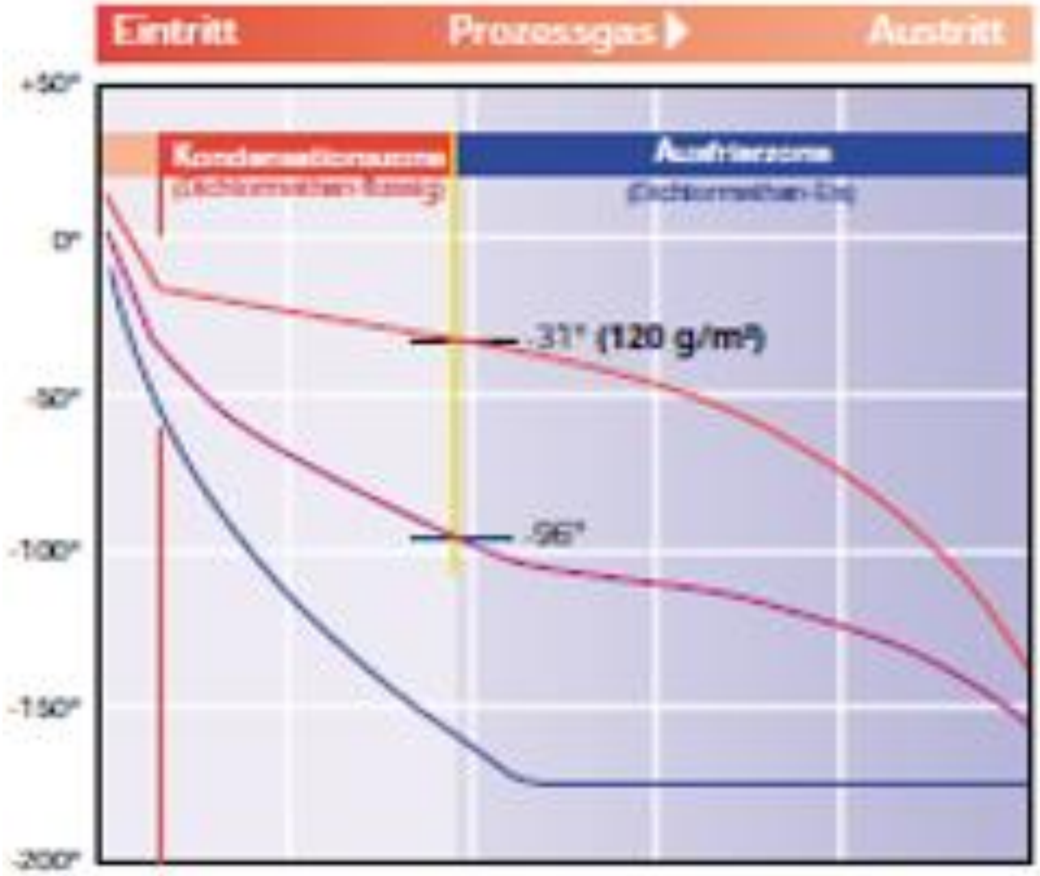
Comparison

Small temperature difference leads to less ice formation and avoids aerosols





Comparison

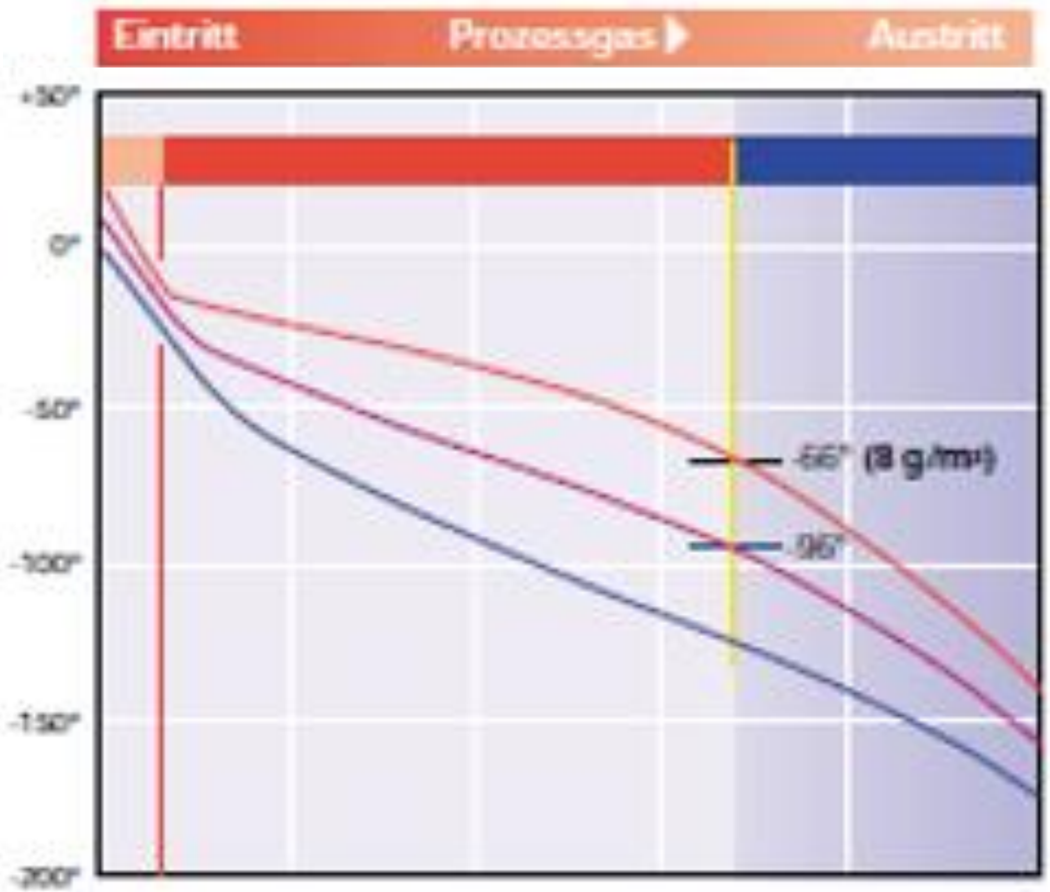


Kühlung mit Stickstoff-flüssig
(6 bar, Siedetemperatur: -174°C)

Ice: 120 g/m³

Temperature Profile of a Cryogenic Condenser

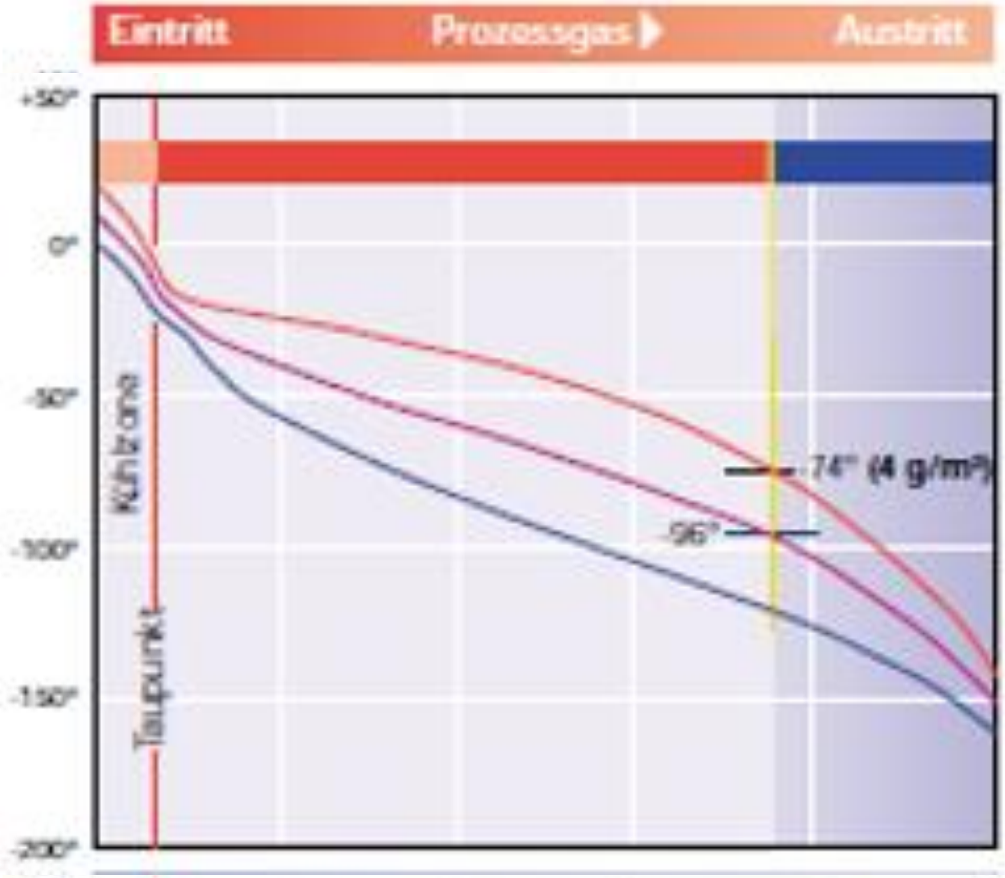
Comparison



Kühlung mit Stickstoff-gasförmig
(Eintrittstemperatur: -174°C)

Ice: 8 g/m³

Comparison



Kühlung mit Stickstoff-gasförmig
(Eintrittstemperatur: -160°C)

Ice: 4 g/m³

Legende:
- Prozessgastemperatur
- Wandtemperatur
- Stickstofftemperatur
- Gefrierpunkt Dichlormethan (-96°C)
- Prozessgastemperatur bei Wandtemperatur <-96°C

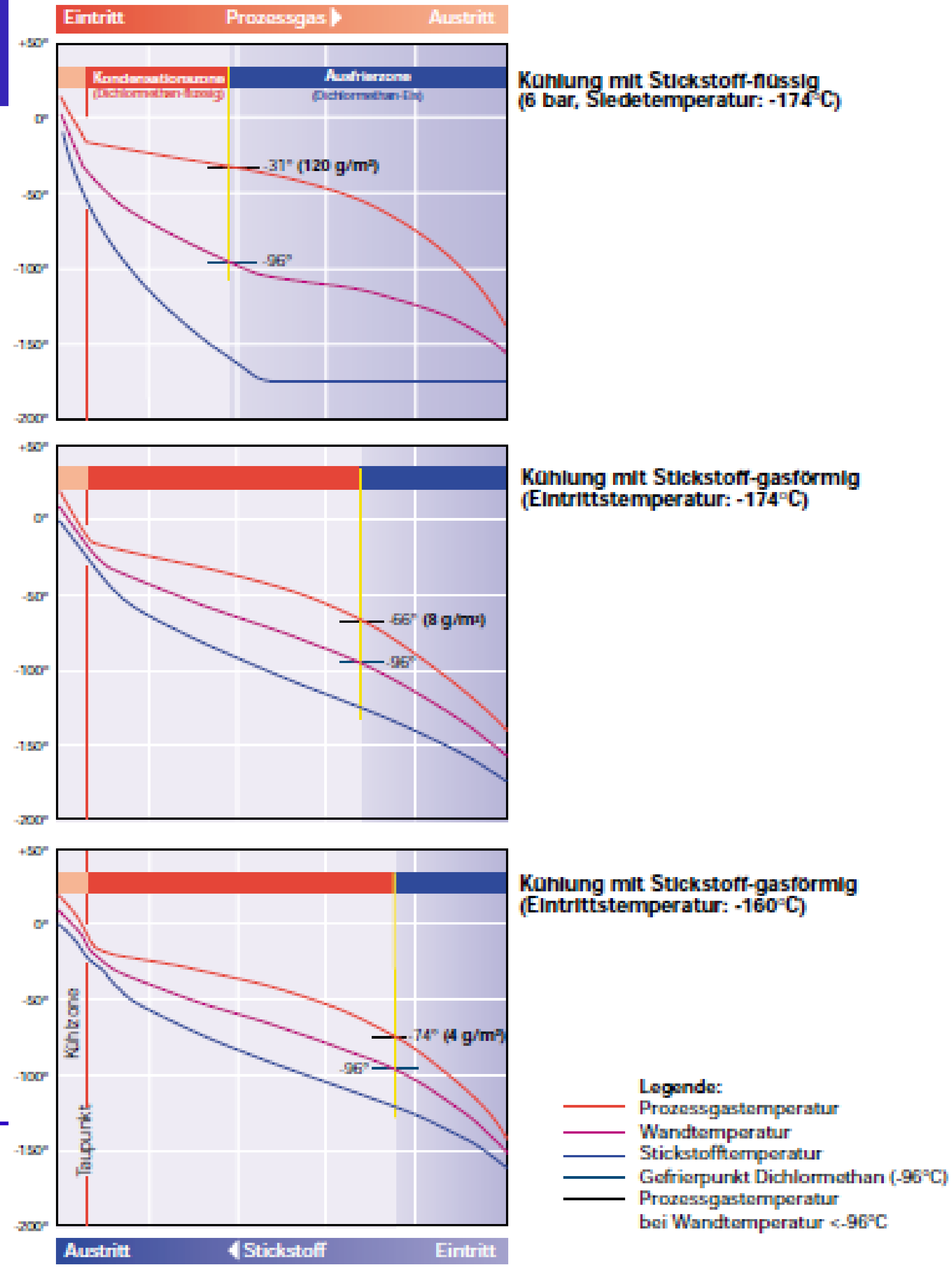
Temperature Profile

Ice:

120 g/m³

8 g/m³

4 g/m³



Avoiding Ice and Aerosols

How to transfer this physical knowlede into process technology ?

A) cooling with cold gas instead of <u>liquid</u> nitrogen

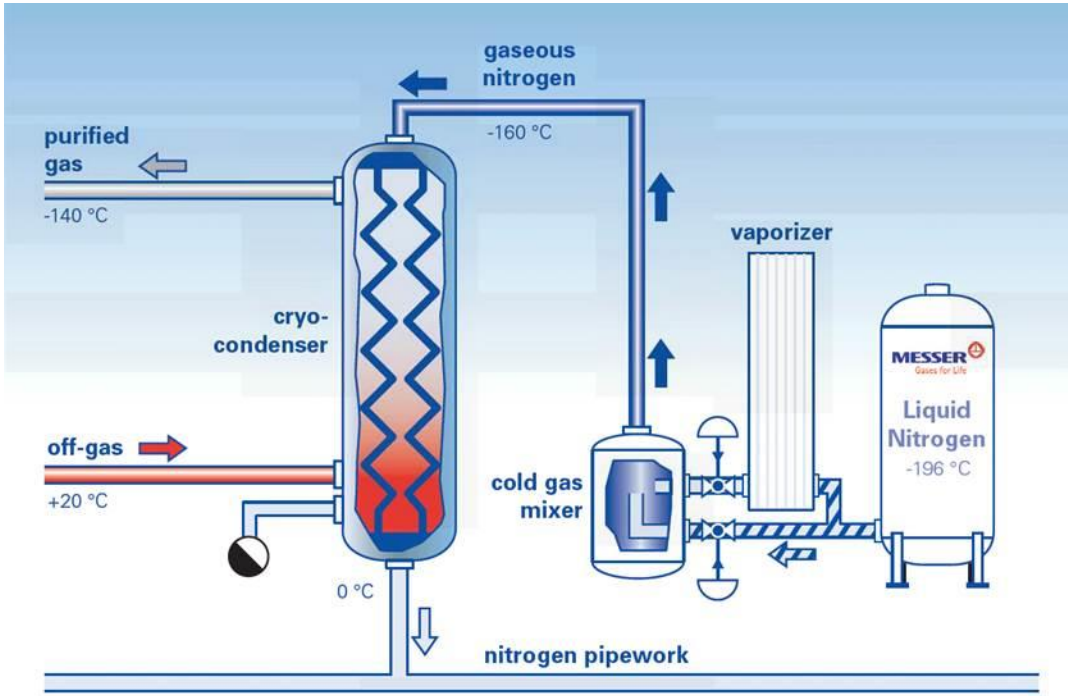
B) transfer of evaporation enthalpy into sensible cold without losses

Cold Gas Mixer

(A)

+ very simple

- wasting of LIN evaporation enthalpy
- high consumption
- seldomly used

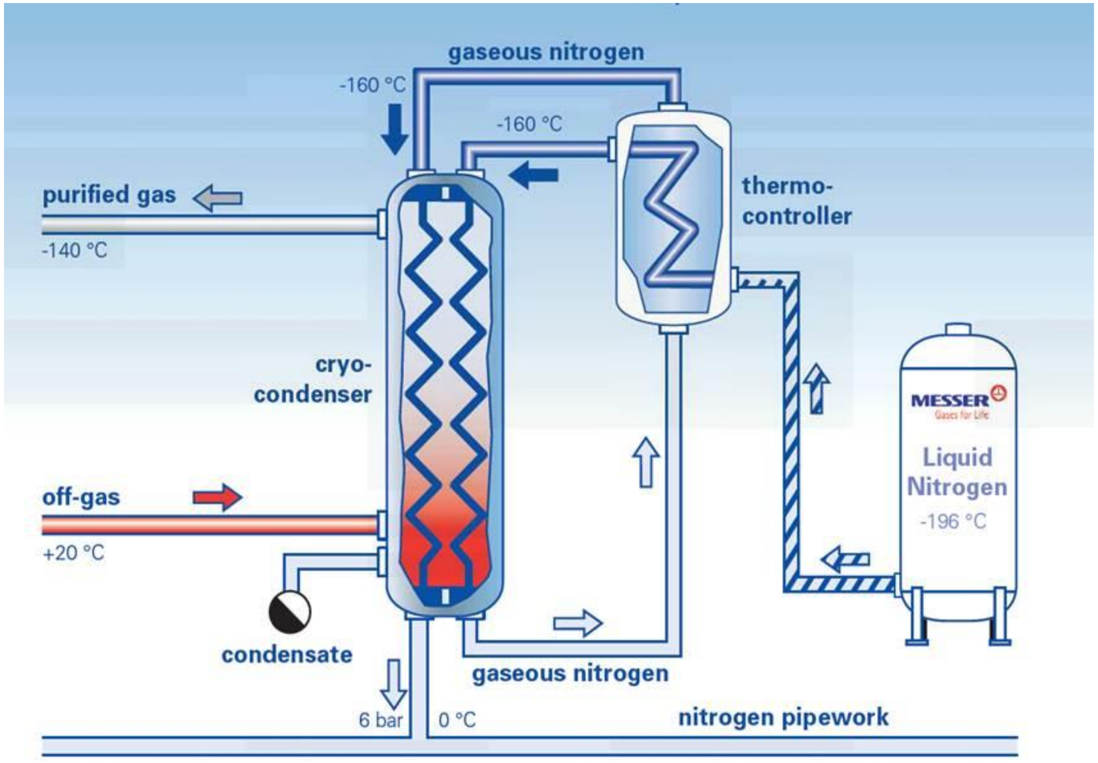


Vaporizer / double Condenser (DuoCondex)

(A+B)

- Thermocontroller
- 2 tube bundles

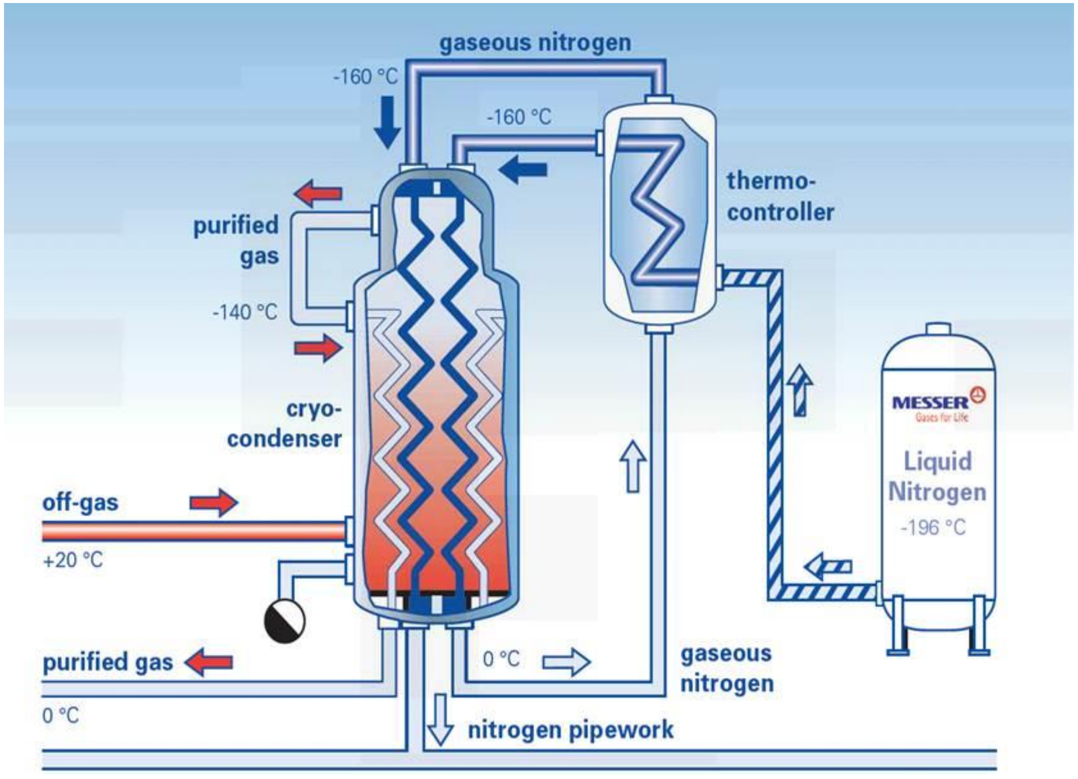
LIN-evaporation enthalpie transfered to GAN-cold without losses



… + Recuperator

3rd tube bundle for recovery of coldnes from purified gas

- **drastical reduction of LIN-consumption**
- **more cold in the condensing zone, thermodynamical advantages**



DuoCondex®

Pilot Plant
for Customer Trials

Summary (Cryocondenser)

Three heat and mass transfer zones:

- **# gas cooling**
- **# vapor condensation (liquefaction)**
- **# vapor sublimation (ice formation)**

Heat transfer is « faster » than mass transfer

- **# fast heat transfer by cooling with evaporating <u>liquid</u> nitrogen**
- **# optimal mass transfer (close to equilibrium) by cooling with cold <u>gaseous</u> nitrogen**

IVAX, Opava
Czech Republic

Photo:

DuoCondex - double unit with precondenser

DuoCondex®

Evonik
Shanghai (1), China

- evacuation of reactors by „cryo pumping“
- recovery of methyl chloride
- capacity: 2.000 kg/h (batch process)
- Installation: 2013

Photo:
„cryo pump“ at Evonik, China

DuoCondex®

Institute of Aircraft Propulsion Systems
University of Stuttgart
Germany

- **Cooling and drying of process air**
- **84.000 kg/h (- 90°C)**
- **Installation: 2008**

<u>Photos:</u>
Process air cooler
Coolant: liquid nitrogen

Thank you

Enschede, CHMT 2019