Gas based technologies for higher productivity in injection moulding

Birmingham, 26th September 2017
Andreas Praller, Linde AG

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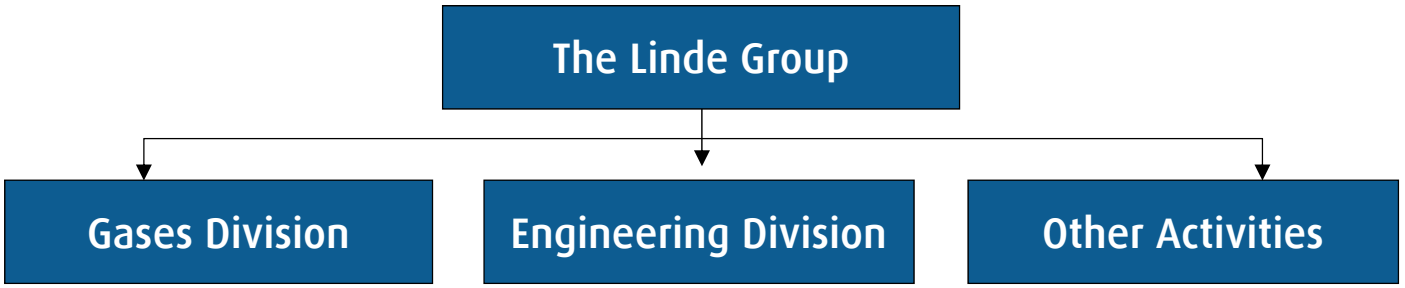
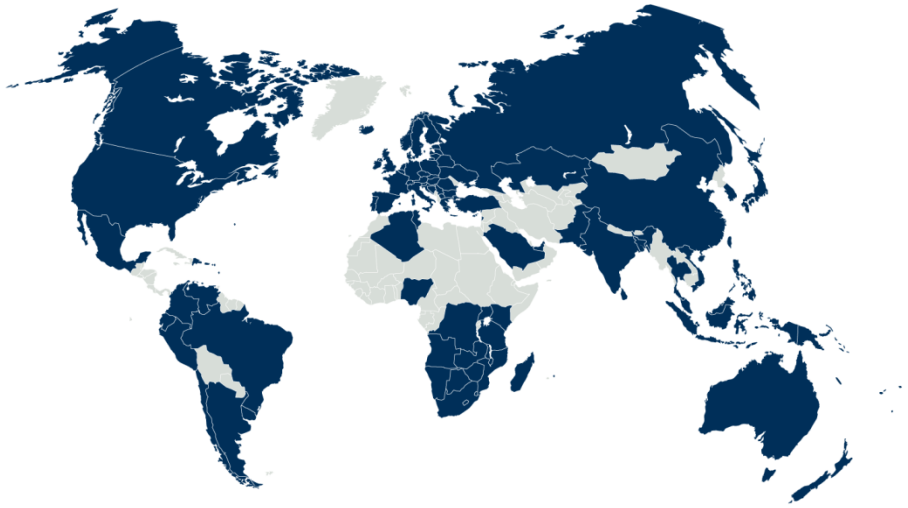
BOC
A Member of The Linde Group

Agenda

1. The Linde Group
2. Overview gas applications in the plastics industry (focus: CO_2 based applications for the injection moulding industry)
3. Spot Cooling of injection moulds with CO_2
4. Gas (assisted) injection moulding with CO_2

The Linde Group
a leading gases & engineering company





- **€16.9bn sales** in 2016
- **59.715 employees** worldwide (2016)
- **Global presence** in more than 100 countries

Gases Division
Wide range of products

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Gases

Air Gases

- Nitrogen
- Oxygen
- Argon
- Rare Gases: Krypton, Neon, Xenon

Other Gases

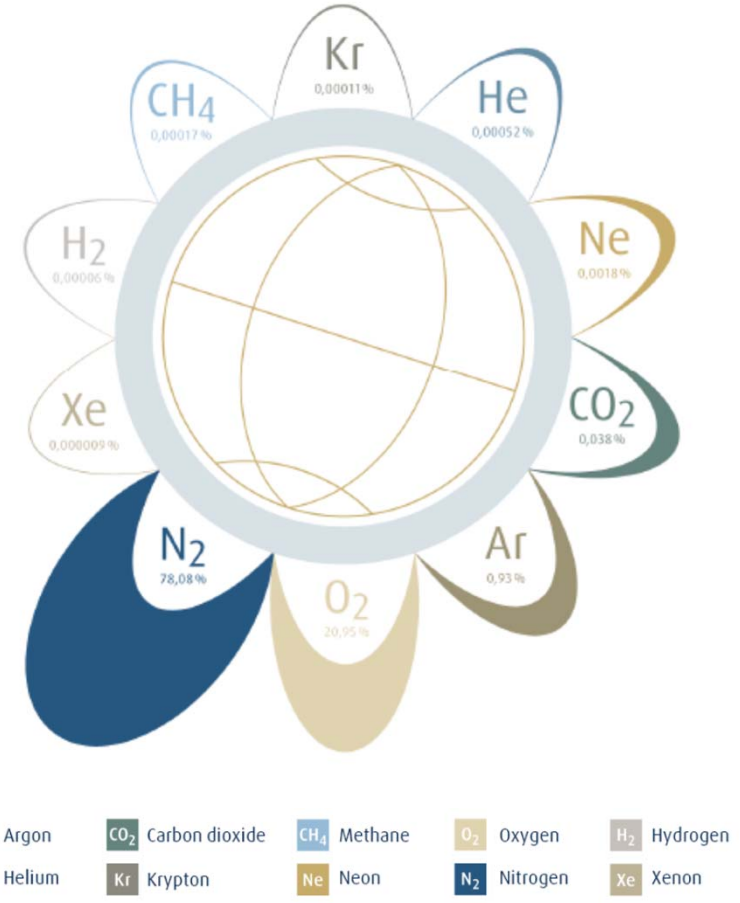
- Acetylene
- Helium
- Propane
- Carbon Dioxide
- Carbon Monoxide
- Hydrogen

Specialty Gases

- Pure Gases
- Specialty Gas Mixtures

Medical Gases

- Medical Oxygen
- Nitric Oxide (NO)
- Nitrous Oxide (N2O)



Gases Division
Wide range of markets and applications

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Healthcare

Food & Beverages

Environment

Metals processing

Metals production

Pulp & Paper

Oil & Gas production

Refineries

Electronics

Speciality Gases

Chemicals

Glas

Diversity and innovation for sustainable and profitable growth.

Application Technology
Scope

- New application opportunities for our products and services through ongoing R&D activities: increase of efficiency, quality, capacity
- Technical and commercialisation support for local sales engineers
- Partner management for technical development and commercialisation
- ~ € 30m investment in Applications and Technologies with a global team of more than 130 employees
- ~ 600 active patent families and ~ 100 new patents granted p.a.

You all know where carbon dioxide is used

But there are more applications .....

Gas applications for the plastics industry

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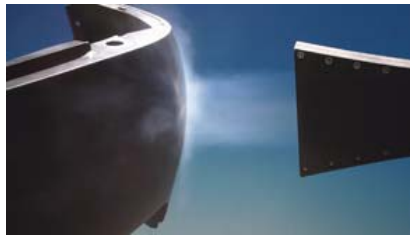
Effective pressure and cooling for **Gas (assisted) injection moulding**


Advanced mould temperature control for shorter cycle times and better part quality


Eco-friendly **Extrusion and Polyurethane foaming** with CO_2 (or nitrogen)


Foam injection moulding
for parts with lower weight and less material

Dry ice cleaning
Manual and automated cleaning solutions for moulds and plastic parts (before painting)



Spot cooling of injection moulds with CO_2

in cooperation with

Cooling of injection moulds

Usually moulds are cooled with **water** (sometimes oil) flowing through cooling channels which are ideally evenly distributed over the tool.

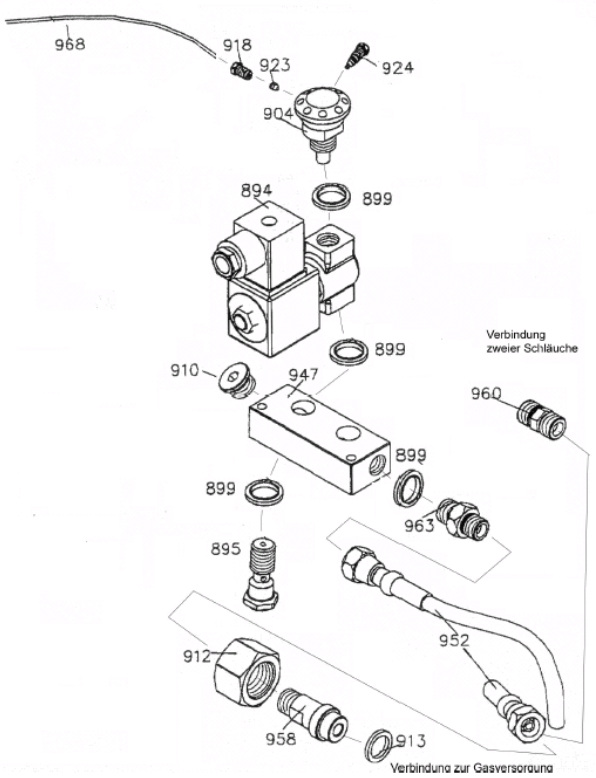
Limitations of water cooling

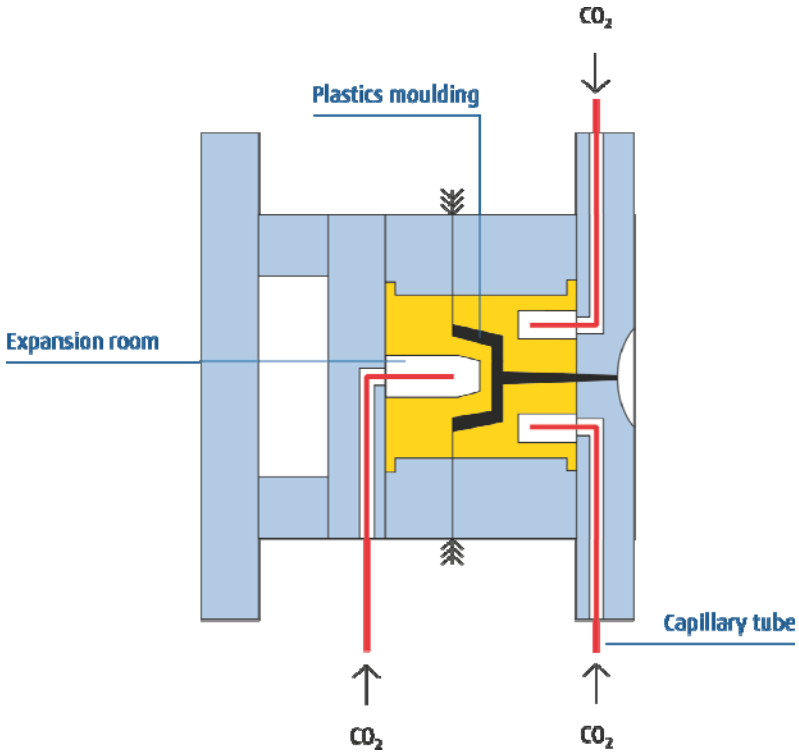
- Water cooling requires channels of **at least 5 mm in diameter**.
  Smaller diameters bear the risk of clogging and/or require a very high water pressure.
- Therefore water cooling channels are often installed where space is available, and not where it might be most efficient.
- **Especially hot spots like narrow cores are often not cooled at all.**
  The cooling time in this areas then determines the total cycle time.

Clogging of water channels when using water with bad quality caused by limescale, corrosion and biological fouling

Principle of Spot cooling

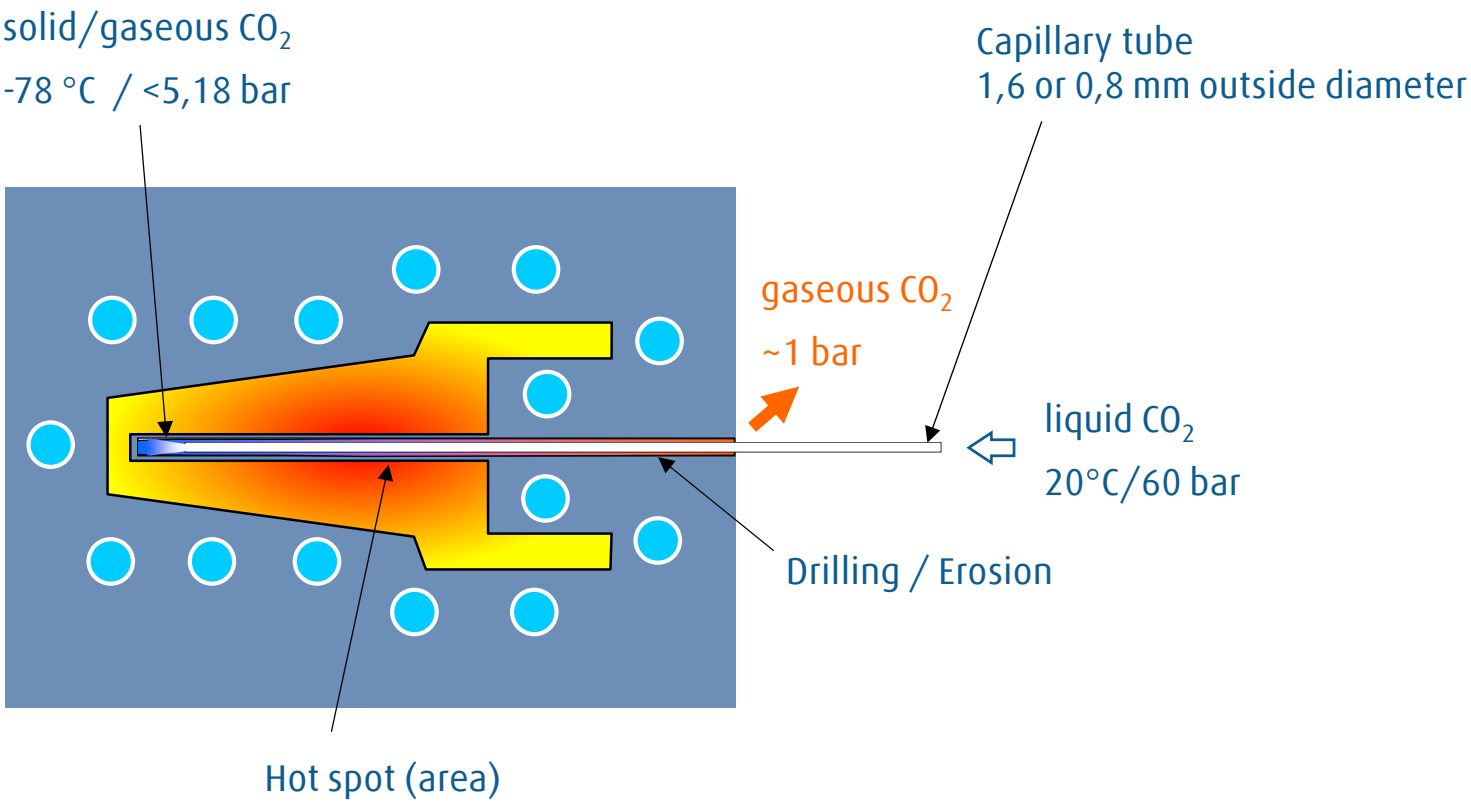
- PLASTINUM Spot Cooling **supplements the cooling with water** in areas where conventional water cooling is unfavourable or impossible.
- CO_2 cools **locally** the **hot spots/areas** of the mould.





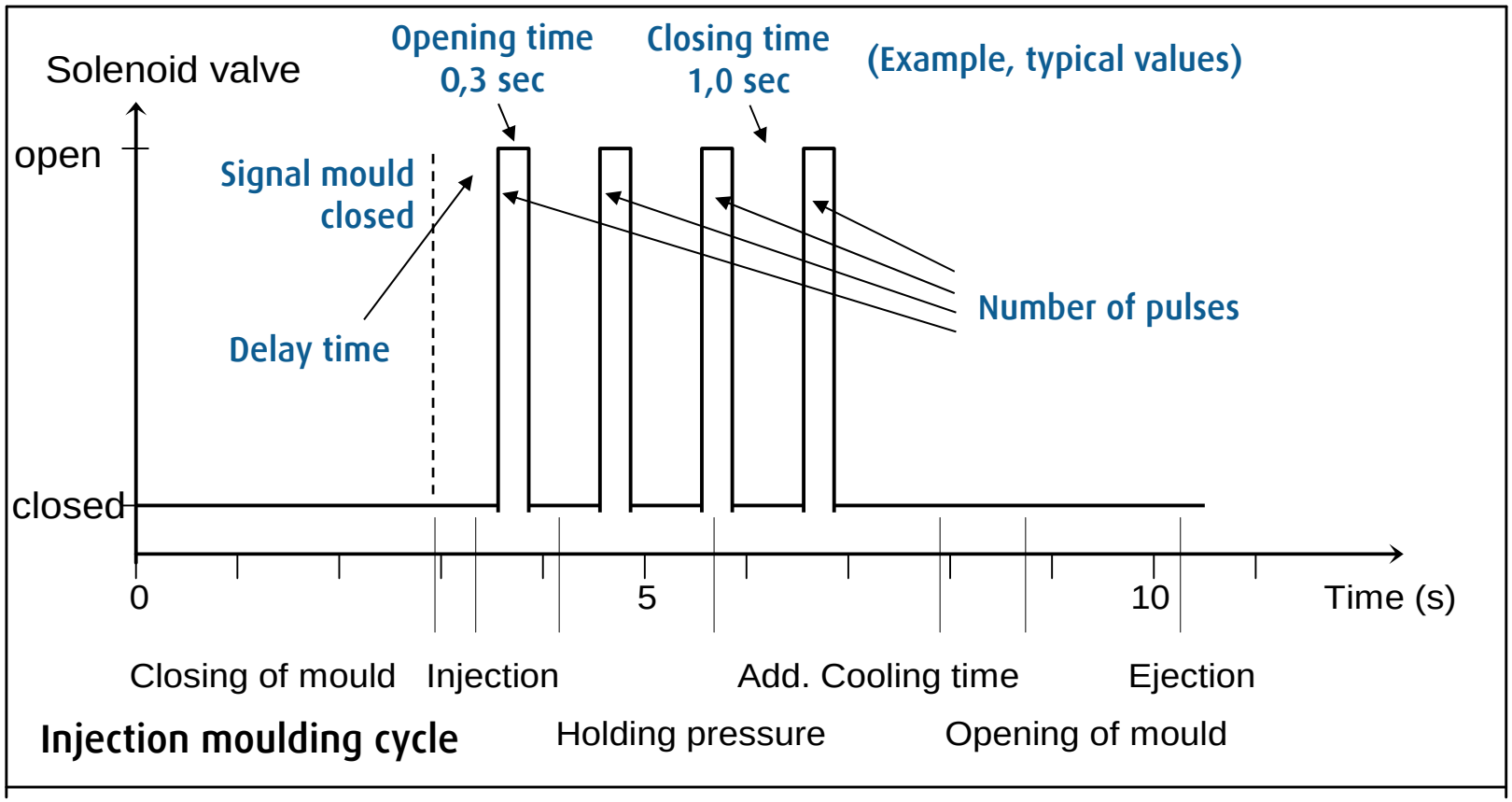
Principle of Spot cooling

Example: Cooling of a long, thin core



Mode of operation

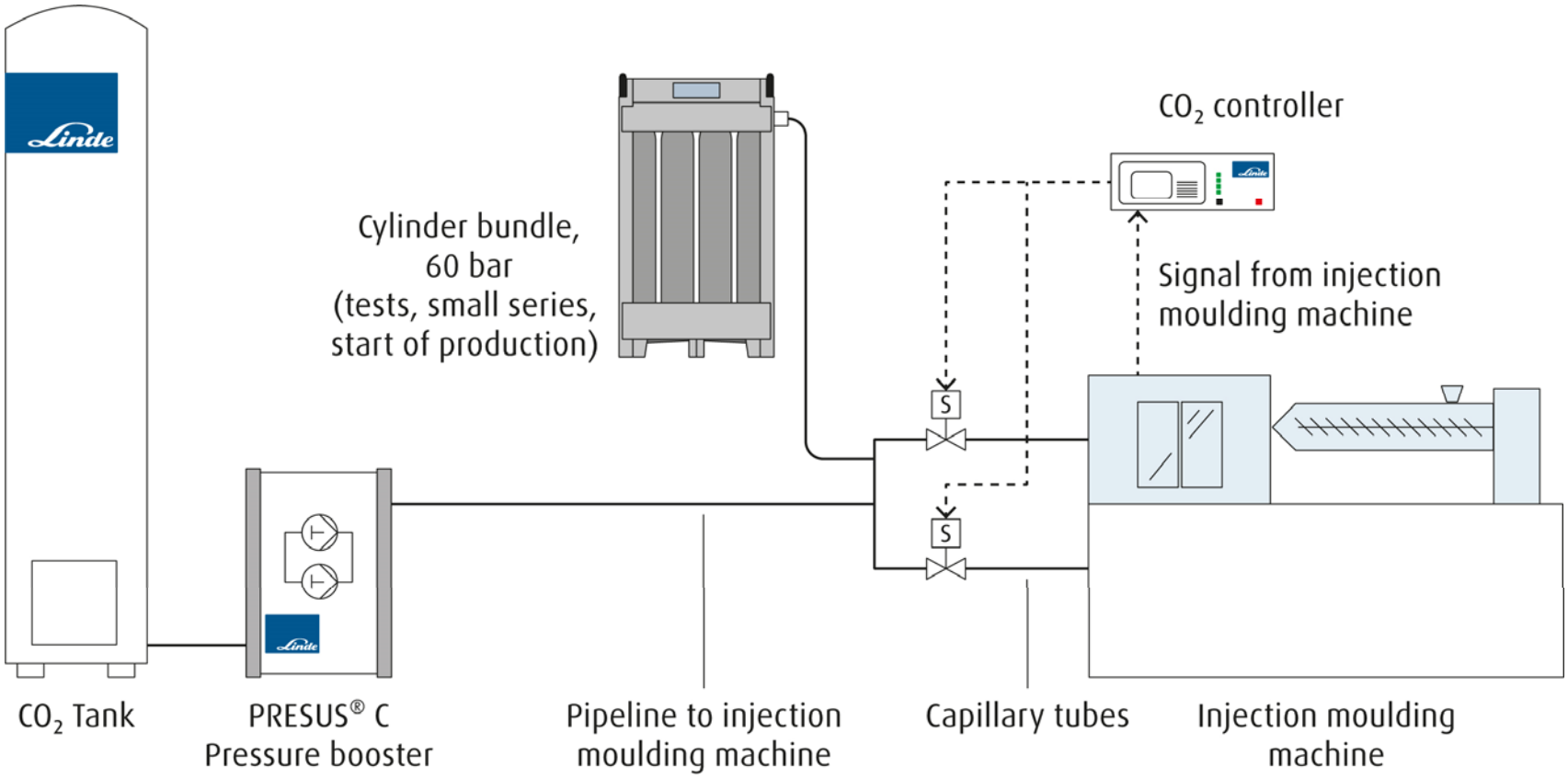
- Discontinuous CO_2 injection, only when polymer melt is injected
- Defined **open/close pulses** (number, length) of the solenoid valve per CO_2 cooling period
- CO_2 cooling starts after CO_2 controller gets signal from injection moulding machine



Advantages

- **Very narrow areas** of the mould can be cooled, cores with approx. 2 mm diameter can be cooled with **thin and flexible capillary tubes**
- **Shorter cycle times** (50 % and more possible) and thus **higher productivity**
- **Even temperatures** over the whole part
- **Higher quality** of the parts, e.g. reduced warpage and no sink marks
- Use with all kind of tool steels
- Little mould modifications, retrofit often possible
- **Low investment costs**

CO_2 supply and customer installation



Case study: Cooling of a long, thin core

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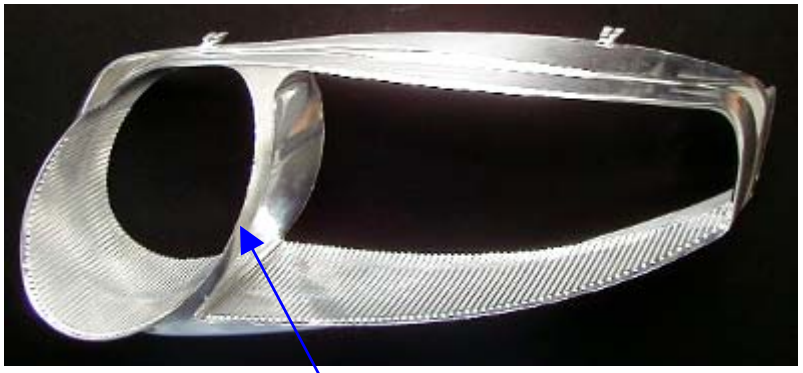
Customer: Foehl, Germany (end customer: Kaercher)

- Part of a pressure washer, pipe of trigger gun
- Cooling of a core with 6 mm diameter and approx. 200 mm length
- Material: PA 66, 30 % GF

- With CO_2 cooling the cycle time is in a normal range (the core is no longer the bottle neck)

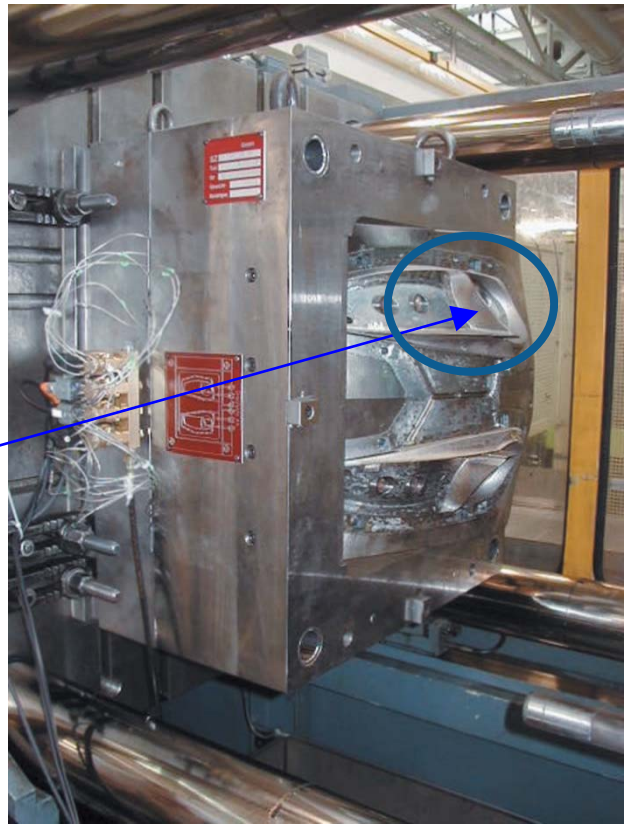
- Remark: The idea to use CO_2 cooling came from the mould maker.

Case study: Cooling of an area of a reflector housing (retrofit solution)



Critical area

It is not possible to cool the middle thin web with water.



Reflector Housing in the mould (2 cavities)

Case study: Cooling of an area of a reflector housing

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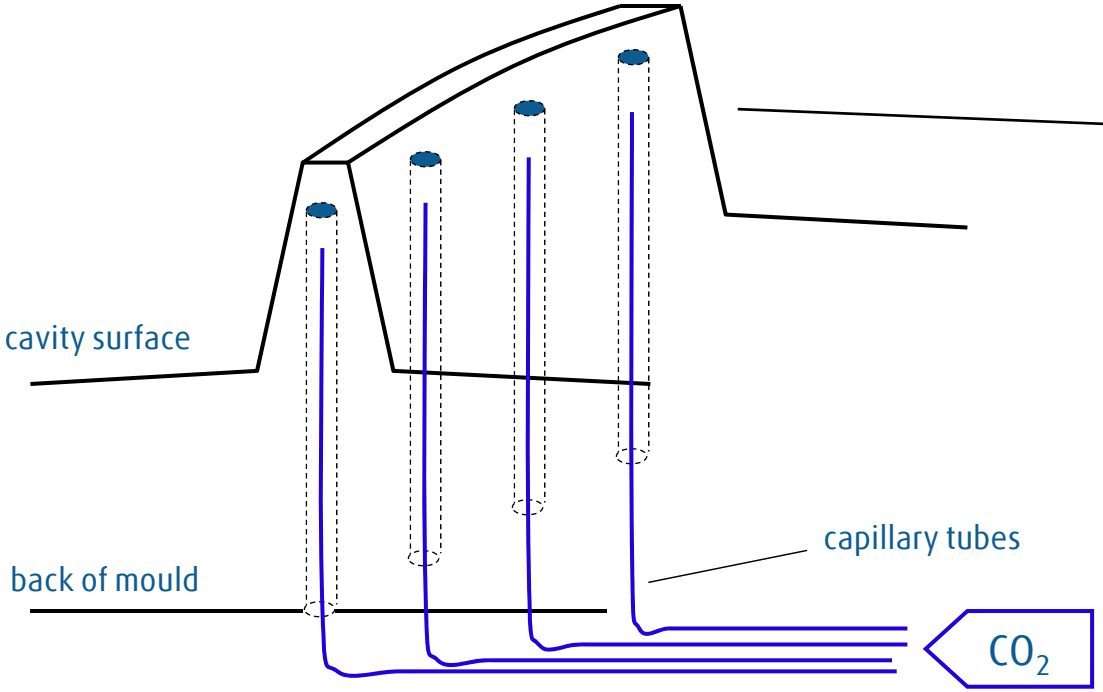
Saved cooling time with CO_2 Spot Cooling: 45 %



Several capillary tubes are installed in the mould.

Gas (Assisted) Injection Moulding with CO_2

in cooperation with

MAXIMATOR®
Maximum Pressure.

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High cooling effect of carbon dioxide

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Why does carbon dioxide cool so efficiently?

- Under typical Gas Injection Moulding GIM pressures carbon dioxide has a **very high density**.
- Significantly **higher specific heat capacity c_p** than nitrogen
  - Nitrogen: 1,041 kJ/(kg K)
  - Water: 4,178 kJ/(kg K)
  - CO_2 (in liquid state): ca. 3,0 kJ/(kg K)
- The big **cooling effect during expansion** of CO_2 contributes considerably to the total cooling.

Density of carbon dioxide

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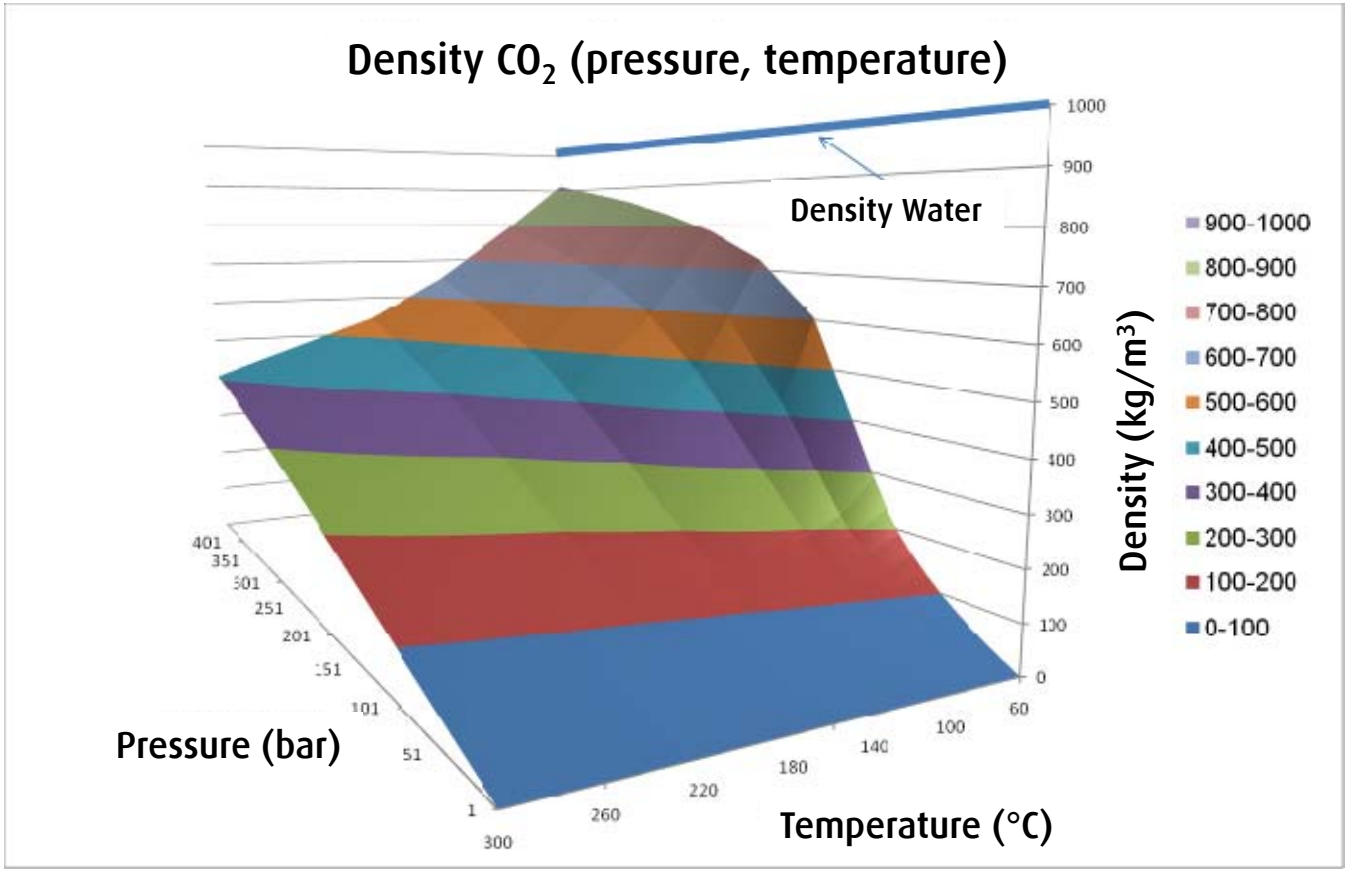
- At approx. 150 bar and higher the density of CO_2 is very high, offering the best cooling performance.
- The higher the pressure, the better the cooling and the cycle time reduction.



PLASTINUM® Gas Injection Moulding with CO_2 Process flow

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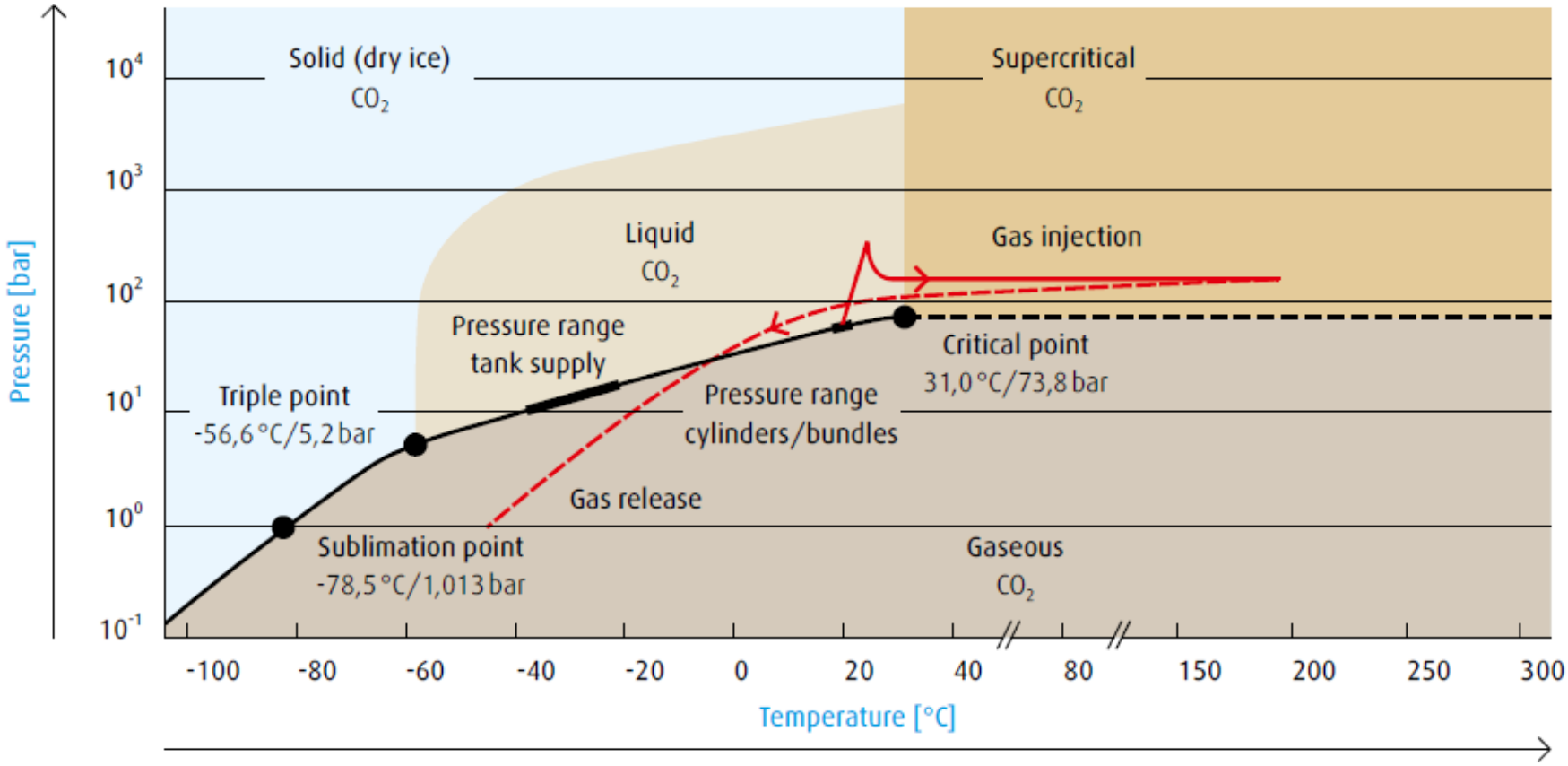
CO_2 phase diagram



The use of liquid CO_2 for GIM at pressures of at least 150 bar is patented by Linde (European patent EP 2474405, patent in China granted, patent application in US).

Advantages

- Excellent cooling properties
- Absolute **dry** process, i.e.
  - no drying / draining of the parts required
  - no problems in case of leakages or breakthrough /bursting of the parts
  - use of conventional tool steels
- Easy process control compared to water injection technology
- The required GIM equipment is not more complex than that for nitrogen, just adopted for carbon dioxide.
- No special polymers required

=> Significantly shorter cooling times compared to GIM with nitrogen

=> Cycle times comparable to or shorter as with Water injection technology

Required equipment, what has to be considered

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- Supply and pressure boosting of liquid CO_2
- Pressure control equipment optimized for liquid CO_2
- Gas injectors (crucial for successful use of CO_2)
  Good results with suitable injectors with annular gaps as well as with actively movable injectors (cross sections and design must be optimized for CO_2)

CO_2 compressor control module (manufacturer: Maximator)

CO_2 supply and equipment concept

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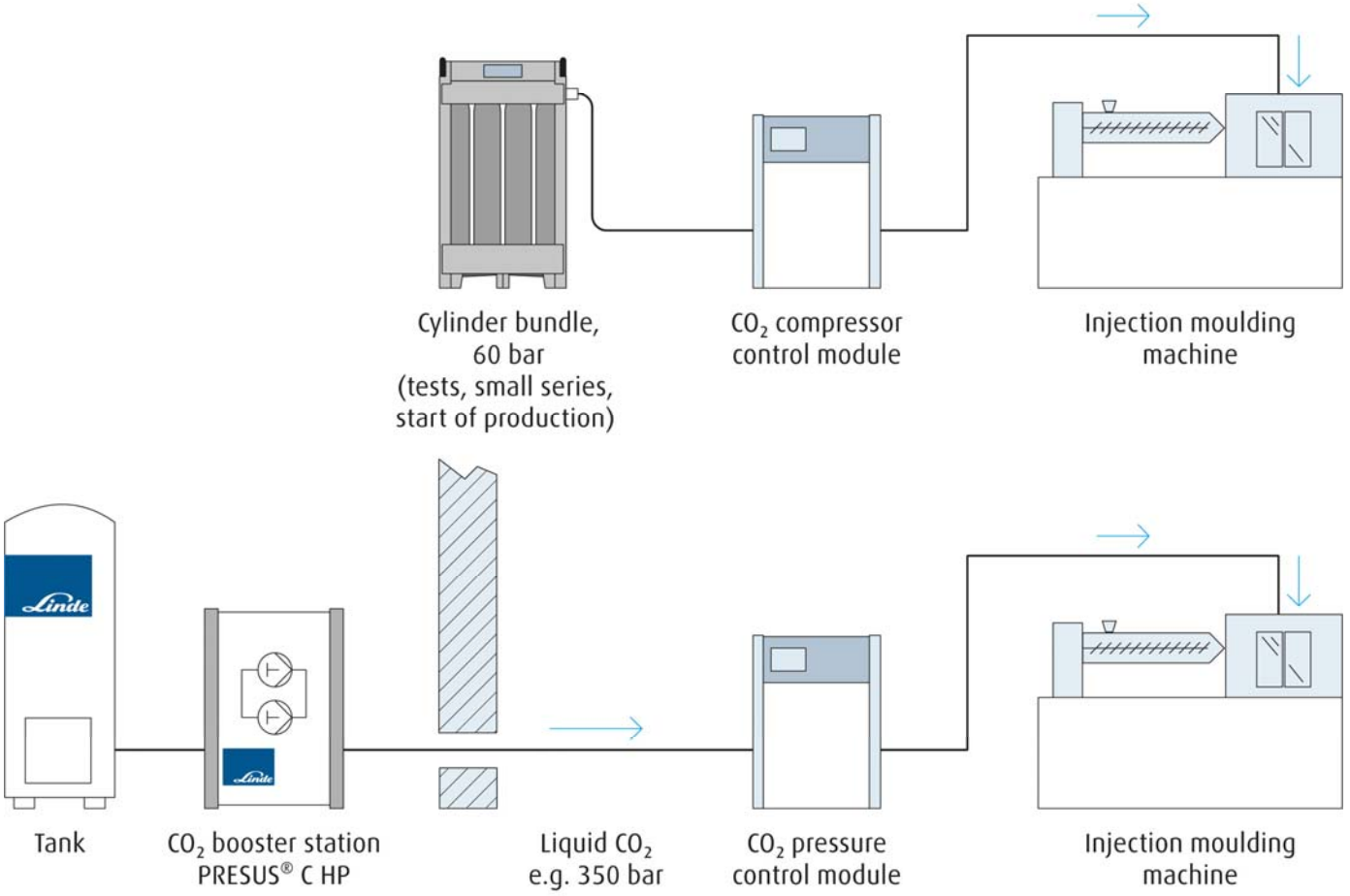
Small series – large volume production



Customer references – suitable parts

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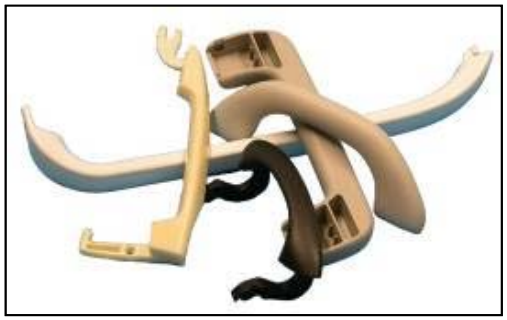
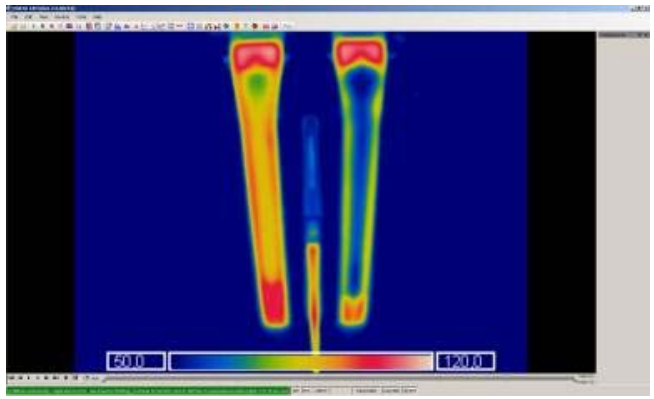
- Refrigerator handles
- Car door panels
- Various car door handles (exterior and interior)
- Bike racks
- Fluid pipes
- Window handles
- Positive tests with many other parts



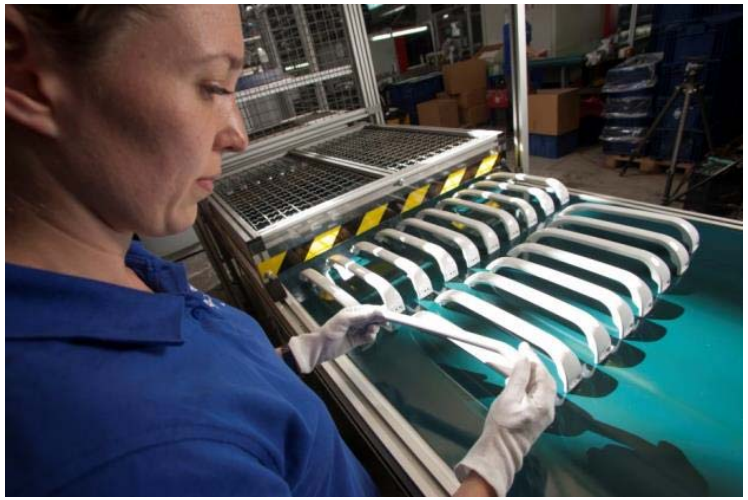
Case study: Refrigerator handle

Company: Engel Formenbau und Spritzguss GmbH, Germany
Material: ABS
Process: Push back

Cycle time reduction with CO_2: 36 %



IR picture 16 sec after mould opening
Left handle: N_2 – Right handle: CO_2



Gas Injection Moulding with CO_2
At a glance

- Significant reduction of cooling and cycle times compared to conventional GIM with nitrogen
- Gas Injection Moulding with CO_2 combines the benefits of water injection technology with the advantages of gas injection with nitrogen
- Retrofitting of existing products usually possible
- Process similar to nitrogen process
- Process equipment (pressure control modules) and gas injectors similar to nitrogen equipment

Thank you very much for your attention !

Visit us in Hall 4, Stand F79