TECHNISCHE UNIVERSITÄT DRESDEN

**Faculty of Mechanical Science and Engineering** Bitzer Chair of Refrigeration, Cryogenics and Compressor Technology

# Efficient Transcritical $CO_2$ cooling

## Investigation on efficiency increasing methods for transcritical R-744 refrigeration systems

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## Introduction

The efficiency (COP) of transcritical carbon dioxide ($CO_2$, R-744) refrigeration systems decreases significantly at high ambient temperatures. This makes these systems unattractive for warm and hot climates. As the physical properties of $CO_2$ are suitable for different means of increasing a cooling systems efficiency, a variety of methods are compared within one system.

| parameter | System operating range |
|---|---|
| Evaporation temperature | -20°C to +5°C |
| Cooling capacity | 4 to 55 kW |
| Maximum electrical compressor power | 25 kW |
| Nominal subcooling capacity (@22°C) | 35 kW |
| Maximum intermediate pressure | 90 bar<br>55 bar using parallel compression |

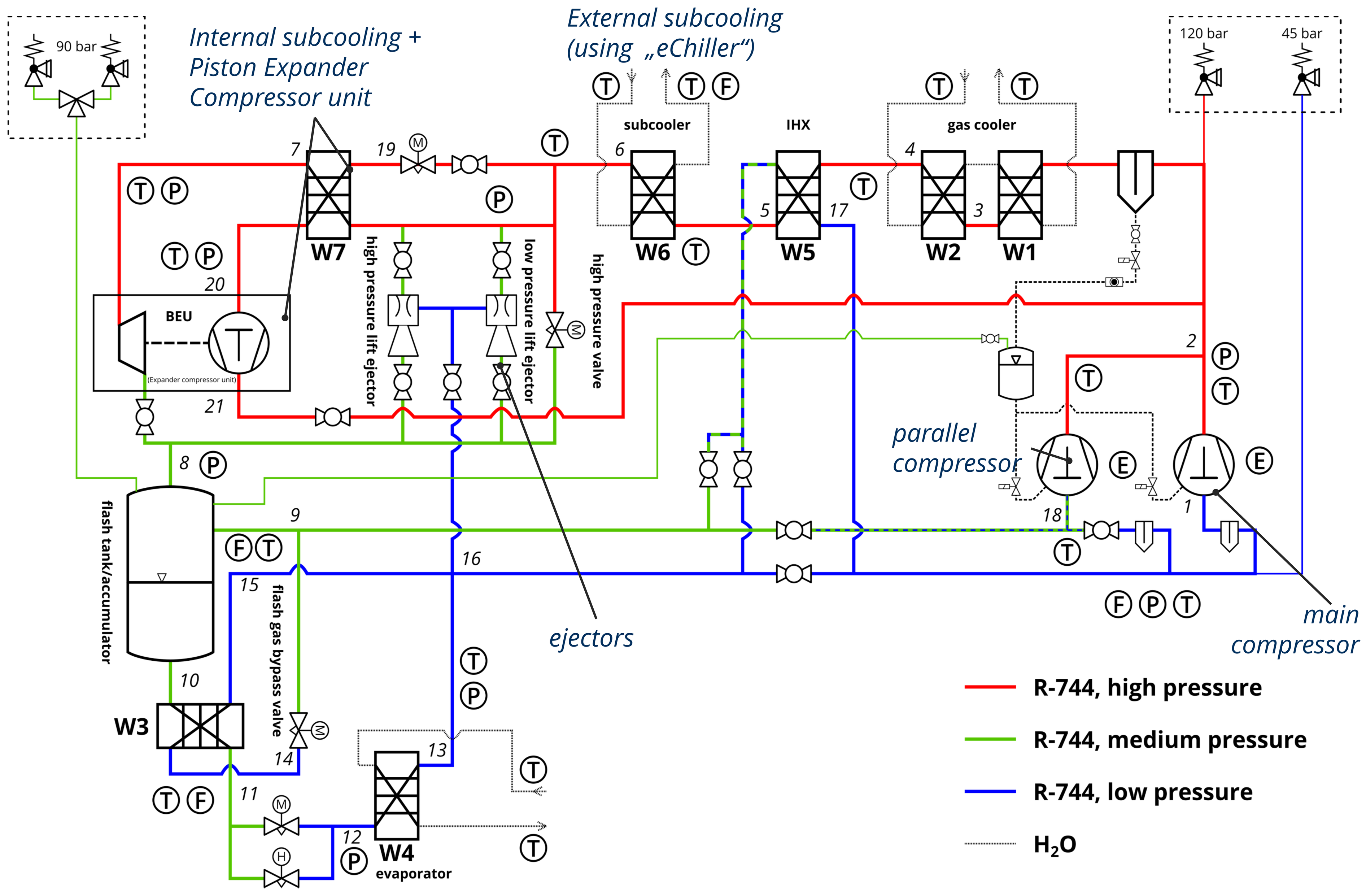


Fig.. 1: PID of R-744 refrigeration system

## Investigated technologies

The transcritical $CO_2$ laboratory refrigeration systems is based on a small commercial system for supermarket cooling and is equipped with additional measurement instrumentation like Coriolis mass flow meters and electrical power measurement for each inverter driven compressor.

The baseline system consists of a main compressor (medium temperature/normal cooling), a gas cooler, high pressure valve, flash tank, flash gas bypass valve and an evaporator with another expansion valve. Furthermore it is equipped with an oil management system.

For increasing the efficiency a parallel compressor is installed, which compresses the flash gas with a smaller pressure ratio than the main compressor and therefore requires less power.

Ejectors can be used to shift load from the main compressor to the parallel compressor. By using expansion work, some gas from the evaporator (low pressure) is recompressed to the flash tank (intermediate pressure).

The expansion work can be also recovered by the expander compressor unit. The gained work is used for compressing a small mass flow for internal subcooling after the gas cooler. This partial mass flow is taken after the gas cooler and throttled with an expansion valve. Afterwards it evaporates and leads to a subcooling of the main mass flow. The main mass flow is expanded in the expander part, whereas the partial mass flow is recompressed to the gas cooler pressure in the compressor part of the expander compressor unit.

Another way of subcooling can be achieved by means of an external chiller. In this experimental system, the "eChiller" is used, which is a chiller unit using water as natural refrigerant. It supplies the subcooler heat exchanger with chilled water down to 14 °C, which leads to a subcooling of the $CO_2$ up to 20K. At small cooling capacities, the system can also work as a subcritical cascade system. A cold water storage can be used for shifting loads or providing a peak load boost.

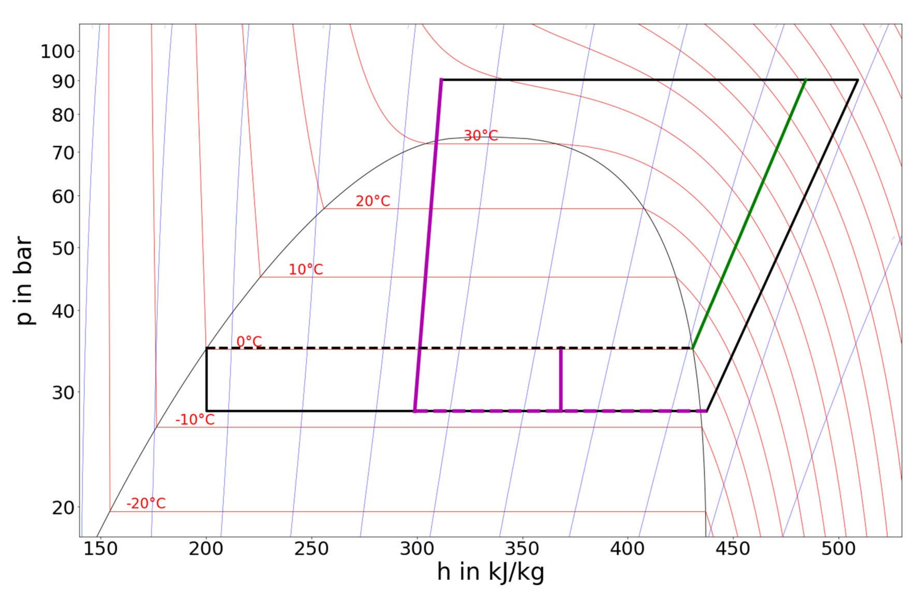


Fig. 2: Cooling cycle using high pressure lift ejector (violet) and parallel compression (green)

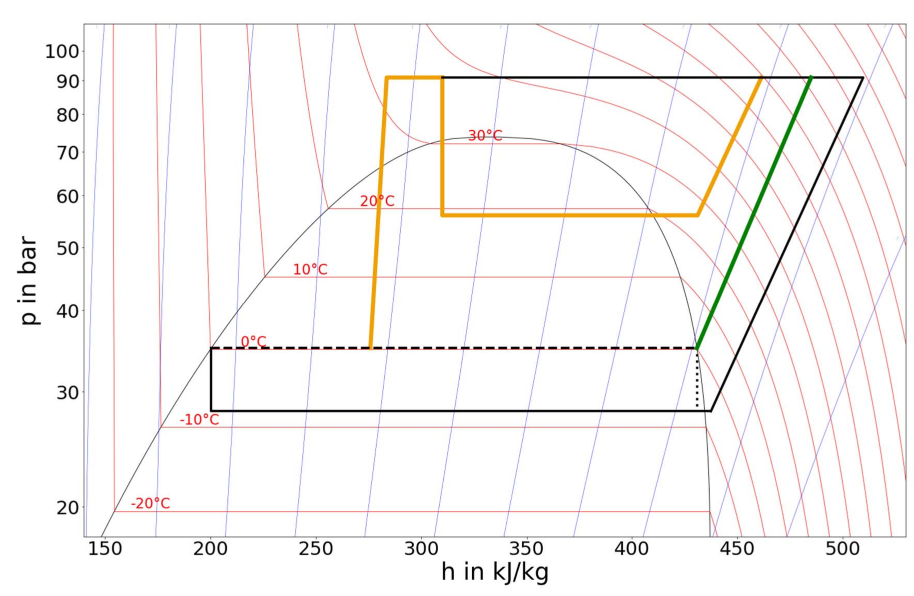


Fig. 3: Cooling cycle using expander-compressor-unit (orange) and parallel compression (green)

## Conclusions and outlook

The presented system provides a broad variety of system designs for being tested and compared against each other. Adding components to the basic system layout promises an increase in cooling capacity and in COP respectively. Using water loops allows an independent adjustment of the operating conditions.

By using the additional components and methods, the efficiency of R-744 refrigeration and cooling systems can be improved significantly. This makes R-744 refrigeration able to compete with systems using conventional refrigerants.


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