Practical aspects of low superheat control
- experimental test of a CO$_2$ system

Chillventa 17OCT18

Jörgen Rogstam
EKA - Energi & Kylanalys AB
Project partners

- EKA
- Wedholms
- GREEN & COOL
- effsys EXPAND
- Swedish Energy Agency
- ALFA LAVAL
- HB Products
- VM PUMPAR

Resurseffektiva kyl- och värme pumpssystem samt kyl- och värmelager

2018-10-22 Jörgen Rogstam
Agenda

• Background
• Application
• Superheat control
• Refrigeration system design
• Results
• Conclusions
• Develop a direct refrigeration system for farm based milk cooling comprising:
  – CO2 refrigeration system
  – Heat recovery function (> 75°C)
  – Evaporator w/ design pressure (> 80 bar)
  – Controls (combined cooling & heating)
• Milking robot and milk cooling tank
  – Robot milking provides an even flow of milk to the tank
• Evaporator integrated in the milk tank
• Direct refrigeration system and tank with integrated evaporator!
  – Fed from the bottom
The milk tank is filled up during 48 hours
  - Offers control challenges – a part of the evaporator is "not active"
Application requirements

• Natural refrigerant – CO2
• Robust system design and function
• Integrated evaporator (direct system)
  – Minimum stand still pressure 80 bar

• Evaporator design challenges
  – Pressure rating
  – Size
  – Cost
  – Oil return
  – Charge
  – Pressure drop
  – Manufacturing
  – ……….
Why low superheat?

- Temperature profile in an evaporator*
  - Two regions – boiling and superheat
  - Less superheat – lower temperature difference

- Milk cooling:
  - Evaporation temperature – ”not to freeze the milk”: > -2°C
    - Max superheat: ~5K (milk temperature: +4°C)

*J. Claesson, KTH, 2004
Boiling vs. Superheat region (area)

- A significant area is used for superheat*
- "Waste of surface/material"

*J. Claesson, KTH, 2004
How to achieve low/no superheat

• Traditional DX:
  – Compact/short evaporator
  – Improved refrigerant distribution
  – Good control
  – 3-5 K superheat possible but difficult
  – Typical superheat > 5 K

• Flooded evaporator (liquid overfeed) = no superheat
  – More common in large refrigeration systems
  – Liquid to be separated after the evaporator
    • Requires vessels and/or more components
  – Difficult to control the overfeed
  – Increases the charge
• Small scale CO2-system
• Prototype system tested w/ heat recovery
Phase 1 prototype conclusions

- Large charge variations between the high and low pressure side
  - Heat recovery control is challenging
- Expansion in one stage is difficult to manage over a wide range of pressure ratios
  - Expansion valve design is critical
- Liquid separation after the evaporator is challenging with CO2
  - Small difference in liquid and vapour density
- High requirements on internal HEX to superheat or ”knock out” liquid
  - Liquid carry over and temperature difference varies

- At this time (2016) – cost effective CO2 condensing units became commercially available!
Phase 2 goal: condensing unit direct system

- Adapted condensing unit
  - Heat recovery function
- Integrated evaporator
  - Superheat control!
Phase 2: condensing unit + indirect system

- Expansion in two steps
- Better refrigerant control @ heat recovery
- …..but superheat control required….!
The HBX-sensor

- Measures:
  - the vapour quality @ the evaporator outlet, and…
  - …controls the expansion valve..
  - ..to allow a vapour quality close to 1 (or just below)….
  - …consequently (ideally)... 0K superheat!
Test system with HBX-sensor
• 0 K superheat control was achieved!
"Longer term" control was achieved as well

The comparisons were not conclusive at the time for testing
Summary

- The HBX-sensor represents a very interesting evaporator control concept!
- 0K superheat is possible and achieved
- Potential operation with “controlled” liquid overfeed is possible
  - Reduces the charge in the system
- Ideally no liquid separator is necessary
  - Saves cost
- Superheat is achieved in an Internal Heat Exchanger (IHEX)
- Reduces the required evaporator size (surface)
  - A key parameter in this application
Thank you for your attention!