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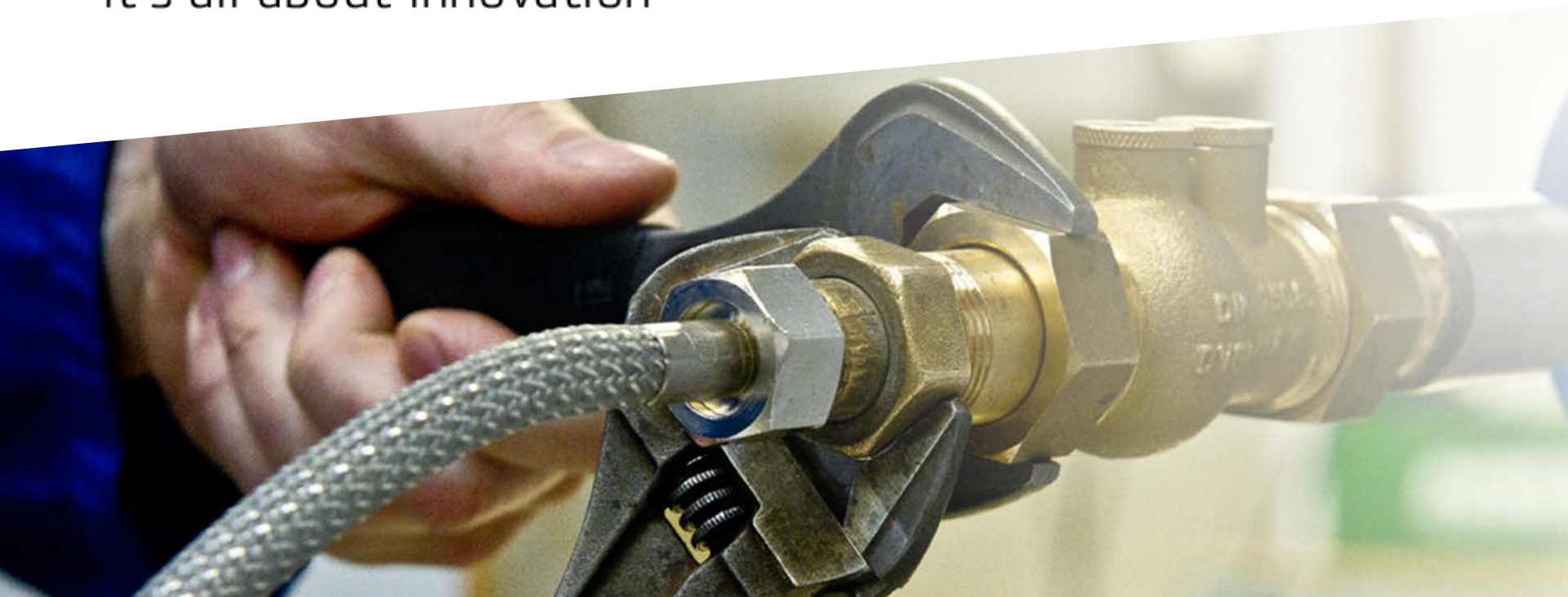
INSTITUTE

# it's all about innovation



# Development of Water Vapor Compressors and future market implementation

Hans Madsbøll, DTI
hm@teknologisk.dk - +45 7220 1263

## IEA Heat Pump Workshop

Danish Technological Instituttet – May 4th 2015

# Water Vapor Compressors

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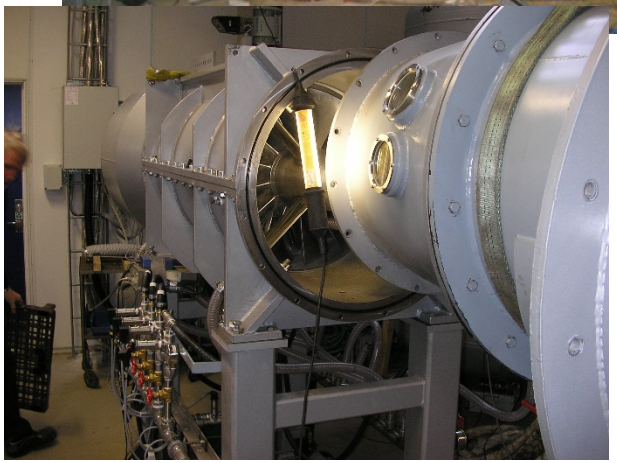
- Two types of prototype turbocompressors developed

Axial



Centrifugal

# Water Vapor Compressors

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Water as refrigerant

- As ‘green’ as it gets
- As safe as it gets

- No global warming effect
- Cheap and easily available
- Non toxic
- Non flamable
- No break-down product
- Low pressure

# Water Vapor Compressors

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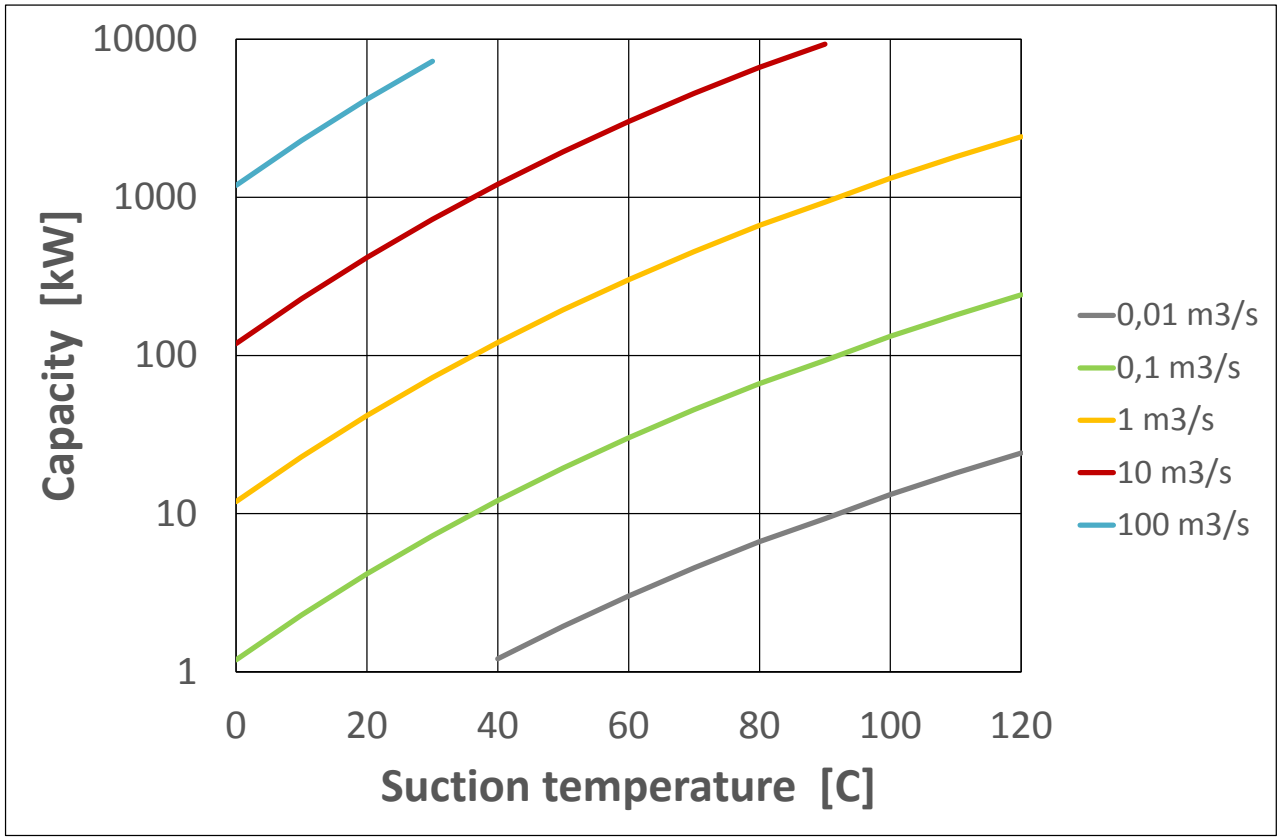
## Water vapor as refrigerant



# Water Vapor Compressors

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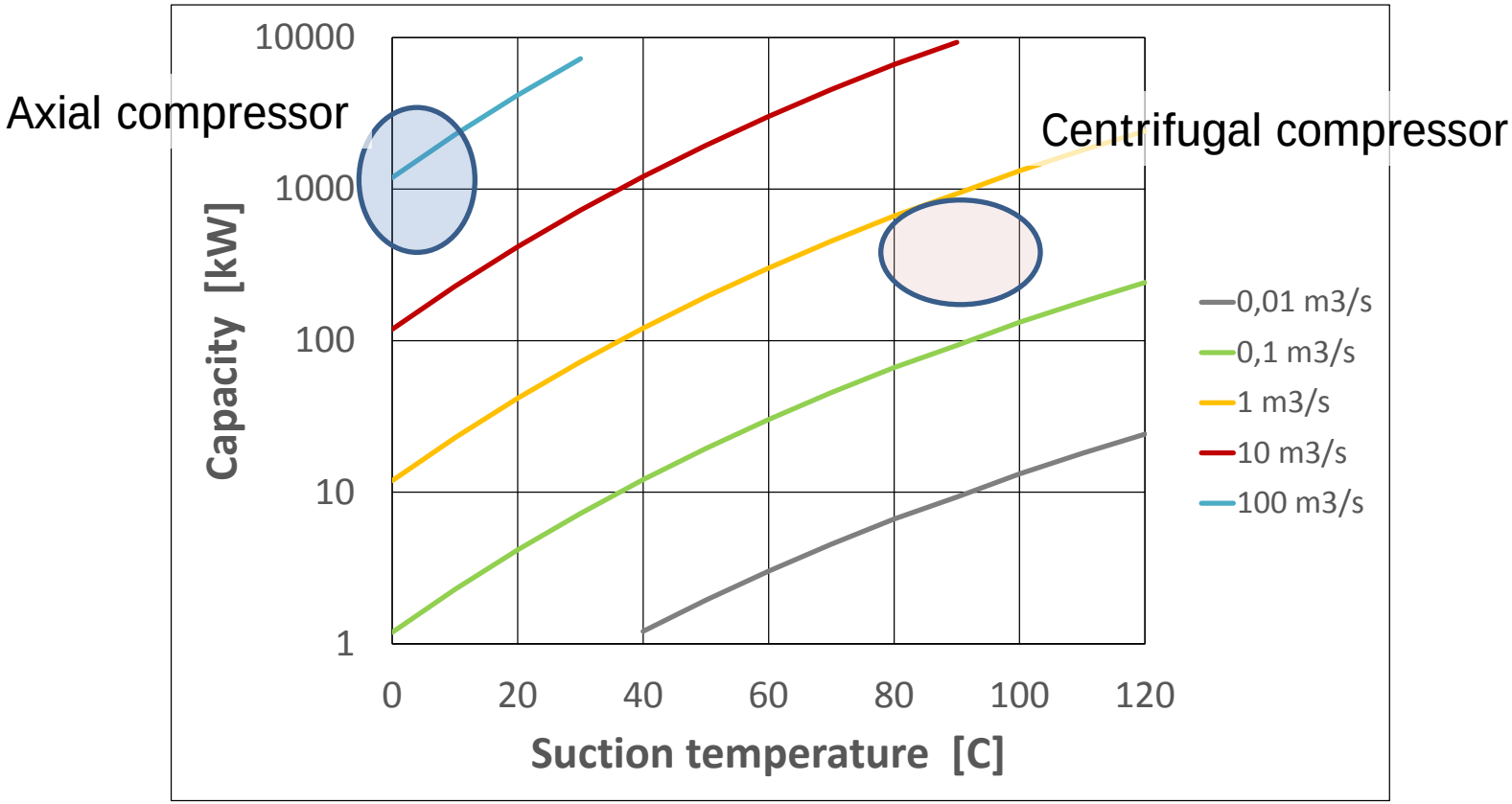
## Water vapor as refrigerant



# Water Vapor Compressors

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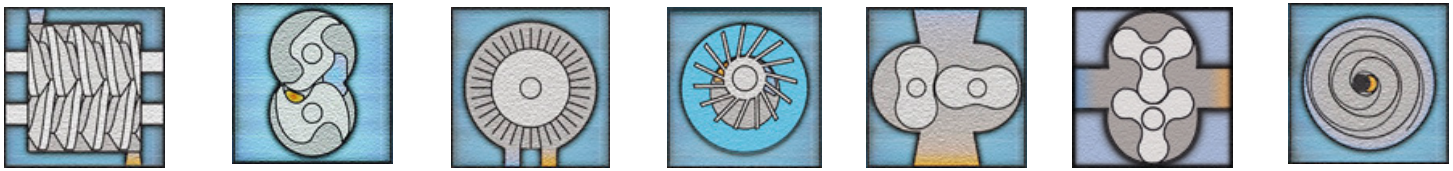
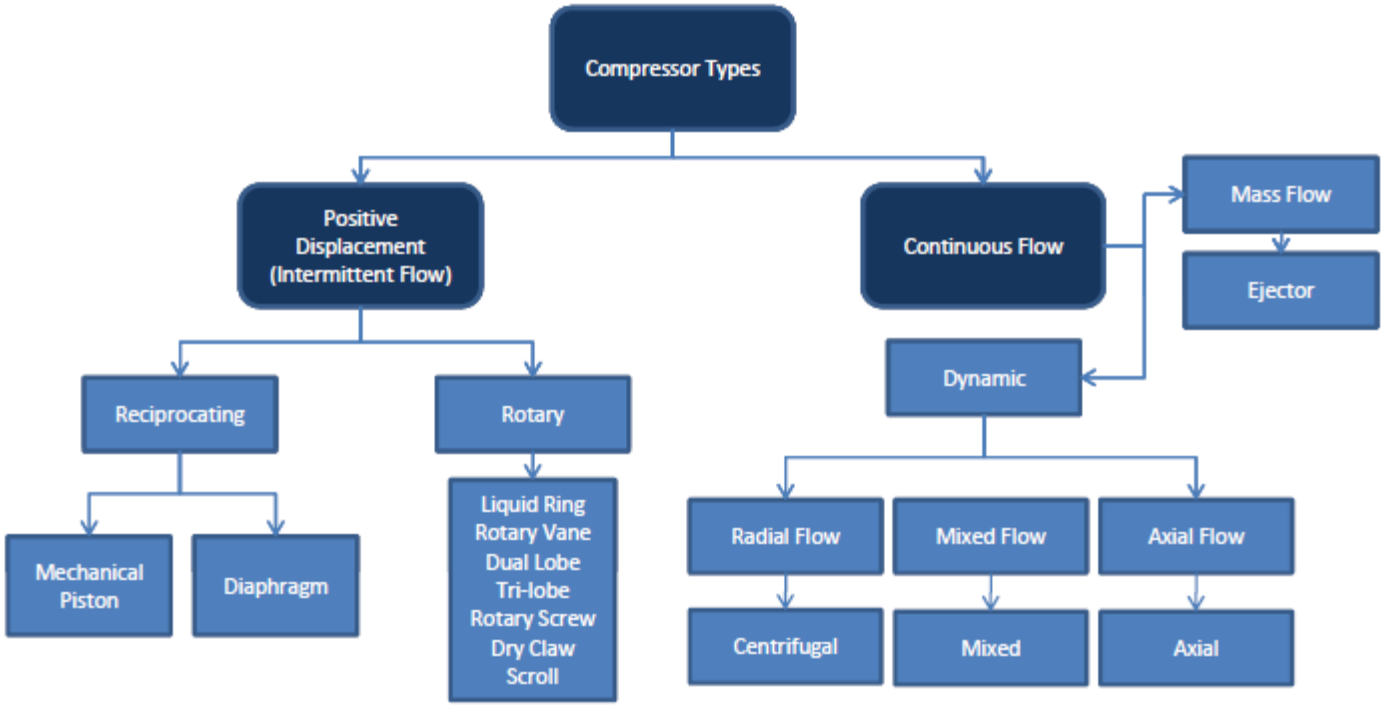
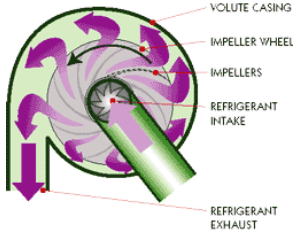
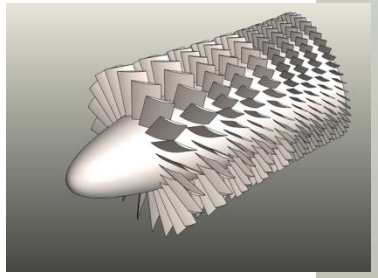
- Feasibility study – identifying optimal compressor type





# Water Vapor Compressors

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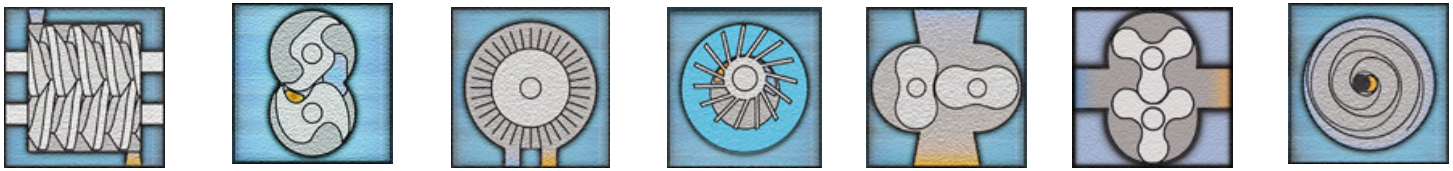
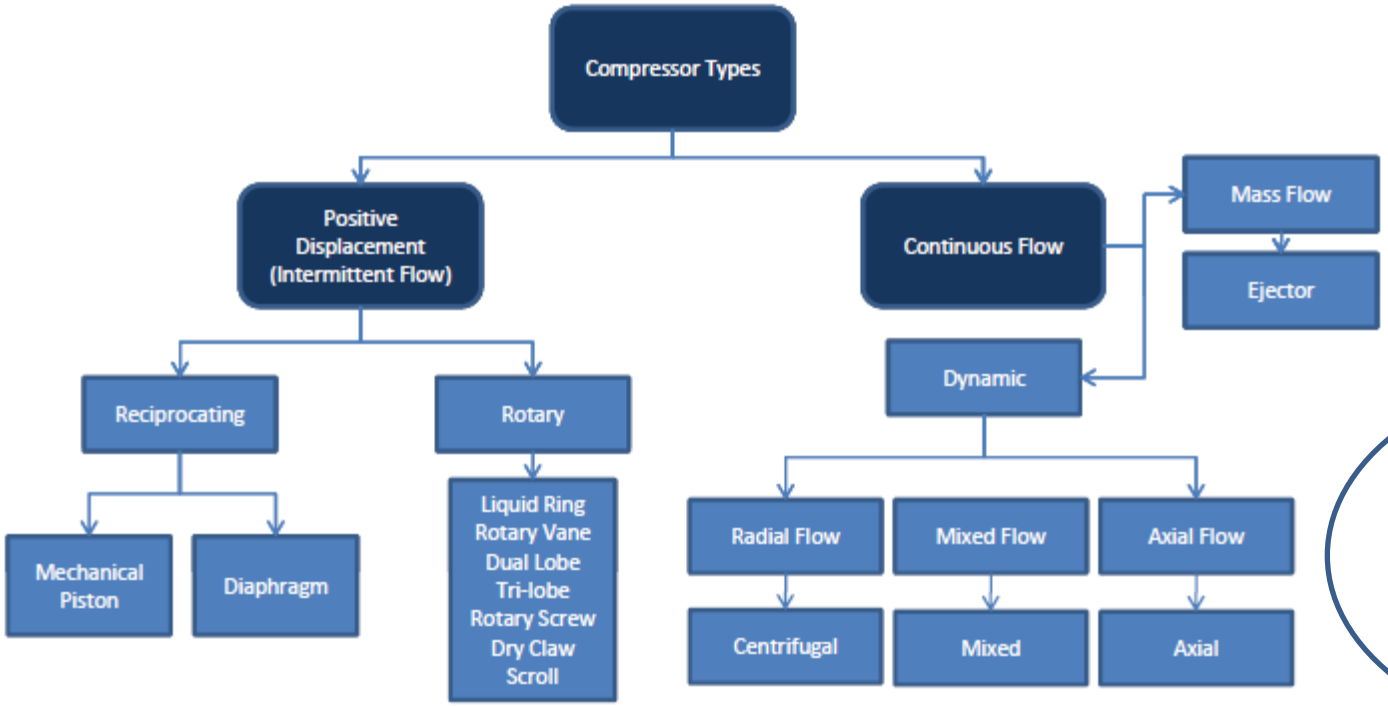
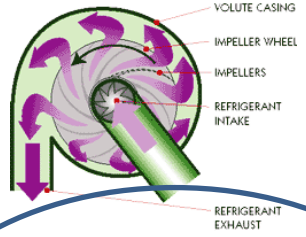
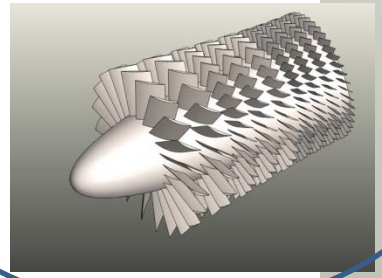
- Feasibility study – identifying optimal compressor type





# Water Vapor Compressors

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- **Axial compressor development process**
- 1998 – 2001 Feasibility study, scaled tests
  - York, DTI (DEA)
- 2003 – 2011 Full scale development of two sizes of prototypes
  - Tokyo, Chubu and Kansai Electical Power Companies, Kobe Steel, DTI, JCD (DEA)
- 2012 – 2016 Commercial chiller development
  - JCD, LEGO, Rambøll, DTI (DEA)
- 2014 – 2016 Evaporator with ice generation
  - DTI, JCD, Augustenborg District Heating, Arla (DEA)

# Water Vapor Compressors

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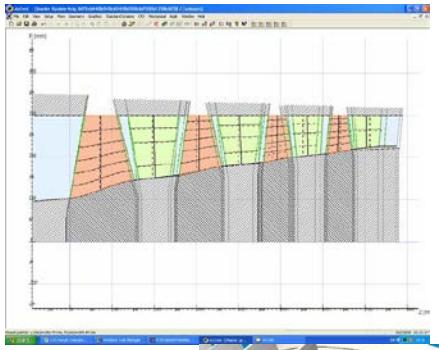
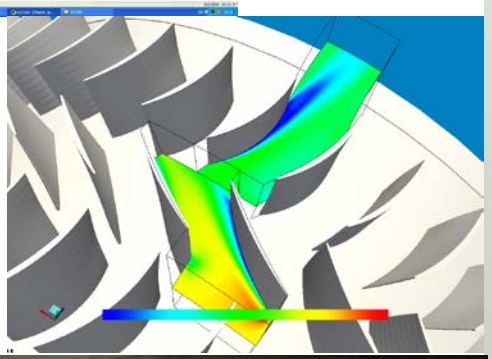
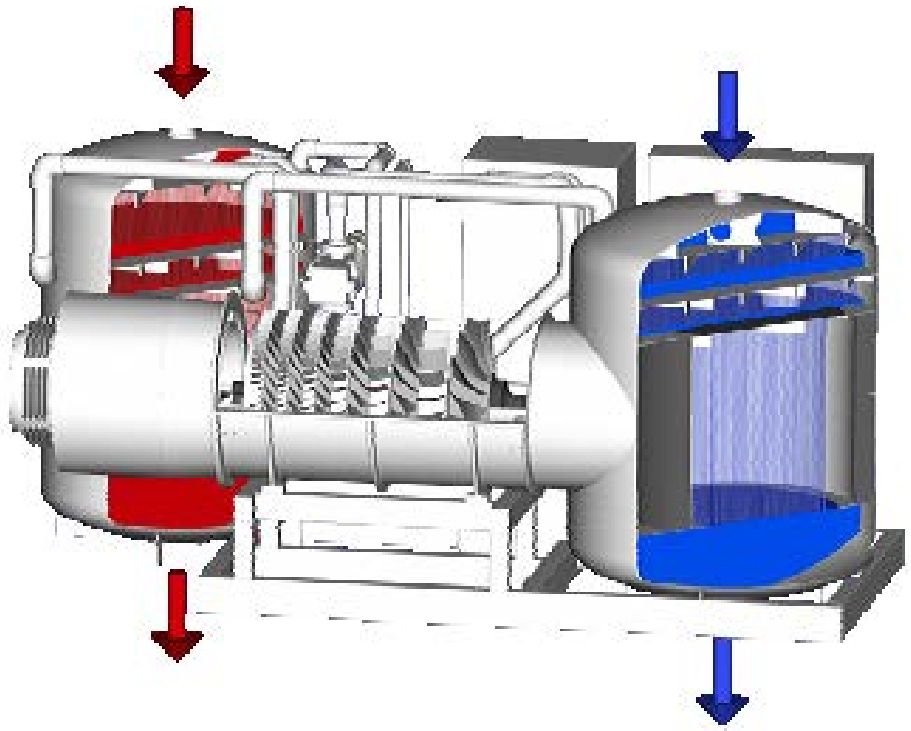
- Axial compressor development process







# Water Vapor Compressors

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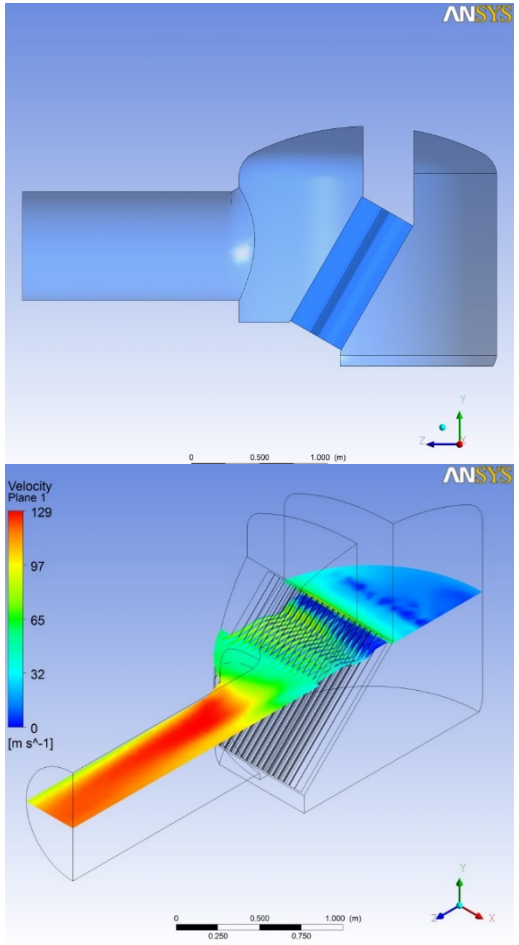
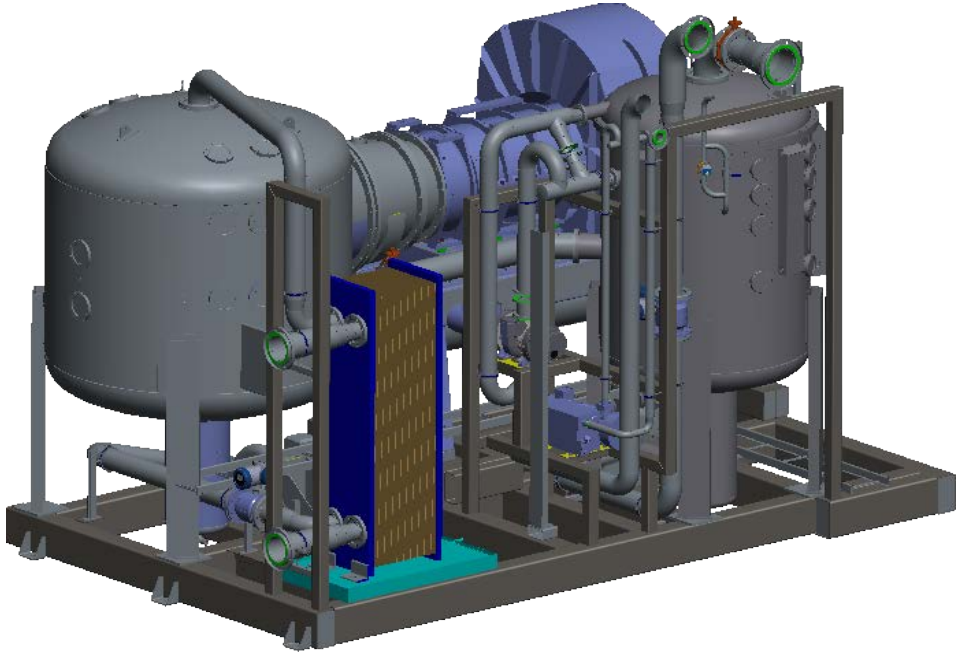
- Axial compressor development process



# Water Vapor Compressors

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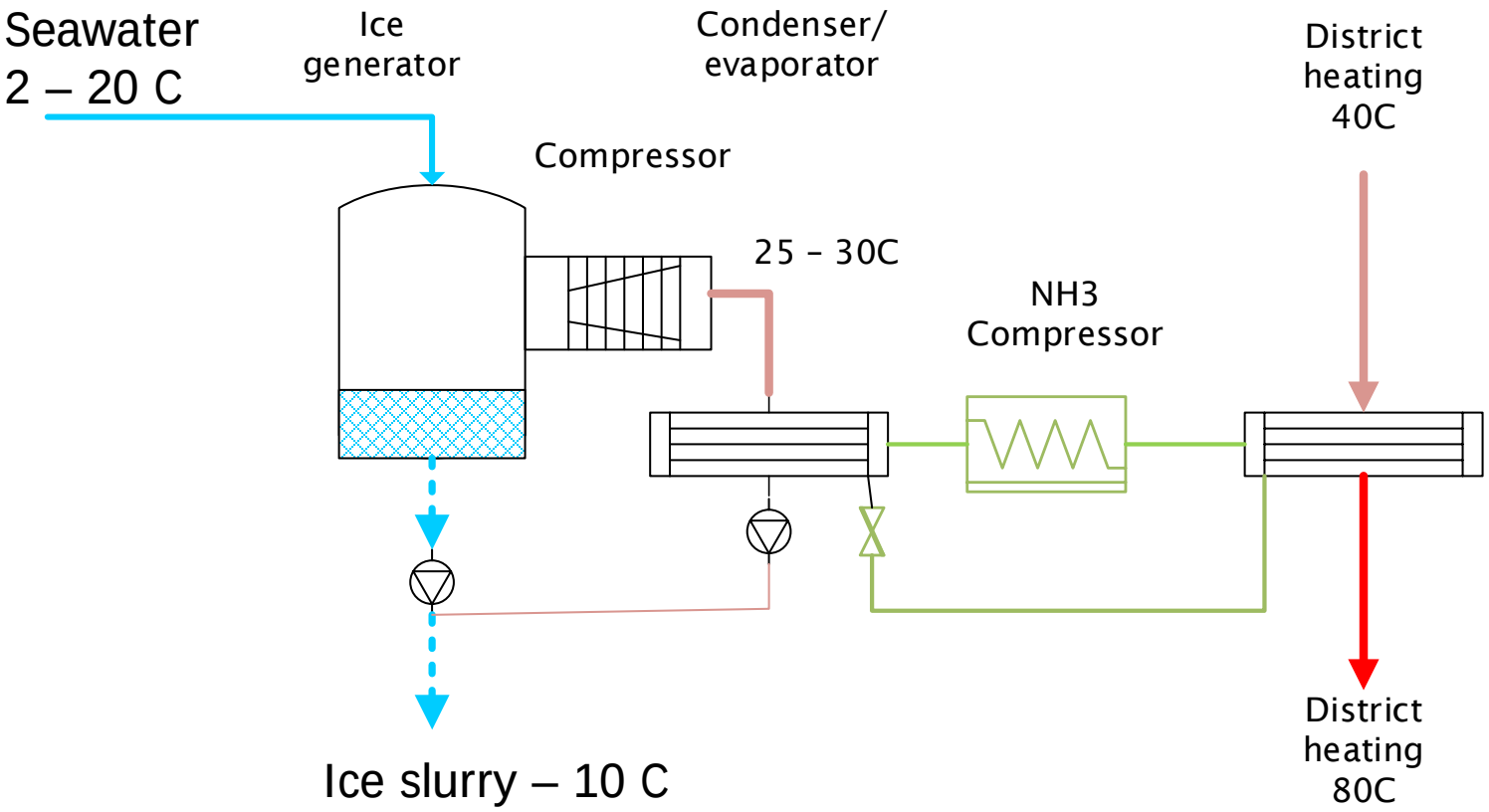
## Augustenborg District Heating – 2MW



# Water Vapor Compressors

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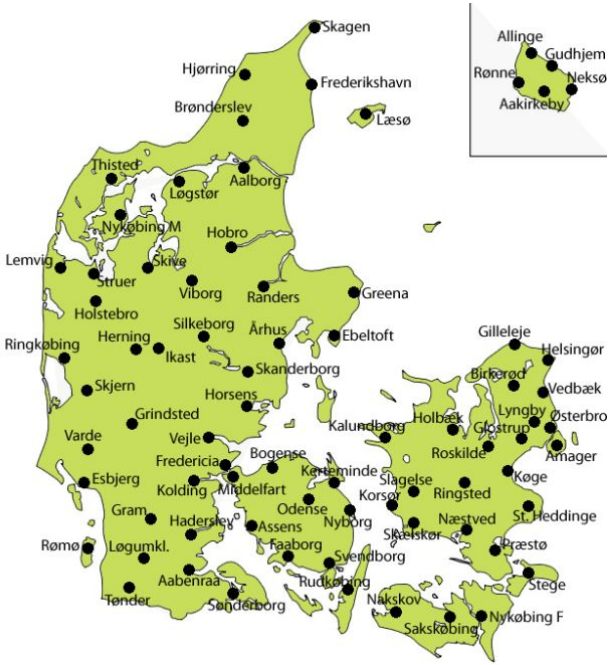
Market potential for sea water based heat pumps

District Heating:

15 – 20 MW per 10000 citizens

DK : 5-7 TW



# Water Vapor Compressors

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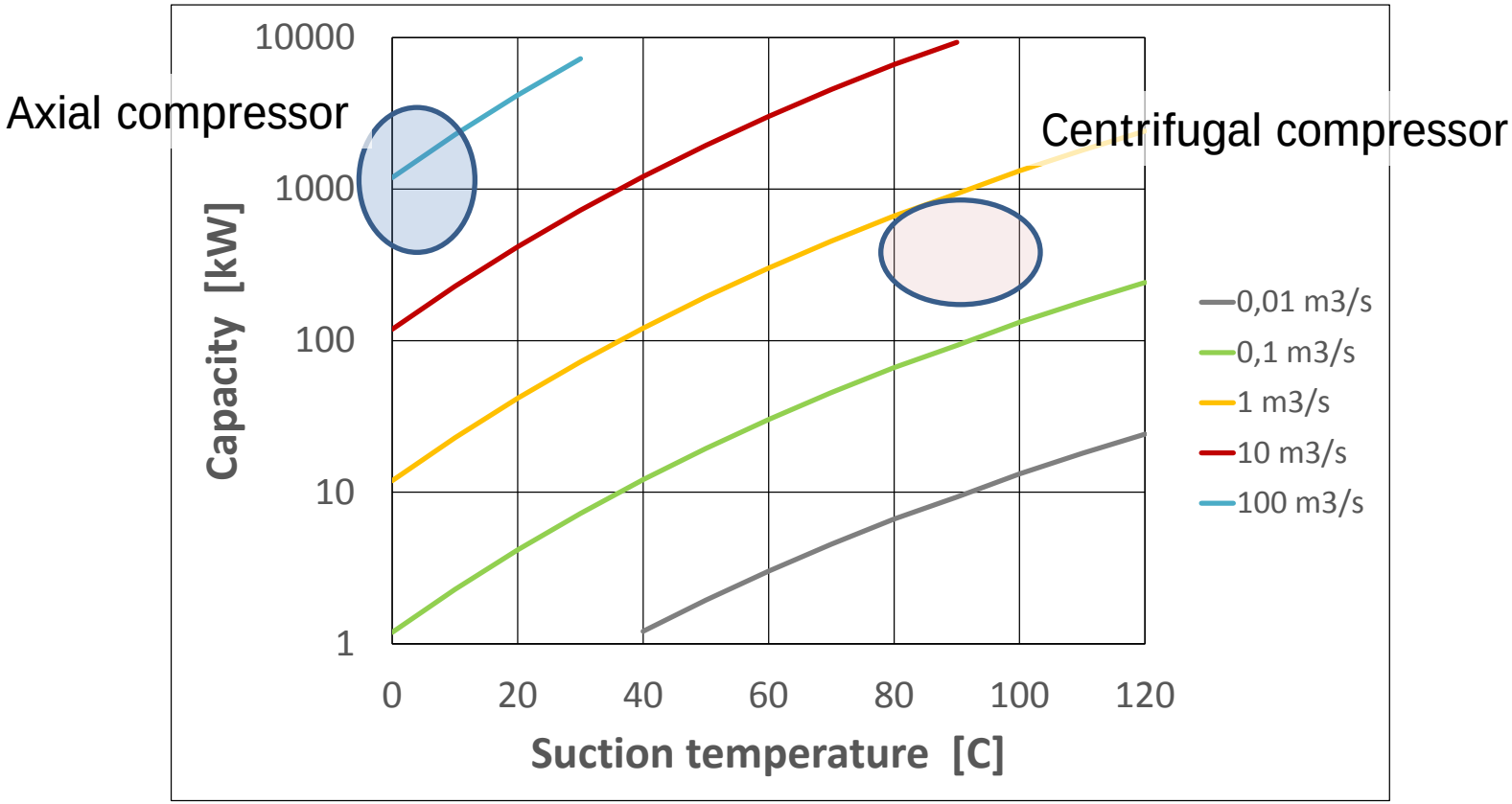
## Water vapor as refrigerant



# Water Vapor Compressors

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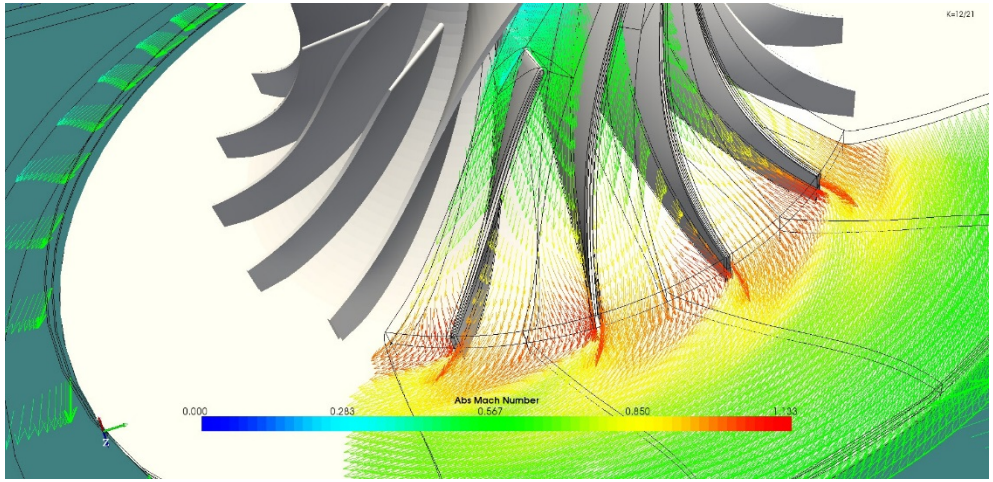
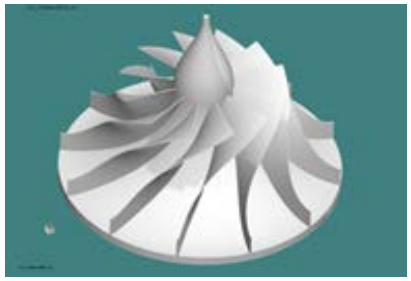
- **Centrifugal compressor development**

- 2012 – 2016 Water vapor compressor based on Rotrex gear
  - DTI, Rotrex, Weel & Sandvig, Spirax Sarco, Xvaporator, Union Engineering, Johnson Controls Denmark



# Water Vapor Compressors

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## Specifications by the project group

| Type of user | Inlet conditions | Capacity | Temperature difference |
|---|---|---|---|
| Heat pump Unit supplier | 65 – 85 C | 100 – 1000 kW | 20 – 30 |
| Steam system supplier | 65 – 144 C | 500 – 1000 kg/h | 15 – 20 |
| Process Industry | 90 - 110 | 100 – 1200 kW | 15 – 35 |
| Waste recovery, concentration | 85 - 110 | 500 – 1000 kg/h | 15 – 20 |
| Process Consultants | 65 - 150 | 0,4 – 3 MW | 15 – 30 |
| Drying consultants | 30 - 130 | 200 – 2500 kg/h | 5 – 30 |

# Water Vapor Compressors

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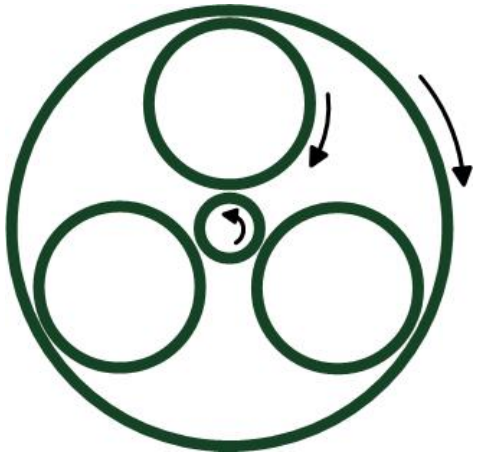
**Rotrex planetary gear**

How it works:



Programme:

C8: 240.000 rpm - 5 kW input power
C15: 200.000 rpm - 15 kW input power
C30: 120.000 rpm - 30 kW input power
C38: 90.000 rpm - 50 kW input power

# Water Vapor Compressors

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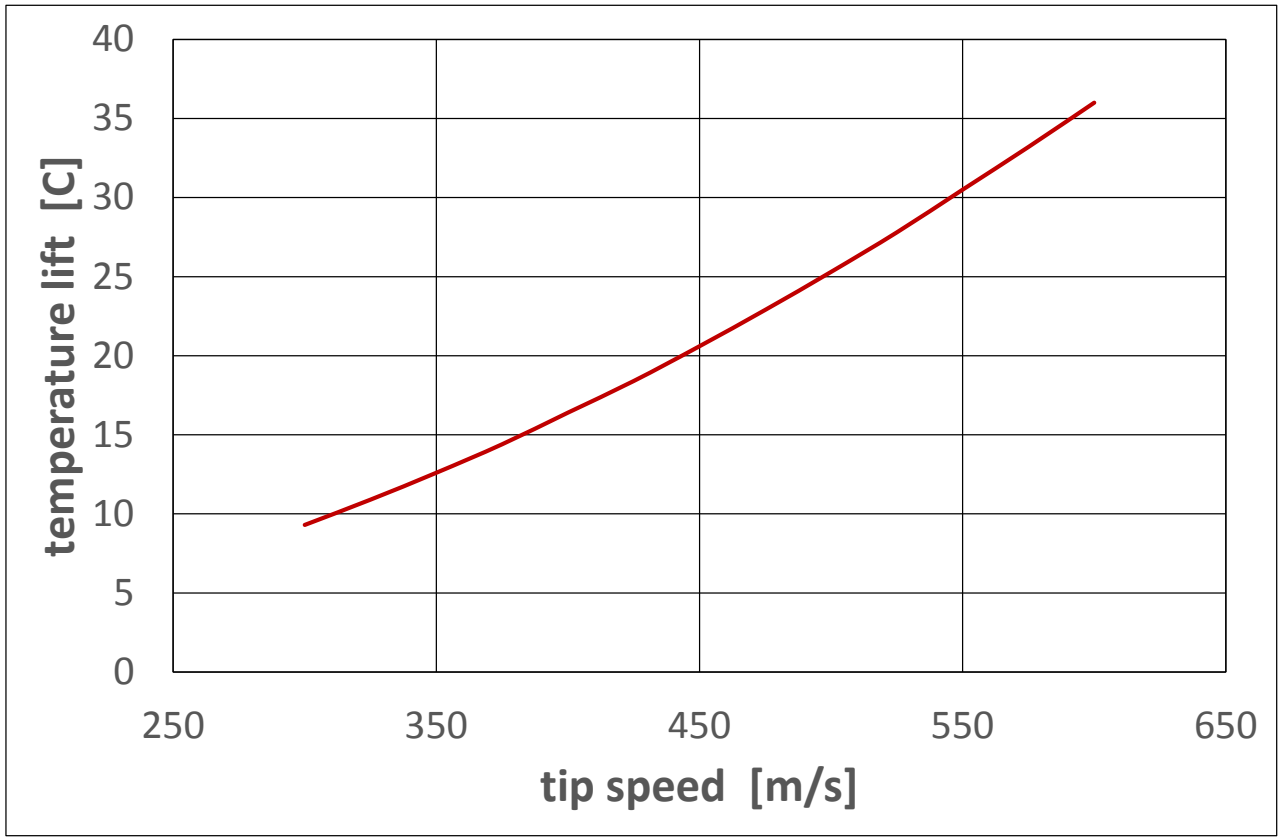
## Water vapor as refrigerant



# Water Vapor Compressors

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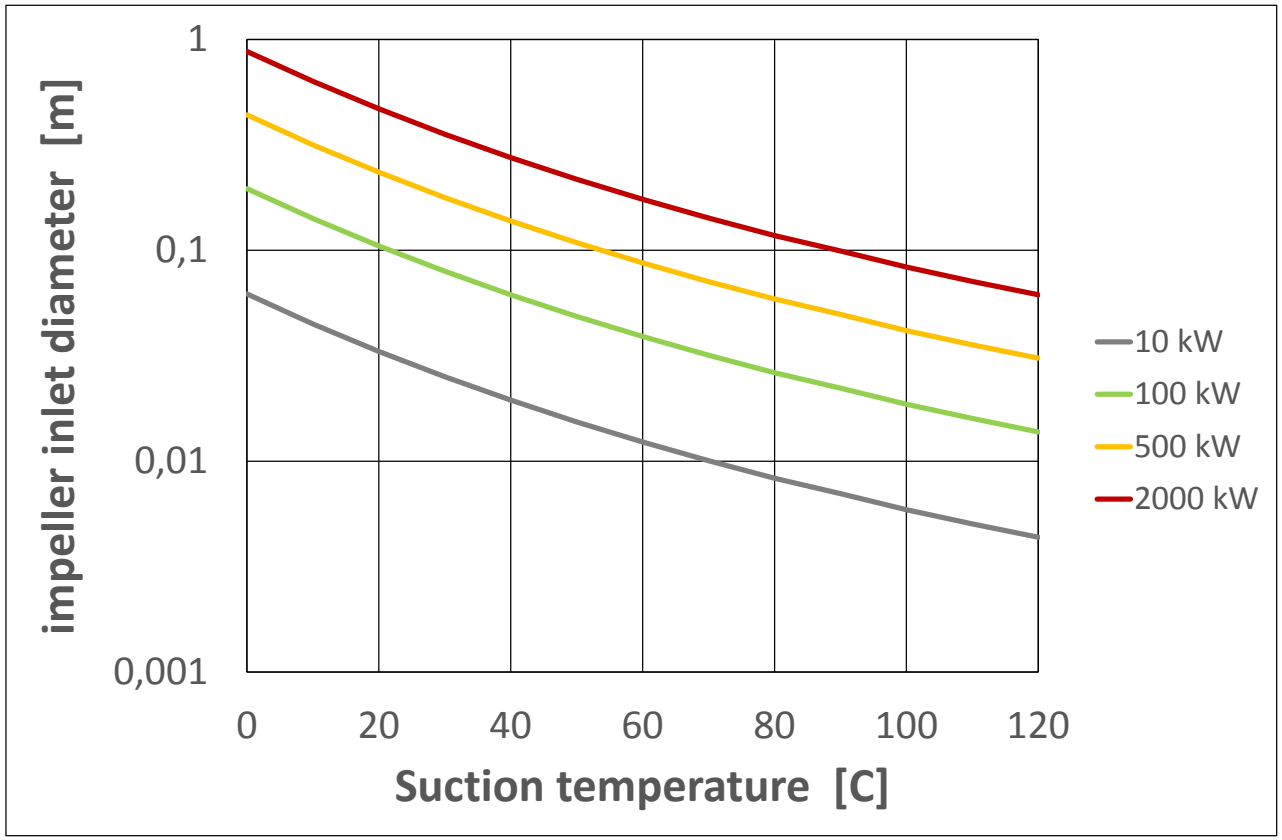
## Water vapor as refrigerant



# Water Vapor Compressors

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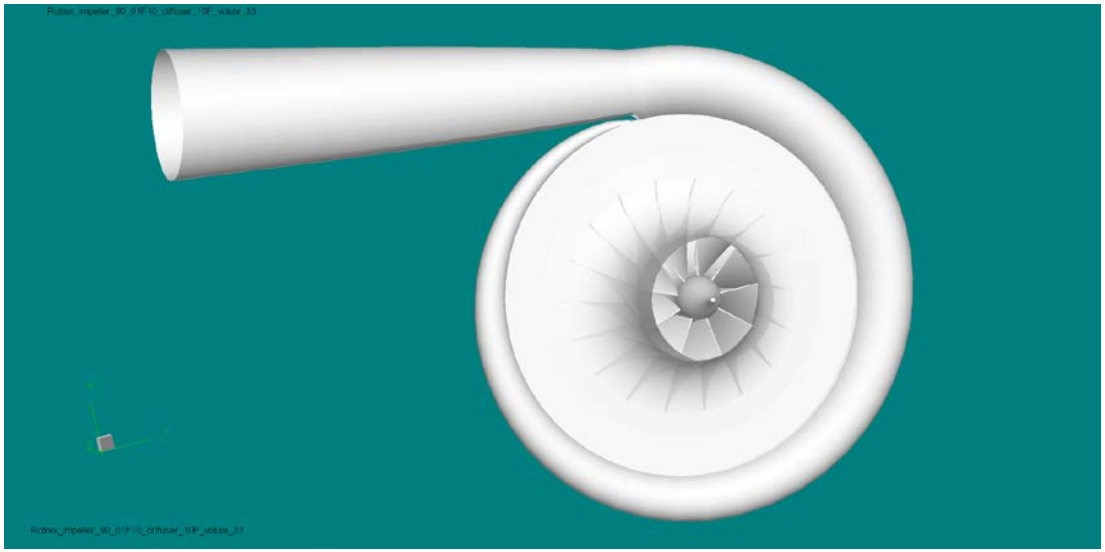
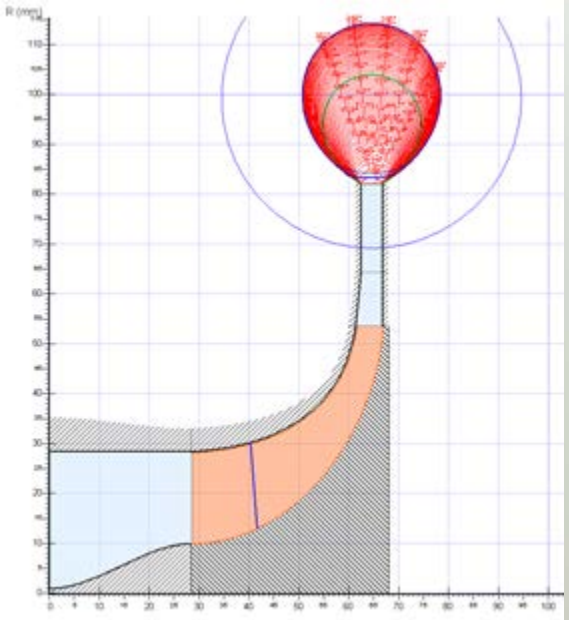
## Final compressor design

Specifications:

| | |
|---|---|
| Speed | 90 krpm |
| PRts | 2.6 |
| dT | 25C |
| Efficiency ts | 75% |
| Volume flow | 0,28 m3/s |
| Capacity at 90 C inlet | 260 kW |





# Water Vapor Compressors

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## Final compressor design

# Water Vapor Compressors

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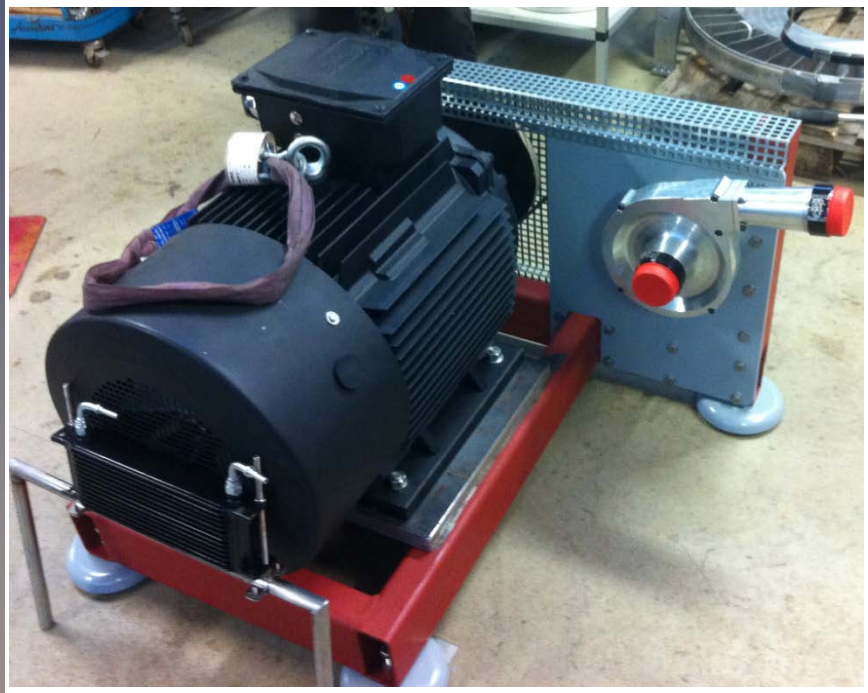
**Testrig configuration at Spirax Sarco and Haldor Topsoe**



# Water Vapor Compressors

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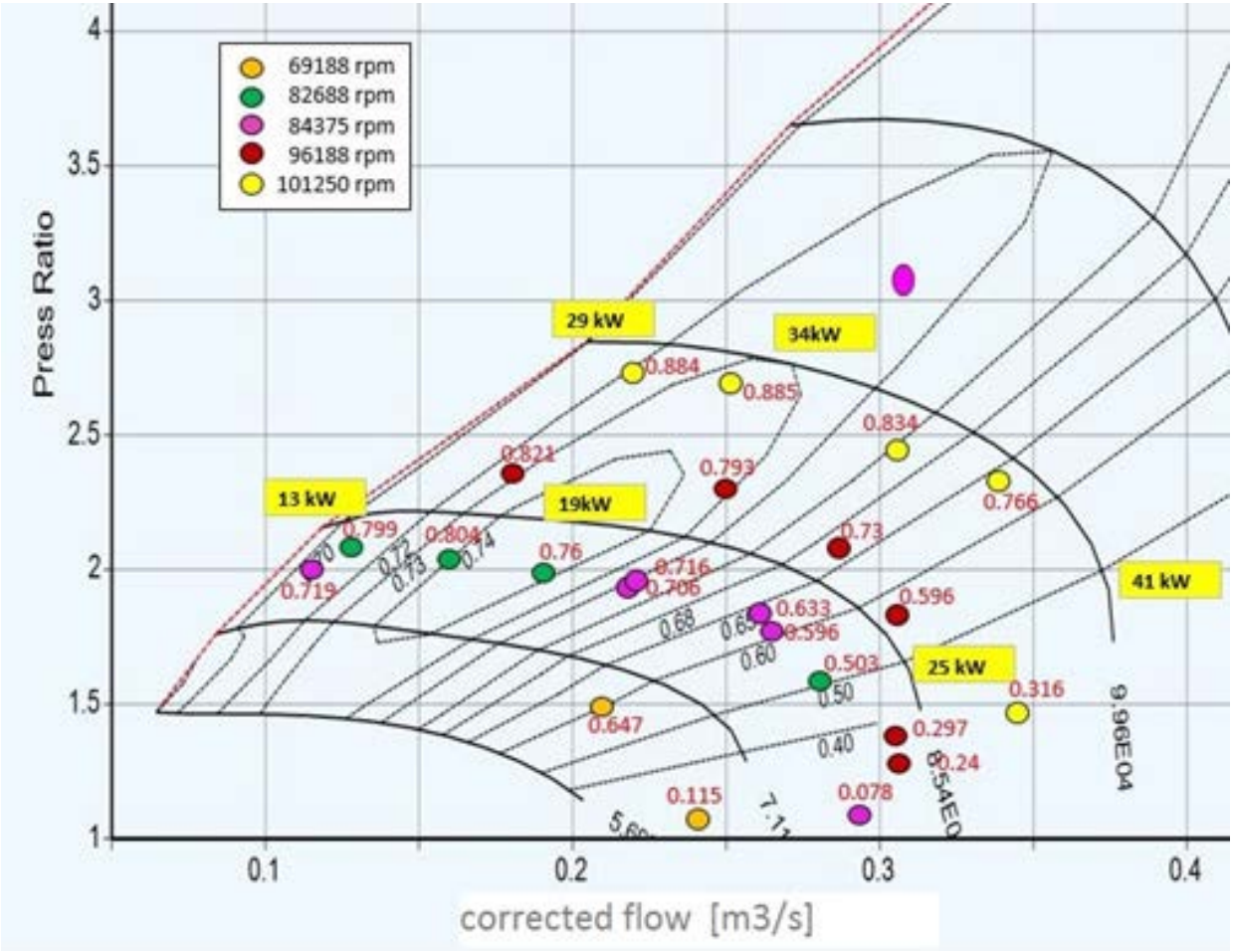
Test results



# Water Vapor Compressors

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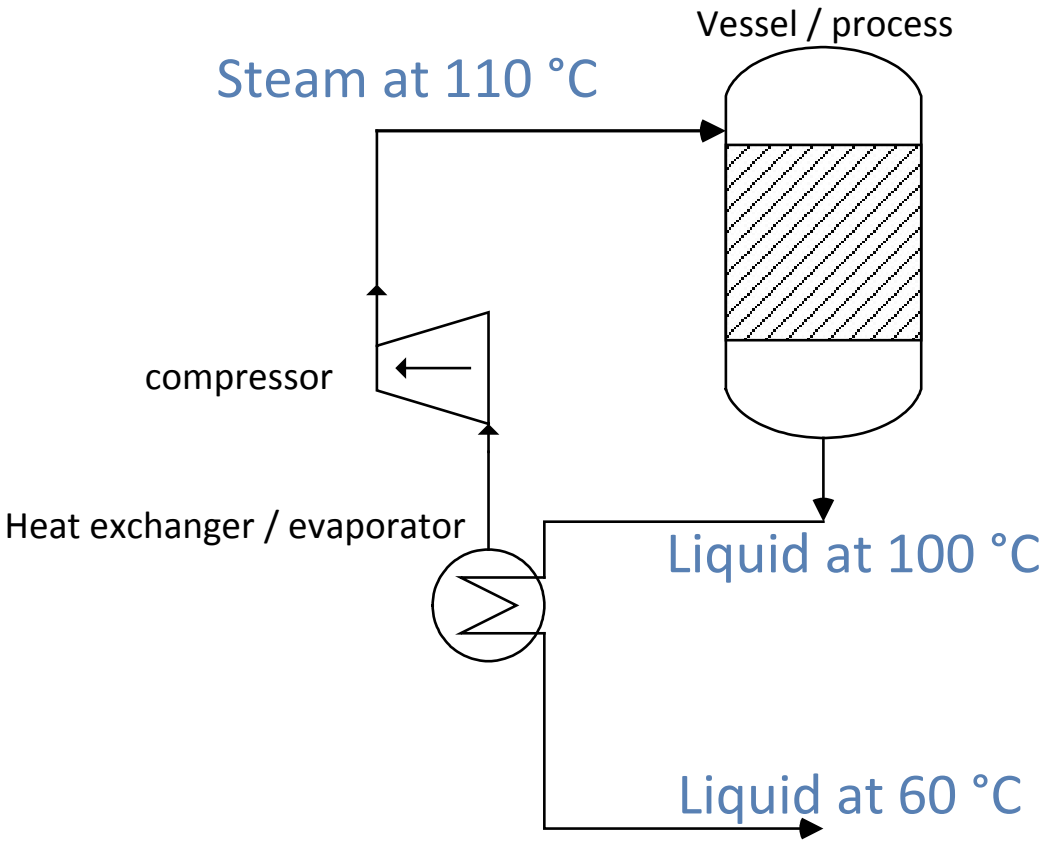
Application example - boiler or steam generator




COP ≈ 4.8

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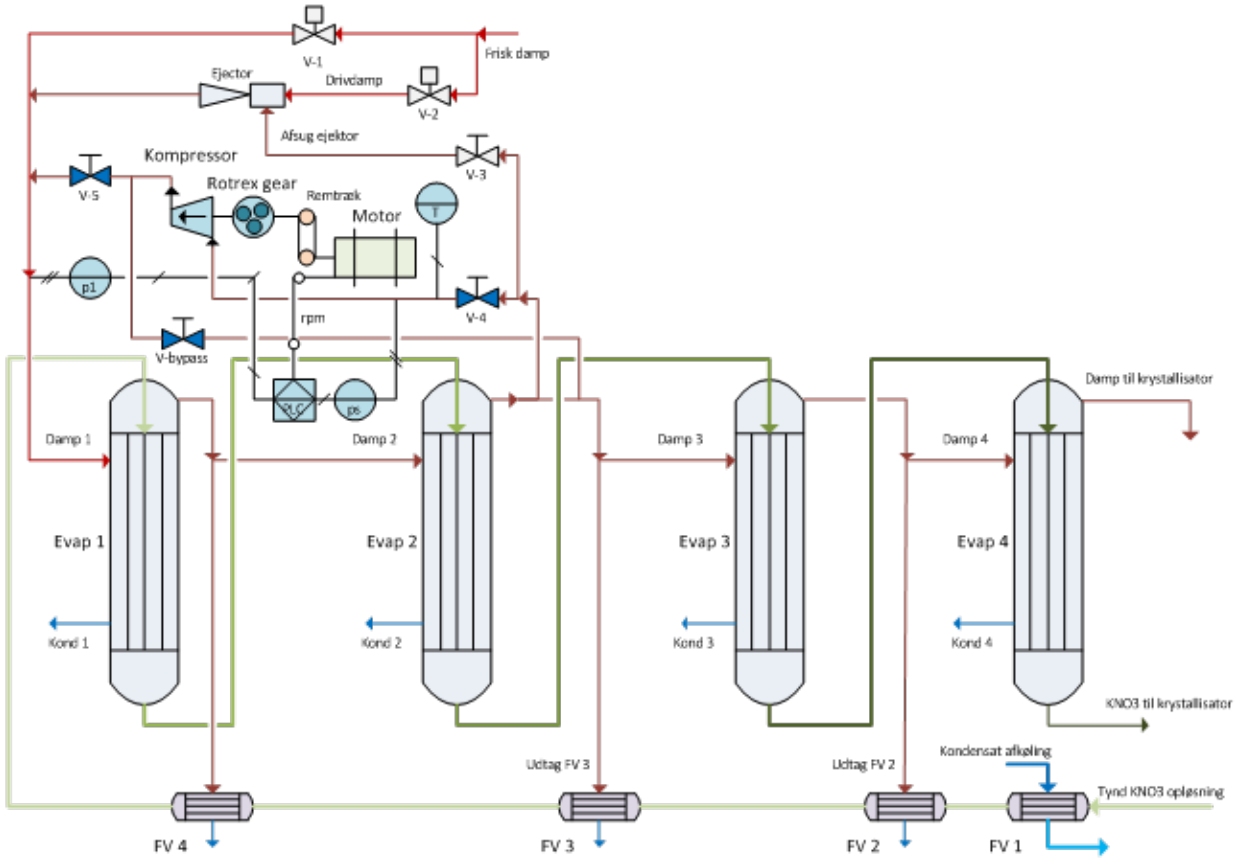
Application example - multi stage evaporation plant



# Water Vapor Compressors

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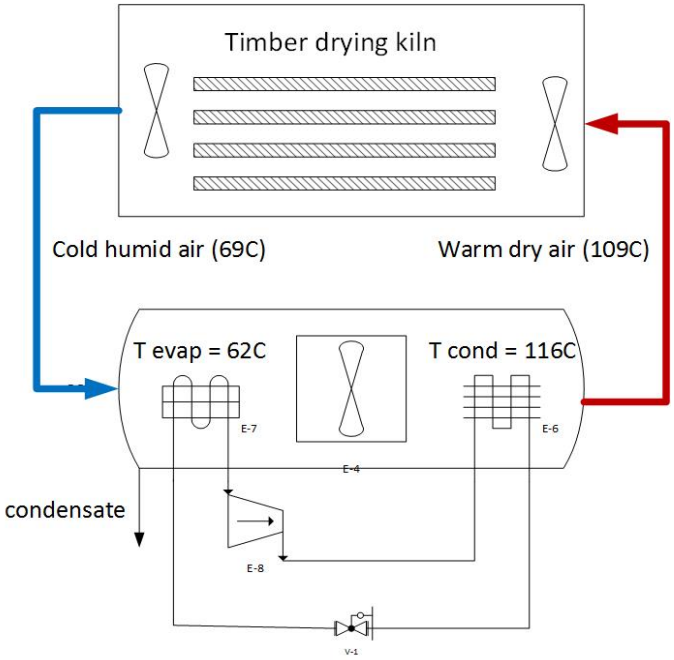
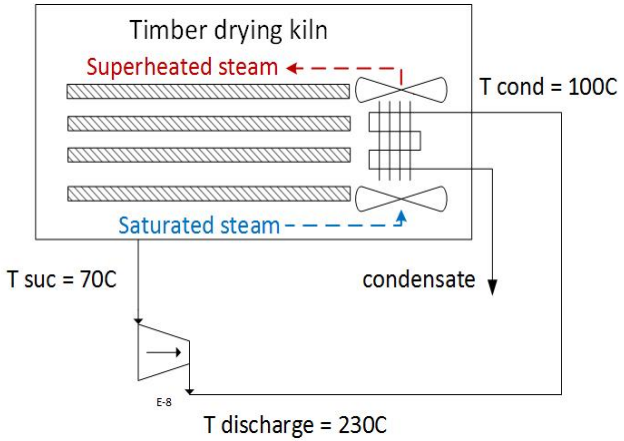
Application example - Drying process with superheated steam




COP ≈ 4




COP ≈ 7

# Water Vapor Compressors

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DK : Annual energy consumption industry (heat) appr 160 PJ

Corresponding to appr 8000 – 10000 MW

Appr 25% can be covered by heat pumps,

that is, 2000 – 2500 MW

| Temperature lift Delta T [C] | Target temperature demand [C] | Estimated COP-value | Percent of all potential heat pump applications |
|---|---|---|---|
| 20 | 100 | 11.2 | 23 |
| | 180 | 13.6 | 1 |
| 40 | 100 | 5.6 | 14 |
| | 180 | 6.8 | 2 |
| 70 | 100 | 3.2 | 35 |
| | 180 | 3.9 | 25 |

# Water Vapor Compressors

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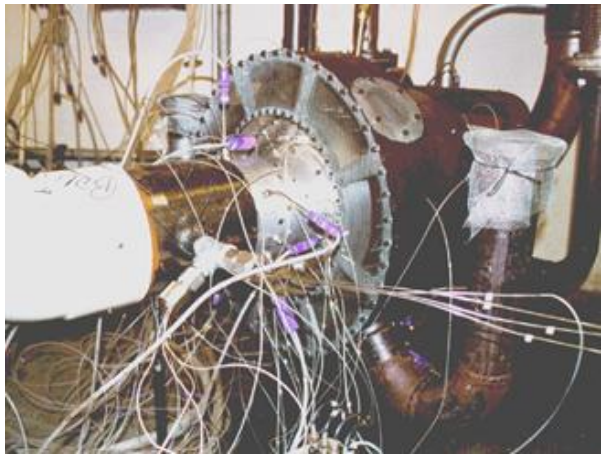

## Thank you for your attention