A High Temperature Heat Pump Using Water Vapor as Working Fluid

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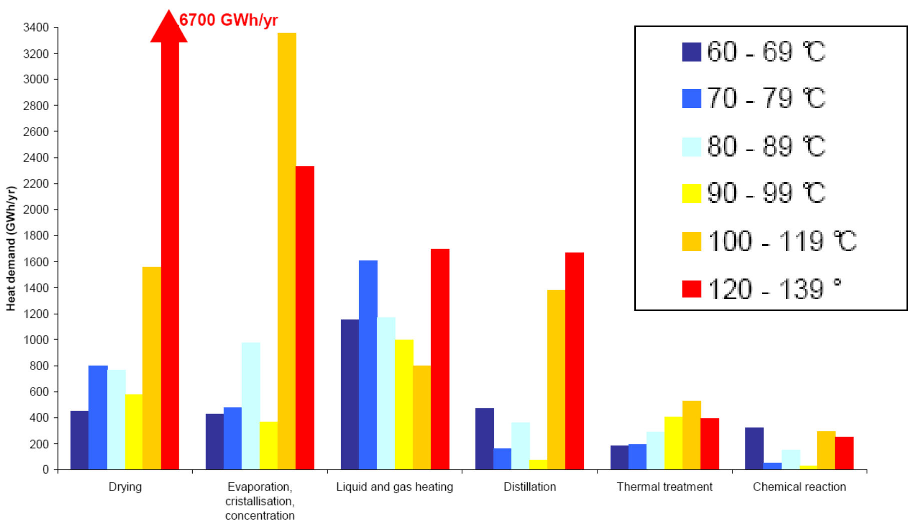
ATMOsphere EUROPE
solutions for europe
natural refrigerants
16-17 March 2015 in Brussels

Johnson Controls

Project driven by market needs:

Distribution of heat demand for industry (France / Source:EDF)



Large needs for heating 100 to 150°C

Lots of waste heat 80 to 90°C

Current heat pump offering mostly limited to ~85°C

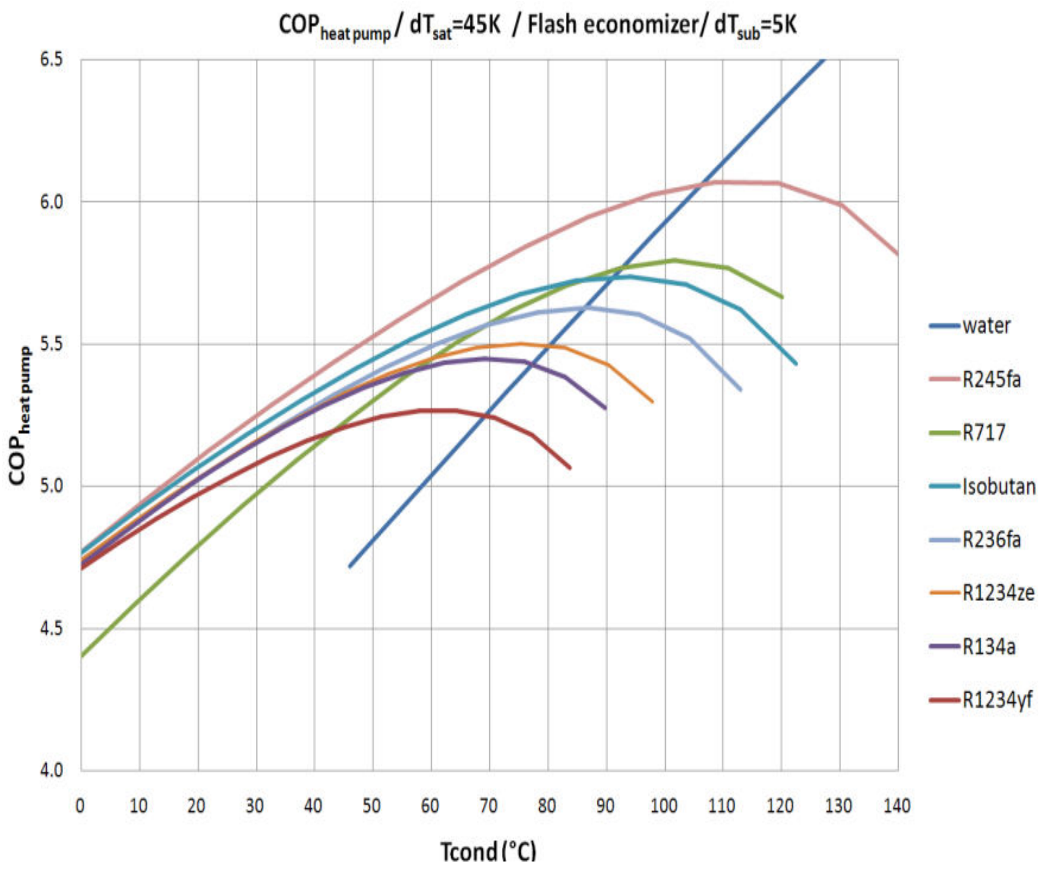
Needs above 100°almost 4 times greater than below

Need to develop high temperature heat pumps for industrial market

Project target: 600 kW @ 90/130°C

Why water vapor ?

Natural refrigerant
Outstanding efficiency at high temperature
Can be used in closed and open loops (direct vapor recompression)



Mechanical Vapor Recompression - MVR

How does it operate ?

When you want to concentrate a fluid, you have to remove the water, by:

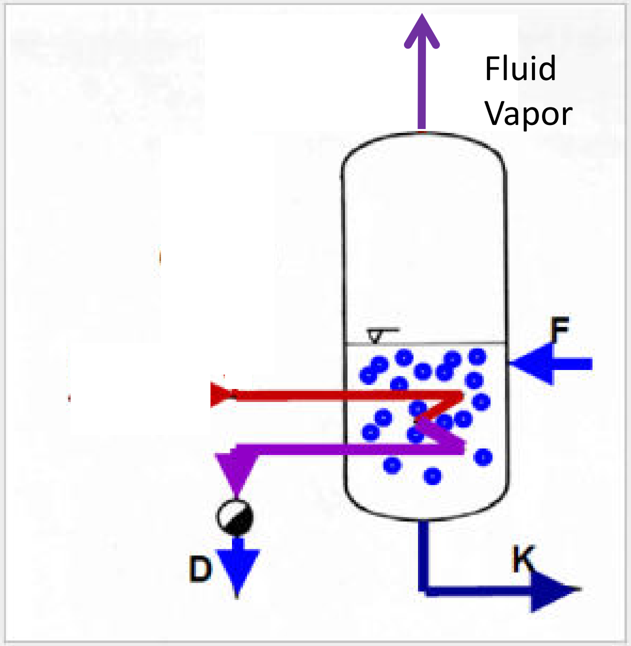
- Increasing the product's temperature above its boiling point
- Providing thermal energy, mainly steam, for heating up

The average of thermal energy consumption from the boiler is around 750 kWh /t fluid vapor evaporated

For the same outcome, if you want to drastically reduce your energy consumption, you can:

- Set up a MVR solution
- Ensure that MVR could provide the required delta P

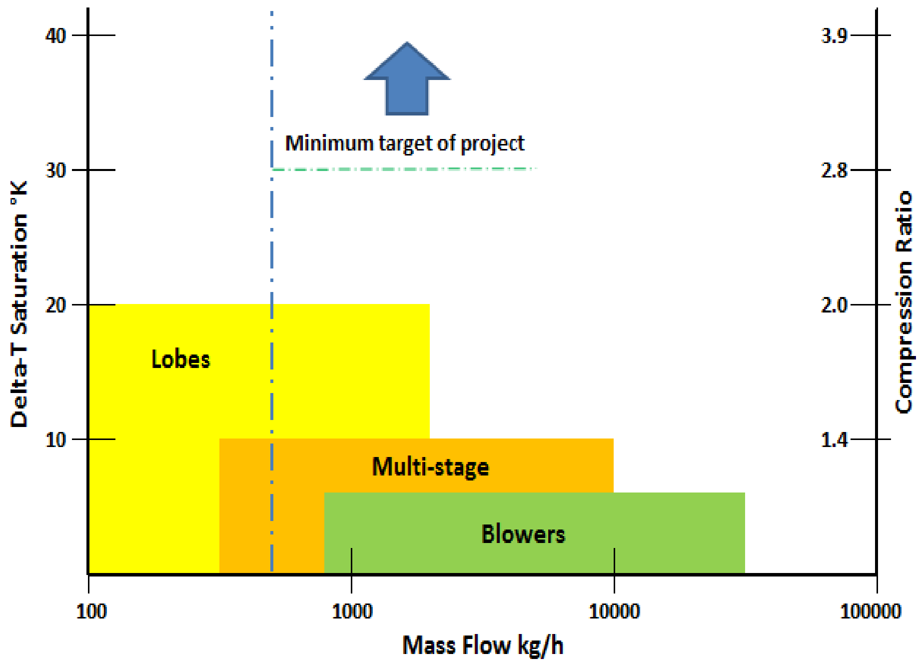
Then the average of electrical energy consumption is around 130 kWh / t fluid vapor evaporated



Principle of mechanical vapor compression, C compressor, D condensate (water), E exhaust vapor, F feed (brine), H heating steam, K concentrate. Prof. Martin Zogg 2008,

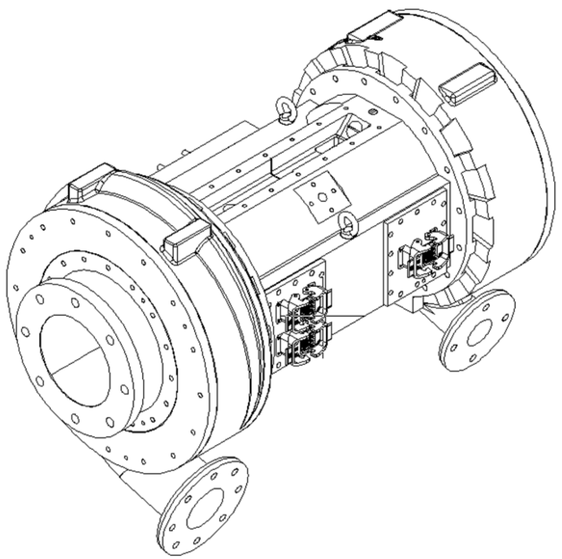
In target range of project:

No offer for closed loop heat pumps.
State of the art for direct vapor recompression is unsatisfactory.



Mass flows assume 90°C saturated suction

Basic Technology Choices:



2 stage centrifugal compressor

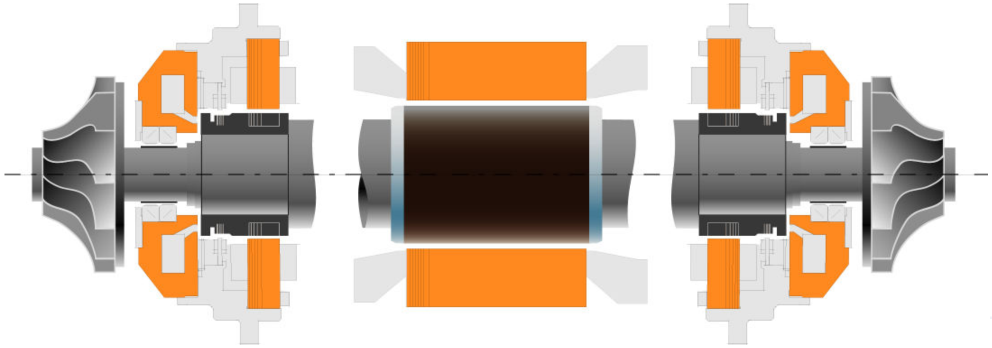
Magnetic bearings (100% oil free)

Synchronous permanent magnet motor

One impeller on each end of motor

Intercooler between both stages

Titanium impellers



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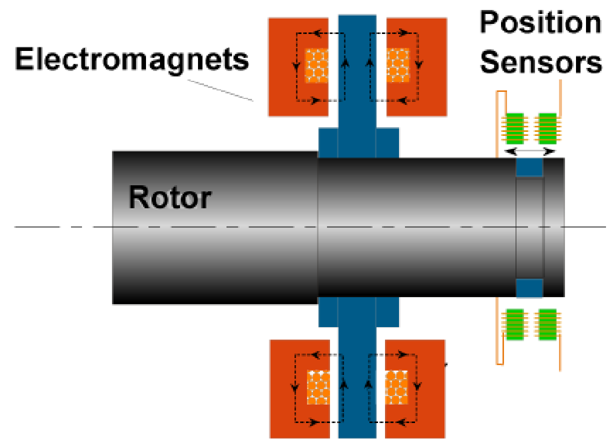
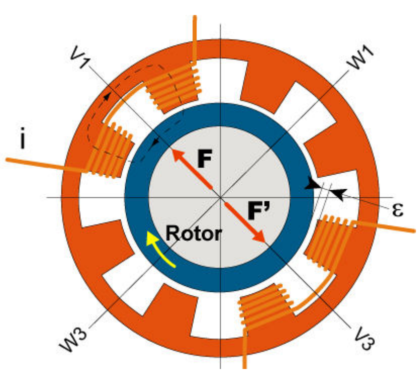
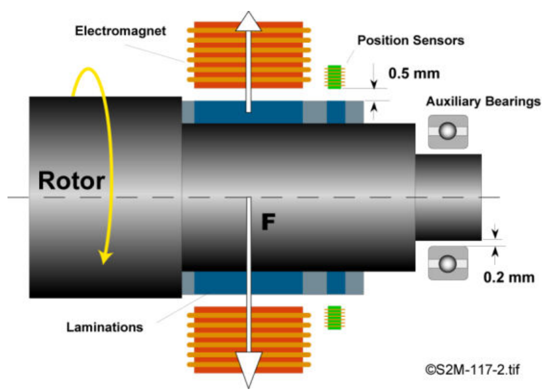
Principles of active Magnetic bearings

Axial bearing (schematic)



Magnetic radial bearing





A proven technology platform: 700 chillers sold in 15 years
With outstanding record of reliability

1998: Nuclear Submarines

2003: Surface ships

2007: Industrial systems & Heat Pumps

2011: Standard « YMC² » Chiller

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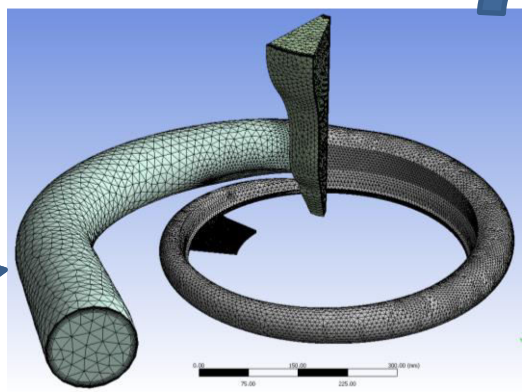
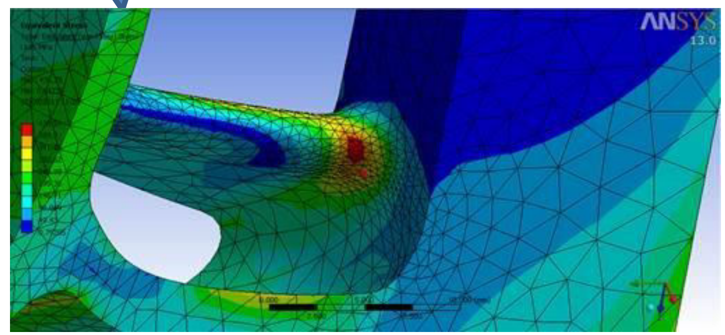
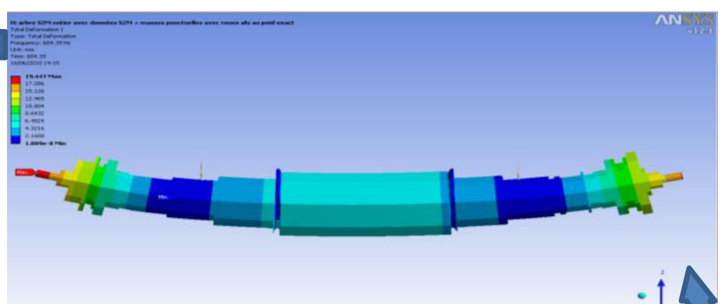
Still many technical challenges, including

Aero design



Mechanical resistance





Rotor dynamics

Impeller manufacturing

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AIR Tests

Initial testing on air → Validate:

Mechanical design of impellers

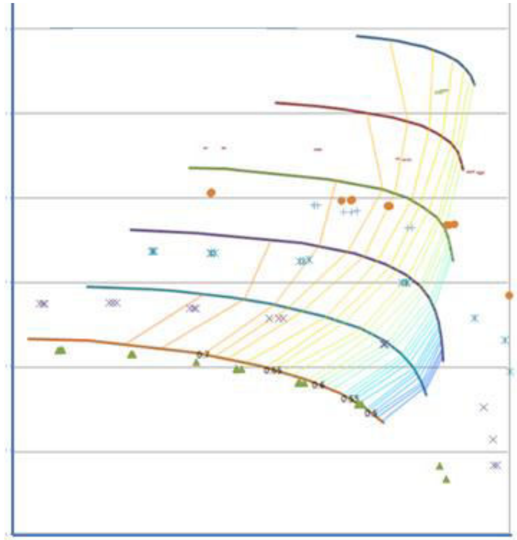
Start / Stop sequences

General good operation

Motor cooling

Labyrinth seals

Etc…



Complete mapping of the aero design of the impellers.

Validation of CFD modeling.

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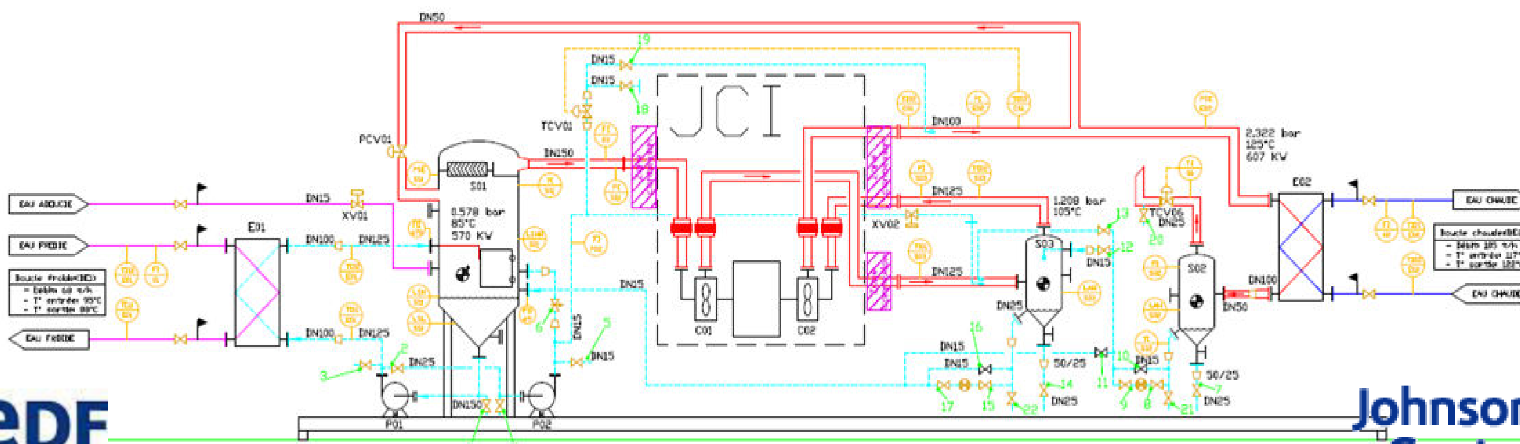
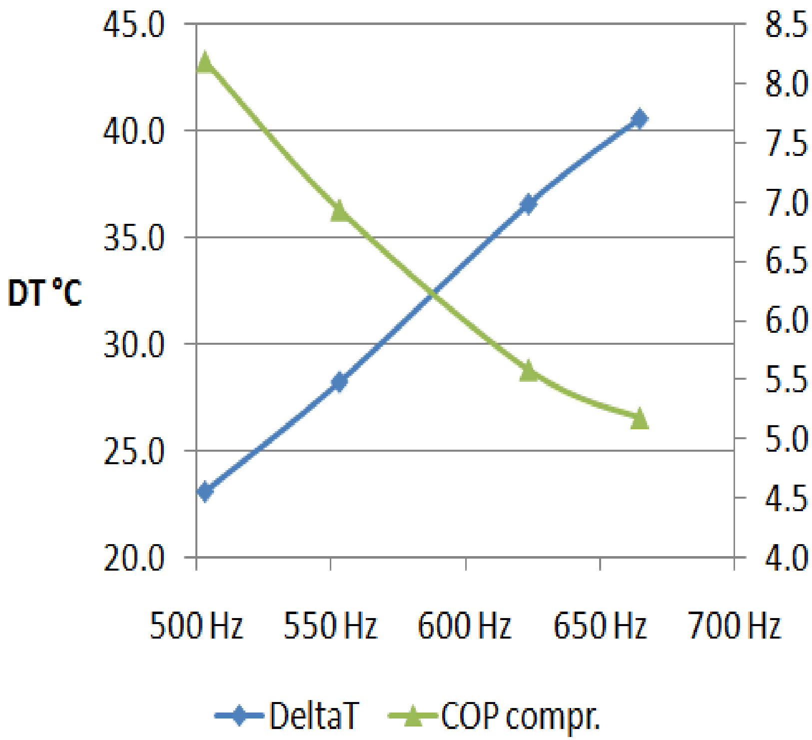
Complete heat pump on EDF test stand

Integration of drive line with exchangers for complete heat pump.
Intergration with EDF test stand providing heat source and sink.
Validation of performance.



Summary of test results



	DeltaT		Heat Power
Speed (Hz)	1st stage	2d stage	(kW)
503	12,1	11,0	389
553	14,4	13,8	433
624	18,4	18,2	480
665	20,5	20,1	618

The objectives of the project are exceed.

DT(Condensation – Evaporation) = 40°C.

Identified some potential for efficiency improvement.

Future perspective

1/ Ongoing investigations to find a site to install the prototype as an industrial demonstration unit. Probably a sugar plant

2/ Perspective to develop a range of industrial machines. Approximate anticipated capacity range:

Stages	Max DT	Motor power (kW)	130	300	440	820
1	20 K	Heating power (kW)	700	1650	2400	4500
2	40 K		1400	3300	4800	9000

Acknowledgements:
The authors wish to thank the French ***ANR***
(Association Nationale de la Recherche)
for partial funding of this project.