Weel & Sandvig ENERGI OG PROCESINNOVATION

SpeedUP High speed direct drive Turbo compressor for Heat pump applications

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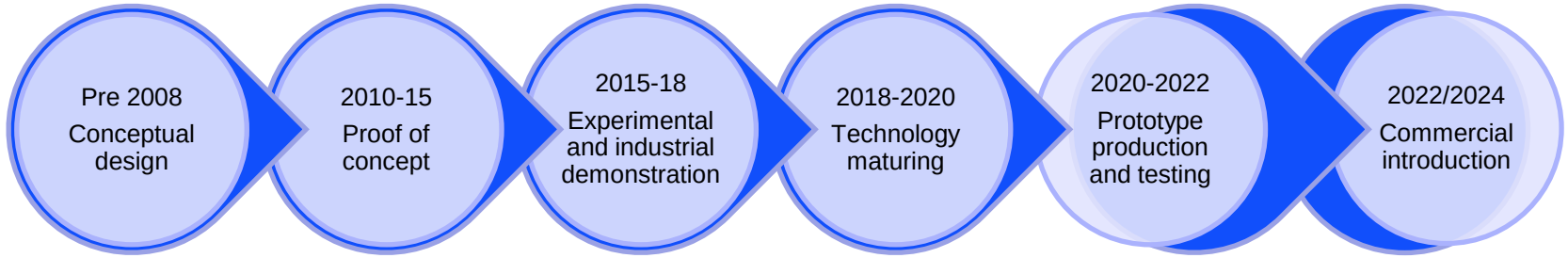
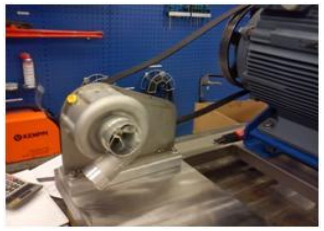
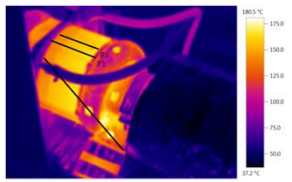
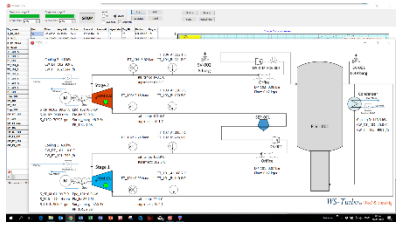
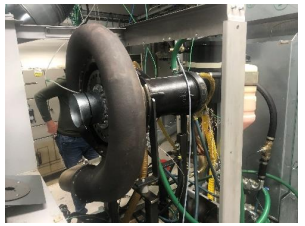
W&S “Long journey” with high temperature heat pumps with water











ROTREX

TEKNOLOGISK INSTITUT

Innovationsfonden

ENERGI STYRELSEN

HALDOR TOPSØE

MARS incorporated

SINTEF

DTU kergy

High speed Turbo and gear derived from automobile industry

Lessons learned: can’t meet Durability

High speed motor direct drive compressor

Derived from micro gas turbine technology

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SpeedUp: direct drive high speed Turbo Compressor for HTHP applications

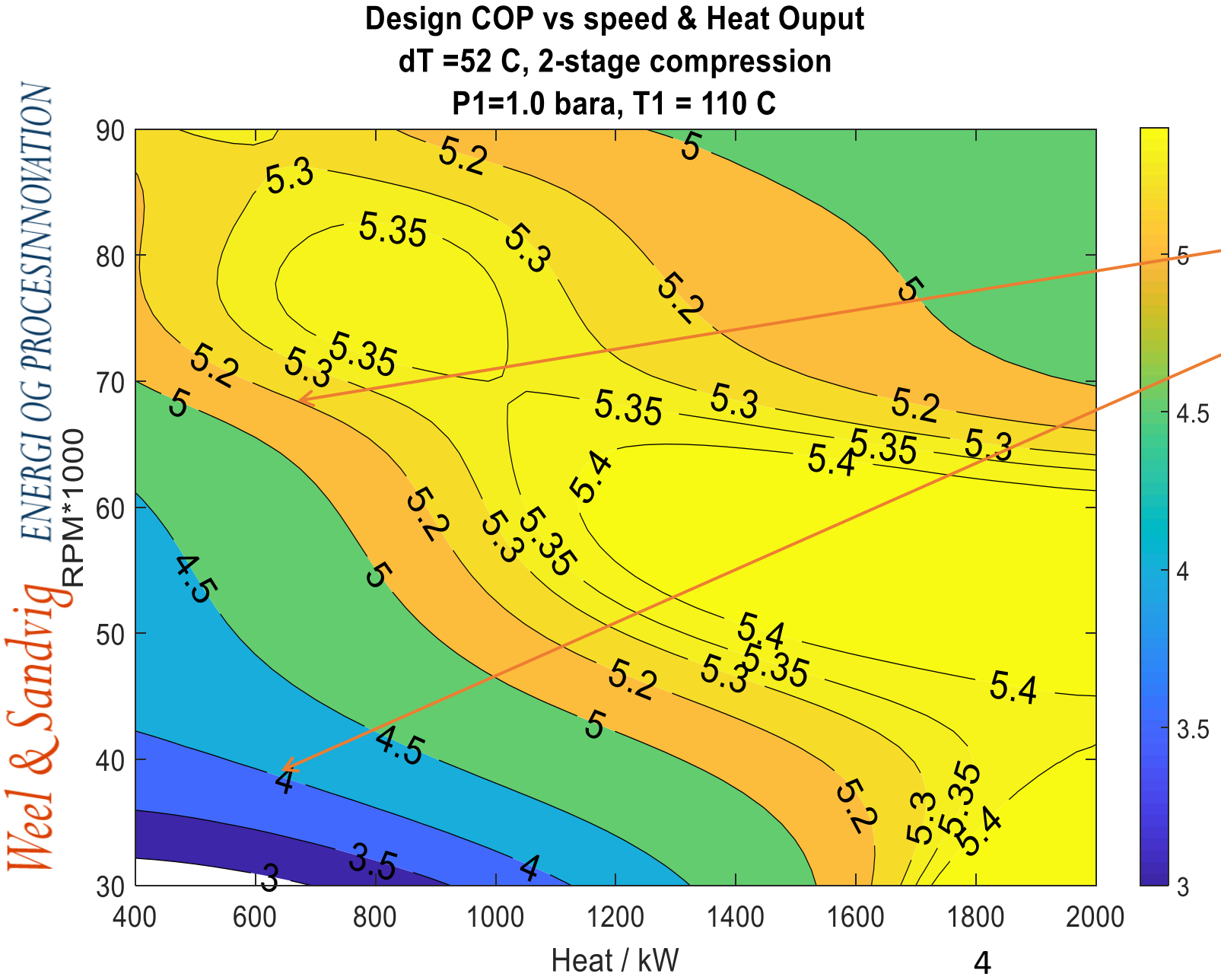
Heat Pump technology Intended to meet potential high temperature heat pumps with sink temperature from 100 – 165 C and heat effect between 600 – 1500 kW/unit:

Typical industrial process application:

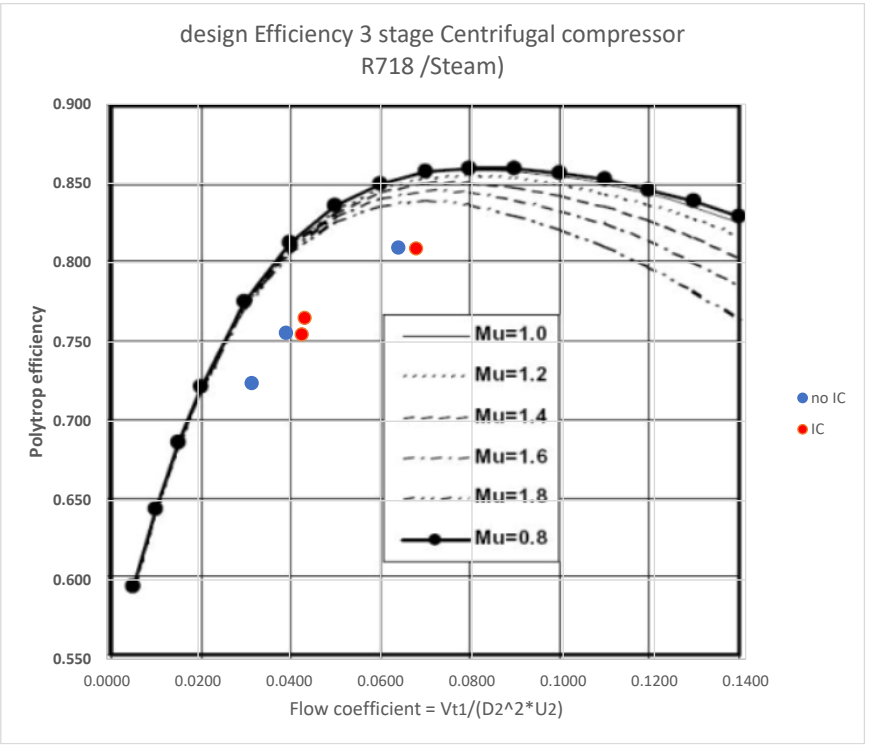
- Distillation dT = 30 - 50 K
- Evaporation (MVR) dT= 15 – 55 K
- drying dT = 50 – 60 K

- SpeedUp Project content:
  - Development of a compact gearless turbo compressor for heat pump applications with water vapor as working media. High speed motor derived Technology with already demonstrated high reliabiliy (5 mio. Accumulated fleet hours, and 30.000 hour between major overhaul).
  - Improved leakage system (new labyrint seals for oil free operation)
  - Investigate optimized Compressor flow path design (CFD and meanline analysis)
  - New balance piston to meet higher axial loads
  - Rotor dynamic
  - Design and installation of new test rig and control system
  - Demonstrate 200 - 500 hours load
- Project Partners Weel & Sandvig, DTU and Ekergy

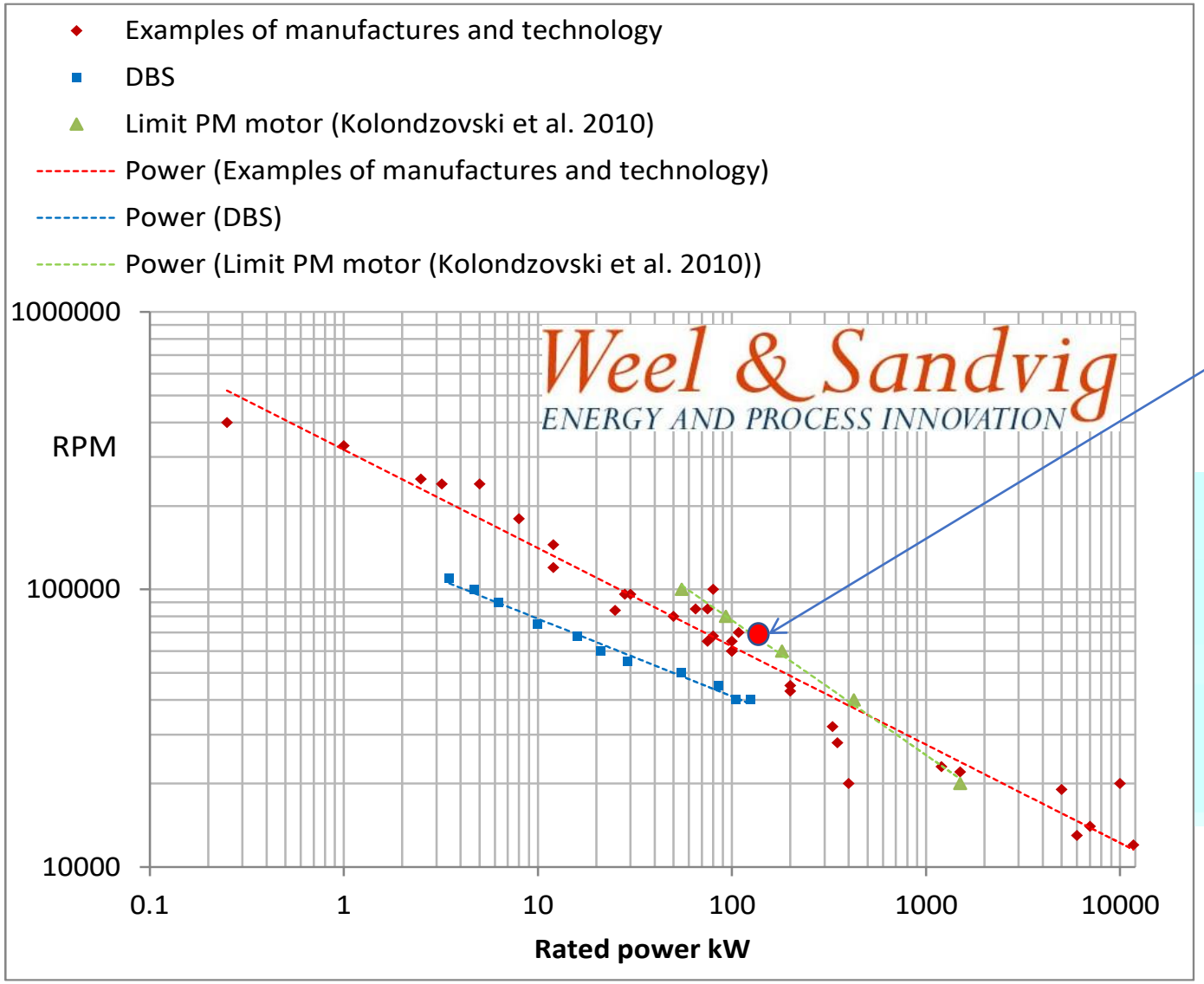
Turbo compressor: why high speed



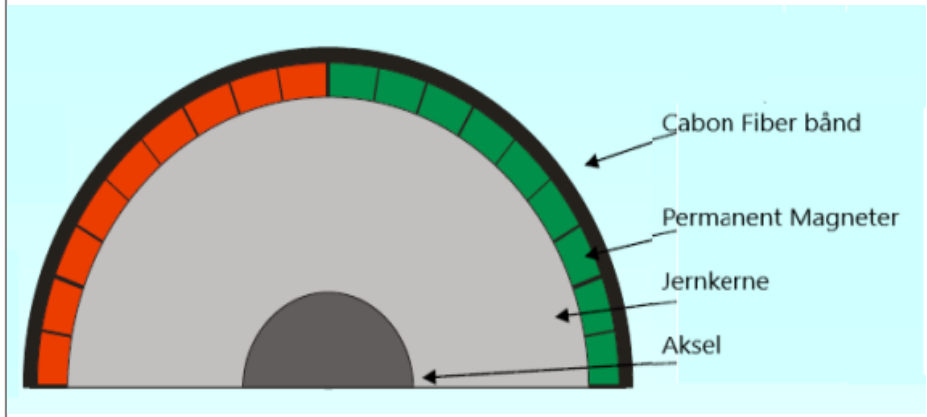
Example: Heat effect
600 kW : Temperature lift 52 K
Suction conditions:
0,22 kg/s, 1,0 bara, 110 C
70000 RPM => COP=5,3
40000 RPM => COP = 4,0
2- stages compression
Tip speed 510 m/s
Impeller diameter=142 mm



High speed motors strength limits (running on the edge)



SpeedUp



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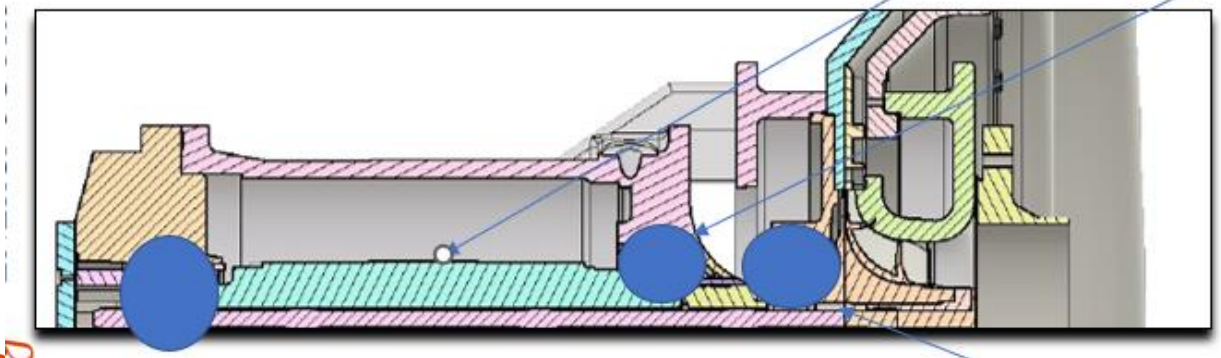
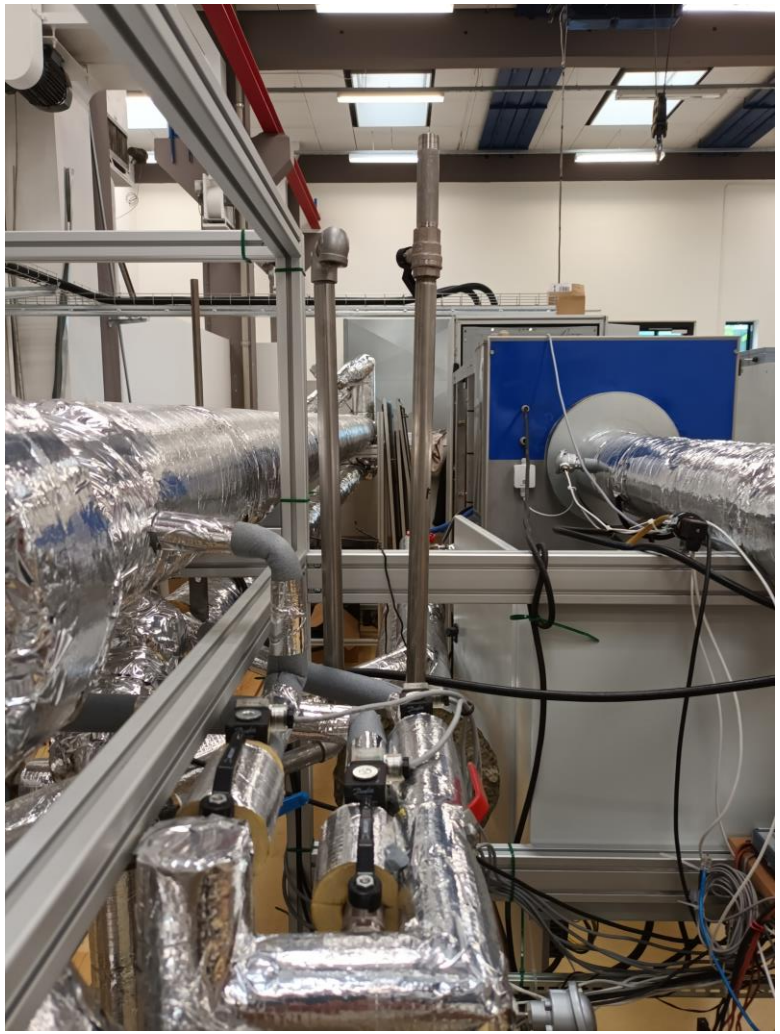
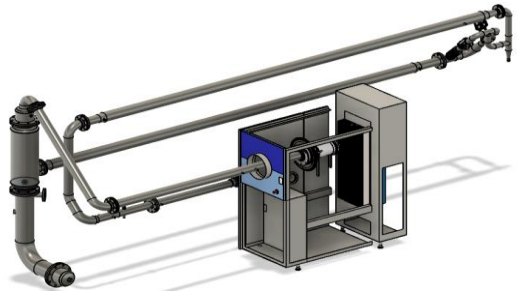
Motor Compressor design SpeedUP

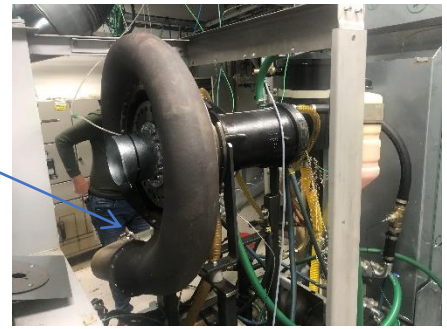


- PM high speed Motor
  - Motor design derived from Micro gas turbine : 100 kW (110 kW)
  - 4 – poles PM design)
  - Up to 72000 RPM
  - Water cooled
  - Ceramic bearings with oil lubrication
  - Bearing squess film damper
  - Air cooling of rotor stator cap
  - Speed control with inverter
  - Oil consumption lubrication 1 – 3 liter/year
- New Compressor:
  - 142 mm Impeller
  - Tip speed 520 m/s
  - Suction volume flow 0.5 – 1.2 m3/s (trim depended)
  - Pressure ratio 2 -2.5 => dT= 20 -27 K
  - Speed: up to 72000 RPM
  - Material: Titanium
  - Diffuser: vaneless or vaned
- New Sealings:
  - 3 sets of labyrinth sealings with active seal control system => oil free operation (seal steam loss 0.002 kg/s)
- New Axial thrust balance piston
- Tie Bolt design
- Heat: 600 – 1500 kW

test plant under construction and finish







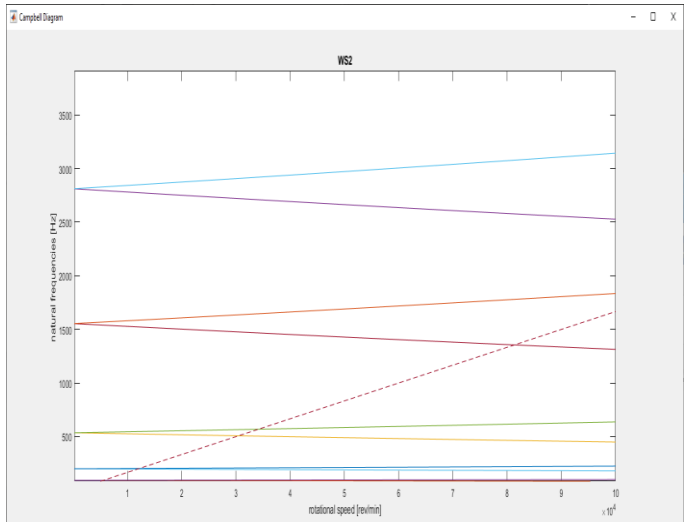
Compressor + motor

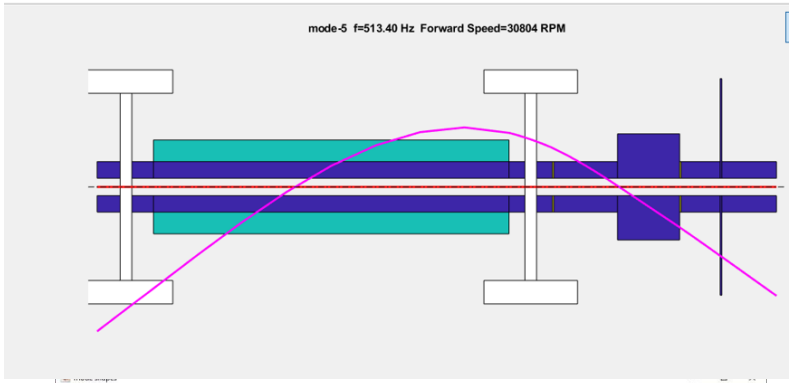
Compressor impeller
PM Rotor, Tie bolt

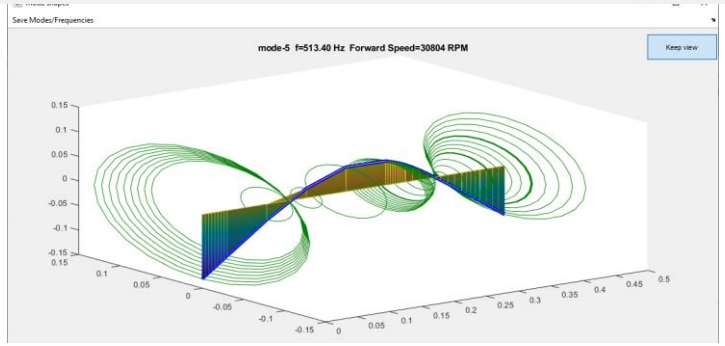
Inverter
& control system

Oil pump + sump + water cooling pump
Motor gap cooling blower
Oil coolers and water coolers

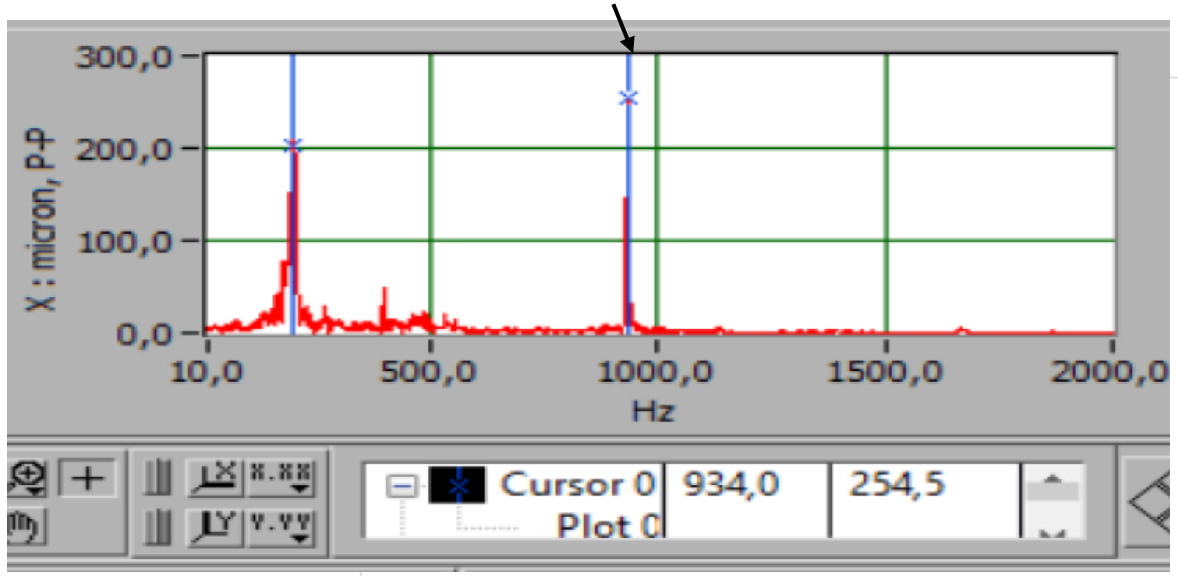
Experince from intially test Rotor dynamic (tie bolt rotor design) & critical speed

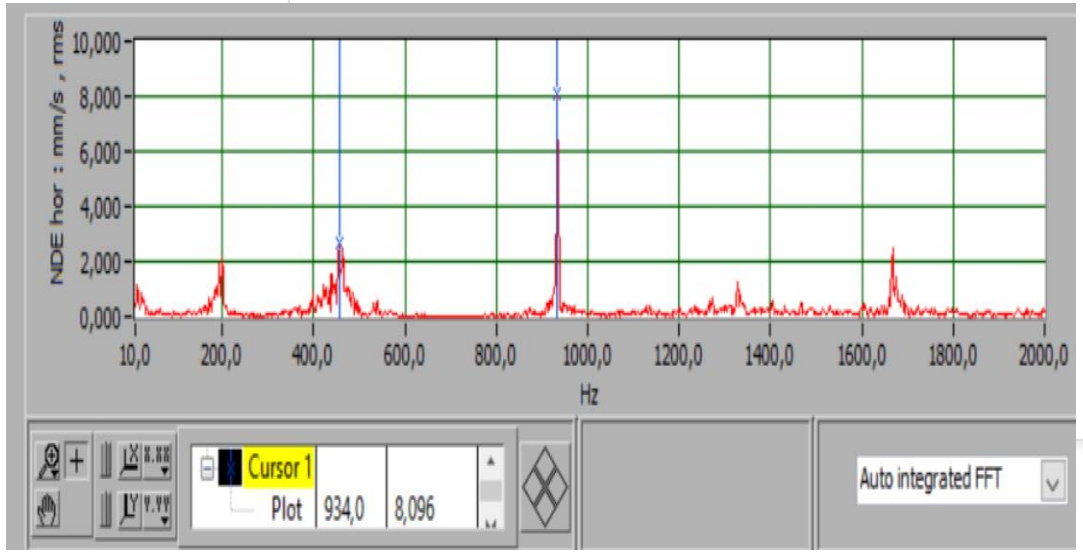




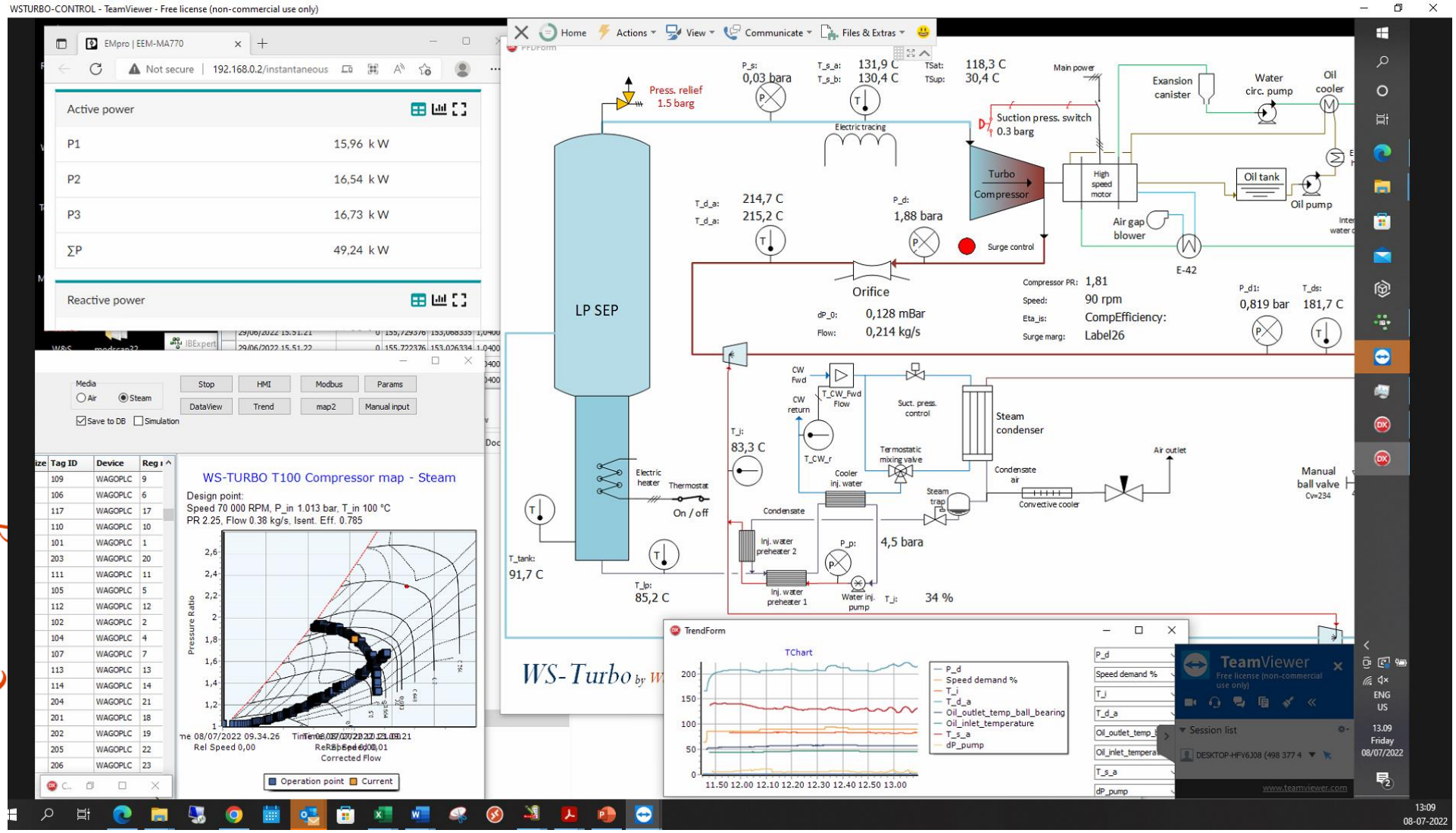


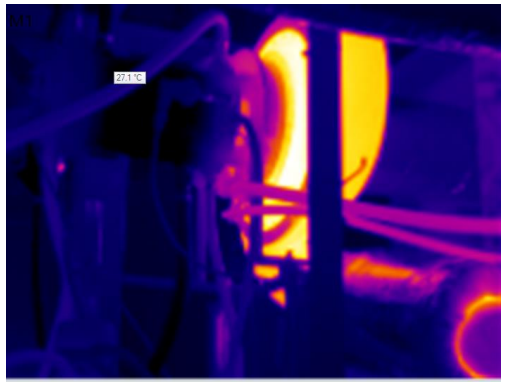
Mesured during intial test after 4th modification
56000 RPM critical speed





Test with steam started in June 2022





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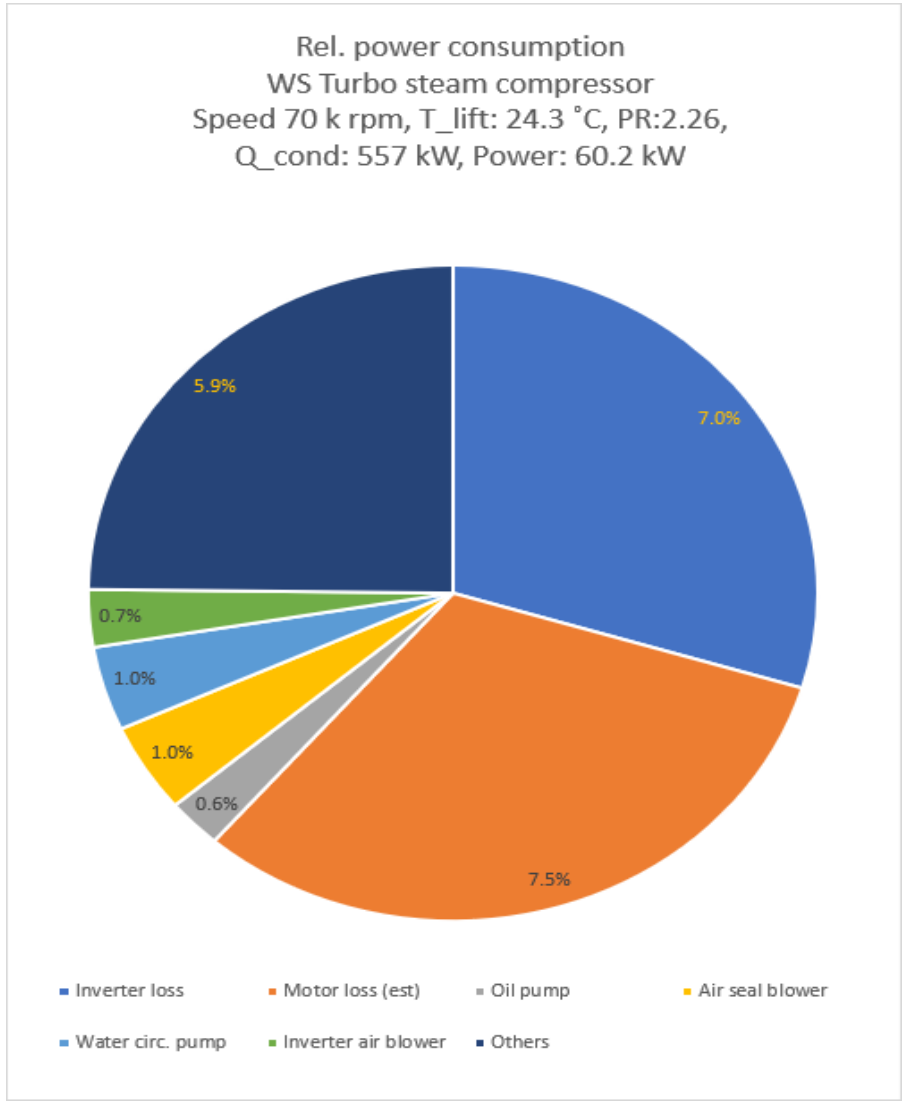
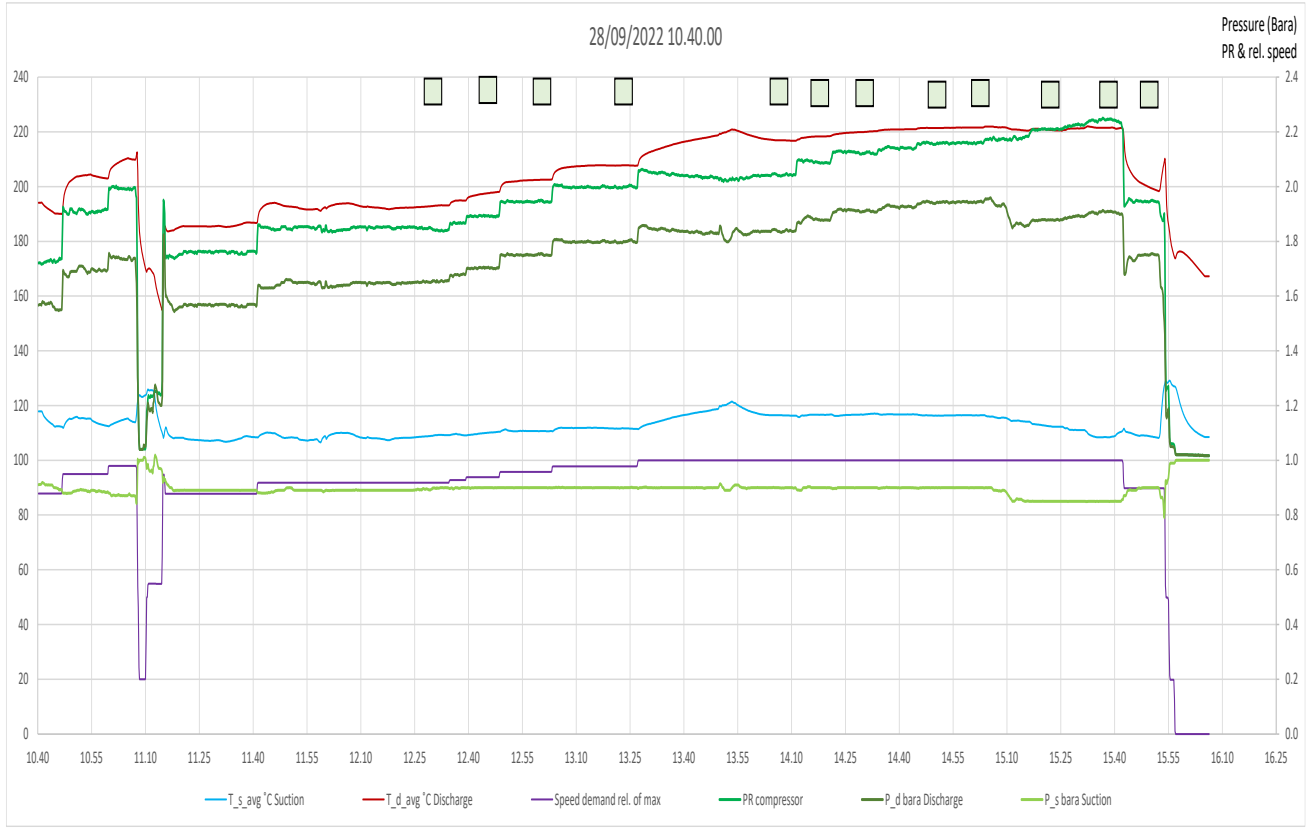
Parasitic loss distribution 100 % speed 60 % Power input





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Overall test result so far and conclusion

- About 100 hours of operation with steam, (major parts of the compressor set hours motor, inverter, aux system, bearings etc have gained 40000)
- Inlet pressure from 0.8 bara to 1.3 bara
- Steam suction capacity 0.2 – 0.6 M3/s (100 % speed)
- Inlet temperature from 110 C to 170 C
- Pressure ratio 1.8 – 2.2 (with actual test rig impeller design, New design up to 2.9 can be achieved)
- Discharge pressure demonstrated: 2.7 bara (130 C saturation temperature) discharge pressure was limited by power input
- Temperature Lift 25 K in one stage
- Measured Compressor isentropic efficiency 0.73 – 0.75
- Loss in motor, Inverter and aux system: Gas Power/Grid Power 0.82 at 80 % power.
- Very smooth and stable operation above 82 % speed (very low vibration level)
- Critical speed area from 68 – 82 % speed must be passed very quickly.
- All safety systems for compressor start up and safe operation worked as expected.
- Some challenges controlling the gas loop system used on the test rig
- Compressor system is on TRL 6-7 and will be ready to test in industrial environment

Heat Pump layout : SpeedUp 2 stage design

Goal:
Heat effect: 500 – 1400 kW/unit
Price label: 1400 -3000 Euro's/kW electricity
Temperature lift 20 – 55 K
COP : 5 - 12

Primary application's:
Source heat : 80 – 120 C

- Drying (2- stages, dT = 55K, COP=5)
- Distillation (2 stages, dT=30 – 50K)
- UHT milk (2 stage, dT=50K)
- MVR (1 stage, dT= 15 -25 K, COP= 10 -15)