CHALMERS
UNIVERSITY OF TECHNOLOGY

Water-based Rankine-Cycle Waste Heat Recovery Systems For Engines:
- Challenges and Opportunities -

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- 3rd International Seminar on ORC Power Systems -

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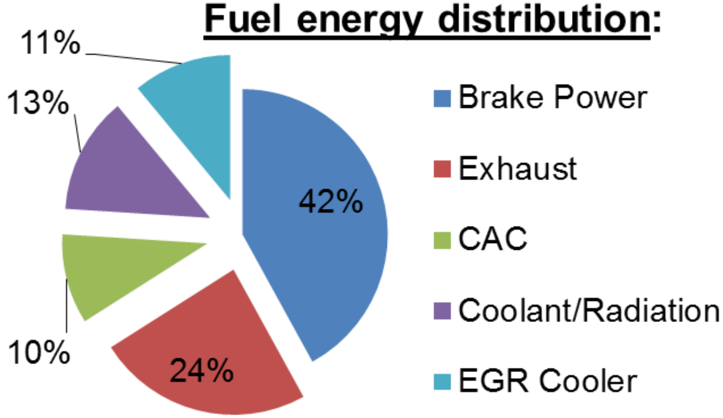
Introduction

Motivation: *Energy balance*

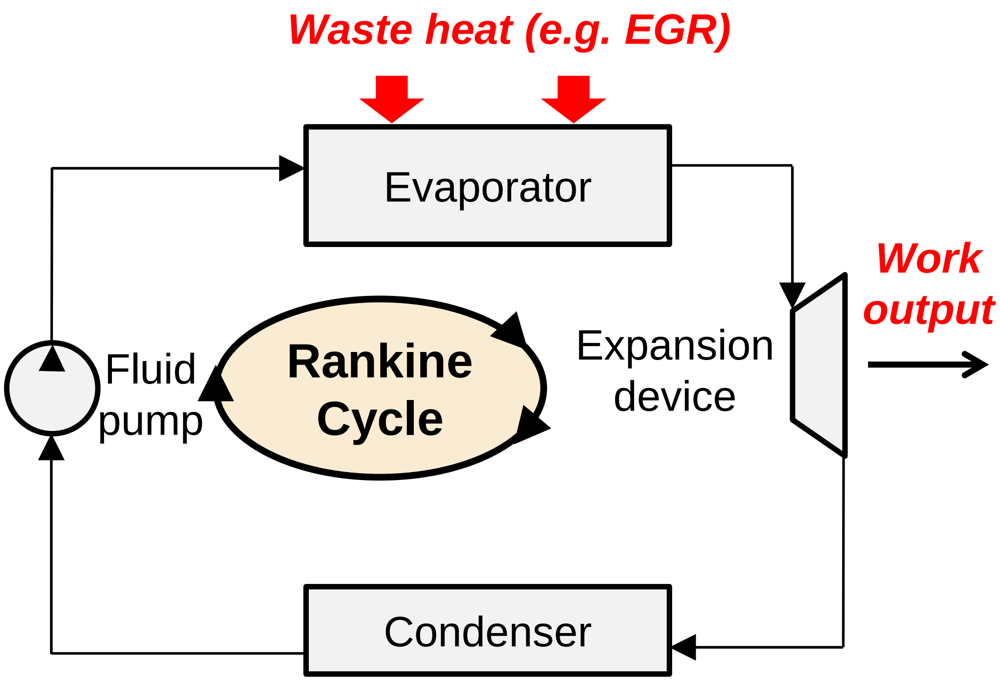
Fuel energy distribution:



Heat Source	Source temperature
Exhaust	320°C
EGR Cooler	470°C
CAC	200°C
Coolant	90°C

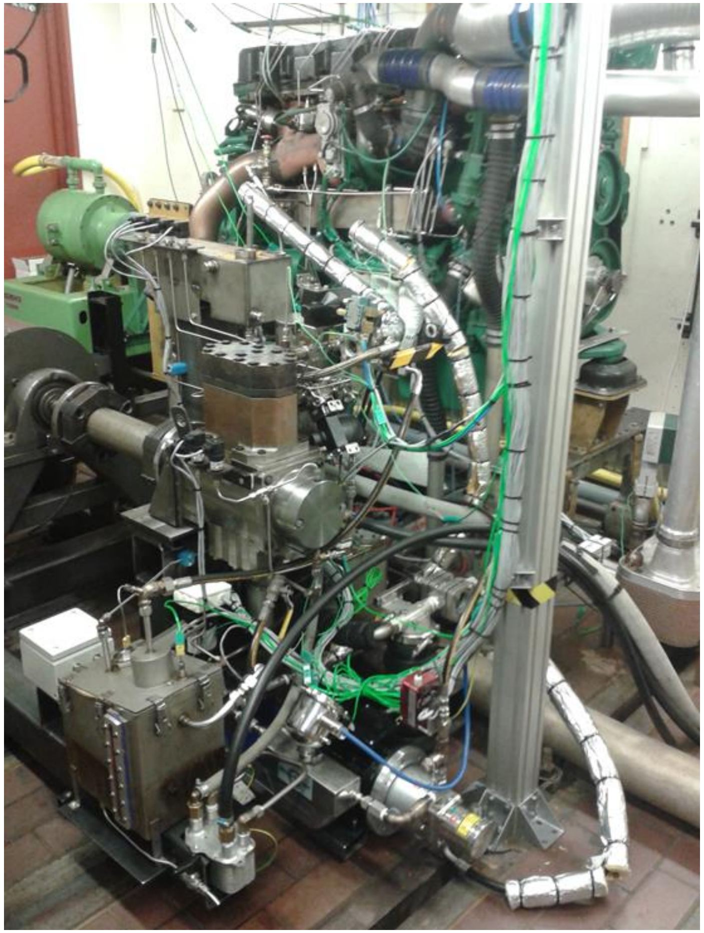
Engine: Volvo D13, B75

Technology: *Rankine cycle*



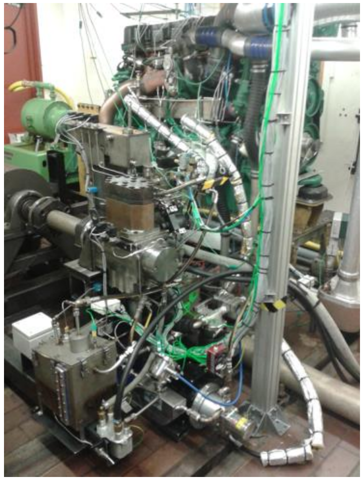
Outline

- Motivation
- Method
- Results
- Conclusion



Motivation

Motivation…



…for the project and the study

- Build a research demonstrator (full-cycle+ engine)
- Validation of components models
- Identification of challenges on component level in a full scale test rig

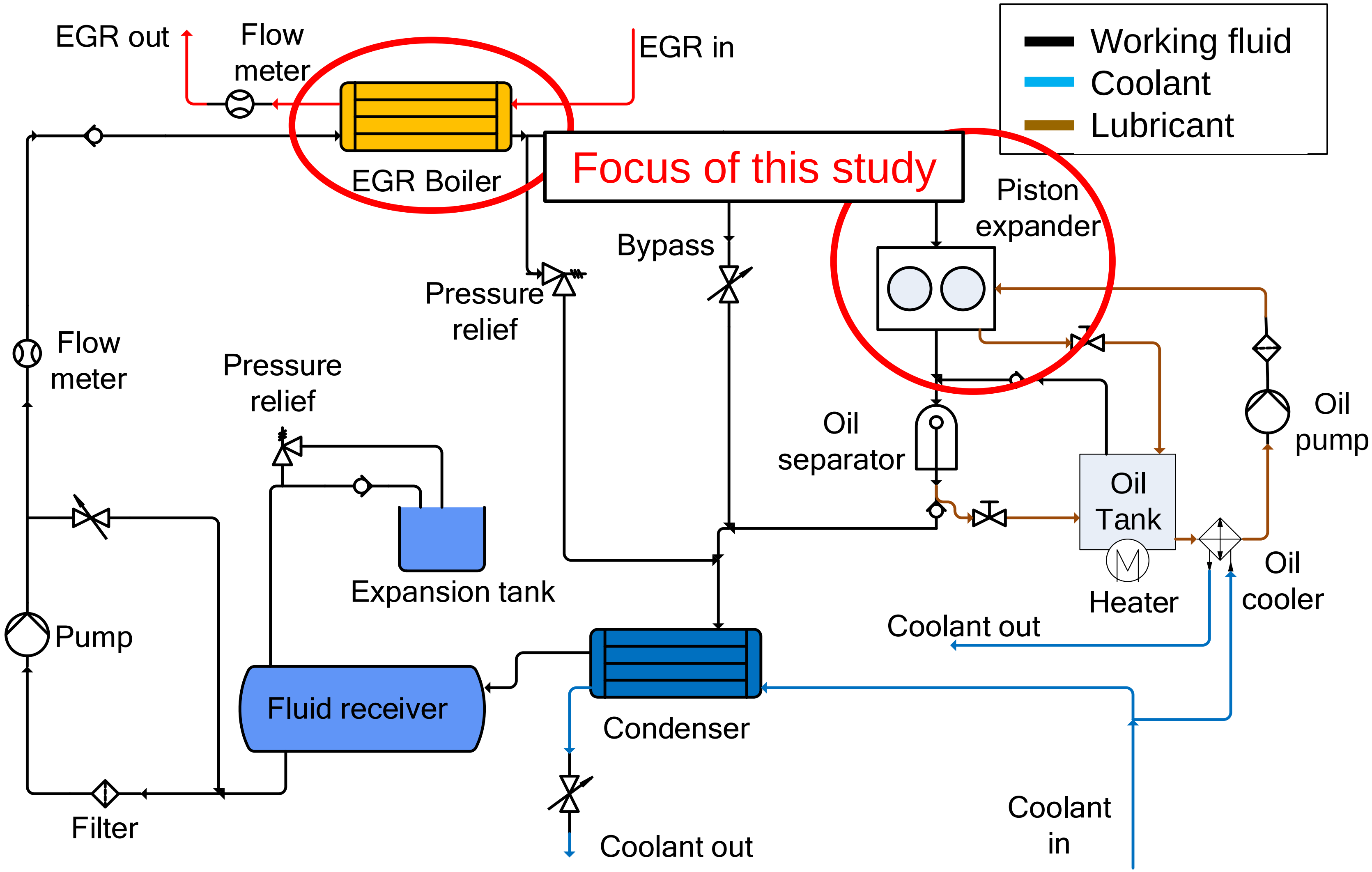
…for water as a working fluid

- Non flammable/poisonous
- Thermal stability
- Availability
- Performance (?)

→ Keep it simple!

Method

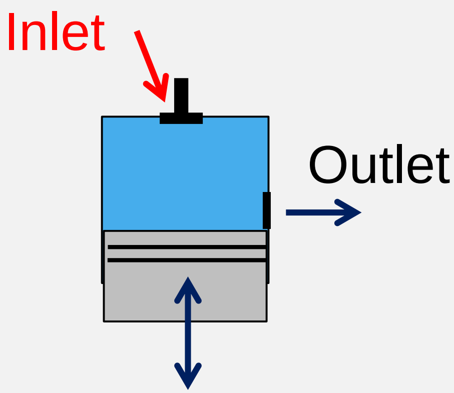
Method – Test rig layout



Method – Component simulation

Piston expander (2 cyl., uniflow)

- Bore/stroke: 90/60 mm ($\mathcal{E}_{geometric}$=21)
- Inlet opening/closing: -17º/34º ATDC
- Outlet opening/closing: 110º/250º ATDC
- Modelling: GT-Suite (1D)



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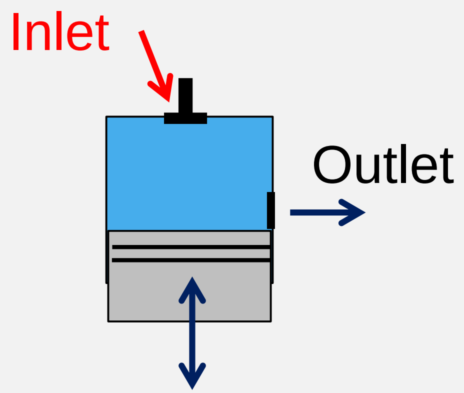
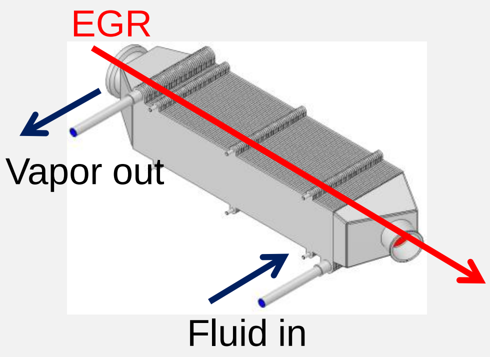
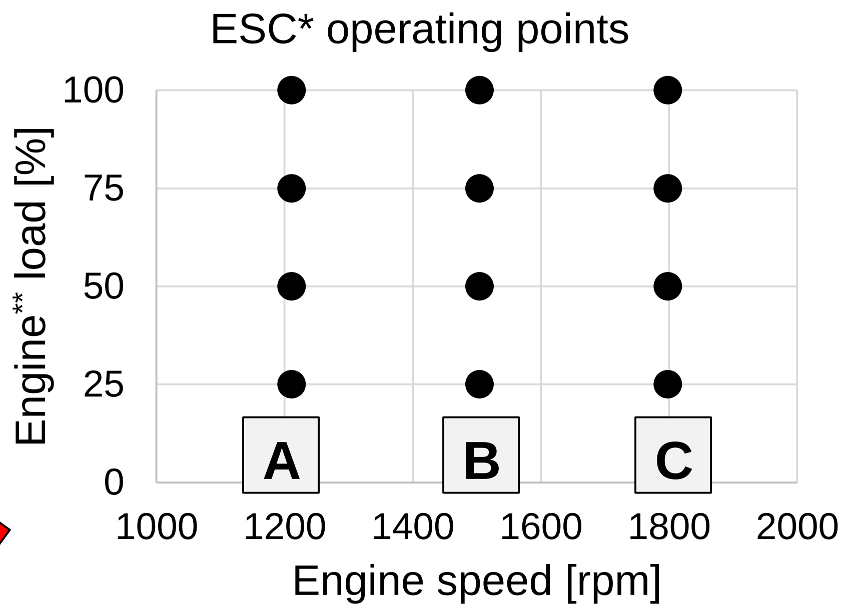




EGR boiler (plate type, counterflow)

- Channels fluid/gas: 22/21 (vertical)
- Fin geometry: Offset strip fin
- Core length/height: 458/95 mm
- Modelling: 0D lumped element, CFD (Ansys)

Method – Tests performed



Rankine expander bypassed

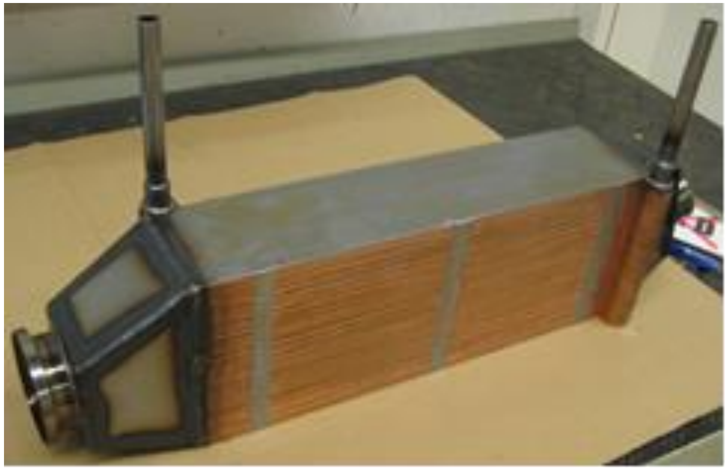
→ **All ESC points**

Rankine expander engaged

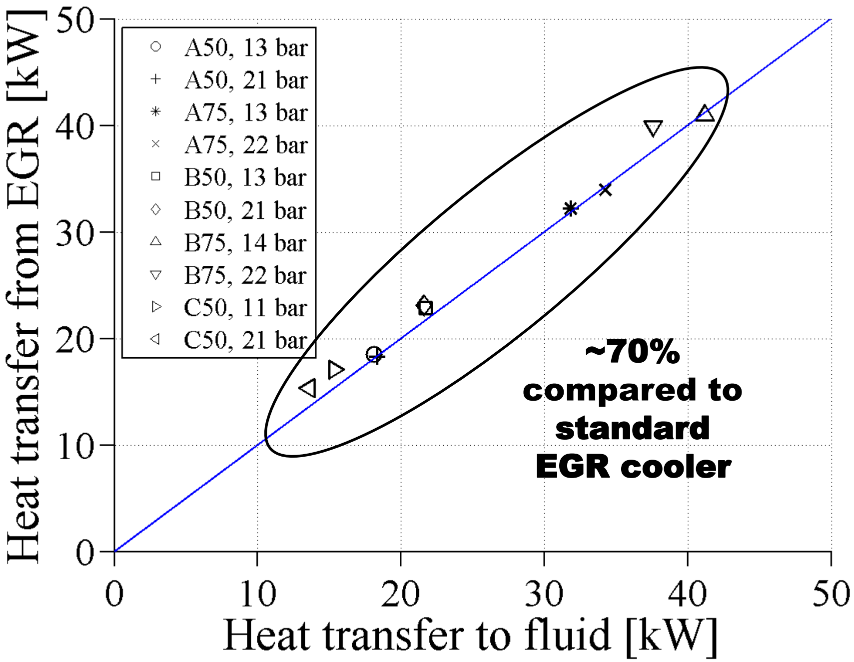
→ **Focus on A100/B100**

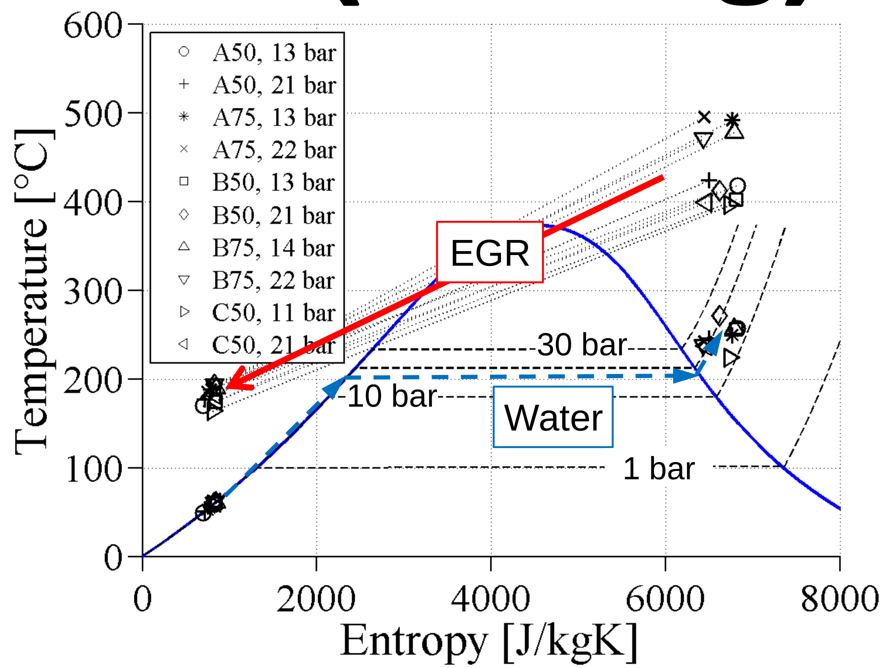
*ESC = European Stationary Cycle, **Engine: Volvo D13 US10

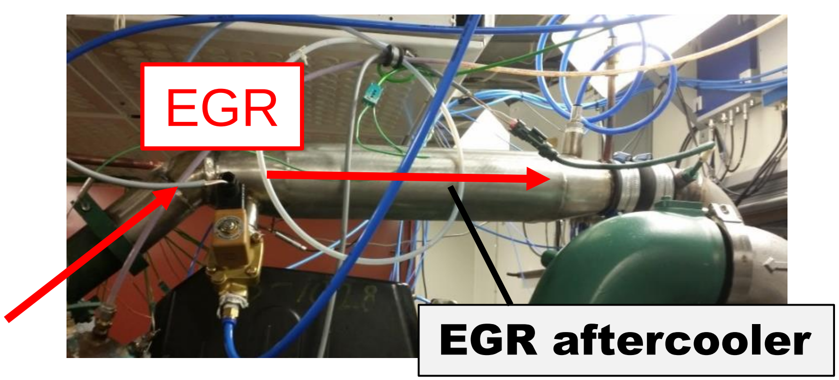
Results – EGR Boiler

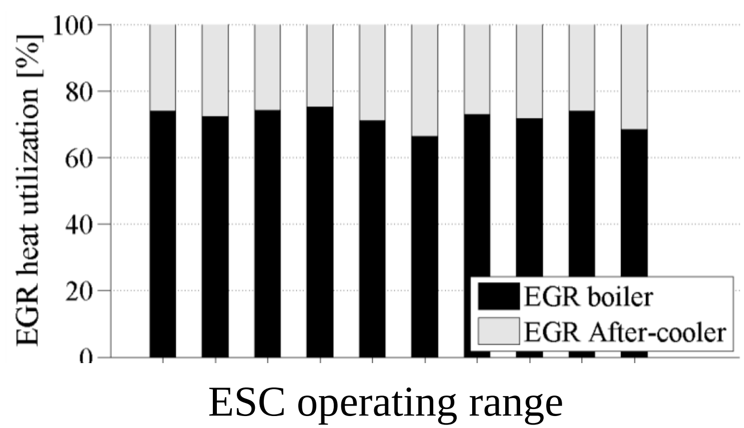


Results – EGR boiler (test rig)

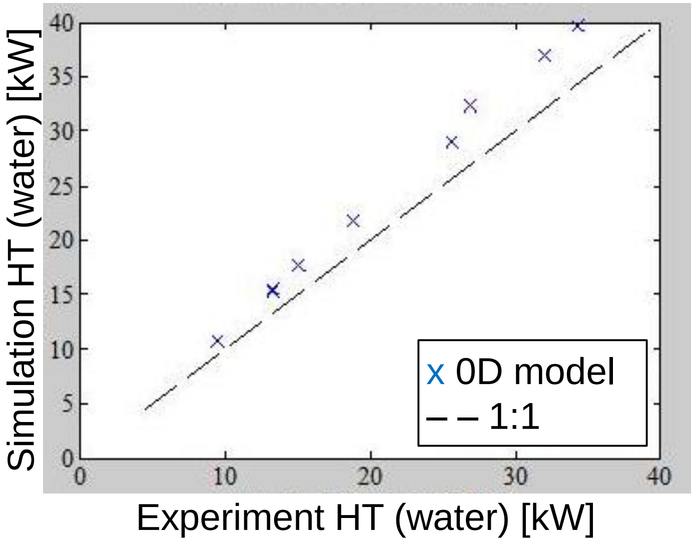


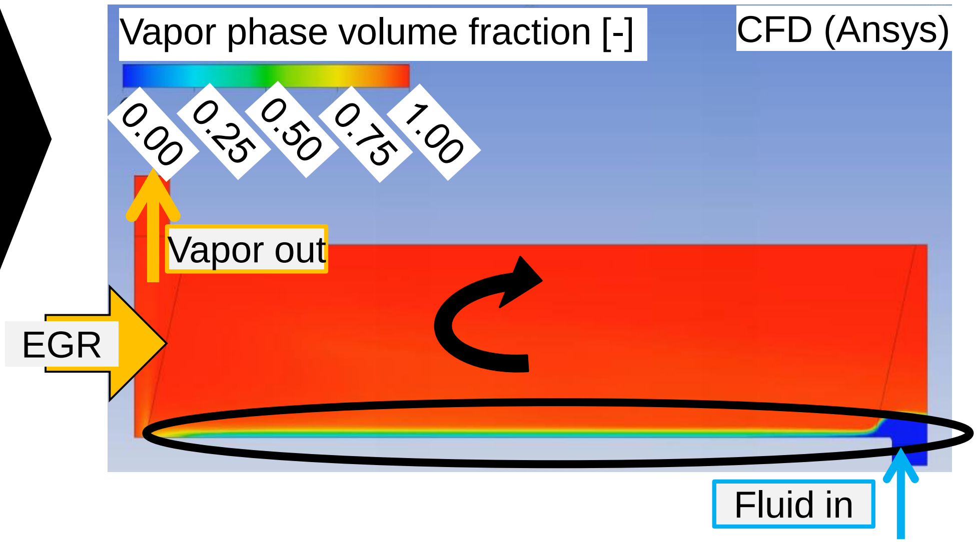


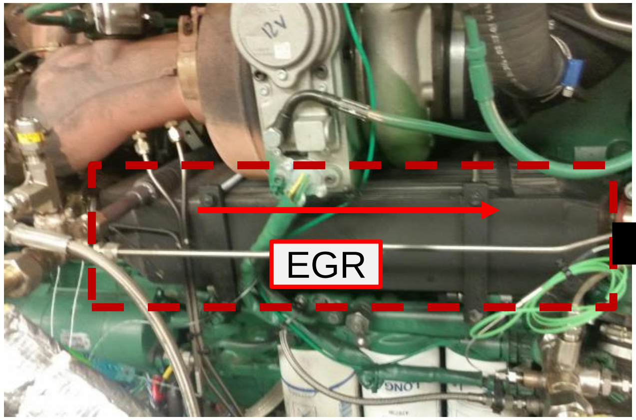


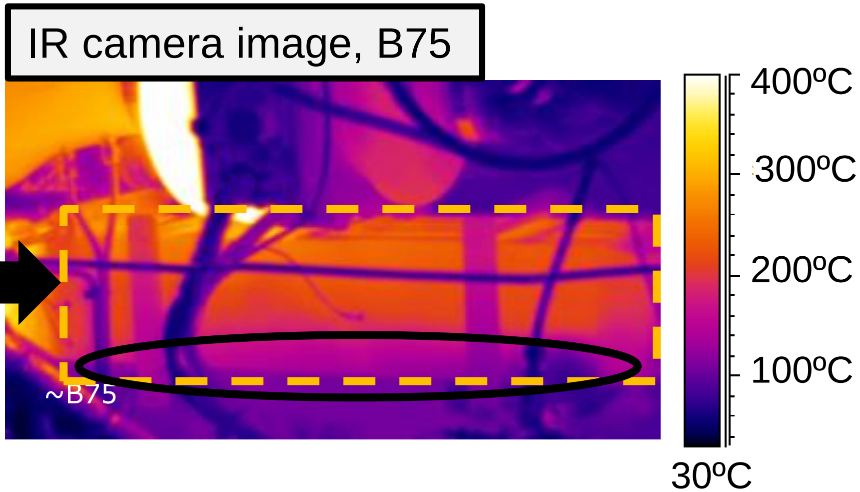


Results – EGR boiler

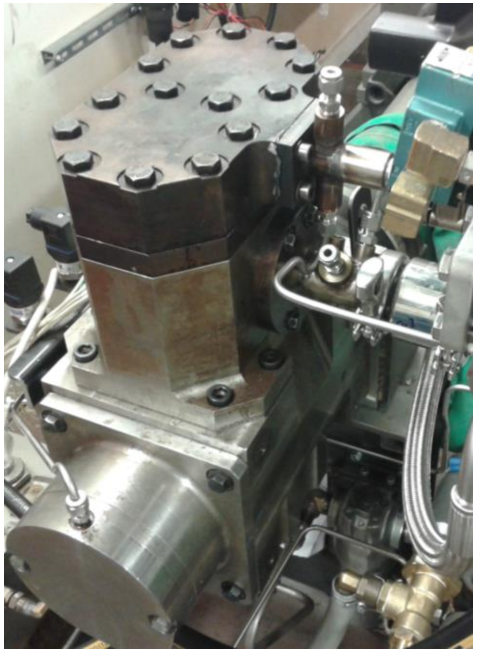




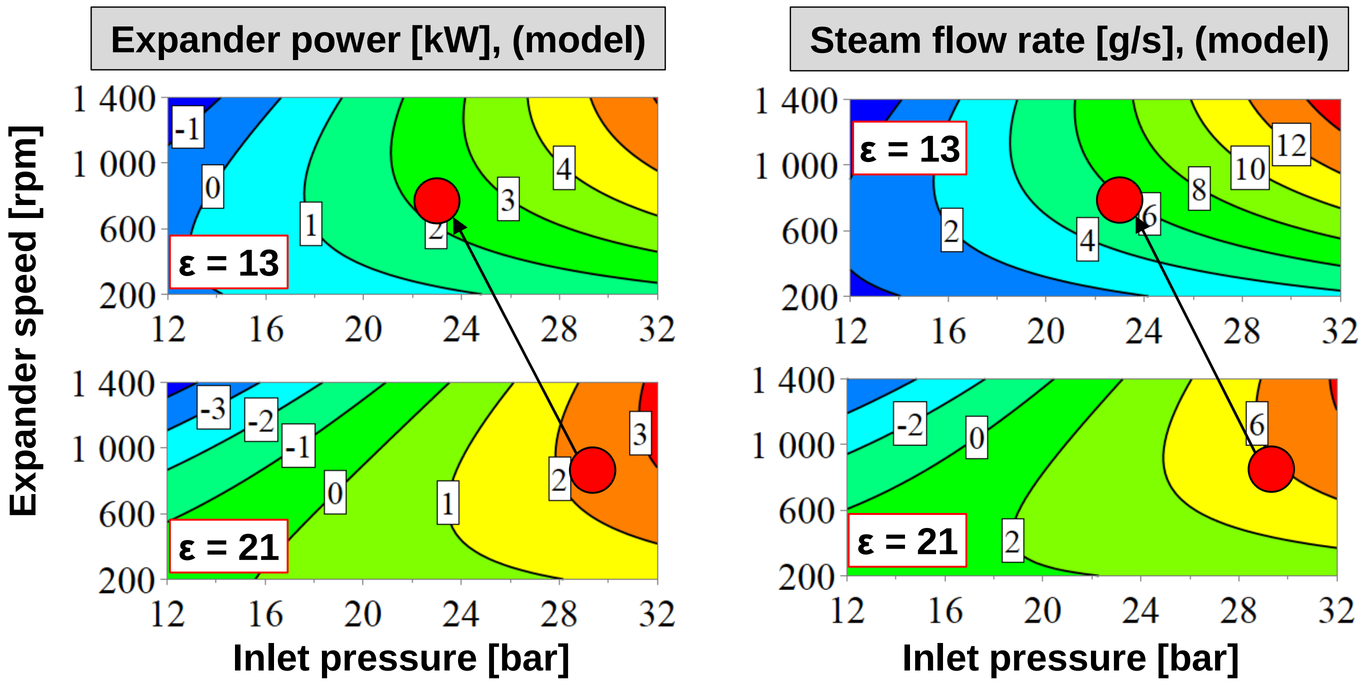




Results – Piston expander



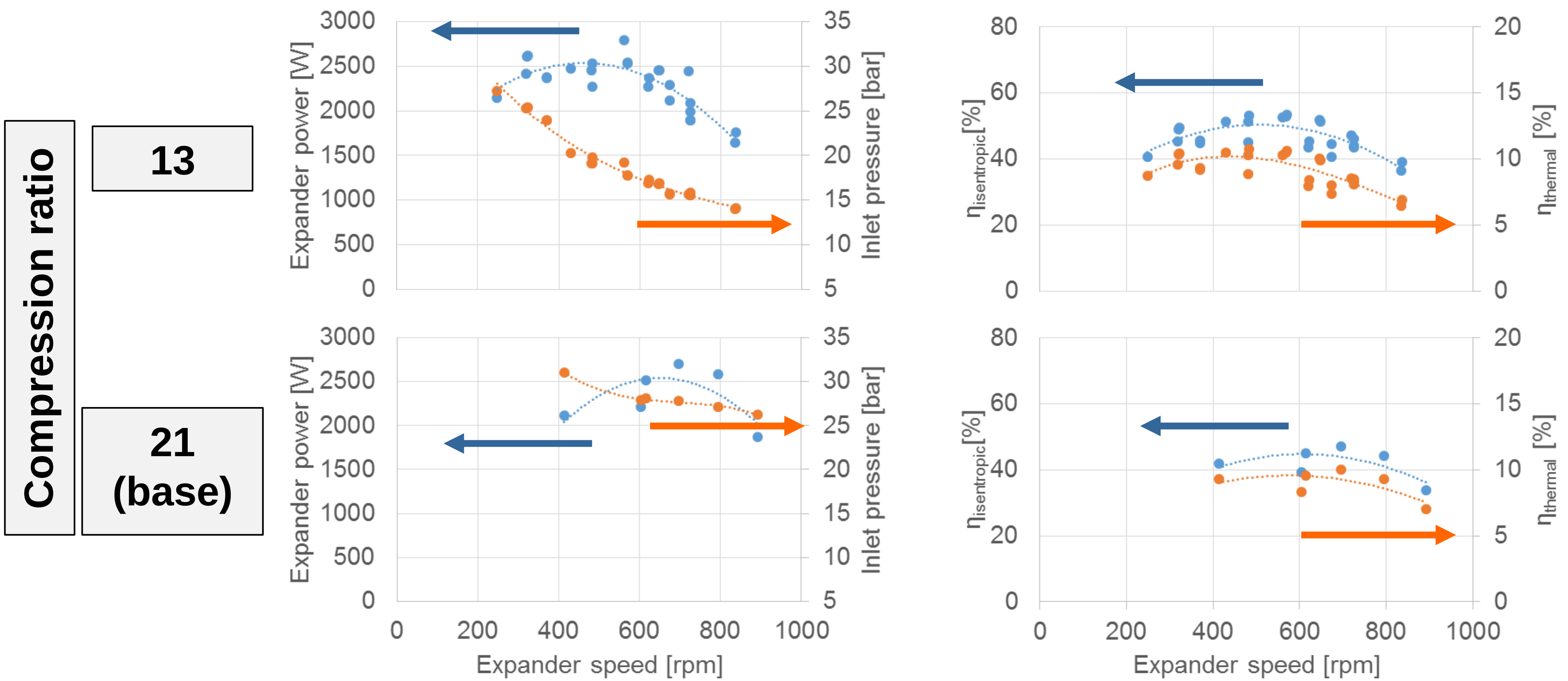
Results – Expander (simulated)



<u>Hypothesis</u>:

Maintaining **<u>power output</u>** and **<u>expander efficiency</u>** at **<u>30% lower admission pressure</u>** when modifying expander **<u>compression ratio from 21 to 13</u>**

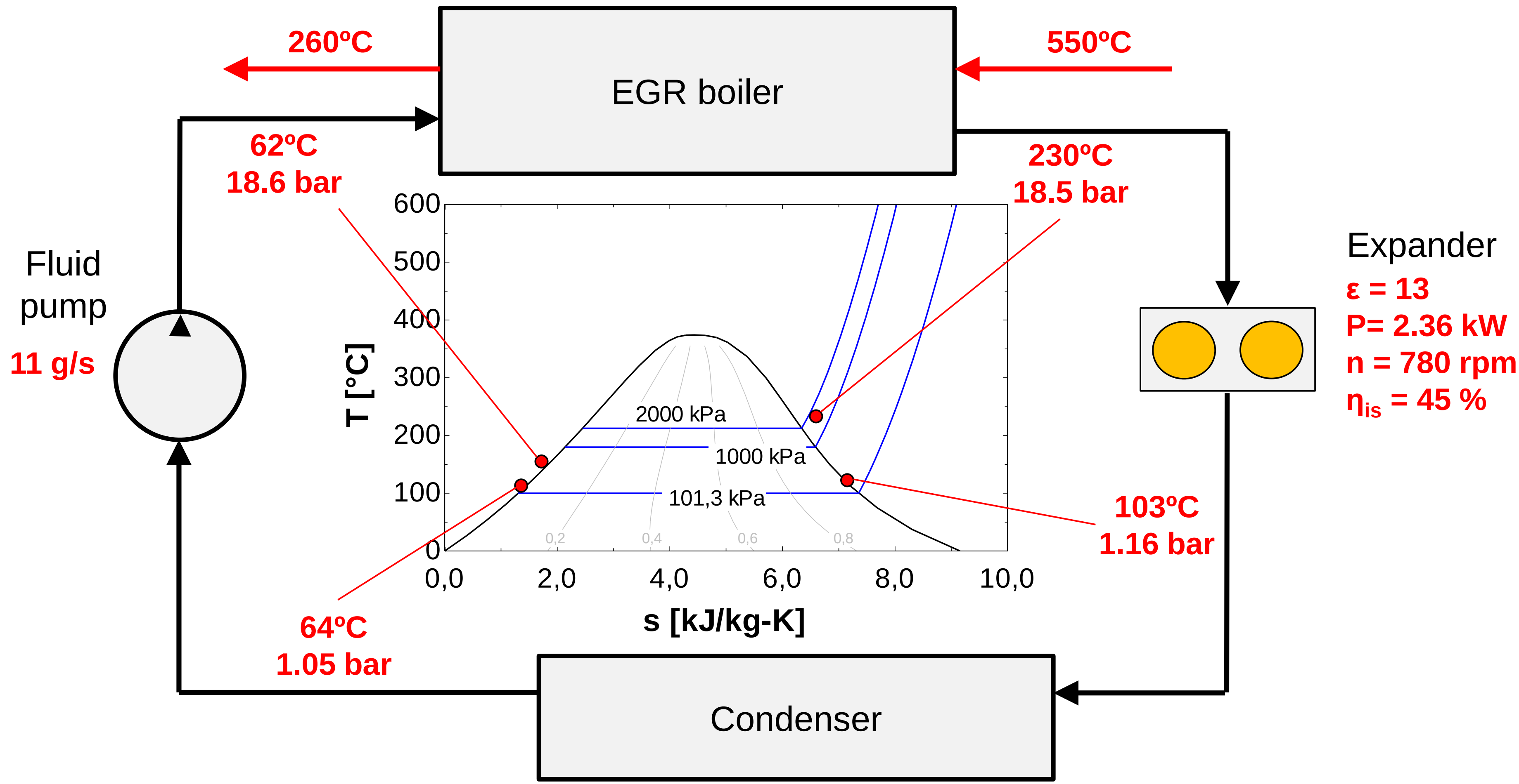
Results – Expander (test, B100)



$$\eta_{isentropic} = \frac{Expander\ power}{Mass\ flow\ \cdot Isentropic\ enthalpy\ drop}$$

$$\eta_{thermal} = \frac{Expander\ power}{EGR\ heat\ transfer}$$

Results – System test (B100)



Conclusion

Conclusion

EGR boiler

- *Internal flow circulation (steam “bubble”) reduced area for effective heat transfer*
- *EGR aftercooler was required to maintain sufficient EGR cooling*

Piston expander

- *High re-compression ratio of current expander design constrained power-output at applied boundary conditions*
  - *Compression ratio 21→13: Maintained power @ 30% lower inlet pressure*

System tests with water

- *Large heat of evaporation and high boiling temperature:*

  → *Very low flow rates (< 15 g/s), challenging to control*

  → *Poor cooling of EGR*

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