CITY UNIVERSITY LONDON

EST 1894

Academic excellence for business and the professions

Multi-Variable Optimisation of Wet Vapour Organic Rankine Cycles with Twin-Screw Expanders

Matthew Read, Ian Smith, Nikola Stosic

Centre for Positive Displacement Compressor Technology, City University London

CITY UNIVERSITY LONDON

Waste heat recovery

Potential heat sources:

- Industrial processes
- Combustion gasses
- Geothermal brines

Low temperatures result in:

- Low cycle efficiency
- High heat transfer area
- High sensitivity to component performance

CITY UNIVERSITY LONDON

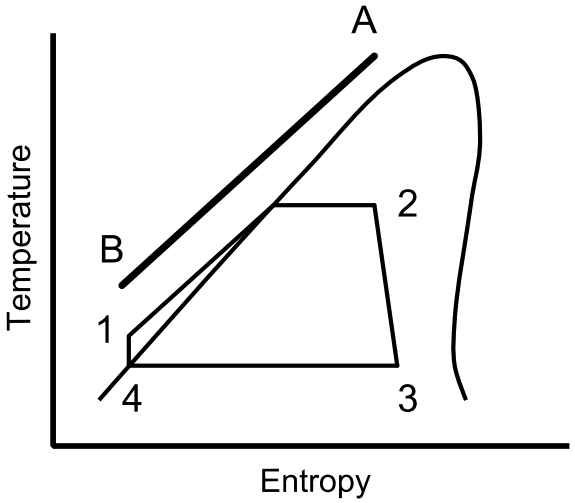
Aims of Research

- Characterise performance of heat recovery systems
- Optimise configuration and operating conditions
- Demonstrate potential savings

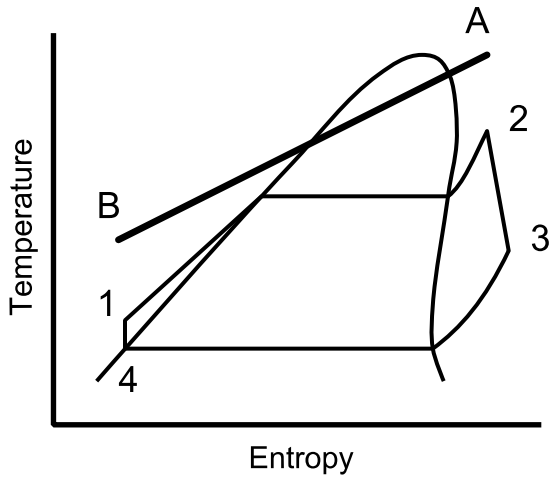
CITY UNIVERSITY LONDON

Organic Rankine Cycles

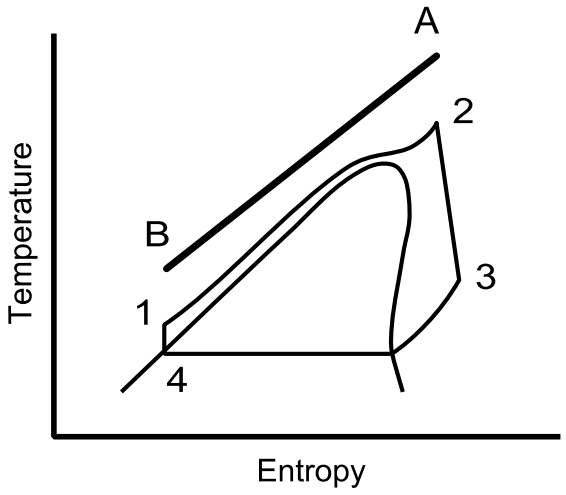
Wet Vapour



Superheated



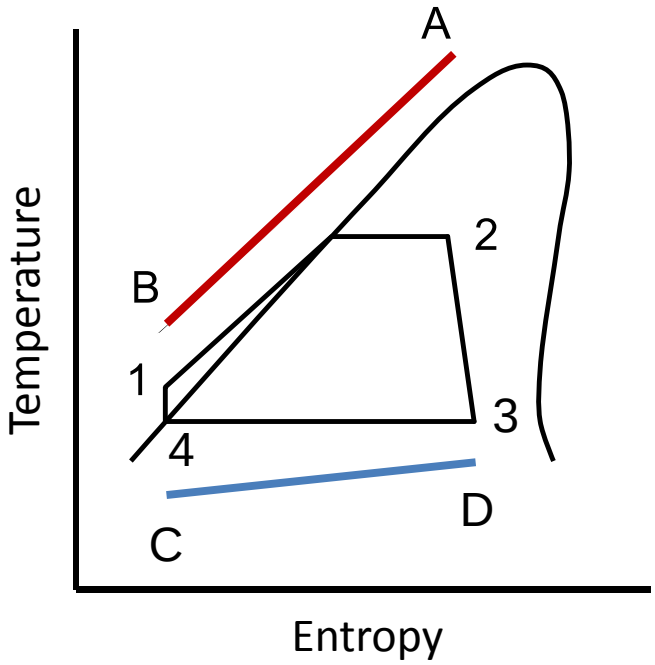
Supercritical

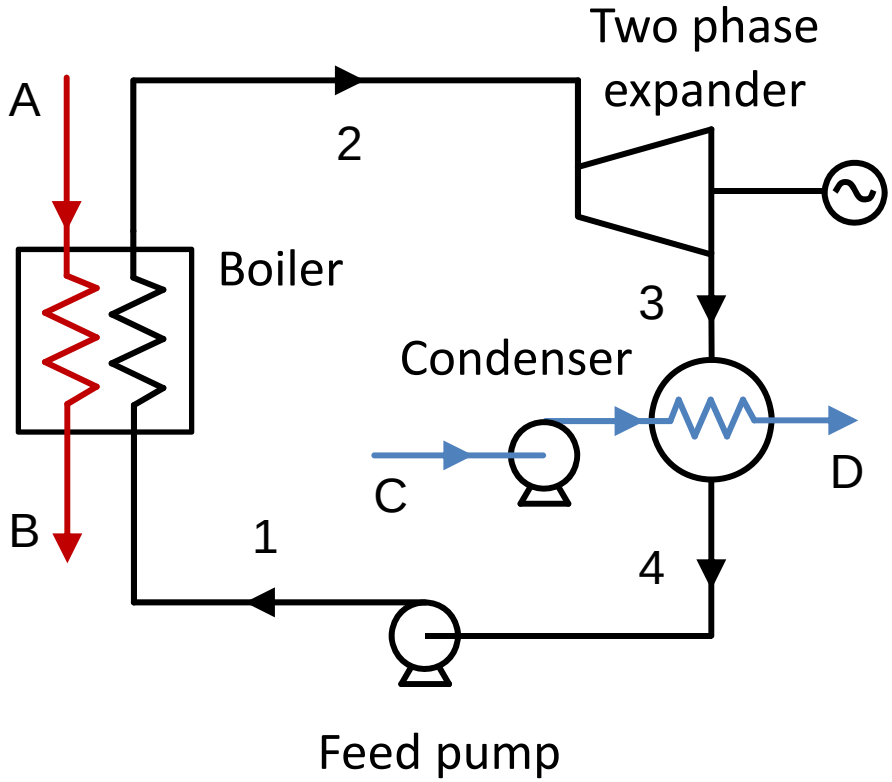


- Cycle influences component selection and design
- Specific application requires optimisation

CITY UNIVERSITY LONDON

Wet Vapour Organic Rankine Cycle (WORC)

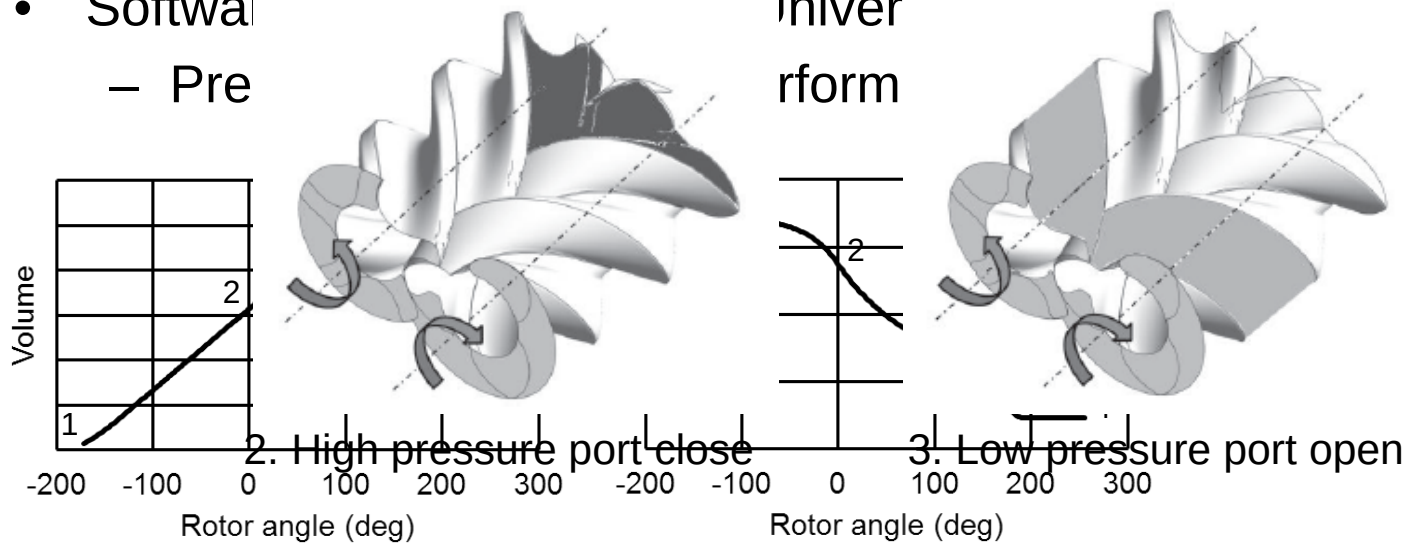




CITY UNIVERSITY LONDON

Twin-screw expanders

- Machine defined by:
  - Rotor dimensions and profiles
  - Port geometry
- Softwa[illegible]Univer[illegible]
  - Pre[illegible]rform



2. High pressure port close 3. Low pressure port open

CITY UNIVERSITY LONDON

Multi-variable optimisation of WORC

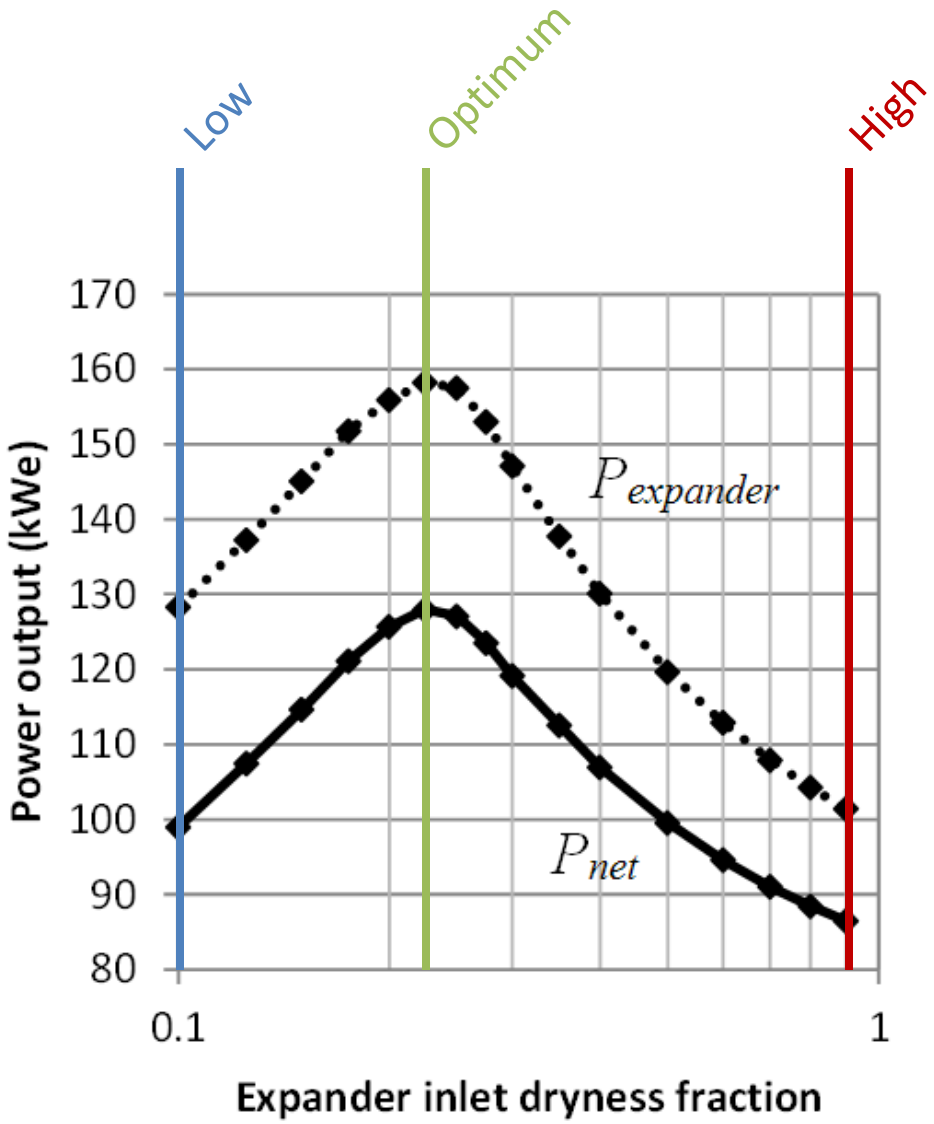
- A particular application defined by:
  - Source fluid max/min temperatures
  - Source flow rate
  - Sink fluid temperature
- Cycle variables include:
  - Working fluid
  - Boiler/condenser pressures
  - Expander inlet dryness fraction
  - Expander speed/BIVR
- Genetic algorithm used to optimise target function…

CITY UNIVERSITY LONDON

Maximising net power

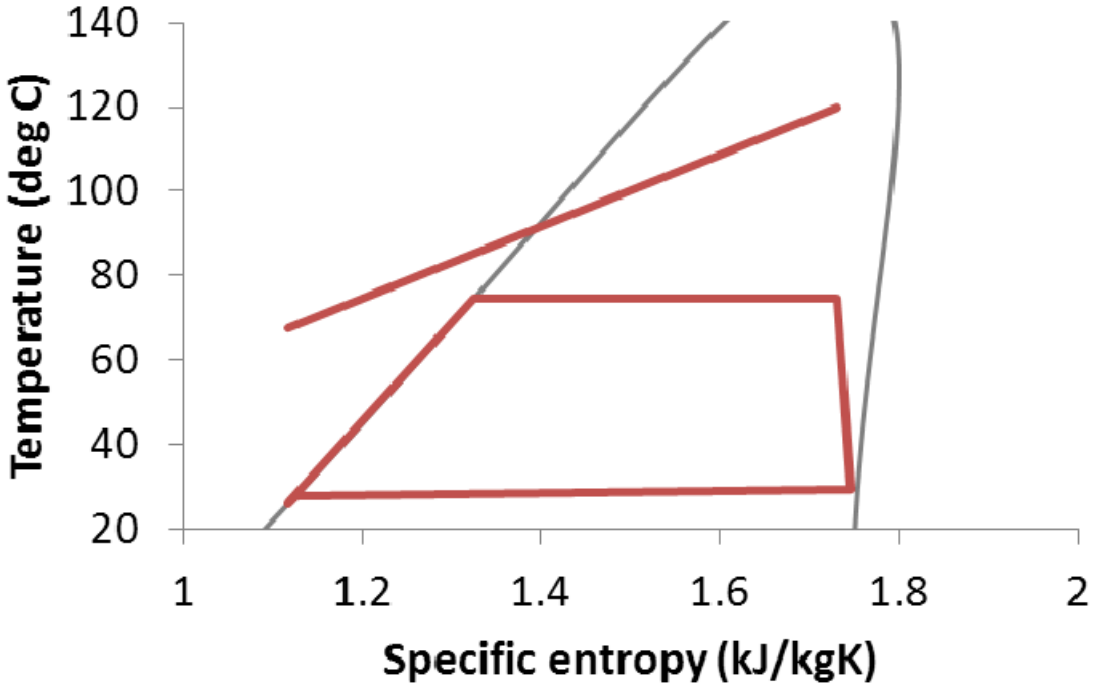
Case study:

- 2.6 MW liquid source fluid
  - 120°C inlet temp.
  - No lower limit
- Water cooled condenser
  - 15°C inlet temp.
- 204mm expander
- R245fa working fluid
- Optimise over range of expander inlet dryness



CITY UNIVERSITY LONDON

Expander inlet dryness cases



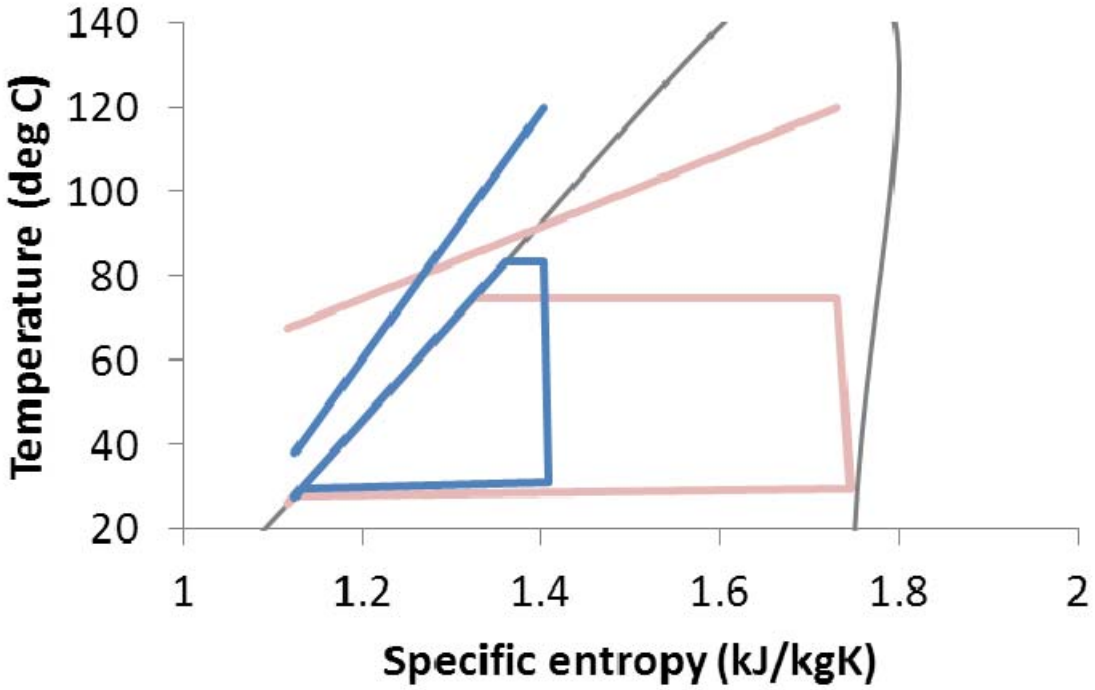
Dryness case:

- High
- Low
- Optimum

BIVR	η_{exp}	P_{net} (kWe)	η_{cycle}
2.39	**73%**	**87**	**6.6%**

CITY UNIVERSITY LONDON

Expander inlet dryness cases



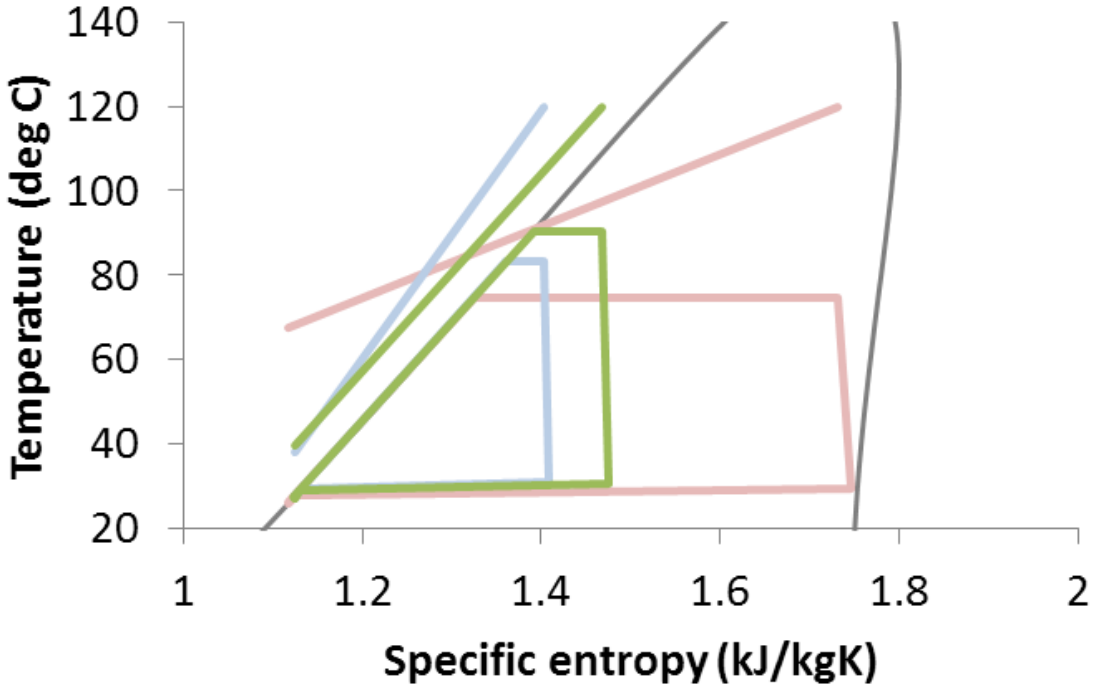
Dryness case:

- High
- Low
- Optimum

BIVR	η_{exp}	P_{net} (kWe)	η_{cycle}
2.39	73%	87	6.6%
4.5	72%	99	4.8%

CITY UNIVERSITY LONDON

Expander inlet dryness cases



Dryness case:

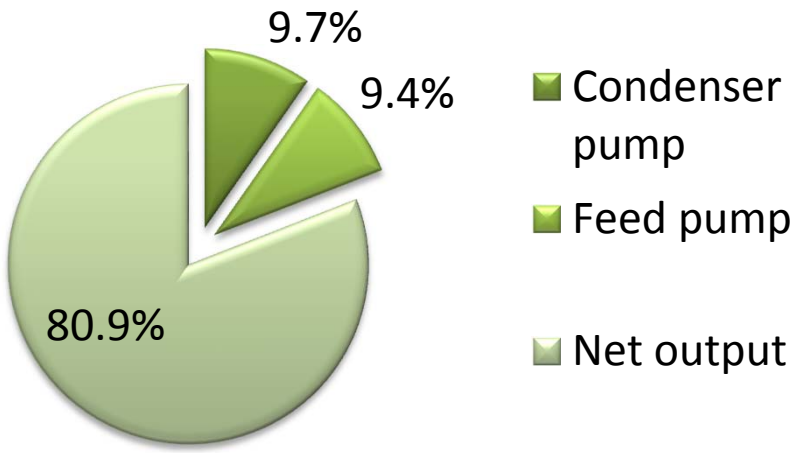
- High
- Low
- Optimum

BIVR	η_{exp}	P_{net} (kWe)	η_{cycle}
2.39	73%	87	6.6%
4.5	72%	99	4.8%
4.5	76%	128	6.3%

CITY UNIVERSITY LONDON

Optimum cycle conditions

- Use of expander power output:



- Expander operation:
  - Inlet dryness = 23%
  - Built-in vol. ratio = 4.5
  - Adiabatic efficiency = 75.9 %
  - Rotor tip speed = 71.5 m/s

CITY UNIVERSITY LONDON

Conclusions

- Optimisation demonstrated using detailed cycle model
- Wet vapour ORC maximises power output
- High efficiency possible with screw expander
- Strong basis for future technical and economic analysis