Test rig design for experimental characterisation of condensation in sCO_2 compressors

Supercritical CO_2 Power Cycles Symposium

DRAFT

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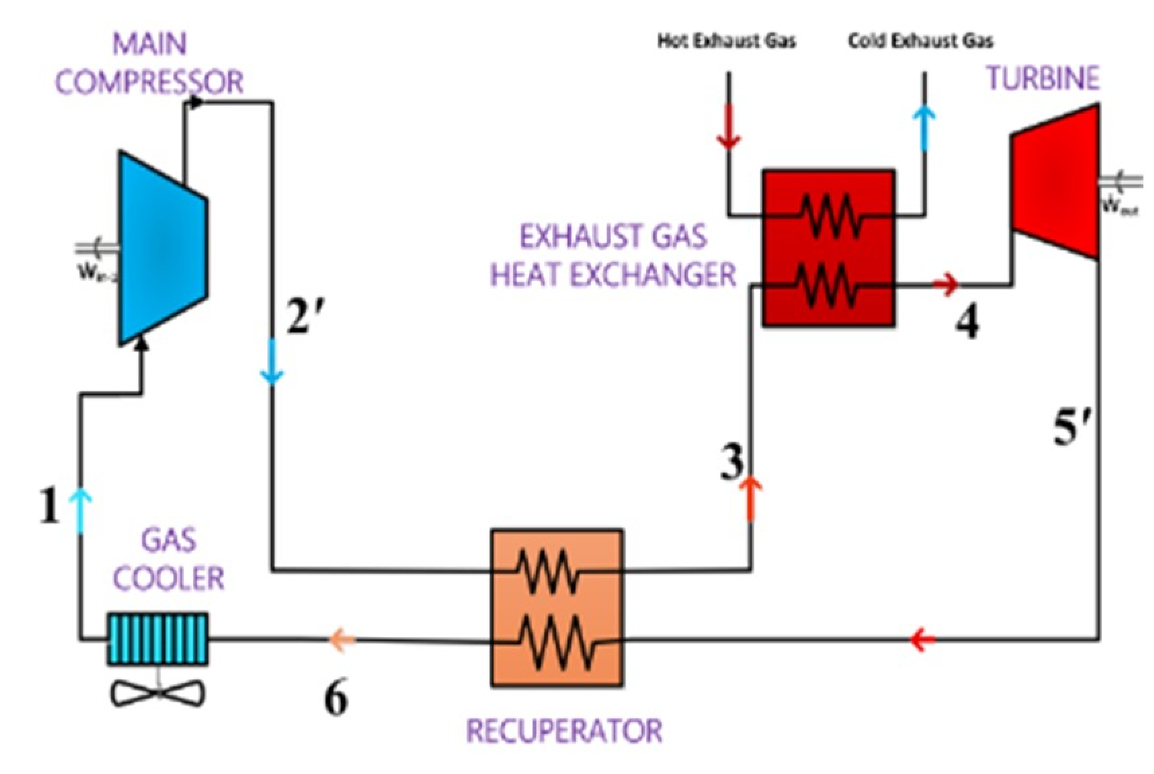
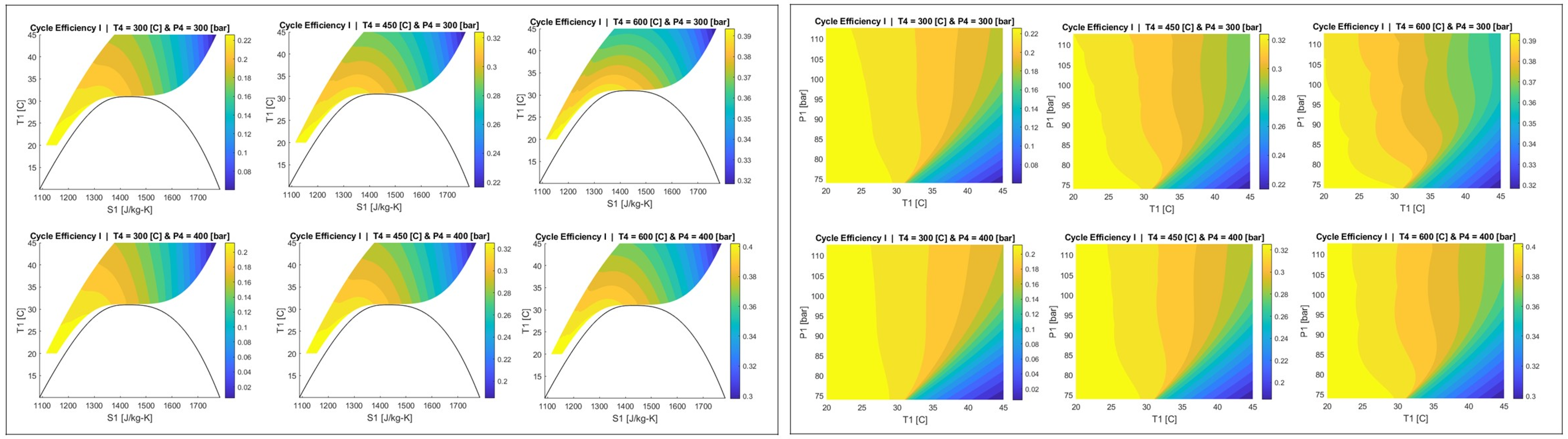


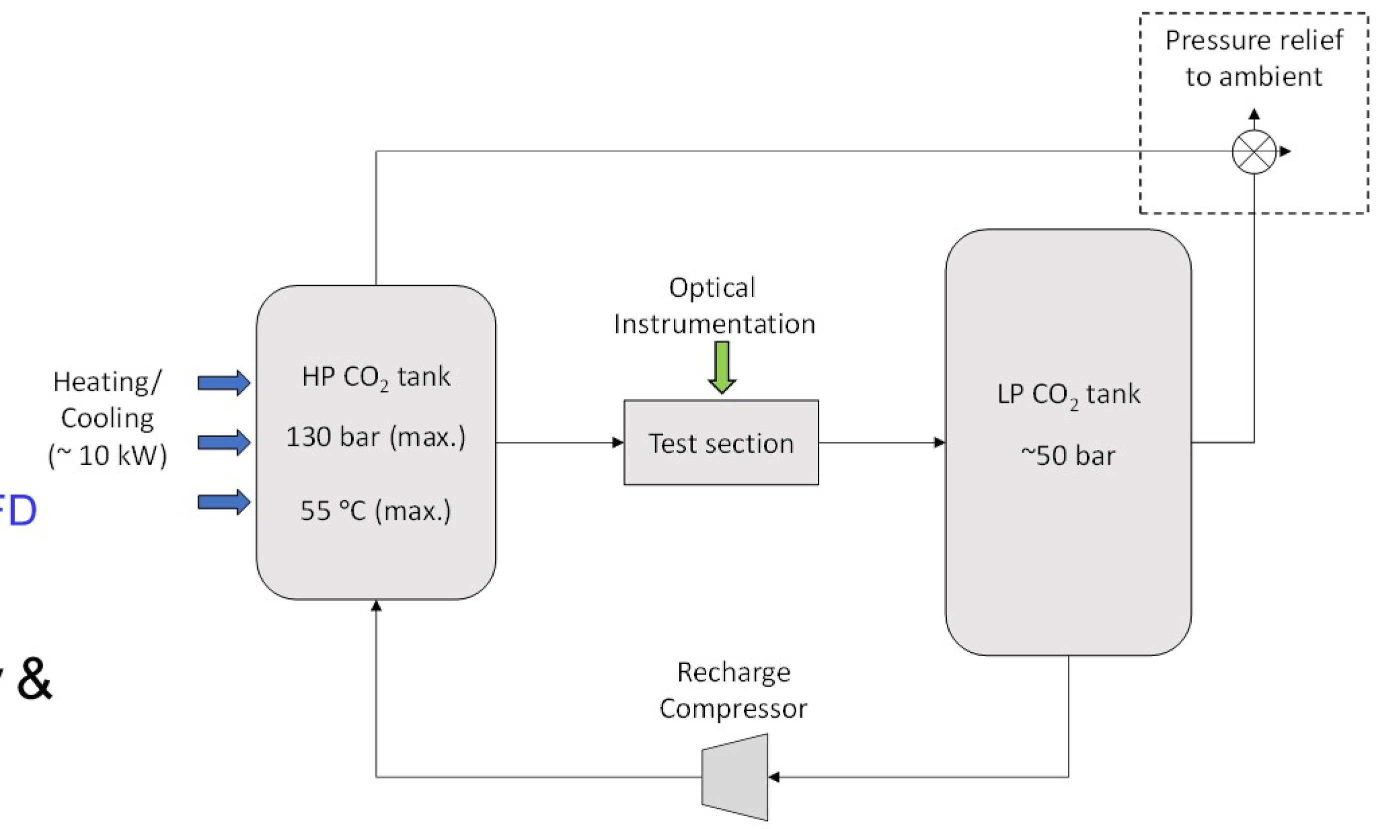
Simple Recuperated sCO_2 cycle

- Industrial WHR potential
  - ~1000 TWh
  - 30% High Temperature (> 270 °C) waste heat stream
- sCO_2 WHR power range
  - 100 kW to 50 MW
- Simple recuperated cycle
  - Best trade-off between efficiency and cost

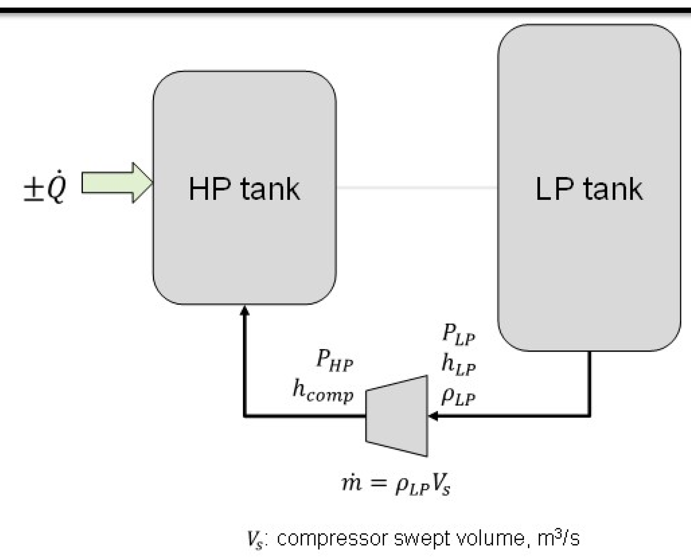


Cycle efficiency plots

- Experimental characterisation to study:
  - Condensation effects @ compressor inlet
  - Validate/update property routine
  - Compare and update numerical 1D and 3D CFD codes
- Assess sCO_2 compressor efficiency & operation



sCO_2 blowdown test rig schematic



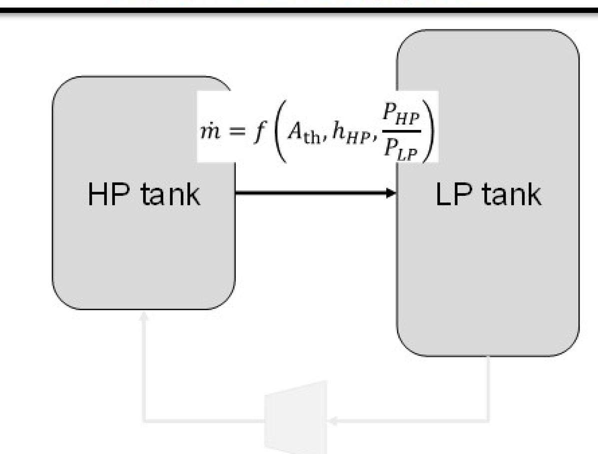
Test rig charging model

$$\frac{d(\rho_{HP}V_{HP})}{dt} = \dot{m}$$

$$\frac{d(\rho_{LP}V_{LP})}{dt} = -\dot{m}$$

$$\frac{d(\rho_{HP}V_{HP}u_{HP})}{dt} = \dot{m}h_{comp} + \dot{Q}$$

$$\frac{d(\rho_{LP}V_{LP}u_{LP})}{dt} = -\dot{m}h_{LP}$$



Test rig blowdown model

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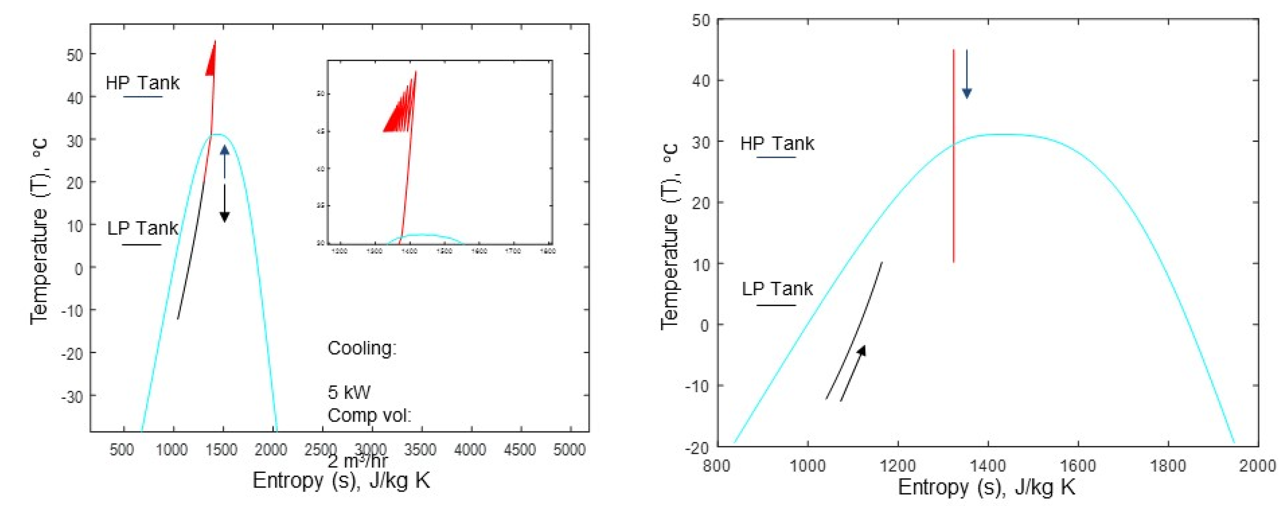
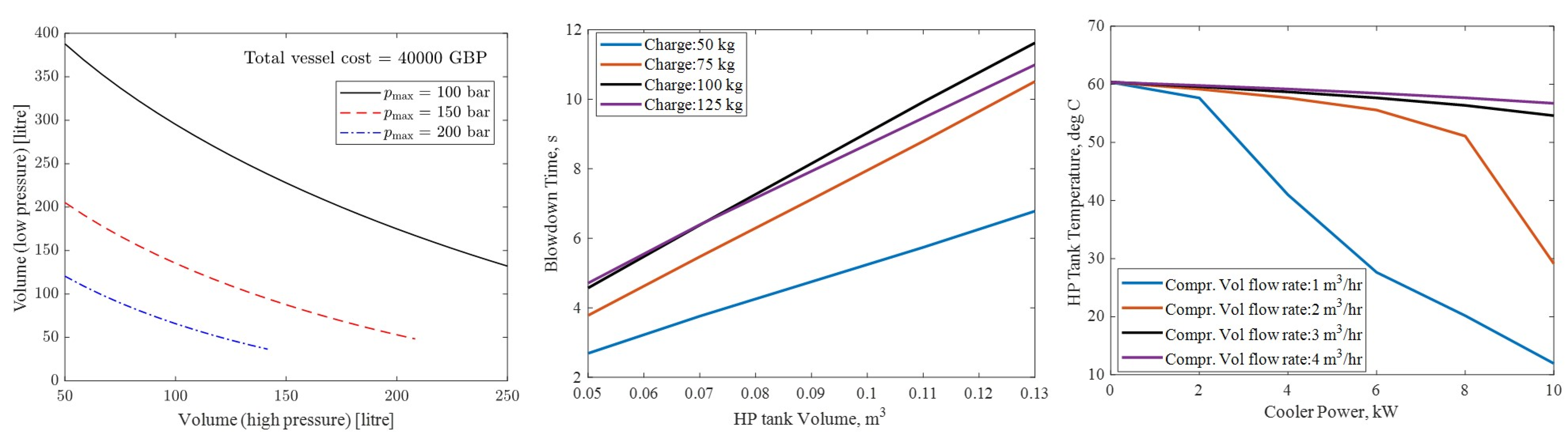
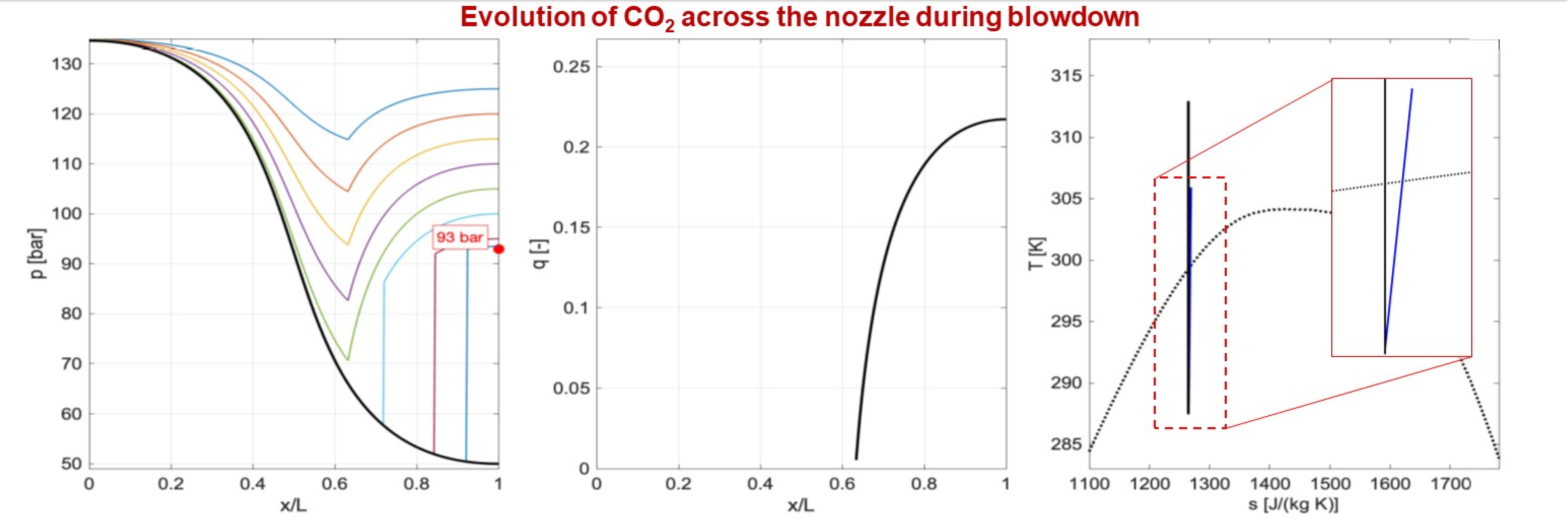


Parameter	HP Tank	LP Tank	Compressor
Total CO_2 charge, kg	100		
Volume, liter	100	185	-
Operating Pressure, bar	130	50	-
Operating Temperature, °C	Min: 32 Max: 55	-20	-
Volumetric flow rate, m^3/hr	-	-	Min: 1 Max: 4
Cooling capacity with water circuit, kW	10	-	-



Parametric studies to size test rig components

Evolution of CO_2 across the nozzle during blowdown



Reservoir conditions: 313 K; 135 bar; nozzle outlet design pressure: 50 bar

Left: pressure profile for a fixed reservoir condition and variable outlet pressure: p_{out} < 93 bar normal/oblique shock occurs at the nozzle exit leading to a full expansion within the nozzle, and two-phase conditions expected within the nozzle. Centre: expected vapour qualities in the nozzle. Right: possibility of shocks transitioning from two-phase conditions upstream of the shock, and supercritical conditions downstream of the shock