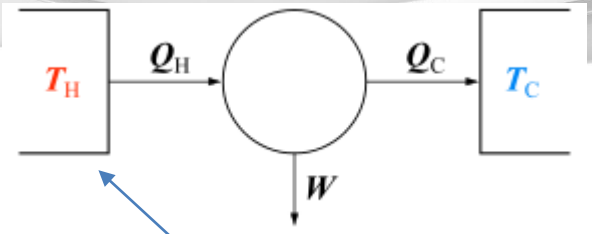
Adapting the Trilateral Flash Cycle for Advantage

Prof Jeremy Miller

Carnot

Nicolas Léonard Sadi Carnot in 1813 at age of 17 in the traditional uniform of a student of the École Polytechnique



Not Infinite Heat Source

Carnot's theorem is a formal statement of this fact: *No engine operating between two heat reservoirs can be more efficient than a Carnot engine operating between the same reservoirs.*

$$\eta_I = \frac{W}{Q_H} = 1 - \frac{T_C}{T_H} \qquad (1)$$

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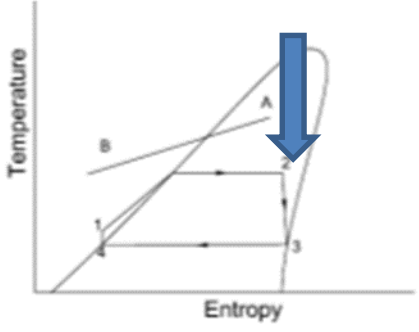
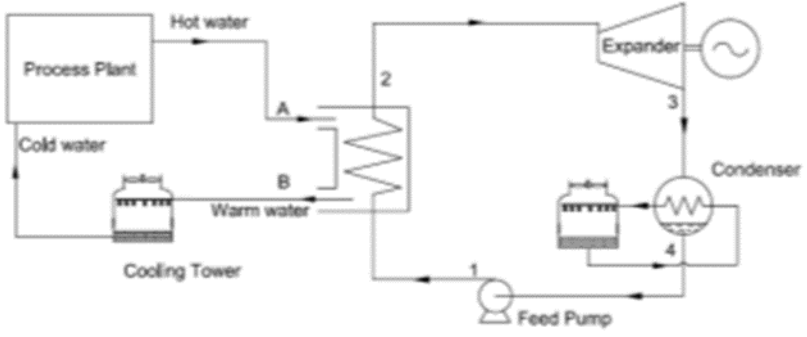
Source

ORC

- Major portion of the heat recovery at constant temperature (Isothermal)
- As heat is removed heat source becomes colder lowering the temperature at which boiling of the refrigerant can take place





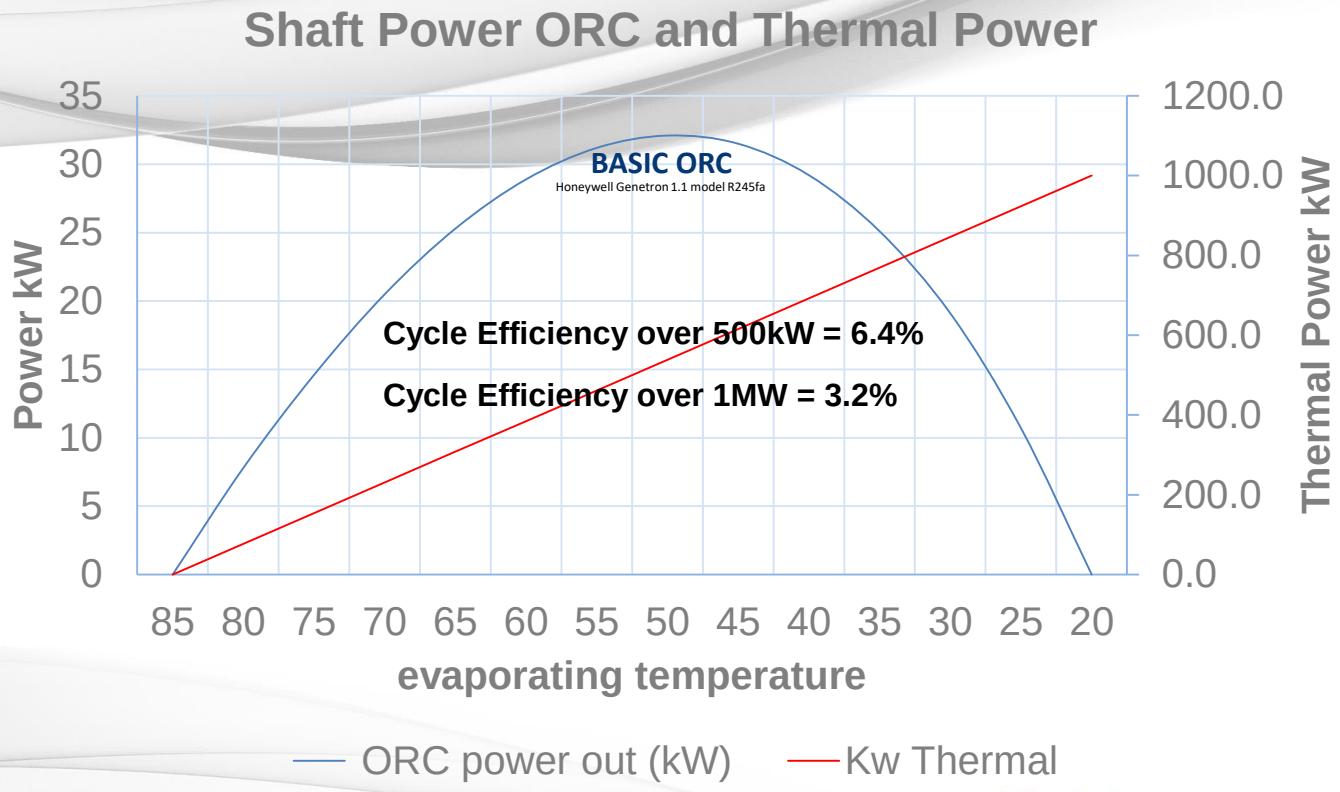
ORC

R245fa

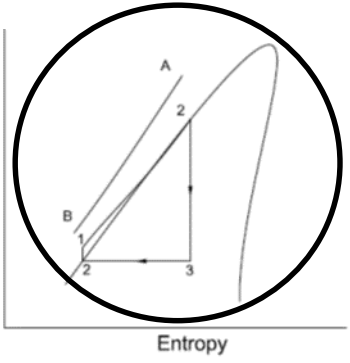
- Latent heat to Specific Heat over 40K range
- = 152 kJ/kg / 49 kJ/kg

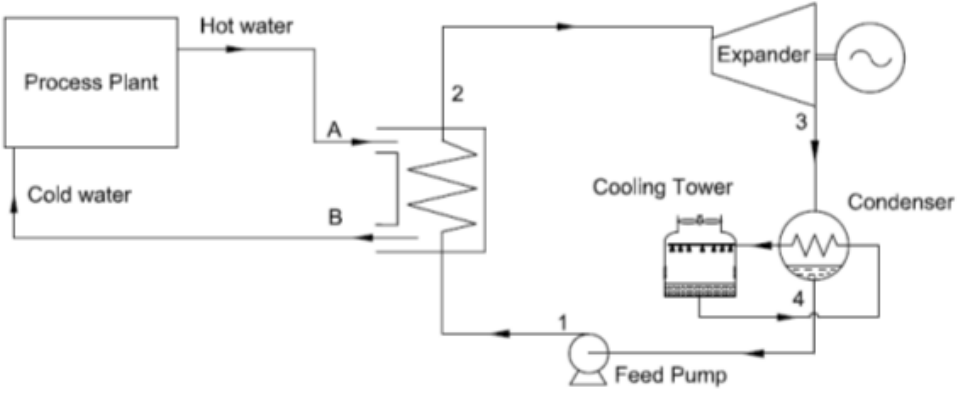
Low Temperature Waste heat

1MW @85C to cold reservoir 20C



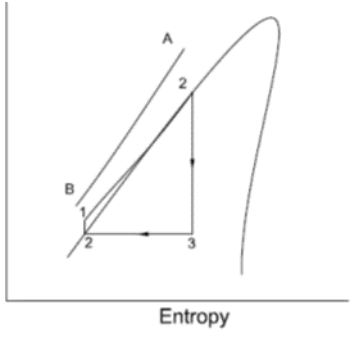
Tri-lateral Flash Cycle (TFC)





Tri-lateral Flash Cycle (TFC)

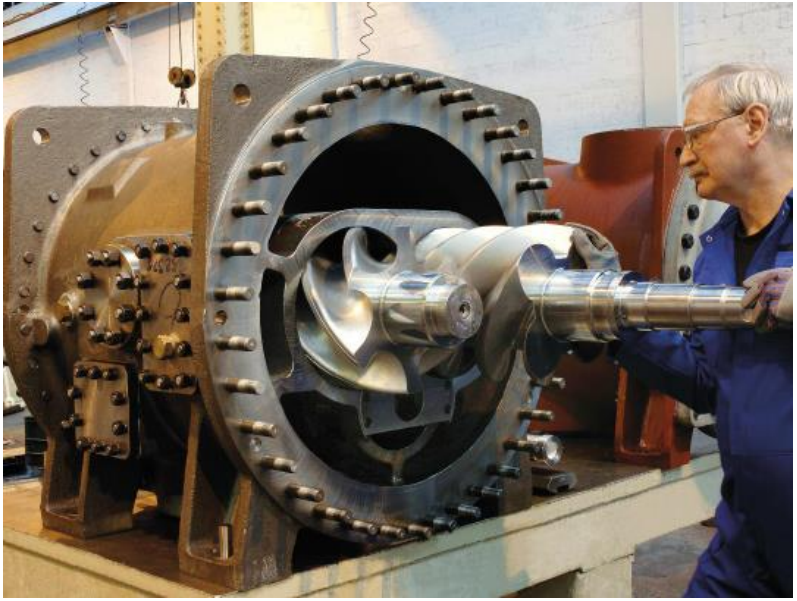
- Expand saturated liquid refrigerant which allows
- Counter-current heat exchange to absorb most of the available heat
- Improved approach to Carnot
- Total cooling
- 2-3 times more shaft power than ORC depending on conditions



TFC Achilles Heel

- Mass flow rate of refrigerant is approx. 3*greater than ORC
- Pumping electrical power can be highly parasitic to the generated output

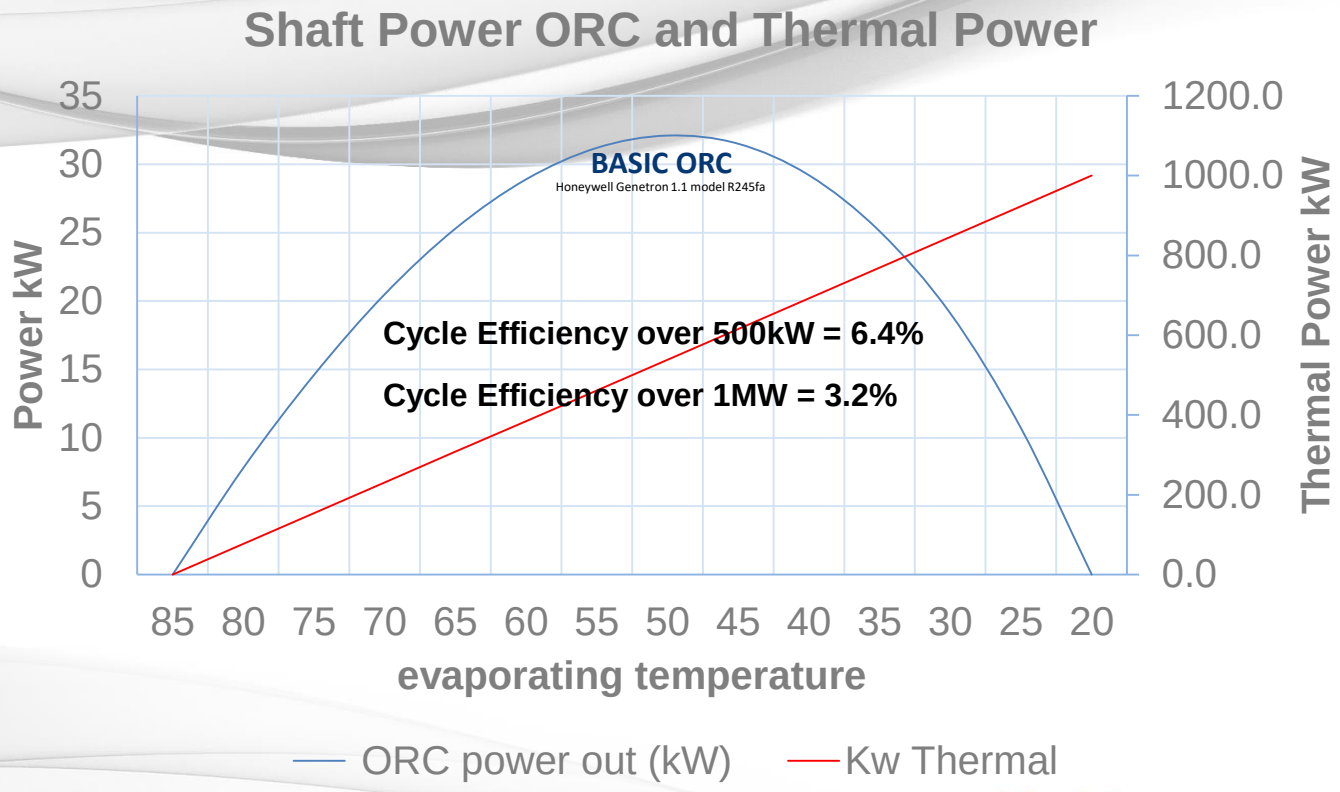
- Solutions
  - Careful selection of Refrigerant and Expander (Engine) combinations



Optimising the Refrigerant and Expander Size with respect to GWP and the environment

Low Temperature Waste heat

1MW @85C to cold reservoir 20C



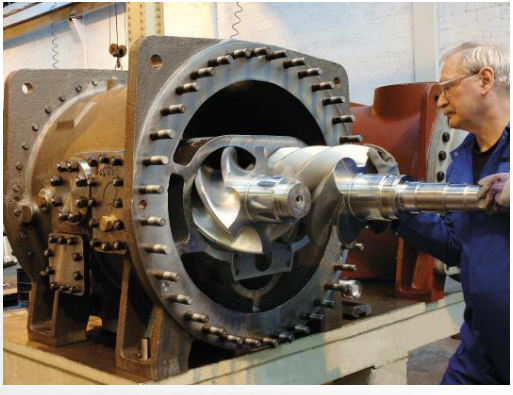
Optimising the Refrigerant (1MW @85C to cold reservoir 20C)

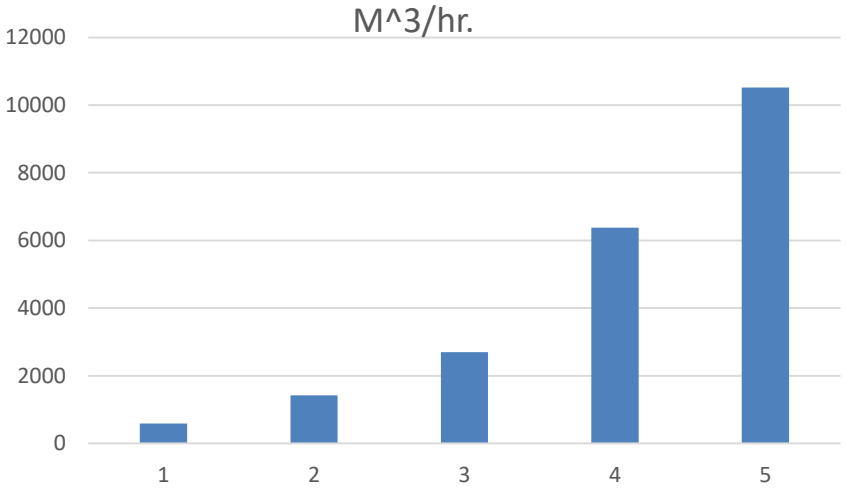
Refrigerant	Shaft Power kW	Pumping Power kW	Net Electrical Power kW	Global Warming Potential (GWP)	Outlet Volumetric Requirement m3/hr
ORC R245fa	37.3	1.3	36.00	950 to 1020	482
TFC R134a	84.9	28.53	52.13	1300	660
TFC R245fa	73.69	10.46	59.55	950 to 1020	2411
TFC R1233zd	72.92	10.2	59.1	6.0	2832

TFC:- R134a to R1233zd change worth £6000/annum in reduced pumping electricity

Screw Compressors

Broad Standard Range



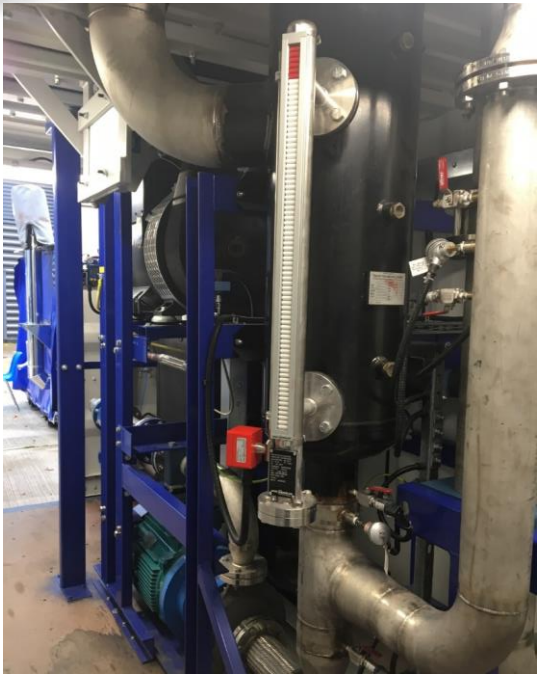


TFC Demonstration Application

Identified an application which provides a closely located source and sink, therefore mitigating one of our identified key risks of the project.

	Description	Pressure (bar)	Inlet Temp (℃)	Outlet Temp (℃)	Flowrate (kg/s)
Source	Flash Steam	1.6 - 2.5	128.88 – 138.99	90℃	0.69
Sink	Ammonia Plant Cooling Water	5	20	35℃	22.2

Prototype System Built



Thank You

Any Questions