DESIGN OF A 150W OTEC PROTOTYPE BASED ON THE KALINA CYCLE AND COMPARISON WITH ORC BASED OTEC

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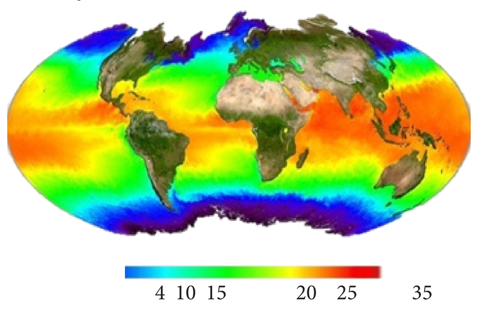
Ocean Thermal Energy Conversion
OTEC

WHAT IS OCEAN THERMAL ENERGY CONVERSION?

Ocean Thermal Energy Conversion (OTEC) is a technology for generating electricity using the temperature difference between the hot surface water and the cold deep water in the ocean. OTEC has the potential to become one of the leading renewable energy technologies in the near future.

- Renewable energy source
- Baseload energy supply
- Cogeneration of multiple products
- Limitless availability



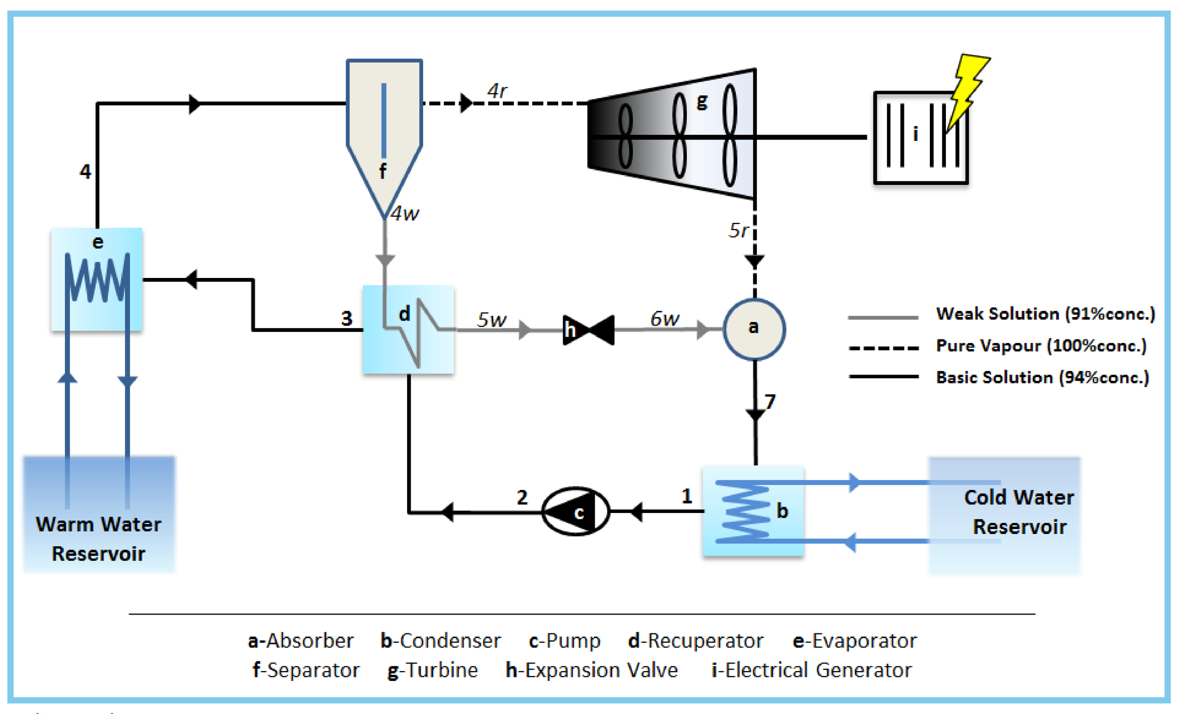
Available temperature difference in the ocean (0-1000m)

PROJECT DESCRIPTION

The OTEC DEMO project aims to design and build a room size demo of an Ocean Thermal Energy Conversion (OTEC) power plant based on the Kalina cycle as a proof of concept. It is also for ultimately providing a comparative analysis between OTEC with a Kalina based cycle and one with ORC based cycles. Fluidprop [1] and Cycle-Tempo [2] software were used to carry out the presented simulations.

KALINA CYCLE

The Kalina cycle is a thermodynamic absorption power cycle and uses an Ammonia-Water mixture as a work fluid. This cycle unlike an ORC-cycle, has two extra components: a separator; to separate the strong solution and weak solution generated after the evaporator; and an absorber to absorb the strong solution after undergoing expansion through the turbine on to the weak solution. It is claimed that the Kalina cycle has a higher efficiency compared to an ORC cycle due to higher exergetic efficiency



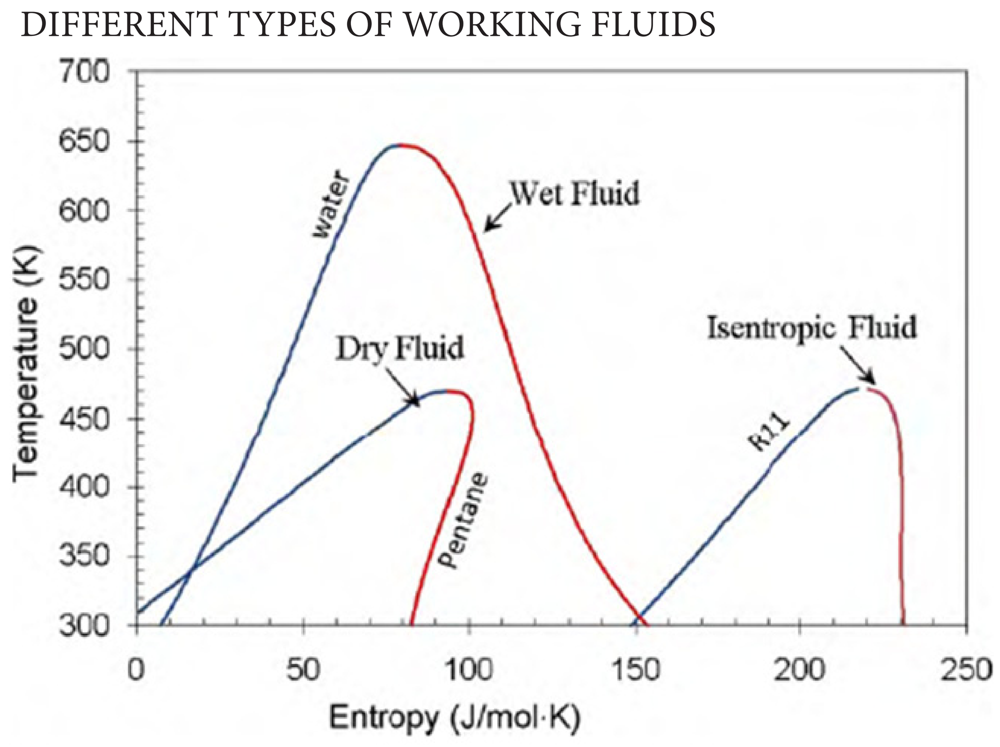
Kalina cycle

TYPES OF ORGANIC FLUIDS

The vapour saturation curve of the T-S diagram is the most crucial characteristic of an organic working fluid in an ORC cycle. Based on the vapour saturation curve they can be categorized into three categories namely; Dry fluid, Wet Fluid and Isentropic fluid. The following are addressed:

- R114 (Dry)
- R32 (Wet)
- R134a (Isentropic)

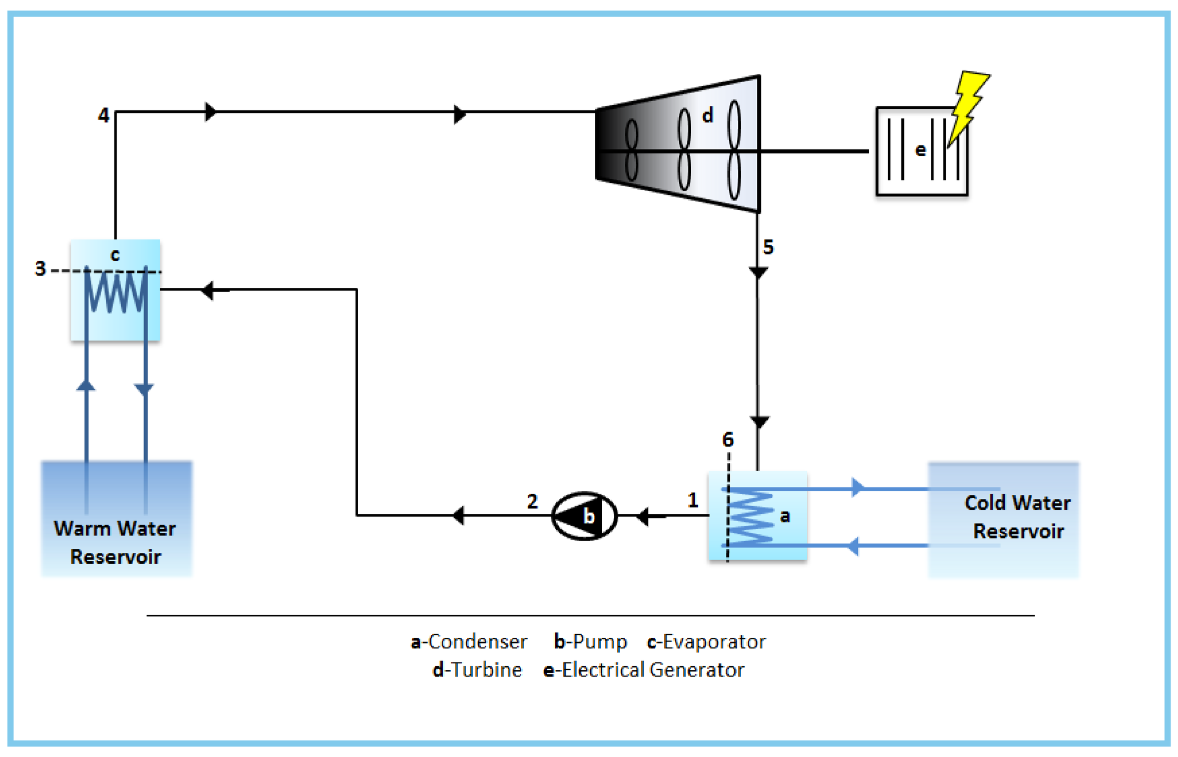
DIFFERENT TYPES OF WORKING FLUIDS



Temperature versus entropy diagram for three types of fluids, dry, wet and isentropic

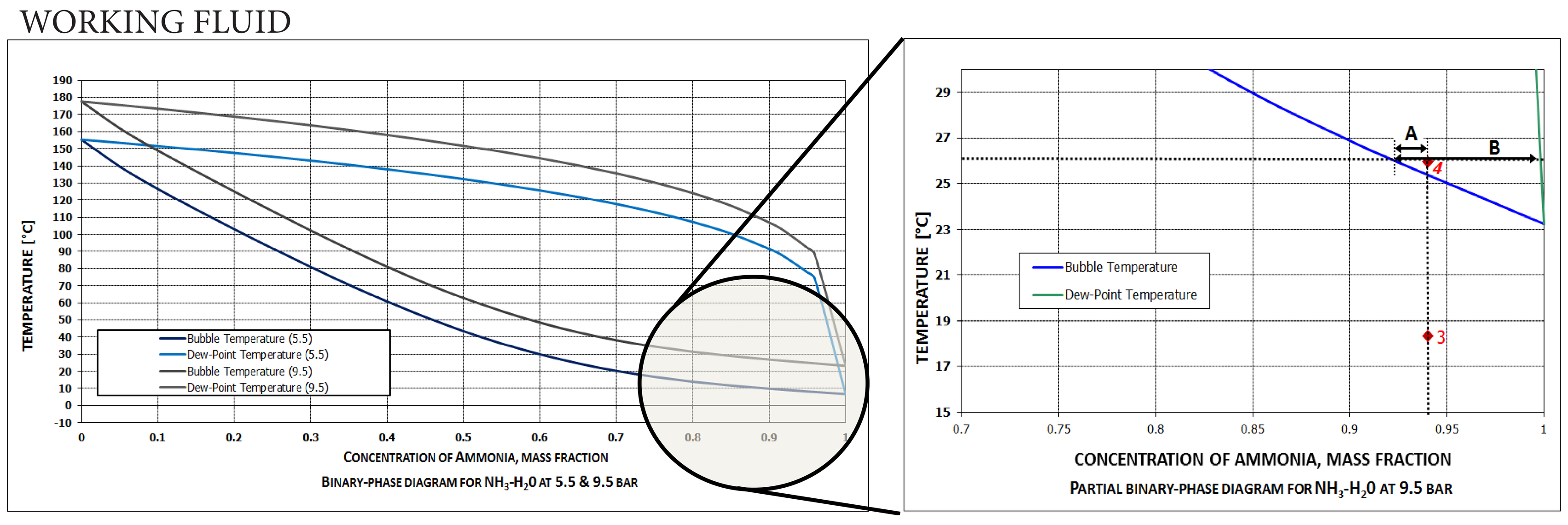
ORGANIC RANKINE CYCLE

The Organic Rankine cycle is a modified Rankine cycle which uses organic fluids like ammonia, alkanes, alkenes or other refrigerants as working fluids instead of water as in a Steam Rankine cycle. The organic fluids have a lower boiling point compared to water and can be used in systems where the hot source temperature is less that conventional Rankine cycle operating temperatures. Since the hot source temperature is lower, directly implies that the net efficiency obtained from these systems are generally lower.



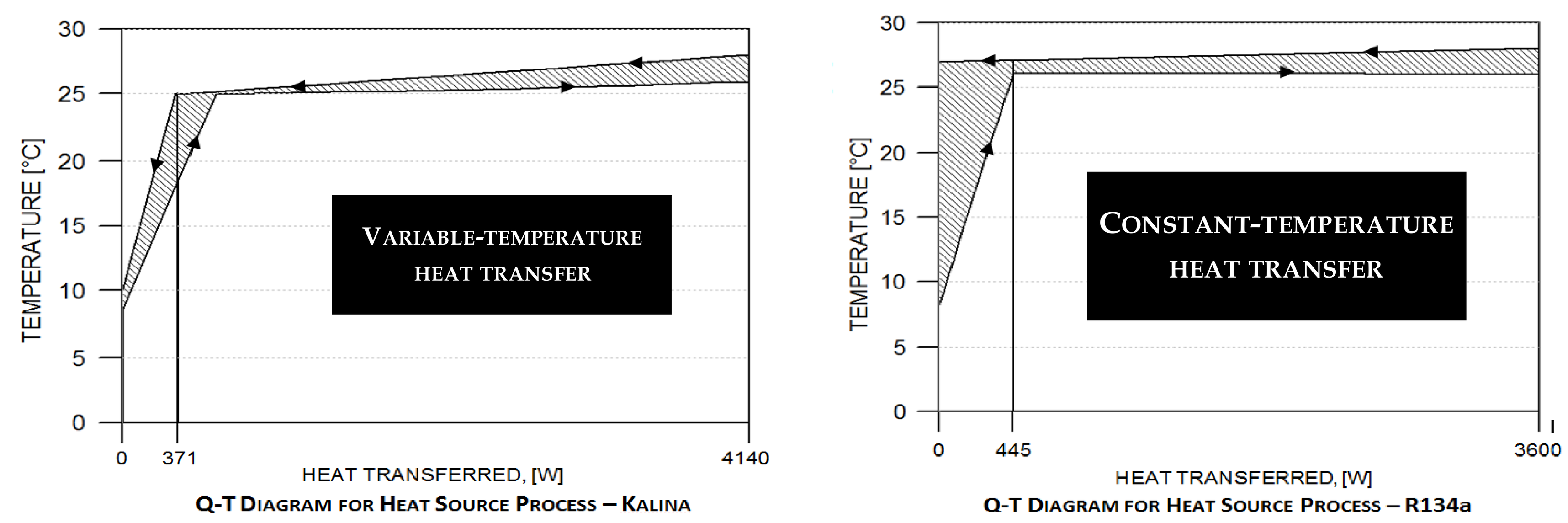
Organic Rankine cycle

WORKING FLUID



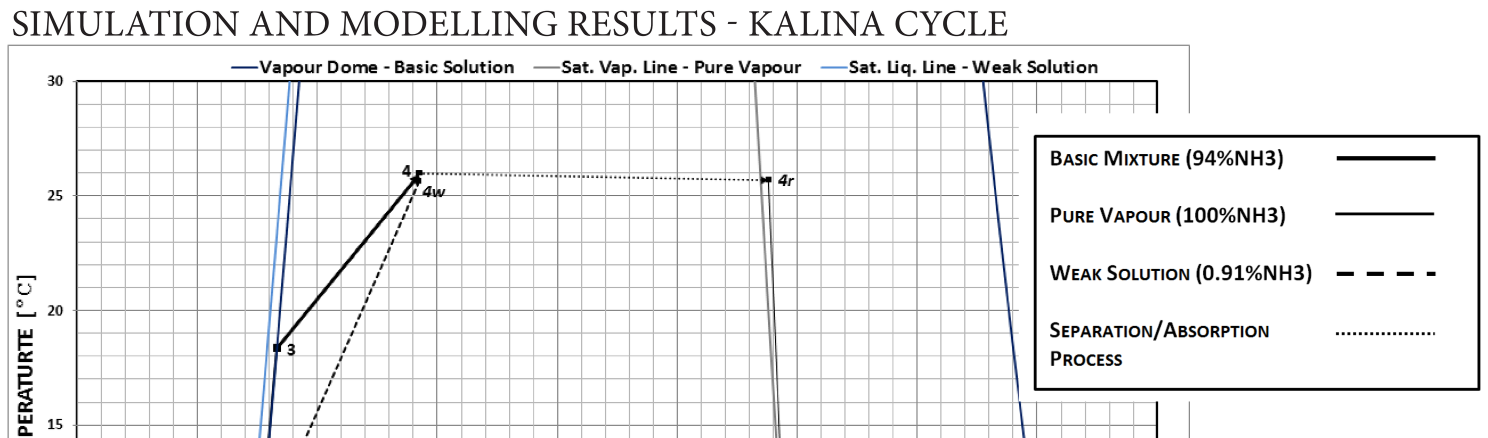
Temperature versus ammonia concentration

COMPARISON BETWEEN VARIABLE AND CONSTANT TEMPERATURE HEAT TRANSFER



Temperature versus heat transferred diagrams, left: Q-T diagram for heat source process - Kalina, right: Q-T diagram for heat source process - R134a

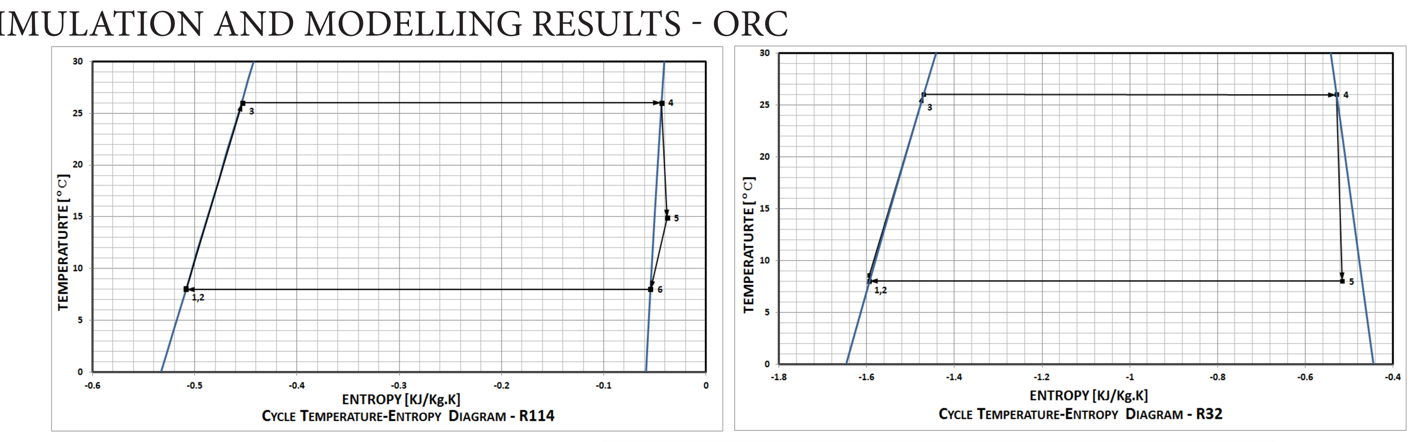
SIMULATION AND MODELLING RESULTS - KALINA CYCLE



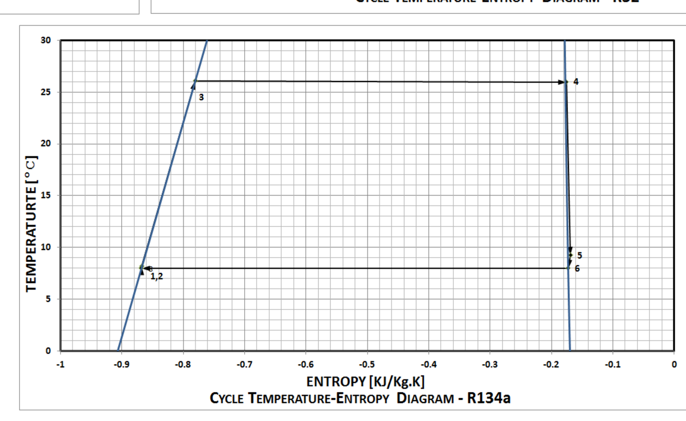
Fluid	Ammonia/Water
Ammonia Mass Concentration [%]	94
Turbine Inlet Temperature [°C]	25.7
Turbine Inlet Pressure [Bar]	9.34
Gross Efficiency [%]	4.10
Net Efficiency [%]	3.36

Cycle temperature versus entropy diagram

SIMULATION AND MODELLING RESULTS - ORC



Fluid	R-32	R-114	R-134a
Turbine Inlet	26	26	26
Turbine Inlet Pressure [Bar]	17.48	2.257	6.86
Gross Efficiency [%]	4.305	4.143	4.106
Net Efficiency [%]	2.72	2.653	2.77



Cycle temperature versus entropy diagram for various refrigerants

CONCLUSION

A comparative study between Kalina based OTEC and ORC based OTEC was performed. It can be observed that the gross efficiencies are more or less the same for ORC and Kalina cycles.

- R-32 wet fluid has the highest gross efficiency whereas the net efficiency for the Kalina cycle is much higher than ORC cycle. Losses for ORC are higher, hence lower net efficiency
- Temperature profile match in heat exchanger is better for Ammonia-water mixture than organic fluid. Hence less losses in heat exchangers
- Lower losses in heat exchangers imply smaller size of heat exchanger, hence lower cost of heat exchangers.
- The prototype of 150W is being constructed as a proof of concept to support the results of the analysis

Therefore based on the prototype could prove Kalina based OTEC has certain advantage over the ORC based OTEC system.

FURTHER RESEARCH AND DEVELOPMENT

- Construction of a 150 W OTEC demo installation and performance testing. Based on the results optimization of the prototype and thermodynamic model.
- Development of prototype with higher output power ~100 kW
- Development of large scale OTEC installation for commercial applications
- Research and development on application of plastic heat exchangers for OTEC applications

These research and development topics will be performed by the current OTEC demo team:
Daniel Baldacchino, Bram Harmsen, Akskay Hattiangadi, Thilak Raj, Srikanth Santhanam and Lu Zheng

References

1. P. Colonna, T.P. van der Stelt, FluidProp: A program for the Estimation of Thermo Physical Properties of Fluids, Energy Technology Section, Delft University of Technology, The Netherlands, 2004, www.FluidProp.com.
2. Delft University of Technology, Cycle Tempo, www.cycle-tempo.nl

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