REHOS Technology Executive Summary

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Abstract:

The REHOS cycle consist of two distinctly different sub-cycles, combined regeneratively, namely an Absorption Heat Transformer (AHT-VC Hybrid) type heat pump, pumping low-grade heat from the environment up to higher temperature, and a simple Organic Rankine Cycle (ORC) utilizing the pumped, higher temperature heat to power a turbine. The AHT is hybridized by the addition of a vapor compressor, forming a Heat Transformer type Heat Pump with an electrical component coefficient of performance (COP_e) very much higher than the conventional vapor compression (VC) heat pumps, as the AHT-VC Hybrid type heat pump use **both electrical and heat energy** for the heat pumping process, while the conventional **VC type use only electricity**. The regenerative coupling of these sub-cycles guarantee no heat is wasted (rejected) from this cycle, and the only thermal losses come from radiation from hot surfaces. This regeneration provide (or rather, recirculation) a large portion of the heat required by the ORC, and only the energy shortfall (after complete heat balance of the cycle) is required to be added by external sources.

The **heat to power conversion efficiency** can therefore be calculated by the **ORC Output Power (with pumping and heat pump compressor power subtracted), divided by this energy shortfall,** and may thus be unbelievably high. This is also described in detail in other publications (listed as references to this document) most of which are published as downloadable pdf files from my website referenced [12].

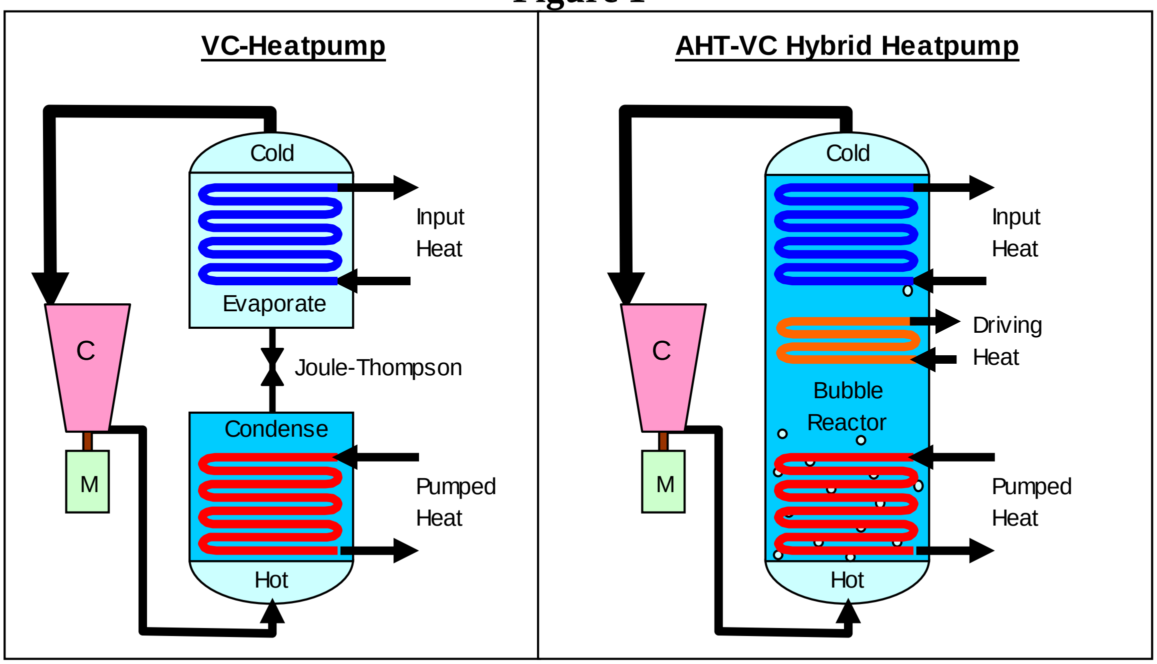
Introduction:

REHOS Technology was already comprehensively described in several documents (see publications at the end of this paper), but it is required to give a technology summary for people not in the technical field to easily understand the REHOS concepts.

Summary of REHOS concepts:

The REHOS thermodynamic cycle consist of two distinctly different sub-cycles combined, namely an Absorption Heat Transformer (AHT-VC Hybrid) type heat pump, pumping low-grade heat from the environment up to higher temperature, and a simple Organic Rankine Cycle (ORC) utilizing the pumped, higher temperature heat to power a turbine. The AHT is hybridized by the addition of a vapor compressor (VC), forming a Heat Transformer type Heat Pump with an electrical component coefficient of performance (COP_e) very much higher than the conventional vapor compression (VC) heat pumps, (the AHT-VC Hybrid type heat pump use **both electrical and heat energy** for the heat pumping process, while the conventional **VC type use electricity only**).

Figure 1

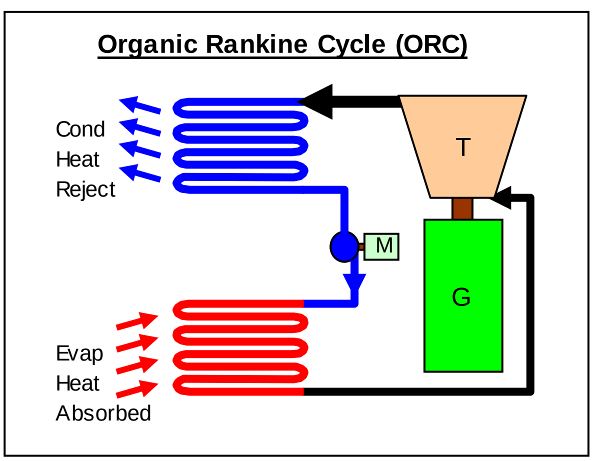


In the sketches of figure 1, the standard Vapor Compression (VC) heat pump on the left show that a refrigerant vapor at low pressure is compressed by the high compression ratio vapor compressor to a higher pressure, where in is condensed, producing the pumped heat output. The high pressure condensate passing through the Joule-Thompson expansion valve is flashed into vapor in the evaporator, absorbing the input heat in the process. All the energy required for the heat pumping process comes from the electrical motor powering the vapor compressor.

The AHT-VC Hybrid heat pump sketched on the right in figure 1, demonstrate the big difference of heat transformer type heat pumps vs the conventional VC types. Firstly, the compressor compression ratio is very much lower than the VC type, as the compressor only need to overcome the hydraulic pressure of the binary liquid column under gravity. The compressor power consumption is therefore much lower. Secondly, the heat transformer type heat pump not only use electricity for the heat pumping process, but also heat, represented in the sketch in figure 1 as "driving heat". The transformer type heat pump use heat to power the desorber function to generate vapor, and then use the vapor absorption (heat generating) function to raise the temperature. In heat transformer type heat pumps like this, the thermodynamic efficiency is reflected in the real coefficient of performance (COP_real) and is calculated as: $COP_{real} = \frac{Heat_{pumped}}{(Heat_{driving\_heat} + W_{compression})}$, but the driving heat is normally part of the input heat, and is therefore not readily seen as a separate amount of heat. It is therefore practical to evaluate performance ignoring the driving heat, by defining an electrical (COP_e) calculated as: $COP_e = \frac{Heat_{pumped}}{W_{compression}}$ and because the driving heat is ignored, COP_e may be calculated to very large values, like 50 - 500 as compression power may be only 10-30% of the driving heat required to power the process, depending on the binary column saturation pressure and differential temperature of the heat being pumped. More about this in the paper [7].

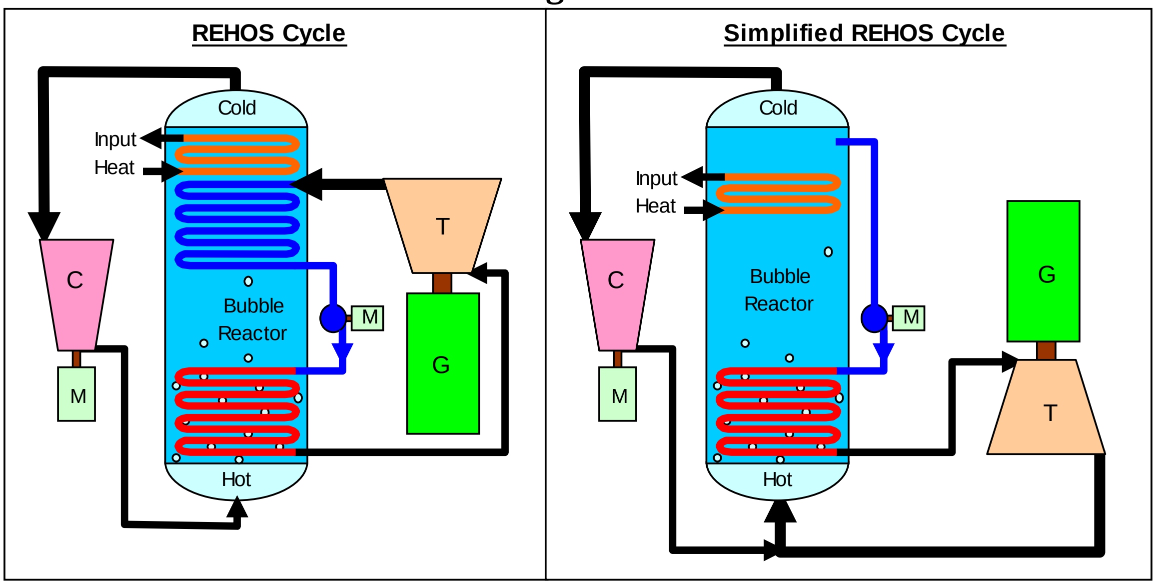
The AHT-VC Hybrid heat pump may be used for the normal refrigeration and air conditioning purposes, or the heat pump may be coupled regeneratively to a power generating cycle like the Organic Rankine Cycle (ORC) utilized for waste heat power generation when low grade (low temperature) heat is available in abundance. The comparison paper of [8] is also useful to see this. Figure 2, below, sketch a typical simple ORC using two heat exchange coils for heat input and heat reject duty. Coupling

Figure 2



the ORC and heat pump regeneratively involve the heat exchange coils of the ORC being made part of the heat pump in a way that the pumped high temperature heat is used to evaporate a refrigerant in the ORC evaporator. The ORC heat rejection low temperature heat exchange coil also form a large part of the heat pump input heat, the balance of which is supplied by a separate heat input exchange coil as shown graphically in the sketch of the REHOS Cycle on the left of figure 3 below.

Figure 3



The power developed by the REHOS cycle as pictured in figure 3 is easily seen as the netto electrical power output (generator output - compressor power - pump power) and the only external heat required to deliver this power is the input heat, calculated by the overall heat balance of the complete cycle. The thermodynamic efficiency of the REHOS cycle calculate to 70 - 90%, as shown in several descriptions, but probably described best in the document [8] written in April 2018.

In the REHOS cycle as sketched on the left of figure 3, the ORC is completely internally isolated from the heat pump operating medium, and may therefore be using any convenient refrigerant suitable for the temperature range where it is used. It has the disadvantage, however, of forcing the desorption process of the heat pump bubble reactor to occur at a single (very small range of temps) low temperature, decreasing the heat pump efficiency slightly as less of the sliding temperature effect in binary mixtures is used. In the Simplified REHOS Cycle sketched on the right of figure 3, the medium used in the ORC is the same volatile component of the binary medium (NH_3 in the NH_3 in aqua binary machine) used for the transformer-type heat pump, making use of direct contact heat exchange of vapor bubbles in the desorption area of the bubble reactor of the heat pump, instead of the heat having to traverse the heat exchanger tubing. It also allow drastically larger temperature glide in the desorber area, extended to the full length of the bubble reactor, again increasing reversibility (and therefore efficiency) in the heat transfer components of the thermodynamic cycle.

Commercial value and diversified use of the REHOS Technology is best seen in [11].

Publications:

1. Paper presented at PowerGen Africa Conference July 2017 and published in the conference proceedings titled "Introducing a novel thermodynamic cycle (patent pending), for the economic power generation from recovered heat pumped from the huge global thermal energy reservoir called earth" by Johan Enslin, Heat Recovery Micro System CC. This paper is also accessible from my website http://www.heatrecovery.co.za/.cm4all/iproc.php/PowerGen-Africa 2017 Proceedings Speaker0_Session19149_1.pdf

2. A Paper titled "The Simplified REHOS Cycle.pdf" was written by Johan Enslin in August 2017 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/The Simplified REHOS Cycle.pdf

3. A Paper titled "Clarifying Process Parameters for the REHOS Cycle Concept_rev3.pdf" was written by Johan Enslin in October 2017 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Clarifying Process Parameters for the REHOS Cycle Concept_rev3.pdf

4. The Paper titled "The Binary NH3-H2O Bubble Reactor_rev1.pdf" was written by Johan Enslin in December 2017, and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/The Binary NH3-H2O Bubble Reactor_rev1.pdf

5. The Paper titled "The Competitive Advantages of REHOS Technology_rev1.pdf" was compiled by Johan Enslin in early January 2018, and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Competitive Advantages of REHOS Technology_rev1.pdf

6. Another paper, "Executive Overview of the REHOS Technology_rev1.pdf" was compiled by Johan Enslin in February 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Executive Overview of the REHOS Technology_rev1.pdf

7. The follow-up document "Clarification of COP calculations for Absorption Heat Transformer (AHT) Type Heat Pumps.pdf" was written by Johan Enslin (to enhance the Executive Overview paper) in March 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Clarification of COP calculations for Absorption Heat Transformer (AHT) Type Heat Pumps.pdf

8. The document titled "Comparison of various Modern Heatpump Technologies for unlocking Commercial Value from Ambient Heat_rev4.pdf" was written by Johan Enslin in April 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Comparison of various Modern

Heatpump Technologies for unlocking Commercial Value from Ambient Heat_rev4.pdf

9. The document "Renewable Energy for Baseload Power" was written by Johan Enslin in April 2017 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Renewable Energy for Baseload Power.pdf

10. The Paper titled "The Proof-of-Concept Model of the REHOS Ejector Heat Pump_Part 1.pdf" was written by Johan Enslin in April 2018, and published on my website. This document was produced for the purpose of detailing the design, construction and theoretical operational performance of the Heatpump and would be followed up with a Part 2 document, representing the experimental process performance of the tested Model. http://www.heatrecovery.co.za/.cm4all/iproc.php/The Proof-of-Concept Model of the REHOS Ejector Heat Pump_Part 1.pdf

11. The Paper titled "Competitive Advantages of REHOS Technology_rev2.pdf" was re-written by Johan Enslin as a 2nd revision of the same titled document published January, in April 2018, and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Competitive Advantages of REHOS Technology_rev2.pdf

12. Website for Heat Recovery Micro Systems where the above publications are available from: www.heatrecovery.co.za