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Reactive working fluids for thermodynamic cycles. The current knowledge level and needed future researches.

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Thermodynamic cycles represent the backbone structure of fossil-fuelled and renewable thermal power systems, refrigerators and heat pumps. The improvement of the cycle architecture, of the unit operations, as well as the optimal selection of the working fluid are the current pathways towards the increase of their efficiency.

Nowadays, these technologies are based on the use of inert working fluids: water or organic molecules in Rankine cycles or air and flue gases in gas turbines; pure fluids or inert mixtures of organic refrigerants in heat pumps and refrigeration cycles.

In 1957, Lighthill proposed to convert the chemical energy derived by the "large energy change involved in dissociating gases" into work [1]. Practically, this idea consists in the use of reactive working fluids, instead of inert ones, in closed power cycles. An example of these reactive fluids is the fluid being site of the reversible dissociation-association reaction N_2O_4 = 2 NO_2. Actually, Lighthill's concept is a novel energy conversion process, where the transformation of thermal energy into mechanical one is made possible by the concurrent thermal and chemical conversion of the energetic state of a reactive fluid, all along a closed "thermo-chemical" cycle. This concept remained quite unexplored in Europe, although in the years 1970' many studies were conducted at the Nuclear Power Institute of the Academy of Science in Byelorussia and three experimental nuclear power plants were built operating with N_2O_4 = 2 NO_2.

Our team is working in a project funded by the European Research Council (project REACHER – www.univ-lorraine.fr/erc-reacher) aiming at designing new reactive fluids [2], characterizing their thermodynamics, designing the optimal cycle's architecture and validating experimentally the results, in a micro-power plant.

With this contribution, we will present the current state of the art on reactive working fluids for thermodynamic cycles and will introduce the challenges of future research needed to qualify and quantify the potential of this unexploited thermodynamic theory.

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[1] Lighthill, M.J. (1957): **Dynamics of a dissociating gas. Part I: Equilibrium flow**, Journal of Fluid Mechanics, 2, 1–32.

[2] Lasala, S., Privat, R., Herbinet, O., Arpentinier, P., Bonalumi, D. and Jaubert, J-N. (2021): **Thermo-chemical engines: Unexploited high-potential energy converters**, Energy Conversion and Management, 229, 113685. doi: 10.1016/j.enconman.2020.113685.

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