Hydrogen refrigeration via kinetic para-ortho manipulation in a vortex tube

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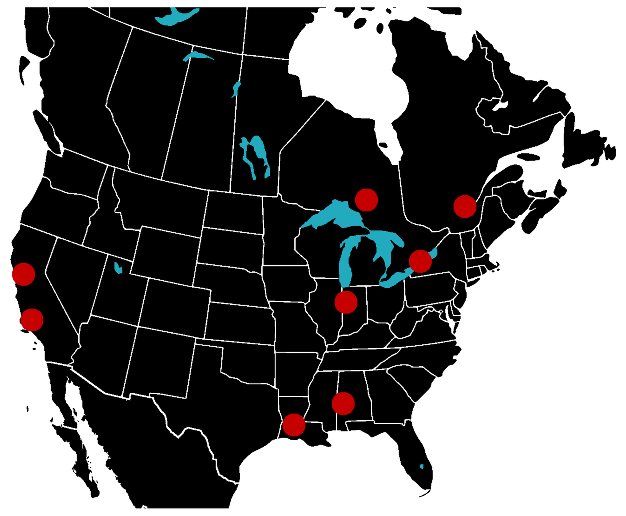
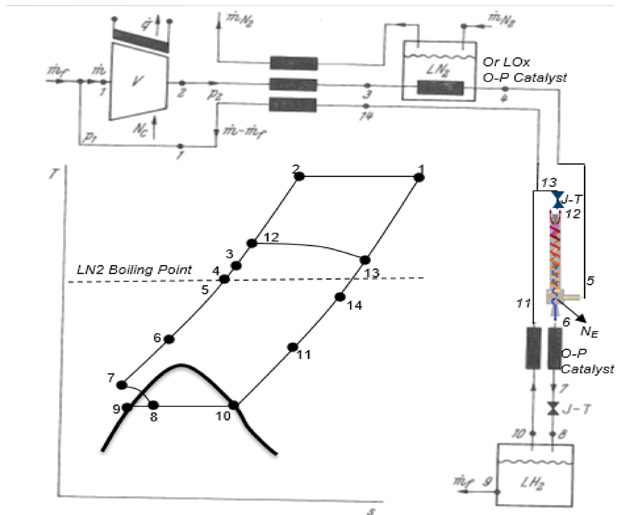
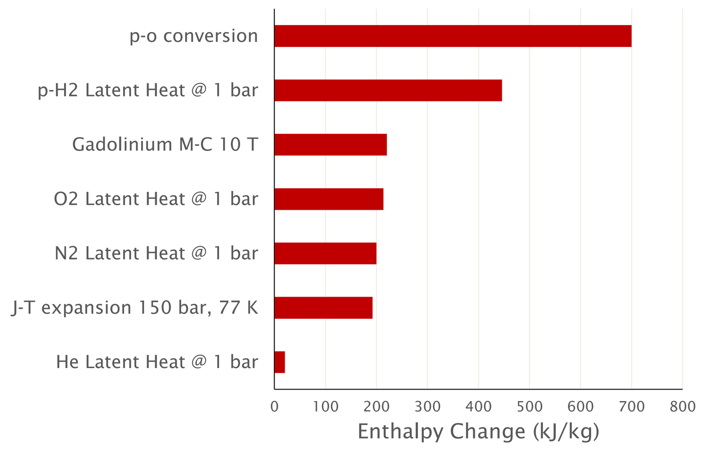


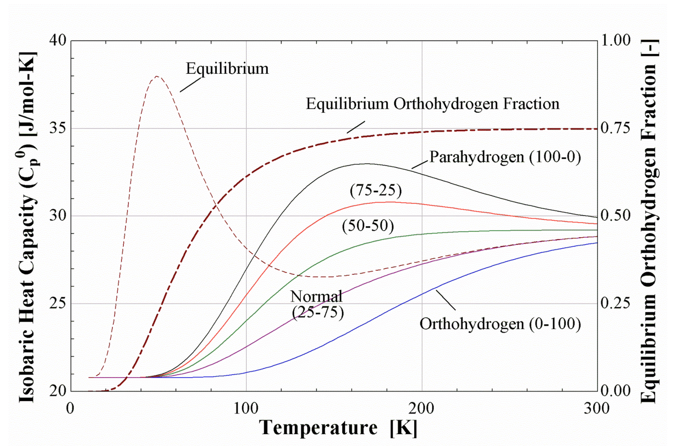
Motivation: The current hydrogen economy in North America is driven by hydrogen liquefied at only 8 plants (shown on the right). 80 – 90% of all shipped hydrogen is liquid, due to the decreased cost and tenfold increase in mass per delivery. Hydrogen fueled vehicles and material handling equipment are now coming into market, and will increase the demand for hydrogen significantly. In addition to these current needs, approximately one billion dollars of renewable energy was lost last year in the United States, due to curtailment of power generation. As more renewables are added to the grid, new low-cost, scalable energy storage is required, and hydrogen is a viable option provided it can be liquefied.

Our research hypothesis is that application of a catalyst to the periphery of a centrifugal hydrogen flow will cause endothermic para-orthohydrogen conversion and bulk cooling – thereby enabling low-cost, efficient, small to medium scale hydrogen liquefaction. With current hydrogen costs broken at around $5.60 for production, $2-$12 for delivery, and $2-3 for dispensing (per kg of hydrogen), this technology would offer significant advantage to hydrogen suppliers over current practice

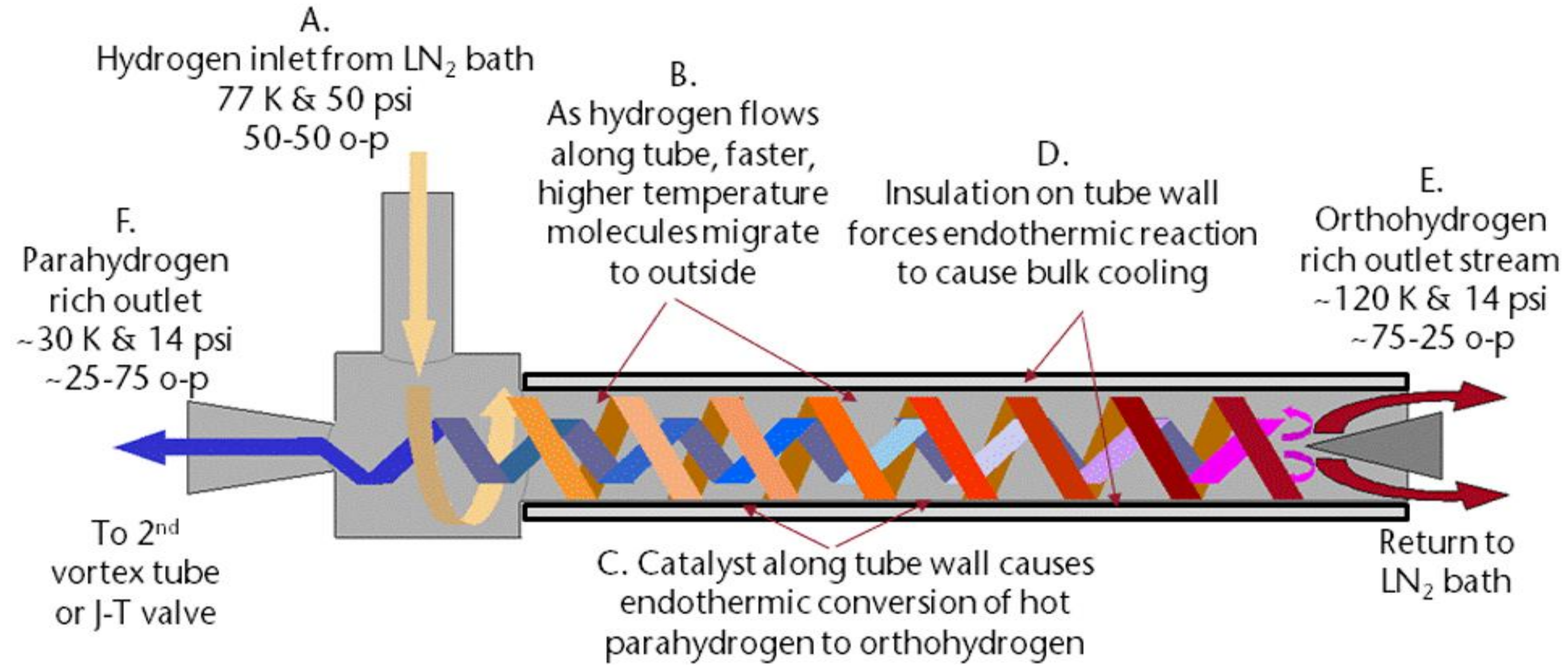
Right: A modified version of the cycle utilizing a catalyzed vortex tube for increased performance. (Image adapted from Peschka 1992)
Below: Enthalpy change compared to other cooling methods, Ortho-Para effects on heat capacity of hydrogen.

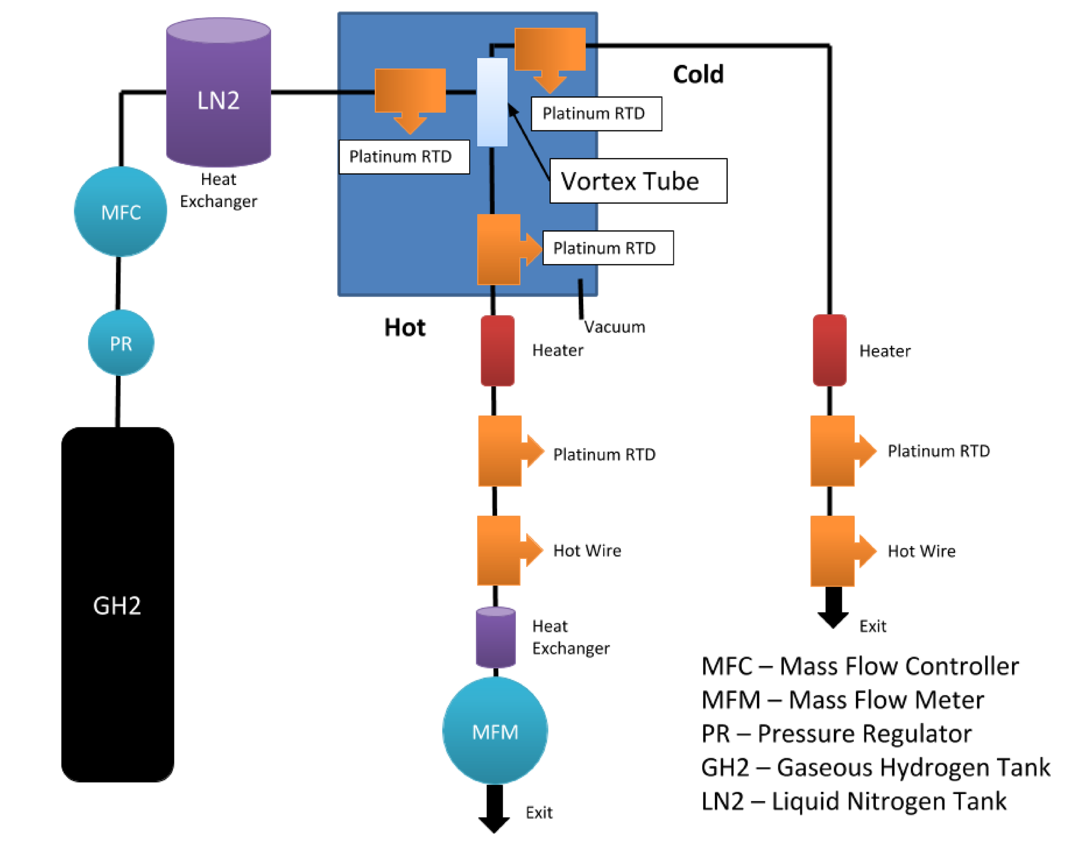






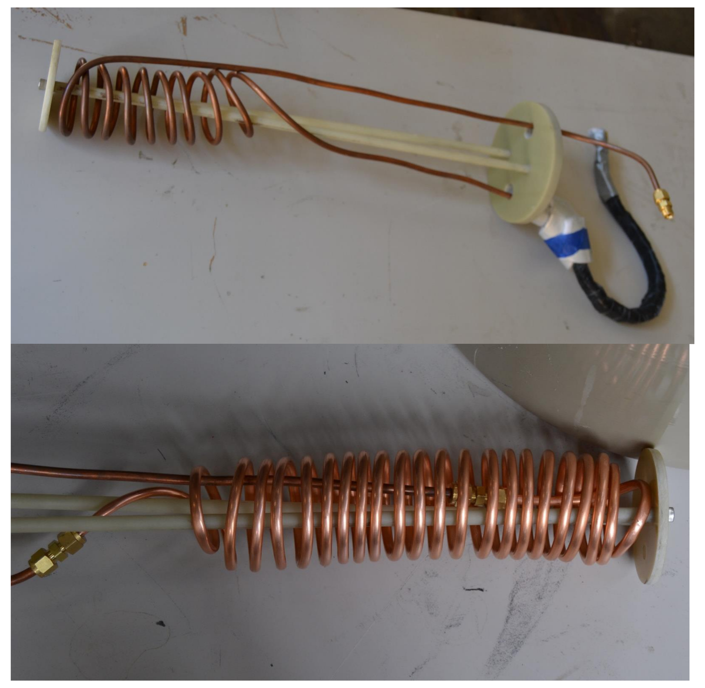
Our Concept:

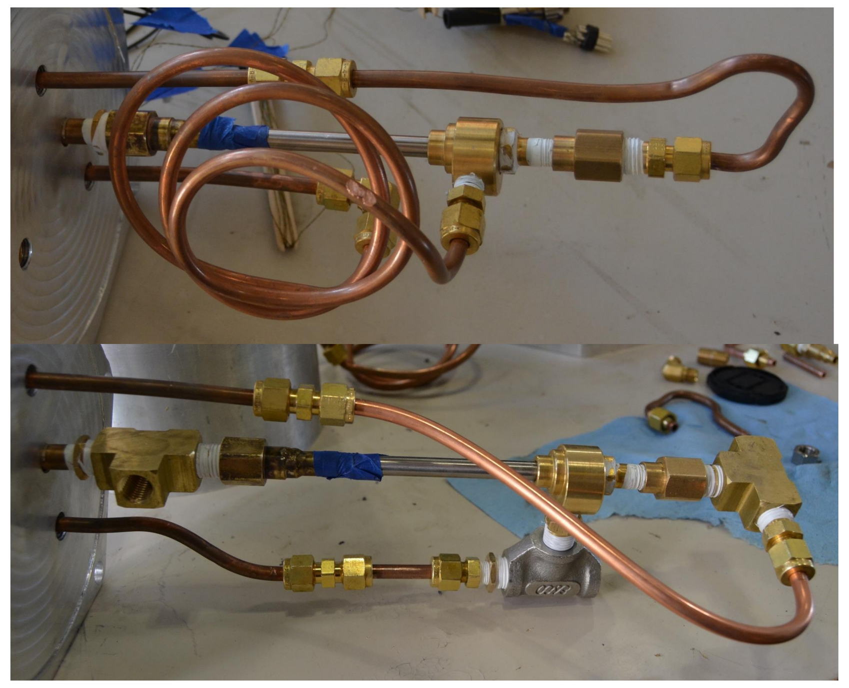




Experimental Deisgn: This experiment is designed to give characterization data for the concept at several levels. First, the experiment serves as a simple proof of concept by taking input, hot output stream, and cold output stream temperature readings, as well as flow rate and pressure of the inlet stream. We verify temperature separation in hydrogen and helium using this data, and can then move on to examine catalyzed performance. Ortho – Para fraction can be assessed by using a temperature reading and a hotwire in concert to measure thermal conductivity, which can then be related back to Ortho – Para fraction. A first test will catalyze the input stream to equilibrium concentrations, and then examine resultant output fractions, and a second test will compare to a Ruthenium-catalyzed vortex tube.

A work in progress: Our concept is currently being developed in the form of a mobile instrumented test stand, as shown in the photos below from development. These photos illustrate the state of the experiment now, as well as some of the stumbling blocks (learning experiences!) along the way. From left to right: 1)Full view of the test stand running hydrogen, 2)Comparison between the original and new heat exchangers. The first heat exchanger was not getting the inlet temperature as cold as was desired, so a new heat exchanger was designed with thinner walls and as many loops as would fit in the dewar, 3)Comparison between the vortex tube before and after temperature sensors were moved. Initially, all temperature sensors were located outside the vacuum chamber, insulated only by Cryogel Z. Heat loads were too high on the sensors to get good measurements of separation, so sensors were moved inside the vacuum chamber for more insulation, 4)When moving the sensors into the chamber, an MLI cylinder was manufactured for radiation shielding, 5)A ground wire for a gas bottle, manufactured to reduce the likelihood of a spark that could ignite hydrogen vapors, and 5)A Trivac DB8 vacuum pump, which pulls the vacuum on my vacuum chamber. Current measurements on the test stand still show that heat load into the vortex tube needs to be reduced to have useful data. As we move forward, additional improvements to the design and testing system will be made.





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