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Docket Number:	22-IEPR-05
Project Title:	Emerging Topics
TN #:	243929
Document Title:	Donald Taylor Comments - Advanced H2 Liquefaction Methods
Description:	N/A
Filer:	System
Organization:	Donald Taylor
Submitter Role:	Public
Submission Date:	7/7/2022 9:38:39 AM
Docketed Date:	7/7/2022

Comment Received From: Donald Taylor
Submitted On: 7/7/2022
Docket Number: 22-IEPR-05

Advanced H2 Liquefaction Methods

Additional submitted attachment is included below.

Regarding Green Hydrogen Production for California:

Please Consider Advancing H_2 Liquefaction Methods

Comments Provided by:
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Cryogenic Liquefaction of Hydrogen for Bulk Transport (LH_2)

Bulk transport of hydrogen (in trucks, trains, & planes), is accomplished using cryogenic liquefaction methods to produce a condensed liquid-phase that is storable and transportable. Taylor Energy is particularly interested in an advanced (emerging) method called thermoacustic cryocooling, which is state-of-the-art (Figure-1) for achieving cryogenic temperatures. These systems are presently available at modest scale, providing cryocooling for nitrogen liquefaction. Extension of thermoacustic cryocooling methods to H_2-liqufaction and scaling to 50 ton/day LH2 capacity would appear to offer real benefits.

Figure 1: Thermoacustic Cryocooler Manufactured by RIX Industries of California

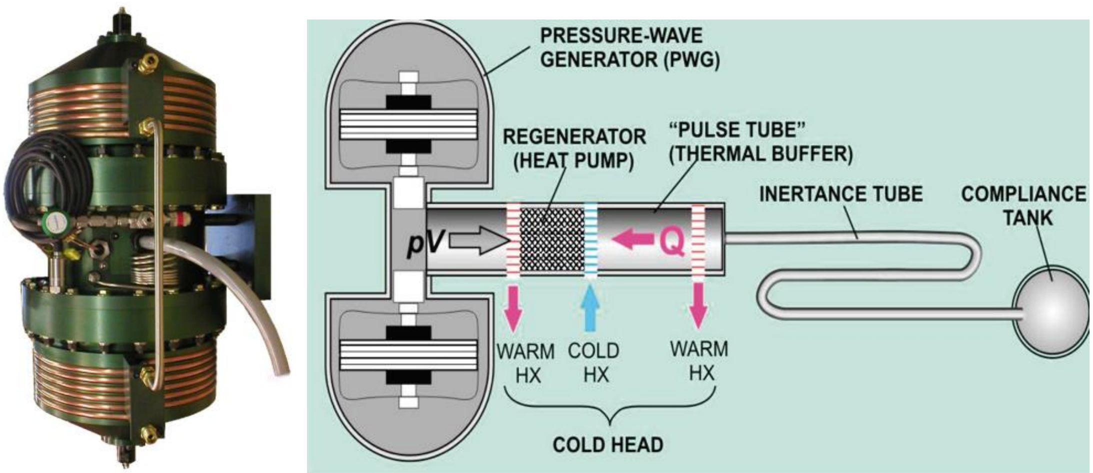
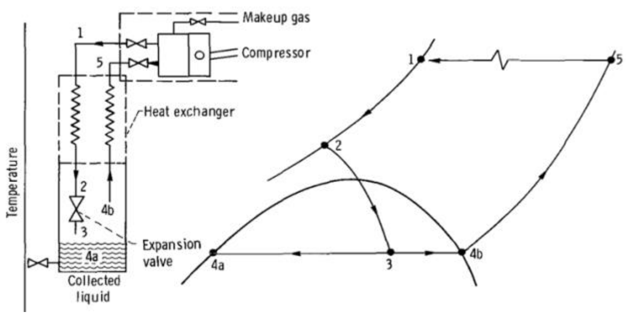


Photo credit: RIX

At commercial-scale, highly efficient turbo-expanders replace a simple Joule-Thompson expansion nozzle for cryo-cooling (Figure02); precision-machined turbo-expanders are the heart of large-scale H_2 liquefaction systems, with 30 ton/day LH_2 as a nominal size for merchant liquid plants.

Figure 2: Process Diagram – Simple Joule-Thompson Liquefier



Looking to the near future, we expect the highly efficient turbo-expander technology will continue to scale up to 100 ton/day LH2 and beyond for high-volume points of distribution. However, it appears that there will also be a need for low-cost simple cycle H_2 liquefaction methods in the 20-TPD to 50-TPD range for diversified LH2 production and distribution.

There will be a dozen diverse methods used to produce economic sources of green hydrogen. For example, herein we have discussed renewable biomass-to-hydrogen methods that could produce 3-million tons/year of gaseous hydrogen; and wind-to-hydrogen methods using floating horizontal turbines designed for offshore H_2 production, with underwater pipelines to the Coast. We would assert that the H_2 liquefaction methods needs to be evaluated, including opportunities to advance the state of-the-art for thermoacustic cryocooling methods, considering the key role that hydrogen is expected to play in California.

Thermoacustic cryocooling methods are rather amazing. The cryocooling part of the cycle does not use moving parts (no precision machined turboexpanders); typically, helium gas at 250-psig is shuttled back and forth through a heat exchanger at 60-Hz using a pressure differential of about 25-psig. Resonate shuttling of helium -- pushed back and forth through a heat-exchanger -- provides cryocooling down to 77°K without difficulty, and beyond with some extension of tech. RIX Industries of California uses two opposed linear electric motors to form a Pressure Wave Generator (**Figure-3**). The linear electric PWG is ideal for some applications where economic green electricity is available.

Figure 3: Replacer Pressure-Wave Generator using Pulse-Detonation Powered PWG

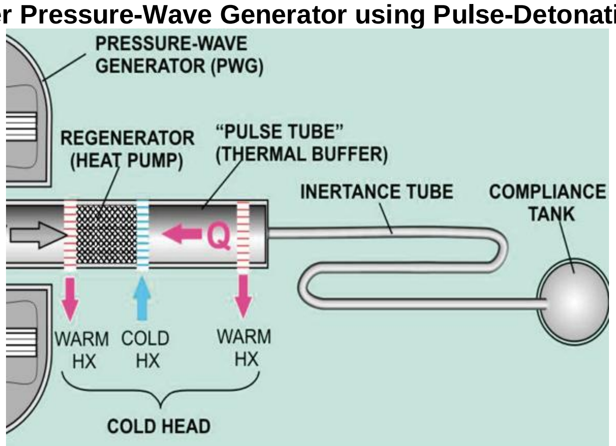


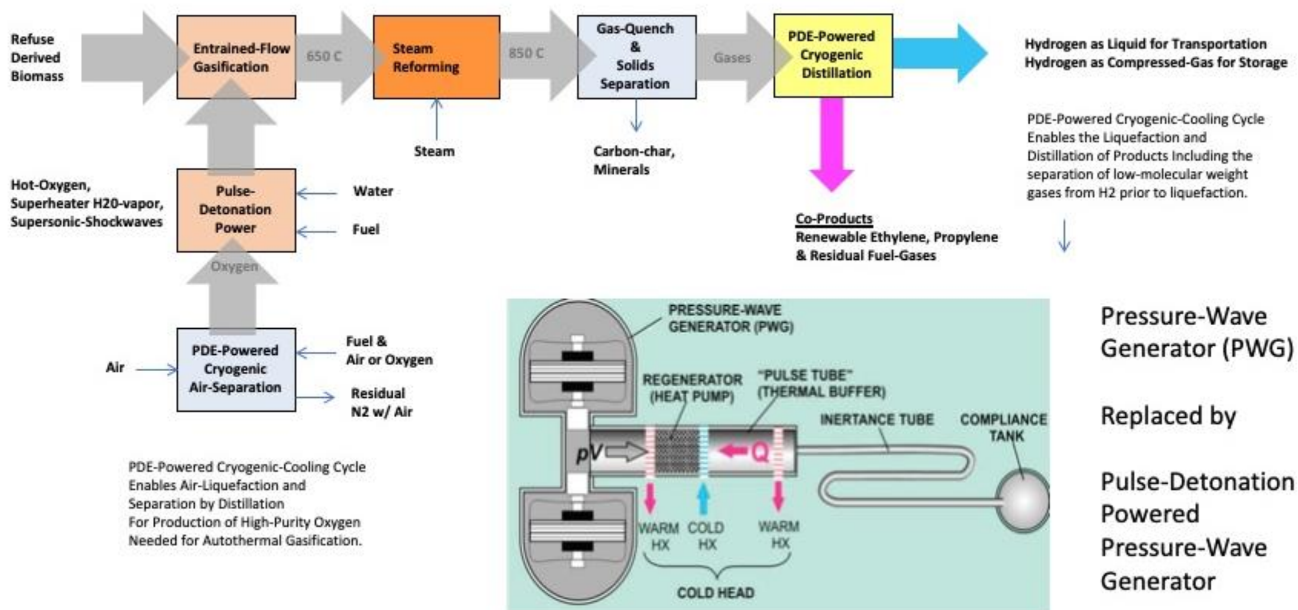
Photo credit: RIX

Taylor Energy is excited by the prospect of replacing the linear-electric motor type Pulse Wave Generator (PWG) with a Pulse-Detonation Powered PWG, which is our area of specialization. In our situation as potential producers of green hydrogen, we would prefer to use hydrogen gas as the green energy source to fuel a Pulse-Detonation powered PWG for cryocooling cycle. In that embodiment, the technical begins to look very attractive because – if there is one thing that Pulse-Detonation power can do – its punch the gas, knocking the gas back and forth with power. Cyclic detonation of air/H_2 mixtures would provide the power to generate pressure waves for thermoacustic cryocooling. In this specific case intended for H_2 producers, electric motors and electric power management subsystems are eliminated from the pressure wave generation system to provide a significant savings.

Relative to biomass gasification, the H_2 fueled Pulse-Detonation powered pressure-wave generator (PWG) can be used for cryocooling integrated with liquefication, distillation, separation, and production of liquid and gaseous hydrogen, and the coproduction of ethylene and propylene, all summarized below (**Figure 4**).

Note that an integrated biomass gasification cycle would use a pulse-detonation powered cryocooler on the front-end to make gaseous oxygen (O_2) via cryogenic air separation, and the same pulse-detonation powered cryocooler on the back end to separate the products through cryogenic distillation and to enable production of liquid-H_2.

Figure-4. Pulse-Detonation Powered -- Oxygen Production, Gasification, and Liquefaction



This integrated biomass gasification cycle would eliminate the largest on-site electric power requirements, which would otherwise consume "renewable" electric power, potentially contracted for a higher cost (and requiring greater system complexity.)

These activities would fit with CE-CERT's R&D objectives at the University of California Riverside, working in collaboration with Taylor Energy, a California Corporation based in Riverside, presently developing thermo-catalytic gasification methods used to convert biomass residues into pipeline-quality renewable-gases.