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Experimental investigation on continuous ortho-para hydrogen conversion in hydrogen liquefaction within the range of 40-80 K

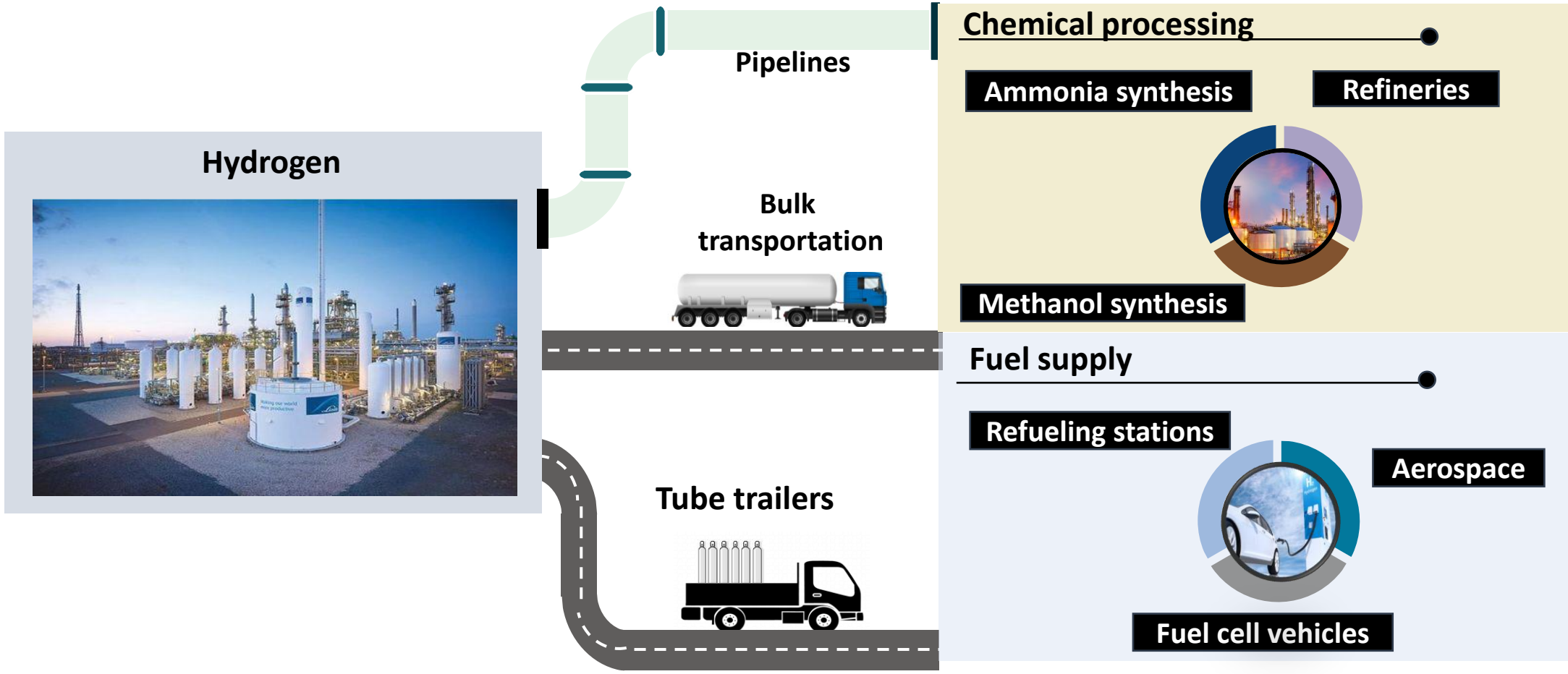
Junjie TENG, Xinyu WEI, Shaolong ZHU, Song FANG, Limin QIU, Kai WANG*

E-mails: j_teng20@zju.edu.cn

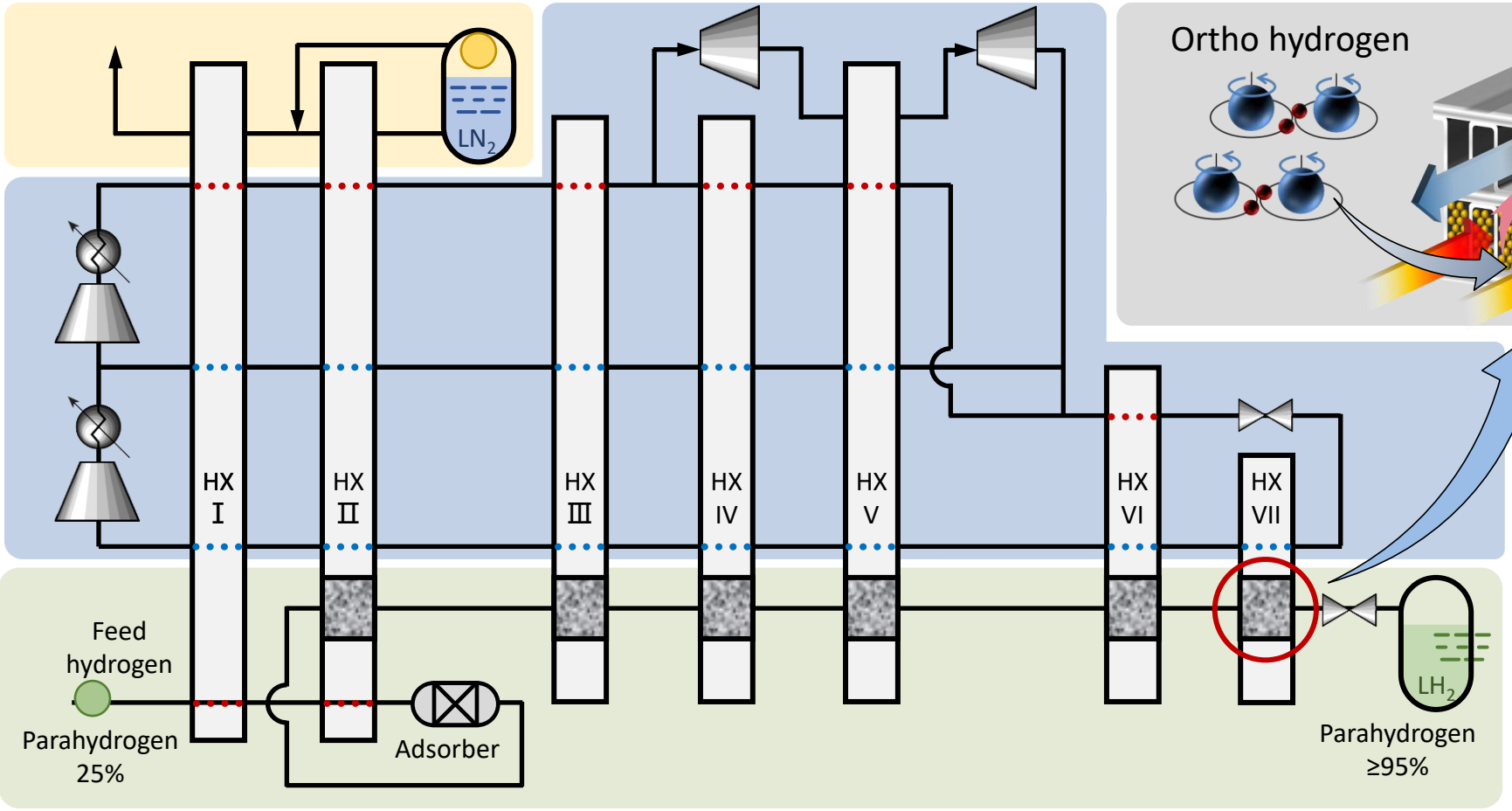
* kaiwang19@zju.edu.cn

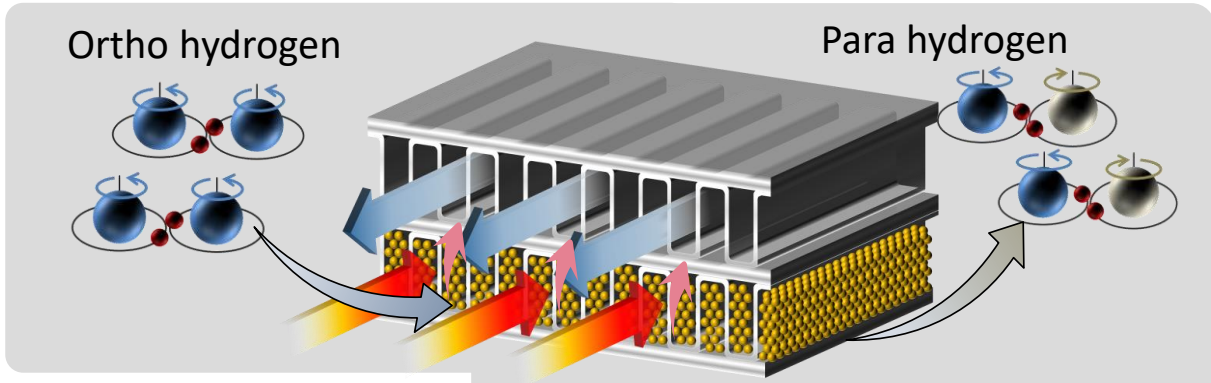
Contents

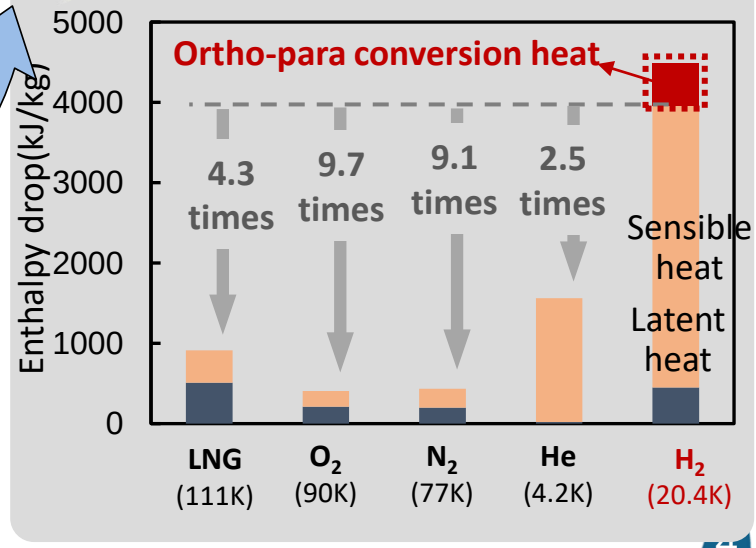
- Hydrogen has been regarded as one of the most promising energy carriers, expected to rise **by 4-5% annually** in the coming years
- The volumetric energy density of LH_2 can be as high as **2.3 kWh/L**



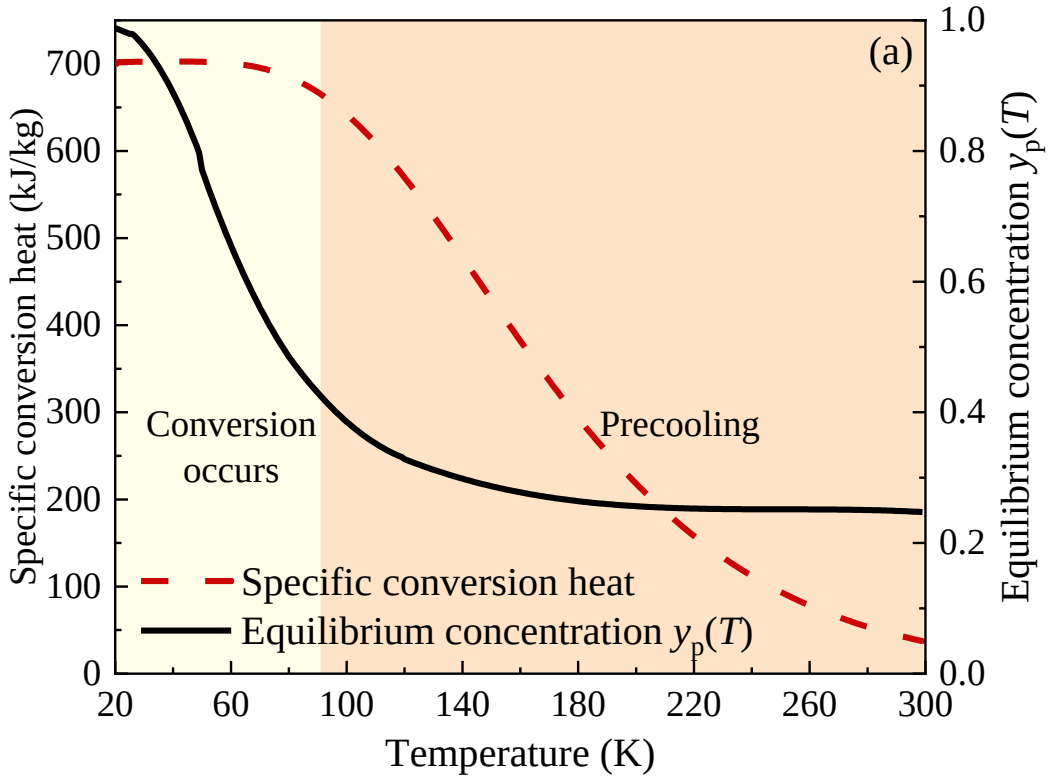
- Hydrogen has two spin isomers, ortho and para hydrogen. The slow rate of spontaneous conversion leads to great **boil-off loss in LH_2 product** if no conversion carried out
- Catalysts filled inside channels to conduct approximate **continuous o-p hydrogen conversion**



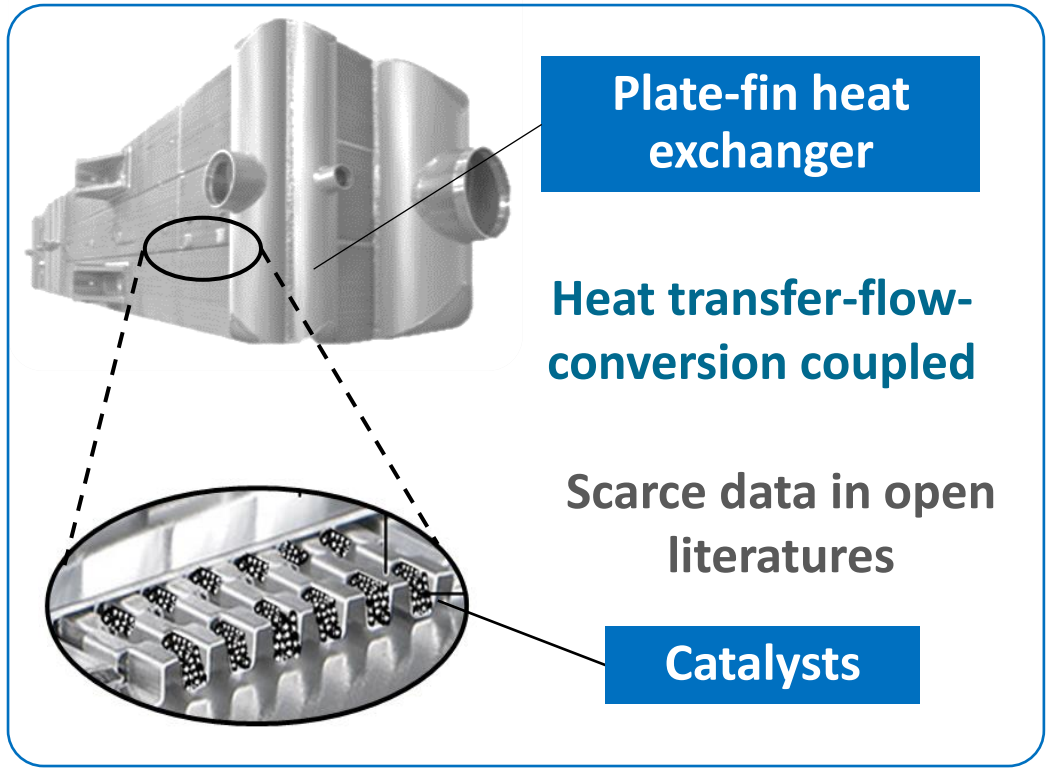




- The conversion heat and the equilibrium concentration vary with temperature
- A complex process of **heat transfer-flow-catalytic conversion** occurs in the cryogenic hydrogen heat exchanger



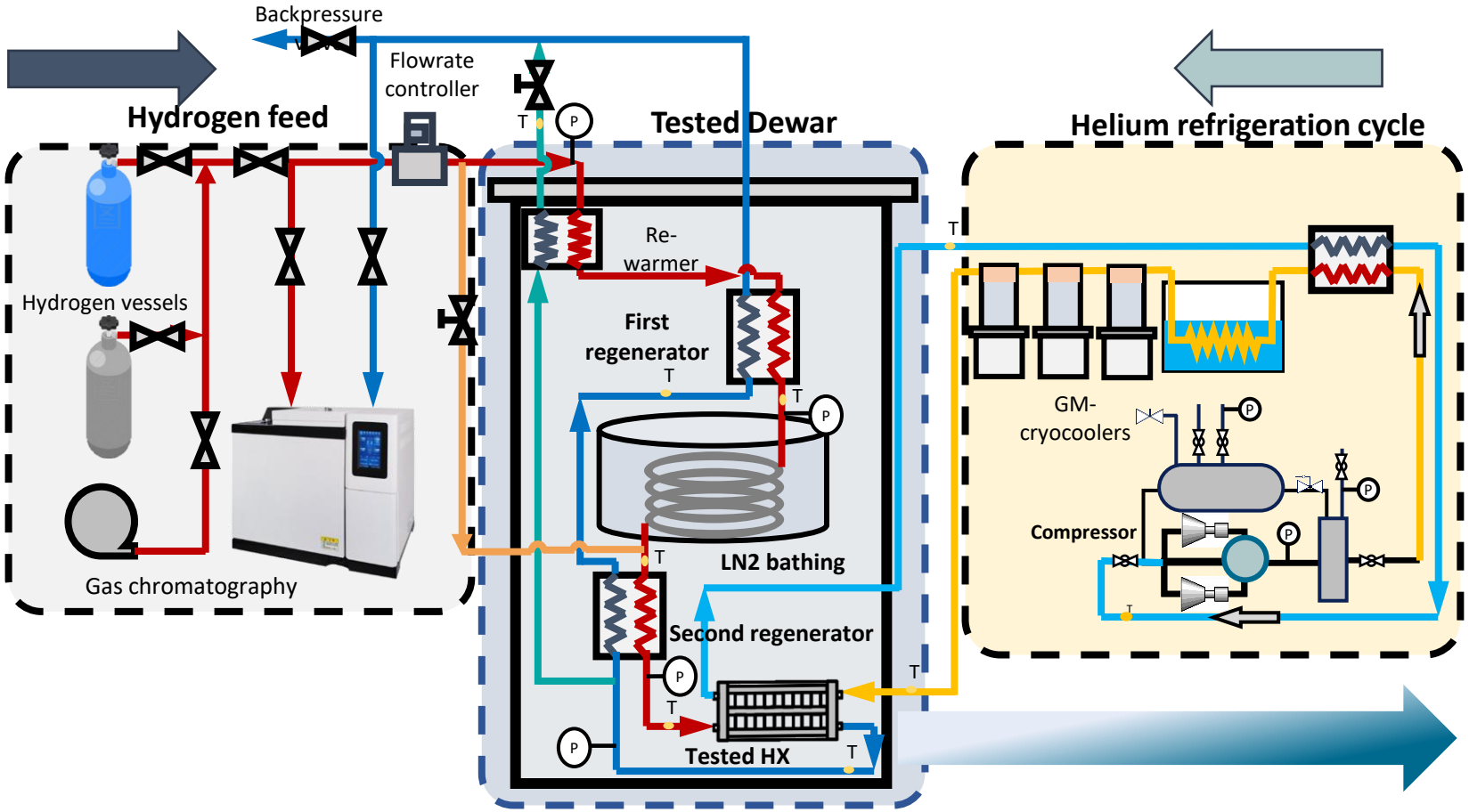
Conversion heat and equilibrium concentration of hydrogen

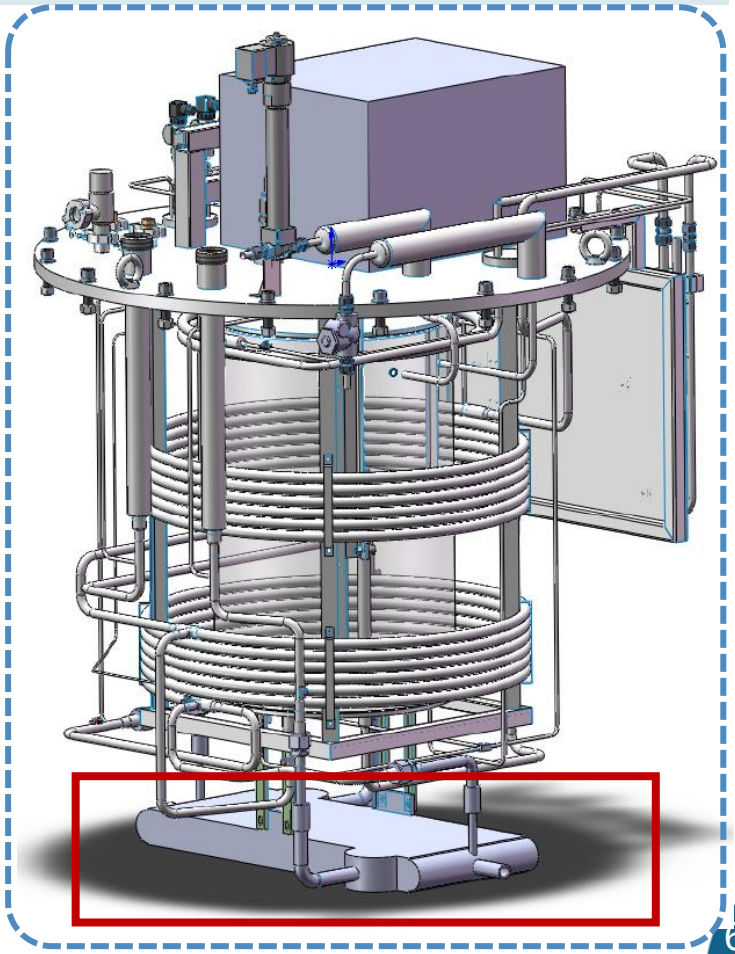


Catalysts-filled plate-fin heat exchangers

Platform diagram

- Hydrogen flows through **two stages of regenerators** and **LN_2 bathing for precooling and pre-conversion** before entering the tested HX
- Helium is refrigerated by three-stage G-M cryocoolers **(30-40 K)**





Platform diagram

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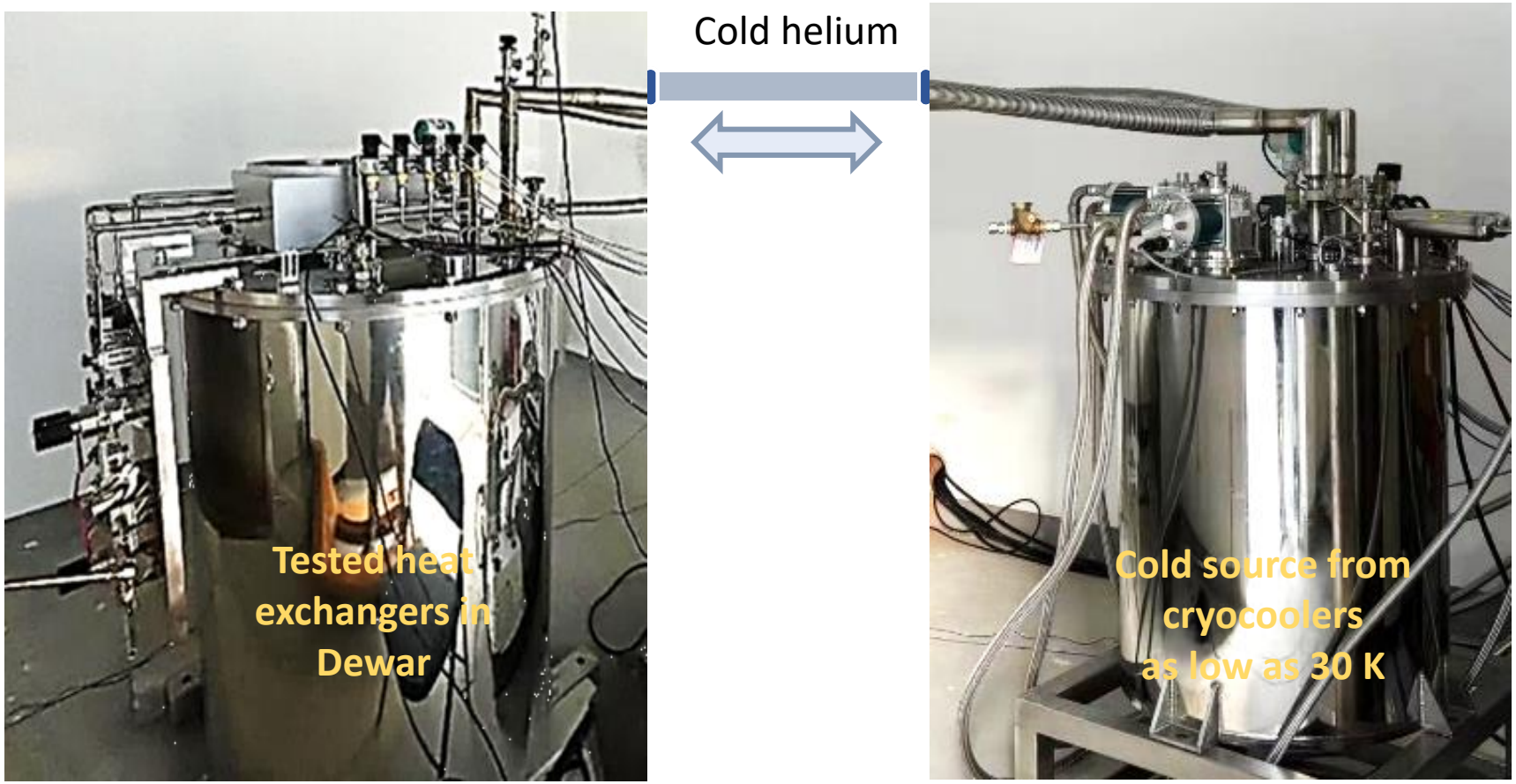
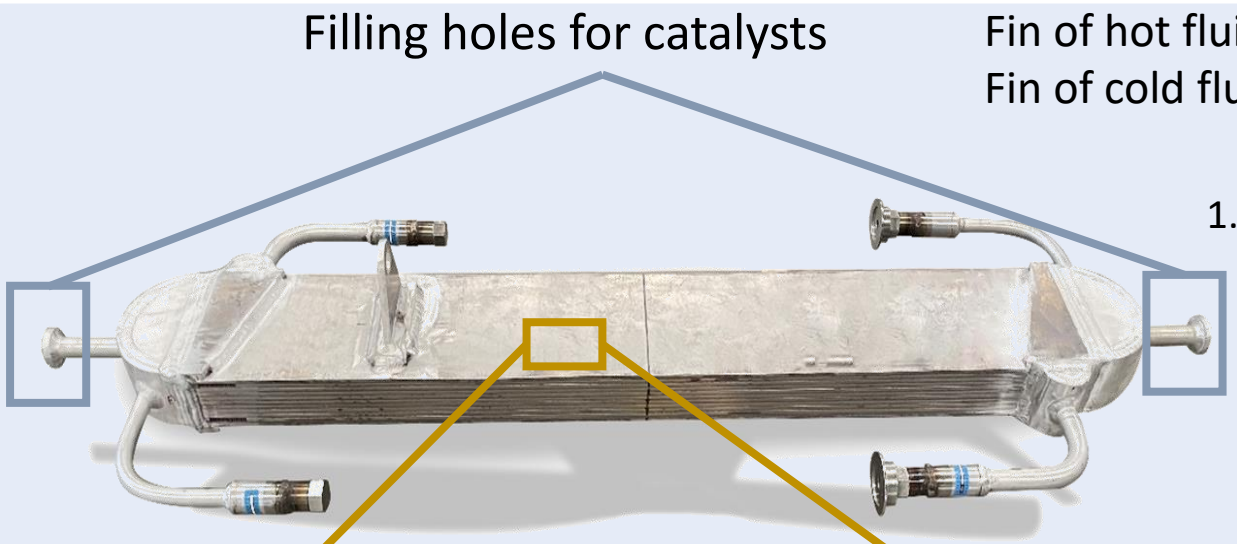
Vacuum-insulated tubes

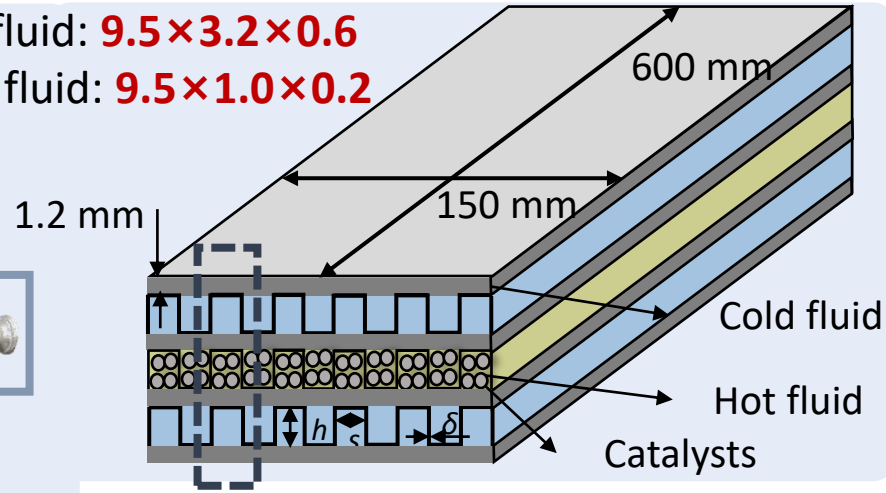


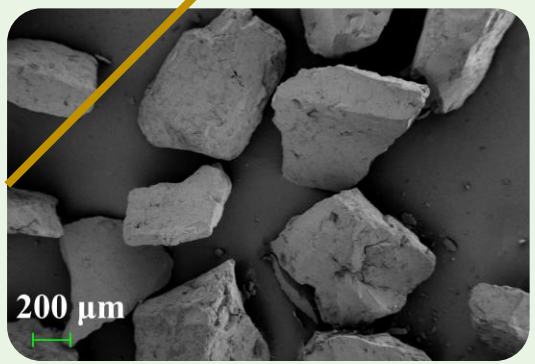
Catalysts filling into heat exchangers

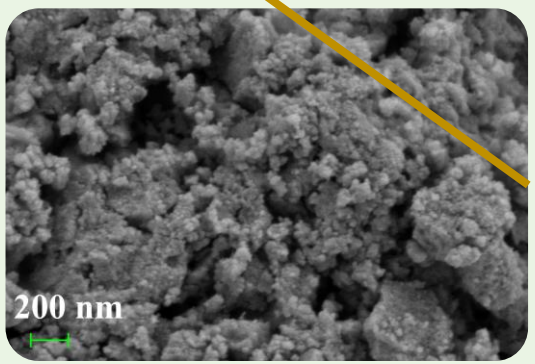
- **One layer of hot fluid** and two layers of cold fluids are constructed
- Catalysts (2.06 kg) are filled inside channels of tested plate-fin HX to conduct continuous conversion

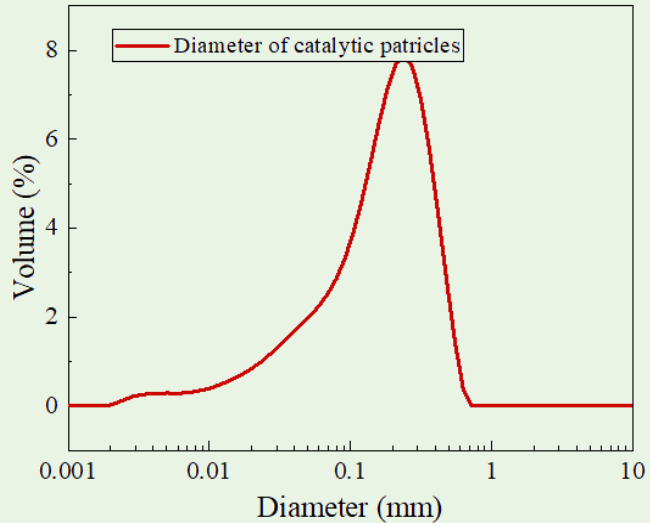


Fin of hot fluid: **9.5×3.2×0.6**
Fin of cold fluid: **9.5×1.0×0.2**



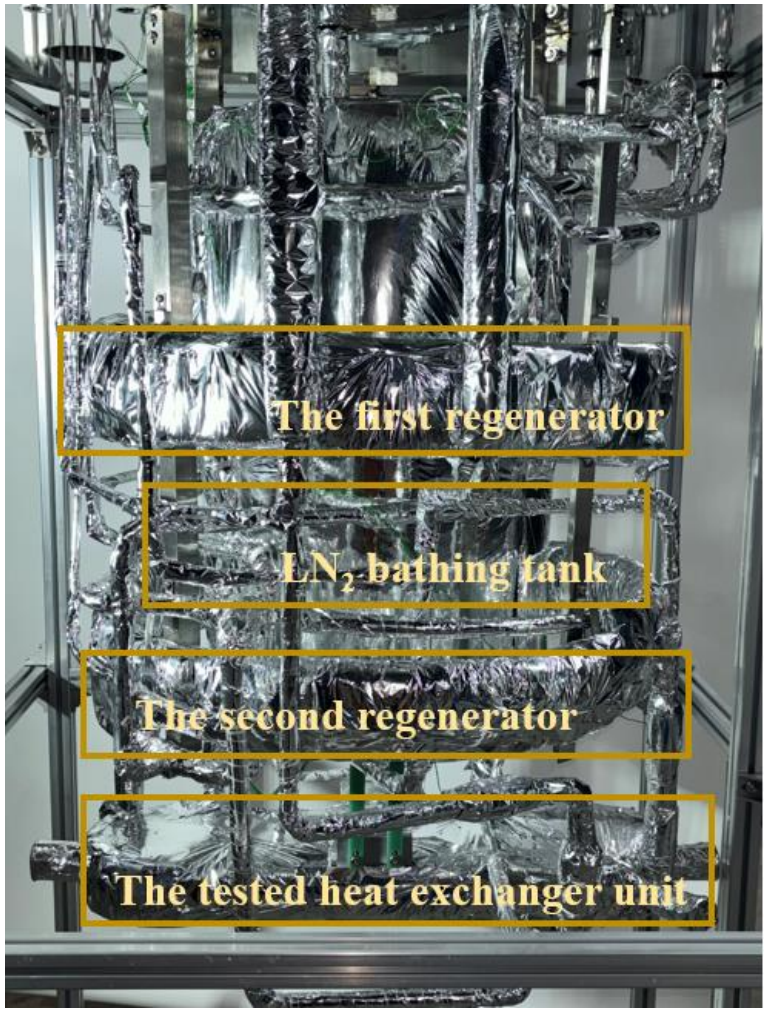




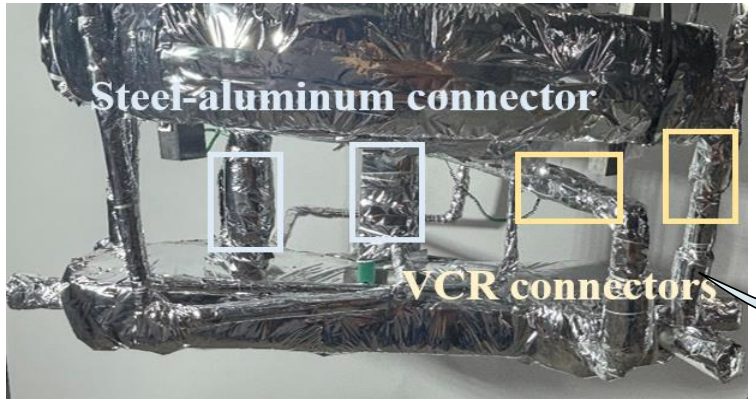


Platform diagram

- Inlet conditions of tested HX are adjustable through bypass valves and controller
- **Thermal-hydraulic-conversion performance** of cryogenic hydrogen heat exchangers can be measured



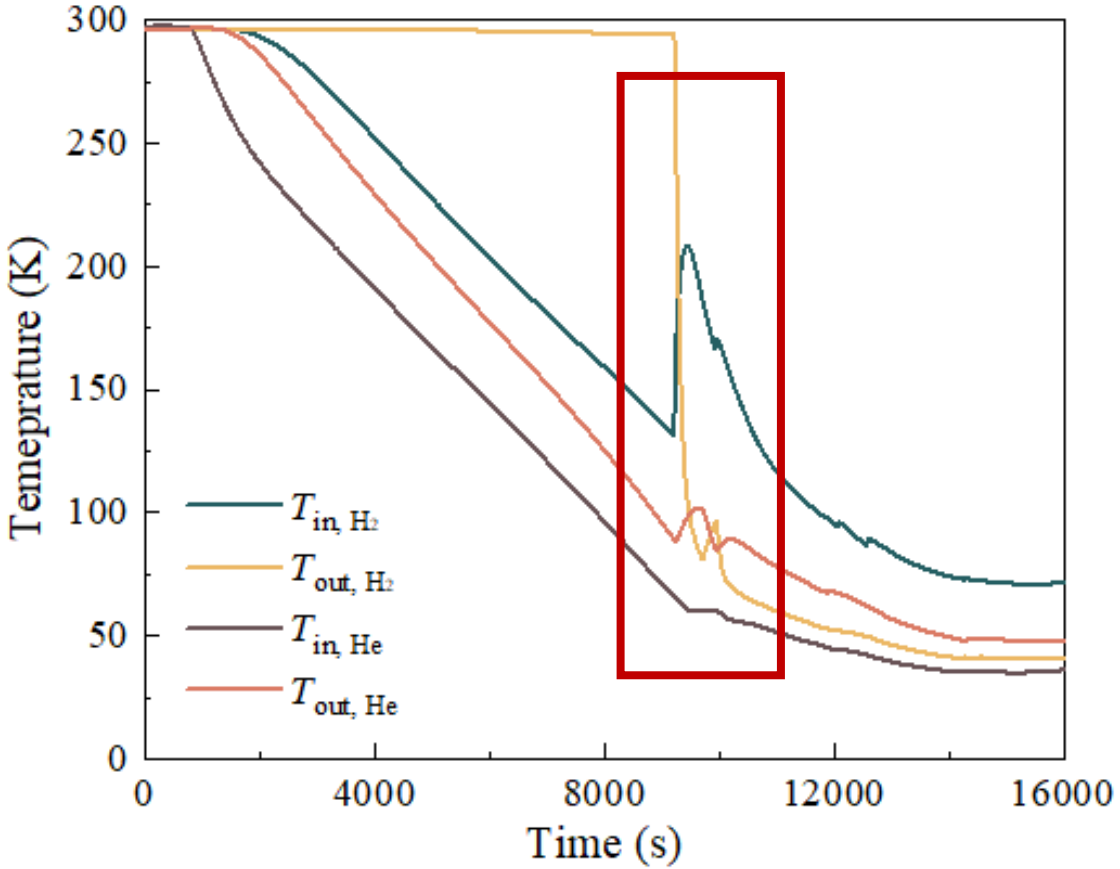
	Testing parameters	Testing conditions
Hot fluid	Inlet temperature of hydrogen	40-298 K
	Inlet pressure of hydrogen	0.1-2.1 MPa
	Flowrate of hydrogen	0-1 g/s (86.4 kg/d)
	Inlet concentration of para-hydrogen	25%-50%
Cold fluid	Inlet temperature of helium	30-298 K
	Inlet pressure of helium	0.1-0.6 MPa
	Flowrate of helium	0-2.5 g/s



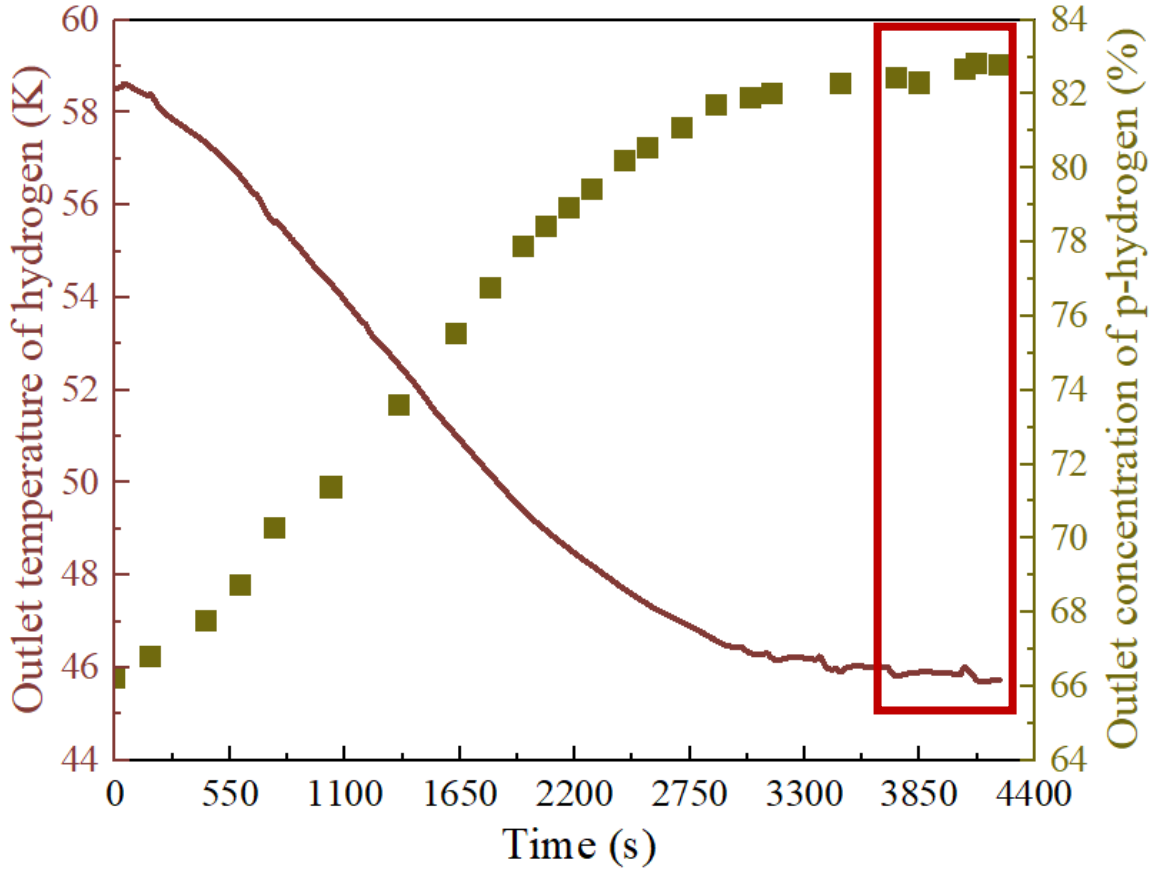
Dismountable connectors are utilized to test **heat exchanger with different structures**

Parameters change during cooling

- Temperature drops gradually for about **3.5 h** to reach the lowest temperature
- Outlet concentration of p-hydrogen rises and then levels off as the hydrogen is cooled (**almost synchronous with the drop in temperature**)

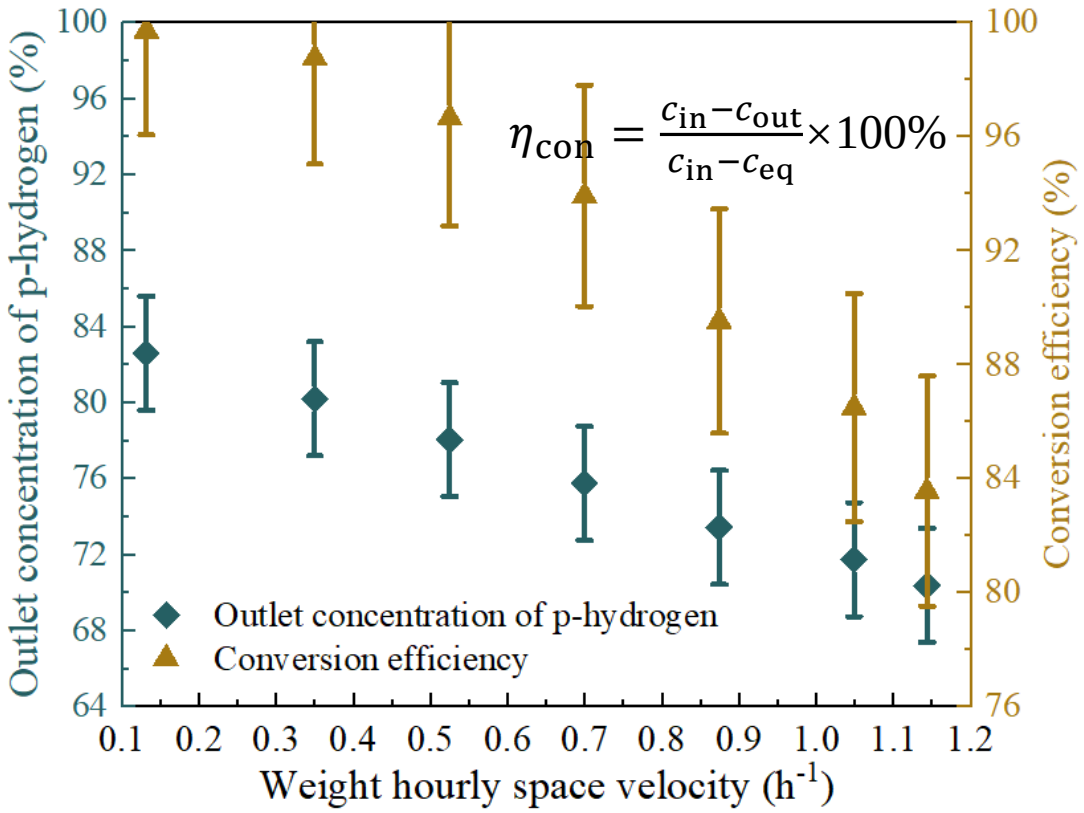


Temperature change

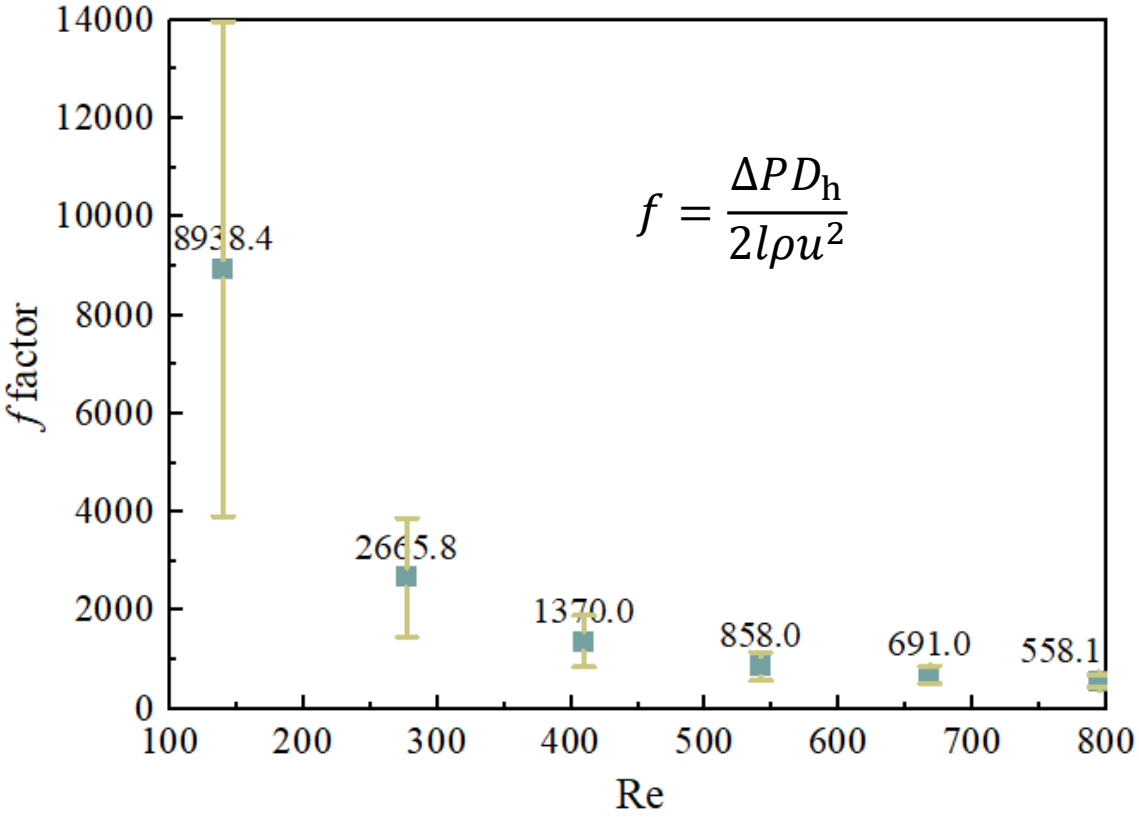


Increasing concentration

- The outlet concentration of p-hydrogen drops as the space velocity increases, so does the conversion efficiency
- Friction factor (*f* factor) utilized to characterize the **hydraulic performance** (slight ΔP under low Re)

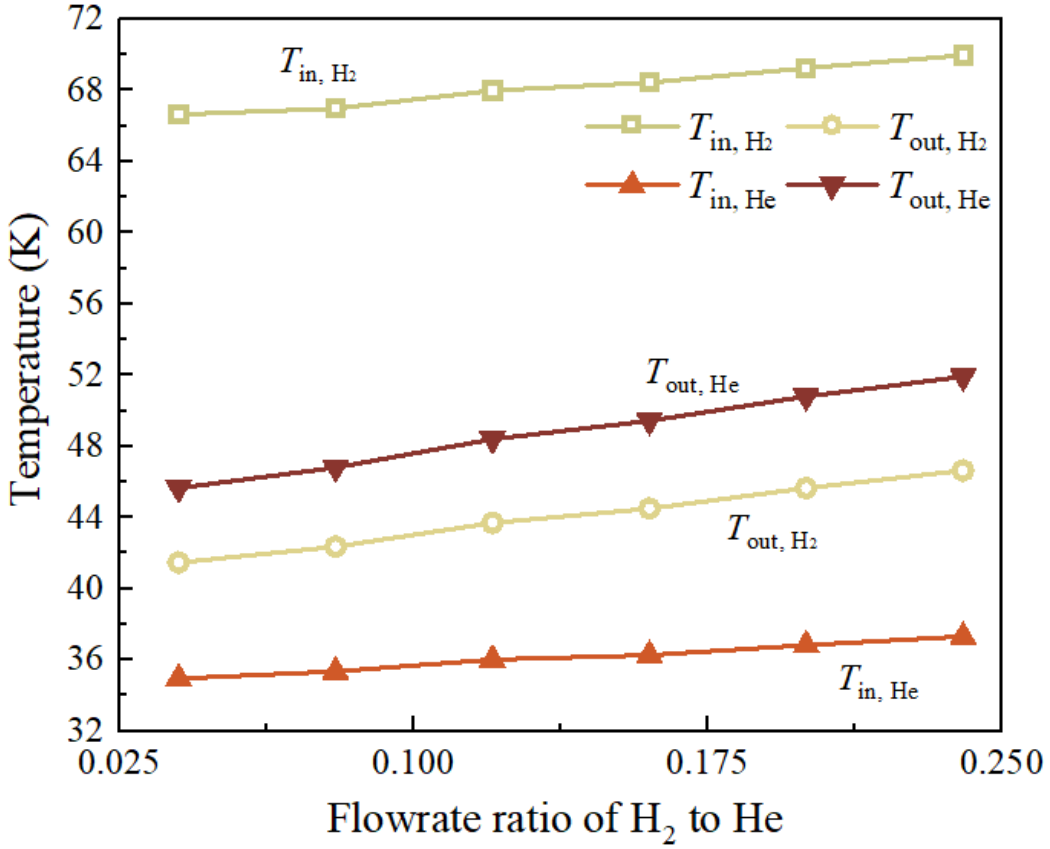


Conversion performance

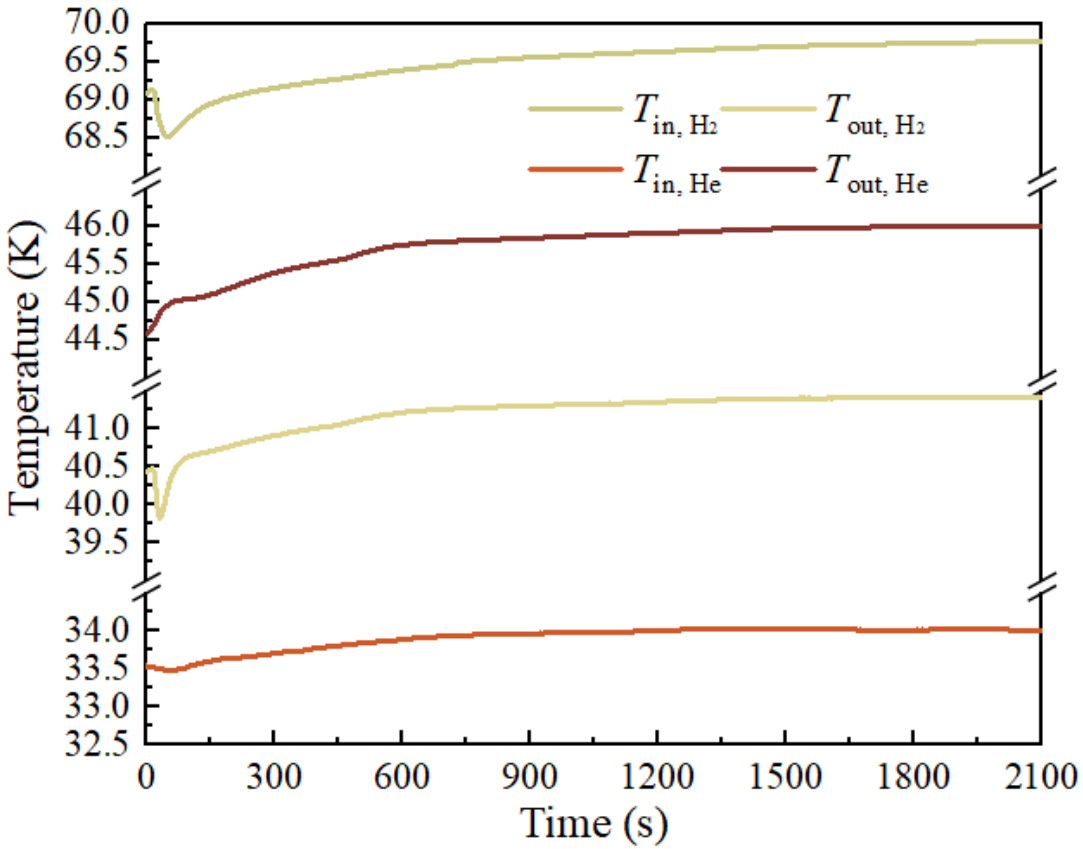


Increasing concentration

- As the flowrate ratio of H_2/He rises, all the inlet and outlet **temperatures tend to increase**
- The temperature exhibits a rapid decline followed by an abrupt rise over a short period after enlarging the flowrate ratio



Temperature change

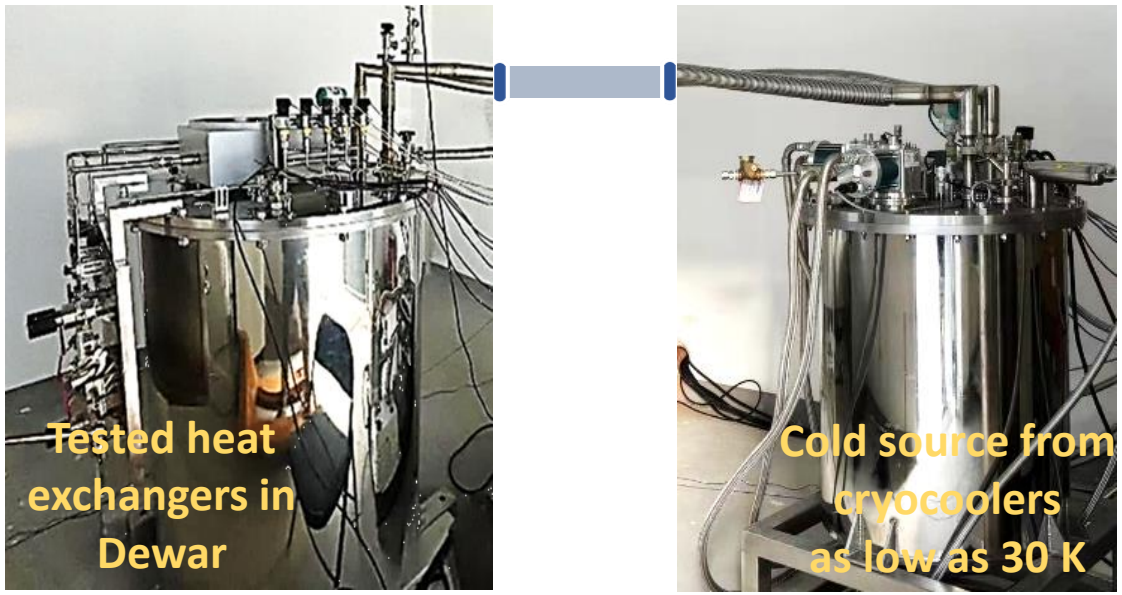


Temperature change after rising the flowrate ratio

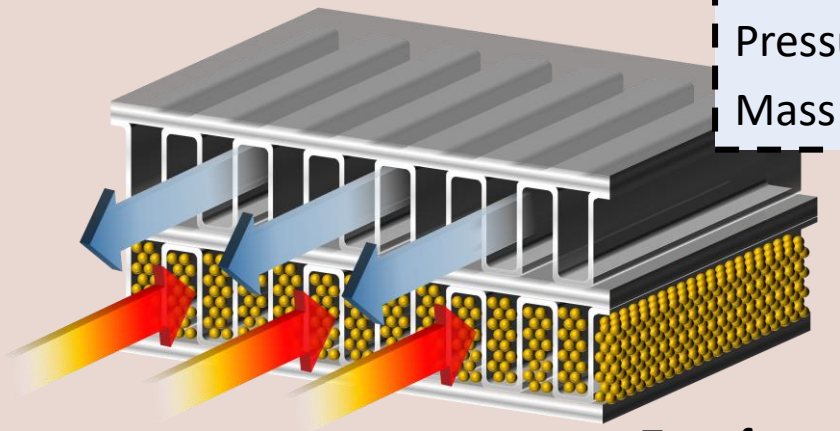
04 Conclusions and future work

- **A testing platform** for cryogenic hydrogen heat exchanger with continuous ortho-para hydrogen conversion is constructed and the **thermal-hydraulic-conversion performance** is measured and evaluated quantitively
- **Precise correlations** for cryogenic hydrogen heat exchangers in the future work

Vacuum-insulated tube



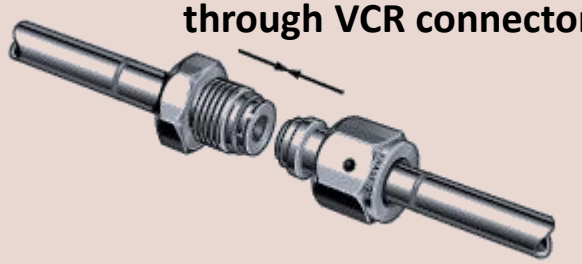
Testing platform



Temperature: 30-298 K
Pressure:0.1-0.6 MPa
Mass flowrate: 0-2.5 g/s

Temperature: 40-298 K
Pressure:0.1-2.1 MPa
Mass flowrate: 0-1 g/s
Composition: 25%-50%

Tests for various heat exchangers through VCR connectors



Thanks for your attention!

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