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C1Po1A-07: Design of a Laboratory-Scale Hydrogen Liquefier Cold Box for Low-Altitude Economy and Modular Deployment

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The rapid development of the low-altitude economy, including hydrogen-powered unmanned aerial vehicles (UAVs) and decentralized hydrogen infrastructure, calls for compact and efficient hydrogen liquefaction systems. This study presents the design of a laboratory-scale hydrogen liquefier capable of producing 50 liters of liquid hydrogen per day (LPD) with a 10% capacity margin. The liquefaction process integrates liquid nitrogen pre-cooling and Gifford-McMahon (GM) cryocoolers, achieving high system reliability within a compact footprint of approximately 1.5m × 1.8m for the core cold box. Additionally, the cold box includes a 150L liquid hydrogen storage tank for holding the liquefied hydrogen produced.

The system's unique advantage of compactness will allow it to be integrated into standard containers in the future, enabling rapid, modular, and expandable liquid hydrogen plant deployments through reserved standard interfaces. This containerized configuration includes a core cold box and auxiliary components making it ideal for laboratory research and field applications. Furthermore, a continuous supply of liquefied hydrogen is possible with the existence of the 150L storage tank, ensuring efficient refueling of UAVs and other applications requiring liquid hydrogen as a fuel source.

The Efficient layout makes it particularly attractive for mobile applications in remote or temporary locations. The system is designed with Expandability in mind, enabling future expansion to meet the increasing demand for hydrogen in various sectors, such as transportation, energy storage, and aerospace. A large proportion of standard components, together with a small number of custom non-standard parts, is incorporated into the design, offering significant potential for cost reduction and scalability in mass production.

This paper represents a potential for flexible and compact hydrogen liquefaction of a small-scale hydrogen liquefier cold box, with promising applications in laboratory and low-altitude economy sectors. Future work will focus on experimental design validation, optimization of key parameters, and scalability for broader adoption in low-temperature hydrogen systems. The compact and space-efficient design, with its storage and rapid deployment capabilities, positions this system as a promising solution for the growing hydrogen economy.

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