Stirling Hydrogen Re-Liquefaction Systems

BOG Solutions for 10 to 2.000+ kg/day

STIRLING CRYOGENICS

Hydrogen Re-Liquefaction

Stirling Cryogenics systems provide an effective solution for managing hydrogen boil-off and preserving valuable liquid hydrogen inventory. Using proven Stirling Cryogenerator technology, these systems capture boil-off gas (BOG) from liquid hydrogen systems and re-liquefy it, eliminating product losses and improving overall system efficiency.

For more than 60 years, Stirling Cryogenerators have been used in hydrogen applications ranging from research laboratories to advanced scientific facilities. In many of these installations, the primary role of the system has been hydrogen re-liquefaction to maintain stable cryogenic inventories. Stirling-based hydrogen re-liquefiers have been used in cold neutron sources and hydrogen/deuterium distillation systems, with some early installations still operating today.

Modern hydrogen infrastructure increasingly requires efficient management of boil-off gas from storage tanks, transport vessels, and liquefaction plants. Stirling Cryogenics addresses this challenge with compact two-stage Cryogenerators capable of producing cooling power down to approximately 20 K, enabling the direct and indirect re-liquefaction of hydrogen vapor.

Configuration

Systems can be configured for re-liquefaction capacities ranging from approximately 10 kg/day to more than 2.000 kg/day, allowing solutions to scale from small research installations and fueling stations to large hydrogen storage and distribution facilities. For ease of installation and integration, complete hydrogen re-liquefaction systems can be delivered in containerized packages, enabling rapid deployment and simplified site integration.

These systems can be integrated with existing liquid hydrogen storage tanks or incorporated into new hydrogen storage installations, providing flexibility for both retrofits and greenfield hydrogen infrastructure projects.

Eliminating Hydrogen Losses

Instead of venting boil-off hydrogen to maintain tank pressure, a Stirling re-liquefaction system actively re-liquefies the hydrogen vapor caused by both tank insulation losses as well as operational losses back into liquid form.

This approach offers several advantages:

- Zero or near-zero hydrogen losses from storage tanks
- Reduced operating costs by recovering product that would otherwise be vented
- Improved safety by minimizing hydrogen release
- Stable tank pressure management without flaring or venting

200 kg/day hydrogen boil-off gas re-liquefaction system as part of a large liquid hydrogen facility at a Korean Institute (2025)

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Modular and Redundant Cryogenic Cooling

Re-liquefaction can be achieved in two ways depending on the installation:

- Direct re-liquefaction of cold boil-off gas: hydrogen vapor is liquefied in the Cryogenerator and returned to the storage tank
- Indirect cooling through a closed helium loop: cryogenic cooling is transferred from the Stirling Cryogenerator into a storage tank heat exchanger using a flow of helium gas, creating in-tank cooling and liquefaction with no need for H_2 transfer

These systems are modular and can be configured with multiple Cryogenerators operating in parallel. Each unit operates independently, allowing one or more Cryogenetators to be offline as needed. This modular approach enables systems to maintain redundancy, scale easily, and control capacity with ease.

Efficient Hydrogen Infrastructure

As liquid hydrogen storage and transport become more common in the transition to a low-carbon energy system, controlling boil-off losses is increasingly important. Stirling Cryogenics re-liquefaction systems provide an energy-efficient solution that allows operators to:

- Maintain liquid hydrogen inventory
- Reduce or eliminate product loss during storage and operation
- Enable long-duration LH_2 storage
- Improve the economics of hydrogen distribution and fueling infrastructure

By transforming boil-off gas back into usable liquid hydrogen, Stirling Cryogenics technology supports more efficient, sustainable hydrogen handling across research facilities, industrial storage sites, and emerging hydrogen energy applications.

Tank pressure	LH_2 Temperature[1]	Electrical Input	SPC-1T Cryogenerator		SPC-4T Cryogenerator	
			Cooling	Liquefaction[2,3]	Cooling	Liquefaction[2,3]
Barg	K	kWh/kg	W	kg/day	W	kg/day
0	20,3	19,5	59	11,5	236	46,0
2	24,6	10,5	97	20,4	388	81,6
4	27,1	7,8	115	26,9	460	107,6
6	29,0	6,1	127	33,9	508	135,6
8	30,6	4,7	136	43,6	544	174,4
10	31,9	3,3	143	62,7	573	250,8

1. Saturation temperature of the LH_2 will determine required cold head temperatures and gross cooling available.
2. Liquefaction rates shown are for direct liquefaction of para-hydrogen with BOG at saturation temperature. Actual net liquefaction rate of H_2 and hence performance numbers will depend on many factors including heat inleak of equipment, operational heat addition, BOG feed temperature to the liquefier, and other factors specific to each application.
3. Table shows single cryogenerator performance. For more capacity multiple units are placed in parallel arrangement.

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