



“Pressure Exergy and Isobaric Storage for Hydrogen in Caverns”

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Hydrogen Storage in Caverns.

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Hydrogen has unique properties:



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Hydrogen has rather unique physical properties:

- Very high calorific value (142 MJ/kg) ... vs 55 MJ/kg for methane.
- Very low density ... less than $(1/8)$ x methane.
- The heat energy density compared to methane in the same cavern / tank is approximately $(142/55) \times (1/8) = \mathbf{0.322}$... i.e. a given cavern / tank containing hydrogen retains less than one-third of the heat energy that would be contained in the same cavern / tank containing methane.

The minimum amount of mechanical work required to compress any gas (isothermally) to fill up a cavern/tank to a given pressure is (almost) independent of the gas. This is called the *Pressure Exergy*.

For hydrogen, the ratio between *pressure exergy* and contained calorific value is higher than for methane or anything else!

For an ideal gas with reference pressure p_0 , compressed to a pressure ratio r and filling a cavern volume V , the pressure exergy is given by:

$$B_{cavern} = p_0 V \times [r \ln(r) - (r - 1)]$$

Pressure (bar)	Heat value (GJ/ m ³)	Pressure Exergy (GJ/ m ³)	Ratio of pressure exergy to stored thermal energy
10	0.1187	0.0014	1.18%
20	0.2375	0.0041	1.72%
50	0.5937	0.0147	2.47%
80	0.9499	0.0272	2.86%
120	1.4248	0.0455	3.20%
170	2.0185	0.0704	3.49%
250	2.9683	0.1131	3.81%

Isobaric Storage



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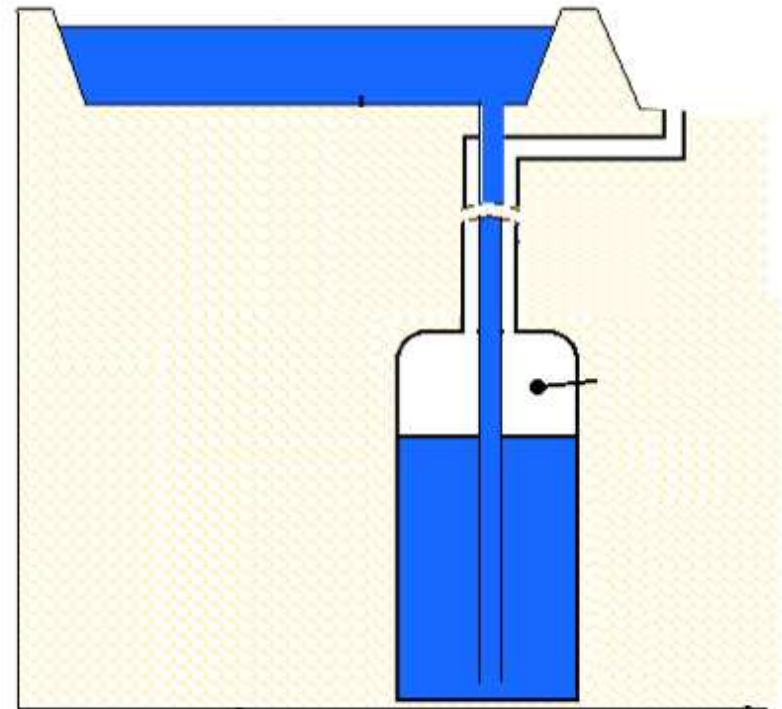
Isobaric Storage is achieved by “pumping” water(brine) into a cavern to displace gas as the gas is removed. If the hydrostatic pressure is similar to the gas storage pressure (and usually it is less), then pumping power can be very low.

Advantages:

- Power-conversion machinery operates at constant conditions (both compressor and expander)
- No cushion-gas: all stored gas can be removed
- No (significant) stress-cycling of the cavern
- No (significant) thermal-cycling of the cavern

Disdvantages:

- Need for large shuttle ponds for brine.
- Henry’s law!



An amount g (mols) of hydrogen dissolves into water in proportion to the pressure of the gas overhead.

$$g = 0.00078 \text{ mol/(kg.bar)} \quad (\text{for pure water})$$

This translates to $m_{\text{hydrogen}} = p(\text{bar}) \times 1.6\text{E-}6 \times m_{\text{water}}$.

Eg. A cavern at 100bar will retain 0.16kg of H_2 in every m^3 of water.

This could be lost as the cavern is re-filled with gas and the water is withdrawn (and de-pressurised)

Density of hydrogen at 100bar (290K) is about 8.36 kg/m^3 .

$\Rightarrow$ Isobaric storage could lose $\sim 1.9\%$ through dissolved H_2 .

Henry's law

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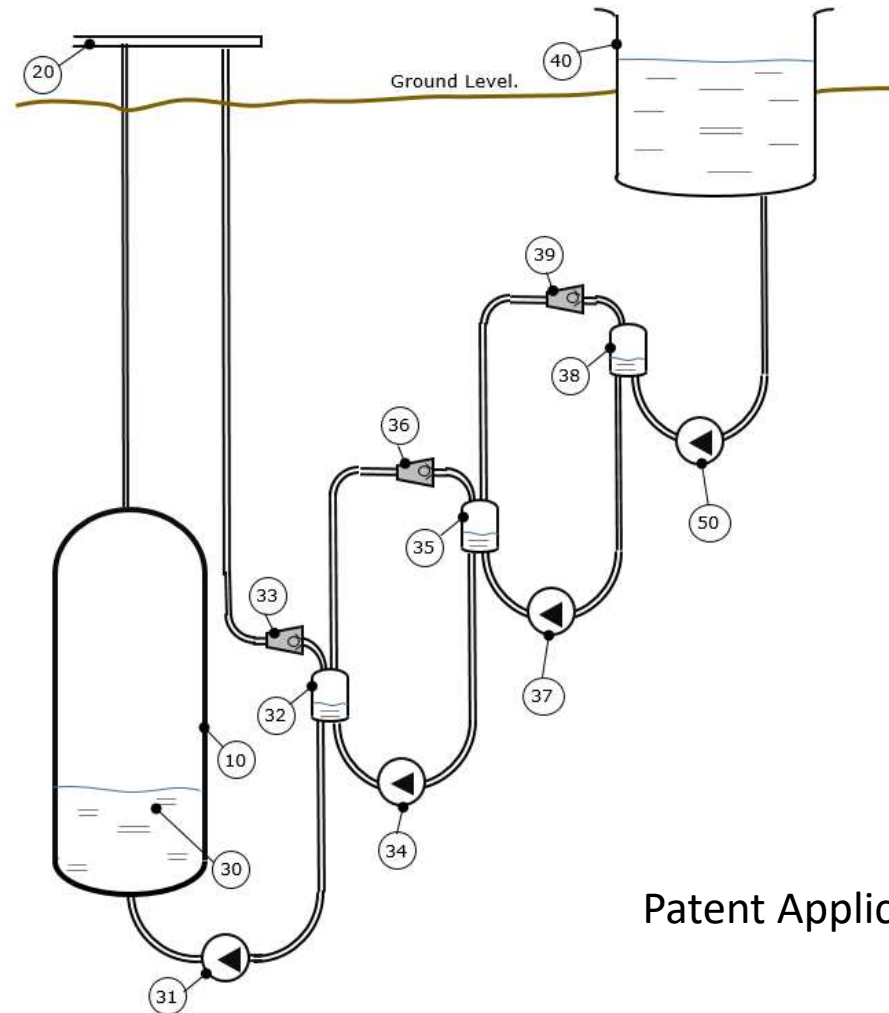
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Henry's law – a first possible solution.

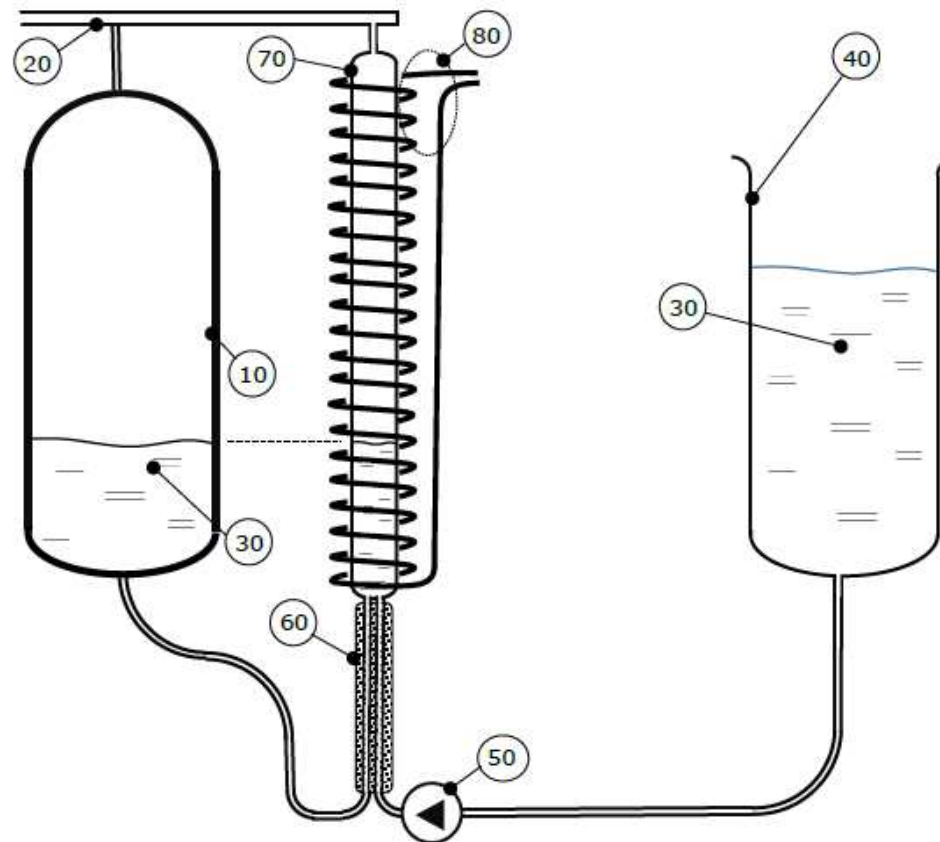


Patent Application GB1913299.2

Henry's law – a second possible solution.



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Patent Application GB2000331.5



Thanks for listening.

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