Executive Summary

Divi-H is a brand new turnkey hydrogen (H_2) polymeric membrane system that separates and purifies H_2 from streams in a wide array of industrial processes, from syngas to off-gas recovery.

Used in H_2, CO, CO_2 recovery, as syngas composition adjustment system as well as a standalone purification system, Divi-H has the largest operational flexibility in the industry.

We stand out from other market membranes for our groundbreaking performances and robustness Compared to others, Divi-H can perform in high acidity feed (high CO2, H_2S) and in much higher temperature with much less pre-treatment than a standard membrane while still yielding high purity H_2.

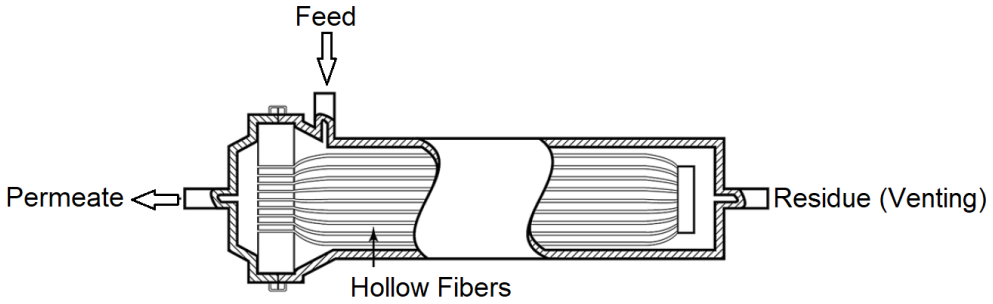
Applications

- Refineries
- Petrochemical industry
- Ammonia
- Methanol production
- Metallurgical production
- Power-to-Gas systems
- Gasifiers

Divi-H is used in the context of:

- Recovery, separation and purification of feedstock
- Pre or post-treatment of feed, either to increase recovery around a PSA unit, as a desulfurization unit or a CO/H_2 ratio adjustment mechanism

Many H_2 industrial processes today still burn their off-gas H_2 for energy. However H_2 gases can be much more valuable if recovered, repurified and re-used.



A Hydrogen Revolution

Membranes for H_2 recovery and purification have been in use in industrial processes since the 1980s. However, they have lacked several attributes wihch limited their use case. H_2S, plasticization, caused by CO2 or heavy hydrocarbon fouling have all limited many of the potential use cases of H_2 membrane due to the high costs of pre-treatment.

Tackling those shortcomings is precisely what DiviGas' Founder. Dr. Ali Naderi wanted to achieve when he designed the Divi-H polymeric hollow-fiber membrane. Through cutting edge angstrom-level polymer manipulation not only is this membrane leading in terms of cost and efficiency, it also opens up completely new use cases where feedstock composition, temperature and pressure conditions were previously a limiting factor.

Divi-H has already proven itself through use cases where no suitable alternative system was available before and is now getting ready to ship its first industrial scale pilots in 2021

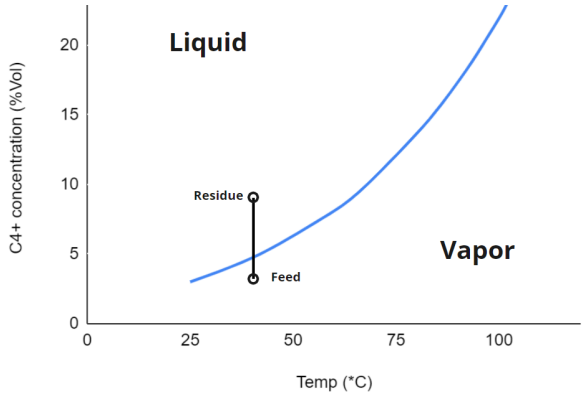
Introduction To Performance

- Purify H_2 up to 99.95% (higher if combined with other systems)
- Can remove H_2S to extremely low parts per million (ppm)
- Tolerant of fluctuating feed conditions and a very large turndown ratio
- Tolerant of high heat, pressure, and acidic environments
- Minimal installation costs, maintenance, no operator needed
- Extremely small physical volume footprint at plant
- Enhanced, long lasting membrane life
- Highest efficiency on the market
- Capacity is modular and linear with no theoratical upper limit
- High pressure residue feed means easy combination with a carbon capture, usage and storage system (CCUS).

Divi-H can be used in new and classic syngas processes

What Sets Divi-H Apart

Heavy Hydrocarbon Fouling Solved



Curve representing the hydrocarbon condensation problem on the residude side of a (typical) hydrogen-permeable membrane. As H_2 is removed from the pressurized feed, the gas becomes enriched in condensable hydrocarbons and its dew point increases.

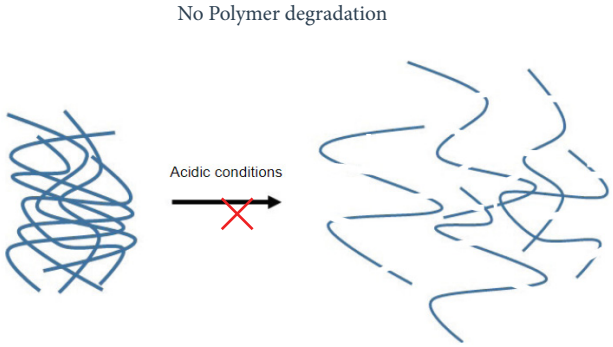
Tolerates any level of Heavy Hydrocarbons

Membranes can suffer major performance failures if the heavy hydrocarbons in the streams pass their dew points and cause fouling.

The graph above shows how a typical membrane (1) performs at around 50°C with a feed at a C_4+ hydrocarbon concentration of around 3%. At this temperature the feed is in gas form, however separation results in a residue stream with a much higher concentration of of C_4+ which would foul.
This is a cause of failure among many membranes today and can be further caused by short spikes in C_4+ concentration or fluctuation feed conditions

Divi-H can operate as high as 150°C meaning that it is completely immune to fouling. At temperature above 100°C it becomes virtually impossible for the gas to hit dew point.

Extreme Acidity Resistance



Simplified illustration of membrane degradation when subjected to acidic conditions and strong solvents. The polymeric chains break, leaving larger-than-designed perforations which causes failure.

Can Withstand much more difficult conditions

H_2S, CO_2 and other hydrocarbons can result in extremely acidic conditions. Typical membranes have to either often replace their membrane due to degradation or are unable to meet some conditions altogether unless paired with a completely separate gas-sweetening unit, adding further capex.

Divi-H was tested through a gel content Test which subjects membranes to extreme solvants. Typically one measures the degradation after a set period to calculate the resistance. Divi-H suffered no degradation at all in extended exposure in extreme conditions and therefore, can be considered acid-gas proof.

This makes DiviGas a much better candidate for difficult sweetening processes than any other membrane before.

High Heat Tolerance Results in High Performance

$$\text{Selectivity}_{\text{(Efficiency)}} = \frac{\text{Permeance of } H_2}{\text{Permeance of } CO_2}$$

Heat ↑ → $\frac{\text{Permeance of } H_2 \uparrow}{\text{Permeance of } CO_2 \downarrow}$

Selectivity ↑ → Price of Membrane ↓

Basic properties of membrane dynamics mechanic present in our membrane. CO_2 is chosen as a benchmark because it has the lowest permeance of any gas. The same equation applies to CO, H_2S and other gases but selectivity will be even higher.

Best in Class efficiency

Divi-H relies on two mechanical processes for separating H_2. The first, 'Molecular Sieving', is what you think of when you think of a filter. The membrane has 'holes' that are shaped to only let through H_2. The second, is 'Solution-Diffusion' where the relative permeation rate of the gases being separated guides the separation.

As heat increases, the permeability of CO_2 and other gases goes down whereas Hydrogen's permeability increases, resulting in a higher selectivity (efficiency).

We have been unable to find any commercialized membrane capable of tolerating above 80°C and most only go as high as 50°C. This partially drives our record-setting economical efficiency but it also means we can operate in gas processes where cooling was prohibitive. Whether for economic or material reasons.

Membrane specification	
Type	Polymeric hollow fiber membrane
Maximum Purity of output gas	99.95 mol%
Peak H_2	>95%
Module size	Length: 1m, Diameter: 25cm
Outer diameter	1 mm
Maximum delta pressure tolerance (ΔP)	22 bar
Maximum operating temperature	170 °C
H_2 Permeances for different membranes @ 150°C	88 GPU, 25 GPU and 15 GPU
H_2/CO_2 selectivity for different membranes @ 10 bar, respectively	16, 35 and 110
Product lifespan	20+ years
Membrane replacement cycle	1-5 years

The pressure trade-offs

Membranes uses pressure to drive the separation process, however pressure can be a valuable asset and compression of H2 streams is one of the most expensive operations. Our optimal pressure delta, meaning the difference in pressure between the inlet feed and the H2 purified stream (but importantly not the residue stream which stays at full pressure) is around 15 bar but can be adjusted to be as low as 5 bar

Maintenance & Other Costs

Divi-H was built with duration in mind, which is why it is specifically resistant to plasticization and membrane aging. The membrane has only a gradual minor reduction of a few percentage in performance after years of non-stop functionality and the containing module system is designed to be switched out effortlessly in a progressive sequence that requires no line shutdown.

From sour gas refineries to caprolactam plants, Divi-H's new tolerance allows membrane separation without many forms of costly pre-treatment

The Science of Breakthroughs

Dr. Ali Naderi has spent over 9 years developing successive inventions that led to this membrane. His PHD thesis was focused entirely on this topic, with the backing of the National University of Singapore, famous for its membrane department led by the legendary Professor Neal Tai-Shung Chung.
He is a member of the Australian Membrane Society and one of only the few elite group of researchers involved in deep HyCO membranes research.
Dr Naderi has been building advanced polymers for over a decade and has created polymeric structures for every high intensity situations, from rocket re-entry shielding to chemical filtering membranes.

Dr. Naderi ended his tenure with NUS in 2019 in order to launch a commercial product that is the accumulation of years of research and combines several of his inventions. From blending, to modifying polimers, all the way through inventing completely new manufacturing processes. All of this to bring a membrane that is far beyond what is available on the market. Divi-H.

DIVIGAS

Get the best in Hydrogen purification

DiviGas is always looking for additional partners to launch pilot programs in a live situation deployment. This involves:

- DiviGas sharing its externally-validated performance data with your organization
- DiviGas running a simulation of your stream on our custom software to give you a simulated output
- DiviGas sending you a customized sample or pilot unit
- Monitoring of pilot data and expectation setting for an industrial scale deployment

We will provide:

- Divi-H membranes
- The complete integrated turnkey module system and system skid & plan customized for your needs
- Flexibility in project execution
- A continuing monitoring of output data against benchmarked metrics
- On-going technical support after plant start-up
- Updates on incoming material upgrades to the membranes which will further cement Divi-H as the best in H_2 purification processing

About DiviGas

DiviGas is a Singapore-based industrial membrane supplier for refineries, chemical and industrial processors. We are dedicated to providing our clients with the leading edge of technological advancement when it comes to gas processes. We work with leading manufacturing partners to provide a complete plug-and-play product package usable right away.

Backed by SGInnovate, the Singaporean Governments' innovation arm, HAX, the hardware accelerator and other industrial investors; DiviGas has already been chosen by several plants for it's unique and excellent technical performance.

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Reach out to us today to become one of our pilot partners