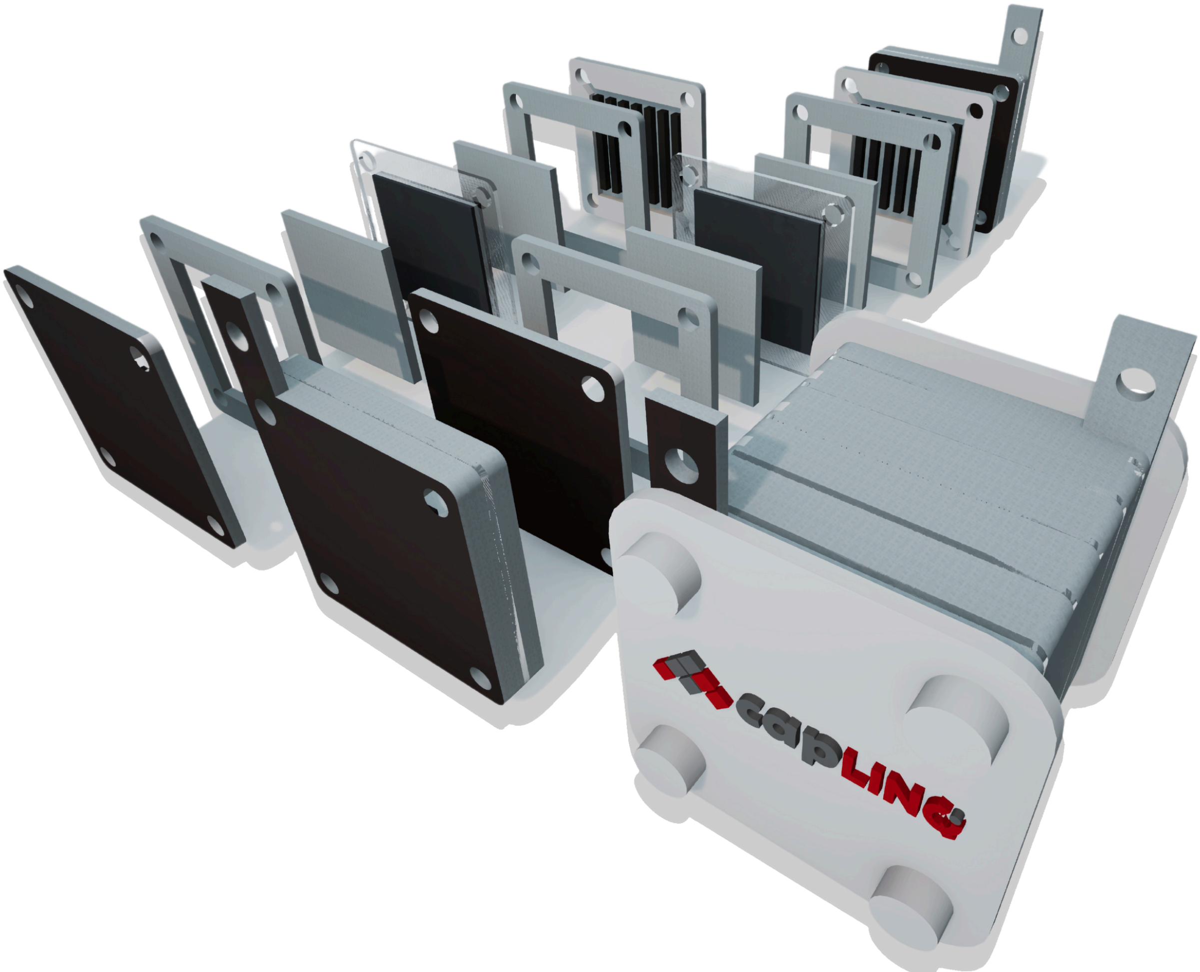
LINQCELL ALK-PCS500

Performance and Stability in Alkaline Electrolysis

Insights into durability, stability, and suitability for long-term hydrogen production



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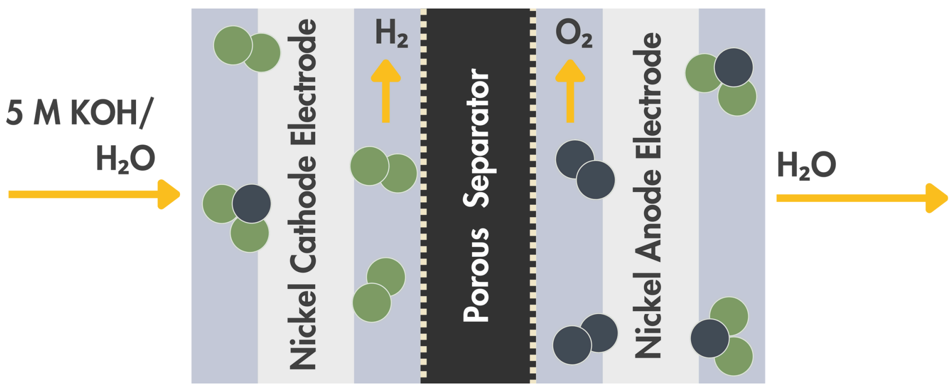
Alkaline Water Electrolyzer
Separators

In alkaline water electrolyzers, **separators** are porous membranes that keep the hydrogen and oxygen gases apart while allowing hydroxide ions (OH^-) to move freely between the electrodes. They help maintain electrical insulation and electrolyte circulation within the cell, ensuring stable performance and safety.



A well-designed separator offers the right balance between:

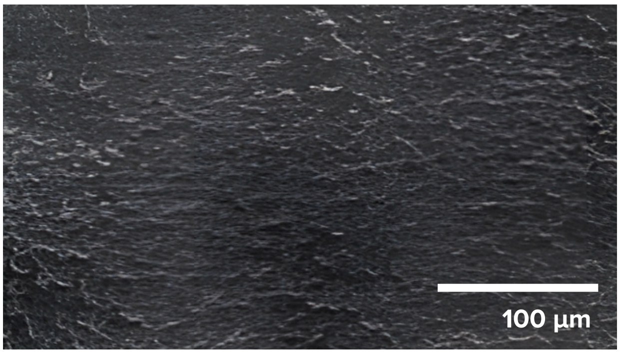
Porosity	Chemical Resistance	Strength

Following the phase-out of asbestos diaphragms, polymer-based diaphragms and membranes have become the standard for modern alkaline water electrolysis systems used in green hydrogen production.

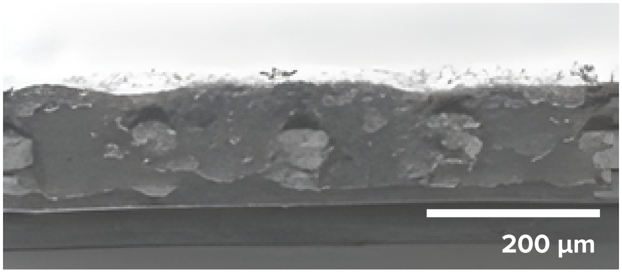
Among these materials, **polyphenylene sulfide (PPS)** has emerged as a leading choice due to its outstanding thermal, chemical, and mechanical stability in strong alkaline environments. PPS, a thermoplastic polymer composed of phenylene rings linked by thioether bonds, maintains performance even at elevated temperatures with a melting point of around 285 °C and continuous use up to 190 °C.

PPS separators are typically produced as woven fabrics or nonwoven needle felts, offering flexibility in balancing ionic conductivity and gas barrier properties. High-porosity PPS felts and meshes deliver excellent ion transport but may require surface modification or composite reinforcement to minimize gas crossover and improve wettability.

Other polymers such as PEEK, PTFE, and PES are also used in alkaline electrolyzer separators, each providing unique combinations of conductivity, chemical resistance, and cost efficiency.

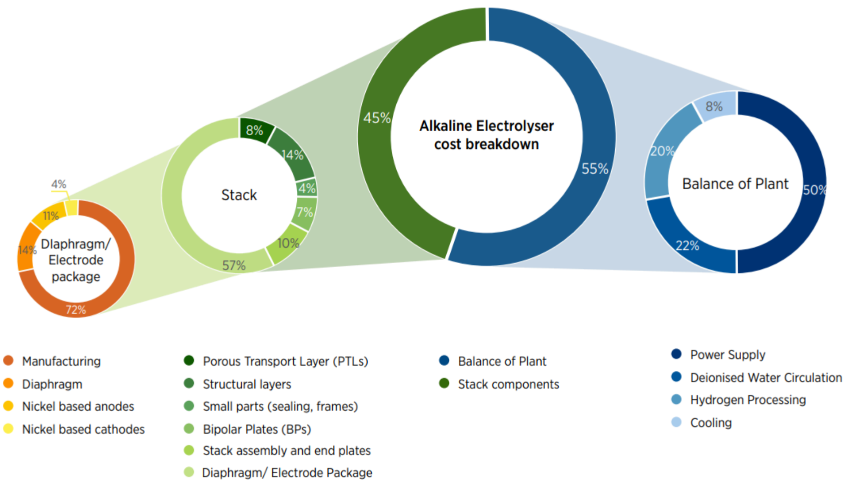


The dense coating layer provides superior gas barrier performance, effectively preventing gas crossover.



The sponge-like pore structure in the cross section provides excellent mechanical strength and high pressure resistance.

Regardless of composition, separators contribute up to 30% of the total CAPEX of an alkaline water electrolyzer. Because they directly affect efficiency, durability, and maintenance, optimizing separator materials and structure plays a key role in **lowering the levelized cost of hydrogen (LCOH).**



International Renewable Energy Agency (IRENA). (2020). Green Hydrogen: Cost and Reduction Potential. Abu Dhabi: IRENA.

Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

This report highlights the performance of LINQCELL ALK-PCS500 for alkaline water electrolysis, focusing on **three key aspects:** material properties, durability, and long-term performance under electrolyzer operating conditions.

LINQCELL ALK-PCS500
Material Properties

ALK-PCS500 is a **composite separator** made of a polyphenylene sulfide (PPS) mesh matrix reinforced with a ceramic nano coating.

- The polymeric PPS matrix provides high strength and high-pressure resistance through its sponge-like pore structure.
- The ceramic nanocoating adds hydrophilicity, improving water management during electrolysis.
- The polymeric binder with nanopores in the dense coating enhances gas barrier properties, preventing gas crossover and mixing during operation.

These design features result in a separator with high bubble point pressure, small and uniform pore size, and excellent peel strength— all of which contribute to stable, efficient, and long-lasting electrolyzer operation.

Property [Unit]	**ALK-PCS500**	**Routine Membrane Option**
Membrane Type	Composite membrane	Composite membrane
Thickness [µm]	500±50	500±50
Porosity [%]	55±10	60±10
Bubble Point [bar]	4±2	2±1
Maximum Pore Size [nm]	<200	<300
Area Resistance[1] [$\Omega \cdot cm^2$]	≤0.2	≤0.2
Gas Permeability[2] [$L/min \cdot cm^2$]	<4.2	3.2±1
Peel Strength [MPa]	>0.2	<0.1
Max. Operating Temperature [°C]	110	110
Maximum Width [cm]	210	175

[1]Measured at 80 °C, 30% KOH
[2]Measured at 5 bar

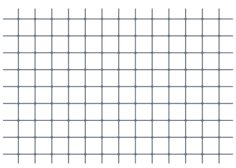
Key Features and Benefits

High **Bubble Point**

Ensures minimal gas crossover even under high differential pressures

High **Peel Strength**

Provides excellent adhesion and mechanical integrity for long-term reliability



Smaller, Uniform **Pores**

Promote consistent ion transport for stable and efficient electrolyzer performance

Cost Reduction

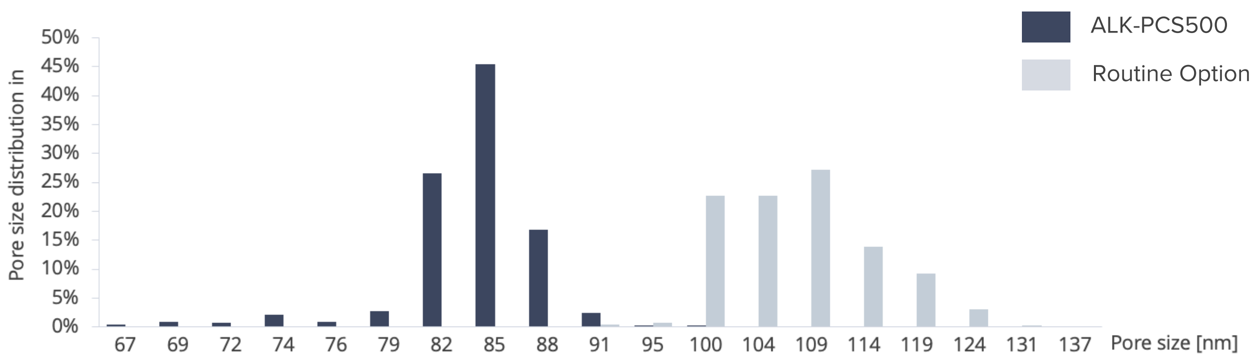
Delivers stable, efficient operation while significantly lowering system cost

LINQCELL ALK-PCS500
Material Properties

Smaller and More Uniform Pores Deliver Balanced Gas Barrier Performance and Moisture Retention

Smaller and more uniform pores provide the **ideal balance between gas barrier performance and moisture retention**. They minimize hydrogen and oxygen crossover to maintain gas purity and safety, while effectively retaining electrolyte for continuous ion transport.

This optimized pore structure prevents drying and supports stable, long-term electrolyzer operation.

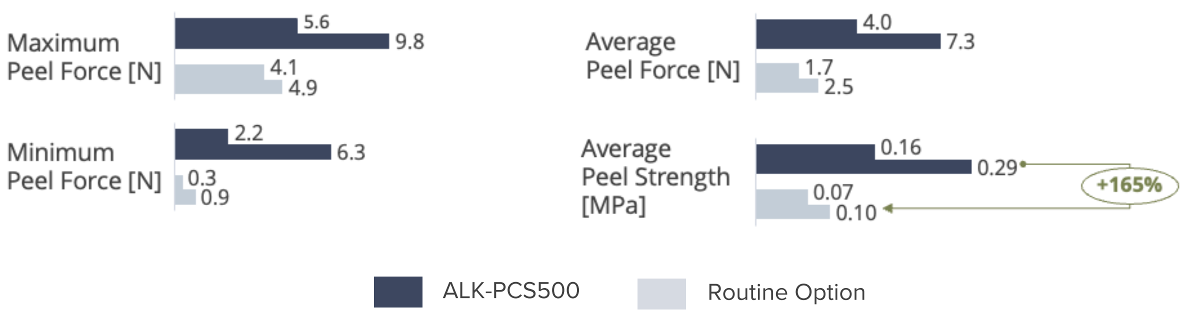


Small and uniform pores enable ALK-PCS500 to achieve better gas barrier and moisture retention performance.

High Peel Strength Ensures Long-Term Separator Integrity

ALK-PCS500 shows a significantly higher peel strength than the routine membrane, reaching 0.29 MPa, a 165% improvement over the benchmark.

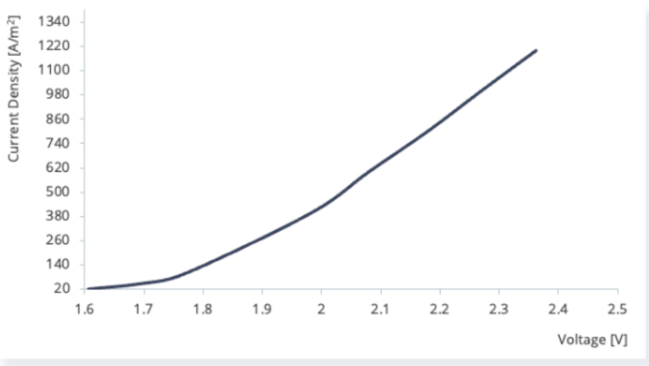
High peel strength means ALK-PCS500 can maintain its **gas-tight layer integrity for longer service life**.



High peel strength means ALK-PCS500 can maintain its gas-tight layer integrity for longer service life.

LINQCELL ALK-PCS500
Performance in Single-Cell Alkaline Water Electrolysis

The **polarization curve of ALK-PCS500** demonstrates excellent electrochemical performance under alkaline conditions (30% KOH) using a nickel mesh anode and LINQCELL CAT-NiAl cathode. ALK-PCS500 consistently operates at lower cell voltages across the entire current density range, confirming its low area resistance. This indicates efficient ion transport and minimal voltage loss, especially in the mid-current density region, resulting in improved overall electrolyzer efficiency. Testing was performed at 30 °C, 1 bar.



Polarization curve of LINQCELL ALK-PCS500 under alkaline conditions (30% KOH, 30 °C, 1 bar, Ni mesh anode, CAT-NiAl cathode)

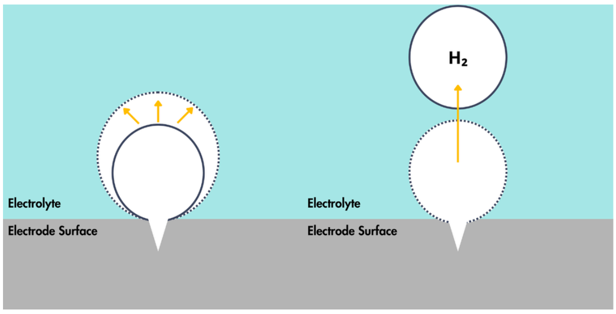
LINQCELL CAT-NiAl Properties

LINQCELL **CAT-NiAl** is a nickel-based electrode with a nickel alloy catalyst layer applied via plasma spray coating. It delivers low overpotential for the hydrogen evolution reaction (HER), offering a cost-effective alternative to platinum catalysts. Based on a **binary Raney nickel** system, it outperforms conventional 80/20 Ni–Al catalysts in HER activity and stability. Even after 1000 hours at 10,000 A/m^2, the cathodes retain coating adhesion, voltage, and performance.

Property	CAT-NiAl	Test Method / Conditions
HER Performance	|Current| at –1.5 V > 1 A	Linear sweep voltammetry –1.5 to –0.3 V vs. Hg/HgO
Mechanical Stability	Weight loss < 1%	Ultrasonication 120 W, 60 min
Electrochemical Stability	Performance decay <2% |Current| at –1.5 V > 1 A	Cyclic voltammetry –1.5 to –0.3 V vs. Hg/HgO (200 cycles) at 30% KOH, 30 (±1)°C

LINQCELL ALK-PCS500
Integrity in the Presence of Gas Bubbles

During alkaline water electrolysis, **gas bubbles** continuously form at the electrode surfaces and interact with the separator. These bubbles can accumulate within or near the separator pores, increasing local resistance and impeding ion transport. Prolonged bubble adhesion may also cause mechanical stress on the separator surface, leading to gradual degradation or delamination in poorly bonded materials.



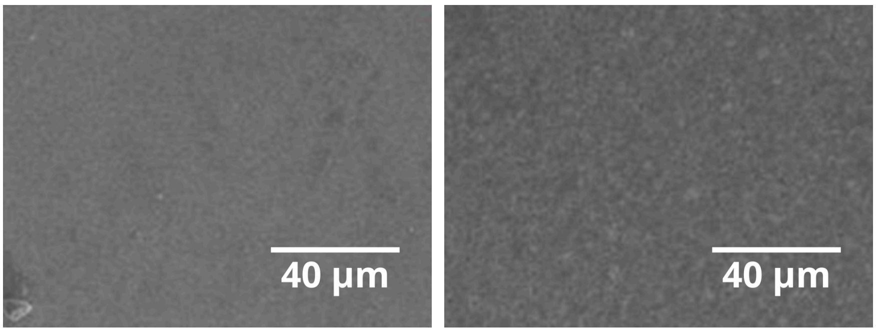
Bubble growth and bubble release during electrolysis

Procedure

The integrity of ALK-PCS500 was evaluated under simulated gas bubble conditions using ultrasonication. Samples were exposed to 30% KOH at 80 °C, with 120 W ultrasonication for 10 hours and 300 W for 4 hours to replicate the mechanical and chemical stress caused by gas bubble formation during alkaline water electrolysis.

Results

ALK-PCS500 maintained its structural integrity with no visible delamination or coating damage, confirming its strong adhesion and durability under harsh operating conditions.



ALK-PCS500 post-test: 80 °C, 30% KOH, 120 W ultrasonic treatment for 10 hours

ALK-PCS500 post-test: 80 °C, 30% KOH, 300 W ultrasonic testing for 4 hours

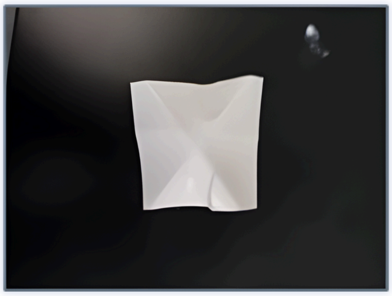
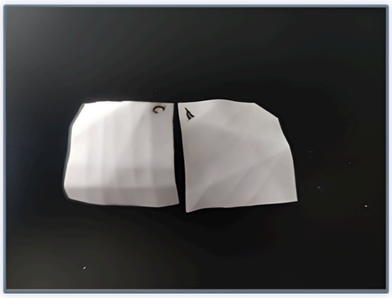
LINQCELL ALK-PCS500
Integrity at Elevated Temperatures

Separators in alkaline water electrolyzers are often **exposed to elevated temperatures** during different stages of use; from drying before cell assembly to prolonged operation in hot, concentrated alkaline environments. These conditions can lead to thermal shrinkage, warping, or loss of mechanical strength in conventional polymer-based membranes.

Procedure

To replicate these high-temperature conditions, ALK-PCS500 was subjected to dry compression at 85 °C for 10 hours and boiling at 30% KOH for 10 hours.

Results

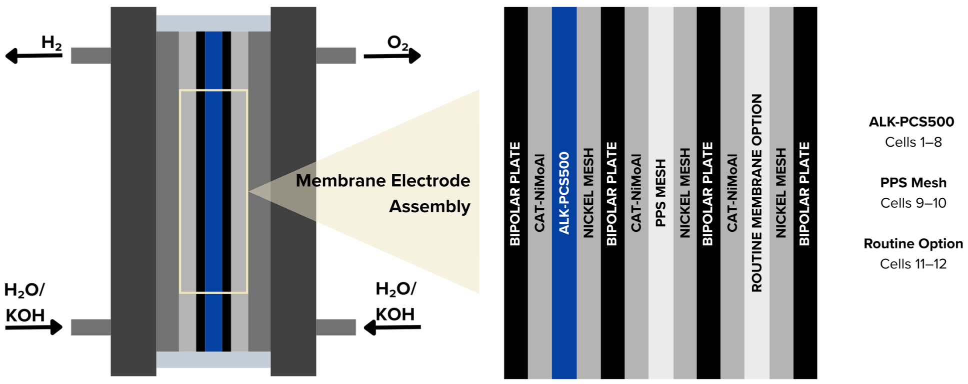
Simulated Condition	Test Condition	ALK-PCS500 Post-test
Membrane drying prior to sealing installation	Dry compression at 85 °C for 10 h	 *Membrane showed no signs of detachment or cracking upon bending*
High-temperature electrolysis operation under harsh alkaline environment	Boiling in 30% KOH for 10 h	 *No detachment or cracking observed; membrane properties remained intact.* • Bubble point = 3.9 bar • Bubble point pore diameter = 0.16 µm • Average pore diameter = 110 nm

LINQCELL ALK-PCS500
Long-Term Durability Validation in Alkaline Electrolyzer

To assess the long-term durability and performance stability of ALK-PCS500, a **5-month operational test** was conducted using a 12-cell alkaline electrolyzer with a total accumulated operational time exceeding 1,000 hours.

Electrolyzer Setup and Test Conditions

The test system consisted of 12 cells, each with a 310 mm diameter, and a production capacity of 1 Nm^3/h.



Electrolyzer test setup

The electrolyzer was operated under the following controlled conditions:

- Alkaline solution temperature: 90 ± 5 °C
- Operating pressure: 1.5 MPa
- Daily runtime: approximately 10 hours per day
- Current densities: alternating between 3000, 3500, and 4000 A/m^2

Post-test Evaluation

After completing the 5-month durability test, the electrolyzer was disassembled for detailed analysis. Each component was benchmarked across **six key aspects** to assess the integrity and performance retention of the ALK-PCS500 and associated parts.

- Component appearance
- Membrane thickness
- Membrane pressure uniformity
- Bubble point
- Mechanical properties
- Mechanical fatigue resistance

LINQCELL ALK-PCS500
Long-Term Durability Validation in Alkaline Electrolyzer

Component Appearance

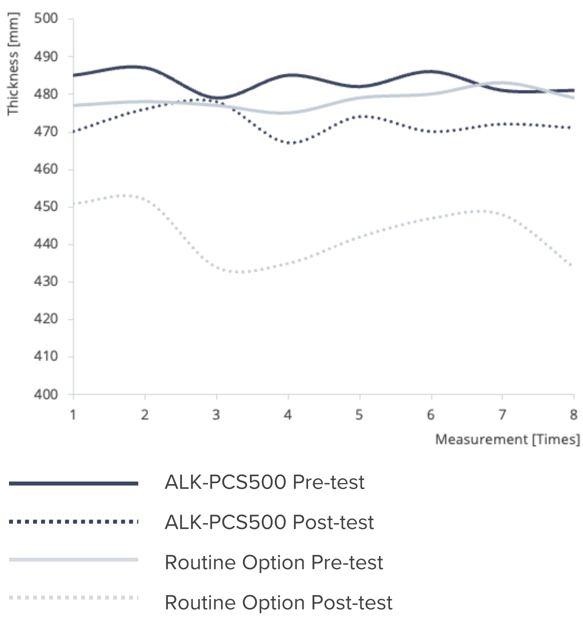
After 5 months of continuous operation, the electrolyzer remained stable with **no significant changes in performance parameters**. Upon disassembly, the ALK-PCS500 membrane and electrodes showed no visible signs of degradation or damage

Disassembled electrolyzer after 5 months of stable operation

Membrane Thickness

Post-test measurements indicated a slight decrease in the average thickness of ALK-PCS500. Given that the membrane's mass density remained stable, the observed change is attributed to **compression effects** under operational pressure.

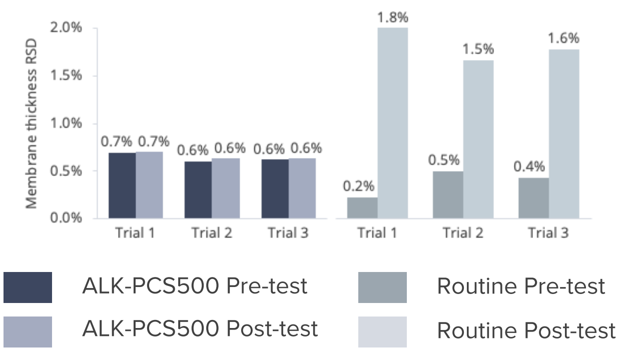
In contrast, the **Routine Membrane Option** exhibited a substantial reduction in thickness, suggesting lower mechanical stability under similar conditions.



LINQCELL ALK-PCS500
Long-Term Durability Validation in Alkaline Electrolyzer

Membrane Pressure Uniformity

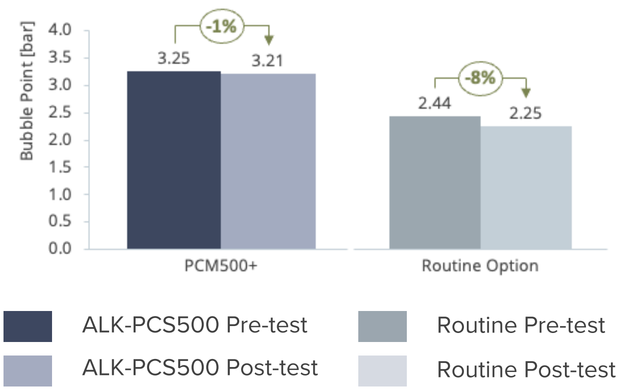
Relative standard deviation (RSD) indicates how much the membrane thickness varies from the average. The change in RSD from pre- to post-test reflects the uniformity of pressure across the membrane.
Only a **minor change** in the RSD of ALK-PCS500 was observed, indicating good pressure uniformity. In contrast, the Routine Option showed a significant increase in RSD, suggesting uneven pressure distribution.



Bubble Point

After >1000 hours of operation, ALK-PCS500 maintained a **high bubble point with only minor change**, confirming stable pore structure and consistent gas permeability.

In contrast, the Routine Option showed both a lower initial bubble point and a larger post-test decrease.

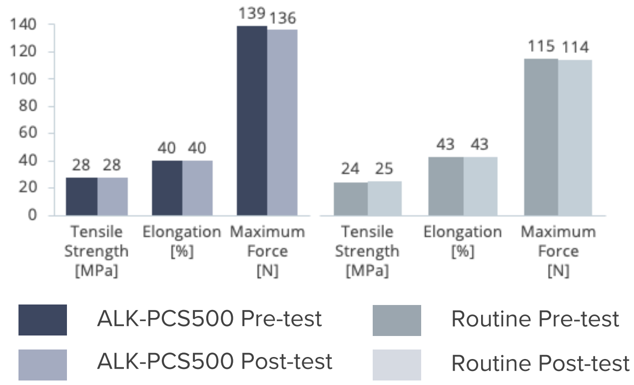


LINQCELL ALK-PCS500
Long-Term Durability Validation in Alkaline Electrolyzer

Mechanical Properties

ALK-PCS500 has a **higher tensile strength and maximum force** than those of the Routine Membrane option, while maintaining a similar elongation before the test.

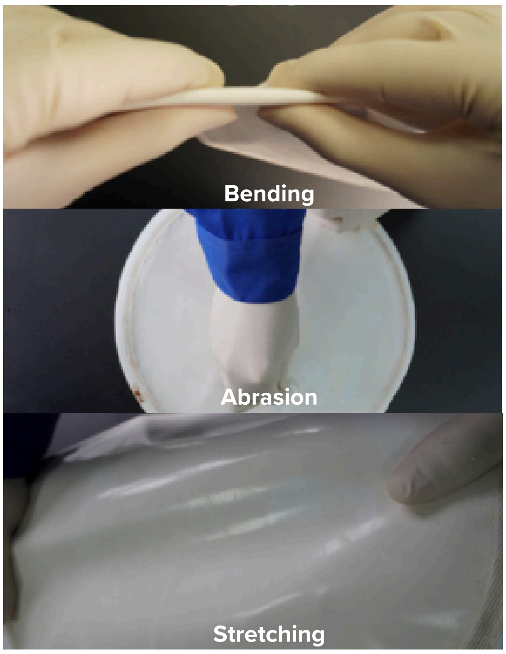
After more than 1000 hours of operation, **no significant changes** were observed the mechanical properties of ALK-PCS500, confirming good structural stability under prolonged use.



Fatigue Resistance

After testing, the membrane underwent bending, stretching, and abrasion evaluations.

No delamination was observed, demonstrating excellent mechanical fatigue resistance.



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