



CHLOR-ALKALI PROCESS EFFICIENCY: A BALANCING ACT

How to select the right membrane to maximize chlor-alkali process efficiency

EXECUTIVE SUMMARY

Following a rich history—dating back to 1892—the chlor-alkali process has evolved to favor membrane technology due to economic and environmental considerations.

Each chlor-alkali environment has its own unique nuances—including brine source/quality, electrical costs, available capital, and experience level of the labor force—making cookie-cutter solutions nearly impossible. Yet, one thing remains consistent across facilities: a desire for more consistent performance and energy savings. Membrane chlor-alkali technology offers unparalleled energy efficiency and superior voltage performance; but, without the proper operating environment, performance is not guaranteed. That's why early and frequent collaboration with membrane suppliers and electrolyzer suppliers is critical to success.



Chlor-Alkali Process Efficiency: A balancing act

This white paper will distill the complicated art of chlor-alkali membrane selection—and subsequent system optimization—into key best practices and considerations to help manufacturers balance their membrane needs and make the right choice for their one-of-a-kind operation.

The chlor-alkali processing landscape

Let's first understand how membrane technology became the industry standard.

Chlor-alkali processing technologies have evolved significantly over the years, in large part due to environmental and safety concerns. A chlor-alkali manufacturer 50 years ago would only have had two choices for chlor-alkali processing: mercury or diaphragm cell. Today, almost all newly installed chlor-alkali units use membrane technology.

Why did the transformation happen? How are the technologies different? Let's take a closer look on the next page.

Why did the
transformation happen?
How are the
technologies different?

Processing options yesterday and today

YESTERDAY

MERCURY CELL

- Phased out in many parts of the world due to environmental and health concerns with mercury emissions. No new cells have been produced since 1970.
- Environmental controls increase production costs.
- Although product quality is highest of all processing options, trace mercury contamination is present in products.

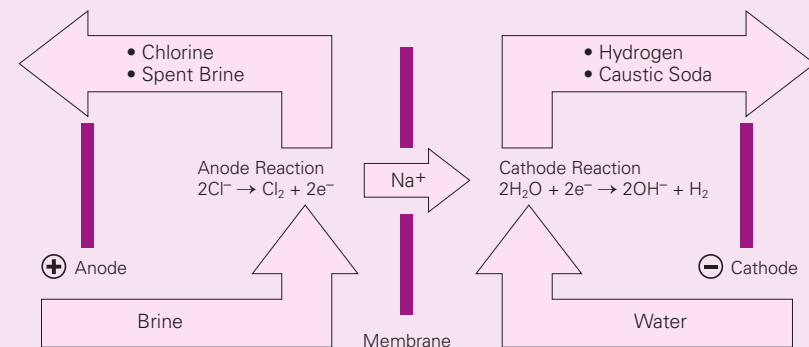
DIAPHRAGM CELL

- Produces a lower caustic concentration cell liquor that must be separated from salt by evaporation and precipitation.
- Requires the highest energy consumption due to evaporation and separation.
- Produces the poorest quality caustic and chlorine of all processing options.
- Many processes use asbestos, creating additional disposal costs and environmental concerns.
- Highest investment of all processing options.

TODAY

MEMBRANE CELL

- 30-year history of success.
- Lowest power consumption of all three technologies.
- Minimal impact to the environment.
- Caustic purity is nearly equal to mercury grade, and chlorine has less oxygen than from the diaphragm process.
- The process of choice for grassroots projects.



Doing the homework: key membrane selection considerations

There's a good chance that most manufacturers are either already using membrane technology in their operations or they are planning to use it in the future. Now what?

There are many different considerations manufacturers need to keep in mind when selecting the membrane that is right for their facility. This list should serve as a good starting point for discussions with membrane suppliers to determine the option that balances manufacturers' needs the best.

There are many different considerations manufacturers need to keep in mind...





membrane selection checklist

✓ **Voltage performance:** With electricity comprising roughly 60% of chlor-alkali operational costs, great voltage performance is not just nice to have, it's a must. When it comes to voltage performance, think of it as a marathon, not a sprint; the membrane must provide great voltage performance not only at startup, but throughout the life of the membrane.

- THINGS TO CONSIDER

- **Equipment:** To obtain the best voltage, you will need the latest low-voltage membranes and a system that is optimized specifically for membrane technology. Generally speaking, older equipment or equipment in poor condition provide a harsher environment for low-voltage membranes.
- **Operating conditions:** To get the most benefit from low-voltage membranes, the brine quality, operating conditions, and skills/training of the operator must be controlled—as they all affect the life of the membrane.
- **Ask for guidance:** Some membranes that are designed to deliver superior voltage performance may not be durable enough for a manufacturer's equipment or operating paradigm. Manufacturers upgrading their class of membrane should work closely with membrane suppliers and electrolyzer suppliers to identify the right option for their operations.

✓ **Current efficiency:** If current efficiency declines, so does production. If capacity is available, electrical current can be increased to maintain production; however, this causes voltage to rise, thus, increasing power consumption. The most important consideration after membrane selection is to follow operating instructions so that current efficiency stays consistent.

- THINGS TO CONSIDER

- **Operating conditions:** The brine quality, operating conditions, and skills/training of the operator all affect the life of the membrane.
- **Ask for guidance:** Manufacturers should work closely with membrane suppliers and electrolyzer suppliers to identify the right option for their operations.

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 **Mechanical durability:** Some membranes are more durable than others; however, the differences are subtle, and all membranes must still be carefully handled and operated.

- THINGS TO CONSIDER

- **During installation:** The temperature and humidity levels of the facility and handling procedures play a role in the life of the membrane, so manufacturers should work to control the environment as much as possible.
- **Operation matters:** Frequent shutdowns, power outages, sudden load shedding, and pressure fluctuations can all mechanically impact the life of the membrane.
- **Older equipment/technology:** Older systems may not be as mechanically forgiving as required by new membranes, and a more durable membrane may be a better choice. Unfortunately, the more durable the membrane, the higher its power consumption.
- **Ask for guidance:** Work closely with membrane suppliers and electrolyzer suppliers to verify choice and suggested procedures for handling and operation.

 **Impurity resistance:** Brine purity is one of the most important keys to achieving long membrane life with constant voltage and current efficiency. Some membranes have improved resistance to some impurities, such as nickel, magnesium, and cobalt (which can raise voltage) and barium and iodide (which can reduce current efficiency and possibly raise voltage).

- THINGS TO CONSIDER

- **Brine source:** Some brine sources contain impurities that are difficult to remove economically, such as aluminum, iodide, and silica.
- **Operation matters:** Regardless of membrane, the brine treatment system must be maintained and operated properly.
- **Ask for guidance:** Newer membranes have increased resistance to certain impurities; however, this enhancement may have an impact on mechanical durability. Work closely with membrane suppliers and electrolyzer suppliers to verify choice and suggested procedures for handling and operation.

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 **Technology and hardware:** Newer equipment is generally better suited for high-performance membranes; whereas, older equipment may require membranes with higher durability.

- THINGS TO CONSIDER

- **Operation matters:** Two identical equipment designs can perform very differently depending on how they are operated.
- **Ask for guidance:** Membrane suppliers can provide training and operating instructions that will help preserve the performance and life of the membrane.

 **Operating conditions:** Temperatures, process stream concentrations, brine purity, and differential pressure all impact the performance of the membrane.

- THINGS TO CONSIDER

- **Striking a balance:** Running at a lower caustic concentration can deliver better voltage performance but lower current efficiency. Running at higher caustic concentrations can deliver better current efficiency but worse voltage performance.
- **Ask for guidance:** There is a range of acceptable concentrations and temperatures for each membrane to optimize performance. Membrane suppliers can provide recommendations to optimize a manufacturer's facility.

After membrane selection, the true test begins

A manufacturer could choose the best membrane for their facility; but, if they don't store, handle, install, and operate it correctly, they will compromise its performance and life span. Membranes are susceptible to mechanical damage during installation as well as operation, and performance and life is highly influenced by operating conditions including brine quality. Extensive training is available from a membrane supplier; however, here are some best practices to maximize membrane performance.

Here are some best
practices to maximize
membrane performance.



Tips to Ensuring a Membrane Performs as Expected

- Membranes must be handled carefully according to the manufacturer's instructions. Actions and equipment that can cut or tear membranes must be managed.
- Membranes must not be allowed to dry out during installation. If membranes shrink, they become wrinkled during operation and are subject to abrasion.
- Startup specifications, including temperature and concentrations, must be followed so that the membranes are properly "conditioned" for performance at a steady state.
- Maintaining the brine's impurity specifications is important to prevent impurity buildup in the membrane, which can reduce current efficiency and raise voltage.
- Maintaining operating conditions, especially concentrations, is important to long membrane life.
- Maintaining low pressure fluctuations is essential to prevent mechanical damage, such as abrasion, to the membrane.
- Monitoring shutdown and standby conditions are also important to prevent ancillary damage to membranes, such as cathode corrosion with nickel absorption in the membrane.

Economic Considerations

The importance of membrane selection and proper operation can be demonstrated by economics as follows:

1. Assume the operation of 200 electrochemical units (ECUs) per day (200 metric tons of chlorine plus 225 metric tons of sodium hydroxide) with an electrical cost of \$0.10/kilowatt-hour and an open market price of \$400/ECU.
2. Consider a voltage rise (or difference) of 40 millivolts (mV). The electrical penalty would be \$19,000/month.
3. Consider a drop in current efficiency from 96% to 95%:
 - If current were raised to make up for the 2 ECU/day drop, the increased power would result in a penalty of \$18,000/month.
 - Alternatively, if the current were not raised, the 2 ECU/day penalty would be worth \$25,000/month if purchased on the open market.

Learning from experience: the power of a membrane partner, not just a supplier

When walking a tightrope, where erring too much on one side (performance or durability) could have disastrous costs, having a partner that is willing to spend the extra time to help manufacturers choose a membrane and optimize its performance over time matters.

Chlor-alkali membrane selection and operation is a complicated art and science with plenty of pitfalls. When choosing a membrane supplier, manufacturers should look for one that will stick by their side as a partner (no matter the size of their operation), one that will come to their site to help them install it correctly or to diagnose issues, one that is willing to receive and evaluate a used membrane to identify problems, one that will help them evaluate their brine, and one that won't disappear between purchases.

About Nafion™ membranes

For more than 30 years, Nafion™ membranes have been the leading, environmentally sound, and reliable product of choice for the chlor-alkali industry.

Why Nafion™?

Nafion™ membranes are specifically engineered to excel across a wide variety of operating conditions and offer consistent voltage performance, current efficiency, mechanical durability, and high impurity resistance over the lifetime of the membrane. This results in:

- Fewer process interruptions
- Limited maintenance downtime
- Reduced lifetime costs and total cost of ownership
- Consistent production quantities
- Reduced lifetime energy consumption

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A partner that has manufacturers' backs

With an endless array of potential equipment limitations, operating conditions, brine purity, and facility challenges, Chemours experts will not only help chlor-alkali manufacturers find the right membrane to meet their needs, but will also stand by their side with services and expertise to help them optimize their process post-purchase.

Chemours scientists (as part of DuPont) invented Nafion™ and have not only the in-depth knowledge, but also the deep commitment to help customers succeed. Whether it's through excellent technical support, routine site visits, or post-mortem analyses, Chemours will help chlor-alkali customers find new ways to optimize their membrane cell to maximize production while minimizing power consumption over time.

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For more information, visit Nafion.com/process-efficiency or call a technical expert:



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