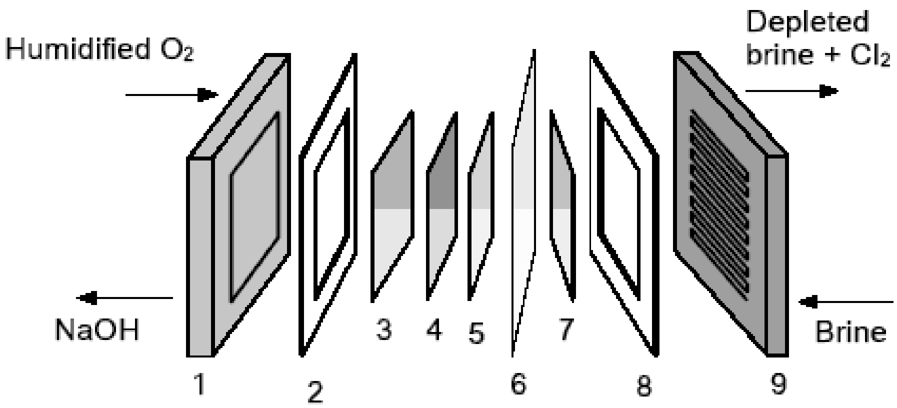
Advanced Chlor-Alkali Technology

Zero-Gap Membrane Chlor-Alkali Cells with Oxygen-Depolarized Cathodes Achieved Energy Savings of 32%

The total U.S. production of chlorine and its co-product, caustic soda (sodium hydroxide), reached 13.4 and 10.5 million tons respectively in 2004. Chlorine and caustic soda are manufactured in electrochemical cells and are one of the most energy-intensive industrial operations. The industry consumes approximately 317 trillion Btu per year, amounting to approximately 2% of the total electric power used in the United States. Three electrochemical cell technologies are used for production: diaphragm, mercury, and membrane cell technologies with approximately 70%, 18%, and 12% market share respectively. Mercury cell is the most energy intensive and consumes about 3,700 kilowatt-hour of electricity per metric ton (kWh/t) of chlorine. Diaphragm cell consumes about 2,900 kWh/t and membrane cell is the cleanest and most energy-efficient chlor-alkali at 2,500 kWh/t.

The Advanced Chlor-Alkali project further reduced energy consumption of membrane cells by significantly lowering the voltage required to overcome electrochemical polarization. The cell voltage was reduced by replacing hydrogen-evolving cathodes with “zero-gap” oxygen-depolarized cathodes. Energy consumed is directly proportional to the total cell voltage therefore, the reduction in cell polarization voltage amounted to an electrical energy savings of up to 32%. Overall the oxygen-depolarized cathode cells including the energy required to produce O_2 provides an energy saving of nearly 28% over conventional membrane cells and 50% over diaphragm cells. This project successfully demonstrated “zero-gap” membrane chlor-alkali cells with oxygen-depolarized cathodes as a practical alternative to the conventional membrane cells.



Components of the oxygen-depolarized cell with the separate gas diffusion cathode and metal cathode hardware: *1 - cathode current collector, 2 - Teflon gasket, 3 - cathode flow-field, 4 - gas diffusion cathode, 5 - hydrophilic spacer (if equipped), 6 - ion exchange membrane, 7 - DSA® coated anode meshes, 8 - Teflon gasket, 9 - integrated DSA® coated anode flow-field/current collector*

Benefits for Our Industry and Our Nation

- Potential industry-wide energy savings up to 45%
- Reduction in carbon dioxide emission
- Reduction in mercury emission from mercury cells

Applications in Our Nation’s Industry

Chlorine is one of the top ten chemicals produced in the United States and is vital to many industries including water, plastic, chemical, and petrochemical. The technology will have applications across the industries.

Project Description

The goal of the project was to develop a chlor-alkali cell using a "zero-gap" cathode design. In this design, an oxygen gas diffusion cathode remains in intimate contact with an ion-exchange membrane. This design can achieve energy savings of at least 30% from lower cell voltage by replacing the hydrogen-evolving polarized cathode with an oxygen-depolarizing cathode.

Barriers

- Existing chlor-alkali membrane technology has been optimized to the extent that no further reduction of the cell voltage is expected from additional cell or membrane modifications.
- Oxygen-supplied cathodes must satisfy two conflicting criteria, high gas permeability and low liquid permeability.
- A stable interface between liquid and gas within the active layer of the cathode must be maintained in order to ensure long-term operation of the cell.
- Existing chlor-alkali membrane cells cannot be simply retrofitted due to the different principles and operating conditions of the oxygen cathodes.
- The presence of oxygen can result in accelerated corrosion of the cathode hardware and other cell components.

Pathways

The following pathways were taken to overcome the barriers related to an oxygen-depolarized cathode:

- Identified factors leading to performance losses of an oxygen-depolarized cathode cell
- Studied effects of cell design, operating conditions, and materials for cathode and other cell components on an oxygen-depolarized cathode
- Optimized cell components and operating conditions.

Results

This project achieved the following results:

- Zero-gap chlor-alkali cells with oxygen-depolarized cathodes offered significant energy savings of as much as 38% at 0.31 amperes per square centimeter (A/cm^2).
- Zero-gap cells with a modified anode structure generated caustic soda with current efficiency above 96% at standard industrial current densities ($\leq 0.4\ A/cm^2$). This matches or exceeds the current norms for conventional membrane cells.
- Significantly reduced generation of peroxide, an unwanted byproduct associated with the oxygen-depolarized cathode reaction.
- Eliminated oxygen-depolarized cathode hardware corrosion problems by utilizing silver-plated cathode hardware which exhibited excellent corrosion resistance both under open-circuit conditions and during electrolysis.

Commercialization

The project results were achieved using laboratory-scale cells, therefore results may differ when using industrial-scale cells. Ideally, future commercialization will involve a team of partners that would include a chlor-alkali producer and a chlor-alkali cell manufacturer.

Currently, there is low interest on the part of the U.S. industry in the new energy-efficient chlor-alkali process due to the high capital investment associated with the implementation of a new technology and the potential of hydrogen evolution from current cell technology having a future commercial value.

Project Reports

This project was completed in September 2004. The final report can be found on the Industrial Technologies Program Web site: http://www.eere.energy.gov/industry/imf/completed_rd.html.

Project Partners

Los Alamos National Laboratory
Los Alamos, NM
(Dr. Jerzy Chlistunoff: jerzy@lanl.gov)

Texas Brine Company, LLC.
Houston, TX

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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Energy Efficiency
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