Chlor-alkali electrolysis plants
Superior membrane process
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*Uhde’s head office*

*Dortmund, Germany*
1. Company profile

Uhde was founded in 1921 and is a company in the Technologies Segment of the ThyssenKrupp Group. With its highly specialized workforce of more than 5,600 employees and its international network of subsidiaries and branches, Uhde, an engineering contractor based in Dortmund, Germany, has to date successfully completed over 2,000 projects throughout the world. Uhde’s international reputation has been built on the successful application of its motto Engineering with ideas to yield cost-effective high-tech solutions for its customers. The ever-increasing demands placed upon process and application technology in the fields of chemical processing, energy and environmental protection are met through a combination of specialist know-how, comprehensive service packages, top-quality engineering and impeccable punctuality.

In the field of chlor-alkali electrolysis Uhde offers a proprietary single element membrane technology, which is marketed by both Uhde and Uhdenora (UHDN), the joint venture company founded in conjunction with De Nora. Both Uhde and Uhdenora carry out intensive research and development to provide their worldwide customers with an ever better performance in the fields of planning, design, construction and aftersales services for electrolysis plants. Their common aim is to optimize the technology and further reduce energy consumption. Uhde and Uhdenora can draw on decades of experience in chlor-alkali electrolysis.

The companies have constructed more than 220 reference plants around the world. Technological experience and flexible market approaches enable Uhde and Uhdenora to effectively meet a wide range of customer requirements.
Uhde has been active in the chlor-alkali sector throughout the world for more than 50 years. During this time we have progressed from mercury and diaphragm plants to modern, environment-friendly membrane plants, which now account for more than 85% of the total 20 million t/year of NaOH (100%) produced by the plants we have built.

Depending on the wishes of the customer, we can construct new plants, expand existing ones or convert mercury or diaphragm plants to membrane technology.

With more than 100 highly skilled, experienced engineers at our company you can be sure that our electrolysis plants are of the highest quality. We provide an extensive range of supplies and services to cater for the diverse needs of our customers – whether it is a large lumpsum turnkey project or a feasibility study.

Throughout the chlorine history of our company we have always had one main focal point: close cooperation with our customers.
From the very beginning Uhde has combined its own highly effective electrolysis cells with a thorough knowledge of the entire chlor-alkali production process. In fact, Uhde is the only company in the world to combine the engineering and supply of equipment for the construction of a chlor-alkali electrolysis plant with the supply of electrolysis cells.

In addition, our portfolio also includes EDC/VCM and PVC plants to enable customers to process the chlorine produced. Uhde is thus a single-source partner you can rely on.
3. The Uhde membrane process
Single-point responsibility

All units for the Uhde membrane process are provided from a single source.
Modern chlor-alkali plants are equipped with a brine circulation system specially designed for membrane technology. Higher sodium chloride depletion in the membrane cells means that the recycle rate and the amount of equipment needed are significantly lower than, for example, in mercury plants of the same capacity. Membrane plants also have an additional brine preparation process specially adapted to the needs of the plant and to the type and quality of the brine used in order to ensure that high-quality brine enters the membrane cells.

The chlorine generated leaves the cells with the depleted brine. If high-purity chlorine is required (e.g. for a downstream VCM plant), hydrochloric acid can be added to the feed brine to reduce the oxygen content in the chlorine produced.

Once the wet chlorine gas has been cooled and filtered, it is either fed directly to the consumer plant (e.g. in the case of a hydrochloric acid plant) or it is dried and compressed before either being fed to the consumer plant (e.g. in the case of a VCM plant) or liquefied for storage in tanks.

The membrane process also involves a catholyte recirculating system. A part stream of the product, 32% caustic soda, is diluted with demineralised water to a concentration of 30% and recycled to the membrane cells as catholyte inlet. The remaining caustic soda product can be concentrated if necessary.

Hydrogen is a valuable by-product of the process and can be supplied to hydrogen consumers, such as hydrochloric acid plants or hydrogen plants once it has been cooled and filtered.

Uhde is the only contractor able to supply complete plant complexes from a single source. Uhde’s membrane process know-how covers all process units shown in the flow chart as well as a number of downstream and utility supply units.
4. The 6th generation
Zero gap over the full membrane area

The Uhde single element

One of the most significant factors affecting the operating costs of a chlor-alkali plant is its on-stream time, which is particularly dependent on the robustness of the electrolysis cells and the reliability of the materials used.

This is especially true in the case of membrane electrolysis plants, in which the relatively sensitive membrane is of central importance. The single element, combines the ideal materials with simple maintenance.

The entire anode compartment is made of titanium and consists of a sheet with a downcomer and the anode - realized as an expanded metal.

The cathode compartment is made of nickel consisting of a sheet, a current distributor (expanded metal), an elastic element and the cathode (woven mesh). In between both compartments the membrane is placed with “zero gap”. Because of this new design the whole membrane area is active in full. The sealing system comprises a TFM frame gasket and GORETEX sealing cords.

The external steel flanges which have electrically insulated bolts with spring washers ensure that the single element remains leakproof throughout its entire service life.

The steel flanges are additionally equipped with rolls in order to reduce the friction and thus to ensure an equal distribution of the contact pressure over all elements inside the electrolyzer rack.
Functional description
Ultra-pure brine enters the anode compartment via an external tube with a nozzle and is distributed across the entire width of the compartment via an internal feed pipe.

A downcomer consisting of a V shape structure utilises the gas lift effect to create a high degree of internal brine circulation, thus ensuring ideal distribution with uniform density and temperature within the compartment. Depleted brine and chlorine leave the compartment via a discharge pipe.

In the cathode compartment there is also a feed tube, which in this case is used to distribute caustic soda, and a discharge pipe, via which the products, hydrogen and caustic soda (32%), leave the single element.

Since there is only a small difference in the caustic soda concentration at the inlet and outlet of the cathode compartment, and as hydrogen and caustic soda are more easily separated than brine and chlorine, the cathode compartment is not equipped with a downcomer. Anodic and cathodic channels are located in the upper section of both compartments.

This design has the following advantages:

- Brine and chlorine on the anode side as well as caustic soda and hydrogen on the cathode side are transported to the upper end of the compartments. The thorough supply of liquid to these sections ensures that the membrane functions properly.

- A higher degree of safety is achieved as both compartments are flooded even when the electrolysis cells are in standby operation mode. That means that the liquid level in the compartments is always high enough to ensure that the membrane is fully submerged, thus preventing the hydrogen and chlorine gases from meeting in the upper part of the electrolysis cell via the membrane.

- The foamy gas-liquid mixture is completely separated inside the channels, resulting in an outlet flow of two homogeneous phases. This total separation of gas and liquid reduces the internal differential pressure fluctuation within the single element to a minimum, ensuring an even longer lifetime of the membrane.
Current flow through the bipolar rack of single elements.
With the implementation of a new full size elastic element into the proven Uhde single element design the positive accomplishments of the past have been extended by the advantages of the newest developments. The combination of a zero gap design with the single element philosophy creates a unique technology which offers 3 key benefits:

**Significant energy saving:**

The increase of the utilizable area of the membrane in combination with the zero gap design across the entire active membrane area lowers the energy consumption significantly. This positive effect is supported by a more equalized current distribution to the membrane and a improved release of gas bubbles reducing possible stagnation of the gas transport inside the single cell.

**100% leakproof throughout the entire service life:**

The Uhde single element design with its unique sealing and hose system ensures a complete leakproof electrolysis cell up to a pressure of 4.7 bar (g). With the torque force applied on the nuts and bolts of the flange system the leak tightness can be ensured during the entire service time.

**Extension of membrane service life:**

Running the membranes in an optimal contact pressure window the zero gap across the full active area is ensured and the service life of the membranes can be increased. The applied contact pressure force between all elements within one stack – smoothly transmitted with minimized friction because of the new rolls on top of the flange system – is the determining factor for the springforce of the elastic elements.

Thus the new design allows the direct control of the contact pressure applied onto the membranes independently of the force responsible for the leak tightness of the single cell element.
The bipolar membrane electrolyzer is a modular concept, with a number of advantages, including low investment costs, low energy consumption and a long service life. The single elements are suspended in a frame and are pressed against each other by using a clamping device to form a “bipolar stack”. Slight pressure is exerted on the stack by spring-tension bolts in order to ensure optimum electrical contact between the elements and an optimal operating pressure between the membrane and the electrodes. Unlike in filter-press electrolyzers, no heavy-duty jack-screws or tie rods are needed to seal the electrolyzer. The elements are all individually sealed, leading to increased operational reliability.

All single elements are connected to the inlet and outlet headers arranged underneath the electrolyzer by means of flexible, transparent PTFE tubes. The inlet tubes, which have small cross-sections, ensure that a constant stream of electrolyte is supplied to the compartment whilst the outlet tubes, which have larger cross-sections, carry the chlorine gas and anolyte as well as the hydrogen gas and catholyte away from the cell. This fail-safe connection system can be used to check that each individual element is working properly by observing the colour and flow of the product streams in these tubes. Up to 210 elements can be installed in one electrolyzer consisting of usually 2 or 3 racks connected in series.
INEOS ChlorVinyls
Tessenderlo, Belgium
Capacity: 307,000 t/year NaOH
7. Technical data

Modular concept for large capacities
150/300/450/600/… mtpd NaOH, 2/4/6/8/… electrolyzers

Operating data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current density</td>
<td>up to 7 kA/m²</td>
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<tr>
<td>Power consumption</td>
<td>see graph</td>
</tr>
<tr>
<td>Cell temperature</td>
<td>88 - 90 °C</td>
</tr>
<tr>
<td>Service life</td>
<td></td>
</tr>
<tr>
<td>anode coating</td>
<td>&gt; 8 years</td>
</tr>
<tr>
<td>cathode coating</td>
<td>8 years</td>
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<tr>
<td>membranes</td>
<td>&gt; 4 years</td>
</tr>
<tr>
<td>gaskets</td>
<td>&gt; 4 years</td>
</tr>
<tr>
<td>compartments</td>
<td>&gt; 20 years</td>
</tr>
<tr>
<td>Active area per element</td>
<td>2.72 m²</td>
</tr>
</tbody>
</table>

Product quality

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caustic soda solution</td>
<td>NaOH 32 % (wt.)</td>
</tr>
<tr>
<td></td>
<td>NaCl &lt; 20 ppm</td>
</tr>
<tr>
<td>Gaseous chlorine</td>
<td>Cl₂ &gt; 98 % (vol.)</td>
</tr>
<tr>
<td></td>
<td>O₂ 0.1 - 1.5 % (vol.)</td>
</tr>
<tr>
<td></td>
<td>H₂ &lt; 0.05 % (vol.)</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂ &gt; 99.9 % (vol.)</td>
</tr>
</tbody>
</table>

Reduction of power consumption for BM 2.7

- BM 2.7 v4
- BM 2.7 v5
- BM 2.7 v5 plus
- BM 2.7 v6

Entry to the market
- 2005
- 2008
- 2011
- 2012
- 2035

Graph showing reduction of power consumption PC [kWh/t NaOH] at 6 kA/m²
The Uhde Compact Cell House

The Uhde Compact Cell House is a largely standardized design which has been optimized particularly with regard to low investment costs, minimal space requirements and simple maintenance.

A number of electrolysers (the exact number depends on the production capacity) are installed side by side and are electrically connected in parallel. A rectifier supplies one or more of the electrolysers with direct current. The electrolysers can be easily serviced by disconnecting the rectifier or by using the individual circuit breakers and isolating switches. The tubes which supply the single elements with brine and caustic soda and discharge the chlorine, caustic soda and hydrogen are arranged underneath the electrolyser such that the single elements can be easily replaced if necessary.

Each electrolyser is equipped with an instrumentation and control unit for adjusting the rate of flow to the cells. Attached to the front of the electrolysers there are two header systems: one supplies the electrolysers with electrolytes and the other collects the products.
### Single element technology

The single element can be replaced quickly and easily. Elements are assembled in the electrolyzer workshop, where leakage tests are then carried out. This ensures:

- highest possible operational reliability,
- easy maintenance,
- cost-optimized membrane replacement and electrode recoating according to schedule,
- no additional investment needed for back-up electrolyzers,
- minimal loss of production.

### High material quality

The anode compartment (Ti), cathode compartment (Ni), gaskets (TFM) and tubes (PTFE) are all made from corrosion-resistant material and guarantee a maximum service life for the single elements. The electrolyzer headers are components with long service life and are made of pure GRP or titanium on the anode side and of PP/GRP on the cathode side.

### Membrane service time

The new elastic element allows a precise control of the contact pressure applied onto the membrane across its entire area. The capability to keep the working conditions of the membrane constant in an optimal operating window ensures the best electrochemical performance and extends the service time.

### Individual sealing system

Each single element is sealed using a flange, bolting and TFM gaskets. All elements are tested prior to operation to ensure that they are 100% leakproof. Costly jackscrew systems, such as those used in filter-press electrolyzers, are not necessary.
**Modular design**

The modular design of single element electrolyzers allows the cell room to be configured in a number of different ways. Each electrolyzer can have up to 210 elements whilst there is no limit to the number of electrolyzers permitted in each cell room. Consequently, the cell rooms can be adapted for different capacities, areas of application and operations etc. whilst the same cell type can be used in all cases. Existing cell rooms can also be easily expanded.

**High current densities**

Single element cells can be operated at a current density of up to 7 kA/m². The cell itself could be run at even higher current densities if it weren’t for the membranes used. The actual operating parameters must be set in accordance with manufacturers instructions.

**No stray currents**

Hardly any stray currents exist, even in the largest electrolyzers which can have up to 210 cell elements. This is attributable to the fact that the electrolyte enters and leaves the cells via long tubes which are situated outside the single element and act as insulators.

**State-of-the-art technology**

Our single element technology and chlor-alkali technology are under constant development and are continually being adapted to meet customer demands. This ensures that our technology is always leading-edge. Each new element generation is compatible with previous generations. Older elements can be replaced during remembraning and recoating processes.
10. Additional features of the Uhde process

**Pressurised cell operation**

The robust design and excellent tightness of the cells allow them to be operated at pressures of up to 350 mbarg. Blowers for the Cl₂ and H₂ are not necessary as air cannot be sucked into the Cl₂ or H₂ lines.

**Brine acidification**

Feed brine can be acidified to improve the quality of the Cl₂. Any risk of membrane destruction in the single element due to over-acidification is eliminated through the internal cell design (downcomer), which ensures effective mixing within the cells.

**Waste gas dechlorination**

Any plant which uses gaseous or liquid chlorine must comply with strict environmental regulations. The waste gas dechlorination unit is an essential feature in this respect and the Uhde design ensures that chlorine cannot escape into the environment under any circumstances.

**Chlorine drying tower**

The chlorine drying tower is part of Uhde’s range of proprietary equipment. A special feature of the tower is that sulphuric acid consumption is at its lowest when the ultimate humidity of the chlorine is also at its lowest. This is achieved through a twostage design within a single tower, thus saving space and investment costs.

**Combined Cl₂/EDC production**

No chlorine liquefaction, storage or evaporation is needed when Uhde’s membrane electrolysis plant is combined with EDC production. The gaseous chlorine is directly introduced into the EDC reactor. Investment and operating costs are reduced and superior operability is guaranteed due to our indepth knowledge of both chlorine and EDC production.

**Brine treatment concept (Uhde BrineTech™)**

The brine treatment unit is of central importance for a membrane electrolysis plant. Efficient brine treatment protects the membranes in the electrolysis cells while at the same time keeping both investment costs and operational costs at a minimum. With its Uhde BrineTech™ approach Uhde is continuously improving the design of brine treatment units with respect to combining operability with the lowest possible investment costs. Uhde can design customized and thus optimized brine systems based on a given salt quality through an elaborate layout programme starting with laboratory and pilot-scale tests. Due to our vast experience regarding precipitation, filtration and other means of brine treatment, Uhde is considered a second-to-none supplier of complete brine treatment solutions.

**Purge-free sulphate concept (Uhde SulfTech™)**

In order to maintain a constant sulphate level in the brine, the conventional approach is to either treat the brine chemically and precipitate the sulphate or to purge out the sulphate with a certain quantity of brine. But neither the disposal of sulphate-containing sludge nor the purging of brine are ideal from either an economic or an environmental point of view. The Uhde SulfTech™ technology obviates the need for chemical treatment or brine purging. Instead, the sulphate is physically removed from the brine and then chemically treated to form gypsum, which can be disposed of as a solid product.

**Compact cell-house design (Uhde ConvertTech™)**

The Uhde ConvertTech™ approach represents a change in process philosophy and layout arrangement. It puts special emphasis on equipment and space saving,
allowing even more competitive investment costs to be achieved by reducing the quantity of steel structures needed in the process building and by optimally using the space underneath the electrolysers – e.g. by placing tanks, pumps and heat exchangers there. Pits in the cell house are avoided and the catholyte system is integrated into the cell house.

**Skid-mounted plant**

The skid-mounted chlorine plant is a plant with a capacity of up to 15,000 t/a Cl₂ consisting of standardized process modules ready assembled in steel skids with a standard container size.

Prior to the delivery these units have passed already several quality tests in the workshop in order to reduce time for erection and any erection risk at site to a minimum.

Thus the costs for tailor made engineering services as well as the costs for onsite erection can be reduced significantly.

This concept supports especially operating companies with a minor demand for chlorine by making them independent from external supply and avoids the transportation of liquid chlorine.

**Salt slurry system**

In order to transport large amounts of salt by pipeline, Uhde offers a salt slurry system developed by Bayer Technology Services and Bayer MaterialScience. The salt delivered is suspended in transport brine and a salt slurry is produced. This slurry can be pumped to the electrolysis plant over distances of several kilometres if needed. Once the salt has been separated out in a storage silo, the transport brine can be reused for transportation. Some of the advantages of the slurry system are:

- transportation costs from the salt unloading bay to the plant site can be drastically reduced
- storing the salt slurry in silos minimises the risk of corrosion to adjacent equipment
- anti-caking agents for the salt are almost superfluous
- environmental protection due to a reduction in salt transportation, e.g. by road

**Performance optimisation**

Uhde’s integrated performance analysis system Uhde Integrator™ ensures continuous monitoring and investigation of cell assembly data and essential operating parameters. It provides information for troubleshooting and optimising plant operation.

**Integrated piping concept (Uhde PipeTech™)**

The material used to construct approx. 80% of all piping and equipment in a chlor-alkali plant is GRP or lined GRP (glass-fibre-reinforced plastic). Uhde’s integrated GRP concept represents an essential part of its chloralkali expertise and is based on more than 30 years of plastics know-how and experience.

Uhde’s standard piping specification and accompanying support specification have been fully stress-analysed and brought into line with the relevant laying instructions, taking into account the special requirements of GRP. The entire system has been certified by the German notified body TÜV.

The integrated GRP concept is complemented by standardised piping routing for recurring piping arrangements, vast GRP fabrication know-how, a pool of qualified, audited fabricators in Europe, and also access to an excellent network of specialists. Our extensive piping know-how has been combined to yield the Uhde PipeTech™ system.
11. Technology services

Our customer services in the field of electrolysis do not stop on plant completion, but also include:

- Consultancy visits
- Technical exchange meetings
- Chlorine Symposium
- Optimization of plant performance
- Full service electrolyzer maintenance
- Benchmarking
- Remembraning/recoating support
- Revamps
- Delivery of spare parts
- Upgrades of cell element

Our regular consultancy visits to customers keep them informed about the latest technical developments or revamping activities, and by organising and supporting technical exchange meetings and symposia, for example the Chlorine Symposium held every 3 years at Uhde’s head office in Germany, we promote active communication between customers, partners and our own specialists. This enables our customers to benefit from the development of new technologies and the exchange of experience as well as troubleshooting information.

We monitor, analyse and optimise plant performance during the entire lifetime of a plant, applying our integrated performance analysis system Uhde Integrator™, which consists of three different levels:

**Level 1:**

- Element administration program Uhde Administrator™
  This program is used to administrate cell components and to record and analyse cell assembly data as well as operating data.

- Uhde data acquisition terminal Uhde Scan™.
  This unit reads information on the electrolysis cell compartments from a bar code and transfers this information to the Uhde Administrator™. It also offers forms for documentation and administration purposes.

**Level 2:**

- Single element analyser Uhde Evaluator™
  This system monitors and safeguard cell element voltages and analyses membrane and coating performance.

**Level 3:**

- Remote condition monitoring
  Data acquired with the Uhde Evaluator™ can be sent by automatic data transfer to Uhde to permit further analysis by our specialists in Germany.
We also provide a support service for our customers during the remembraning and recoating of single elements, i.e. the renting out of cell elements or supervision of cell assembly by our specialists. And the direct delivery of spare parts has always been part of our technology services, too.

On top of this, it has always been Uhde’s aim to enable all customers to profit from new developments. The “Single Element Upgrade” programme for performance improvement is one of these recent developments. By removing the anode in the anode compartment of older versions of the Uhde single element and replacing it with the latest anode type, element performance can be significantly improved, resulting in:

- massive power savings as well as
- a reduction of CO₂ emissions

Ideally, an element upgrade is carried out during the regular element recoating phase. While the cathodes are being recoated as usual, the anode is equipped with brand new, freshly coated electrodes.

This approach minimises both the downtime of the electrolysis plant and maintenance costs.

For more information, see our brochure "Continuous improvement through integrated services".
12. Services for our customers
Uhde is dedicated to providing its customers with a wide range of services and to supporting them in their efforts to succeed in their line of business.

With our worldwide network of local organisations and experienced local representatives, as well as first-class backing from our head office, Uhde has the ideal qualifications to achieve this goal.

We at Uhde place particular importance on interacting with our customers at an early stage to combine their ambition and expertise with our experience.

Whenever we can, we give potential customers the opportunity to visit operating plants and to personally evaluate such matters as process operability, main-tenance and on-stream time. We aim to build our future business on the confidence our customers place in us.

Uhde provides the entire spectrum of services associated with an EPC contractor, from the initial feasibility study, through financing concepts and project management right up to the commissioning of units and grass-roots plants.

Our impressive portfolio of services includes:

- Feasibility studies/technology selection
- Project management
- Arrangement of financing schemes
- Financial guidance based on an intimate knowledge of local laws, regulations and tax procedures
- Environmental studies
- Licensing incl. basic/detail engineering
- Utilities/offsites/infrastructure
- Procurement/inspection/transportation services
- Civil works and erection
- Commissioning
- Training of operating personnel using operator training simulator
- Plant operation support/plant maintenance
- Remote Performance Management (Teleservice)

Uhde’s policy is to ensure utmost quality in the implementation of its projects. We work worldwide to the same quality standard, certified according to: DIN/ISO 9001/EN29001.

We remain in contact with our customers even after project completion. Partnering is our byword.

By organising and supporting technical symposia, we promote active communication between customers, licensors, partners, operators and our specialists. This enables our customers to benefit from the development of new technologies and the exchange of experience as well as troubleshooting information.

We like to cultivate our business relationships and learn more about the future goals of our customers. Our after-sales services include regular consultancy visits which keep the owner informed about the latest developments or revamping options.

Uhde stands for tailor-made concepts and international competence. For more information contact one of the Uhde offices near you or visit our website:

www.uhde.eu