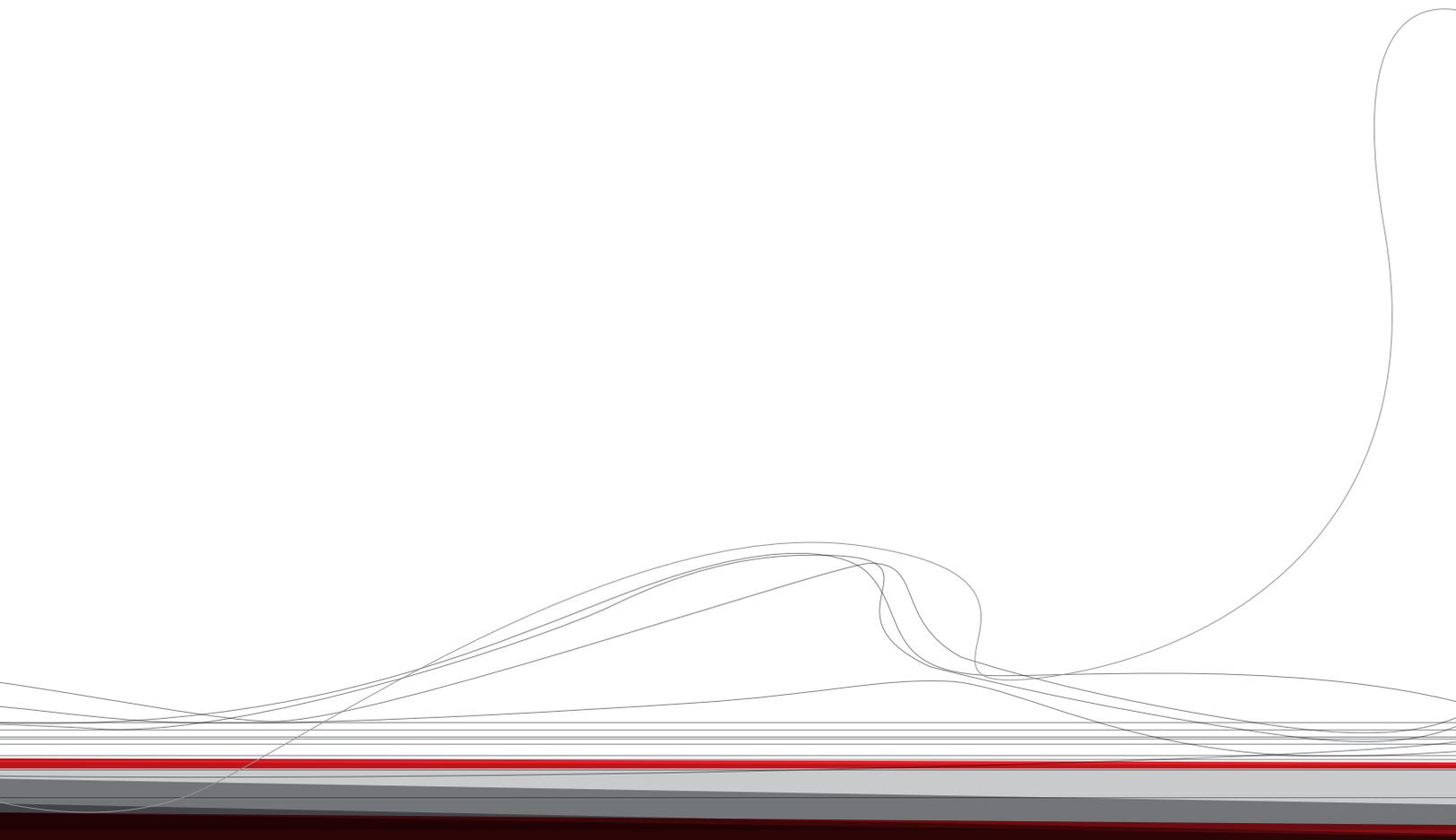


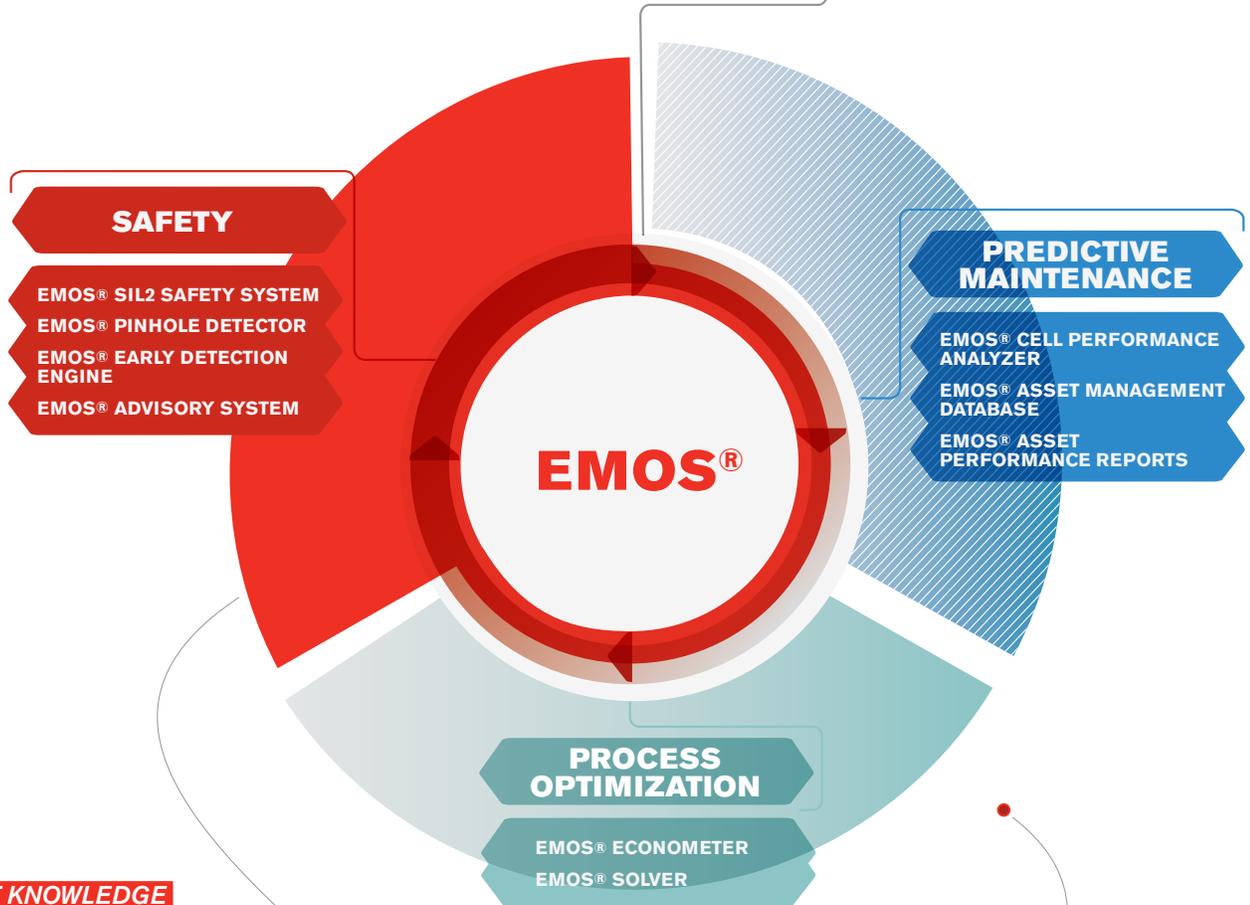


MORE THAN JUST MONITORING

R2



A GLOBAL APPROACH



IT'S ALL ABOUT KNOWLEDGE AND EXPERTISE...

R2 specializes in the design, development, and implementation of intelligent systems geared at industrial safety process, predictive maintenance and process optimization. Since its inception in 1989, R2 has devoted its information technology know-how and electrochemical expertise to developing, producing and delivering practical solutions to the electrochemical industries. Backed by unique expertise and knowledge, gained from monitoring over 35,000 cells in 20 different countries, R2 offers a series of tools for the chlor alkali industry. These tools provide:

- **Increased safety**
- **Energy cost reduction**
- **Optimized asset use**
- **Production cost optimization**

CONCERNED ABOUT SAFETY? WE R2

IT'S ALL ABOUT PRECISION AND SPEED

EMOS® SIL2 Safety System

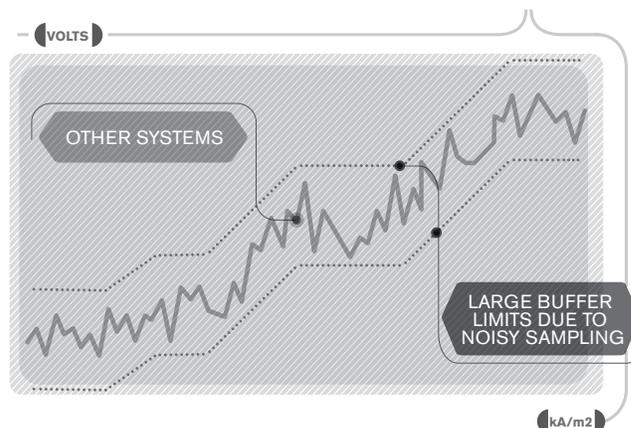
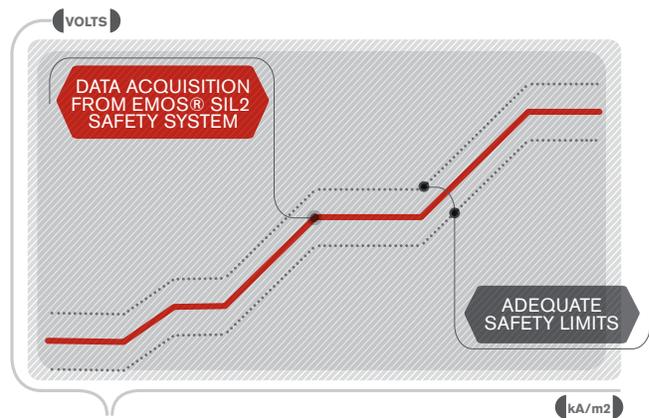
- High precision measurement of 1.5mV
- Protection against all known events
- No false trips
- Autonomous, plant network independent

Traditional VMS systems with fixed trip values will only provide adequate protection to the electrolyser when at full and stable load. R2 offers a safety system that does much more. Only with acute precision, speed, and stability, can tight limits be set to provide protection at any point of operation without causing any false trips.

The autonomous hardware and embedded event detection algorithms have been designed and built to meet the SIL2 rating. This translates into a very high reliability with a failure rate below 0.1% and self-diagnosis routines.

R2 not only designed a great platform but has also implemented a series of event detection algorithms to protect the electrolyser against all known hazards including:

- Anode coating loss
- Cathode coating loss
- Electrode passivation
- Membrane poisoning
- Insufficient electrolyte feed
- Cell temperature control failure
- Electrolyte concentration control failure
- Differential pressure out of range
- Leaking cells
- Membrane pinholes, tears and blisters
- Short circuits

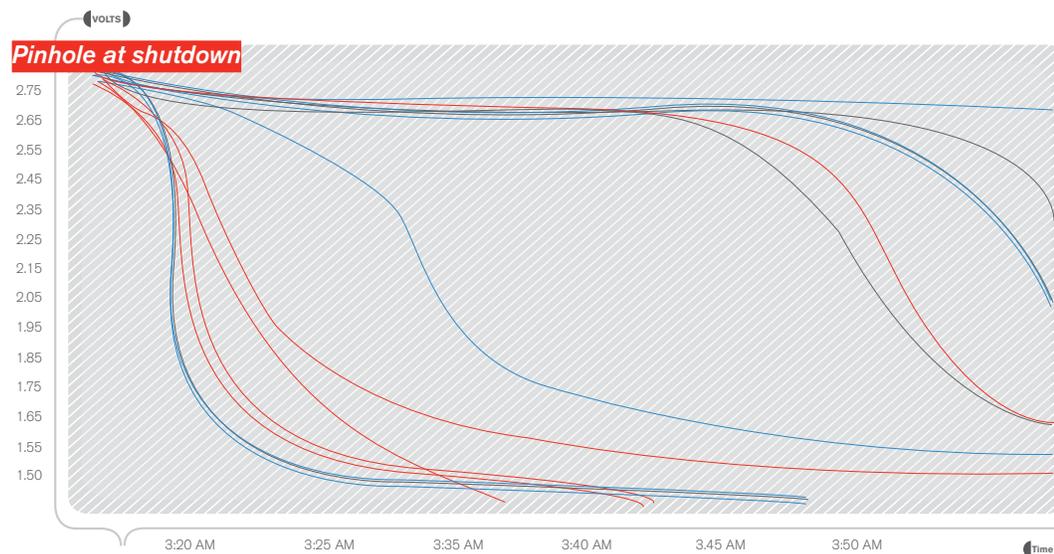
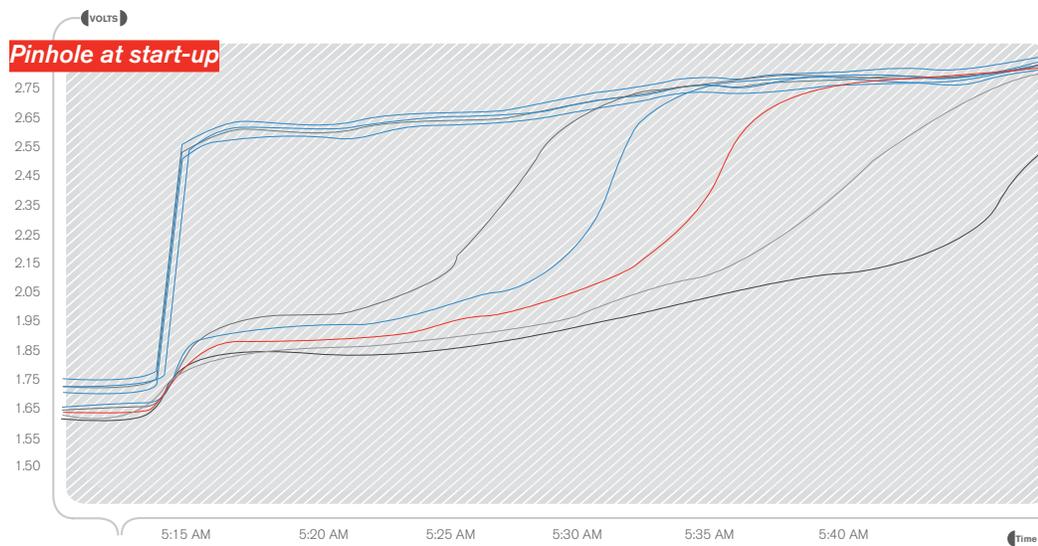


PINHOLE DETECTION DURING START-UP AND SHUTDOWN

EMOS® Pinhole Detector

Depending on the size and position, a membrane pinhole can become a serious hazard. R2's revolutionary approach to pinhole detection integrates a unique tool for the automatic detection and severity classification of pinholes within the EMOS® Monitoring software package. This tool automatically detects pinholes immediately after a shutdown and also during start-up, analyzes their severity and notifies the operator.

Our integrated Pinhole Detector automatically identifies membranes with pinholes at their earliest stages. It allows for the close tracking and follow up on affected elements to minimize coating degradation and production loss. The user can then efficiently manage their removal during planned shutdowns and avoid delays during plant start-ups. This wouldn't be possible without the unparalleled precision and speed of our proprietary high accuracy Voltage Monitoring System EMOS®.



A STEP FURTHER

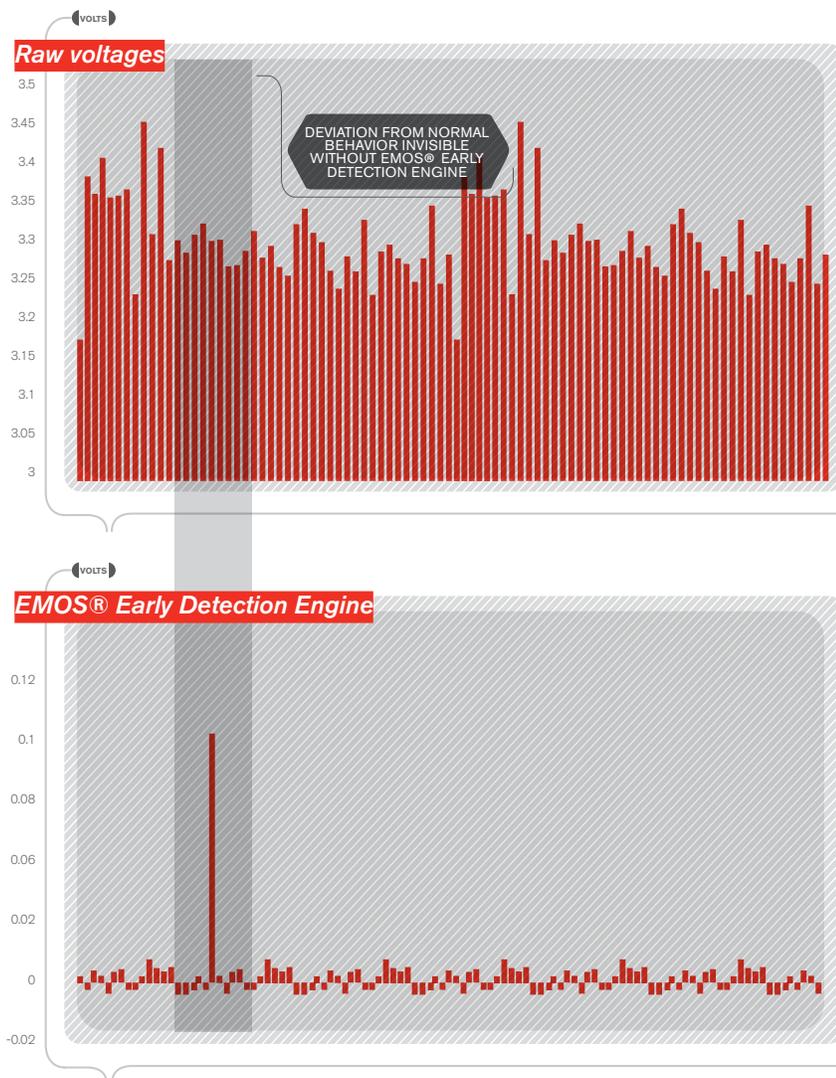
EMOS® Early Detection Engine

- Detects abnormal behavior of individual cells
- Prevents irreversible damage to electrolyser components
- Avoids unplanned shutdowns

With individual voltage trips enabled, unsafe situations are avoided by shutting down the electrolyser in case of a malfunction. Unfortunately, in some cases a performance loss is irreversible, resulting in either significantly increased production costs or high maintenance costs and high production losses to replace the damaged components. In many cases, the unplanned shutdown could have been avoided by detecting a deviation in cell behaviour before it became hazardous. The EMOS® Early Detection Engine detects any change in the performance of electrolytic cells as early as possible and minimizes the economic consequences.

All industrial electrolytic cells are showing from start-up high differences in performance and are aging differently. To really follow the decrease in performance of an electrolytic cell, it shouldn't be compared to the rest of the cells. Instead, the detection of decreasing performance of cells should be based on the modelling of the behaviour of the individual cells.

EMOS® Early Detection Engine compares in real-time the actual voltage of the cells with a predicted voltage, which is calculated based on the individual "normal" performance of the cells and the actual operating parameters. Should a cell start to behave outside of its normal parameters, an alarm will be sent to the operator.



TURNING DATA INTO INTELLIGENCE

EMOS® Advisory System

- **Pattern identification and recognition of hazards**
- **Recommends corrective actions**
- **Reduces human factor**

Sometimes, things are not as they appear. One slowly escalating parameter might not be problematic but alongside other situations, it could be hazardous. With EMOS® Advisory System, all of the plant parameters and relationships are monitored, covering all possible phases of electrolyser operation: from filling to full load and back to draining. If a situation occurs, the operator will be advised on the action to take in order to reduce or eliminate the threat.

There are limits to the human capacity to monitor an industrial production facility. It's easy to get overwhelmed by the amount of data being displayed in a control room. Using EMOS® Advisory System, an artificial intelligence is overlooking the process and will offer guidance to keep the production running safely and avoid costly unplanned shutdowns.



For example, although the voltage is not really high, the EMOS® Early Detection Engine signals an alarm. On the right, the EMOS® Advisory System informs you that it had detected an insufficient electrolyte feed and recommends that you reduce the load or shutdown the electrolyser immediately.



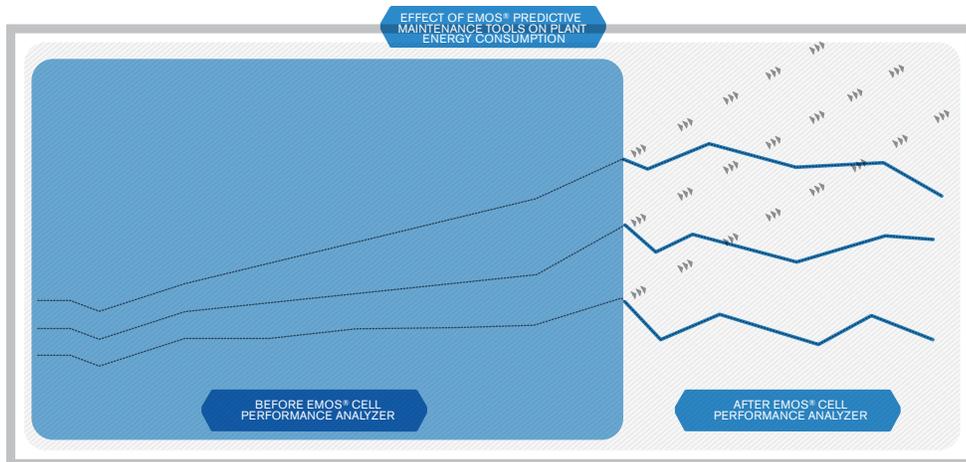
You can see here from the pattern that the EMOS® Advisory System identified the event 8 hours before the voltage even came close to reaching the trip level. Plenty of time in order to fix the problem before you are at risk and lose production.

CONCERNED ABOUT MAINTENANCE? WE R2

SWITCHING TO PREDICTIVE MAINTENANCE

EMOS® Cell Performance Analyzer

- Identification of underperformers
- Reduced maintenance costs
- Energy savings
- Characterization of all elements: anode, cathode and membrane
- Current Efficiency (CE) of single membranes with $\pm 0.25\%$ accuracy
- U_0 with a precision of ± 2.5 mV



A plant's profitability depends on one thing: producing a high quality product for as little as possible. An excellent way to reduce production costs is to change the maintenance strategy from time-based to performance-based.

As a matter of fact, a reduction of 15 to 20% of the plant's performance is attributable to 3 to 5% of cell elements that are underperforming. Locating and replacing those underperformers and keeping the over performers leads to substantial energy savings.

EMOS® Cell Performance Analyzer offers complete characterization of single cell elements: anode, cathode and membrane, giving you true insight into your electrolyser.

KEEPING TRACK

EMOS® Asset Management Database

- User friendly database software
- Easy drag & drop functions for keeping track of:
 - Component locations
 - Component status
- Integrated data error-checking



This specialized software is designed to store, track, and manage all relevant cell component information (coating type, membrane type, batch information, location in plant, service history, inspection reports etc). It allows the user to build, commission, and decommission cell assemblies with an easy drag-and-drop functionality. It can also collect, store, and correlate cell specific lab data analysis and maintenance information, and is configurable for both filter press and single cell electrolyser designs. The application ensures that the data is chronologically consistent and free of common data entry errors. It can even manage and analyze multiple plants.

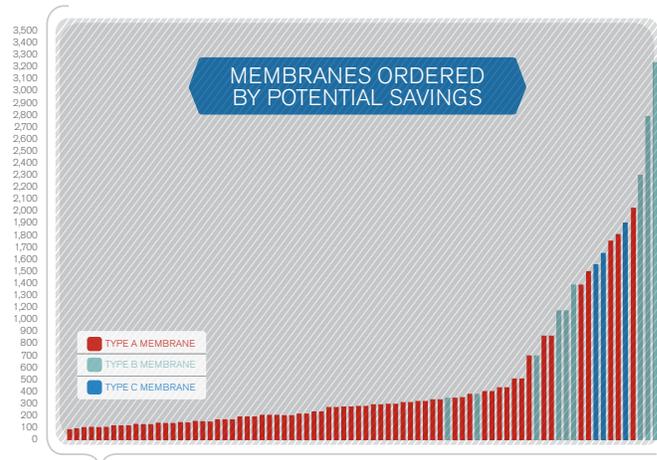
PERFORMANCE-BASED DECISIONS

EMOS® Asset Performance Reports

- Performance-based maintenance
- Energy savings
- Better planning of plant shutdowns
- Reduced production loss
- Asset use optimization

This tool provides customizable analysis and reporting capabilities based on the combined information from EMOS® Safety System, EMOS® Asset Management Database, and EMOS® Cell Performance Analyzer. The flexible component administration enables the analysis and correlation of cell component performance based on evolution (aging time but also production based), type, supplier etc., as well as operating parameters.

The EMOS® Cell Performance Analyzer is one of several predefined interactive reports within this module which allow you to track the economic performance of individual cells and cell components (coatings and membranes) in order to determine the optimal replacement or maintenance time. It allows ranking of the cells according to the calculated achieved savings by replacing them. At the same time all component information from the Asset Management Database is available.



CONCERNED ABOUT OPTIMIZATION? WE R2

FOR KEY PERFORMANCE RESULTS: THE PERFECT SETTINGS

The chlor-alkali process is very energy intensive (electricity, steam etc.) and the energy efficiency of an electrolyser is determined by the complex inter-relationships between many different process parameters. Slight changes in operational set points such as temperature or caustic concentration can have a significant impact on the overall energy efficiency of the system. R2's research has shown that 3-5% savings in energy consumption can be achieved by operating the plant at optimum set points for caustic concentration and temperature. In order to achieve this, R2's response is twofold.

EMOS® Econometer

EMOS® Econometer calculates key performance indicators and allows precise online and real-time analysis of the specific energy consumption. This information is used to identify the performance of your plant depending on the operational parameters and displays the theoretical savings onto a dashboard. It calculates:

Production Rate (t/d)

Utilization Rate (% of max. production)

Deviation from planning

Normalized Specific Energy Consumption (kWh/t)

Production Cost (/t)

Current Efficiency

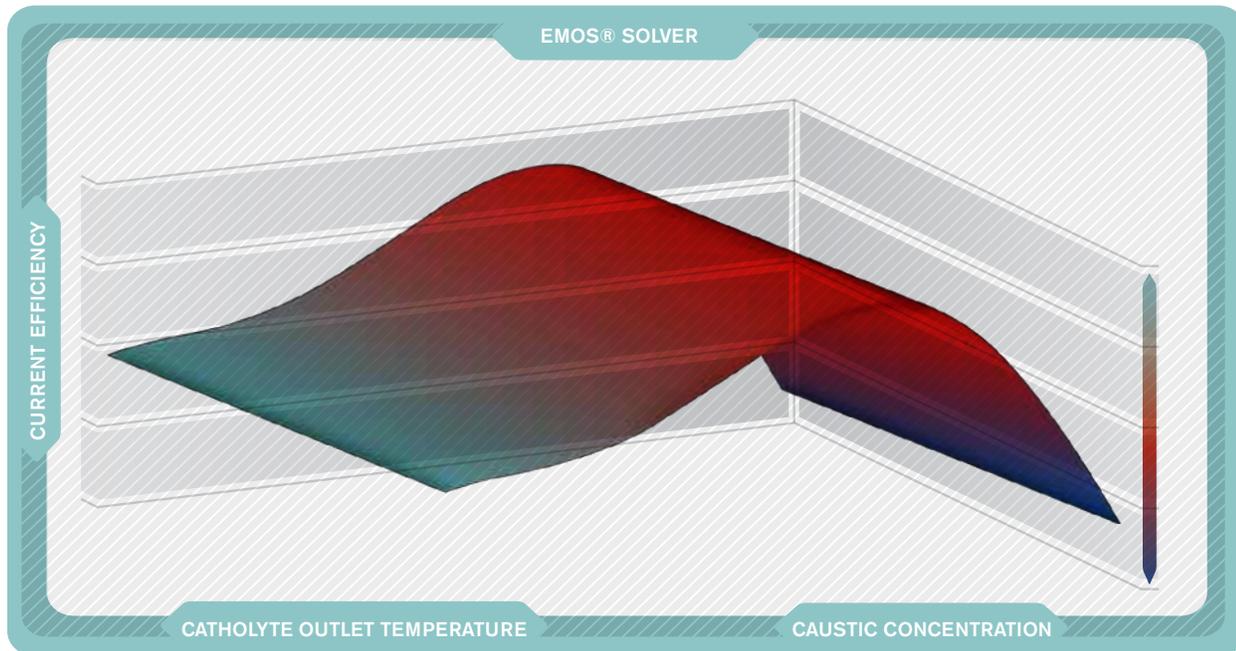


THE ULTIMATE BALANCE BETWEEN ENERGY CONSUMPTION AND PRODUCTION OUTPUT

EMOS® Solver

- Optimization of process parameters
- Energy reduction
- Production cost savings

The EMOS® Solver contains a neural network based model, learned from your plant's past performance, which calculates the optimum operating set-points for temperature and caustic concentration at any given time. It communicates with the DCS and advises the operator to change set-points to optimize the specific energy consumption (all within limits specified by the technology supplier) resulting in incredible savings.



OUR EXPERTS AT YOUR SERVICE: ANALYSIS AND CONSULTATION SERVICES

As an independent third party with a long history in the chemical industry and a global network of specialists, R2 can offer producers and technology suppliers neutral analysis & consultation services including:

- Analysis of equipment/plant maintenance strategies
- Analysis of equipment/plant performance/economy
- Calculation of potential savings by proactive asset management (performance based maintenance with aging prediction/early detection by neural networks)
- Calculation of potential savings with neural network based optimization of process parameters

Especially for clients from the electrochemical industry we provide:

- Performance determination/warranty management for electrode coatings, membranes and cells
- Predictive and preventive maintenance strategies
- Remembraning/Recoating planning (component selection trials, time schedule)
- Analysis/optimization of overall plant performance/economy
- Risk assessment, safety analysis and optimization

Early detection and precise determination of performance degradation is the key to minimize damages and to develop fast design changes and/or improved process parameters.



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