ENERGY SAVING SOLUTIONS AND LATEST DEVELOPMENT IN COATINGS TECHNOLOGY

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Our daily activities are driven by our values

DE NORA IDENTITY

**MISSION**
One company
Comprehensive portfolio
Performing products
Services and applications

- Balance between global mindset and respect of our history
- Integrity and fairness
- Passion and results orientation
- Focus on people and respect of diversity
- Innovation and proactive attitude

Innovation and proactive attitude
Balance between global mindset and respect of our history
Integrity and fairness
Passion and results orientation
Focus on people and respect of diversity
Innovation and proactive attitude
DE NORA AT A GLANCE

AMS
- Texas
- Pennsylvania
- California
- Ohio
- Brasil

EMEA
- Italy
- Germany
- UK
- Abu Dhabi
- India

APAC
- China
- Singapore
- Japan

355 Patent families
19 Locations
90+ Years of Innovation
€425m 2017 Revenues
1500+ People

36% Sales split
26% Electrode Technologies

4500+
152 m

4
111 m

4
600+
162 m

38% Sales split
38% Water Technologies
OUR COMMITMENT

Delivering innovative products and solutions to diversified industries to address customers’ needs.

ELECTRODE TECHNOLOGIES
electrochemistry at your service

- Chlorine & Caustic Soda
- Electronics
- Mining
- Cathodic protection
- Renewable energy storage
- Pools
- Surface finishing
- Pulp & Paper
- Cathodic protection
- Renewable energy storage
- Industrial water treatment

WATER TECHNOLOGIES
water made easy

- Municipal
- Oil & Gas
- Marine
- Energy
- Pulp & Paper
- Food Processing & Sanitising
FUTURE CHALLENGES

- Climate change
- Population growth
- Carbon footprint
- Resource scarcity

Strategic arenas

- Energy storage
- Mining
- Water treatment
- Energy savings and resource recovery
DE NORA UNIQUE EXPERTISE

Coating domain, cell design engineering, cell mechanical manufacturing

R&D labs: coating development

- 3 R&D facilities (Italy, US, Japan)
- +100 researcher involved
- 30 lab-scale membrane C/A cells
- several testing protocols

Cell design engineering

- Engineering services for tkUCE
- R&D projects
- Prototyping and field testing

Electrodes & Cell manufacturing

- Production, commercialization, technical assistance and services for dimensional stable electrodes with precious metal coatings
- New assembly, repair and re-activation of Chlor-Alkali Membrane cells
- Laser welding
- Robot TIG welding
- …
- …
ENERGY SAVING SOLUTION

Concerns both cells and electrodes!

Cell modification: Zero Gap retrofit

Activated electrodes: cathodes and anode

- NRG®, the ultimate cathode coatings family
- New generation of anode coatings
De Nora do Brasil is prepared to apply anodic and cathodic coating up to 35,000 m²/year of activated surface.

<table>
<thead>
<tr>
<th>Part of the building</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Activities</td>
<td>1800</td>
</tr>
<tr>
<td>Coating Activities</td>
<td>1700</td>
</tr>
<tr>
<td>Administration</td>
<td>900</td>
</tr>
<tr>
<td>Warehouse</td>
<td>300</td>
</tr>
<tr>
<td>Others</td>
<td>100</td>
</tr>
<tr>
<td>Total Area</td>
<td>45000</td>
</tr>
</tbody>
</table>

**ACTIVATION TYPES:**
- Anodic
- Cathodic
- Platinization

**EXPANSION PROJECT:**
ZERO GAP RETROFIT

Zero Gap totally removes the ionic ohmic drop related to the catholyte gap: a significant cell voltage reduction is obtained!

Zero Gap retrofit is obtained by installation of a package:

- The old cathode screen is used as current collector
- A fine activated cathode screen shifts up to gently touch the membrane
- In between them a durable elastic element is inserted
- Every component is designed to meet electrical, mechanical, fluid dynamic specifications
New installations – Zero Gap embedded in the most recent C/A cell technologies:
  - TKUCE (formerly UHDE/UHDENORA and CEC)
  - AKC / BLUESTAR

Existing installations (finite gap, narrow-gap or out-of-date zero-gap) - Zero Gap achievable by retrofit
  - ELTECH MGC
  - AK FC, NCS, NCH
  - AGC Azec / CEC CME (monopolar) and BiTAC (bipolar) / UHDE-UHDENORA BM2.7 *
  - INEOS BiChlor

Not all cells are equal → there is not an optimal Zero Gap retrofit solution equal for all cells → De Nora offers the Zero Gap solution tailored for each cell
DE NORA: A UNIQUE BLEND OF DIFFERENT EXPERTISE
RETROFIT EXAMPLE: MGC 30

- Easy Installation Concept

- No change on the element structure
Anode remeshing is like normal recoating procedure.

Original cathode mesh is maintained and used as current distribution. No need of coating.

Mattress is fixed on current distributor by resistant welding.

Possible to retrofit cathode package on site.

Flynet is installed on mattress. Welding is not used for Flynet.
RETROFIT EXAMPLE: MGC 30

- Compensates for Fatigue of Cathode Springs
- Flat Cathode Profile – No “Pinch” Points
- Improved IR Drop (Anode-Cu Voltage)
- Cathode “Recoating” done by replacing Flynet at Site
- Coatings for Polarized and Non-Polarized Cell Rooms
RETROFIT EXAMPLE: MGC 30

Manufacturing Process of MGC 30 Element
MGC 30 Membrane Electrolyzer
Customer 1
- 6.0 kA;
- 4.11 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 300 mV saving.

Customer 2
- 6.0 kA;
- 4.11 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 250 mV saving.

Customer 3
- 6.8 kA;
- 4.25 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 200 mV saving.
Bipolar Ion-Exchange Membrane Chlor-alkali electrolyzer

Cell module (or single element) vs filter press:
- Separated anode pan and cathode pan
- Pans have dimples to improve the cell-to-cell electrical contact and to minimize the current path through titanium

In theory, very narrow gap (cathode «spiders»).

In practice, exhausted cells have space for:
- superimposed activated anodic mesh (optional – on site revamping vs factory recoating)
- thin elastic elements and activated cathodic fine mesh (on site cold installation)

Once anodes and cathodes are upgraded, the standard assembly procedure of Cell Module is maintained:
- Cathode pan on the assembly table
- Gasket positioning
- Membrane positioning
- Gasket positioning
- Anode pan on the cathode
Peculiarity of retrofit of Cell Modules vs Filter Press technology:

- elastic element compression is directly linked to electrolyzer tightening force

CV reduction of ZG retrofit cells
(incl. new anode electrode, new membrane, cathodic ZG):

- up to 200-250 mV @ 3 kA/m²
- up to 250-300 mV @ 4 kA/m²

vs reconditioned elements
- up to 25-50 mV @ 3-4 kA/m²

**RETROFIT EXAMPLE: INEOS BICHLOR™**

ZG benefit (cathode-cathode cell voltage)
Cathodes:
- Full Zero Gap compensating for fatigue of exhausted Cathode Spiders
- Adoption of NRG® cathodic coating family
- Cathodic package On-Site Installation Option (cathodes never leave C/A plant)
- On-site training for elastic element and activated fine mesh installation
- Cathode “recoating” done by replacing activated fine mesh at Site

Anodes:
- recoating On-Site Installation Option (superimposed activated mesh)

Diagnostics and follow-up
NRG® CATHODE COATINGS
NRG®, THE ULTIMATE CATHODE COATINGS

NRG®, the ultimate De Nora cathode coating generation, is characterized by a series of “must have” that differentiate it from any other cathode coating available in the market:

- The lowest overpotential for hydrogen discharge (HOV)
- The longest stability of HOV during time
- The highest robustness against operational upsets
- Insensitiveness against catholyte pollutants
- Smooth surface to prevent abrasion effect on membrane
- Suitable for the application on all geometries

All coatings are proven on industrial basis:

- Noble Metals based
- Designed to be offsets resistant
- Long durability of performance
- High quality and industrial reproducibility / Multiple sites manufacturing
NRG®®, THE ULTIMATE CATHODE COATINGS

**Total Robustness**
- Ni-Oxide
- Ni-Raney
- NRG I, II
- NRG-V
- NRG-R

**Activity Index**
- **Low Activity**: HOV>120 mV
- **Medium Activity**: 90<HOV<120 mV
- **High Activity**: 70<HOV<90 mV
- **Very High Activity**: HOV<70 mV

**Robustness Index**
- **High Robustness**
- **Medium-Low Robustness**
- **Low Robustness**

**Area of Excellence**
- Old Galvanic type
- Commercial coating 1
- Commercial coating 2
WHAT IS A GOOD PERFORMING ANODE?

What is the criterion to define a “good performing” Anode?
It must satisfy the customer production needs

For Chlor-alkali anode coating, this basically means:
✓ High activity
✓ Good selectivity
✓ Long and predictable life
✓ Promptness

By thermodynamics, $O_2$ is favorite against $Cl_2$

The nature of DSA® anode plays a key role to promote $Cl_2$ evolution

Anode selectivity depends on different parameters: coating composition, morphology, architecture and manufacturing

The setup of parameters is always a trade-off among activity, selectivity, promptness, life and cost!
HISTORICAL COATINGS
DE NORA KNOW HOW

-0,7
-0,6
-0,5
-0,4
-0,3
-0,2
-0,1
0
0,1
0,2
0,3
0,4
0,5

O2/Cl2 Delta vs state of art (% start-up no acidification)

Voltage Delta vs state of art

-60 -50 -40 -30 -20 -10 0 10

Values refer to current density from 4 kA/m² to 7 kA/m²

- Low Chlorate
  Customer very sensitive to chlorate side production

- Normal Oxygen
  Chlorine and Brine quality within the industry standard

- Low Oxygen
  Customer sensitive to oxygen side production

- Very Low Oxygen
  Customer very sensitive to chlorine purity

Normal Oxygen
Chlorine and Brine quality within the industry standard

Low Oxygen
Customer sensitive to oxygen side production

Very Low Oxygen
Customer very sensitive to chlorine purity

Low Chlorate
Customer very sensitive to chlorate side production

Domestic Research - Your future

DE NORA

HISTORICAL COATINGS

11th TECHNICAL SEMINAR
WCC GST SAFETY WORKSHOP
TABLE TOP EXPO
November, 14-16, 2018
Monterrey, Mexico

JP202N
DN112
DN212
JP202R

COV < 30 mV
30 < COV < 40 mV
40 < COV < 60 mV
COV > 60 mV

Values refer to current density from 4 kA/m² to 7 kA/m²
HISTORICAL COATINGS FEATURES

- Production lines in the different production sites of DN group: Japan, Germany, USA, China, India, Brazil

- Years of proven performance in the field

- Widely used on all type of technologies and different substrates:
  - BM, BiTAC, AK, AGC, MGC…
  - expanded mesh, perforated plate…

- Low Chlorate family: JP202N, DN112
  - Low sub-production of chlorate

- Low Oxygen family: JP202R, DN212
  - Especially suitable for plants that require low oxygen level <1.00% at high efficiency without acidified brine
LATEST COATING
DE NORA FORERUNNER

O2/Cl2 Delta vs state of art (% start up-no acidification)

HISTORICAL COATINGS

- Low Chlorate
  Customer very sensitive to chlorate side production

- Normal Oxygen
  Chlorine and Brine quality within the industry standard

- Low Oxygen
  Customer sensitive to oxygen side production

- Very Low Oxygen
  Customer very sensitive to chlorine purity

- Very High Activity
  COV < 30 mV

- High Activity
  30 < COV < 40 mV

- Medium Activity
  40 < COV < 60 mV

- Low Activity
  COV > 60 mV

Values refer to current density from 4 kA/m² to 7 kA/m²

Voltage Delta vs state of art
Features

- Last added to DN portfolio:
  - Commercially available since few years with thousand of sqm already in operation after an intense qualification (lab scale to industrial size pilot).

- Latest coating feature:
  - Development work on new precursors: exploitation of chemical species different from the ones traditionally used within DN to achieve new morphology;
  - Good cell voltage in line with the best traditional De Nora coatings;
  - Normal oxygen in line with the traditional De Nora coatings in the whole range of efficiency range;
  - Fast break-in: promptness higher than traditional De Nora coatings.
Development of latest coating has opened the way for a new generation of anode coating to achieve further improvement.

Driver: maximize the value given to the customer achieving even more demanding features and creates a new coating family with modular performance depending on the single customer needs;

Promptness is the new key value that besides activity and selectivity characterizes the new generation.
NEXT COATING

Features

Normal Oxygen
Chlorine and Brine quality within the industry standard

Low Oxygen
Customer sensitive to oxygen side production

Very Low Oxygen
Customer very sensitive to chlorine purity

Low Chlorate
Customer very sensitive to chlorate side production

HISTORICAL COATINGS

NEXT COATINGS

DN190
Next Excellence

DN112

DN212

JP202R

NEXT COATING

Features

Values refer to current density from 4 kA/m² to 7 kA/m²
NEXT COATINGS

Features

Next Excellent coating
- Development made to achieve the excellence in performance in the low chlorate field.
- Selectivity feature improved
- Improved cell voltage respect to the best traditional De Nora coatings
- Fast break-in: promptness higher than traditional De Nora coatings

Next high edge coating: Flagship
- Superior coating, combining high voltage saving
- With excellent chlorine purity.
- Ideal for high current density operation
- Selectivity favored at high current density in the whole efficiency range
- To maintain the high level of performance the same polarization used for the cathode is necessary during the shutdown events
- Fast break-in

Both are available for industrial test
CONCLUSIONS
De Nora is unique:
- **world-wide presence** with coating factories and mechanical workshops
- De Nora **expertise** is a peculiar blend of coating domain, cell design engineering, cell mechanical manufacturing

De Nora energy saving solution deals with both cells and electrodes!

De Nora **Zero Gap retrofit**:  
- Great opportunity for Power Saving  
- Based on top-quality design, top-quality components, top-quality installation

De Nora **NRG® cathode coatings** are capable to secure reliable and durable power saving even at extreme operating conditions

A new generation of De Nora **anode coatings** is approaching, able to achieve even more demanding features with modular performances depending on the single customer needs
Thank you for your attention

Questions?