Next Generation Membrane
F-8080 & F-8080HD

January 2016
1. Concept of new Membranes
2. Feature of new Membranes
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
1. Concept of new membrane
2. Feature of new Membrane
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
Developments of Flemion

- low CV
- high stability of CV and CE
- high durability against impurities

Target is the Best Performance

F-8080 & F-8080HD

Duraiblity against “Dehydration”

1st Step

F-8000 Series

F-890 Series

2nd Step

F-8020 SP

3rd Step

New Generation C polymer

Differences F8020SP vs. F8020

Second Step

1. Lower water content of S-layer
   → Higher Mechanical Strength & Stability

2. Minor increase of Ion-exchange capacity of C-polymer
   → Reduced sensitivity to brine impurities:
   → Extended stability of CE and CV also at high current density operation

AGC confirmed these improvements are very effective in commercial plants, then moved to the next step.
Third Step --- Enhance the Feature of F-8020SP

1. Much lower water content of S-layer
   → Higher mechanical strength & stability

2. Further increase of Ion-exchange capacity of C-polymer
   → Reduced sensitivity to brine impurities:
      → Extended stability of CE and CV also at high current density operation

3. Improved uniformity of channels in C-polymer
## Line up of new Membranes

### Membrane Types F-808XXX / Features & Properties

<table>
<thead>
<tr>
<th>R&amp;D Development Name</th>
<th>Type</th>
<th>Current Density (kA/m²) (*)</th>
<th>Cl- in NaOH</th>
<th>Current Efficiency (initial, expected)</th>
<th>Voltage at same CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8080</td>
<td>S/P</td>
<td>7 &gt; medium</td>
<td>approx. 97%</td>
<td>lowest</td>
<td></td>
</tr>
<tr>
<td>F-8080HD</td>
<td>S/P</td>
<td>6 &gt; low</td>
<td>approx. 97%</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>F-8081</td>
<td>P</td>
<td>7 &gt; medium</td>
<td>approx. 97%</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>F-8081HD</td>
<td>P</td>
<td>5 &gt; low</td>
<td>approx. 97%</td>
<td>medium</td>
<td></td>
</tr>
</tbody>
</table>

S/P: Sacrificial Fiber & Permanent Fibers  
P: Permananet Fibers only (approx. 50% higher mechanical strength)  
(*) Depending on Electrolyzer Types and Operating Conditions
## Expected Performance Data of Flemion Membrane

<table>
<thead>
<tr>
<th></th>
<th>Current Efficiency (%)</th>
<th>Voltage Difference at 6 kA/m² (mV)</th>
<th>Resistance against Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8020</td>
<td>approx. 97%</td>
<td>0</td>
<td>medium</td>
</tr>
<tr>
<td>F-8020SP</td>
<td>approx. 97%</td>
<td>-30</td>
<td>high</td>
</tr>
<tr>
<td>F-8051</td>
<td>approx. 97%</td>
<td>0</td>
<td>high</td>
</tr>
<tr>
<td>F-8080</td>
<td>approx. 97%</td>
<td>-60</td>
<td>highest</td>
</tr>
<tr>
<td>F-8080HD</td>
<td>approx. 97%</td>
<td>-10</td>
<td>highest</td>
</tr>
</tbody>
</table>
1. Concept of new Membrane

2. Feature of new Membrane

3. Difference between F-8080 and F-8080HD

4. Performance Data

5. Summary

6. Line-up of new membranes
Features of Next Generation Membrane F-8080 series

Compared with F-8020SP, F8000 series

1. High Durability against Brine Impurity
   • Especially, resistance against Ca upset is much better

2. Lower Cell Voltage (F-8080) and Stability

3. Wider Operating Window

Uniform Channel by “Optimized C-polymer”
Conventional C-Polymer

Cross Section

Dehydrated by:
stronger brine, caustic, impurities or other operating conditions

Various size of ion channels

Relatively narrow channel will lose the function in strongly dehydrated state.
Optimized C-Polymer

F-8080 & F-8080HD

Cross Section

Due to uniform channel size, ion channels with uniform size do not lose function

Dehydrated by: stronger brine, caustic, impurities or other operating conditions

Ion Channel
F-8080 series keep good current efficiency over widest range of NaOH strength
CE Curves vs. Temperature

1.5dm² Lab. Cell, 4 kA/m², NaOH: 32%, NaCl: 200g/l

F-8080 series have the widest range.
Ca / Sr upset

0.25 dm² Lab. Cell, 6 kA/m², 85 deg-C, NaOH : 33 %, NaCl : 230 g/l

F-8080 series have the highest durability against Ca/Sr-upset
I / Ba Addition

0.25 dm² Lab. Cell, 6 kA/m², 80 deg-C, NaOH : 32%, NaCl : 190g/l

⇒ I/Ba=20/1 ppm continuous addition

F-8080 have the highest durability against I/Ba
Cell Voltage Stability (I / Sr addition)

1.5 dm² Lab. Cell, 6 kA/m², 90 deg-C, NaOH : 32 %, NaCl: 200 g/l

F-8080 series have the most stable C.V.

F-8080 series have the most stable C.V.
1. Concept of new Membrane
2. Feature of new Membrane
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
Frequent Load Tensile Test

Repetition of Test until Membrane Rupture (Sum of the value to Various Direction)

- F-8020SP
- F-8080
- F-8080HD

F-8080HD is twice as robust for frequent load as F-8080
Cl₂ gas stagnation on anode side and high caustic strength on cathode side. In this condition, membrane will have salt crystals.
Test for Deterioration by Cl\textsubscript{2} Stagnation

- F-8080 has same durability for Cl\textsubscript{2} gas stagnation with very low voltage.
- F-8080HD has much higher durability for Cl\textsubscript{2} gas stagnation with lower voltage.
Low NaCl in NaOH at Low C.D. and High Temp.

AZEC-M3 Pilot Cell, 2kA/m², 32% NaOH

F-8080HD has lower NaCl in NaOH.
1. Concept of new Membrane
2. Feature of new Membrane
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
Commercial Size Pilot Cell

4-7kA/m², 83~88°C NaOH:32%, NaCl:190~200g/l

F-8080 has the lowest Cell Voltage!
And Good Efficiency at Current Density 4-7 kA/m²

Voltage Comparison

<table>
<thead>
<tr>
<th>Membrane</th>
<th>Cell Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8020</td>
<td>+30~+60mV</td>
</tr>
<tr>
<td>F-8020SP</td>
<td>0</td>
</tr>
<tr>
<td><strong>F-8080</strong></td>
<td><strong>- 30mV</strong></td>
</tr>
</tbody>
</table>

6kA/m², 90°C, NaOH:32% corrected voltage
## F-8080 Evaluation in Commercial Cell

( at Customers & AGC Plants )

<table>
<thead>
<tr>
<th>Plant</th>
<th>CV against F-8020 (mV)</th>
<th>CV against F-8020SP (mV)</th>
<th>CE (%)</th>
<th>Current Density (kA/m²)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant-A</td>
<td>-50</td>
<td>-25</td>
<td></td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Plant-B</td>
<td>-30</td>
<td>(97%)*</td>
<td></td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Plant-C</td>
<td>-70</td>
<td>-25</td>
<td>96.5% &lt;</td>
<td>4.2</td>
<td>less CV increase</td>
</tr>
<tr>
<td>Plant-D</td>
<td>-25</td>
<td></td>
<td></td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Plant-E</td>
<td>-50</td>
<td>97% &lt;</td>
<td></td>
<td>6&lt;</td>
<td>Lowest voltage</td>
</tr>
<tr>
<td>Plant-F</td>
<td>-50</td>
<td></td>
<td>96%</td>
<td>4.5</td>
<td>Lowest voltage</td>
</tr>
<tr>
<td>Plant-G</td>
<td>-60</td>
<td>-30</td>
<td>97.5% &lt;</td>
<td>3</td>
<td>* Test Cell</td>
</tr>
<tr>
<td>Plant-H</td>
<td>-50</td>
<td></td>
<td></td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>

voltage: at 32%NaOH, 90°C
- F-8080 shows most stable voltage more than three years operation.
• F-8080 shows 96% current efficiency more than three years.
1. Concept of new Membrane
2. Feature of new Membrane
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
1. High Durability against Brine Impurity
   • Especially, resistance against Ca upset is much better

2. Lower Cell Voltage and Stability
   • 30 mV lower than F-8020SP for F-8080

3. Wider Operating Window
Contents

1. Concept of new Membrane
2. Feature of new Membrane
3. Difference between F-8080 and F-8080HD
4. Performance Data
5. Summary
6. Line-up of new membranes
## Line up of new Membranes

### Membrane Types F–808XXX / Features & Properties

<table>
<thead>
<tr>
<th>R&amp;D Development Name</th>
<th>Type</th>
<th>Current Density (kA/m²) (*)</th>
<th>Cl- in NaOH</th>
<th>Current Efficiency (initial, expected)</th>
<th>Voltage at same CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8080</td>
<td>S/P</td>
<td>7 &gt; medium</td>
<td>approx. 97%</td>
<td>lowest</td>
<td></td>
</tr>
<tr>
<td>F-8080HD</td>
<td>S/P</td>
<td>6 &gt; low</td>
<td>approx. 97%</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>F-8081</td>
<td>P</td>
<td>7 &gt; medium</td>
<td>approx. 97%</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>F-8081HD</td>
<td>P</td>
<td>6 &gt; low</td>
<td>approx. 97%</td>
<td>medium</td>
<td></td>
</tr>
</tbody>
</table>

**S/P:** Sacrificial Fiber & Permanent Fibers

**P:** Permanent Fibers only (approx. 50% higher mechanical strength)

(*) Depending on Electrolyzer Types and Operating Conditions
Thank you