초청강연

Chemical Free Ultra Pure Water Production

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1. Introduction

UPW (Ultra Pure Water) is an indispensable for Microelectronics and other industries. It is very important to be stable and reliable for UPW production. The Chemical Free UPW production system which I would like to introduce hereunder consists of;

1) Pretreatment
2) Double Pass RO with Interstage Caustic Injection
3) Continuous Electro-Deionization
4) Final Polishing

and Nos. 2) and 3) are key technologies for this system.

Benefits of this system are;

- Increased System Reliability
- Reduced Risk Exposure
- Lower Operating Cost

2. Double Pass RO with Interstage Caustic Injection vs. Conventional Double Pass RO

2.1 Conventional System

Figure 1 shows Conventional Double Pass RO.

- TOC Reduction in the Make-up System is as follows;
    - 2000 ppb in feed
    - 200 ppb after 1st Pass RO with 90% Rejection
    - 30 ppb after 2nd Pass RO with 85% Rejection
- Silica Reduction
- TDS Reduction
- High frequency of MB (Mixed Bed) regeneration
    - CO_2 load on MB (25ppm CO_2 in RO = 25 ppm out)
    - TDS
    - Silica

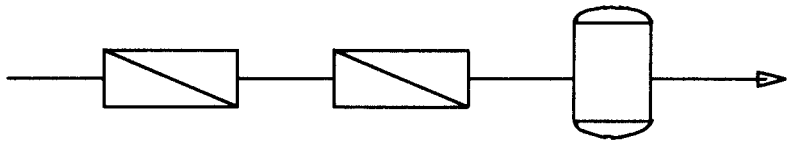

Figure 1 **Conventional Double Pass RO**

2.2 Double Pass RO with Caustic Injection

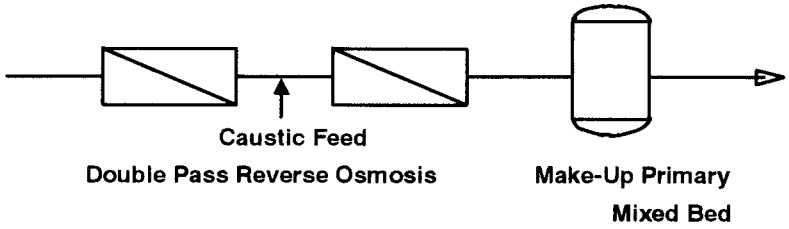

Figure 2-1 **Double Pass RO with Caustic Injection**

- Rejection of Ions and TOC
  - CO_2 converted to HCO_3 to provide greater CO_2 removal
  - Silica converted from silicic acid to a silicate
- Extended MB run length
- Minimal use of caustic between passes
- Reduced bio growth on 2nd pass RO's

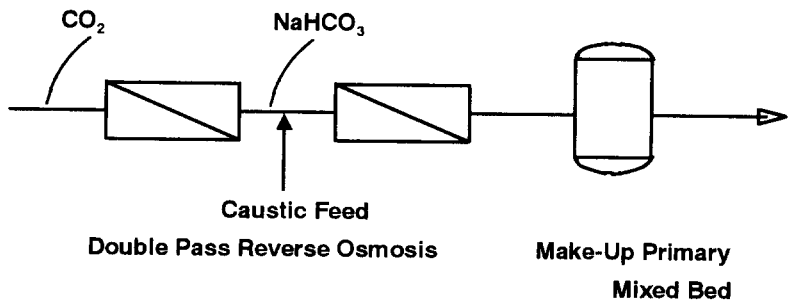

Figure 2-2 Double Pass RO with Caustic Injection

- CO_2 Removal
  - CO_2 will pass through an RO membrane
  - CO_2 drops to - zero at a pH - 8.3

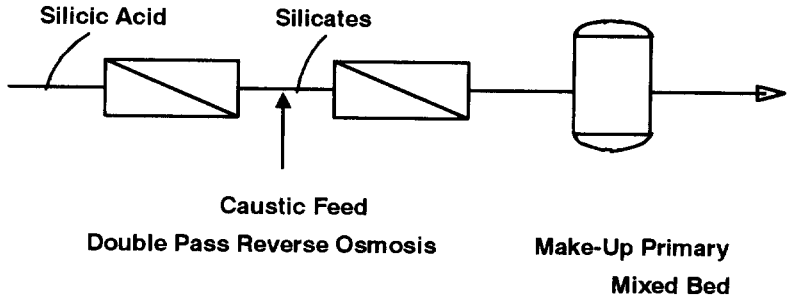

Figure 2-3 Double Pass RO with Caustic Injection

- Silica Removal
  - Silicates rejected better than Silicic Acid

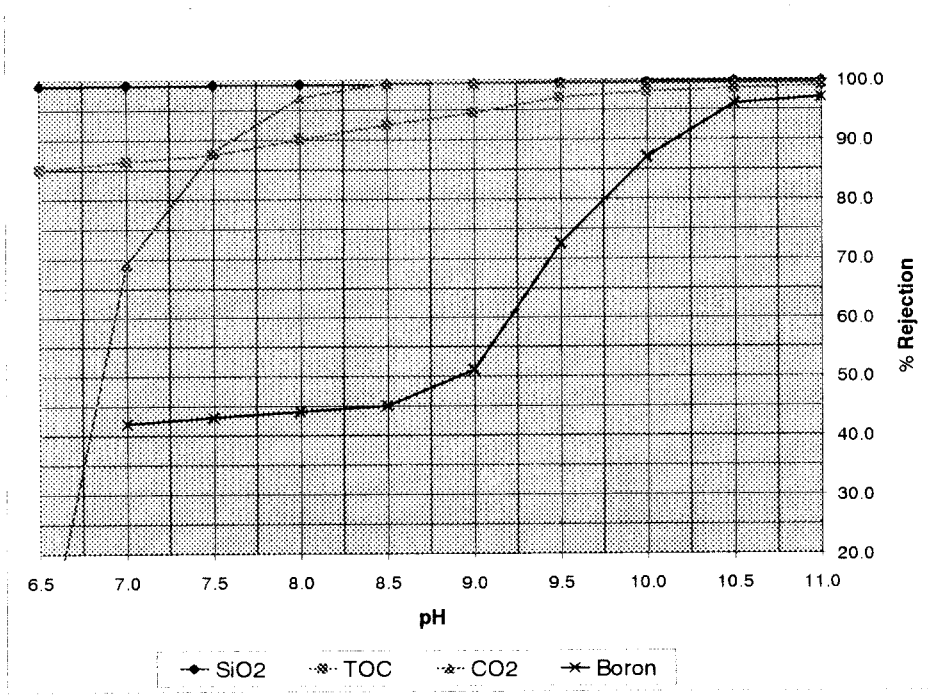

Figure 3 Rejection Curves of Double Pass RO vs. PH

2.3 Summary

- Greater rejection of ions and TOC
  - CO2 converted to HCO3 to provide greater CO2 removal
  - Sillica converted from silicic acid to a silicate

- Extended MB run length
  - Fewer regeneration
  - Less chemical handling
  - Operating cost savings

- Minimal use of caustic between passes
- Reduced bio growth on 2nd pass RO's
- Consistent and improved water quality

3. Continuous Electro-Deionization (CEDI)

CEDI technology is a continuous process for producing high-purity water without the problems and costs associated with regeneration chemicals and waste neutralization. It is used to further deionize RO product water and remove carbon dioxide, silica and total organic carbon (TOC).

CEDI Systems use ion exchange membranes, ion exchange resins and electricity to produce consistent high-quality water with no regeneration downtime. When fed with RO product water, CEDI Systems achieve better than 99.5% salt removal and produce up to 18Ohm-cm (0.055 micromho/cm) resistivity quality water.

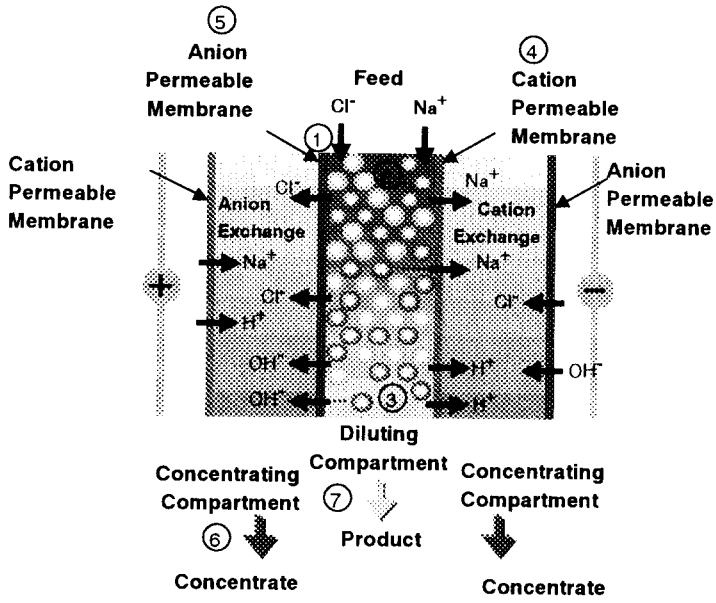

Figure 4 How Continuous Electro-Deionization Works

① Feed water entering the system flows inside resin/membrane compartments. The feed stream flows parallel to the membrane surface.

② Resins capture dissolved ions.

③ Electric potential drives captured cations through cation membranes and captured anions through anion membranes.

④ Caption-permeable membranes transport cations out of the concentrating compartment, but prevent anions from leaving the diluting compartment.

⑤ Anion-permeable membranes transport anions out of concentrating compartment, but prevent cations from leaving diluting compartment.

⑥ Waste stream flushes concentrated ions from system.

⑦ Product water leaves system.

- CEDI Systems must be fed with RO product water shown as Table 1.

Temperature	10-35°C
Min. Pressure	1.38 bar
Max. Pressure	4.14 bar at 35°C
Max. Total Chlorine	<0.02 ppm
Iron	<0.01 ppm
Manganese	<0.01 ppm
Sulfide	<0.01 ppm
Silt Density Index (SDI_{15})	<4
pH	4 - 10
Particle Prefiltration (RO feed)	No filtration required
Max. Total Hardness with RO feed is typically:	80% recovery: <5.0 ppm 90% recovery: <1.0 ppm 95% recovery: <0.5 ppm

Table 1 Feed Water Specifications

- Figure 5 shows an example of product water quality by CEDI.

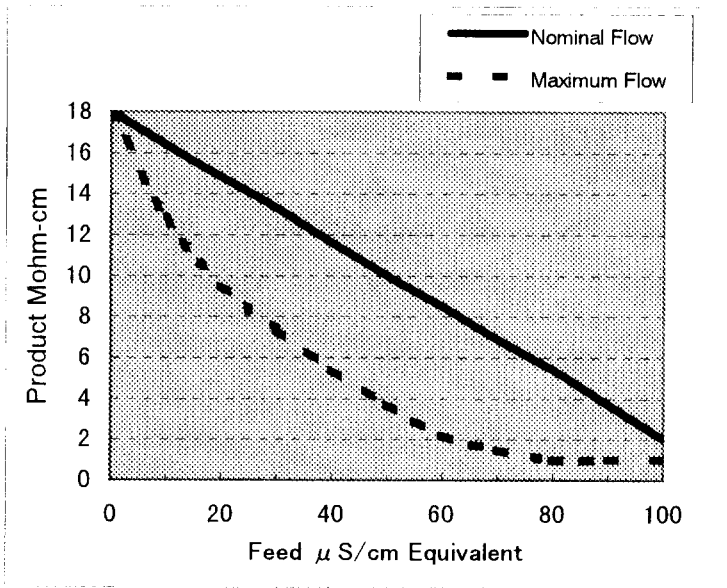

Figure 5 CEDI H-Series System Performance

- CEDI Modules (Figure 6-1 and 6-2)
  The reject stream is recirculated with a centrifugal pump for high recovery typically 90-95%.

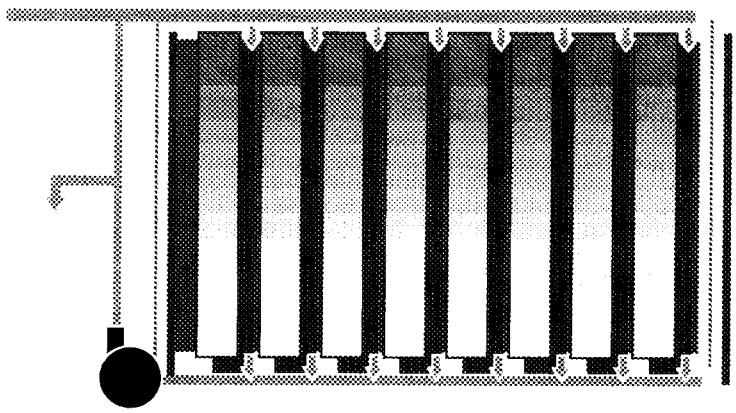

Figure 6-1 CEDI Module

More compartments are added between Electrodes to increase flow Capacity shown as Figure 6-2.

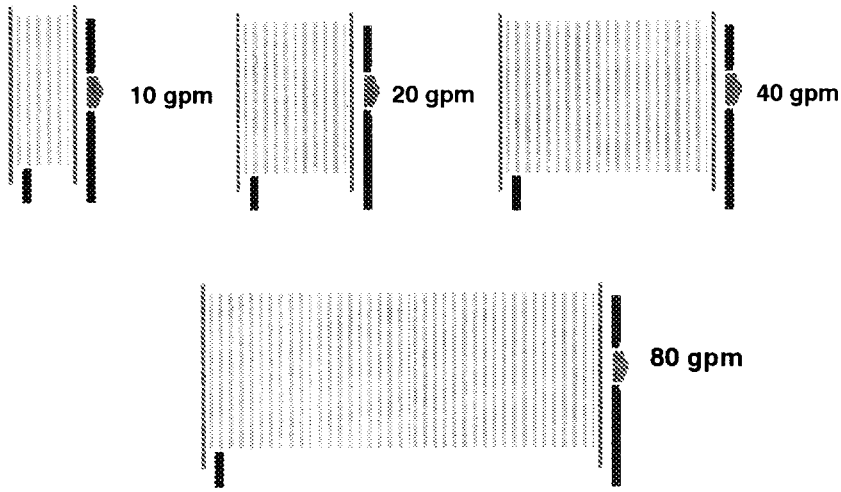

Figure 6-2 CEDI Compartments

- Performances
  - Over 1200 CEDI installations worldwide
  - Over 200 electronics installations worldwide

- Summary
  - Membrane, resin & electricity
  - Continuous regeneration without chemicals
  - No waste neutralization required

4. Chemical Free UPW Production Examples

- General FAB Requirements
  - For 0.25 - 0.18 micron geometries
  - For 20,000 Wafer starts per month, 300 mm
  - 250.0 m3/h usage
  - 18.2 Meg-Ohm resistance
  - <1 ppb TOC
  - <0.5 ppb Silica

- Feed Water Analysis (Typical)
  - * pH 7.5
  - * Turbidity 2.5 NTU
  - * Temperature 15 Deg. C
  - * Alkalinity (as CaCO3) 22 mg/l
  - * Total Hardness (as CaCO3) 47 mg/l
  - * Sulfate 27.7 mg/l
  - * Chloride 3.9 mg/l
  - * Silica 0.5 mg/l
  - * TDS 90 mg/l
  - * Total Iron 0.13 mg/l
  - * TOC 2.5 mg/l

- Final Water Quality
  - * Resistivity 18.2 MegOhm
  - * TOC less than 1.0 ug/l
  - * Particles - counts/liter > 0.05μ less than 300
  - * Particles - counts/liter >0.10μ less than 100
  - * Dissolved Oxygen 1.0 ug/l
  - * Bacteria/100 ml by Culture less than 1.0 CFU/liter
  - * Reactive Silica 0.5 ug/l

- Operation Cycle for CEDI shows stable and reliable water quality as shown in Figure 7.

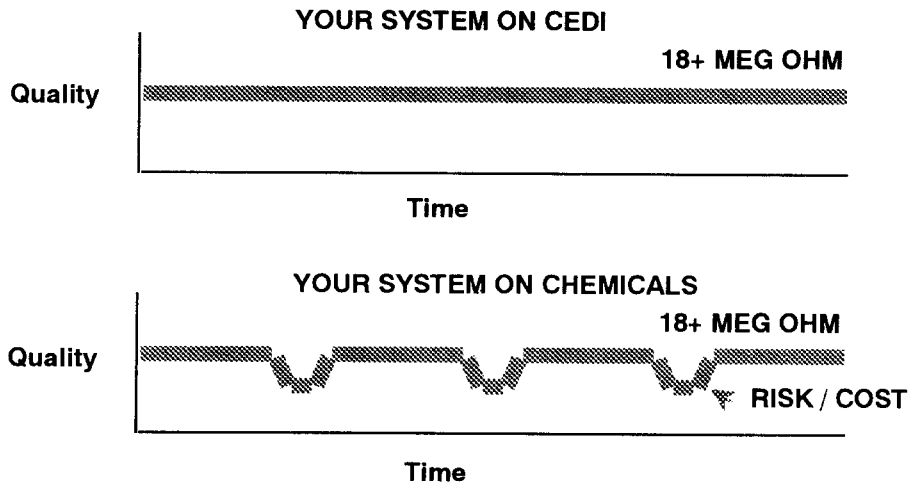

Figure 7 UPW OPERATING CYCLE

5. Cost Comparison

- Capital Cost Comparison
  Chemical Free vs. Conventional System
  * Conventional Make-up US$ 9,525,000
  * Chemical Free Make-up US$ 9,706,000

  Difference = US$ 181,000 (less than 2% of total system cost)

- Operating Cost Comparison
  * Conventional Make-up US$ 65,672/month
  * Chemical Free Make-up US$ 53,906/month

  Difference = US$ 11,766/month (in favour of Chemical Free)

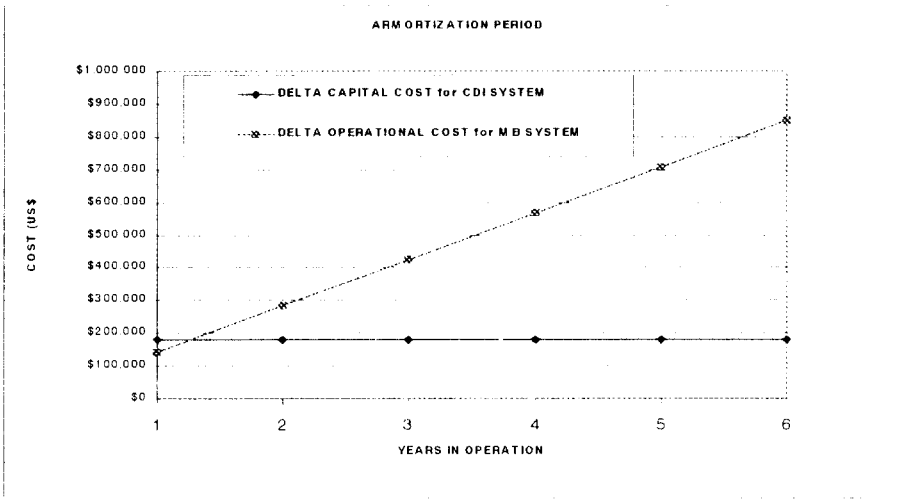

Figure 8 CAPITAL vs. OPERATING COST 1200 GPM/272 M3/HR UPW SYSTEM

6. Advantages

- Design Advantages
  - Competitive capital costs
  - Lower operating costs
  - Lower maintenance costs
  - No chemicals down stream of the RO make-up system
  - Minimal wastewater produced
  - Less space needed
  - Readily available, field proven technology
  - No bulk chemical storage or handling
  - No on-site resin regeneration
  - Reduced Manpower & consumable costs
  - Reduced risk of system contamination
  - Reduced risk of system failure
  - Improved operating safety