**The Four Membrane Processes**

Reverse Osmosis (RO) is the tightest possible membrane process in liquid/liquid separation. Water is in principle the only material passing through the membrane; essentially all dissolved and suspended material is rejected. The more open types of RO membranes are sometimes confused with nanofiltration (NF).

True NF rejects only ions with more than one negative charge, such as sulfate or phosphate, while passing single charged ions. NF also rejects uncharged, dissolved materials and positively charged ions according to the size and shape of the molecule in question. Finally, the rejection of sodium chloride with NF varies from 0-50 percent depending on the feed concentration. In contrast, “loose RO” is an RO membrane with reduced salt rejection.

This effect has proven desirable for a number of applications where moderate salt removal is acceptable since operating pressures and power consumption are significantly lowered. So, in exchange for less than complete salt removal, costs are reduced.

Ultrafiltration (UF) is a process where the HMWC, such as protein, and suspended solids are rejected, while all LMWC pass through the membrane freely. There is consequently no rejection of mono- and di-saccharides, salts, amino acids, organics, inorganic acids or sodium hydroxide.

Microfiltration (MF) is a process where ideally only suspended solids are rejected, while even proteins pass the membrane freely. There is, however, quite a gap between real life and this ideal situation.

**Membrane Materials**

The selection of membranes offered by the various suppliers in the business may appear to be confusing since many materials may be used to make membranes, and they are provided under an array of trade names. In reality, relatively few materials are actually used in quantity, and only a few basic membrane types form the bulk of the membranes being sold and used.

**Integral Membranes**

Cellulose acetate (CA) is the “original” membrane and is used for RO, NF and UF applications. The material has a number of limitations, mostly with respect to pH and temperature. The main advantage of CA is its low price, and the fact that it is hydrophilic, which makes it less prone to fouling. There are many “die hard” membrane users who insist on buying “the same membrane as last time,” and who simply stay with CA because it works for them. An inherent weakness of CA is that it is can be eaten by microorganisms.

Polysulfone (PSO) in a number of varieties has been used for UF and MF membrane since 1975. PSO’s main advantage is its exceptional temperature and pH resistance. PSO is practically the only membrane material used in high quantity for a number of food and dairy applications. As a rule, PSO membranes do not tolerate oil, grease, fat and polar solvents. However, there is one type of hydrophilic PSO membrane which apparently defies this rule and seems to work well with oil emulsions.

Polyvinylidenedifluoride (PVDF) is a traditional membrane material, but it is not used much because it is difficult to make membranes with good and consistent separation characteristics. Its main advantage is its high resistance to hydrocarbons and oxidizing environments.
**Composite Membranes**

Also called thin-film composite membranes, they appear under various acronyms such as TFC and TFM, and were made to replace cellulose acetate RO membranes. The main advantage is the combination of relatively high flux and very high salt rejection, 99.5% NaCl rejection commonly achieved with composite RO membranes. They also have good temperature and pH resistance, but do not tolerate oxidizing environments. Composite membranes are made in two-layer and three-layer designs, the precise composition of which is proprietary. Generally speaking, a thin-film composite membrane consists of a PSO membrane as support for the very thin skin layer which is polymerized in situ on the PSO UF membrane. The three layer design has two thin film membranes on top of the PSO support membrane.

**Membrane Structure**

Literally all RO, NF and UF membranes are asymmetric. This differentiates most membranes from common filters, e.g. coffee filters, which are symmetric or, in other words, are identical on both sides of the filter. Membranes have a tight top layer facing the product to be treated. This layer is also called the skin layer. It is thin, typically <$0.1 micron. The membrane itself is 150 - 250 micron, the bulk of the membrane simply providing structural support for the skin layer. The asymmetric structure means that the pores are wider and farther away from the surface, which prevents the pores from being plugged. This provides good fouling resistance, since foulants have a tendency to either be totally rejected or to pass all the way through a membrane.

**Membrane Module**

The spiral wound element type is the workhorse in the membrane world. The spiral wound element design was originally made exclusively for water desalination, but the very compact design and the low price made it attractive to other industries. After a lot of trial and failure, redesigned elements emerged which can be used for a variety of industrial applications in the dairy industry, the pulp and paper industry, for high purity water, and at high temperature and extreme pH, but the number of membrane companies who really can and will develop and supply spiral wound elements for extreme applications is in many cases limited to one.
Systems Overview

Reverse Osmosis
Nano-Filtration
Ultra-Filtration
Replacement Membranes
Packaged Systems
“E” stands for Excellence

GE Water & Process Technologies has come a long way from pioneering RO technology back in 1969. GE is now leading the commercialization of RO technology to ensure faster delivery rates, ease of operation and straightforward controls.

Today, the E-Series line represents excellence in standard industry RO machines. When purchasing an E-Series, you get the time-saving simplicity and service to make selection, delivery and installation, as easy as shopping in your local appliance store. Unmatched product and technical support is available 24 hours a day. And since GE manufactures all the critical components and integrates them into the E-Series line, you save money.

For years, loyal GE customers have associated the E-Series name with quality, durability and simplicity. But it’s time for us to set the record straight. The “E” in our E-Series name actually stands for many things.

E8

Like all of our standard RO machines, the E8 RO (Figure 1) comes completely assembled, ready for use. E8 models are available in configurations ranging from 57,000 to 144,000 gpd (9 to 23 m³/hr). All machines come standard with a Tonkaflo® multi-stage centrifugal and packed with Desal® membrane elements. The smart controls keep it simple and operate the entire system. Plus, our E8 ROs are priced for the budget-conscious consumer.

More features that make the E8 your best choice:

- Appliance-like selection. Complete systems delivered skid-mounted, ready to use.
- No assembly; plug-and-play simplicity.
- Easy to order.
- Just one part number per machine.
- Complete factory support for any and all inquiries.

Sample of Ideal Applications:

- Boiler feedwater
- Safe drinking water
- Process ingredient water
- Ion exchange pre-treatment

“E” is for Endurance

Precise engineering results in machines that are efficient and dependable for years of worry-free use. And now, it’s all packaged in a cost-effective machine for a variety of RO uses. It’s called the E4.

E4 and E4H

The E4 and E4H RO machines (Figures 2 and 3) are constructed with the same advanced technology GE has been building on for years and backed by the same expertise that goes into our high-end medical market and large industrial.

Many E4 and E4H models are available in configurations ranging from 1,800 to 43,200 gpd (0.3 to 6.8 m³/hr). Features include:

- Pre-engineered standard configurations.
- All models available in economy (ECN) and deluxe (DLX) packages to suit virtually any RO need. ECN models include instrumentation packages that are considered “extras” on competitors’ equipment.
- All models utilize multi-stage centrifugal pumps.
- Variable concentrate and recycle flow control valves provide system flexibility.
Vertical frame design of E4 provides high-volume output with a small installation footprint.

Sample of Ideal Applications
- Car Wash
- Whole home or office RO
- Product dilution or mixing
- Spot free product rinses
- Restaurant/Grocery

Figure 2: E4

Figure 3: E4H

“E” is for Economic

Our E-Series machines are designed to offer customers a competitive, but high quality RO system that offers more value than the competition, and still fits in your budget. The E2 is a perfect example. (Figure 4)

E2

The E2 is simply a cost-effective RO machine for a variety of uses. Variable concentrate and recycle flow control valves give performance flexibility. The tremendous water savings also reduces the cost of operation.

The E2 is available in configurations ranging from 375 to 2,535 gpd (0.06 to 0.33 m³/hr), making it ideal for applications such as whole home RO, metal plating, car wash, restaurant, greenhouse watering, grocery stores and much more. Features include:

- All models available in economy (ECN) and deluxe (DLX) packages to meet any budget and operational requirement. ECN models include instrumentation packages that are considered “extras” on competitors’ equipment.
- Small compact design provides high-quality, high-volume output
- Smart packaging ensures major components are easily accessible
- Sample of Ideal Applications
  - Greenhouse watering
  - Car Wash
  - Grocery stores

Figure 4: E2

“E” is for Ease

E-series machines have been designed with the owner in mind. We have over 30 years of experience, which help us choose the proper controls, instruments and alarms for optimum operation and worry-free control. While engineering our E-Series line, we also kept the installation requirement in mind and worked to keep the systems compact for initial installation and minimization of floor space (a precious commodity in any plant.)

EZ Kits

With flow rates ranging from 375 to 10,800 gallons per day, GE offers EZ Kits (Figure 5), quality RO kits in a pre-engineered package that comes ready-to-
assemble with the help, guidance and expertise of a qualified water conditioning professional. All kits are packaged for shipment by ground, air, or ocean freight.

Figure 5: EZ Kit

EZ Kit features include:

- Simple, adjustable flow controls, providing you with the versatility to make easy adjustments.
- Quiet centrifugal pumps minimize noise in larger RO units.
- High-quality construction features stainless steel membrane housings ensures years of dependable performance.
- Expandable design lets you enlarge your basic unit by adding more GE membrane elements and, in some cases, a larger pump.
- Space-saving configuration keeps all components within the supporting frame for compact installations.
- Optional electrical and upgrade from economy to deluxe design.

EZ-2 Kits are available with flow rates ranging from 375 to 2535 gpd (58 to 400 Lph), utilize 2.5 inch diameter GE membranes(s) and GE housing(s).

EZ-4 Kits are available with flow rates ranging from 1500 to 10,800 gpd (236 to 1700 Lph), utilize a 4.0-inch diameter Desal membranes(s) and GE housing(s).

Additional features include Hytrex* sediment filtration, fully adjustable flow controls, and GE's exclusive, efficient water saving design. Available options include automatic ON/OFF controllers and pump upgrades, along with flow meter and low inlet pressure switch kits.
E4 Series 60 Hz
Reverse Osmosis Machine 2,200 to 13,200 gallons per day

When you mention reverse osmosis (RO), GE Water & Process Technologies is the first name to come to mind. Our E-series RO machines (Figure 1) are designed for durable operation, high quality product water production, easy installation and straightforward control.

General Properties

Typical Applications
- Process ingredient water
- Rinse water
- Food ingredient water

- Safe drinking water
- Boiler feed water
- Ion exchange pre-treatment

Standard Economy Features (ECN)
- 1-micron pre-filter
- Automatic inlet shut-off valve
- Permeate and Concentrate flow meters
- Remote machine on/off capability
- Thermal Motor Protection
- Pre-filter, post-filter, primary, and final pressure gauges
- Flow control center including concentrate and recycle valves

Deluxe (DLX) Features – in addition to ECN features
- Autoflush system
- Low inlet pressure switch
- Digital conductivity meter with programmable relay
- Alarms: Low Inlet Pressure, Motor Starter overload

Table 1: Operating Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Pressure</td>
<td>220 psig (15 bar)</td>
</tr>
<tr>
<td>Maximum Recovery</td>
<td>75%</td>
</tr>
<tr>
<td>Nominal Rejection</td>
<td>95-98%</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>55-85 °F (13-30 °C)</td>
</tr>
<tr>
<td>Minimum Inlet Pressure</td>
<td>30 psig (2 bar)</td>
</tr>
<tr>
<td>Design Temperature</td>
<td>77 °F (25 °C)</td>
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</tbody>
</table>
When you mention reverse osmosis (RO), GE Water & Process Technologies is the first name to come to mind. Our E-series RO machines (Figure 1) are designed for durable operation, high quality product water production, easy installation and straightforward control.

**General Properties**

**Typical Applications**
- Process ingredient water
- Safe drinking water
- Boiler feed water
- Ion exchange pre-treatment

**Standard Economy Features**
- 5-micron pre-filter and housing, 20" (50.80 cm)
- Automatic inlet shutoff valve
- Motor thermal protection
- Pre/Post-filter and primary/final pressure gauges
- Permeate and concentrate flow rotameters
- Permeate conductivity meter
- ALARMS: Low inlet pressure, high amp draw
- Feed water flush on shut down

**Deluxe (DLX) Features – In addition to ECN Features**
- Accutrak RO microprocessor controller
- SD card for collection of operating data
- Permeate and concentrate paddlewheel flow sensors
- Inlet pH sensor
- Permeate tank level monitoring
- Chemical dosing pump for antiscalant dosing or pH adjustment
- Clean in Place (CIP) system, 5 HP (3.7 KW)
- ALARMS: Low inlet pressure, high concentrate and permeate pressure, high temperature, high permeate conductivity, high/low pH, motor fault, and fill-time exceeded

**Table 1: Operating Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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General Properties

Typical Applications
- Process ingredient water
- Safe drinking water
- Boiler feed water
- Ion exchange pre-treatment

Standard Economy Features
- Energy saving 400 ft² (37.2 m²) membrane elements
- SS high-pressure piping
- 1-micron pre-filter and SS housing
- Automatic inlet shut-off valve
- PLC control

- Lakewood Instruments* 2450 controller
  - Digital permeate and concentrate flow meters
  - Digital conductivity meter
  - Modern Monitoring
- ALARMS: Low inlet pressure, starter overload trip, high temperature [105°F (41°C)], high permeate conductivity
- Remote machine on/off capability
- Autoflush system
- Pre-filter, post-filter, primary, and final pressure gauges

Deluxe (DLX) Features – in addition to ECN features
- Digital pH controller system
- Chemical dosing pump for pH adjustment
- Permeate purge
- Permeate purge disable capabilities
- ALARMS: High permeate pressure, high/low pH
- Clean-In-Place pump plumbed, wired and mounted; remote tank

<table>
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<tr>
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</tr>
</tbody>
</table>
PRO E-Cell* EU Series
Integrated RO/EDI Machines 10 to 23 m³/h 50 Hz

Features
- RO and EDI systems on common skid
- 2 pass RO with interpass caustic injection
- RO Pump VFDs and EDI Power control/DC Drive mounted on skid
- RO permeate flush sequence on shutdown and divert to drain on startup
- Siemens control system with Simatic PLC and HMI interface
- CE certified

Instrumentation
- Flow Meters: RO Permeates, RO Concentrates
- EDI Product, EDI Concentrate, EDI Electrode
- Pressure Gauge: Pre & Post Cartridge Filter
- Primary, Final, Interstage, RO Permeate, RO Concentrate, RO Pump Discharge, EDI Feed, EDI Product, EDI concentrate, EDI Electrode, EDI Dilute Feed
- Pressure Switch: RO Feeds, RO2 Permeate
- RO Concentrates
- Pressure Transmitter: RO Primary, RO Final
- RO Permeate, EDI Feed, EDI Product, EDI Concentrate, EDI Electrode, EDI Dilute Feed
- Conductivity/Temperature: RO Feed, RO1 Permeate, EDI Product (resistivity)
- pH Meter: RO Feed (both passes)
- ORP: RO Feed pass1

Options
- HART protocol instruments

Accessories
- PRO E-CELL EU Clean-in-Place unit
- PRO Multi-Media filters
- PRO Activated Carbon and Softeners
- PRO Chemical Feed Systems
- Transfer Pumps and Storage Tanks

Operating Parameters
- Design Recovery RO: 75% Pass 1; 85% Pass 2
- Design Recovery EDI: 90-95%
- Design Temperature: 15°C
- Operating Temperature Range: 5-29°C
- System Inlet Pressure: 2-4 Bar

Materials of Construction
- High-pressure piping: 1.4404 Stainless Steel
- Low-pressure RO & EDI piping: DIN PVC-U
- EDI dilute piping: DIN Standard Polypropylene
- Frame: Epoxy-coated carbon steel
- Enclosure: IP54
- Fasteners/Victaulic: Zinc-plated

Membrane Elements and Housings
- Membrane elements: GE AK-400
- Average membrane flux: 22lmh pass 1
- 33lmh pass 2
- Membrane rejection: 99.0 to 99.5%
- Housing material: Fiberglass
- Housing Pressure Rating: 31 bar

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MUNI Series 60 Hz
Reverse Osmosis & Nanofiltration Machines
50 gpm to 1 mgd (11.4 to 102.2 m³/hr)

Features
- GE Fanuc Quickpanel, 12.0-inch color display, text and pictorial operating screens, touchscreen controls
- GE Fanuc Versamax, communication: Ethernet
- 4-20 mA instruments on QuickPanel
- Primary and final pressure transmitters
- UL 508 listed

Instrumentation
Flow Meters..............................Permeate, concentrate
Conductivity.................................Feed, Permeate
pH ..........................................................Feed
Pressure Gauges.........................Pre-filter, post-filter, pump discharge, primary, interstage, final concentrate, permeate
Pressure Transmitters...............Pump discharge, primary, interstage, final concentrate, permeate
Pressure Switch............................Low feed, High permeate, concentrate
ORP ..........................................................Feed
Instrument Center........................Thorton 770 Max

Options Available
- Allen-Bradley Control Package
- Soft Starters
- Variable Frequency Drives
- SCADA: 75pt trending package with desktop PC
- Electric-actuated operating valves
- MUNI Multi-Media filters
- MUNI Clean-in-Place units
- MUNI chemical feed systems
- Transfer pumps and storage tanks

Documentation Included
- Operation and maintenance manual
- Drawings: piping and instrumentation, electrical and general dimensional

Operating Parameters
Typical feedwater recovery rate...............75-85%
Design temp........................................60ºF (15.6ºC)
Typical operating range ...........35 to 85ºF (1.6 to 29.4ºC)
Nominal membrane rejection % ......Membrane Specific
Minimal inlet pressure .........................30 psi

Materials of Construction
High-pressure piping............316 Stainless Steel, Sch. 10
Low-pressure piping.....................Sch. 80, PVC
Frame ........................................................Painted blue carbon steel
Enclosure .................................................NEMA 12 (painted blue)
Clamps/fittings.................................Zinc-plated

Membrane Elements & Housings
Membrane Model..................MUNI–LERO, RO, or NF
Style..................................................Spiral-wound elements
Manufacturer........................................GE
# ZeeWeed* 1500 Module

Hollow-Fiber Ultrafiltration Technology

## Module Dimensions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>1920 mm (75&quot;)</td>
</tr>
<tr>
<td>Diameter</td>
<td>180 mm (7&quot;)</td>
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</tbody>
</table>

## Module Weight

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Shipping Weight</td>
<td>27 kg (60 lb)</td>
</tr>
<tr>
<td>Lifting Weight</td>
<td>27 – 34 kg (60 – 75 lb)</td>
</tr>
</tbody>
</table>

## Membrane Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Membrane Surface Area</td>
<td>51.1 m² (550 ft²)</td>
</tr>
<tr>
<td>Material</td>
<td>PVDF</td>
</tr>
<tr>
<td>Nominal Pore Size</td>
<td>0.02 micron</td>
</tr>
<tr>
<td>Surface Properties</td>
<td>Non-Ionic &amp; Hydrophilic</td>
</tr>
<tr>
<td>Fiber Diameter</td>
<td>0.9 mm OD / 0.47 mm ID</td>
</tr>
<tr>
<td>Flow Path</td>
<td>Outside-In</td>
</tr>
</tbody>
</table>

## Operating Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Module Inlet Pressure</td>
<td>380 kPa (55psi)</td>
</tr>
<tr>
<td>TMP Range</td>
<td>0 to 275 kPa (0 to 40 psi)</td>
</tr>
<tr>
<td>Max. Operating Temperature</td>
<td>40°C (104°F)</td>
</tr>
<tr>
<td>Operating pH Range</td>
<td>5.0 – 10.0</td>
</tr>
</tbody>
</table>

## Cleaning Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Cleaning Temperature</td>
<td>40°C (104°F)</td>
</tr>
<tr>
<td>Sodium Hypochlorite</td>
<td>1,000 ppm (as Cl₂), pH &lt;10.5 Maximum 1,000,000 ppm·hrs</td>
</tr>
<tr>
<td>Caustic</td>
<td>pH &lt;12 Maximum 2,000 hrs</td>
</tr>
<tr>
<td>Acid</td>
<td>pH &gt;2</td>
</tr>
</tbody>
</table>
Z-PAK Series 60 Hz
Pressurized UF Platform
250-1000 gpm (56.8-227 m³/hr)

Key Features
- Repair-in-place module design
- Flexible rack/pump skid combinations to suit flow range and application

Pump Skid Instrumentation
Flow Meters Permeate
Turbidity Permeate
Pressure Feed, Pump Discharge, Permeate
Pressure Switch Feed, Pump Discharge

Options Available
- Block and bleed valves
- Backwash tank and pump skid
- Clean-in-Place tank and pump skid
- Chemical feed systems
- Air supply system
- MIT system
- Additional instrumentation

Operating Parameters
Recovery 92-98%
Operating temperature range 32 to 104°F (0 to 40°C)
Max inlet pressure 75 psi (517 kPa)
Max membrane feed pressure 55 psi (379 kPa)
Operating TMP range 0 to 40 psi (0 to 275 kPa)
Operating pH range 5.0 to 10.0

Materials of Construction
Air piping Stainless Steel, Sch. 10
Low-pressure piping Sch. 80, PVC
Frame Painted blue carbon steel
Enclosure NEMA 12 (painted blue)
Clamps/fittings Zinc-plated

Membrane Modules
Membrane Model ZeeWeed 1500
Style Pressurized UF Hollow Fiber
Manufacturer GE
Membrane type PVDF (Polyvinylidene fluoride)
Average membrane flux Application Dependant
Module material PVC
Module cap connection Victaulic or Compression

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