수처리용 역삼투막 제조 및 System 설계

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서론

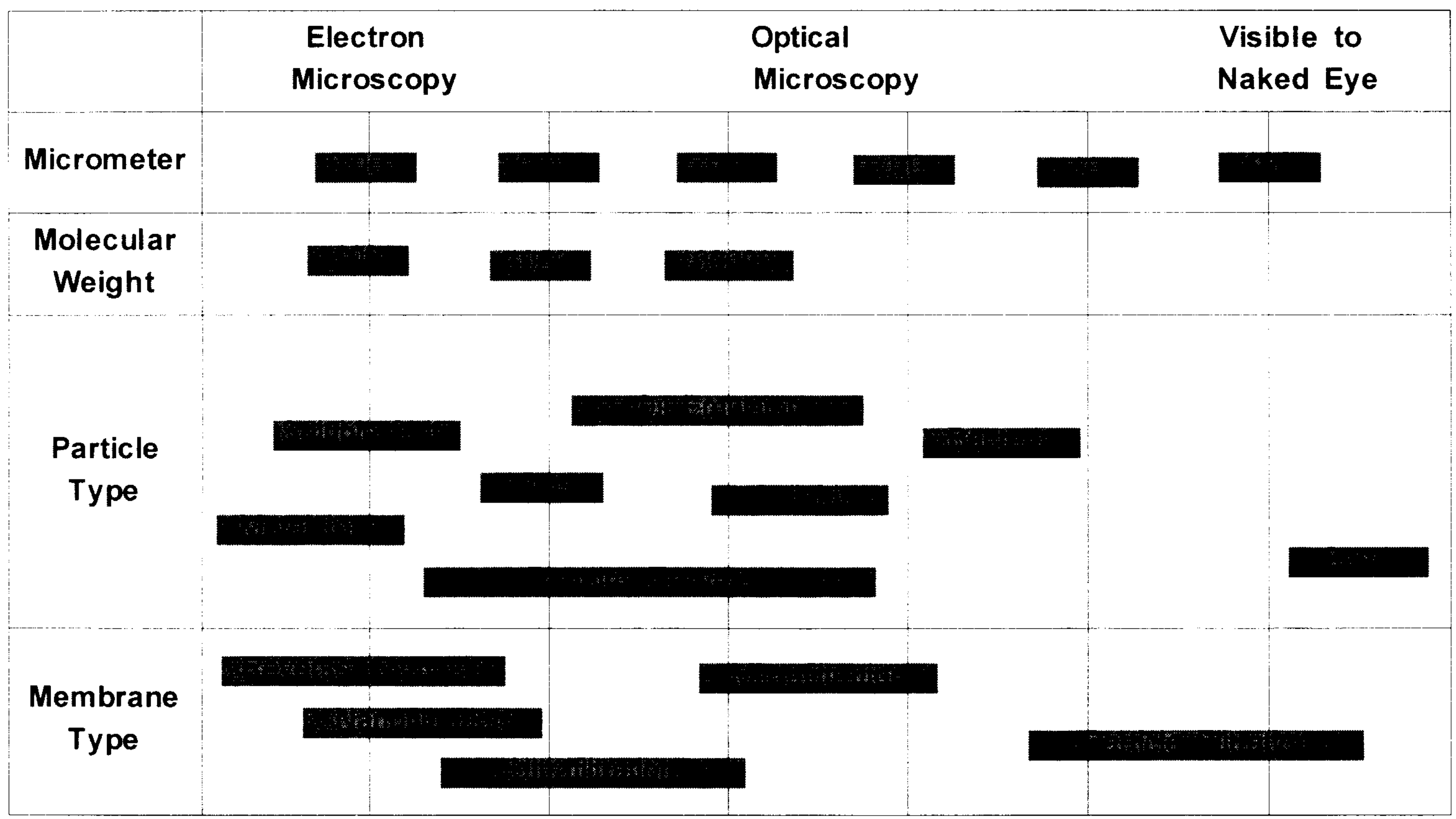
산업발전에 따라 발생하는 각종 오염물질에 의한 양질의 물 부족현상을 해결하거나 산업적으로 특정물질을 분리하기 위하여 새로운 분리기술이 개발되고 있으며 이는 앞으로 인류에 대한 가장 절실한 기술로 떠오를 것이다.

이러한 측면에서 분리막은 가장 효율적인 분리기술로 여겨져 지난 30년간 눈부신 발전을 해왔고 최근 국내에서도 소재개발과 함께 이를 응용한 분리막 **System**개발이 활발히 이루어지고 있다.

분리막에 의한 공정은 상변화가 없는 분리공정이므로 에너지 측면에서 효율적이며 공정자체가 간단하여 점차 보편적인 기술로 자리를 잡아가고 그 기본원료가 부직포, 중공사나 장 · 단섬유이므로 주로 화섬회사위주로 소재개발이 주로 되고 있다.

본 발표에서는 최근에 국내에서 생산되기 시작한 역삼투막의 제조방법과 이를 이용한 **System**설계기술에 대하여 총괄적으로 소개하고자 한다.

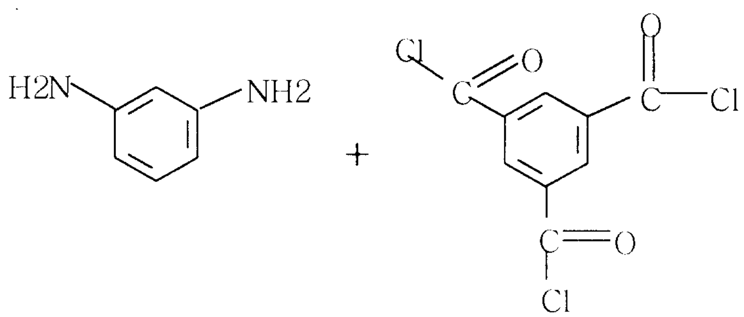
General Filtration Spectrum



R/O 막의 개발 및 사업 역사

년도	주요사항	비고
1959	· Reid & Breton : CA film에 의한 탈염가능성 확인	
1962	· Loeb & Sourirajan : Asymmetric CA membrane 발명	
1964	· Francis : CA-TFC 개념을 NTIS에서 발표	
1969	· Riley : CA Bilayer로 이루어진 최초의 복합막 개발	
1972	· J. Cadotte : NS-100 개발 (PEI + TDI)	North Star R&D Institute
· · · ·	· · · ·	
1978	· J. Cadotte : "FT-30" 개발	〃
1982	· Filmtec (J. Cadotte) "FT-30" 양산	R : 99.1% FLUX : 25 GFD
1992	· DOW : UOP/Hydranautics와의 특허분쟁서 패소 UOP/Hydranautics/Toray/Desal' → "FT-30" 유사제품 본격 생산	
1995	· Hydranautics : ES-10 생산	R : 99% FLUX : 50 GFD

"CSM" Basic Chemistry & Process Variables



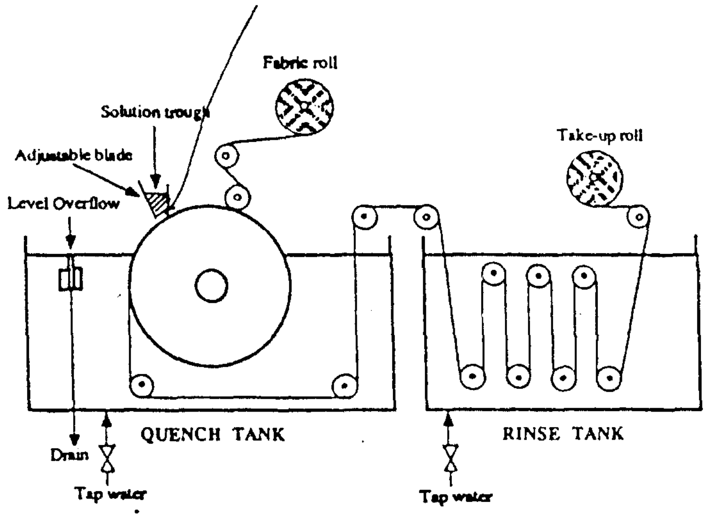
- **Properties of porous support membrane**
  - · Polymer concentration
  - · Humidity
  - · Surface pore size, distribution and uniformity
  - · Wetting characteristics
  - · Residual surface water and solvent
  - · Substrate tightness
- **Amine solution**
  - · Solubility in solvent
  - · Concentration
  - · Additive compatibility (wetting agent, acid acceptors)
  - · Coating characteristics
- **Acid chloride solution**
  - · Solubility in solvent
  - · Stability
  - · Reactivity
  - · pH
  - · Concentration

TFC R/O 막의 제조공정 ("C S M")

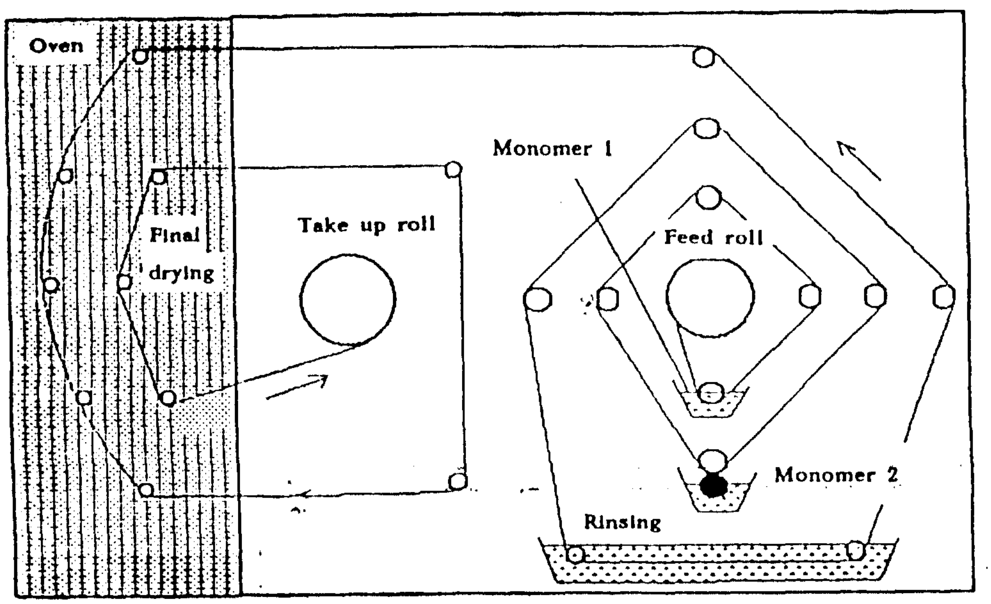
제조 공정		생산 제품
부직포 or Tafetta (150 ~ 200 μ)		
↓		
Polysulfone coating on Nonwoven fabric (150 ~ 200 μ)		
↓		
Coagulation & Rinsing	→	Microfiltration Ultrafiltration Membrane
↓		
Amine & Acid Chloride coating (0.2 ~ 0.3 μ)		
↓		
Drying & Rinsing	→	R/O Membrane
↓		
Moduling winding	→	R/O Module

R/O 막의 제조설비 요약도

Casting M/C



Thin Film Coater



업체별 R/O 막 물성

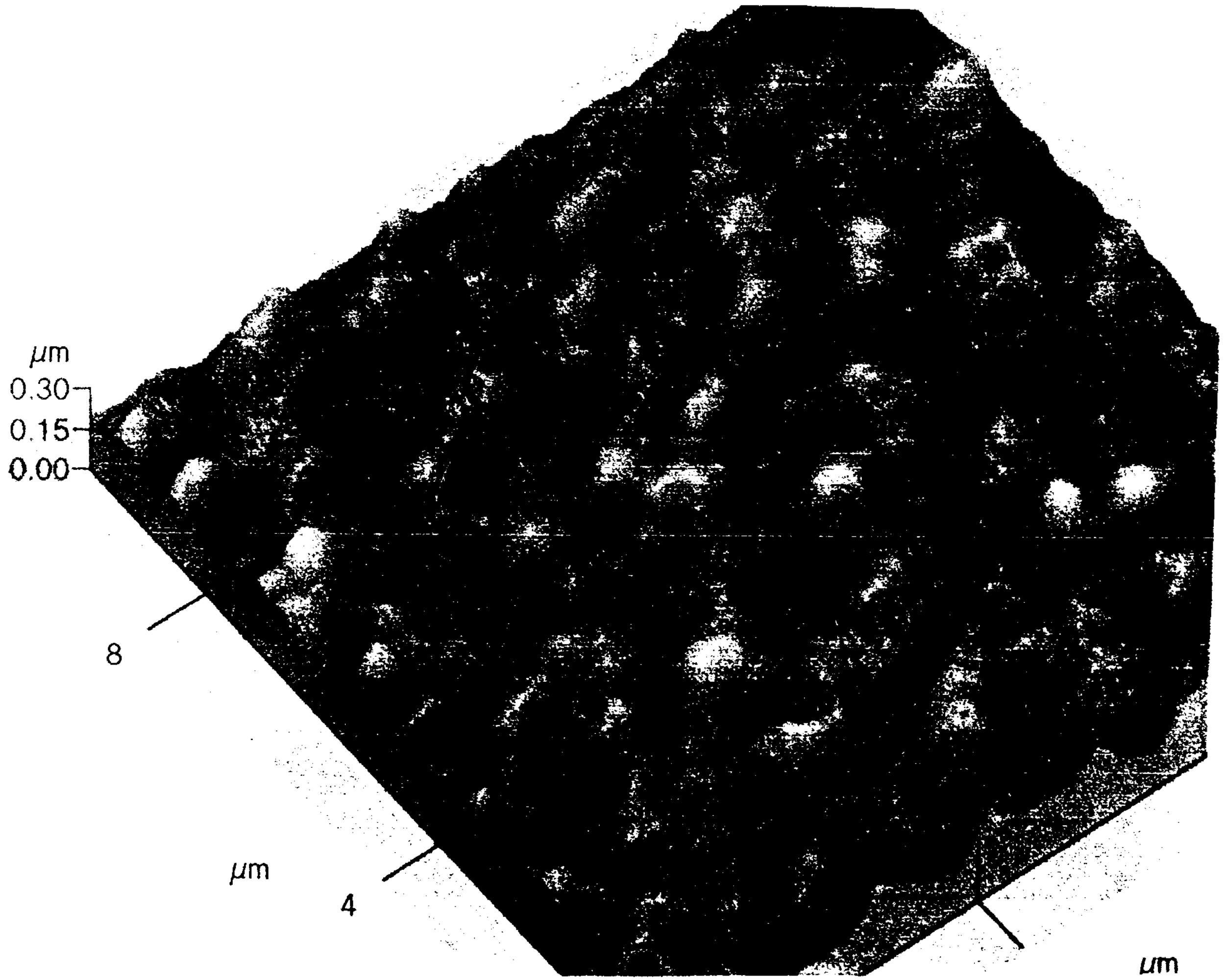
	FilmTec	Hydranautics	Toray	Fluid System	Desalination /Osmonics	Cheil Synthetics
핵심개발자*	Dr.Cadotte	Dr.Tomaschke	Dr.Kurihara	Dr.Chau	Mr.Tombray	
Basic Chemistry**	MPD+TMC	MPD+TMC +Salt	MPD+TAB +TMC	MPD+TMC+ Citric acid post treat't	MPD+TMC	MPD+TMC+ Post treat't
막 기본물성*** (B/W) Rejection(%) Flux (GFD) at 225psi,2000ppm	99 ↑ 25 ↑	99 ↑ 25 ↑	99.5 ↑ 23 ↑	98 ↑ 25 ↑	98 ↑ 25 ↑	99.0 ↑ 25 ↑
제조 환경	일반 room	일반 room	Clean room	일반 room	일반 room	Clean room

註)※) 각사에서 R/O막을 최초로 개발했던 핵심개발자이며 은퇴한 사람도 있음.

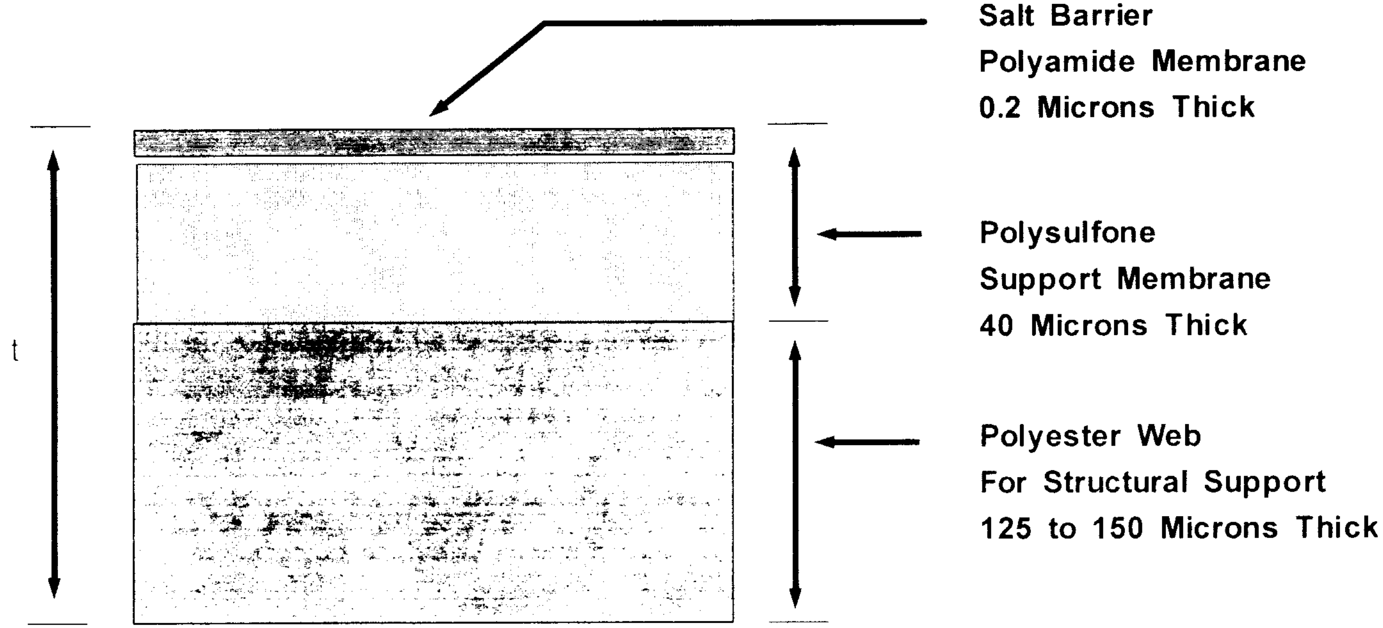
※※) 각사 특허상에 나와있는 핵심 기술임.

※※※) 각사 샘플을 입수하여 제일합섬(주) 실험실에서 측정한 결과와 각사 기술자료중 우수한 물성을 참조한 것이며 계속 개선되고 있음

AFM Scanning of RO Membrane Surface

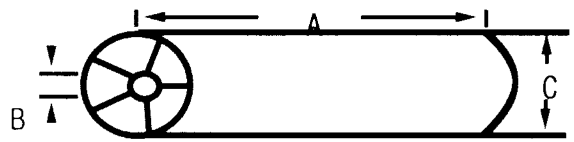


Typical Construction of Thin Film Composite Membranes



t = Approx. Total Thickness = 175 microns = 7 mils * 1.0 mil = 25.4 microns

Typical Spiral-Wound Polyamide Membrane Element Dimensions and Specifications



Typical Model Designation	Typical Flow Rates GPD#	Dimension, Inches			Dry Weight Boxed
		A	B	C	
4025	1300	25.00	0.625	3.88	5 lbs
4040	2100	40.00	0.625	3.88	12 lbs
8040	8000	40.00	1.187	7.88	32 lbs

Gallons per day when operated under Specified Brackish Water Conditions :

Feed Solution = 2,000 ppm NaCl
Feed Pressure = 225 psig
Temperature = 25℃
Recovery = 10 %

R/O System Design

● 기본설비 구성

Raw Water Supply → **Pretreatment** → **R/O** → **Product Water Treatment**

Raw Water Supply:
- Open Intake
- Beach wells
- Brackish wells
- Tap water

Pretreatment:
- Chlorination
- Dechlorination
- Floculant
- Media Filtration
- UV
- Acid

Product Water Treatment:
- Chlorination
- UV sterilization

R/O feed requirements:

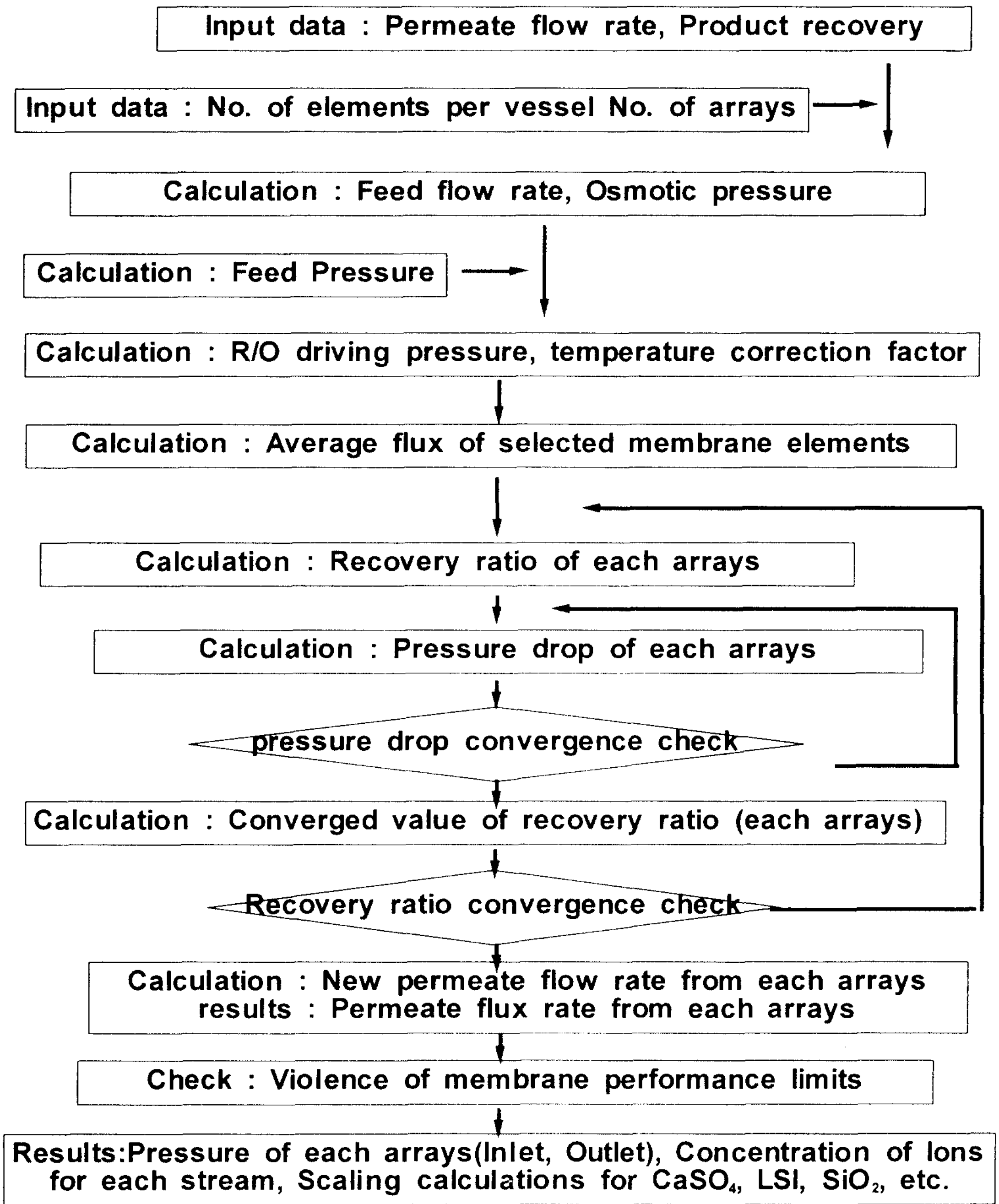
· Required Quality
· Temperature : <45℃
· pH range : 2 - 11
· Free chlorine : <0.1ppm
· SDI : <5
· NTU : <1
· Biological Activity : controlled
· LSI : controlled
· Fe, Al, Zn : <0.1ppm

● R/O Array 설계

원수 조건 / 생산수 조건 / 필요 수량 → **R/O Simulation Program** → **Array 설계**

· Filmtec : "RO System Design"
· Hydranautics : "RODESIGN"
· 제일합성 : "CSI R/O design"

Simulation Program Flow Chart



Design Criteria of Simulation Program

● Flux

Water Type	SDI	Average Flux	Flux Decline(%/yr)
Surface	2~4	8~15	8~10
Well	<2	14~18	~5
RO	<1	20~30	2~4

● Salt Passage increase per year

3~10%

● Scale potential estimate

- $CaCO_3$: via Langelier Saturation Index

  LSI = pHb - pHs

  if LSI > 0 : Scale forming

  if LSI = 0 : Neutral

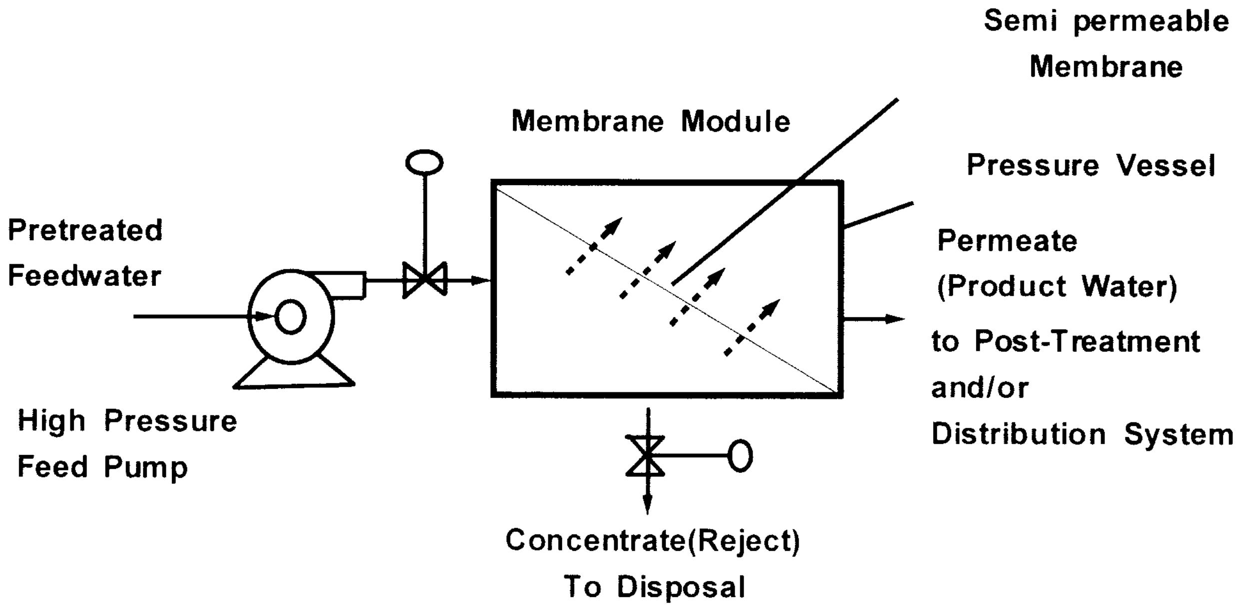
  if LSI < 0 : Corrosive tendencies

- $CaSO_4$, $BaSO_4$, $SrSO_4$: IPb vs. Ksp

  if IPb 〉. Ksp : Precipitation

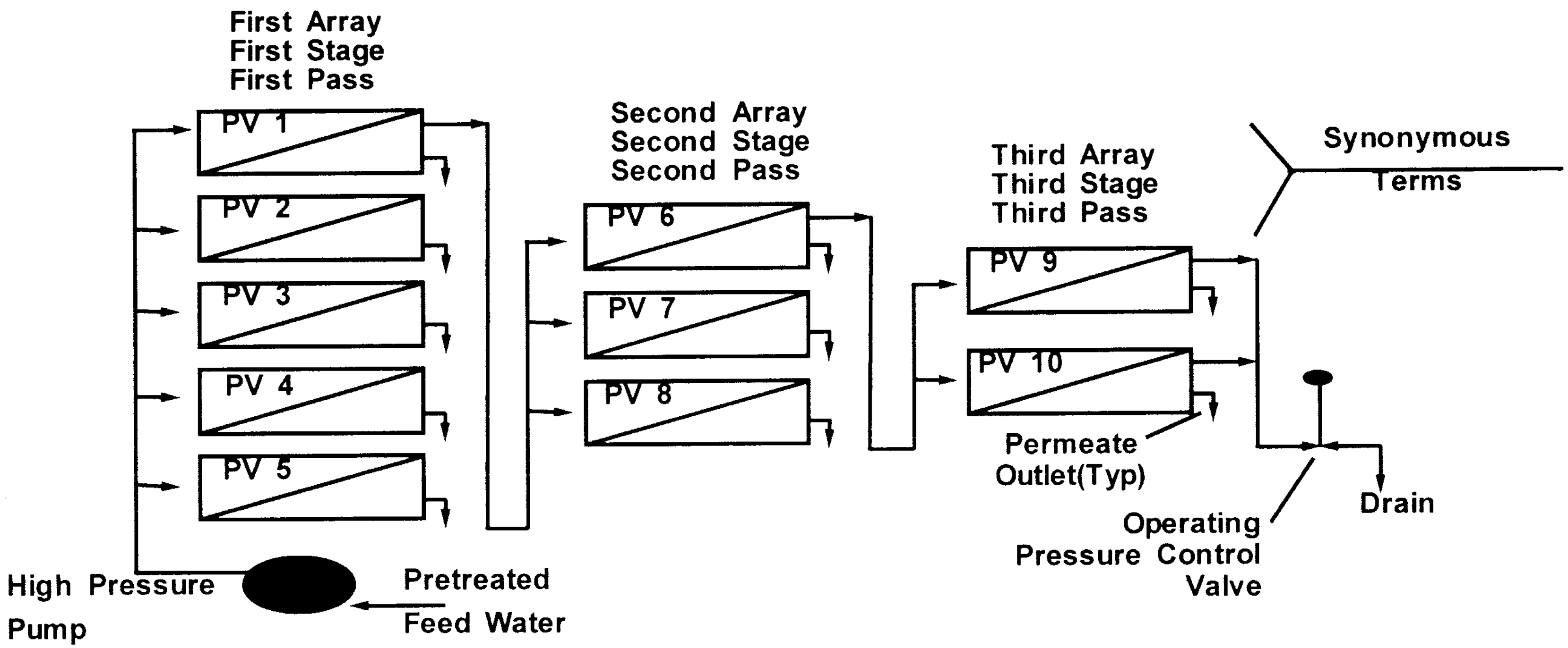
  if IPb ≤. Ksp : NO Precipitation

Typical RO/NF/UF Flow Schematic



Recovery (in percent) = Y = (Permeate Flow Rate/Feed Flow Rate) · 100

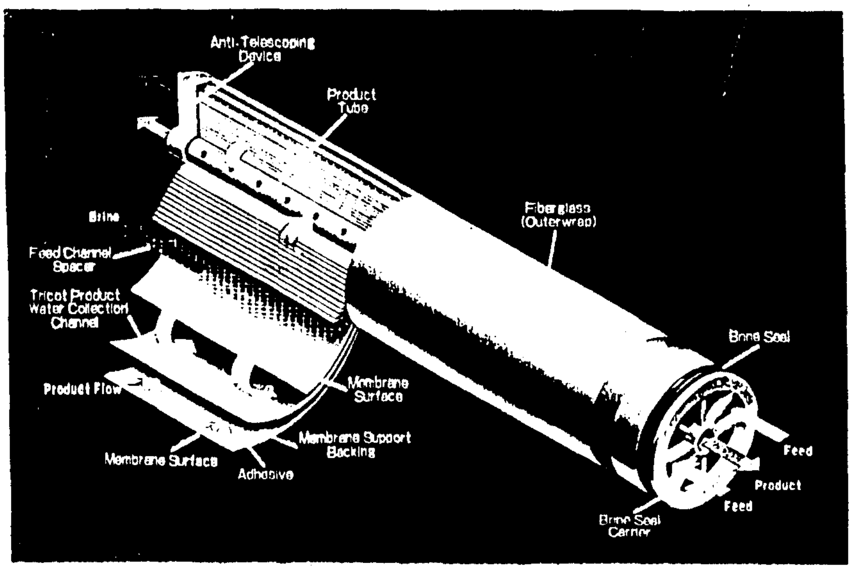
Concentrate Staging of RO Pressure Vessel
Typical for RO Plants Designed for High Recovery



RO Feed Water Quality Considerations

- Suspended Solids
- Dissolved Solids (Water Analysis)
  - Ionic Constituents
  - Sparingly Soluble Salts
  - Silica
  - Iron and Manganese
- Organics
- Colloidal Fouling
- Microorganism
- Oxidants
  - Chlorines
  - Ozone
  - Permanganate
- pH

R/O 막의 Fouling 형성과정



1. Suspended solids are slowly deposited.

2. Micro-organism slowly grow and multiply.

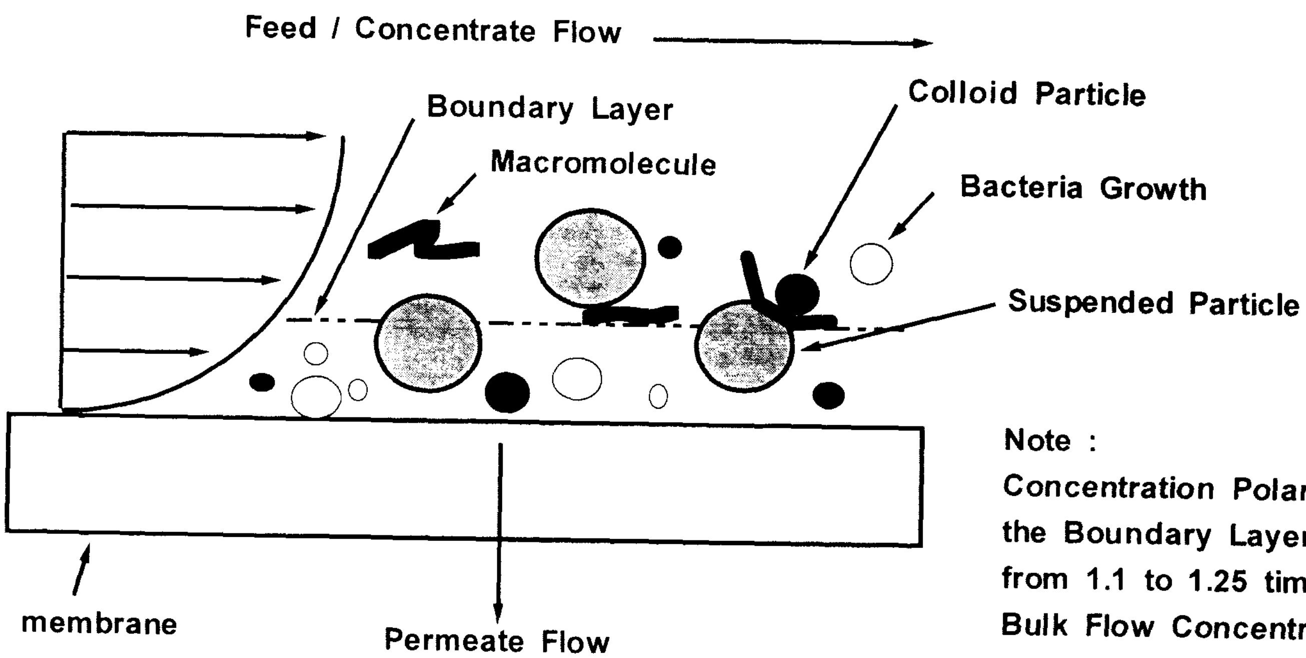
3. Scaling may take place.

4. Oxidizing agents(Chlorine) attack the membrane.

↓ ↓

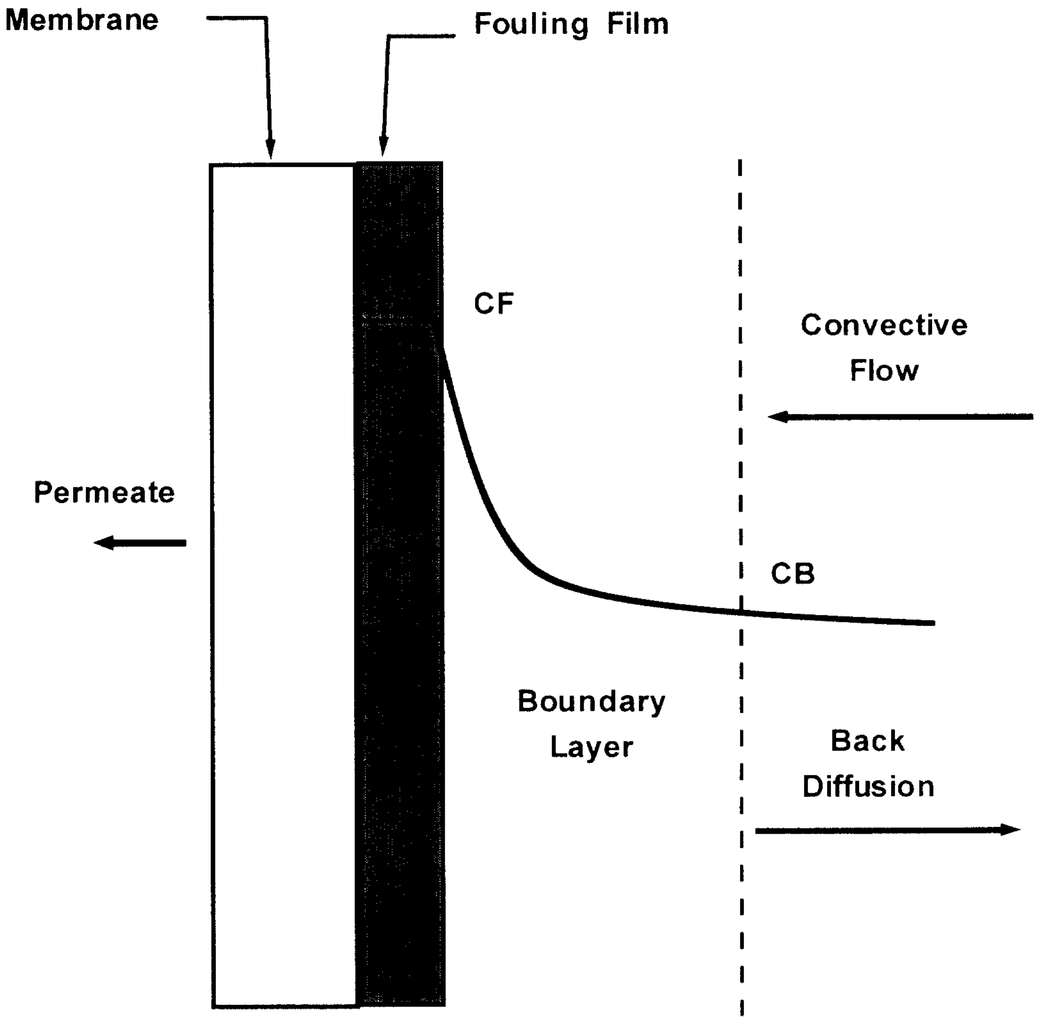
Increase in Pressure Drop
Loss in Permeate Flow
Increase in Permeate TDS

Membrane Fouling



Note :
Concentration Polarization within the Boundary Layer may range from 1.1 to 1.25 times the Bulk Flow Concentration

Concentration Polarization



CB = Salt Concentration of Bulk Flow
CF = Salt Concentration of Fouling Film

Typical Flux Decline Curve