

1.

- 1-1.
- 1-2.
- 1-3.
- 1-4.

2.

(REVERSE OSMOSIS MEMBRANE)

- 2-1.
- 2-2.
- 2-3.
- 2-4.
- 2-5. CSM

3.

CSM

- 3-1. CSM
 - 3-2.
 - 3-3. (brackish water)
 - 3-4. (sea water)
 - 3-5. (NF)
 - 3-6. (UF)
 - 3-7. 4 inch
 - 3-8. 8 inch
- 가

4.

(WATER CHEMISTRY)

- 4-1.
- 4-2.
 - 1)
 - 2)
 - 3)
 - SDI(Silt Density Index)
 - (Turbidity)
 - (Zeta Potential)
 - SCD (Streaming Current Detector)
- 4-3.
 - pH
 - (Alkalinity)
 - SO₄(Sulfate)

- Cl(Chloride)
- F(Fluoride)
- NO₃(Nitrate)
- S(Sulfide)
- PO₄(Phosphate)
- (Silica)
- (Hardness)
- Na(Sodium)
- Fe, Mn(Iron and Manganese)
- Ba, Sr(Barium and Strontium)
- Al(Aluminum)
- Cu, Zn(Copper and Zinc)

5. (PRETREATMENT)

5 - 1.

5 - 2.

-
- LSI (Langelier Stability Index)
- SDSI(stiff and davis stability index)
- (solubility product)

5 - 3.

- 1) (Acid Injection)
- 2)
- 3) (Water Softning)

■

■

- 4) (lime)

5 - 4.

5 - 5.

- 1)
- 2) (oxidation filtration)
- 3) (coagulation)
- 4) (activated carbon filtration)
- 5)

5 - 6. (Jelcleer)

6. (OPERATION)

6 - 1.

6 - 2.

- 1)

2)
6 - 3.

1)
2)
3)

6 - 4.

1)
2)
3)

7. (CLEANING IN PLACE)

7 - 1.
7 - 2.
7 - 3.
7 - 4.
7 - 5.
7 - 6.
7 - 7.
7 - 8.

8.

8 - 1.
8 - 2.
8 - 3.
8 - 4. Code Line

9. (TROUBLE SHOOTING)

9 - 1.
9 - 2.

1)

■ / /
■ pH /

2)

■ TDS
■
■

9 - 3.

1)
2)
3)

9-4. 가
9-5.

10.

10- 1.
10- 2. 가
10- 3. 가
10- 4.
10- 5.
10- 6.
10- 7.
10- 8.
10- 9.
10-10. CO₂ pH
10-11.
10-12.
10-13. CO₂가
10-14.
10-15.
10-16.
10-17.
10-18.
10-19.
10-20. SDI
10-21. CSM
10-22. (TCF)
10-23.

CSM

Reverse Osmosis Membrane

1.

1-1.

1-2.

1-3.

1-4.



SAEHAN
(주)새한

1-1.

■

: 254-8

■

: 14 ()

■

: 1

: (), (), (VP Y)

, ,

■

: 287

: , , , (PET),

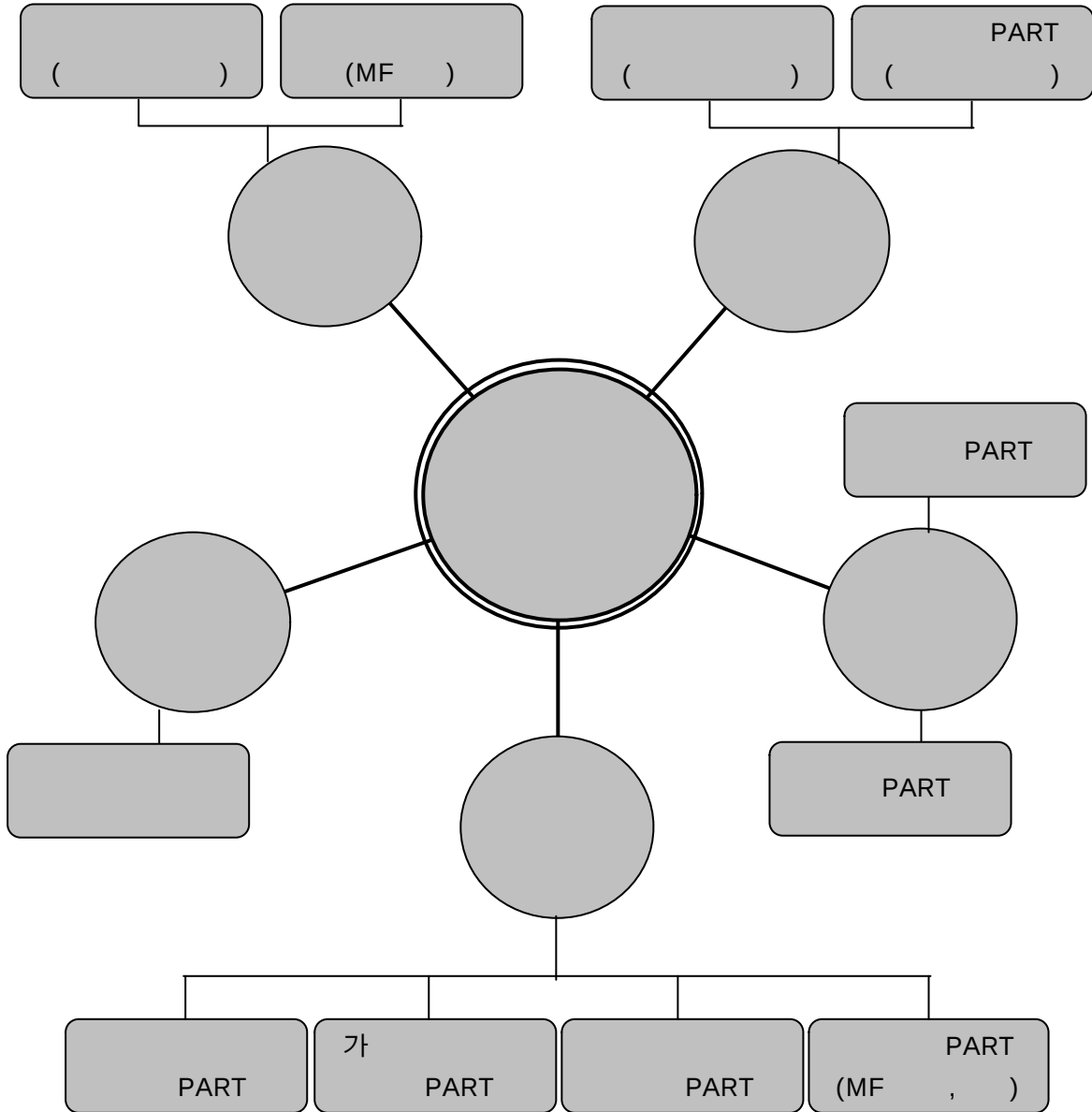
1 - 2 .

- 1972 ()
- 1974 1 ()
- 1977
- 1982
- 1985
- 1987
- 1988
- 1988 가 (,)
- 1989
- 1989
- 1990 PP (spunbond) , (spandex)
- 1991
- 1994 ISO-9002
- 1994
- 1995
- 1995 가 ,
- 1995 2 (, , , PS ,)
- 1996
- 1996 ,
- 1996 ,
- 1997 IR 52 , KT
- 1997 " " , ISO14001, 9002
- 1999 (TSI)
- 2000 (DSI)

1 - 3 .

- 1990 ()
- 1993 LAB.
(brackish water) & (sea water)
- 1994 (日) (3)
(美) F.D.A. (6)
(pilot plant) 가
가 .
- 1995 ()
가
- 1996
, ,
(ASI, ARGO, IONICS)
- 1997 (IR52, 2) --
(8040 : 2 /) --
가 : 50%
LP, pumpless
KT
ISO 14001, ISO 9002
- 1998 (SW) (~99 2)

1 - 4 .



CSM

Reverse Osmosis Membrane

2.

2-1.

2-2.

2-3.

2-4.

2-5. CSM



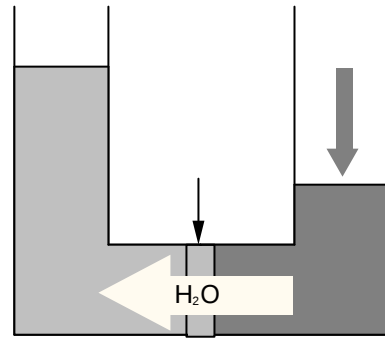
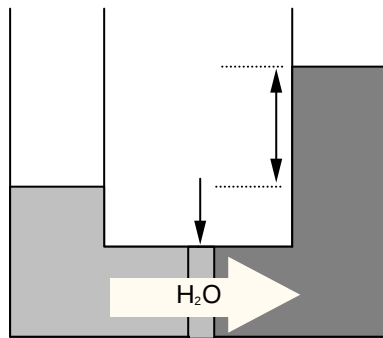
SAEHAN
(주)새한

2 - 1 .

(electro dialysis), (distillation) (ion exchange) (reverse osmosis),
가
(COD) 4~10ppm (TDS)
100ppm

2 - 2 .

(50 μ m) 가 (0.2 0.8 μ m) .
 가 가
 가 . " "
 " " . 가
 " (reverse osmosis)" .



2 - 3 .

CSM ()

(ASYMETRIC MEMBRANE)... (cellulose acetate, CA type)
Lobe Sourirajan 가 100~200 μ m
가 0.25~1 μ m μ m

가 1/1000
가
가

(COMPOSITE MEMBRANE)... (polyamide, PA type)
() ()
) 가 CARNELL & CASSIDY ,
FRANCIS (coating)

가 .

(reverse osmosis membrane)

가 pH 가 ,

가 .

pH

3.

가 ,

.

pH		2 ~ 12	4 ~ 6	pH
(Kgf/cm ²)		15	30	
(%)	(TDS)	99+	98	
	(SiO ₂)	99+	95	
/				
3		30% ↑	100% ↑	
		99% → 98.7 %	98% → 96%	
			가	

2 - 4 .

- 1) .
- 2) .
- 3) . (3가 > 2가 > 1가)
- 4) (hydration number), .
- 5) 가 .
- 6) 가 , , 가 , , .
- 7) . > >

- CSM
- 1) (permeate flux), (salt rejection)
 - 2) 가 가
 - 3) pH
 - 4)
 - 5)
 - 6) 가
 - 7) , 가
 - 8)

2 - 5 . CSM

(BE, BN CSM)

NO		(%)	
1	(NaF)	99	42
2	(NaCN)	98	49
3	(NaCl)	99	58
4	(SiO ₂)	99	60
5	(NaHCO ₃)	99	84
6	(NaNO ₃)	96	85
7	(MgCl ₂)	99	95
8	(CaCl ₂)	99	111
9	(MgSO ₄)	99	120
10	(NiSO ₄)	99	155
11	(CuSO ₄)	99	160
12		35	30
13		25	32
14		70	46
15		90	60
16	(Urea)	70	60
17	(pH2)	94	90
18	(pH5)	99	90
19	(Glucose)	98	180
20	(Sucrose)	99	342
21		99	-
22	(BOD)	95	-
23	(COD)	97	-

(BE, BN CSM)

NO		(%)
1	(Na)	97
2	(Ca)	99
3	(Mg)	99
4	(K)	98
5	(Fe)	99
6	(Mn)	99
7	(Al)	99
8	(NH ₄)	99
9	(Cu)	99
10	(Ni)	99
11	(Zn)	99
12	(Sr)	98
13	(Cd)	99
14	(Ag)	99
15	(Hg)	99
16	(Cl)	99
17	(HCO ₃)	98
18	(SO ₄)	99
19	(NO ₃)	96
20	(F)	98
21	(SiO ₂)	99
22	(PO ₄)	99
23	(Br)	98

CSM

Reverse Osmosis Membrane

3.

3-1. CSM

3-2.

3-3. (brackish water)

3-4. (sea water)

3-5. (NF)

3-6. (UF)

3-7. 4 inch

3-8. 8 inch

가



1. CSM

RE - 8040 - BN

- RE : (Reverse Osmosis Element)
- UE : (Ultrafiltration Element)
- NE : (Nanofiltration Element)

- 80 : 8.0 inch
- 40 : 4.0 inch
- 25 : 2.5 inch

- 40 : 40 inch
- 21 : 21 inch

1)

- B : (Brackish water membrane)
- T : (Tap water membrane)
- S : (Sea water membrane)

2)

- N : (Normal grade)
- E : (Extended area effective)
- R : (High rejection)
- L : (Low pressure use)

					/
		RE-4040-BN	10 /	95 10	98 12
SKC		RE-4040-BN	10 /	96 03	99 가
		RE-8040-BN	100 /	96 05	
S&T		RE-8040-BN	30 /	96 09	
		RE-8040-BN	30 /	96 10	
		RE-8040-BN	400 /	96 12	
		RE-2540-S		96 12	
		RE-8040-BE	30 /	97 07	
SDI()	가	RE-8040-BN	250 /	97 07	
		RE-4040-SR		97 08	
		RE-8040-BN	150 /	97 09	
		RE-8040-BN	30 /	97 10	
		RE-8040-BE	100 /	97 10	
		RE-4040-BL		97 10	
		RE-8040-BN	50 /	97 10	
SK()		RE-8040-BN	120 /	97 12	
		RE-4040-BL	3 /	97 12	
		RE-8040-BE	27 /	98 01	
		RE-8040-BE	100 /	98 01	
		RE-8040-BN	100 /	98 01	CA PA

					/
		RE-8040-BN	60 /	98 03	
		RE-8040-BN	60 /	98 03	
		RE-8040-BE	100 /	98 03	
		RE-8040-BN	20 /	98 05	
		RE-4040-SR	320	98 06	
LG		RE-9040-BE	30 /	98 07	
		RE-8040-BE	540 /	98 08	
		RE-8040-BE	200 /	98 09	
		RE-4040-BN	2 /	98 12	
		RE-8040-BN	100 /	99 04	
		RE-8040-SN	15 /	99 04	
		RE-8040-BE	40 /	99 05	
		RE-8040-BE	40 /	99 05	
		RE-8040-SN	100 /	99 05	
LG		RE-8040-BN	120 /	99 05	
		RE-8040-BE	20 /	99 08	
		RE-8040-BE	20 /	99 08	
		RE-8040-BE	190 /	99 10	
	2	RE-8040-BE	15 /	99 10	
LG		RE-8040-BN	10 /	00 01	

			BRACKISH WATER MEMBRANE				
			RE2521BN	RE2540BN	RE4021BN	RE4040BN	RE8040BN
Performance	Flux	GPD	250	600	800	2000	9000
		m ³ /D	0.9	2.3	3.0	7.6	34.1
	Salt rej.	%	99.0	99.0	99.0	99.0	99.5
Test Condition	pressure	psig	225	225	225	225	225
	temperature		25	25	25	25	25
	NaCl(MgSO ₄)	ppm	2000	2000	2000	2000	2000
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7	6.5-7
	recovery	%	15	15	15	15	15
Operating Limits	max. SDI	-	5	5	5	5	5
	max. turbidity	NTU	1	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15	15
	max. temperature		45	45	45	45	45
	pH range	-	3-10	3-10	3-10	3-10	3-10
	max. recovery	%	20	20	20	20	20
Size	effective area	ft ²	12	27	35	75	345
		m ²	1.1	2.5	3.3	7.0	31.8
	element length	inch	21	40	21	40	40
	element diameter	inch	2.5	2.5	4.0	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	-	1.125
	permeate tube outer diameter	inch	0.75	0.75	0.75	0.75	-
	permeate tube intrusion	inch			0.5	0.5	0.1
Guide(Max.)	surface water	gfd	18	18	18	18	18
		m ³ /D	0.8	1.8	2.4	5.1	23.5
	softened well water	gfd	23	23	23	23	23
		m ³ /D	1.0	2.4	3.0	6.5	30.0
	RO permeate	gfd	28	28	28	28	28
		m ³ /D	1.3	2.9	3.7	7.9	36.6

3. (brackish water membrane)

			BRACKISH WATER MEMBRANE				
			RE2521BL	RE2540BL	RE4040BL	RE4040BE	RE8040BE
Performance	Flux	GPD	350	700	2600	2200	11000
		m ³ /D	1.3	2.6	9.8	8.3	41.6
	Salt rej.	%	98.0	98.0	98.0	99.0	99.5
Test Condition	pressure	psig	150	150	150	225	225
	temperature		25	25	25	25	25
	NaCl(MgSO ₄)	ppm	2000	2000	2000	2000	2000
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7	6.5-7
	recovery	%	15	15	15	15	15
Operating Limits	max. SDI	-	5	5	5	5	5
	max. turbidity	NTU	1	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15	15
	max. temperature		45	45	45	45	45
	pH range	-	3-10	3-10	3-10	3-10	3-10
	max. recovery	%	20	20	20	20	20
Size	effective area	ft ²	12	27	75	85	400
		m ²	1.1	2.5	7.0	7.9	37.2
	element length	inch	21	40	21	40	40
	element diameter	inch	2.5	2.5	4.0	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	-	1.125
	permeate tube outer diameter	inch	0.75	0.75	0.75	0.75	-
	permeate tube intrusion	inch			0.5	0.5	0.1
Guide(Max.)	surface water	gfd	18	18	18	18	18
		m ³ /D	0.8	1.8	2.4	5.8	27.3
	softened well water	gfd	23	23	23	23	23
		m ³ /D	1.0	2.4	3.0	7.4	34.8
	RO permeate	gfd	28	28	28	28	28
		m ³ /D	1.3	2.9	3.7	9.0	42.4

			TAP WATER MEMBRANE			
			RE2521TE	RE2540TE	RE4021TE	RE4040TE
Performance	Flux	GPD	300	700	1050	2000
		m ³ /D	1.1	2.6	4.0	7.6
	Salt rej.	%	98.0	98.0	98.0	98.0
Test Condition	pressure	psig	225	225	225	225
	temperature		25	25	25	25
	NaCl	ppm	2000	2000	2000	2000
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7
	recovery	%	15	15	15	15
Operating Limits	max. SDI	-	5	5	5	5
	max. turbidity	NTU	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15
	max. temperature		45	45	45	45
	pH range	-	3-10	3-10	3-10	3-10
	max. recovery	%	20	20	20	20
Size	effective area	ft ²	12	27	35	75
		m ²	1.1	2.5	3.3	7.0
	element length	inch	21	40	21	40
	element diameter	inch	2.5	2.5	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	-
	permeate tube outer diameter	inch	0.75	0.75	0.75	0.75
	permeate tube intrusion	inch			0.5	0.5
Guide(Max.)	surface water	gfd	18	18	18	18
		m ³ /D	0.8	1.8	2.4	5.1
	softened well water	gfd	23	23	23	23
		m ³ /D	1.0	2.4	3.0	6.5
	RO permeate	gfd	28	28	28	28
		m ³ /D	1.3	2.9	3.7	7.9

3. (brackish water membrane)

			TAP WATER MEMBRANE			
			RE2521TL	RE2540TL	RE4021TL	RE4040TL
Performance	Flux	GPD	350	700	800	2200
		m ³ /D	1.3	2.6	3.0	8.4
	Salt rej.	%	98.0	98.0	98.0	98.0
Test Condition	pressure	psig	150	150	150	150
	temperature		25	25	25	25
	NaCl(MgSO ₄)	ppm	2000	2000	2000	2000
	pH	-	6.5 - 7	6.5 - 7	6.5 - 7	6.5 - 7
	recovery	%	15	15	15	15
Operating Limits	max. SDI	-	5	5	5	5
	max. turbidity	NTU	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15
	max. temperature		45	45	45	45
	pH range	-	3 - 10	3 - 10	3 - 10	3 - 10
	max. recovery	%	20	20	20	20
Size	effective area	ft ²	12	27	35	345
		m ²	1.1	2.5	3.3	31.8
	element length	inch	21	40	21	40
	element diameter	inch	2.5	2.5	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	-
	permeate tube outer diameter	inch	0.75	0.75	0.75	0.75
	permeate tube intrusion	inch			0.5	0.5
Guide(Max.)	surface water	gfd	18	18	18	18
		m ³ /D	0.8	1.8	2.4	5.1
	softened well water	gfd	23	23	23	23
		m ³ /D	1.0	2.4	3.0	6.5
	RO permeate	gfd	28	28	28	28
		m ³ /D	1.3	2.9	3.7	7.9

			SEA WATER MEMBRANE				
			RE2521SN	RE2540SN	RE4021SN	RE4040SN	RE8040SN
Performance	Flux	GPD	225	500	600	1500	6200
		m ³ /D	0.9	1.9	2.3	5.7	23.4
	Salt rej.	%	99.2	99.2	99.2	99.2	99.2
Test Condition	pressure	psig	800	800	800	800	800
	temperature		25	25	25	25	25
	NaCl(MgSO ₄)	ppm	32000	32000	2000	32000	32000
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7	6.5-7
	recovery (about)	%	10	10	10	10	10
Operating Limits	max. SDI	-	5	5	5	5	5
	max. turbidity	NTU	1	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15	15
	max. temperature		45	45	45	45	45
	pH range	-	3-10	3-10	3-10	3-10	3-10
	max. recovery	%	20	20	20	20	20
Size	effective area	ft ²	12	27	35	74	310
		m ²	1.1	2.5	3.3	6.9	29.0
	element length	inch	21	40	21	40	40
	element diameter	inch	2.5	2.5	4.0	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	-	1.125
	permeate tube outer diameter	inch	0.75	0.75	0.75	0.75	-
	permeate tube intrusion	inch			0.5	0.5	0.1
Guide(Max.)	sea water	gfd	16	16	16	16	16
		m ³ /D	0.7	1.6	2.1	4.2	18.9
	softened well water	gfd	22	22	22	22	22
		m ³ /D	1.0	2.2	2.9	5.8	25.8
	RO permeate	gfd	28	28	28	28	28
		m ³ /D	1.3	2.9	3.7	7.4	32.9

4. (sea water membrane)

			SEA WATER HIGH REJECTION MEMBRANE	
			RE4040SR	RE8040SR
Performance	Flux	GPD	1000	4000
		m ³ /D	3.8	15.1
	Salt rej.	%	99.5	99.5
Test Condition	pressure	psig	800	800
	temperature		25	25
	NaCl(MgSO ₄)	ppm	32000	32000
	pH	-	6.5 - 7	6.5 - 7
	recovery	%	10	10
Operating Limits	max. SDI	-	5	5
	max. turbidity	NTU	1	1
	max. chlorine concentration	ppm	0.1	0.1
	max. feed flow rate	m ³ /hr	3.63	16
	min. concentration flow	m ³ /hr	0.91	3.6
	max. pressure drop/element	psig	15	15
	max. temperature		45	45
	pH range	-	3 - 10	3 - 10
	max. recovery	%	20	20
Size	effective area	ft ²	74	310
		m ²	6.9	29.0
	element length	inch	40	40
	element diameter	inch	4.0	8.0
	permeate tube inner diameter	inch	-	1.125
	permeate tube outer diameter	inch	0.75	-
	permeate tube intrusion	inch	0.5	0.1
Guide(Max.)	sea water	gfd	16	16
		m ³ /D	4.3	18.7
	softened well water	gfd	22	22
		m ³ /D	5.8	25.8
	RO permeate	gfd	28	28
		m ³ /D	7.4	32.9

			NANOFILTRATION MEMBRANE				
			NE2540	NE4021	NE4040	NE8040-N	NE8040-E
Performance	Flux	GPD	1000	1300	2700	12000	14000
		m ³ /D	3.8	4.9	10.2	45.4	52.9
	MgSO ₄ (NaCl) rej.	%	99.5(40)	99.5(40)	99.5(40)	99.5(40)	99.5(40)
Test Condition	pressure	psig	225	225	225	225	225
	temperature		25	25	25	25	25
	NaCl(MgSO ₄)	ppm	2000	2000	2000	2000	2000
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7	6.5-7
	recovery (about)	%	15	15	15	15	15
Operating Limits	max. SDI	-	5	5	5	5	5
	max. turbidity	NTU	1	1	1	1	1
	max. chlorine concentration	ppm	0.1	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	3.63	3.63	16	16
	min. concentration flow	m ³ /hr	0.22	0.91	0.91	3.6	3.6
	max. pressure drop/element	psig	15	15	15	15	15
	max. temperature		45	45	45	45	45
	pH range	-	3-9	3-9	3-9	3-9	3-9
	max. recovery	%	20	20	20	20	20
Size	effective area	ft ²	27	35	75	345	345
		m ²	2.5	3.3	7.0	31.8	31.8
	element length	inch	40	21	40	40	40
	element diameter	inch	2.5	4.0	4.0	8.0	8.0
	permeate tube inner diameter	inch	-	-	-	1.125	1.125
	permeate tube outer diameter	inch	0.75	0.75	0.75	-	-
	permeate tube intrusion	inch		0.5	0.5	0.1	0.1
Guide(Max.)	surface water	gfd	20	20	20	20	20
		m ³ /D	2.0	2.6	5.7	26.2	26.2
	softened well water	gfd	28	28	28	28	28
		m ³ /D	2.9	3.7	7.9	36.6	36.6
	RO permeate	gfd	35	35	35	35	35
		m ³ /D	3.6	4.6	10.0	45.7	45.7

			ULTRAFILTRATION MEMBRANE			
			UE2521-PF	UE2540-PF	UE4040-PF	UE8040-PF
Performance	Flux	GPD	500	1000	3500	14000
		m ³ /D	1.9	3.8	13.2	52.9
	Rej' Molecular weight(MWCO)	-	50K~100K	50K~100K	50K~100K	50K~100K
Test Condition	pressure	psig	20	20	20	20
	temperature		25	25	25	25
	Concentration	-	pure water	pure water	pure water	pure water
	pH	-	6.5-7	6.5-7	6.5-7	6.5-7
Operating Limits	max. SDI	-	5	5	5	5
	max. turbidity	NTU	1	1	1	1
	max. chlorine c oncentration	ppm	0.1	0.1	0.1	0.1
	max. feed flow rate	m ³ /hr	1.36	1.36	3.63	16
	min. concentration flow	m ³ /hr	0.22	0.22	0.91	3.6
	max. pressure drop/element	psig	15	15	15	15
	max. temperature		45	45	45	45
	pH range	-	3-10	3-10	3-10	3-10
	max. recovery	%	20	20	20	20
Size	effective area	ft ²	12	27	75	345
		m ²	1.1	2.5	7.0	31.8
	element length	inch	21	40	40	40
	element diameter	inch	2.5	2.5	4.0	8.0
	permeate tube inner diameter	inch	-	-	-	1.125
	permeat tube outer diameter	inch	0.75	0.75	0.75	-
	permeat tube intrusion	inch			0.5	0.1
Guide(Max.)	surface water	gfd	35	35	35	35
		m ³ /D	1.6	3.6	9.9	45.7
	softned well water	gfd	40	40	40	40
		m ³ /D	1.8	4.1	11.4	67.2
	RO permeate	gfd	45	45	45	45
		m ³ /D	2.0	4.6	12.8	75.6

4.

4-1.

4-2.

1)

2)

3)

- SDI(Silt Density Index)
- (Turbidity)
- (Zeta Potential)
- SCD (Streaming Current Detector)

4-3.

- pH
- (Alkalinity)
- SO₄(Sulfate)
- Cl(Chloride)
- F(Fluoride)
- NO₃(Nitrate)
- S(Sulfide)
- PO₄(Phosphate)
- (Silica)
- (Hardness)
- Na(Sodium)
- Fe, Mn(Iron and Manganese)
- Ba, Sr(Barium and Strontium)
- Al(Aluminum)
- Cu, Zn(Copper and Zinc)



1.

4 - 1 .

(scale) 가 . , 가 .

■

mg/L : 1,000g 1mg . , 1,000,000g 1g
→ ppm (Parts Per Million)

ppm AS CALCIUM CARBONATE (AS CaCO_3) :

-
- 가
- CaCO_3 (:100, 2가) 가
- 가 1
-

EX) 'A'가 CaCO_3 (MW:200) 3가 가 ,
'A' CaCO_3 ;
'A' .

$$A \text{ concentration as } \text{CaCO}_3 = A \times \frac{100(\text{CaCO}_3)}{200(A)} \times \frac{3(A)}{2(\text{CaCO}_3)}$$

- CaCO_3

가 10% 가 .
가 10% .

4 - 2 .

1) (ION)

- ;
(alkalinity) - (HCO_3^-) , (CO_3^{2-}) , (OH^-)
- SO_4^{2-}
- Cl^-
- F^-
- NO_3^-
- ;
(hardness) - (Ca^{2+}) , (Mg^{2+})
- Na^+
- K^+

2) (ION)

- ;
- SiO_2
- S(2가)
- PO_4^{3-}
- ;
- Fe(2가, 3가)
- Mn(2가)
- Al(3가)
- Ba
- Sr
- Cu
- Zn

3)

■ SDI(Silt Density Index)

(fouling index) (membrane) (fouling)
 가 . 0.45 μ m (SS,
 suspended solid)
 47mm 30 psig 500mL
 (T₀) 15 (T) 500mL
 (T₁) 가 (T
).

$$SDI = 100 \times \frac{1 - (T_0 / T_1)}{T}$$

SDI (RO membrane)
 . SDI SS
 (foulants)
 SDI 가
 SDI
 SDI가 3
 5

■ (Turbidity)

가 (fouling potential)
 (turbidometer, nephelometer)
 가 1.0 (RO membrane) (fouling)
 NTU(Nephelometric Turbidity Unit)
 SDI 가 가

· SDI

(foulants)

· SDI가

가

■ (ZETA potential)

(SS, suspended solids)

(-) 가

가 (-) (SS)

가 가 0 (SS)

가 가

가

가

(media filter)

가 0

(RO system)

(pretreatment)

■ SCD (Streaming Current Detector)

SCD

가 · SCD

(suspended particle)

(neutralization)

SCD

가

4 - 3 .

■ pH

pH (salt) . pH가
 . pH가 CO₂가
 pH가 HCO₃ CO₃

■ (Alkalinity)

(Alkalinity) . HCO₃
 (bicarbonate), CO₃(carbonate), OH(hydroxyl) . H⁺
 pH .
 HCO₃ ¹⁾. pH8.3
 . pH가 8.3
 CO₃ . (buffer solution, pH
) pH
 (CaCO₃)
 pH가 가 . HCO₃
 HCO₃ . HCO₃가
 HCO₃ CO₃
 .
 (CaCO₃)
 (CaCO₃)
 (salt)

■ SO₄(Sulfate)

Ca(calcium), Mg(magnesium), Ba(barium), Sr(strontium) 2가
 SO₄(sulfate) . 2가
 가 . SO₄
 pH 가 SO₄
 (scale) 2가

¹⁾ 10- 10

■ Cl(Chloride)

(scale) Cl(chloride)
 Cl (salt) Cl 304
 Cl 가 ppm 31
 6

■ F(Fluoride)

F(fluoride) F가
 (CaF₂, calcium fluoride) (salt)

■ NO₃(Nitrate)

NO₃(nitrate) 가
²⁾ NO₃ 가
 NO₃ NO₂(nitrite)가

■ S(Sulfide)

가 (H₂S, hydrogen sulfide)
 가
 H₂S 가 가 (degasifier)
 (media filter)

■ PO₄(Phosphate)

3가 - PO₄(phosphate) 가
 pH (calcium phosphate)
 pH 가 PO₄가
 가

²⁾ 2 2-5

- (Silica)
(silica)
가 . pH 9 가 H_4SiO_4 $\text{Si}(\text{OH})_4$
(silicic acid) . pH H_4SiO_4
가 . pH가 8 SiO_3 (silicate anion)가 pH Ca
(calcium), Mg(magnesium), Fe(iron), Al(aluminum) (salt) .
가
(ammonium bifluoride) .
가 .
pH . 가 20 ppm
가 .

- (Hardness)
Ca(calcium) Mg(magnesium) 가
(scale)
.
 PO_4 (phosphate) (Surfactant)
.
 HCO_3 (bicarbonate), CO_3 (Carbonate), SO_4 (sulfate), F
(fluoride), SiO_3 (silicate) ,
.

- Na(Sodium)
Na (sodium salt) 가
가 .
³⁾ .
.
Na

³⁾ 2 2-5

■ Fe, Mn(Iron and Manganese)

Fe(iron) Mn(manganese) (Fe²⁺)
 (Fe³⁺) . Fe , (steel)
 , 가
 . 가
 Fe Mn 0.05ppm 가
 . 가
 . , 가 Fe Mn
 (fouling)

■ Ba, Sr(Barium and Strontium)

Ba(barium) Sr(strontium) .
 0.01ppm SO₄(sulfate)
 (scale) .
 Ba Sr 가 .

■ Al(Aluminum)

Al(aluminum) . Al
 가 .
 (Aluminum Sulfate - Al₂SO₄, Sodium Aluminate - NaAlO₂).
 Al . Al,
 Fe(iron) (-) .
 SiO₃(silicate)가 .
 Al pH가 가 5.3
 . Al
 (media filter) .

■ Cu, Zn(Copper, Zinc)

Cu(copper) Zn(zinc)

. (salt) pH가 가
pH 가

Cu Zn 가 가

. (PA type)
(peracetic acid, hydrogen peroxide, chlorine)
가 .

5.

5-1.

5-2.

-
- LSI (Langelier Stability Index)
- SDSI (stiff and davis stability index)
- (solubility product)

5-3.

- 1) (Acid Injection)
- 2)
- 3) (Water Softning)
-
-
- 4) (lime)

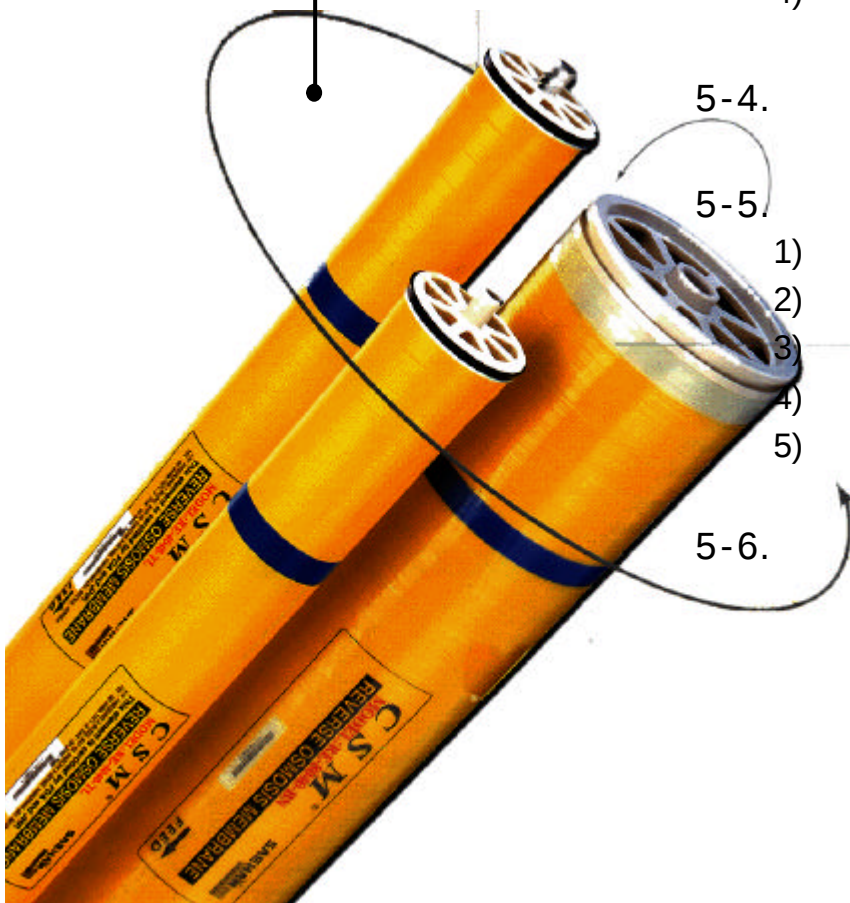
5-4.

5-5.

- 1)
- 2) (oxidation filtration)
- 3) (coagulation)
- 4) (activated carbon filtration)
- 5)

5-6.

(Jelcleer)



5 - 1.

(fouling, scaling)

(salt)

(scaling)

(fouling)

(foulants) 가

■

■

가

■

가 가

CIP(Cleaning In Place)

5

(PRETREATMENT)

2. (SCALE CONTROL)

5 - 2. (SCALE CONTROL)

가 (concentrate) . (concentrate)
 (salt) 가 (scale)
 .
 가
 .
 가
 .

5 - 2.1

Calcium Carbonate	CaCO_3	Silica ()	Si(OH)_4
Calcium Sulfate	CaSO_4	Calcium Silicate	CaSiO_3
Calcium Fluoride	CaF_2	Magnesium Silicate	MgSiO_3
Strontium Sulfate	SrSO_4	¹ Ferrous Silicate	FeSiO_3
Barium Sulfate	BaSO_4		

2가 (ferric ion, Fe^{2+}), (manganic, Mn^{3+}), (aluminum, Al^{3+})

- (salt concentration in concentrate)

(concentrate)

(salt)

(1 -)

(concentration factor)

$$= \frac{1}{1 -}$$

, .

가

가

(concentration polarization)

가

(turbulence)

(spiral wound)

가 10

20%

$$= \frac{1}{1 -}$$

$$= \frac{1}{1 -} / = 1.1 \sim 1.2$$

- LSI (Langelier Stability Index)

LSI

(CaCO₃)

(scale)

가

가 10,000ppm

. LSI가 0

가

0

가

가

LSI

. LSI가

$$LSI = pH - pH_s$$

$$pH_s = (9.3 + A + B) - (C + D)$$

$$A = \frac{\log_{10}[TDS] - 1}{10}, \text{ ppm}$$

$$B = -13.12 + \log_{10}(T + 273) + 34.55$$

$$C = \log_{10}[Ca^{2+} \text{ as } CaCO_3] - 0.4,$$

$$D = \log_{10}[\text{Alkalinity as } CaCO_3]$$

pH_s : Saturation pH, $CaCO_3$ 가

pH

■ SDSI (Stiff and Davis Stability Index)

가 5,000ppm

LSI

가

. TDS가 10,000ppm

LSI

SDSI가

.

$$SDSI = pH - pCa - pALK - K$$

ALK : Total Alkalinity Concentration

K : Ionic Strength

■ (Solubility Product)

(salt)

가 .

$$K_{SP} = []^X \times []^Y$$

K_{SP}

. pH,

. CO_3 (carbonate)

.

가 .

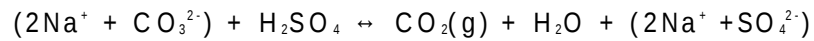
가 .

5 - 3. (SCALE CONTROL)

1) (Acid injection)

(calcium carbonate scale) 가

pH . HCO_3^- (bicarbonate) .
 pH가 6.0 HCO_3^- 80% 가 ¹⁾ .



HCO_3^- CO_3^{2-} (carbonate) pH HCO_3^- 가
 . , pH

·
 · SO_4^{2-} (sulfate)
 (silica) ·
 가

· , pH가 ·
 가
 , (cellulose acetate type)
 (calcium carbonate) pH가 가

·
 (SS) ·
 (multi media filter) ·
 가 가 가

2) (Scale inhibition and dispersion)

(scale inhibitor) (salt)

가 가

¹⁾ 10-10 CO_2 pH

3. (SCALE CONTROL)

■ (scale inhibitor)

SHMP(Sodium Hexa-Meta-Phosphate)가 가

가 . SHMP 20ppm

SHMP

COOH PO₄ 가 1,000 5,000

(polyacrylate)가 . CO₃(carbonate) SO₄(sulfate)

3) (water softning)

(RO system) 가

(calcium), (magnesium), (iron)

■

가 .

가 (Ba, Ca, Mg, Sr)

Na

NaCl

pH

CO₂가

NaCl

가 .

가 50%

10

가

가

가

Na 가 .

Na .

10% NaCl 1.0GPM/ft³ .

1GPM/ft³ NaCl . 가 NaCl

1.5GPM/ft³ NaCl .

가 가 . NaCl 가

■

(brackish water) .

pH가 가 COOH

COOH 가 pH 4.2

HCO₃

HCO₃

HCO₃

Na 가 Na 가

가

HCO₃ 가

가

가

가

pH가 3.5 6.5

. pH가 (mineral acid) 가 가
pH

:

. 가 (Na)

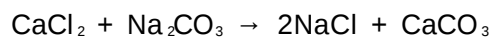
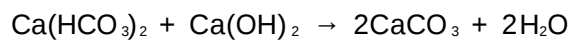
: (cation) 가

(Chlorine)

. 가

4) (Lime softening)

(Ca(OH)₂) CO₃ CO₃
(soda ash, Na₂CO₃) 가
200 (brackish water)



(sodium aluminate) 2 (ferric chloride)
(calcium carbonate), (silicic acid complex),
(aluminum oxide), (iron) . 70
(silicic acid) (lime)

5

(PRETREATMENT)

3. (SCALE CONTROL)

(magnesium oxide)

1ppm

(Ba),

(Sr)

가

pH

가

가

(floculent,

)

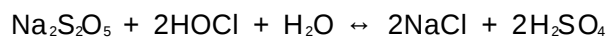
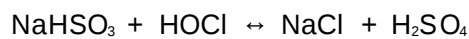
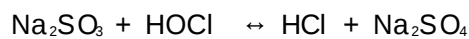
5 - 2.2 (scale)

Carbonate		HCO ₃ CO ₂
	/	
Sulfate		
	/	
		(Sulfate) 가
() Silica		
	(dispersant)	

5 - 4.

가 ()
 (PA type)
 가 (CA type)
 (NaOCl)
 (chloramine)
 (THM)

Na_2SO_3 (sodium sulfite), NaHSO_3 (sodium bisulfite, SBS), $\text{Na}_2\text{S}_2\text{O}_5$ (sodium metabisulfite), $\text{Na}_2\text{S}_2\text{O}_3$ (sodium thiosulfate)
 1ppm 가



가
 ORP . ORP 가
 175 mV
 (-100 -200 mV) (SQ)
 (+)

5

(PRETREATMENT)

5.

5 - 5.

(silt),

, ,

,

.

.

.

(alum), 2 (ferric chloride),

(cataionic polyelectrolyte)

.

(CIP)

.

.

가

SDI가

SDI 5

, 4

(coagulation), (flocculation),
(media - filtration), (micro - filtration), (ultrafiltration)

.

1) (media filtration)

(SS, suspended solids)

, (ganet), (anthracite)

(gravity filter) (pressure filter)

.

■

. 가 가

.

.

.

.

가

가

.

5.

가

■

20 GPM/ft²5 GPM/ft²

가

(anthracite)

가

(SS)

(aluminium silicate)

가

(anthracite)

가

(silica sand)

가

가

(garnet)

(silica sand)

(

anthracite)

(anthracite)	0.8 - 0.9 mm	54 lb/ft ³	14" - 16"
(garnet)	30 × 40 MESH	130 lb/ft ³	8" - 10"
(garnet)	8 × 12 MESH	144 lb/ft ³	6"

(multi-media filter)

10psig (0.7

Kg/cm²)

가

가

15psig(1.0 Kg/cm²)

(SS)

5.

가 가

15GPM/ft²

50%

(Depth Filtration)

가 (mechanism)

(flowrate) 가 (inertial force) (momentum)

(diffusive force) 가 (submicron)

(random motion)

(hydrodynamic force)

ment)

(rotational move-

가

가

(van der waals force)

가 (shear force)

2) (oxidation filtration)

(Fe²⁺, Mn²⁺)

가

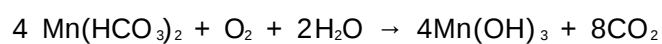
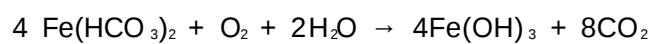
가 2가

(chlorine)

가 5 ppm

2가

가

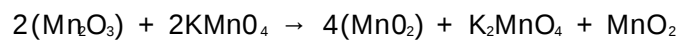


5.

(Fe₂) (Mn₂) pH
 . SDI가 5
 가 0.1 ppm . 가
 가 (FeCO₃) 가 Fe₂
 가 .
 가 .
 . pH 6 가 0.5 ppm
 (Fe₂) 가 4 ppm
 (Cl₂), (KMnO₄) . (greensand)
 birm .

■ (greensand filtration)

(galuconite sand, green sand) , (manganese
 oxide) (manganese greensand) .
 , , (H₂S)
 . 0.01 ppm .
 (1 /ft³) .



2 ppm (Fe₂)
 . 가 가 .

	(Cl ₂)	(Cl ₂)
Fe ₂ I ppm(ION)	1.3 ppm	1.3 ppm
Mn ₂ 1 ppm(ION)	2.6 ppm	2.6 ppm
H ₂ S 1 ppm(SULFUR,S)	4.4 ppm	5.0 ppm

■ BIRM FILTRATION

birm filtration (Fe₂) pH
 가 가 . birm 가 . 가
 .

3) (coagulation)

■

(zeta potential),
 (van der waals force),

가 (+)가 SS 가
 가 .

5.

■

가
(foulant)가 . (anti-scalant)
SDI
SDI가

CIP 가
가

가

(NaCl) . 1% (chlorine) 가

■

	CATIONIC POLYMER	POLYACRYL AMINE
	CATIONIC DETERGENT	DODECYL AMINE
	ANIONIC DETERGENT	DODECYL BENZENE
	FERROUS SULFATE	FeSO_4
	FERRIC SULFATE	$\text{Fe}_2(\text{SO}_4)_3$
	FERRIC CHLORIDE	FeCl_3
	ALUMINUM SULFATE	$\text{Al}_2(\text{SO}_4)_3$, ALUM
	ALUMINUM POTASSIUM	$\text{Al}_2(\text{SO}_4)_3\text{K}_2\text{SO}_4$
	PAC(POLYALUMINUM CHLORIDE)	$\text{Al}(\text{OH})_n\text{Cl}_{6-n}$

4) (activated carbon filtration)

(activated carbon) , ,
 . (van der waals)
 . , humic acid
 fulvic acid .
 (chlorine) (chloramine)

가 .

■ (THM)

(THM) .
 가 .
 ,
 . THM (UV)
 . UV가 THM Cl^-
 .
 THM
 EBCT(Empty Bed Contact Time) .
 가 EBCT .
 3 EBCT가 .

$$V = (Q \times \text{EBCT}) \times 97.48$$

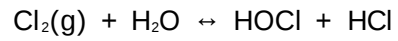
V : (FT³)

Q : (water flowrate, GPM)

■ (chlorine) (chloramine)

(chlorine) (hypochloric acid) (HCl)

가



가

1g Cl_2 5g
10

6 1

(SS)

12 GPM/ft²

가

10

NaOH(pH 10)

(chloramine)



5)

(cartridge microfiltration)

5

(PRETREATMENT)

5.

가

가

5 25 μ m

(nominal)

60% 80%

가

가

가

1 μ m

가

DEPTH FILTER

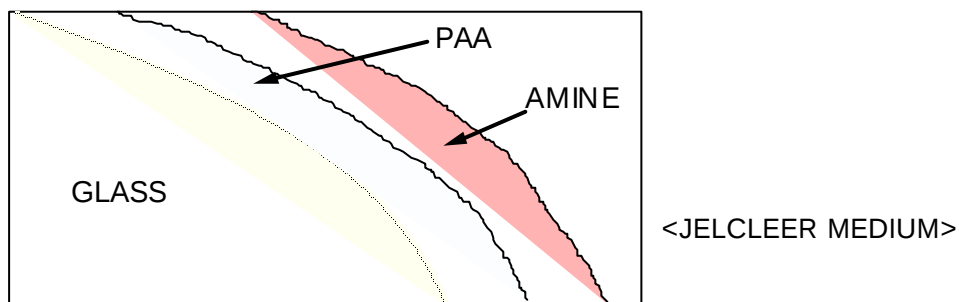
가

5 - 6. (JELCLEER)

1.

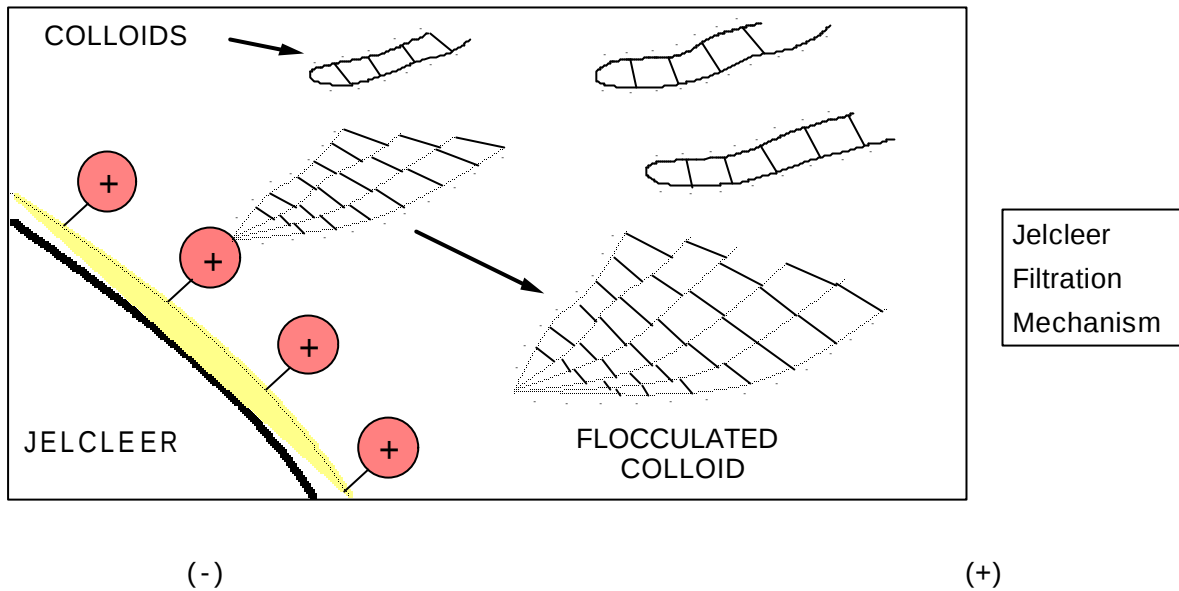
가
, () 가
(foulants) 가 .
가
가
가
가
가
(JELCLEER filtration system) .

2.

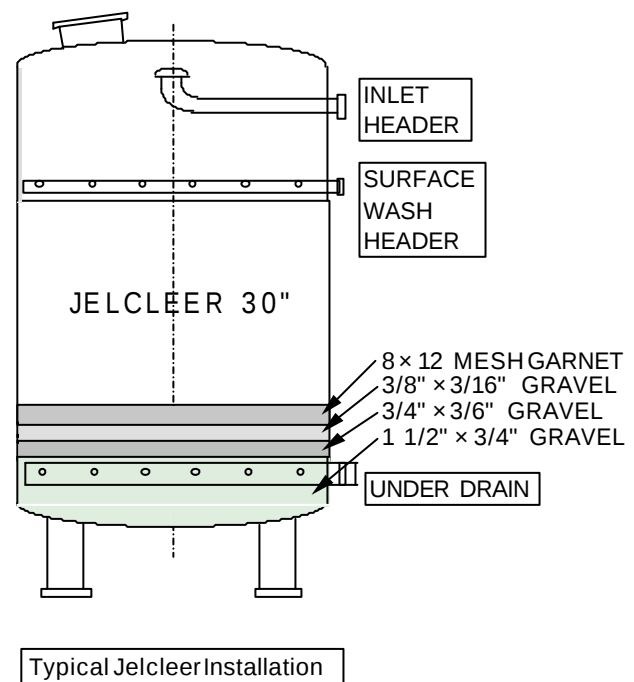


(JELCLEER) (polyacrylate ester) 4
(quaternary amine) (glass bead) .
(polyacrylate ester)
(housing)

3.



(+) 가



4.

1)

- :
- : 97 pounds/ft³
- : 0.260 0.330 mm
- : 1.7
- : 2.3 2.6

2) 가

- PH : 4 9
- : 2 50
- : 30 Inches
- : 0.1 ppm
- : 3 ppm
- : 12 GPM/ft² (25)
- 가 : 2 7 GPM/ft²

3) 가

가 가 가 .

■ : 가 (mudball)

■ : SDI 가 가

4)

■ .

■ 가 가가

5

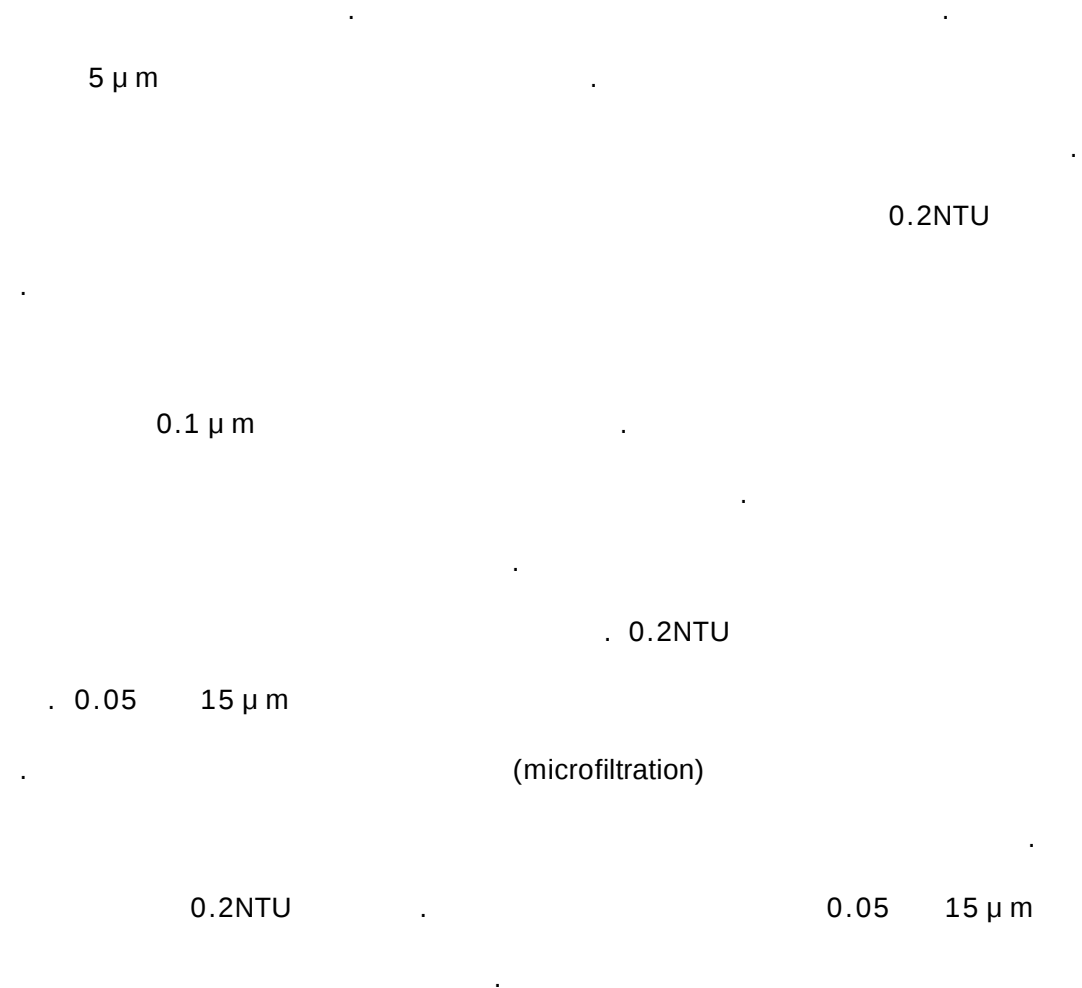
(PRETREATMENT)

6. (JELCLEER)

-
- 가
-
- 가

5. (jelcleer)

가 (multi-media filtration)



6.

1)

가 10NTU 10 PU
(Platinum Unit) 0.2NTU,
SDI 1 5

2) (foulant)

가 (fouling)
(cleaning) 가 가
가 10NTU가
(pilot test)

3)

0.2NTU , 5PU , SDI 1 5
10NTU 가
(
pH,).

4)

0.2NTU , 4 SDI
가 가
가 (fouling)

5

(PRETREATMENT)

6. (JELCLEER)

5)

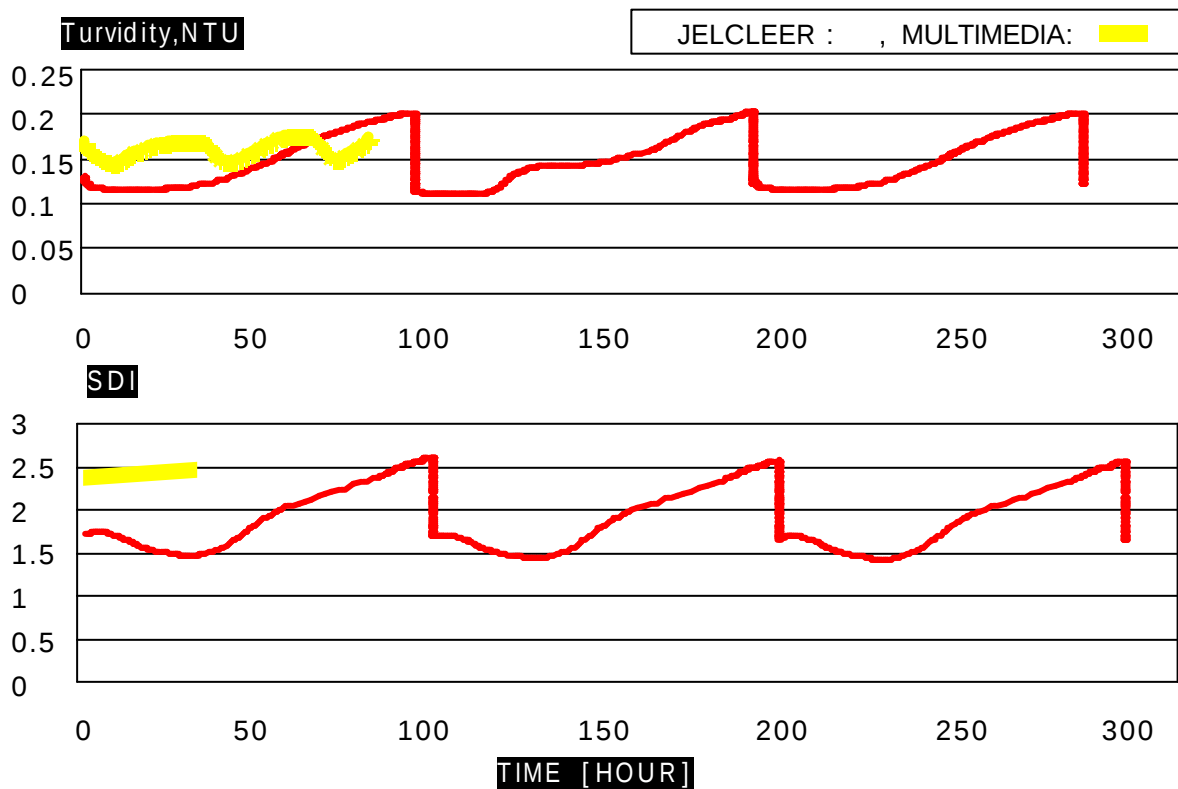
0.2NTU, SDI 5

가

7. (pilot test)

1) OCHACO

- (oregon) , PRINEVILLE .
- (multimedia filtration) .
- , .
- 5 GPM/ft² .



(PRETREATMENT)

6. (JELCLEER)

5

DIAMETER R, u	FEED		FILTRATE		REMOVAL [%]
	[No/ml]	[%]	[No/ml]	[%]	
0 - 1	1.14×10^6	40.7	9.21×10^4	37.5	91.9
1 - 2	1.14×10^6	40.7	1.23×10^5	50	89.2
2 - 3	2.76×10^5	9.9	3.07×10^4	12.5	88.9
3 - 4	9.21×10^4	3.3	-	-	100
4 - 5	6.14×10^4	2.2	-	-	100
5 - 6	3.07×10^4	1.1	-	-	100
6 - 7	-	-	-	-	-
7 - 8	3.07×10^4	1.1	-	-	100
8 - 9	-	-	-	-	-
9 - 10	3.07×10^4	1.1	-	-	100
TOTAL	2.79×10^6	100	2.45×10^5	100	-

2) ()

■ : 1997. 02. 3 02. 14 (10)

■ : () 1

■ : () →

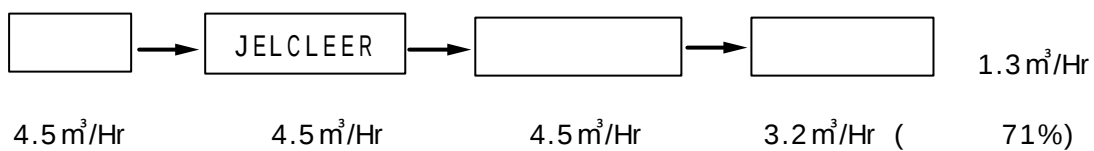
■ : () 1

■ : ()

■ : ()

()

■ (pilot)



■

1. : SS .

2. : 가 .

	(JELCLEER)				M/F		()			()		
							PH	COD		PH	COD	
	SS		SS									
2/4	10.1	2.1	1.9	0.31	1.3	1.3	6.7	25	5563	5.7	0	100
5	9.6	1.9	1.5	0.30	1.2	1.3	6.9	30	5832	5.6	0	95
6	11.3	2.2	2.1	0.30	1.3	1.3	6.8	28	5936	5.8	0	90
7	9.3	2.1	1.8	0.29	1.3	1.3	6.5	26	5995	5.7	0	84
8	10.5	2.3	1.3	0.27	1.3	1.2	6.7	22	6021	5.9	0	83
9	13.0	3.1	1.9	0.27	1.3	1.3	6.7	28	6341	5.8	0	79
10	12.1	1.9	2.0	0.26	1.3	1.3	6.8	30	6531	5.6	0	75
11	11.5	2.1	1.6	0.25	1.3	1.3	6.8	29	6645	5.7	0	76
12	12.1	2.0	1.4	0.25	1.3	1.3	6.7	28	5931	5.8	0	75
13	11.4	2.1	1.5	0.24	1.3	1.3	6.8	25	5865	5.6	0	73

3) LG FW

■ : 1997. 01. 14 01. 20

■ : LG 2

■ :

■ : LG () 2

■ : ()

■ : LG () /

() /

■

: SS .

DATE					
01/14	09:30 - 10:00	0.28	0.20		Q = 8m ³ /Hr
01/14	15:00 - 15:30	0.34	0.18		
01/15	09:30 - 10:00	0.30	0.17		
01/15	15:00 - 15:30	0.33	0.10		
01/16	09:30 - 10:00	0.38	0.07		Q = 5m ³ /Hr
01/16	15:00 - 15:30	0.40	0.13		
01/17	09:30 - 10:00	0.43	0.10		
01/17	15:00 - 15:30	0.33	0.17		
01/18	09:30 - 10:00	0.34	0.08		
01/18	15:00 - 15:30	0.37	0.11		
01/19	09:30 - 10:00	0.41	0.14		
01/19	15:00 - 15:30	0.44	0.13		
01/20	09:30 - 10:00	0.39	0.10		
01/20	15:00 - 15:30	0.38	0.09		

CSM

Reverse Osmosis Membrane

6.

6-1.

6-2.

1)

2)

6-3.

1)

2)

3)

6-4.

1)

2)

3)



SAEHAN

(주)새한

6 - 1 .

가

가

(CIP)

가

¹⁾

가

가

¹⁾
가

0.1~0.2 μm

(CIP)

가

가

6 - 2 .

1)

가

가 .

- : , SDI, , , pH, TDS,
-
-
-
-
- ,
-
-

2)

- 가

- 가
가

- 가

30 . 가 (60psig)

. 30

가

- 가

- (4.0 kg/cm²
) 가

-

-

- , pH, ,
가

- 1 가 .
- .
- 가
- .

6 - 3 .

1)

- ()
(sand filter), (multi-media filter),
(activated carbon filter)
- (free chlorine)
- (softner)
-
- SDI(Silt Density Index)
- SDI
- pH
- pH
-

2)

■

■ LSI(10,000 ppm) SDSI(10,000 ppm)

■

가 가

■

가

(가

가)

■

■

,

■

TDS, TDS

가

(가

가)

■

$$\times \text{TDS} + \times \text{TDS} = \times \text{TDS}$$

3.

■

■

가 가



3)

■

(, 가)

■

■

■

(, , , , pH,)

6 - 4 . (data normalization)

, 가

가

1

■ (fouling, scaling)

■

■ (O-ring, ,)

■ ()

■ (normalized salt rejection)

■ (normalized differential pressure)

■ (normalized permeat flux)

■ 가 (normalized operating pressure,
)

4. (DATA NORMALIZATION)

1) (salt rejection)

TDS

가

$$= \frac{\text{TDS} - \text{TDS}}{\text{TDS}} \times 100$$

TDS

TDS

$$\text{TDS} = \frac{\text{TDS} + \text{TDS}}{2}$$

$$= \frac{\text{TDS} - \text{TDS}}{\text{TDS}} \times 100$$

$$\text{TDS} = \text{TDS} \times \frac{1}{1 - \quad}$$

가

(가)

1가

2가

TDS

가

TDS

TDS

2).

2) (pressure differential, differential pressure, delta-P, ΔP)

가

1

가

가

가

$$= \frac{X(2X + \quad)^{1.5}}{(2X + \quad)^{1.5}}$$

3) (normalized permeate flowrate)

$$Q_N = Q_0 \times \frac{P_I - \frac{DP_I}{2} - P_{PI} - p_I}{P_O - \frac{DP_O}{2} - P_{PO} - p_O} \times \frac{TCF_I}{TCF_O}$$

$$\begin{aligned} P_I &= \quad, & P_O &= \\ P_I &= \quad, & P_O &= \\ P_{PI} &= \quad, & P_{PO} &= \\ \pi_I &= \quad^{3)}, & \pi_O &= \\ &(\quad + \quad)/2 \\ TCF_I &= \quad^{4)}, & TCF_O &= \\ Q_N &= \quad, & Q_O &= \end{aligned}$$

2)

(TDS)

3) (10-11,12)

4) (10-22)

가
가 , (),
.

CSM

Reverse Osmosis Membrane

7.

7-1.

7-2.

7-3.

7-4.

7-5.

7-6.

7-7.

7-8.



7-1.

(silt), , ,

가

(CIP, Cleaning In Place) .

가

가 .

(,)

가

(PA type)

pH

.

, :

(EDTA,)

.

().

.

7

(CLEANING IN PLACE)

2.

7-2.

(,)

(SDI , ,)

(, ,)

(, , , ,)

가

(, , , ,)

((BaSQ), (SiO₂))

7 - 3 .

SDI

(0.45 μ m)

가

가

7

(CLEANING IN PLACE)

4.

7 - 4 .

- (normalized permeate flux) 15%
- (가 (normalized operating pressure) 15% 가)
- (normalized salt passage) 15% 가
- (25 48)
- 15% 가
- , , pH, ,
- 가 가 (data normalization)¹⁾
- , 가
- 가 가

¹⁾ 6 6-4

5. (CLEANING TANK)

7-5. (cleaning tank)

가

1.2

7

(CLEANING IN PLACE)

6.

7 - 6 .

- 1) pH .
- 2) .
- 가 () .
- 3) pH가 pH . pH가 0.5
- 가 가 . 1
- 4) .
- 5) 30 .

ELEMENT DIAMETER (INCH)	FEED FLOW RATE PER PV	
	GPM	m ³ /hr
2.5	5	1.1
4	10	2.3
8	40	9

- 6) . 20
- () .

7

(CLEANING IN PLACE)

7.

7-7.

CSM

(가)

(pH)

가

pH

pH

()	50	35	30	25
pH	3 - 10	2 - 11	2 - 11.5	2 - 12

(%)

Inorganic	0.2% (Hydrochloric Acid) 0.5% (Phosphoric Acid) 2.0% (Citric Acid)	HCl H ₂ PO ₄ C ₃ H ₄ (OH)(CO ₂ H ₃)
Metal Oxides	0.5% (Phosphoric Acid) 1.0% (Sodium HydroSulfite)	H ₂ PO ₄ Na ₂ S ₂ O ₄
(沈泥) Silt	0.1% (Sodium Hydroxide) 0.025% 12 (Sodium Dodecylsulfate)	NaOH
BioFilms	0.1% (Sodium Hydroxide) 1.0% -4 Sodium Ethylene Diamine Tetra-acetatic Acid	NaOH Na-EDTA
Organics	0.025% 12 (Sodium Dodecylsulfate) 0.1% 3 (Sodium Triphosphate)	Na-DDS Na ₅ P ₃ O ₁₀
Silica	0.1% (Sodium Hydroxide) 1.0% -4 Sodium Ethylene Diamine Tetra-acetatic Acid	NaOH Na-EDTA

7

(CLEANING IN PLACE)

8.

7 - 8 .

Chlorine	0.1ppm	- 가
Sodium BiSulfite(SBS)		
Hydrogen Peroxide	0.2 %	- pH 3 25 가
Peracetic Acid	0.2 %	- 가
Formaldehyde	0.5 3 %	-
4 Iodine Quaternary Germicide		- ,

CSM

Reverse Osmosis Membrane

8.

8-1.

8-2.

8-3.

8-4. Code Line



1.

8 - 1 .

1 : .

2 : (port) .

3 : (end closure) .
((port) .)

4 : (interlock) (securing ring, locking ring set).

.

8 - 2 .

1 : (element interface hardware)

- ()
- (End - connector)

2 : ¹⁾() .

3 : .

- , ,
-
- (antitelescoping) ²⁾

- 50% (,)
- ()
- O - (O-ring) (interconnector) O - (O-ring)

- (가)

· 가	
·	
· / (50/50) 가	
·	
· 가 (brine seal)	

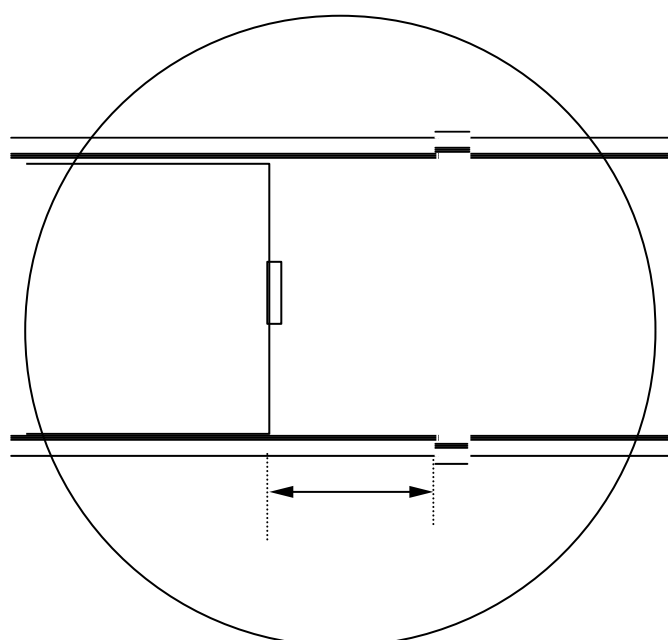
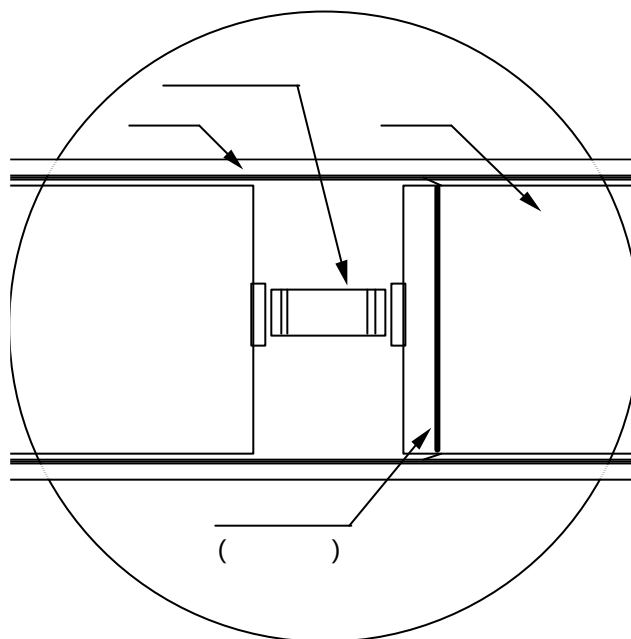
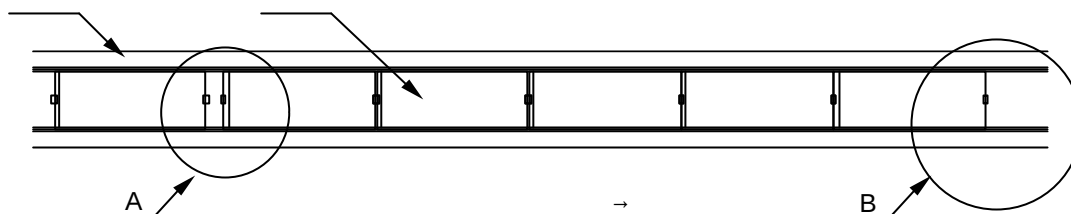
- ()

¹⁾ (brine seal) 가

²⁾ 가 .(3)

가 . (3 가 .(3)

2.



8 - 3.

1 : (shell) (head seal)
(
가 .)

2 : (head)
- (head) (.)
- (head seal) .

3 : (interlock) (.)
(.)

4 : .

CSM

Reverse Osmosis Membrane

9.

9-1.

9-2.

1)

■ / /
■ pH/

2)

■ TDS
■
■

9-3.

1)

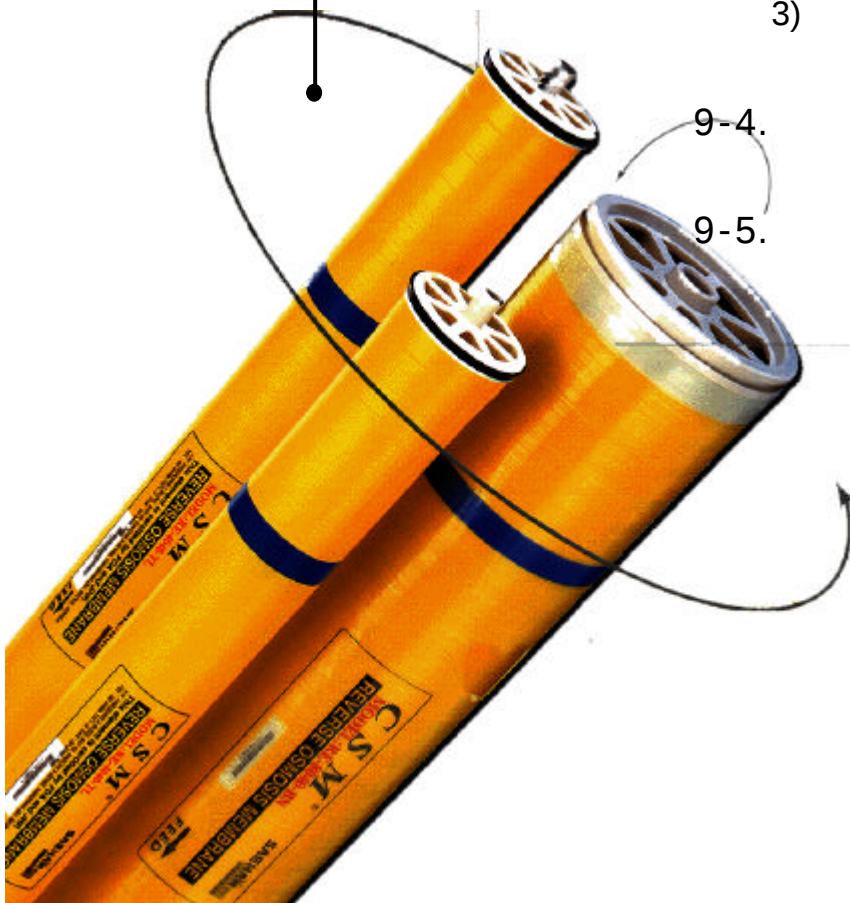
2)

3)

9-4.

가

9-5.



SAEHAN

(주)새한

9 - 1.

가 (permeate flux) 가 (salt rejection) . ,
가 (fouling) (CIP) ,
(scaling) .
가
가
가
가 (system
performance normalization)¹⁾ 가
²⁾ .

¹⁾ 6 6-4

²⁾ ()

9 - 2.

가

.

가

.

,

.

.

가

.

-

-

,

가

,

.

-

.

-

가

가

.

.

$$(\%) = \left(1 - \frac{\text{TDS}}{\text{TDS}} \right) \times 100$$

가

가

.

,

.

$$(\%) = \left(1 - \frac{\text{TDS}}{\text{TDS}} \right) \times 100$$

, TDS

TDS

.

2.

$$TDS = \frac{TDS + TDS}{2}$$

90~99 %

· , , , . 2가
가 1가 pH
가 , (sulfate)
2가 , (chloride) 1가 .

1)

(Calibration)

■

3

가 가
(probe)
가
(probe)가 가 (trap)
(probe)

■

가 (Fouling) 가
가

가 가 . 가 "
(bucket-and-stopwatch method)" .

. 가

2.

- 가
(CIP tank)
- "
(mass balance)
- 가
(mechanical pressure guage)
- 가
가
1/4
(throttle valve)
- (quick-connect fitting)
- (重荷) (deadweight tester)
- pH
pH
- 가
가³⁾

³⁾ 10-22

2.

가

2)

가 ,

가

■

TDS

TDS

2

1

, 3 2

⁴⁾ 1

TDS

(base line)

■

(interconnector)

(plastic tube)

(Central Tube)

TDS

# (Membrane #)	TDS (ppm)
# 1 ()	12
# 2	10
# 3	14
# 4	10

⁴⁾

CSM-PRO2000

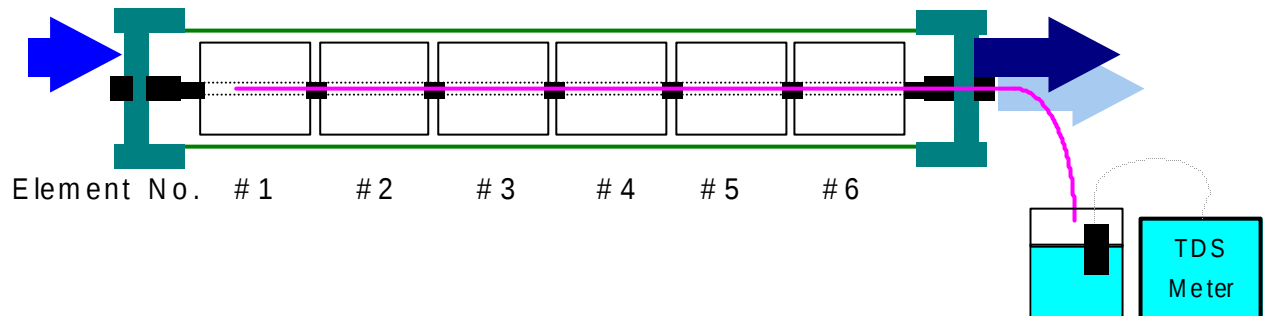
9

(TROUBLE SHOOTING)

2.

# 5	26
# 6 ()	18

#5



가

가

[illegible]

3.

가

가

(auto shut-off valve)

■

가

가

가

가

가

(0.1ppm)

. 3가 (ferric

3

ion)

가 (ferric ion)

3가

가

/

가

■

가

(ham-

mering)

가

(telescop-

ing)⁵⁾

가

⁵⁾

(telescoping)

(central pipe)

(spiral wound)

(O - ring)

가 (throat valve)

■

- X (compound x degradation)

(CA type)

가

X(compound X)

가

가

.

(CA type)

(PA type)

.

(ammonium sulfate)

3.

(SBS)

X

2) (Tail-end)

가

가

(suspendid solid)

, pH

■

$$= \frac{1}{1 - \quad}$$

75%

4

가

가

, 가

75%

90%

가

가

10 (

4)

가

(Scaling)

(Fouling)

가

6)

(turbulence)

가

6) 3

3.

가

- (scaling) (fouling)

가 (Suspended Solid)

(sulfate) 가 (silica) 가

7)

가

(telescoping)

15%

(CO₃)

LSI

⁸⁾ 2.0 (sulfate)

가

pH

가

SHMP

(sulfate)

Orthophosphate

⁷⁾ 가

tion polarization)

가
(concentra-

⁸⁾ 5 5-2 LSI

3.

3

가

SHMP

5 ppm

■ pH

pH가

가

. pH

가

, HCO_3^-

가

pH

(Feed Channel)

가

pH 가

가

pH가

■

가

가

가

가

(mechanical damage) 가

■

가

3.

가

가 가

가 . PVC
().

■

가

■

■ 가

가 , 가

■

가

CSM

■

가

3.

가 .

가 .

(flux balance)

4)

■

. (SBS, sodium bisulfite)

가

가 .

,
가

가

가

. ,
.

(fouling)

. , 가
. , 가

■

가

가

가

가 .
,

가

■

가

■

. 가

pH

pH

, pH

가 11

. PA

CA

PA

가
pH

CSM

pH가

⁹⁾

⁹⁾ 7 7-7

9 - 4. 가

가 . 가 , 가
가 .

가 , ,
15 % 가

가 가

가

가 . , pH

1) (Front-end) 가

■

가 가
가 . 20 , 30 , 40
10

가 .

가 가
가 .

4. 가

pH ,

.

- (breakthrough)
 , , (Diatomaceous Earth)
 가 .

5

, (diatomaceous earth)

.

.

가 . 1 가
 (foulant)
 () .

.

(coal) (coconut
 shell) 95 .

(backwashing) . SDI

.

■

1 .

.

.

.

.

. ,

.

- (Telescoping,)

4. 가

(leaf)가

, 가 가

2) (Tail-end) 가

가

(homogeneous) 가 가
(ammonium bifluoride)
(silicate)

(homogeneous)

가

(foulants) 가 가
(homogeneous)

4.

가

(barium sulfate)

3)

가

■ (Brine Seal, U - Cup)

가

■

가
(fouling)

가

가

가

■

(fouling)
(PA type)

4)

가

■

가

가

9 - 5.

1)

(foulant) . (foulant)
 가
 . (foulant) 가
 가 . , 가
 .

2)

가 가 가
 가
 . 가 15
 %, 2000 ppm NaCl, 25 , 225 psi(15.3 Kg/cm²)
 , .

3)

(foulant)가
 . pH
 3, 4 가 가
 (sulfate) (silica) pH가
 0.1 HF(hydrofluoric acid)
 .

4)

300
 가
 . 가 가
 .
 가 가 ,

5.

5)

(foulant)

가

가

가

가

(polarized light)

(foulant)

(calcium sulfate)

6) FT - IR

(peak)

FT - IR

7) SEM / ED X

CSM

Reverse Osmosis Membrane

10.

10- 1.

10- 2. 가

10- 3. 가

10- 4.

10- 5.

10- 6.

10- 7.

10- 8.

10- 9.

10-10. CO₂ pH

10-11.

10-12.

10-13. CO₂가

10-14.

10-15.

10-16.

10-17.

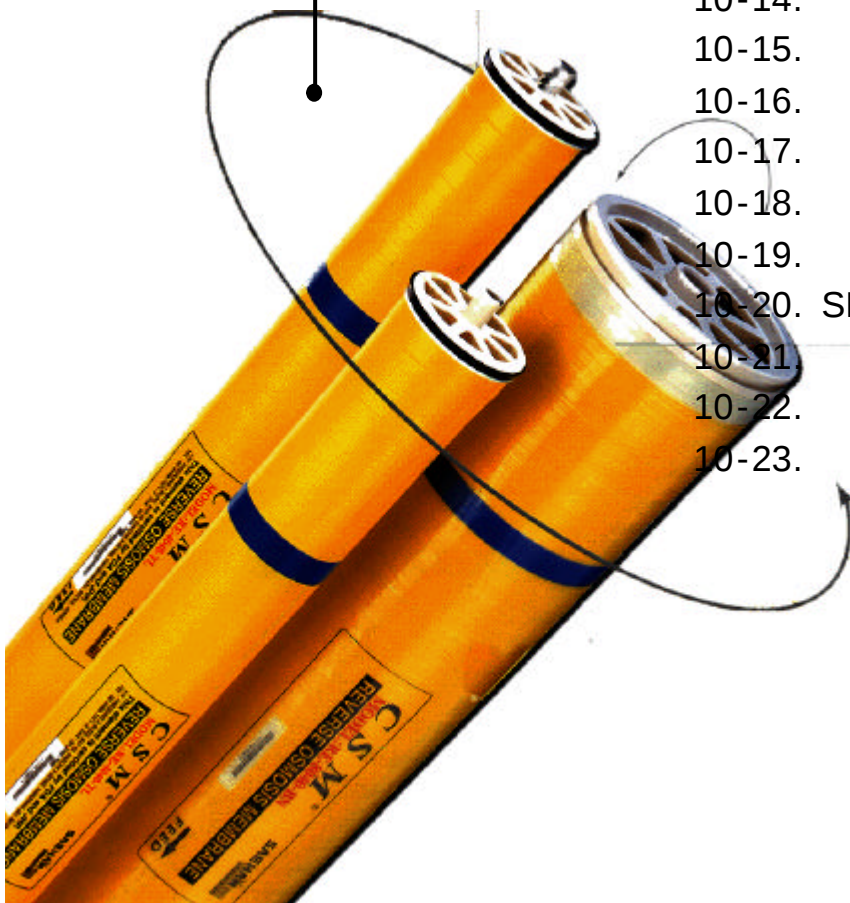
10-18.

10-19.

10-20. SDI

10-21. CSM
10-22. (TCF)

10-23.



SAEHAN

(주)새한

10-1.

()

■

—

— 1

—

— , , 가

18.0-20.0%,

SBS 1.0%

. 1

1.0 %

SBS

—

, ,

■

— , , ,

()

가 .

—

가

■

()

—

— 25

150 ppm

—

, , ,

—

, ,

1.

- 45
- SDI 5.0, 1NTU
-

■ ()

-
- Ca, Ba, Sr
- (Water Hammer)
- (antiscalant) ()

■ (CIP, Cleaning In Place)

- 10 15% 가 ()
- CIP
- (, , 가)

■

-
- (Back Pressure) 5 psig
- pH가 2.0 , 11.0
- ()
- ()

■

- 3
- : 10% , 가 : 10%
-
- 3

2. 가

10-2. 가

(Check list)

1		
2	pH ()	
3		
4	(check valve)가	
5		
6		
7		
8		
9	(bypass)	
10	(chlorine) , 가	
11		
12	(time delay relays)	
13		
14	,	
15	가	
16		
17		
18		
19		
20		
21	가 ,	
22	가	
23		
24	, , 가 가	
25	가	
26	가	
27	가	
28	0.3bar(5psig) 가	
29	가 () 가	
30		

10 - 3. 가

/			/	/	/	/	/	/	/
	가								
	(mg/ ℓ)								
	SDI								
	(NTU)								
	()								
pH									
(psig, Bar, kg/cm ²)									
	1								
	2								
(psig, Bar, kg/cm ²)									
	1								
	2								
(gpm, M3/Hr)	R/O								
	(%)								
(μs/cm) TDS(mg/l)									
	(%)								

10 - 4.

			Equiv.Weight	mg CaCO ₃ / ℓ	eq/ ℓ
	NH ₃	17.0	17.0	2.94	0.0588
	CO ₂	44.0	44.0	1.14	0.0227
()	SiO ₂	60.0	60.0	0.83	0.0167
	Al ⁺⁺⁺	27.0	9.0	5.56	0.111
	NH ₄ ⁺	18.0	18.0	2.78	0.0556
	Ba ⁺⁺	137.4	68.7	0.73	0.0146
	Ca ⁺⁺	40.1	20.0	2.50	0.0500
	Cu ⁺⁺	63.6	31.8	1.57	0.0314
2가	Fe ⁺⁺	55.8	27.9	1.79	0.0358
3가	Fe ⁺⁺⁺	55.8	18.6	2.69	0.0538
	H ⁺	1.0	1.0	50.0	1.0000
	Mg ⁺⁺	24.3	12.2	4.10	0.0820
	Mn ⁺⁺	54.9	27.5	1.82	0.0364
	K ⁺	39.1	39.1	1.28	0.0256
	Na ⁺	23.0	23.0	2.18	0.0435
()	HCO ₃ ⁻	61.0	61.0	0.82	0.0164
()	CO ₃ ²⁻	60.0	30.0	1.67	0.3333
	Cl ⁻	35.5	35.5	1.41	0.0282
	F ⁻	19.0	19.0	2.63	0.0526
	OH ⁻	17.0	17.0	2.94	0.0588
	I ⁻	126.9	126.9	0.39	0.0079
	NO ₃ ⁻	62.0	62.0	0.81	0.0161
(tri - basic)	PO ₄ ³⁻	95.0	31.7	1.58	0.0315
(di - basic)	HPO ₄ ²⁻	96.0	48.0	1.04	0.0208
(mono - basic)	H ₂ PO ₄ ⁻	97.0	97.0	0.52	0.0103
	SO ₄ ²⁻	96.1	48.0	1.04	0.0208
	HSO ₄ ⁻	97.1	97.1	0.52	0.0103
	SO ₃ ²⁻	80.1	40.0	1.25	0.0250
	HSO ₃ ⁻	81.1	81.1	0.62	0.0123
	S ²⁻	32.1	16.0	3.13	0.0625
()	SiO ₂	60.0	60.0	0.83	0.0167

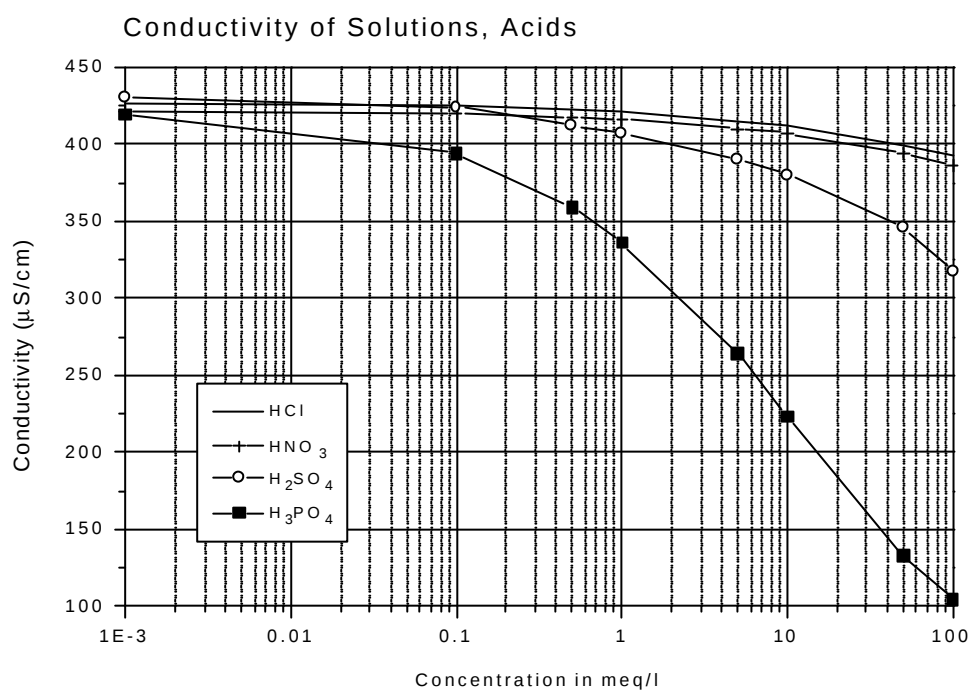
10-5. (海水)

		(mg/L)
		0.05
		152
		65
		410
		19700
		1.4
		< 0.02
		1310
		<0.01
		< 0.7
		390
	()	0.04~8
		10900
		13
		2740
TDS		35000 mg/L
pH		8.1

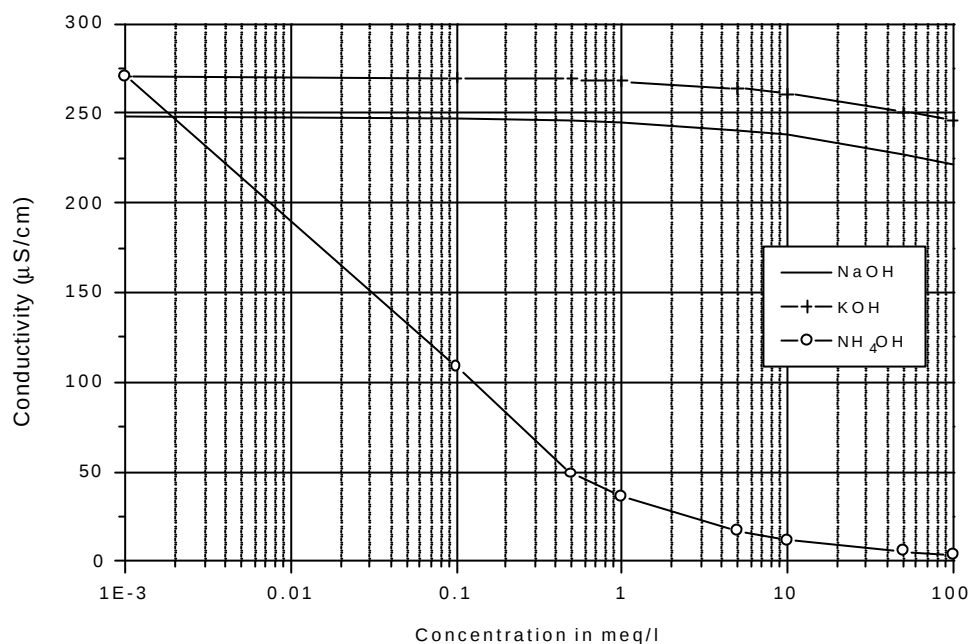
10 - 6. ()

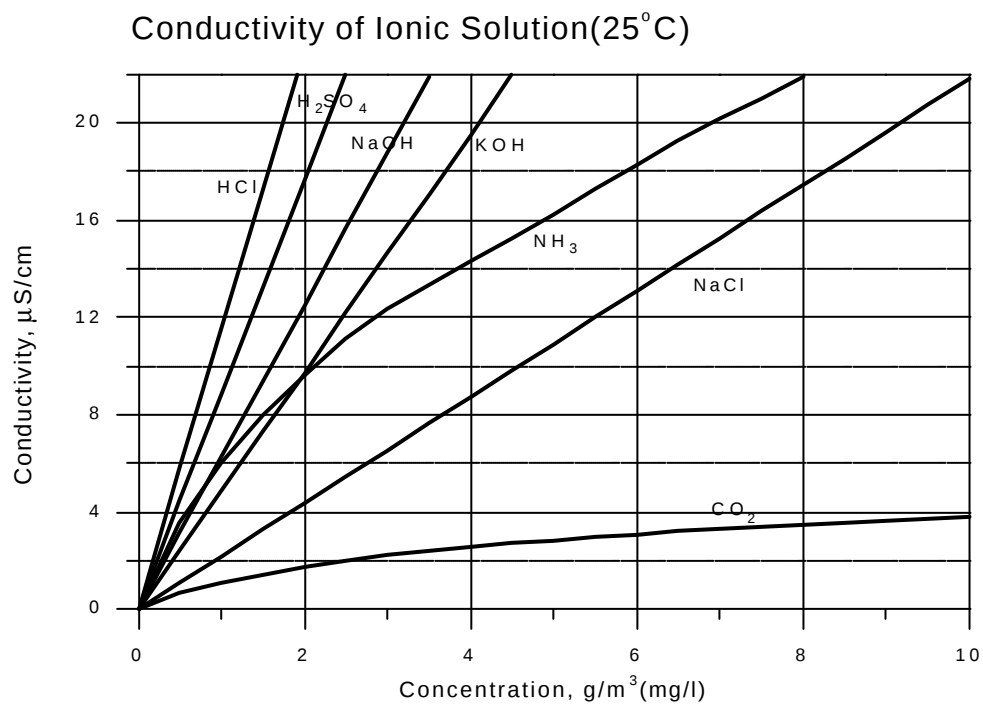
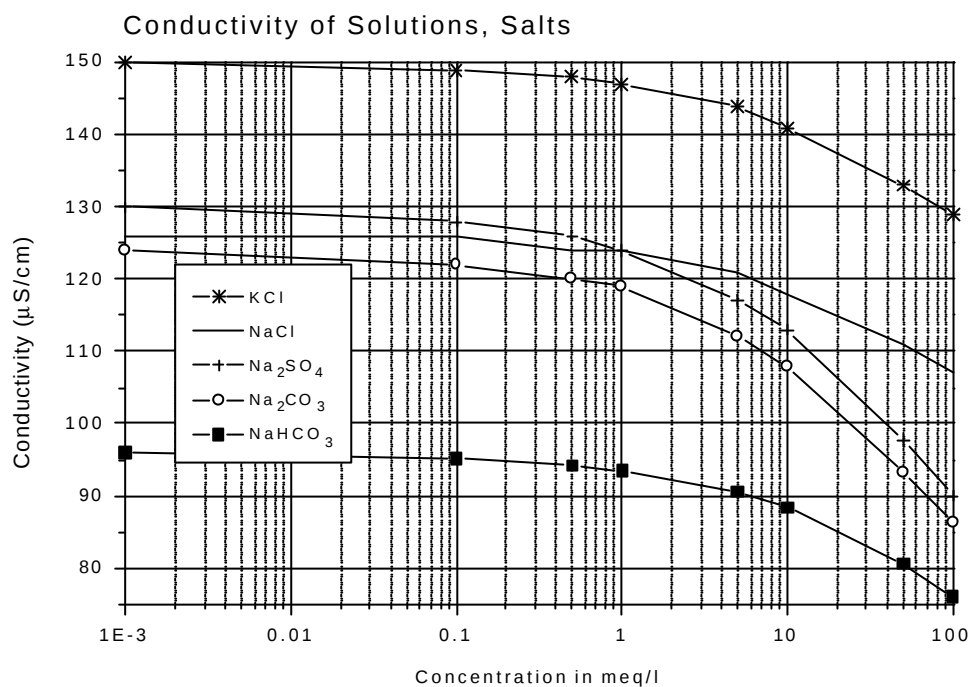
		()	(Solubility product)	- Log K
	Al(OH)_3	20	1.9×10^{-33}	32.7
	BaCO_3	16	7×10^{-9}	8.15
	BaSO_4	25	1.08×10^{-10}	9.97
	CaCO_3	25	8.7×10^{-9}	8.06
	CaF_2	26	3.95×10^{-11}	10.61
	CaSO_4	10	6.1×10^{-5}	4.21
	CuS	18	8.5×10^{-45}	44.07
2	Fe(OH)_3	18	1.1×10^{-36}	35.96
3	Fe(OH)_2	18	1.64×10^{-14}	13.78
	PbCO_3	18	3.3×10^{-14}	13.48
	PbF_2	18	3.2×10^{-5}	7.50
	PbSO_4	18	1.06×10^{-8}	7.98
	MgNH_4PO_4	25	2.5×10^{-13}	12.6
	MgCO_3	12	2.6×10^{-5}	4.58
	Mg(OH)_2	18	1.2×10^{-11}	10.92
	Mn(OH)_2	18	4×10^{-14}	13.4
	NiS	18	1.4×10^{-24}	23.85
	SrCO_3	25	1.6×10^{-9}	8.80
	SrSO_4	17.4	2.81×10^{-7}	6.55
	Zn(OH)_2	20	1.8×10^{-14}	13.74

10-7.



Conductivity of Solutions, Alkalies





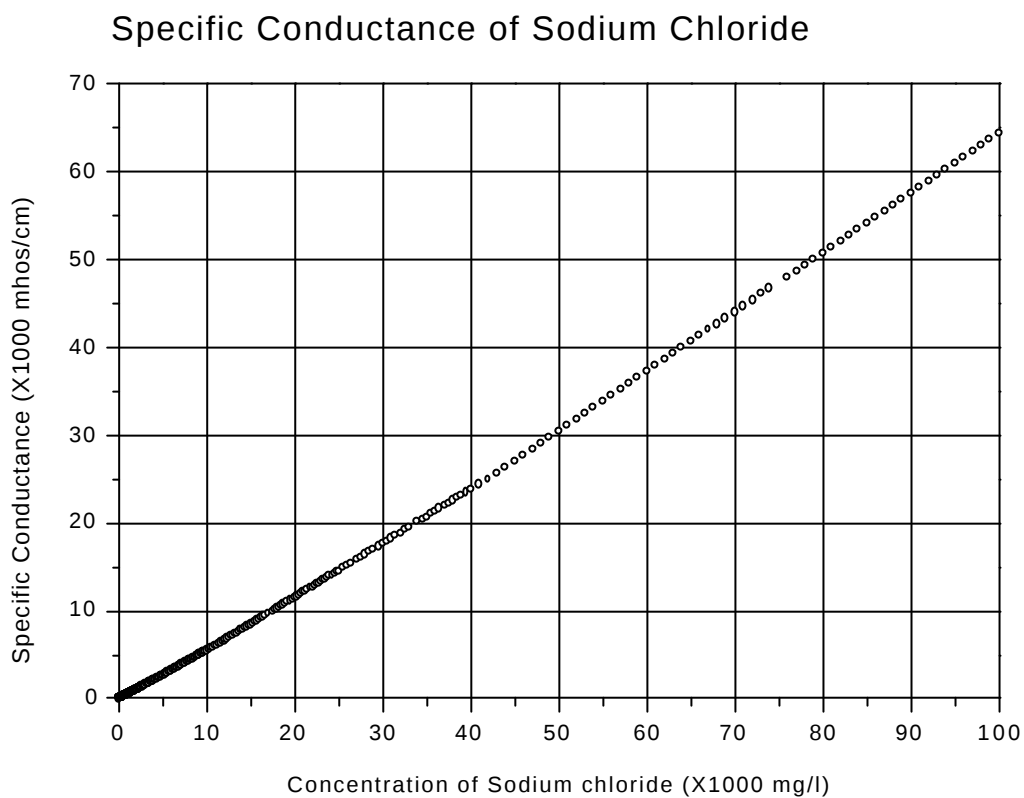
8.

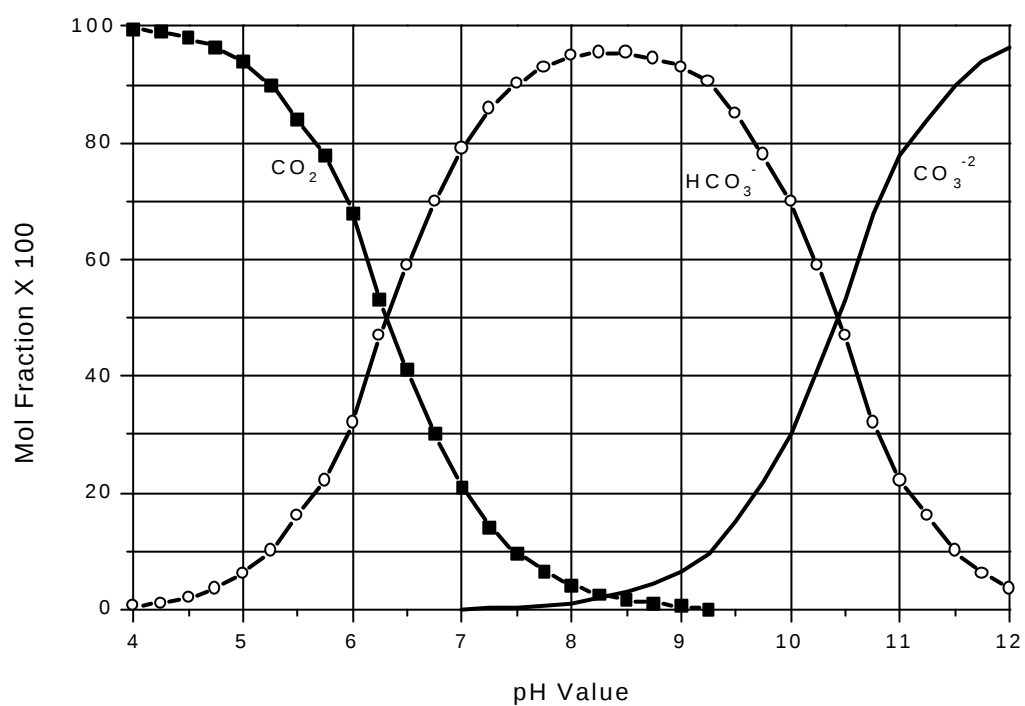
10-8.

	20 (68)	25 (77)	100 (212)
(H ⁺)	328	350	646
(Na ⁺)	45	50.1	155
(K ⁺)	67	73.5	200
(NH ₄ ⁺)	67	73.5	200
(Mg ⁺⁺)	47	53.1	170
(Ca ⁺⁺)	53.7	59.5	191
(OH ⁻)	179	197	446
(Cl ⁻)	69.0	76.3	207
(HCO ₃ ⁻)	36.5	44.5	-
(NO ₃ ⁻)	65.2	71.4	178
(H ₂ PO ₄ ⁻)	30.1	36.0	-
(CO ₃ ⁺⁺)	63.0	72.0	-
(HPO ₄ ⁺⁺)	-	53.4	-
(SO ₄ ⁺⁺)	71.8	79.8	234
(PO ₄ ⁺⁺⁺)	-	69.0	-

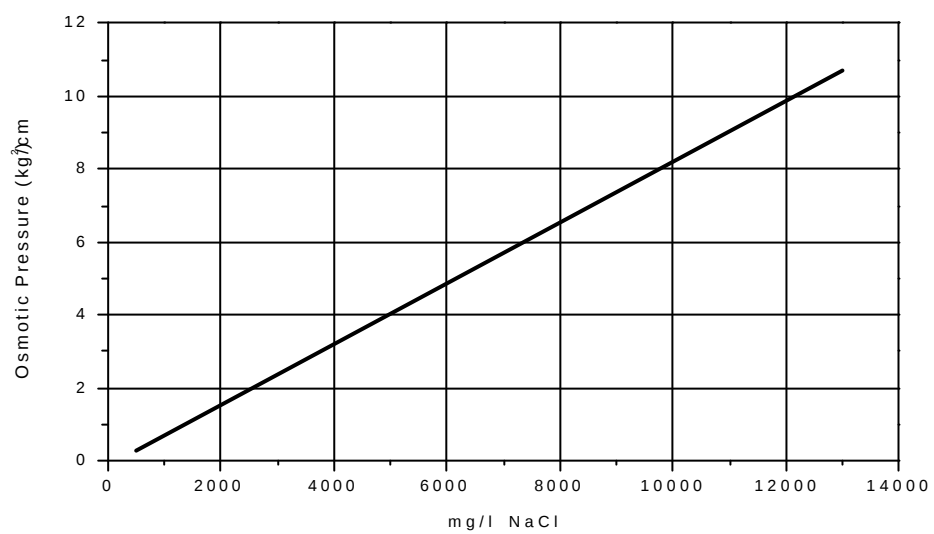
: $\frac{nS / cm}{meq / L}$

10 - 9.

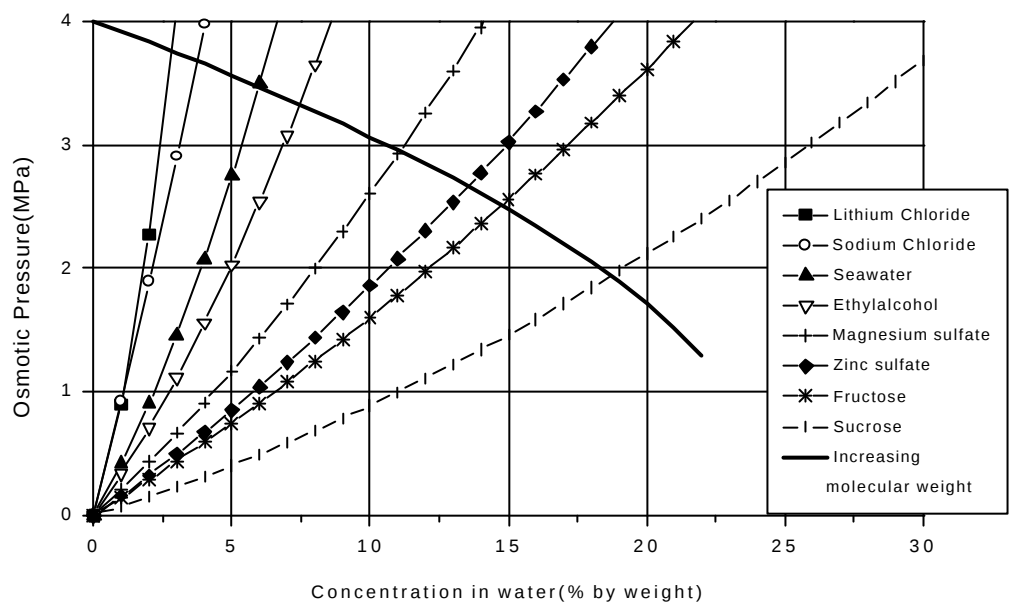


10. CO₂ pH10-10. CO₂ pHIonization of CO₂ solutions as Function of th pH at 25°C

10-11.



10 - 12 .



10-13. (lon) CO₂가

(sec.)	pH	(min.)	pH
0	6.960	2.5	6.263
10	6.928	3	6.198
20	6.702	3.5	6.160
30	6.526	4	6.141
60	6.434	4.5	6.129
90	6.400	5	6.103
120	6.315	5.5	6.091

10-14.

()	(MΩ · cm)	
5	62.1	59.8
10	45.5	42.8
15	31.2	31.7
20	26.3	23.9
25	18.3	18.3
30	14.1	13.9
35	9.75	11.3
40	7.66	9.10
45	7.10	7.36
50	5.80	6.00

10 - 15.

						CO ₂	O ₂	
sand filter	**		*					
A/C	**		*		**			*
MF	****		**					
R/O		***	****	*****	***			****
V.D.G						****	****	
M.B.D		****			*			**
M.B.P		****		****				
U/V				****				
(UF)			****	****	*			****

: * , ** , *** , ****

16.

10-16.

	S S	B O D	C O D	T D S			
	M	M	M	L	/ /	UF/RO	
	L	M	H	M	/ /	RO	/
	H	H	H	M	/	UF/RO	/
	M	L	L	M	/ / /	MF/UF/RO	/ /
	H	M	M	M	/	UF/RO	/
	L	L	L	M	/ /	RO	/
	H	H	H	H	/ /	RO	/
	M	M	M	L	가 /	UF/RO	

10-17.

(Kgf/cm ²)	< 20	75 ~ 100		100 ~ 125		125 ~ 150		> 150	
pH	10.5~ 11.0	8.5~ 9.0	9.0~ 9.5	8.5~ 9.0	9.0~ 9.5	8.5~ 9.0	9.0~ 9.5	8.5~ 9.0	9.0~ 9.5
	0	-		-		-		-	
D.O.	0.5 ↓	0.007 ↓		0.007 ↓		0.007 ↓		0.007 ↓	
Fe	0.3 ↓	0.02 ↓		0.02 ↓		0.01 ↓		0.01 ↓	
Cu	-	0.01 ↓		0.01 ↓		0.005 ↓		0.003 ↓	
N ₂ H ₄	-	0.01 ↑		0.01 ↑		0.01 ↑		0.01 ↑	
SiO ₂	-	0.04 ↓	0.02 ↓	0.04 ↓	0.02 ↓	0.03 ↓	0.02 ↓	0.02 ↓	
	700 ↓	-		-		-		-	
(μs/cm ²)	-	0.3 ↓		0.3 ↓		0.3 ↓		0.3 ↓	
	4 ↓	-		-		-		-	
PO ₄ ³⁻	10~40	-		-		-		-	
: , Seartor									

18.

10 - 18.

		256Kb	1Mb	4Mb~ 16Mb	16Mb~ 64Mb	64Mb~ 256Mb	256Mb~ 1Gb
(MΩ · cm)		17~18	17.5~18	>18	>18.1	>18.2	>18.2
(pcs/Mℓ)	0.1 μm	50~150	10~20	<5			
	0.05μm			<10	<5	<1	
	0.03μm					<10	<5
	0.02μm						(<10)
(cfu/ ℓ)		50~200	10~50	<10	<1	<0.5	<0.1
TOC(ppb)		50~100	30~50	<10	<5	<2	<1
(ppb)		50~100	30~50	<50	<10	<5	<1
(ppb)		10	5	<1	<1	<0.5	<0.1
(ppt)		1000	100~500	<100	<10~50	<5	<1

10 - 19.

(Ca)	(CO ₃)	(Ba)	SDI
(Mg)	(HCO ₃)	(Sr)	
(K)	(Cl)	(Fe)	TOC
(Na)	(NO ₃)	(Al)	(F)
	(SO ₄)	(Cu)	(SiO ₂)
		(Zn)	
			pH
			(TDS)

20. SDI

10-20. SDI

	SDI	(GFD)	(%)
R/O	<1	38	40
UF	<1	35	25
	<3	28	12
	3 5	18	11
	3 5	15	9.5
	<5	20	8

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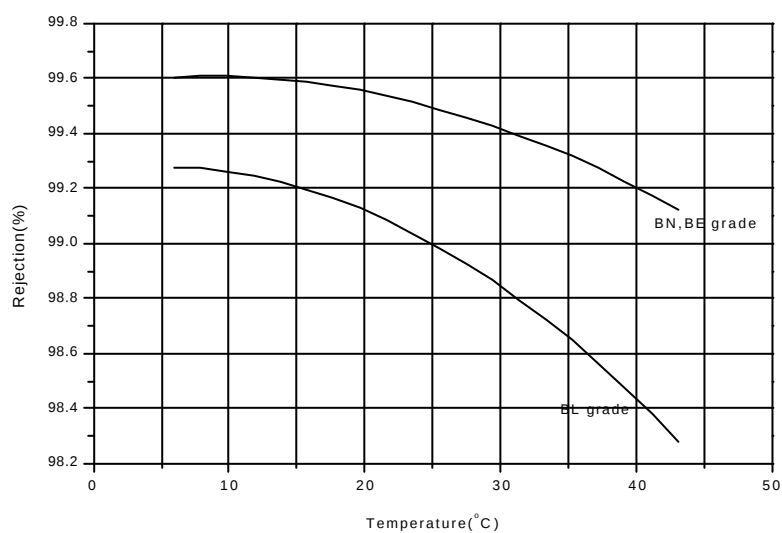
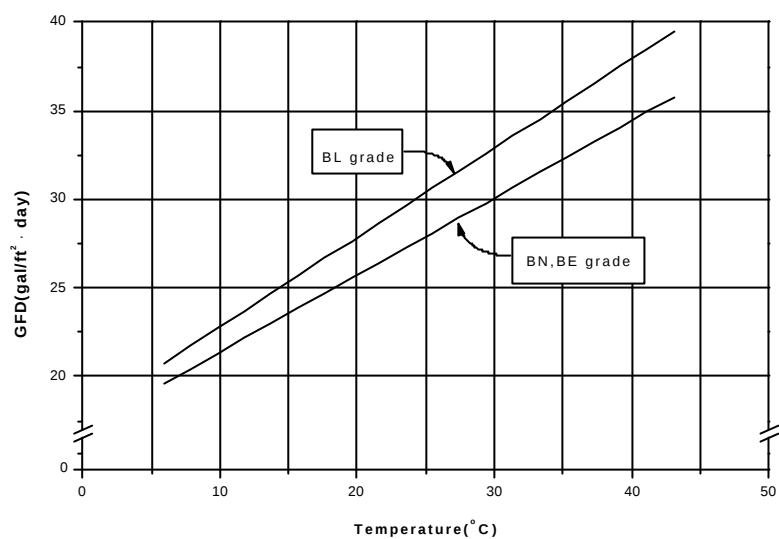
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10-21.

CSM

1)

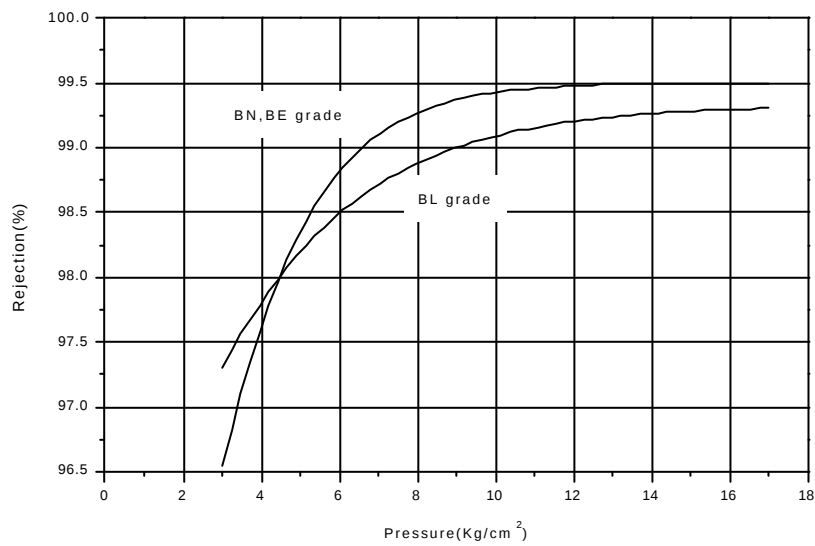
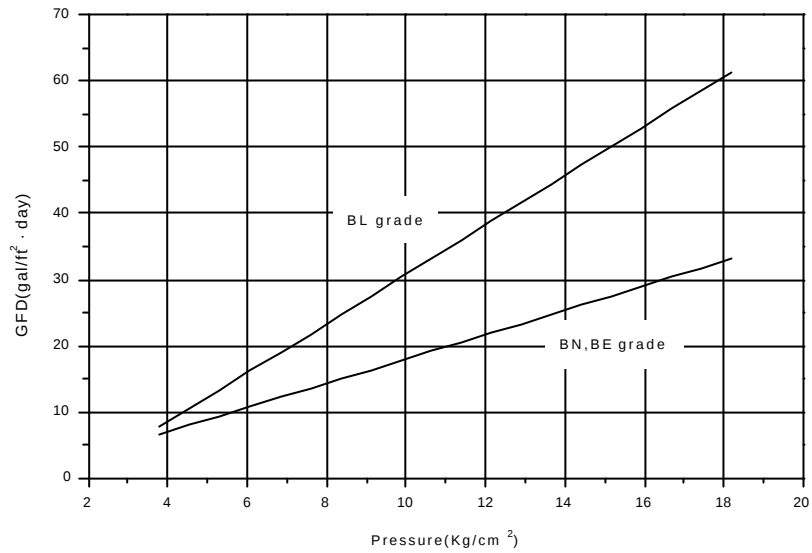
CSM



<	>					
	(ppm)	(Kg/cm ²)	()	(%)		
BN, BE grade	2,000	15		15	25	15%
BL grade	2,000	10		15	Drain	

2)

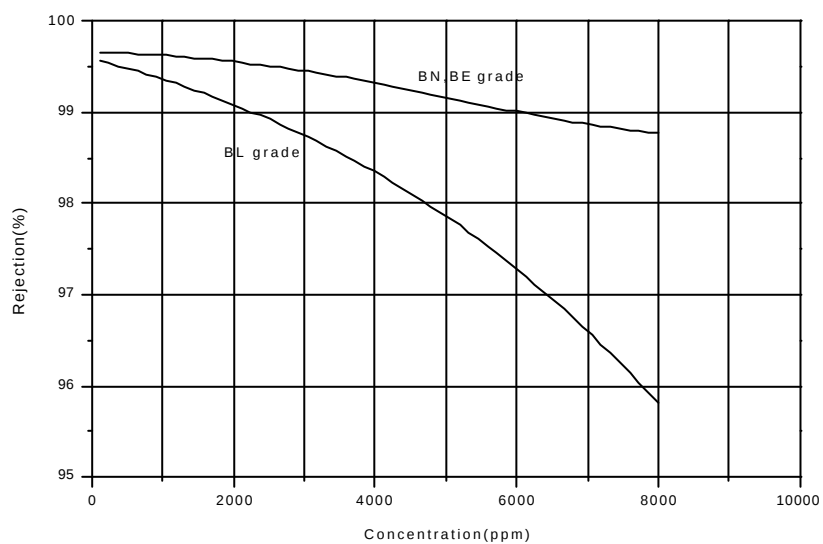
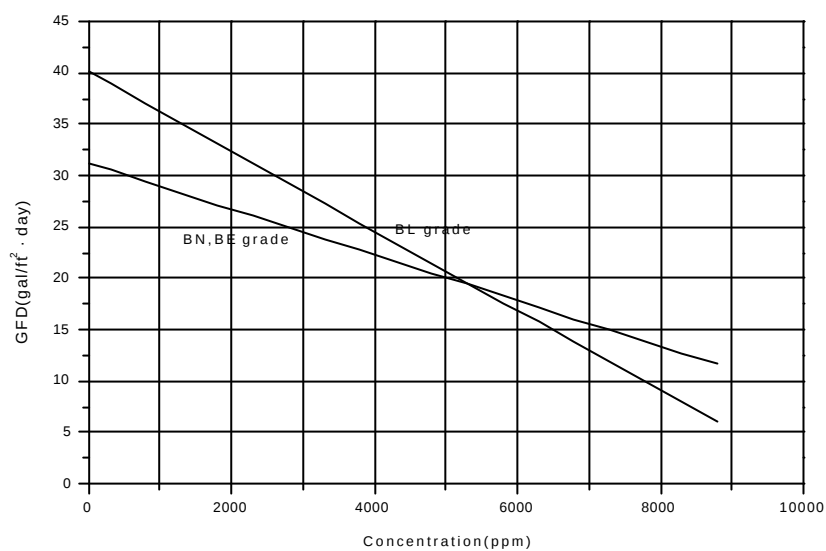
CSM



<	>					
	(ppm)	(Kg/cm²)	()	(%)		
BN, BE grade	2,000		25	15	15Kg/cm²	15%
BL grade	2,000		25	15	Drain	

3)

CSM

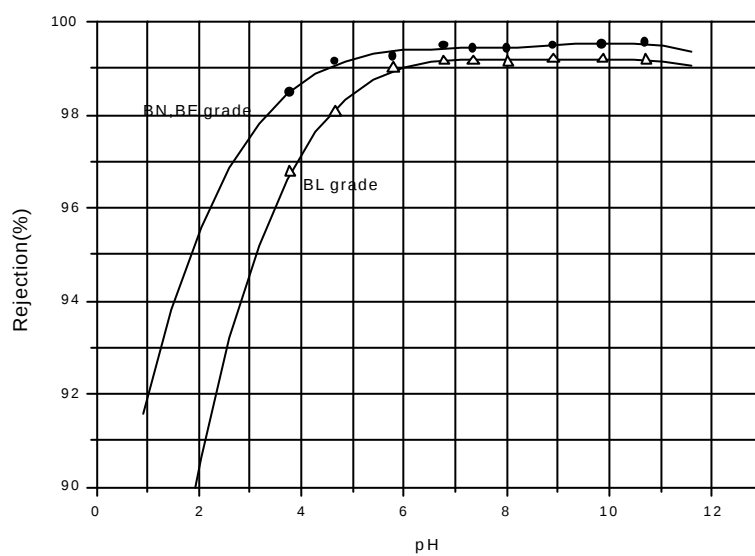
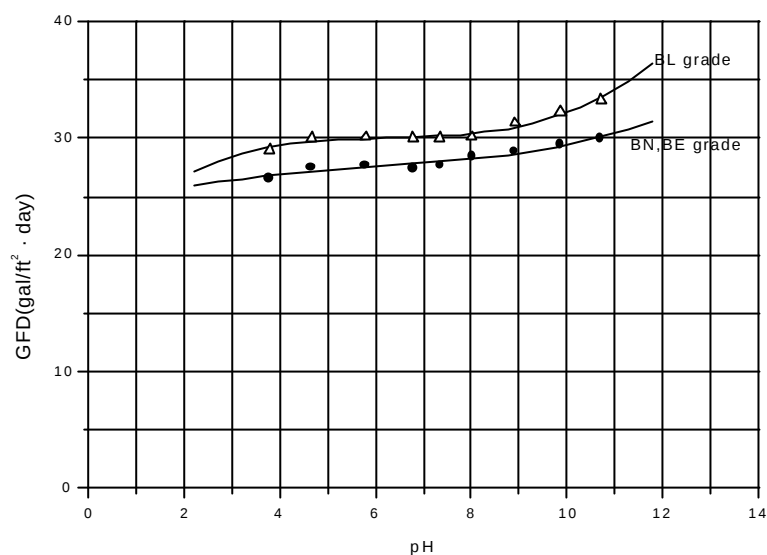


< >

	(ppm)	(Kg/cm ²)	()	(%)	
BN, BE grade		15	25	15	2000ppm 15% Drain
BL grade		10	25	15	

4) pH

CSM

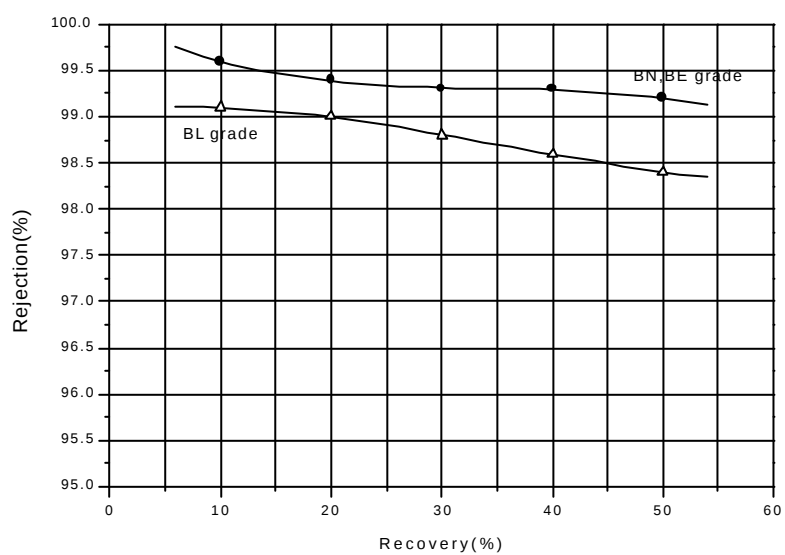
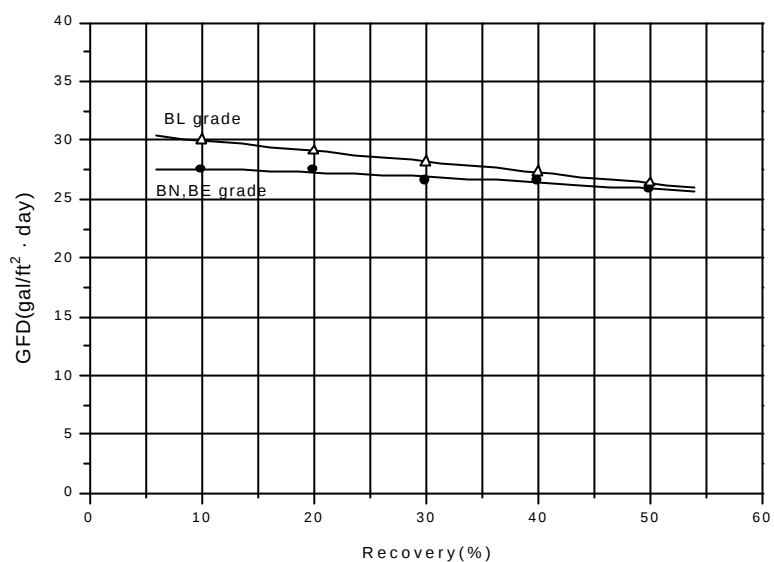


< >

	(ppm)	(Kg/cm ²)	()	(%)	
BN, BE grade	2,000	15	25	15	
BL grade	2,000	10	25	15	

5)

CSM



<	>				
	(ppm)	(Kg/cm²)	()	(%)	
BN, BE grade	2,000	15	25		
BL grade	2,000	10	25		

10-22. (Temperature Correction Factor, TCF)

1) BN, BE, TN grade

Temp	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	2.134	2.125	2.117	2.108	2.100	2.091	2.083	2.074	2.066	2.058
6	2.049	2.041	2.033	2.025	2.017	2.009	2.001	1.993	1.985	1.977
7	1.969	1.961	1.953	1.945	1.937	1.930	1.922	1.914	1.907	1.899
8	1.892	1.884	1.877	1.869	1.862	1.855	1.847	1.840	1.833	1.825
9	1.818	1.811	1.804	1.797	1.790	1.783	1.776	1.769	1.762	1.755
10	1.748	1.741	1.734	1.728	1.721	1.714	1.707	1.701	1.694	1.688
11	1.681	1.675	1.668	1.662	1.655	1.649	1.642	1.636	1.630	1.623
12	1.617	1.611	1.605	1.598	1.592	1.586	1.580	1.574	1.568	1.562
13	1.556	1.550	1.544	1.538	1.532	1.526	1.521	1.515	1.509	1.503
14	1.498	1.492	1.486	1.481	1.475	1.469	1.464	1.458	1.453	1.447
15	1.442	1.436	1.431	1.425	1.420	1.415	1.409	1.404	1.399	1.394
16	1.388	1.383	1.378	1.373	1.368	1.363	1.357	1.352	1.347	1.342
17	1.337	1.332	1.327	1.322	1.318	1.313	1.308	1.303	1.298	1.293
18	1.288	1.284	1.279	1.274	1.270	1.265	1.260	1.256	1.251	1.246
18	1.288	1.284	1.279	1.274	1.270	1.265	1.260	1.256	1.251	1.246
20	1.197	1.193	1.188	1.184	1.180	1.175	1.171	1.167	1.163	1.158
21	1.154	1.150	1.146	1.142	1.138	1.133	1.129	1.125	1.121	1.117
22	1.113	1.109	1.105	1.101	1.097	1.093	1.089	1.085	1.082	1.078
23	1.074	1.070	1.066	1.062	1.059	1.055	1.051	1.047	1.044	1.040
24	1.036	1.032	1.029	1.025	1.021	1.018	1.014	1.011	1.007	1.004
25	1.000	0.996	0.993	0.989	0.986	0.983	0.979	0.976	0.972	0.969
26	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970
27	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
28	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912	0.912
29	0.885	0.885	0.885	0.885	0.885	0.885	0.885	0.885	0.885	0.885
30	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859
31	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833
32	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809
33	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786
34	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763
35	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741
36	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
37	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
38	0.680	0.680	0.680	0.680	0.680	0.680	0.680	0.680	0.680	0.680
39	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661
40	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643

2) BL grade

Temp	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	2.088	2.080	2.072	2.064	2.056	2.048	2.039	2.031	2.024	2.016
6	2.008	2.000	1.992	1.984	1.977	1.969	1.961	1.954	1.946	1.938
7	1.931	1.923	1.916	1.908	1.901	1.894	1.886	1.879	1.872	1.865
8	1.857	1.850	1.843	1.836	1.829	1.822	1.815	1.808	1.801	1.794
9	1.787	1.780	1.774	1.767	1.760	1.753	1.747	1.740	1.733	1.727
10	1.720	1.714	1.707	1.701	1.694	1.688	1.681	1.675	1.669	1.662
11	1.656	1.650	1.644	1.638	1.631	1.625	1.619	1.613	1.607	1.601
12	1.595	1.589	1.583	1.577	1.571	1.565	1.560	1.554	1.548	1.542
13	1.536	1.531	1.525	1.519	1.514	1.508	1.502	1.497	1.491	1.486
14	1.480	1.475	1.469	1.464	1.459	1.453	1.448	1.443	1.437	1.432
15	1.427	1.421	1.416	1.411	1.406	1.401	1.396	1.391	1.385	1.380
16	1.375	1.370	1.365	1.360	1.355	1.351	1.346	1.341	1.336	1.331
17	1.326	1.321	1.317	1.312	1.307	1.302	1.298	1.293	1.288	1.284
18	1.279	1.275	1.270	1.265	1.261	1.256	1.252	1.247	1.243	1.238
18	1.279	1.275	1.270	1.265	1.261	1.256	1.252	1.247	1.243	1.238
20	1.191	1.187	1.182	1.178	1.174	1.170	1.166	1.162	1.158	1.153
21	1.149	1.145	1.141	1.137	1.133	1.129	1.125	1.121	1.118	1.114
22	1.110	1.106	1.102	1.098	1.094	1.090	1.087	1.083	1.079	1.075
23	1.072	1.068	1.064	1.060	1.057	1.053	1.049	1.046	1.042	1.039
24	1.035	1.031	1.028	1.024	1.021	1.017	1.014	1.010	1.007	1.003
25	1.000	0.997	0.993	0.990	0.986	0.983	0.980	0.976	0.973	0.970
26	0.971	0.971	0.971	0.971	0.971	0.971	0.971	0.971	0.971	0.971
27	0.942	0.942	0.942	0.942	0.942	0.942	0.942	0.942	0.942	0.942
28	0.915	0.915	0.915	0.915	0.915	0.915	0.915	0.915	0.915	0.915
29	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888
30	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863
31	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838
32	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815
33	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792
34	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770
35	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748
36	0.728	0.728	0.728	0.728	0.728	0.728	0.728	0.728	0.728	0.728
37	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708
38	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689
39	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670
40	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652

3) 가

Temp	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	1.999	1.992	1.985	1.977	1.970	1.963	1.955	1.948	1.941	1.934
6	1.927	1.920	1.913	1.906	1.899	1.892	1.885	1.878	1.871	1.864
7	1.857	1.851	1.844	1.837	1.830	1.824	1.817	1.810	1.804	1.797
8	1.791	1.784	1.778	1.771	1.765	1.759	1.752	1.746	1.740	1.733
9	1.727	1.721	1.715	1.709	1.702	1.696	1.690	1.684	1.678	1.672
10	1.666	1.660	1.654	1.648	1.642	1.637	1.631	1.625	1.619	1.613
11	1.608	1.602	1.596	1.591	1.585	1.579	1.574	1.568	1.563	1.557
12	1.552	1.546	1.541	1.535	1.530	1.525	1.519	1.514	1.508	1.503
13	1.498	1.493	1.487	1.482	1.477	1.472	1.467	1.462	1.457	1.452
14	1.446	1.441	1.436	1.431	1.426	1.422	1.417	1.412	1.407	1.402
15	1.397	1.392	1.387	1.383	1.378	1.373	1.368	1.364	1.359	1.354
16	1.350	1.345	1.341	1.336	1.331	1.327	1.322	1.318	1.313	1.309
17	1.304	1.300	1.295	1.291	1.287	1.282	1.278	1.274	1.269	1.265
18	1.261	1.256	1.252	1.248	1.244	1.240	1.235	1.231	1.227	1.223
19	1.219	1.215	1.211	1.207	1.203	1.199	1.195	1.191	1.187	1.183
20	1.179	1.175	1.171	1.167	1.163	1.159	1.155	1.151	1.148	1.144
21	1.140	1.136	1.132	1.129	1.125	1.121	1.118	1.114	1.110	1.107
22	1.103	1.099	1.096	1.092	1.088	1.085	1.081	1.078	1.074	1.071
23	1.067	1.064	1.060	1.057	1.053	1.050	1.047	1.043	1.040	1.036
24	1.033	1.030	1.026	1.023	1.020	1.016	1.013	1.010	1.006	1.003
25	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.978	0.975	0.971
26	0.968	0.965	0.962	0.959	0.956	0.953	0.950	0.947	0.944	0.941
27	0.938	0.935	0.932	0.929	0.926	0.923	0.920	0.917	0.914	0.911
28	0.908	0.906	0.903	0.900	0.897	0.894	0.891	0.889	0.886	0.883
29	0.880	0.877	0.875	0.872	0.869	0.867	0.864	0.861	0.858	0.856
30	0.853	0.850	0.848	0.845	0.842	0.840	0.837	0.835	0.832	0.829
31	0.827	0.824	0.822	0.819	0.817	0.814	0.812	0.809	0.807	0.804
32	0.802	0.799	0.797	0.794	0.792	0.789	0.787	0.785	0.782	0.780
33	0.777	0.775	0.773	0.770	0.768	0.766	0.763	0.761	0.759	0.756
34	0.754	0.752	0.749	0.747	0.745	0.743	0.740	0.738	0.736	0.734
35	0.731	0.729	0.727	0.725	0.723	0.721	0.718	0.716	0.714	0.712
36	0.710	0.708	0.705	0.703	0.701	0.699	0.697	0.695	0.693	0.691
37	0.689	0.687	0.685	0.683	0.681	0.679	0.677	0.675	0.673	0.671
38	0.669	0.667	0.665	0.663	0.661	0.659	0.657	0.655	0.653	0.651
39	0.649	0.647	0.645	0.643	0.642	0.640	0.638	0.636	0.634	0.632
40	0.630	0.628	0.627	0.625	0.623	0.621	0.619	0.618	0.616	0.614

4) 가

Temp	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	1.910	1.903	1.897	1.890	1.884	1.877	1.871	1.864	1.858	1.851
6	1.845	1.839	1.832	1.826	1.820	1.814	1.807	1.801	1.795	1.789
7	1.783	1.777	1.771	1.765	1.759	1.753	1.747	1.741	1.735	1.729
8	1.723	1.717	1.711	1.706	1.700	1.694	1.688	1.683	1.677	1.671
9	1.666	1.660	1.655	1.649	1.643	1.638	1.632	1.627	1.622	1.616
10	1.611	1.605	1.600	1.595	1.589	1.584	1.579	1.574	1.568	1.563
11	1.558	1.553	1.548	1.542	1.537	1.532	1.527	1.522	1.517	1.512
12	1.507	1.502	1.497	1.492	1.487	1.483	1.478	1.473	1.468	1.463
13	1.458	1.454	1.449	1.444	1.439	1.435	1.430	1.425	1.421	1.416
14	1.412	1.407	1.402	1.398	1.393	1.389	1.384	1.380	1.375	1.371
15	1.367	1.362	1.358	1.353	1.349	1.345	1.340	1.336	1.332	1.327
16	1.323	1.319	1.315	1.311	1.306	1.302	1.298	1.294	1.290	1.286
17	1.282	1.278	1.273	1.269	1.265	1.261	1.257	1.253	1.249	1.245
18	1.242	1.238	1.234	1.230	1.226	1.222	1.218	1.214	1.211	1.207
19	1.203	1.199	1.195	1.192	1.188	1.184	1.181	1.177	1.173	1.170
20	1.166	1.162	1.159	1.155	1.151	1.148	1.144	1.141	1.137	1.134
21	1.130	1.127	1.123	1.120	1.116	1.113	1.109	1.106	1.103	1.099
22	1.096	1.092	1.089	1.086	1.082	1.079	1.076	1.072	1.069	1.066
23	1.063	1.059	1.056	1.053	1.050	1.047	1.043	1.040	1.037	1.034
24	1.031	1.028	1.025	1.021	1.018	1.015	1.012	1.009	1.006	1.003
25	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973
26	0.970	0.967	0.965	0.962	0.959	0.956	0.953	0.950	0.947	0.945
27	0.942	0.939	0.936	0.933	0.931	0.928	0.925	0.922	0.920	0.917
28	0.914	0.912	0.909	0.906	0.904	0.901	0.898	0.896	0.893	0.890
29	0.888	0.885	0.883	0.880	0.877	0.875	0.872	0.870	0.867	0.865
30	0.862	0.860	0.857	0.855	0.852	0.850	0.847	0.845	0.842	0.840
31	0.837	0.835	0.833	0.830	0.828	0.825	0.823	0.821	0.818	0.816
32	0.814	0.811	0.809	0.807	0.804	0.802	0.800	0.797	0.795	0.793
33	0.790	0.788	0.786	0.784	0.781	0.779	0.777	0.775	0.773	0.770
34	0.768	0.766	0.764	0.762	0.760	0.757	0.755	0.753	0.751	0.749
35	0.747	0.745	0.743	0.740	0.738	0.736	0.734	0.732	0.730	0.728
36	0.726	0.724	0.722	0.720	0.718	0.716	0.714	0.712	0.710	0.708
37	0.706	0.704	0.702	0.700	0.698	0.696	0.694	0.692	0.690	0.689
38	0.687	0.685	0.683	0.681	0.679	0.677	0.675	0.673	0.672	0.670
39	0.668	0.666	0.664	0.662	0.661	0.659	0.657	0.655	0.653	0.652
40	0.650	0.648	0.646	0.645	0.643	0.641	0.639	0.638	0.636	0.634

10-23.

1)

$$1 \text{ cm} = 0.3937 \text{ inch} = 0.03281 \text{ ft}$$

$$1 \text{ inch} = 2.54 \text{ cm} = 0.08333 \text{ ft}$$

$$1 \text{ ft} = 30.48 \text{ cm} = 12 \text{ inch}$$

2)

$$1 \text{ m}^3 = 1000 \text{ L}$$

$$1 \text{ m}^3 = 35.3165 \text{ ft}^3$$

$$1 \text{ m}^3 = 264.186 \text{ gal}$$

$$1 \text{ m}^3() = 1 \text{ ton}$$

$$1 \text{ ft}^3 = 7.48 \text{ gal}$$

$$1 \text{ gal} = 0.1337 \text{ ft}^3$$

$$1 \text{ gal} = 0.00378 \text{ m}^3 = 3.785 \text{ L}$$

3)

$$1 \text{ m}^2 = 10.764 \text{ ft}^2$$

$$1 \text{ ft}^2 = 0.092903 \text{ m}^2$$

4)

$$1 \text{ kg/cm}^2 = 14.22 \text{ psig}(\text{pound per square inches, lb/in}^2)$$

$$1 \text{ psig} = 0.07031 \text{ kg/cm}^2$$

$$1 \text{ atm} = 1.0332 \text{ kg/cm}^2$$

$$1 \text{ kg/cm}^2 = 0.9678 \text{ atm}$$

5)

$$1 \text{ GPD}(\text{gal/day}) = 0.0001575 \text{ m}^3/\text{hr} = 0.1575 \text{ L/hr} = 0.00378 \text{ m}^3/\text{day}$$

$$1 \text{ GPM}(\text{gal/min}) = 0.06308 \text{ L/hr} = 3.785 \text{ LPM}(\text{L/min})$$

$$1 \text{ L/hr} = 6.349 \text{ GPD}$$

$$1 \text{ gfd}(\text{gal/ft}^2\text{day}) = 0.00001463 \text{ m/hr} = 0.01463 \text{ L/m}^2\text{hr}$$

$$1 \text{ L/m}^2\text{hr} = 68.353 \text{ gfd}$$

$$1 \text{ mg/L} = 1 \text{ ppm}$$

$$1 \% = 10,000 \text{ ppm}$$