에너지절약형 VSA MF Membrane 수처리 시스템
Effective Water Treatment Process by Hollow Fiber MF Membranes; VSA(Vibrating & Stripping by Air) Process

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ABSTRACT

MF membrane element was specially designed for water purification and VSA process which can solve the fouling problem. Especially VSA process is developed for the SK Chemicals' asymmetric microfiltration hollow fiber membranes. In case of outside-to-in filtration process, MF membrane element showed the excellent flux stability caused by cleaning ability of VSA process. Simultaneous back-washing with VSA considerably enhances cleaning efficiency. From the result, the possibility of the replacement of chemical coagulation and sand filtration process with newly developed VSA process was revealed.

INTRODUCTION

Recently, many membrane and system makers have developed anti-fouling or easy-cleaning technologies. Generally, besides back-washing, new methods controlled by air for active membrane cleaning have been introduced to the water treatment industries. Those processes enable to remove particles and microorganism from industrial water effectively. But in some cases which contain high suspended solids, it has been found that severe pretreatment should be requested for the operation of those systems.

The feasibility of replacement of chemical addition- coagulation and sand filtration process with SKMF-VSA Process has been studied. SK Chemicals uses industrial water 12,000 m3/d for cooling tower and pure water supply. So, the bench-scale system was set up for the feasibility test and we got the good result from short-term experiment. In some sense, that is the brief basic result about possibility. Recently, pilot-scale full automatic VSA system has been operated without any suspension. First of all, preliminary result from bench-scale test was reviewed in this paper.

EXPERIMENT

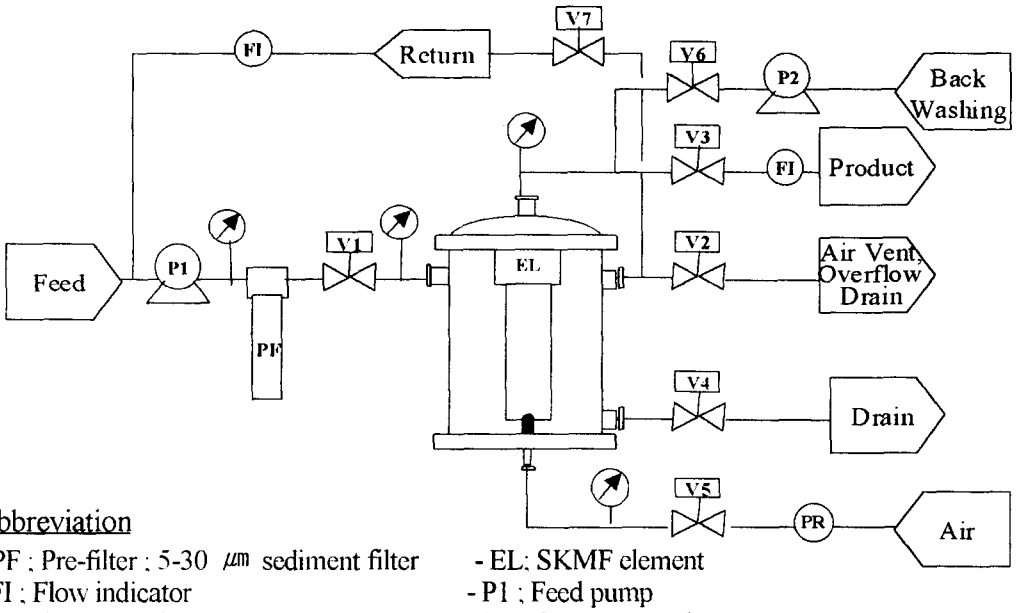
Flow Diagram and Procedure

VSA process has been applied to the industrial water treatment from Hangang-river. We have studied about the several key points for large amount of water treatment. We focused on the possibilities as follows;

(1) Reliability of VSA process for long-term operation
(2) Cleaning efficiency of VSA with or without back-washing
(3) Removing ability about suspended solids and microorganism
(4) Long-term stability of SKMF-VSA without pre-filtration

SKMF-VSA system was operated according to the scheme of flow diagram as below mentioned. Effective operating scheme was achieved by valve and pump shut-off control. Special functions of SKMF-VSA are as follows;

(1) Back-washing and VSA process for long-term stable water flow rate
(2) Compressed air inlet and air-vent ports
(3) Outside-to-in filtration element housing which is specially designed for SKMF-VSA



Abbreviation

- PF ; Pre-filter ; 5-30 ㎛ sediment filter
- EL; SKMF element
- FI ; Flow indicator
- P1 ; Feed pump
- P2 ; Back-washing pump
- PR ; Pressure regulator
- V1 ; Feed shut-off valve
- V2 ; Air Vent and overflowed water drain valve
- V3 ; Permeate valve
- V4 ; Drain valve
- V5 ; Compressed air valve
- V6 ; Back washing valve
- V7 ; Concentrate return valve

Test Condition

The microfiltration membrane was made by polysulfone and has the shape of asymmetric section structure. Outer surface of MF membrane has smoother surface than that of inner surface. VSA

process is not effective for cleaning with opposite structure. So, it is very important to use outside skin MF membranes. SKMF element was both-ends-potted type cartridge. There is a perforated tube inside of the hollow fiber bundle and compressed air is ejected from the small pores on the tube. Compressed air ejected from the tube vibrates the hollow fiber membranes like harp strings. Therefore foulant on the membrane surface can be easily stripped by air bubble and back-washing pressure.

Severe condition was applied to bench test for the reliability. Basically dead-end filtration process was used.. Operating pressure was 1 Kg/cm2 and back-washing pressure was 1.5 Kg/cm2. VSA cleaning was performed every 2 hours for 2 minutes. Back-washing was performed simultaneously with VSA. Average water quality was as follows;

- Feed water ; Hangang River water without any pretreatment including precipitation
- Turbidity ; 4 – 5 N - SiO2 ; 7 – 8 mg/L
- Temperature ; 2.5 – 6.0 ℃ - Air pressure ; 40 NL/min(38L/min) at 1.2 Kg/cm2

RESULT AND DISCUSSION

VSA including back-washing and back-washing process were performed separately. We could find the result that VSA cleaning effect is better than back-washing only. From the result of Fig.1, VSA can be regarded as an effective membrane cleaning method.

Flux decline of SKMF element was examined with or without pre-filtration. In case of direct filtration without pre-filter, we could get the good result similar to the process with 25 ㎛ pre-filtration. The flux through 25 ㎛ pre-filter decreased rapidly and eventually there was little permeate after 3 hours passed because of clogging. VSA process enabled to operate MF element system without pretreatment. We operated VSA system without pre-filter for river water purification. Microorganisms were perfectly removed. In case of SS, conventionally use analytical method could not evaluate accurately. So, for further precise analysis we used SDI parameters. All the permeated water showed the value below SDI 3. Two months' pilot test result (Fig.2.) for the Hangang river showed that the possibility of the replacement of clarification and sand filtration.

CONCLUSION

From the test result, we could find that VSA enables to operate MF system effectively. VSA had the possibility to be used for the replacement of clarification and sand filtration process. VSA cleaning had shown more effective method than conventional back-washing process. Two months' pilot test showed the stable water flow rate of minimum 750 L/hr.EL at 1Kg/cm2. Of course, because it is short-term result, we should operate VSA for a long time. We are going to investigate the effect of temperature, turbidity and various operating parameters.

Fig.1. Comparison between VSA and Back-washing Effect for Membrane Cleaning

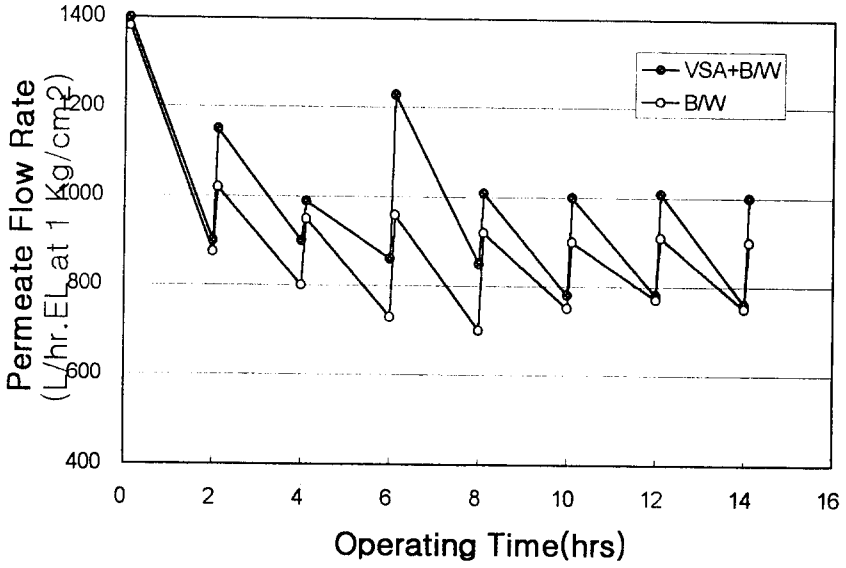
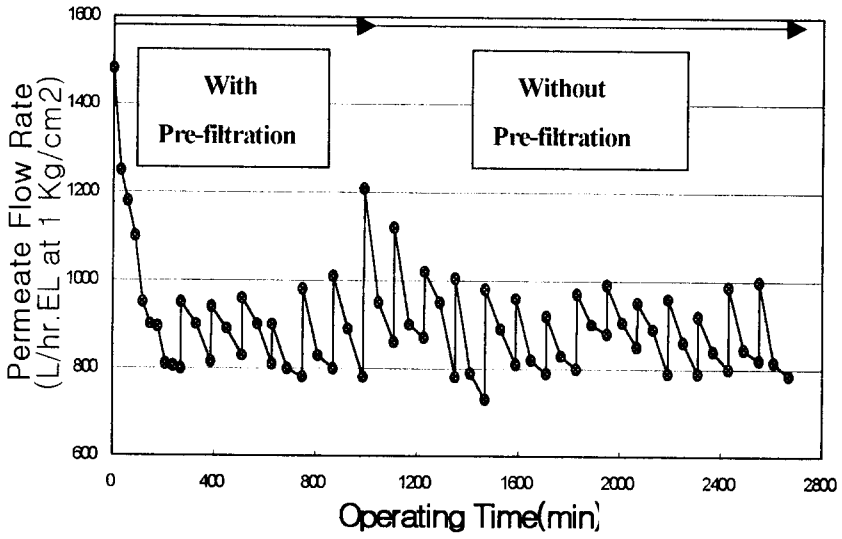


Fig.2. Direct Filtration by VSA without pre-filter and conventional filtration with pre-filter



REFERENCES

[1] K. Scott, "Handbook of Industrial Membranes", 1st ed., Elsevier Advanced Technology, 1995, P 575

[2] K. Miura and M. Okazaki, Maku, **20(5)**, (1995), 328

Membrane Technology Feature

- ***Competitive Process for Water treatment***
  - Replacement of Conventional Process (Coagulation & Sedimentation, Sand Filtration)
  - High Performance with Ozone, A/C & Bioprocess
  - Safe Process against Feed Quality Fluctuation
  - Cost Effective Process ; Labor, Chemicals, Construction
- ***Reclamation of Water & Resources***
  - Closed-loop System
  - Reuse of Municipal and Industrial Wastewater
- ***Solution of Environmental Problem***
  - Clean Technology

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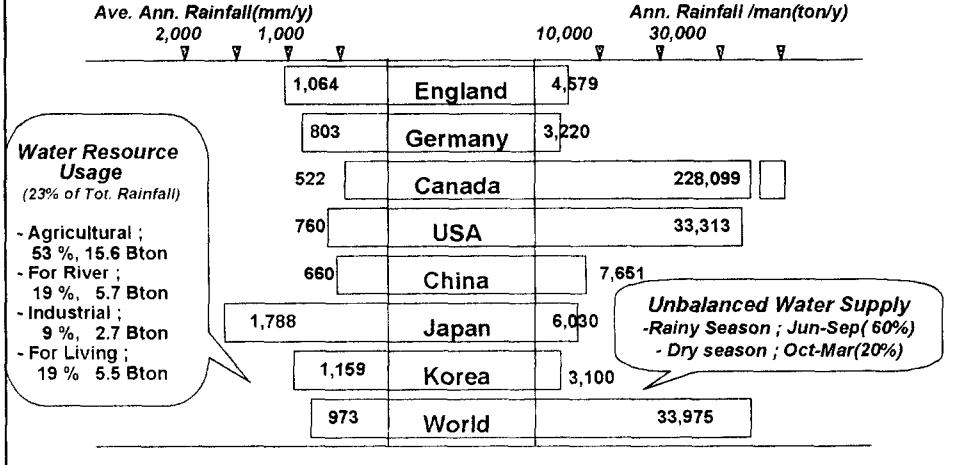
Water Resource Situation in Korea



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Water Treatment System Needs in Korea

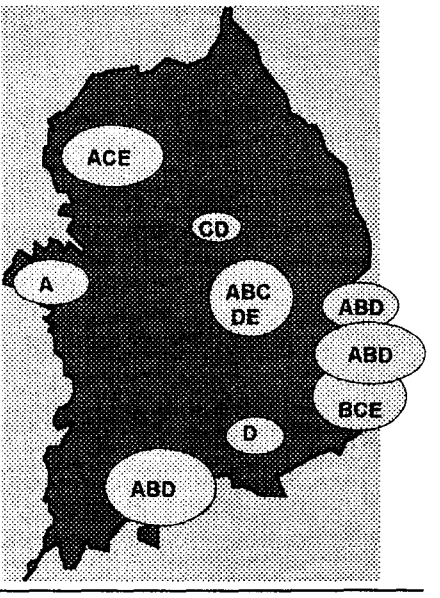
A ; Water Deficient Region
- Kyong-In, Taegu, Ulsan, Pohang

B ; Contaminated Water Region
- Nakdong-river, Taegu, Pohang, Ulsan, Pusan, Yochon

C ; Need of Drinking Water Purification
- Kyong-In, Taegu, Pusan, Ulsan, Taejon, Kwangju

D ; Need of Pure Water
- Taegu, Kumi, Changwon, Ulsan, Chongju, Yochon

E ; Need of Water Reuse
- Seoul, Pusan,Taegu, Ulsan, Yochon



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Needs for Water Treatment in Korea

Water Contamination & Deficiency

- **Curtailment of Operation**
- **Quality Deterioration**
- **Safety Problem of Drinking Water**
- **Raise in Water Price**
- **Regulation ; Quality & Quantity Control**

Needs

- ***Membrane; High Efficient Purification Process***
- ***Water Reuse***
  - Municipal Wastewater
  - Effluent from Plant
  - Cooling Water
- ***Development of New Water Resources***
  - Sea Water Desalination
  - Ground Water/ Rainwater

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Needs for Membrane in Water Treatment

- Long-term Flux Stability, Intergrity & Reliability
- Anti-fouling
- Easy Operation and Effective Membrane Cleaning
- Perfect Removal of Microorganisms and Particles
- Cost-effective Process
- Life Cycle

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Key Idea of Optimized Process

- Easy Cleaning ; VSA(Vibrating & Stripping by Air)
- Simultaneous Effect of VSA and Back-washing
- Cost-effective Large Module; Housing Type
- High Flux and Microorganism Removal ; MF
- Anti-fouling and Long-term Stability ; Outside Skin Hollow Fiber Membrane
- High Recovery Rate ; Dead-end, Partial Return
- Large Membrane Area ; Thinner Diameter Hollow Fiber

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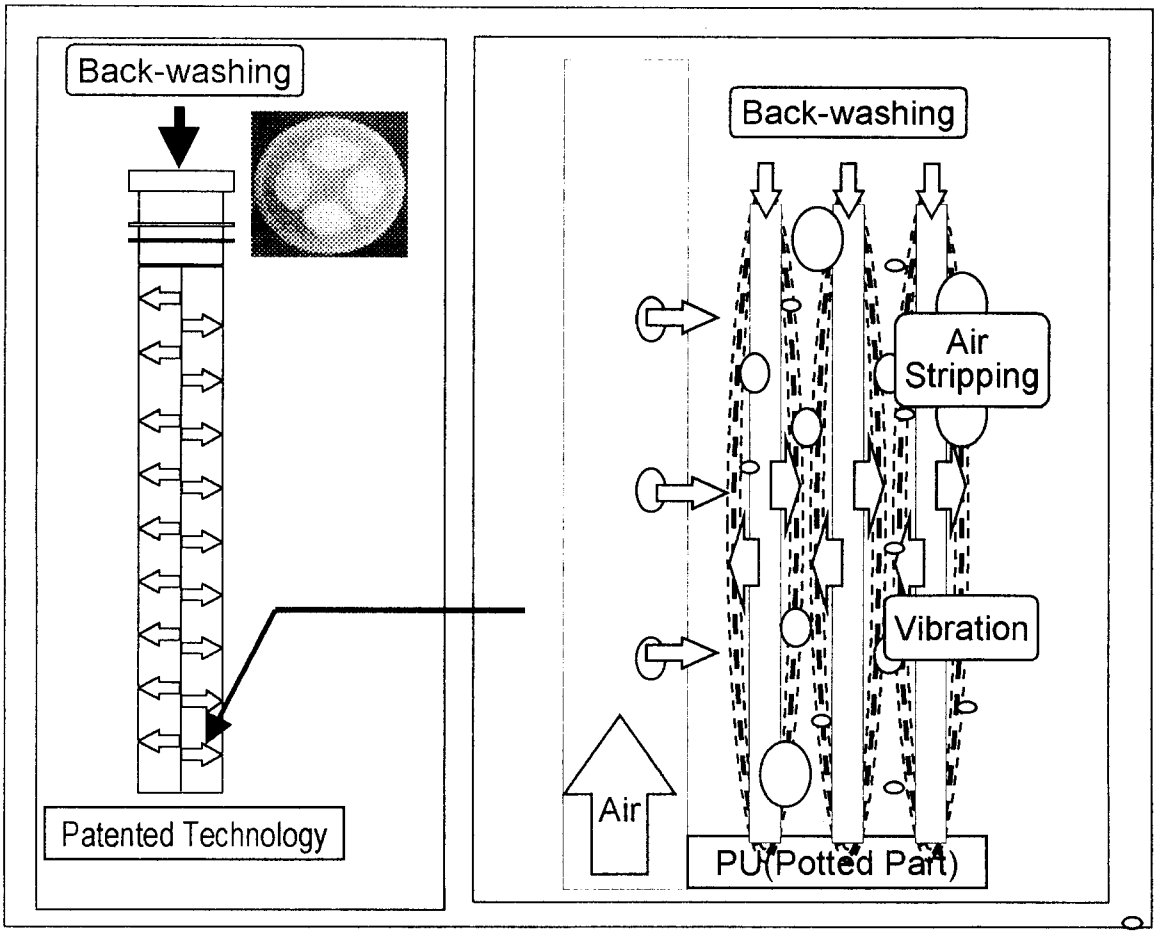
Characteristics of VSA Process

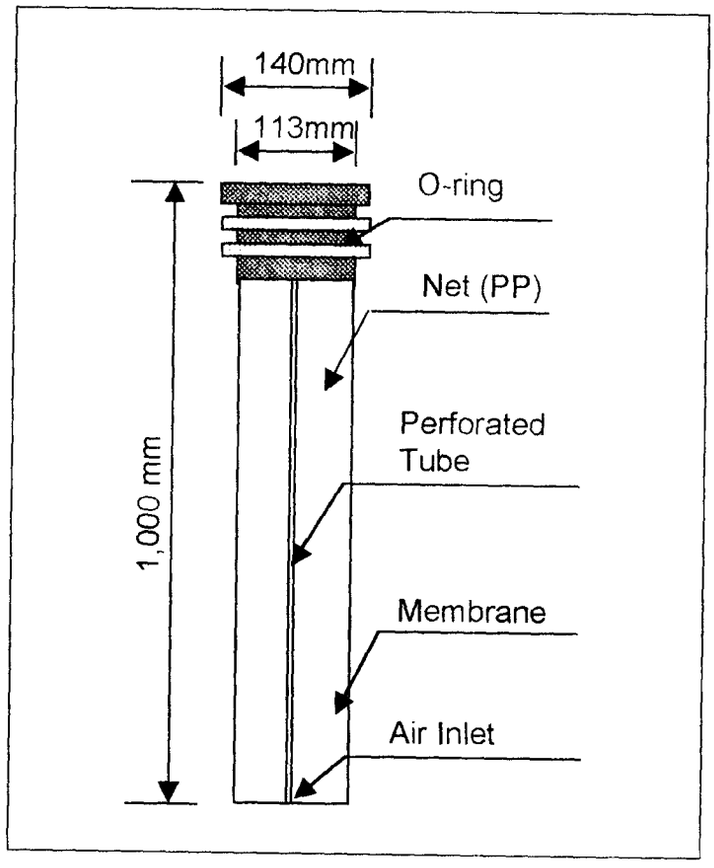
SKMF element made of MF hollow fiber membranes is specially designed for the large scale water treatment. SK Chemicals' hollow fiber MF membranes have thinner diameter and asymmetric porous structure,which enables large membrane area and high water flow rate. VSA process is newly developed cleaning process by SK Chemicals for long-term stable performances.

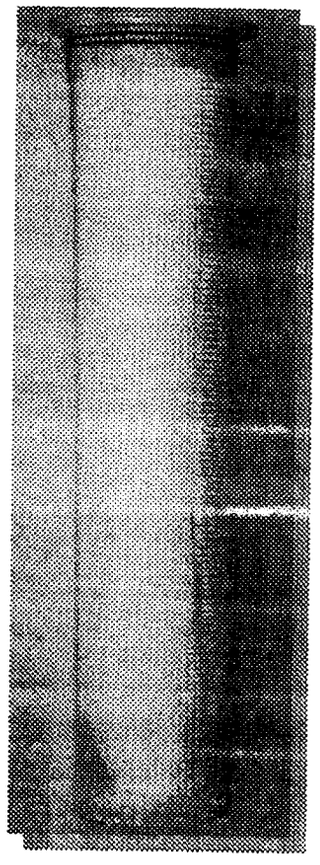


Feature of VSA Process

1. VSA is the unique patented technology by SK Chemicals.
2. VSA can remove fouling materials easily from the surface of hollow fiber membranes.
3. Simultaneous back-washing with VSA considerably enhance cleaning efficiency.
4. VSA sometimes enables pretreatment-free process.
5. Stable water flow rate shows economical competency and long-term reliability.

Feature of SKMF Element and VSA Housing

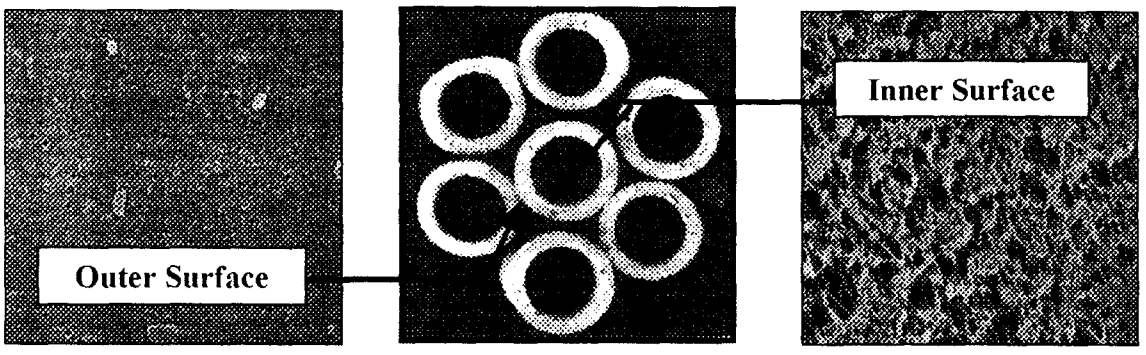




Element Specifications

1. Membrane ; 0.01 ㎛ Pore size Polysulfone hollow fibers(ID/OD ; 0.4/0.6 mm)
2. Membrane area ; 19 ㎡/Element
3. Operating Conditions ;
   - Max. Inlet Pressure ; 3 Kg/㎠
   - Optimum Transmembrane Pressure ; 0.5 - 1.5 Kg/㎠
   - Max. Temperature ; 40 ℃
   - pH Range ; 2 -13
   - Backwashing Pressure ; 1.5-2.0 Kg/㎠
   - Flushing Air Pressure ; 1.0-1.5 Kg/㎠, 40-80 NL/min.element
4. Operating style ; Outside-to-in, Dead-end & Partial Cross-flow filtration
5. Materials ;
   - Adhesive ; Polyurethane
   - End Cap and Adapter ; ABS
   - Tubular Net ; Polypropylene

Superane Hollow fiber MF Membrane(SKMF)



Feature of SKMF Hollow fiber Membrane

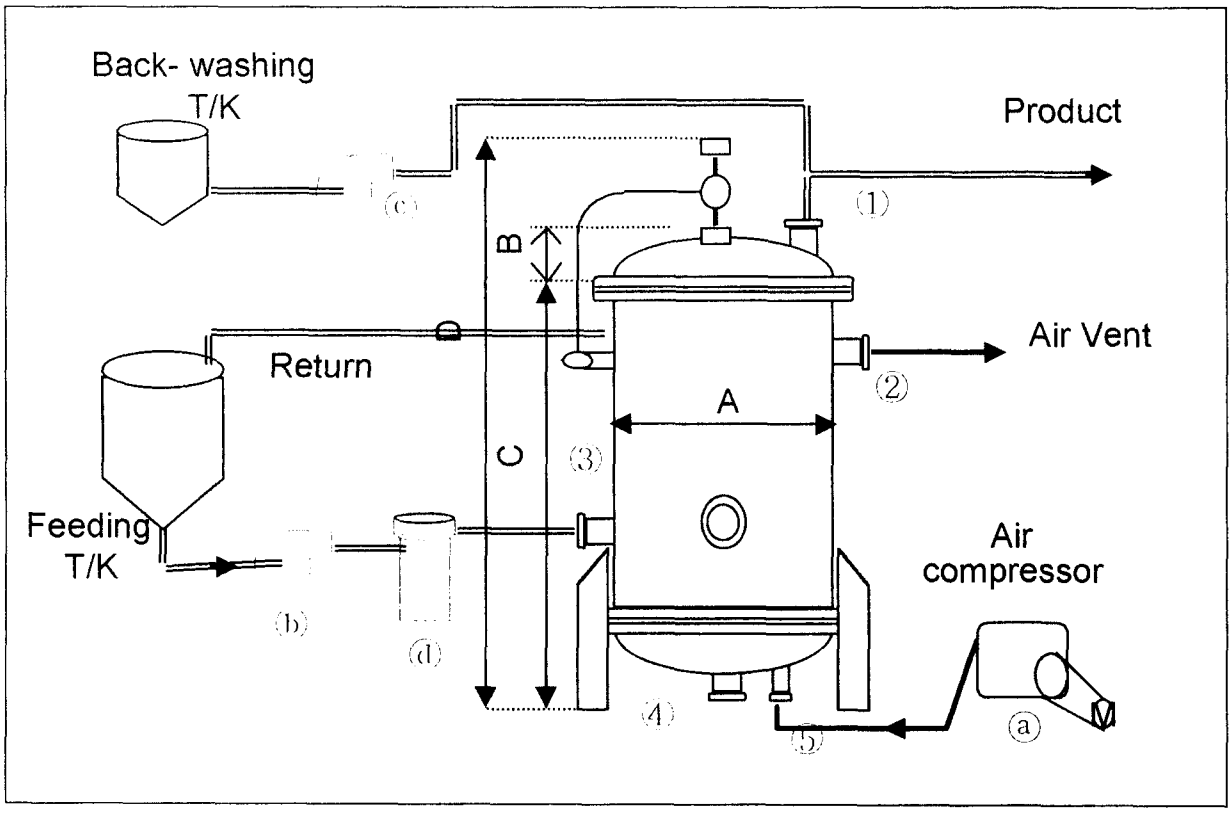
1. SKMF has the asymmetrical cross-section structure. The pore size of outer surface is smaller than that of inner surface. So, SKMF has the merit of high flow rate compared with the conventional microfiltration and is similar to skin filtration membrane alike ultrafiltration membrane with active skin layer.

2. SKMF has the reliable rejection performance against suspended solids and microorganism by its severe pore size(0.01㎛) smaller than conventional MF pore size.

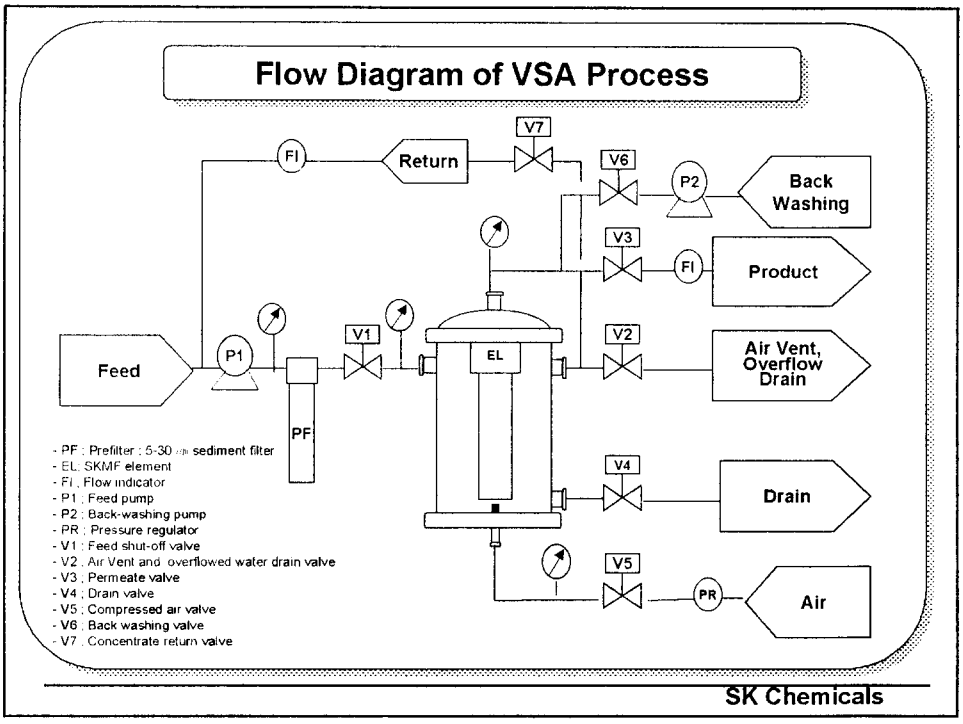
3. SKMF has strong chemical resistance and mechanical properties. SKMF is made from polysulfone. Polysulfone can resist under full range of pH and high temperature condition. It is available in the field of drinking water, industrial water and various applications of pretreatment and final filtration(POU). SK Chemicals is developing PAN membranes in order to minimize membrane fouling, those will be applied to water reclamation from effluents and membrane bioreactor system as submerged module.

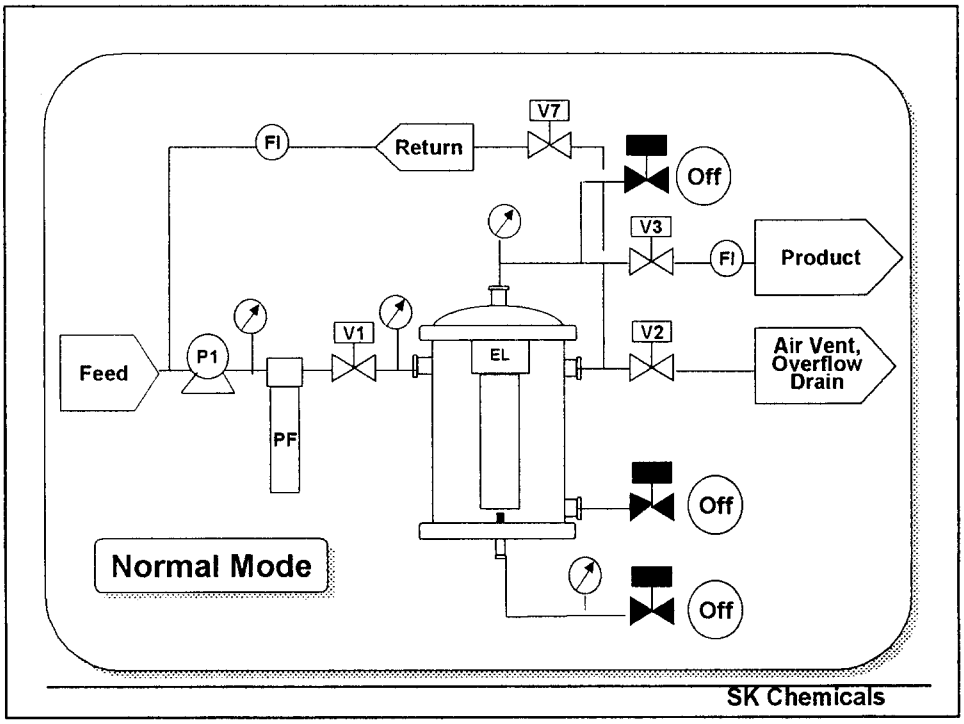
4. SKMF has the long-term stability by easy cleaning with VSA process and quick recovery with cleaning chemicals.

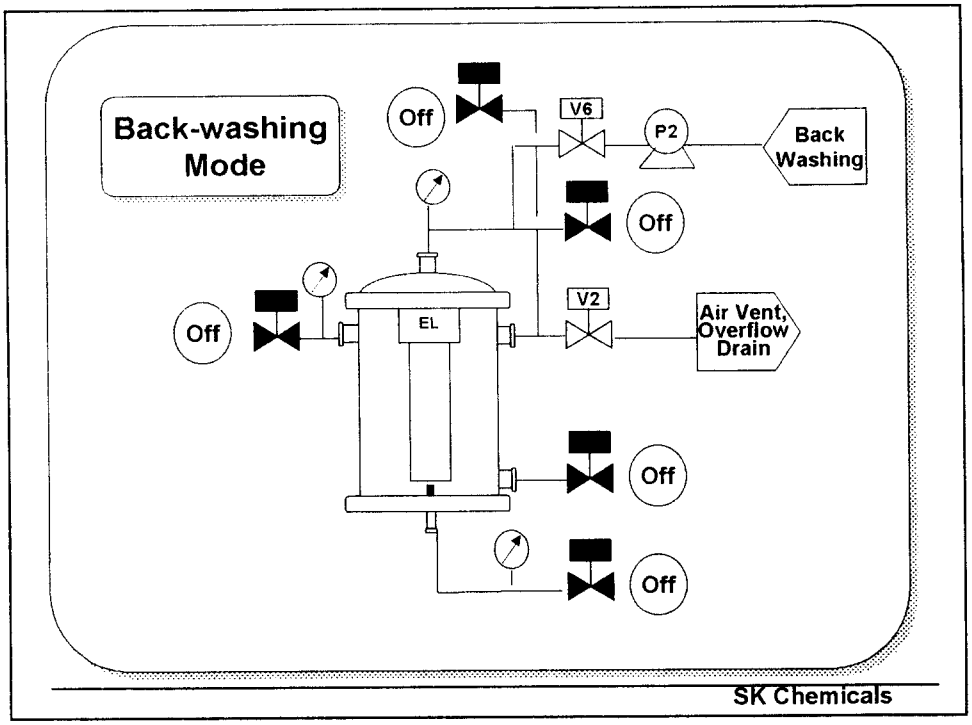
Schematic Diagram & Specification of Element Housing

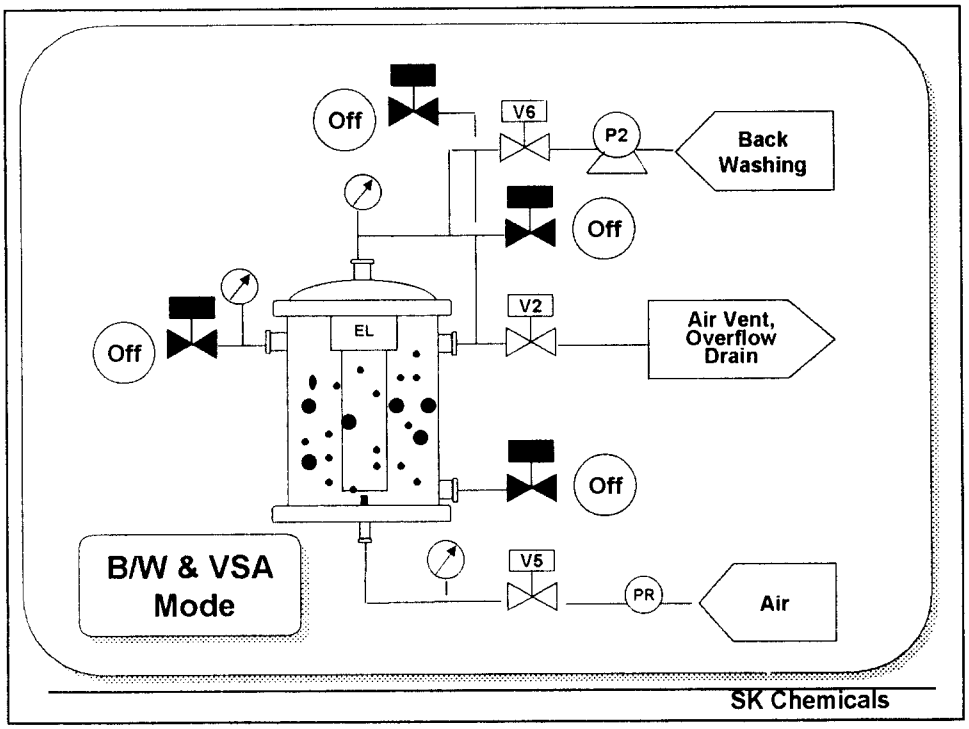


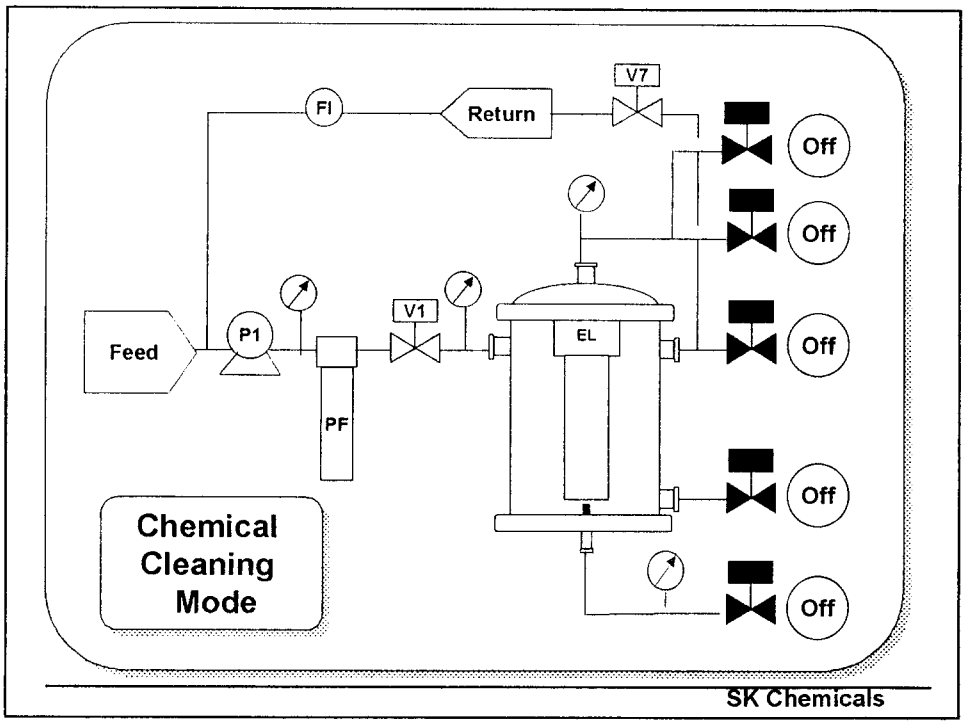
Parameters	EL 7 ea	EL 20 ea	EL 28 ea	EL 48 ea
A (mm)	500	750	1,000	1,200
B (mm)	175	230	280	330
C (mm)	1,224	1,270	2,300	2,500
D (mm)	2,000	2,100	2,300	2,500
① Permeate	40A	50A	65A	80A
② Air Outlet	40A	50A	65A	80A
③ Feed Inlet	25A	40A	50A	65A
④ Drain	50A	80A	100A	125A
⑤ Air Inlet	25A	40A	50A	65A
ⓐ Air Comp.	175 ℓ/min	475 ℓ/min	700ℓ/min	1,200 ℓ/min
ⓑ Feed Pump	18 ㎥/hr	50 ㎥/hr	70 ㎥/hr	120 ㎥/hr
ⓒ B/W Pump	12 ㎥/hr	30 ㎥/hr	45㎥/hr	72㎥/hr
ⓓ Prefilter	Pore size 5 ~ 30 ㎛			

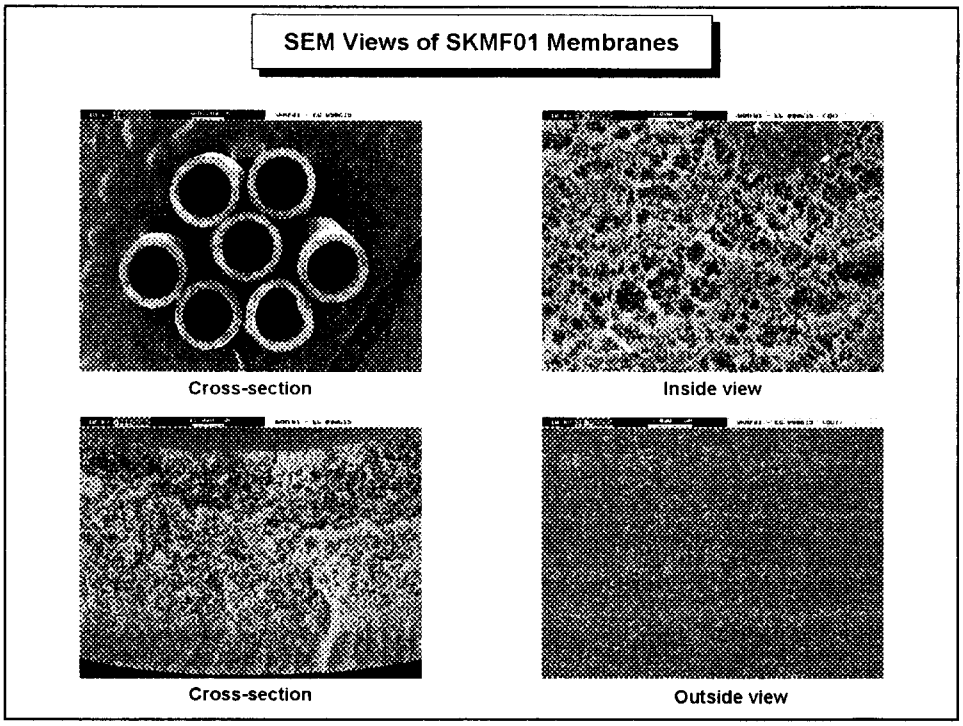

Flow Diagram of VSA Process
FI
Return
V7
V6
P2
Back Washing
V3
FI
Product
V1
EL
V2
Air Vent, Overflow Drain
Feed
P1
PF
V4
Drain
V5
PR
Air
- PF : Prefilter : 5-30 ㎛ sediment filter
- EL: SKMF element
- FI : Flow indicator
- P1 : Feed pump
- P2 : Back-washing pump
- PR : Pressure regulator
- V1 : Feed shut-off valve
- V2 : Air Vent and overflowed water drain valve
- V3 : Permeate valve
- V4 : Drain valve
- V5 : Compressed air valve
- V6 : Back washing valve
- V7 : Concentrate return valve
SK Chemicals


FI
Return
V7
Off
V3
FI
Product
Feed
P1
V1
EL
V2
Air Vent, Overflow Drain
PF
Off
Normal Mode
Off
SK Chemicals

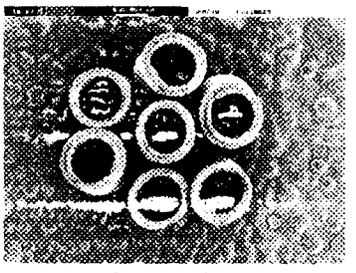

Back-washing Mode
Off
V6
P2
Back Washing
Off
Off
EL
V2
Air Vent, Overflow Drain
Off
Off
SK Chemicals


Off
V6
P2
Back Washing
Off
Off
EL
V2
Air Vent, Overflow Drain
Off
B/W & VSA Mode
V5
PR
Air
SK Chemicals

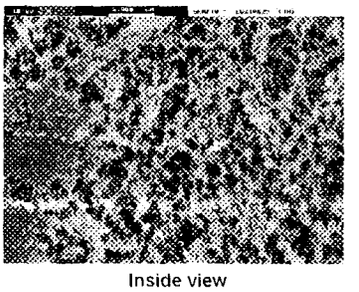

V7
FI
Return
Off
Off
V1
P1
Feed
EL
Off
PF
Off
Chemical
Cleaning
Mode
Off
SK Chemicals


SEM Views of SKMF01 Membranes
Cross-section
Inside view
Cross-section
Outside view

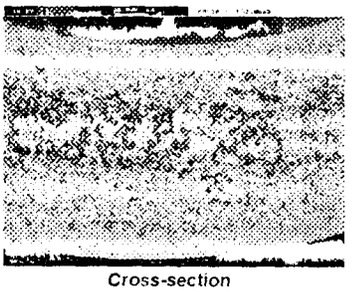
SEM Views of SKMF10 Membranes



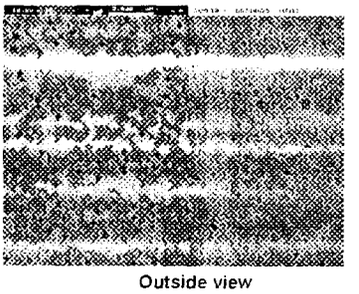
Cross-section



Inside view

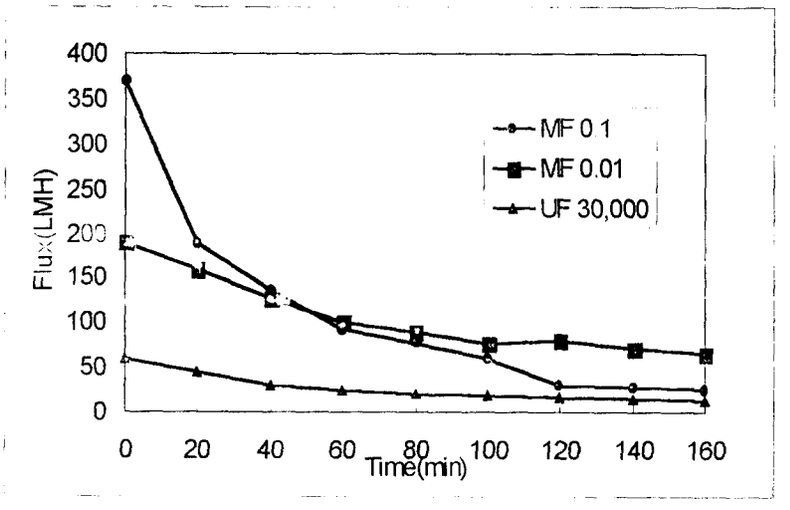


Cross-section



Outside view

Flux Decline of Membranes



- Operating Conditions : 25 C, 1 kg/m, Dead-end Filtration
- Feed Water ; NTU 6 , Pure Water Contaminated with River Silt

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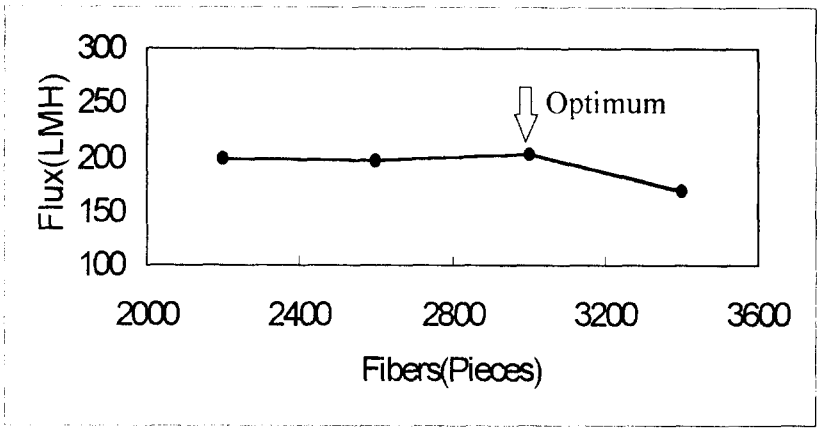
Hollow Fiber Bundle Density in Element



- Operating Conditions ; 25℃, 1 kg/㎠, Dead-end Filtration
- Feed Water ; Pure Water
- Bundle Size ; Hollow Fibers are fiexed in 1mL x 4cmD Tube
- **Flux of SKMF01 Membrane Cartridge ; 450 LMH, 1"D x 30 cmL, 0.3 m2**

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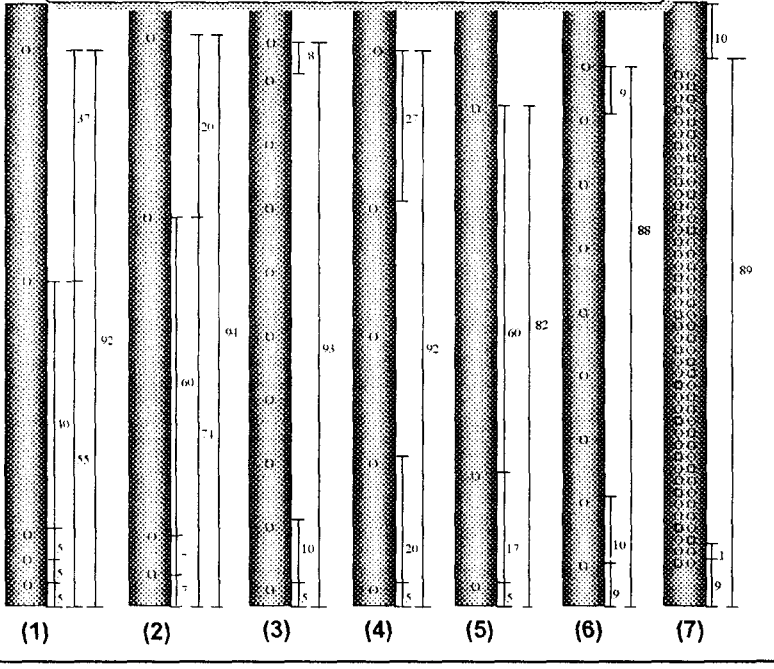
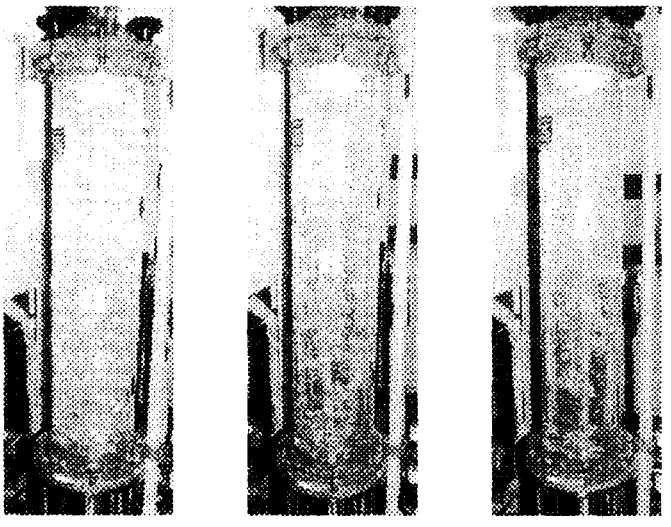
Design of Air Diffusing Tube in Element



Air Bubble Shapes in Elements



(1) (2) (3)

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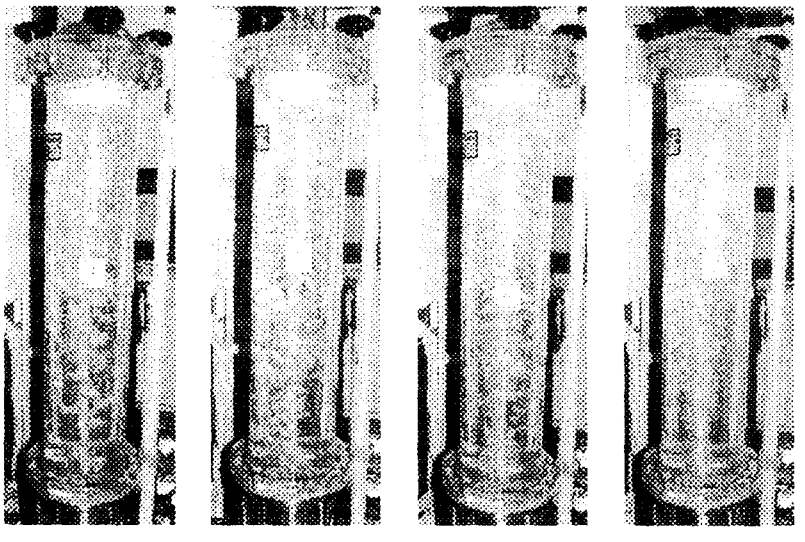
Air Bubble Shapes in Elements



(4) (5) (6) (7)

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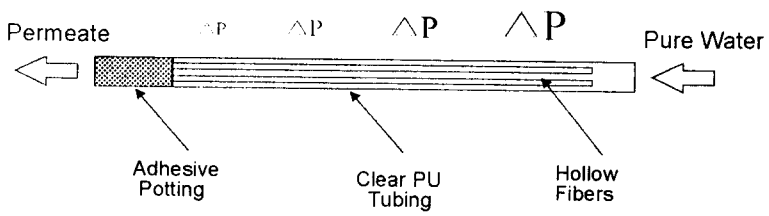
Length of Membrane and Pressure Drop



	Pore Size	Fiber Size	Water Flux*
SKMF01	0.01㎛	0.4/0.6 mm(ID/OD)	450 LMH
SKMF10	0.1㎛	0.7/1.0 mm(ID/OD)	700 LMH

* Water flux was measured at 1 Kg/cm2, 25℃ by 1"Dx30cmL Cartirdge with dead-end filtration mode.

Test Samples ;
SKMF01 - 120cm, 100cm, 80cm, 60cm, 40cm, 20cm - 5 pieces
SKMF10 - 120cm, 100cm, 80cm, 60cm, 40cm, 20cm - 5 pieces

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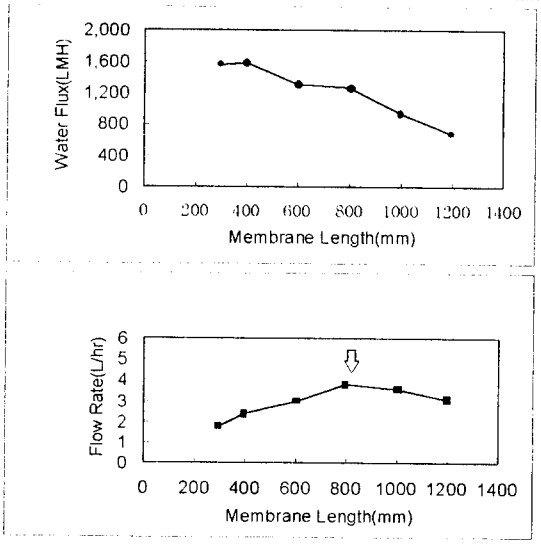
Length of Membrane and Pressure Drop Effect



●Operating Conditions ; 25℃, 1 kg/㎠, Dead-end Filtration, Pure Water

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Replacement of Prefiltration with MF-VSA

Object ;

- Replacement of Conventional Treatment with MF Membrane (Chemical Coagulation & Sand Filtration)
- VSA Cleaning Effect
- Flux Stability

Test Condition ;

- Feed Water Hangang-River Water without any pretreatment
- Turbidity ; 4 - 5 NTU
- SiO2 ; 7 - 8 mg/L
- Temperature ; 2.5 - 6.0 ℃
- Compressed Air ; 40 NL/min at 1.2 Kg/cm2
- Operating Pressure ; 1 Kg/cm2
- Back-washing Pressure ; 1.5 Kg/cm2

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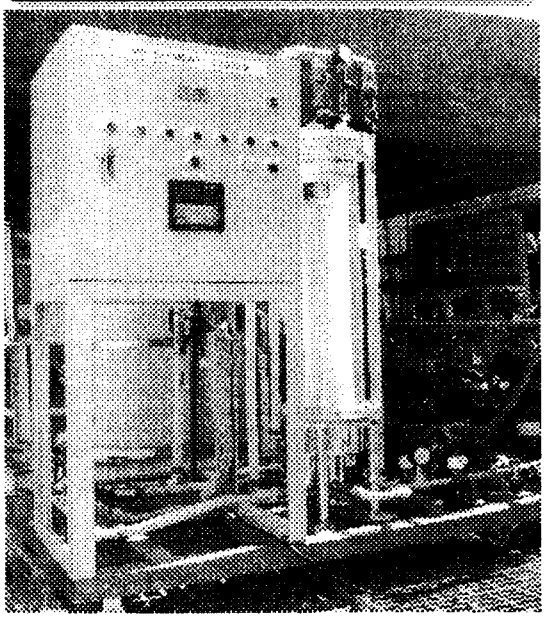
Automatic SKMF-VSA System



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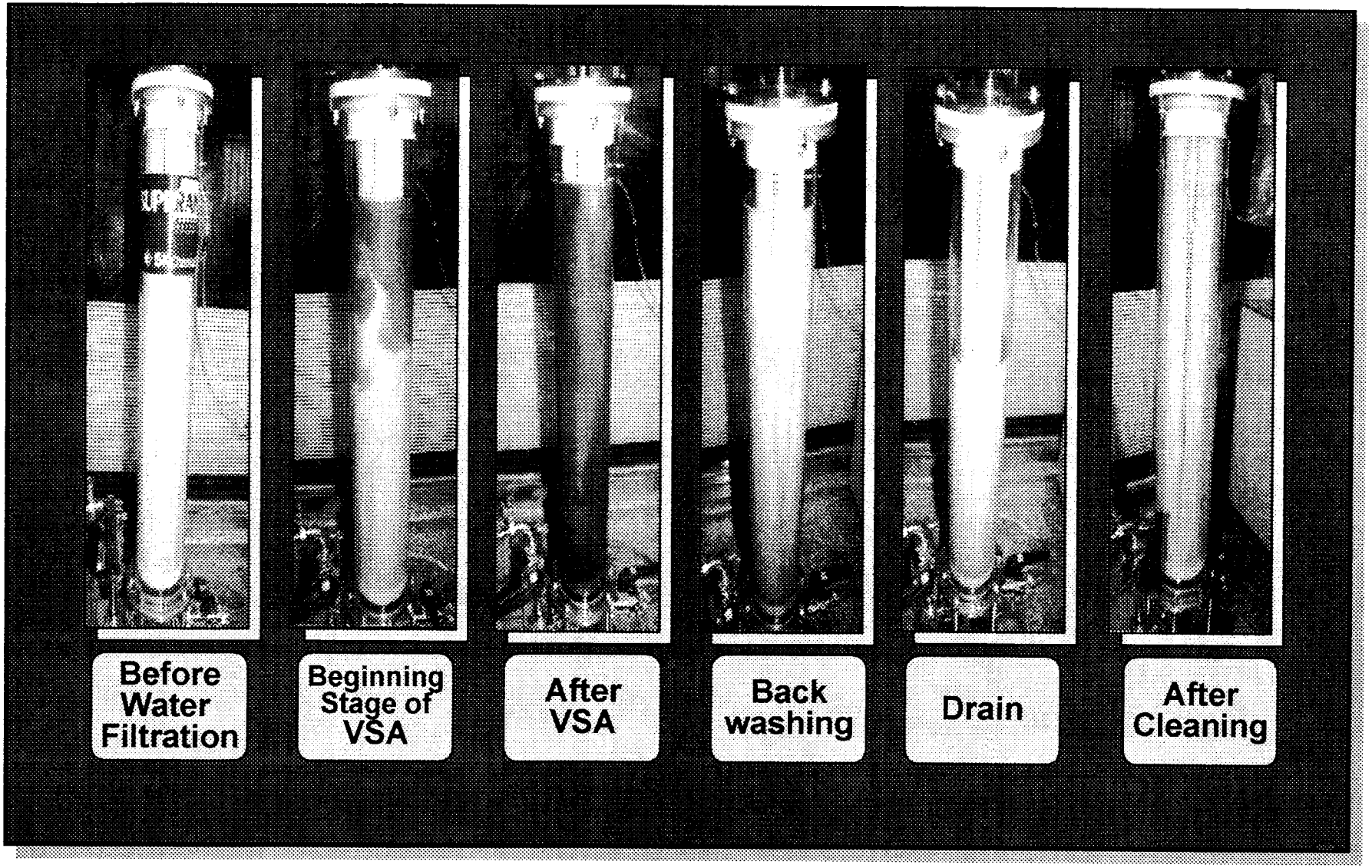
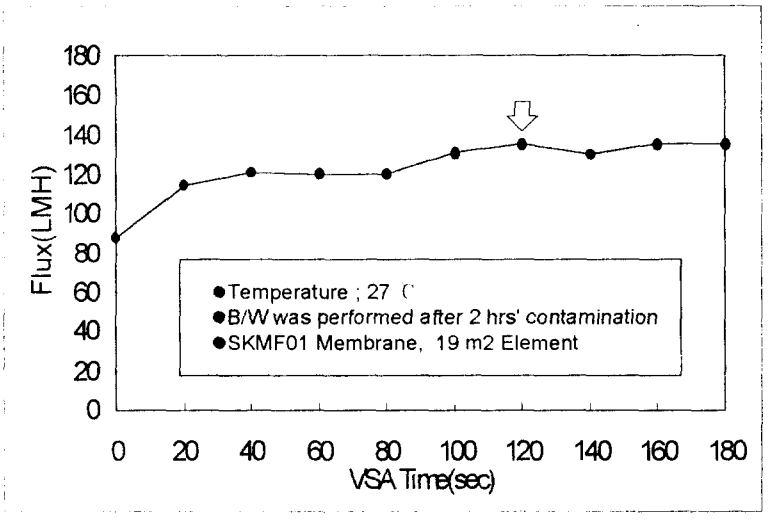
Cleaning Effect by VSA Process



Cleaning Effect According to the VSA Time



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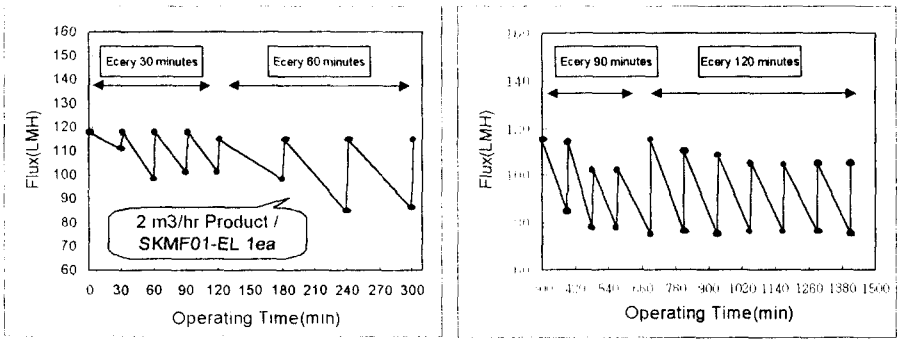
Cleaning Effect According to the VSA Term



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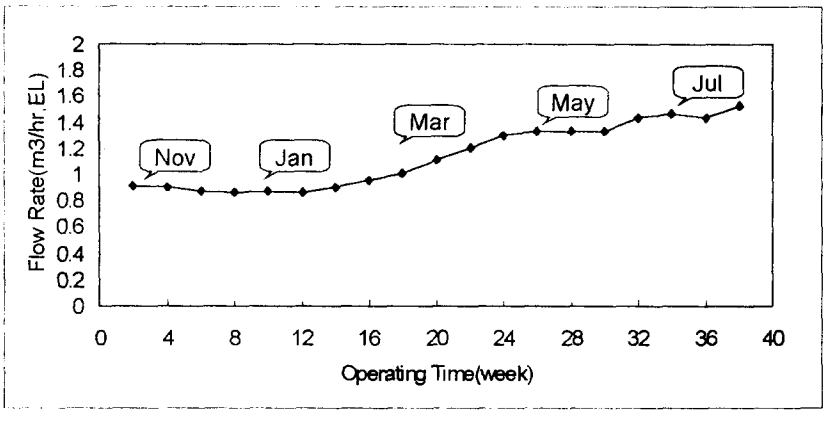
Operating Result of VSA System for River Water



- Operating Conditions ; 1 kg/㎠, Dead-end Filtration, VSA every 2hrs for 2 min.
- Feed Water ; River water without prefiltration
- Element ; SKMF01-EL ; 19 m2

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Feasibility of VSA System for the Industrial Effluent Recycle

- SK Chemicals' Suwon Plant ; Polymer Addition, Activate Sludge
- Feasibility for the recycle ; Stable Water Permeate Rate
- Possibility for the pretreatment of RO
- High Recovery ; Dead-end Filtration & VSA Cleaning
- Water Quality

Item	Wastewater	Effluent	MF Treated
pH	4,8	7.5	7.4
COD(ppm)	920	14.6	13.5
SS(ppm)	142	4.0	ND
n-Hexane(ppm)	246	4.0	3.0
Turbidity(NTU)	-	2.25	0.66
Bacteria(CFU/ml)	-	7,000	0

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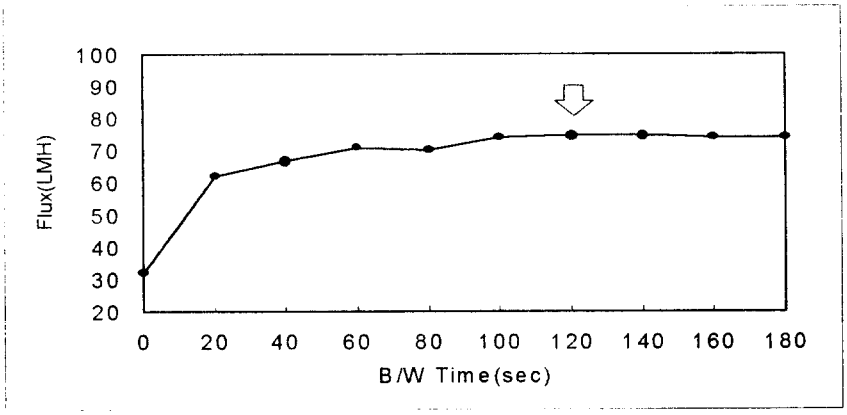
Cleaning Effect of VSA System for Industrial Effluent



●Operating Condition
- Operating Pressure ; 0.5 Kg/cm2, Back Washing Pressure ; 0.5 Kg/cm2
- Temperature ; 26-27 (
- Membrane was contaminated with effluent for 1 hr. Initial Flux ; 140LMH

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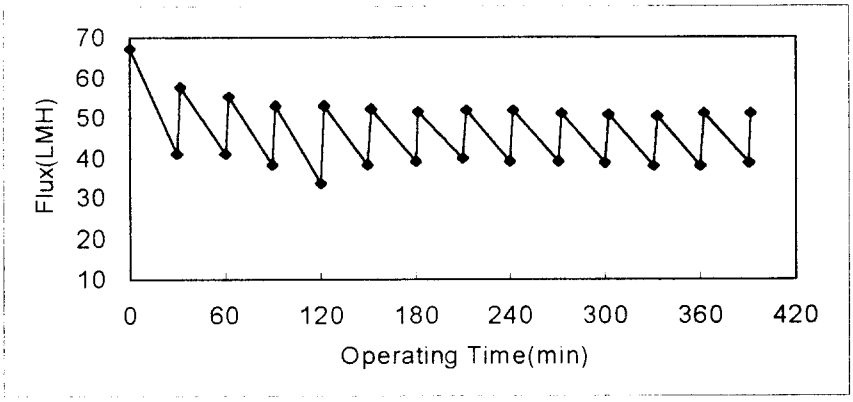
Flux of VSA System for Industrial Effluent



●Operating Condition
- Operating Pressure ; 0.5 Kg/cm2, Back Washing Pressure ; 0.5 Kg/cm2
- Temperature ; 26-27 (
- Membrane was contaminated with effluent for 1 hr. Initial Flux ; 140LMH
- VSA Term ; Every 30 minutes

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Conclusion

1. VSA showed the possibilty of direct water filtration.
2. Hollow fiber bundle density, membrane length and inner air diffuse tube affect the membrane element performance.
3. Outside skin of membrane should be smooth for the continuous outside-to-in filtration.
4. VSA process showed more effectivecleaning performance than back-washing.
5. VSA term and cleaning time was optimized.
6. Potential Applications
   - Industrial water supply without coagulation and sand filtration
   - Pretreatment of RO
   - Water reuse from industrial effluent
   - Drinking water supply from river water

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