MF Membrane Application for Water Treatment in Japan

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1. INTRODUCTION

Membrane Technology, which has been in use for over twenty five years, has established itself as one of the principle separation methods. With improved technology, Reverse Osmosis ("RO") has been applied to large volume water treatment facilities. UF and MF Membrane Technology has, up until recently, been applied to small scale water treatment facilities.

The fouling of membrane has restricted the growth of Membrane Technology in Water Treatment. Membrane fouling compound found in water causes the loss of flux across the membrane by absorbing to membrane and plugging their pores.

Various methods have been used in the reduction and prevention of membrane fouling. For RO, a conventional pre-treatment system removes the pollutants, preventing the function decline of RO membrane by keeping SDI < 4 as the standard condition of feed water. UF and MF Membrane Technology that must have pre-treatment function within itself, are required to keep its ability not to be influenced by fouling.

The Continuous Microfiltration ("CMF") in the paper overcomes the fouling with the air backwash and is operated in direct flow mode at a low pressure producing a high flux. Surface river water, secondary sewage water and another process water can be treated in higher quality by CMF compared with conventional water treatment processes.

2. MEMBRANE MICROFILTRATION WITH AIR BACKWASH

a) Hollow Fibre Membrane

Membrane used in the systems are hollow fibre polypropylene membrane with a mean pore size of 0.2 micron. The membrane module consists of more than several thousand hollow fibres of 320 micron in inside diameter and 620 micron in outside diameter. The high porosity of the membrane (70% porosity) allows operation at a very low pressure. As well, this unique membrane has enough elasticity. (Fig. 1)

b) Effect and function of Air Backwash

The membrane microfiltration system uses a gas backwash to clean the hollow fibre membranes. This backwash is automatically controlled by a "PLC" (Programmable Logic Controller).

Gas at high pressure (600 kpa) is injected into the center of the hollow fibres and bursts through the membranes, removing the foulants which have accumulated on the membrane surface. As the gas passes through the membrane, it expands the membrane and shakes loose any built-up impurities. Then, then contaminants are forcibly carried away into the feed stream. The operation takes about one minutes to complete, depending on feed water quality.

Fig. 2 and Fig. 3 show the backwash mode and demonstrate the gas backwash respectively.

c) Module arrays

Table 1 shows the module type and Fig. 4 illustrates M10C module. Modules are connected by an interlocking arrangement which reduces external plumbing requirements (see Fig. 5). Feed passes from the outside of the hollow fibre into the center, or lumen, and exits as filtrate. Suspended solids and micro-organisms are collected in the outside surface of the hollow fiber.

The system is available on a range of sizes from 4 to 55 litres/second (individual blocks of 6 to 90 modules).

Fig. 6 is a small size plant. The large plant is Maxibloc 90M10C (55 litres/second) which has 1,350m² surface area, as shown in Fig. 7. For larger plants, multiple Maxiblocs are manifolded together (refer Fig. 8)

d). Membrane Test

Membrane integrity is tested by means of an on-line pressure hold test which employs the bubble point principle used in the pharmaceutical industry and can detect a single broken fibre (Fig. 9), The CMF unit is equipped with a "Membrane Test" switch located on the operator's control panel.

3. RE-USE OF SEWAGE SECONDARY EFFLUENT

a) Tokyo Metropolitan Government

The Tokyo Metropolitan Government has developed a new advanced waste water treatment for recreational water re-use of sewerage secondary effluent by the combination of MF and RO, and has installed this at it's Ochiai Sewerage Works in Tokyo's Shinjuku Ward in 1993.

Fig. 10 illustrates the flow diagram. Table 2 and Table 3 show membrane module specifications and Operating conditions, respectively. As shown in Table 4, MF membrane shows excellent separation performance. The RO permeate quality is quite good.

b) Japan Institute of Waster Water Engineering Technology

The Japan Institute of Waste Water Engineering Technology ("JIWET") is carrying out research and development for the practical application of 'Seseragi' plants (Fig. 11). 'Seseragi' plants are a compact sewage treatment plant having applied the latest technology for re-using sewage water.
JIWET has issued guidelines for membrane technology for 'Seseragi Plants'. Fig. 12 shows a case study of a CMF plant.

4 DRINKING WATER TREATMENT

The conventional process such as coagulation-sedimentation-sand filtration-disinfection is an effective and vital operation in most cases of drinking water treatment.

Recently, due to a worsening quality of water resources, scarcity of adquate installation location, shortage of skilled workers, and the increasing stricter requirements for high quality drinking water, new technology has become increasingly required.

The Japanese Ministry of Health and Welfare has conducted research and development programs named MAC 21 (MAC: Membrane Aqua). They have issued guidelines for the application of Membrane Technology.

Table 5 shows the operation result of CMF. CMF provides consistent filtrate despite wide variation at turbidity or high levels at organic materials in Edo River water. It has been observed that the filtrate quality is almost the same at MF and UF. This result indicates that MF is more effective in flux compared to UF.

A CMF 900M10 x 6 unit (membrane surface area 5,400m^2 (has been operating at San Jose, CA, USA. It has been supplying drinking water of less than 0.1 NTU without co-agulant from Saratoga Creek water, which has wide variation of 1 to 100 NTU at turbidity (Fig. 13).

RECOVERY OF INDUSTRIAL WASTE WATER

RO is needed for the recovery of industrial waste water in order to avoid accumulation and an increase soluble matters in water.

Effluent from waste water facilities changes the quality of water significantly. The conventional pre-treatment of RO is hard to supply good quality feed water to RO in the industrial waste water recovery system.

A combination system of CMF and hollow fiber type RP (30m^3/hr) has been operating at Sony's factory (producing TV brown tubes) in Japan. Raw water for membrane plant comes from an activated sludge process.

Hollow fiber type RO which is sensitive to feed water quality is easily applied using CMF. A combination of CMF and RO systems is available, easy to use, and producing good and effective results.

As well as this Sony factory, there are many other plants in Japan which are utilising CMFs for the recovery of industrial water.

Installation of CMF units in Japan has now reached almost 150 units. Worldwide, the number installed totals more than 500 units.

In Conclusion, I sincerely hope that this new technology will be useful to the continued development of Membrane Technology.

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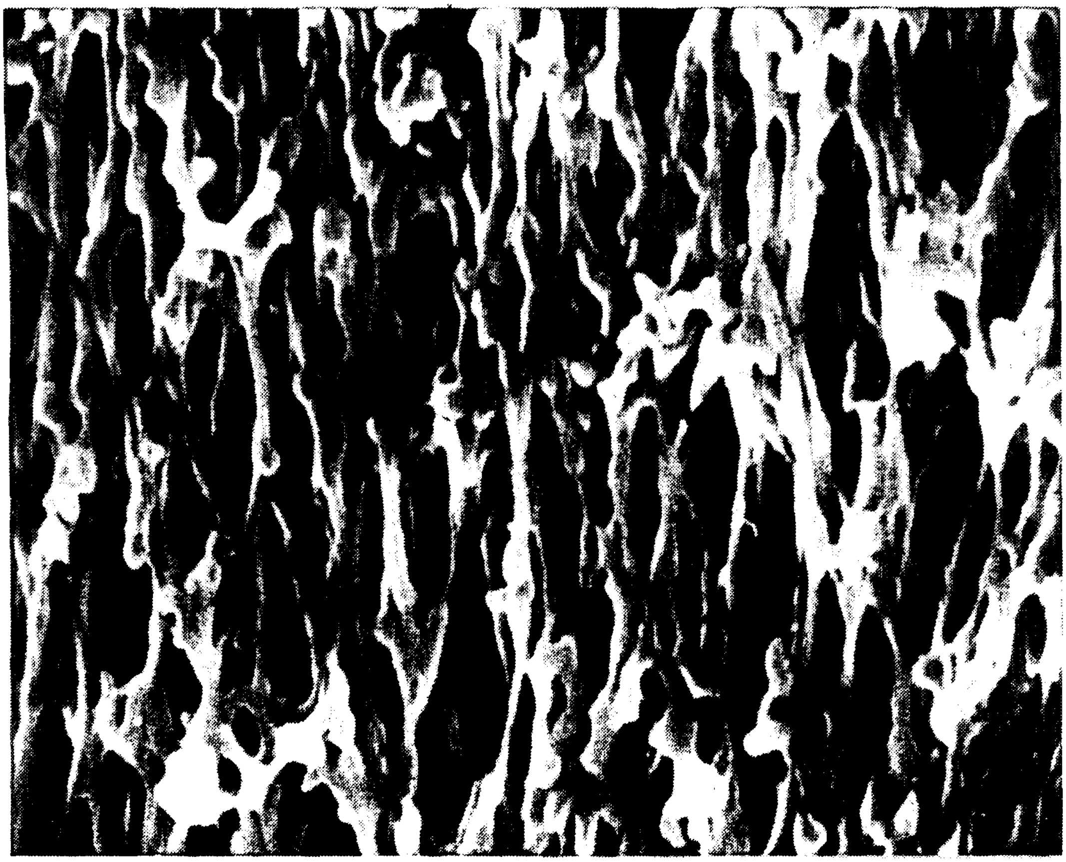


Fig 1. CMF membrane surface (electron micrograph 11,000 x magnification)
Elongated pores designed for backwash

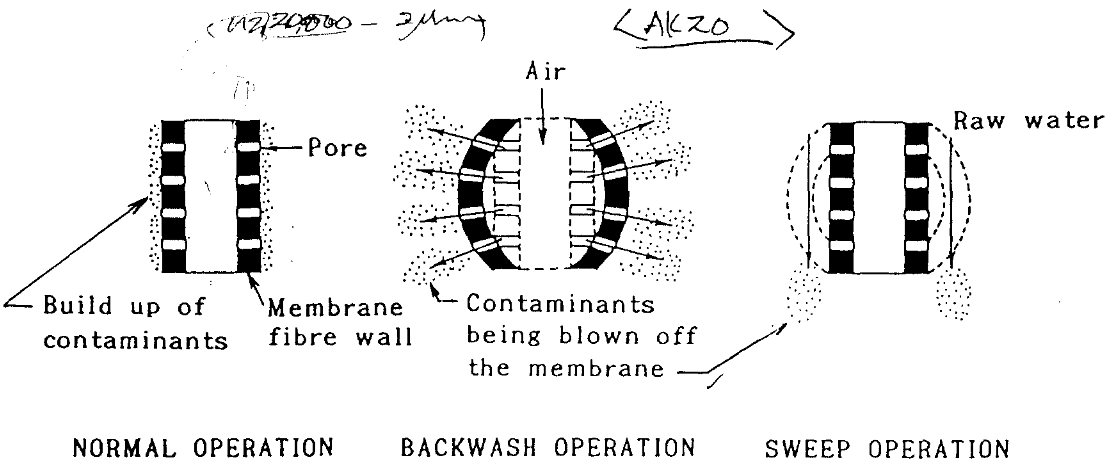


Fig 2. The membrane under normal operation and during gas backwash

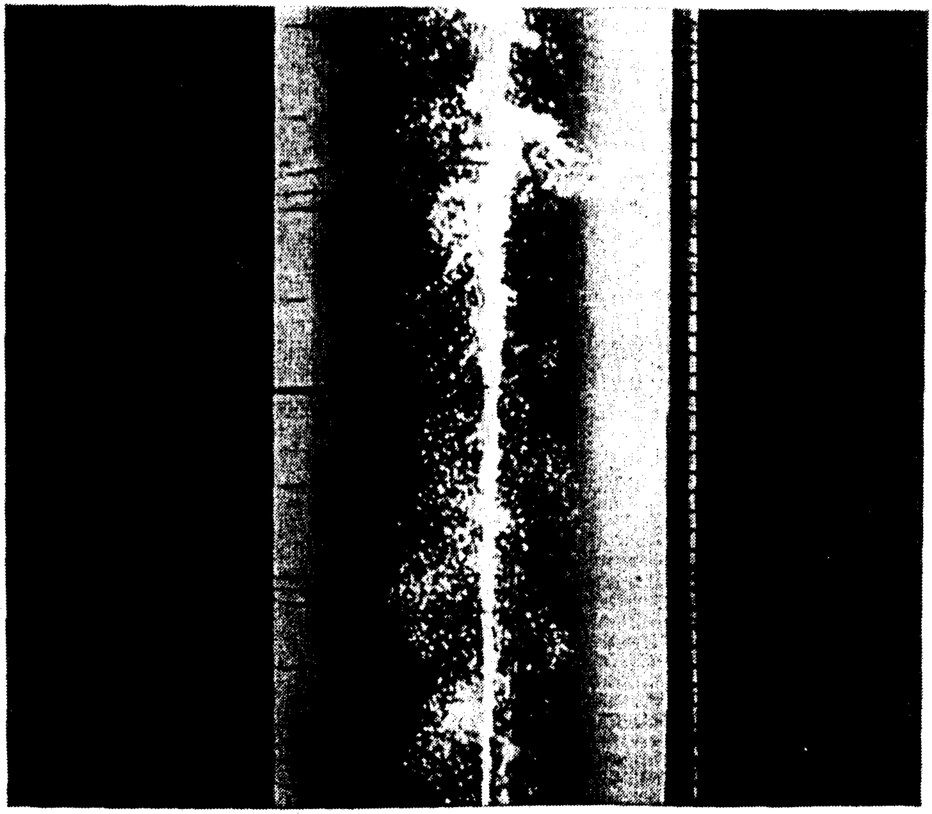


Fig 3. Gas backwash on a single fibre demonstrates the energy generated to clean the membrane surface.

Table 1. Specification of MEMCOR modules

Items		Specification			
Type		M1	M2	M10	M10C
Membrane area(m^2)		1	2	10	15
Membrane material		Polypropylene or PDVF			
Pore size		0.2 μ m			
pH range		2 - 13			
Housing	Material	ABS		Nylon/SUS 316 or Nylon	
	Seal Materials	Polyuretan			
Size		108W x 507H	108W x 970H	180W x 1748H	
Weight (kg)		2.6	3.0	18.6	

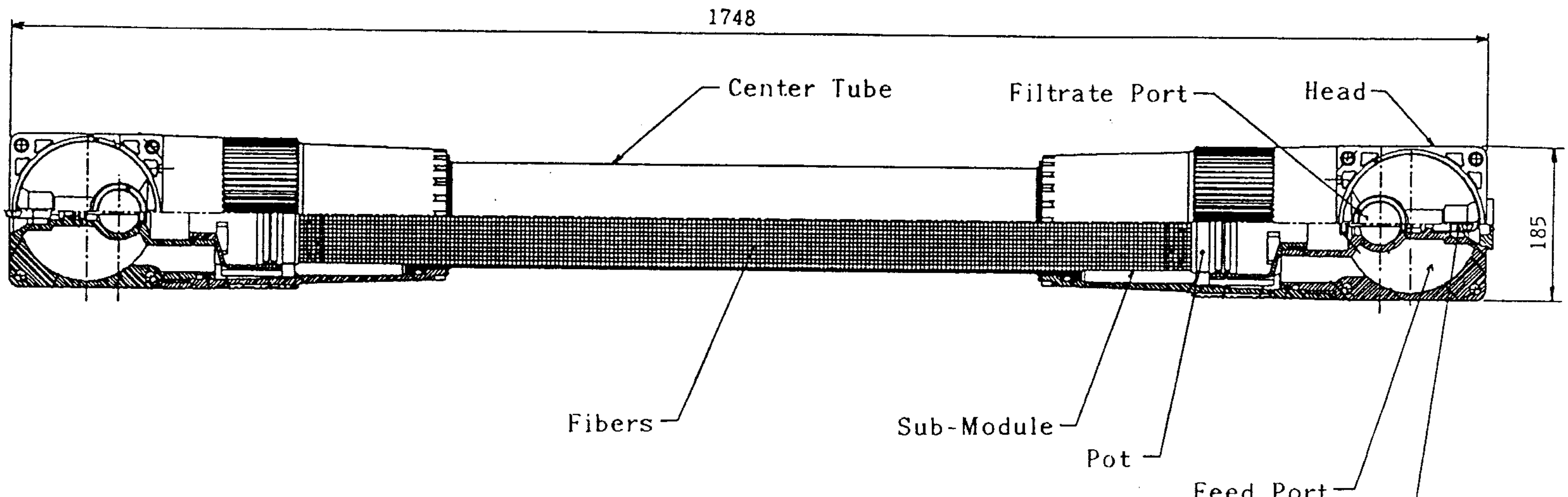


Fig 4. A cross section of a MEMCOR M10C Module

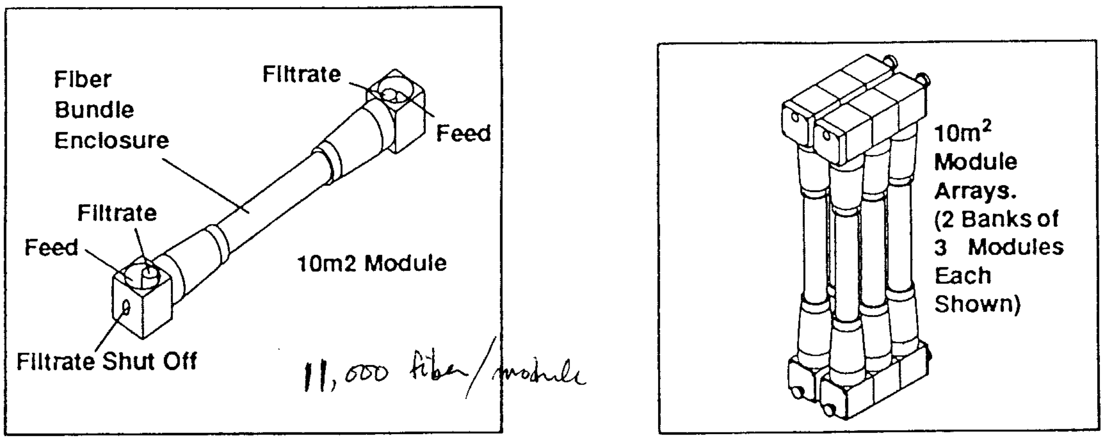
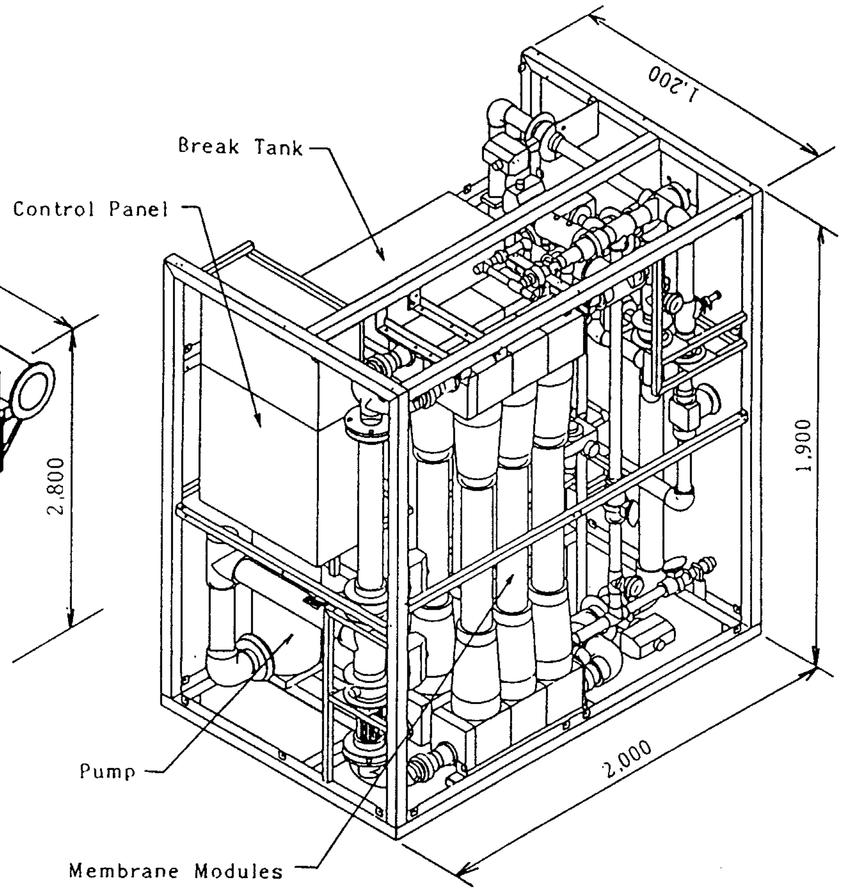
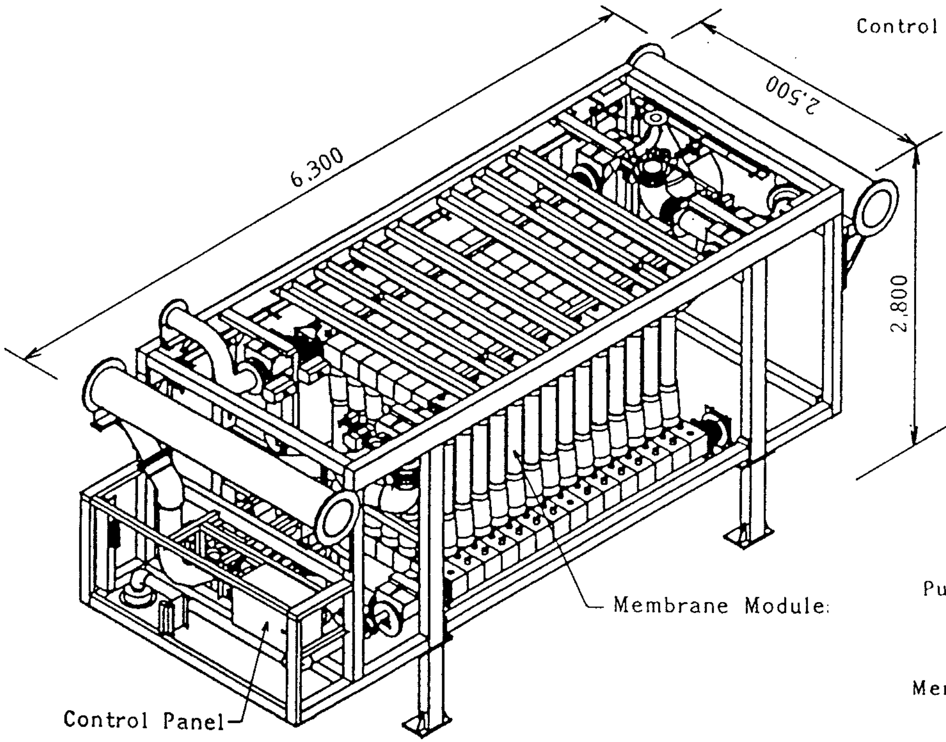


Fig. 5 Module arrays



<u>Fig. 6</u> A CMF 6M10c (90m² Membrane area)



<u>Fig. 7</u> A MAXIBLOCK 90M10C (1,350m² of Membrane area 90 modules)

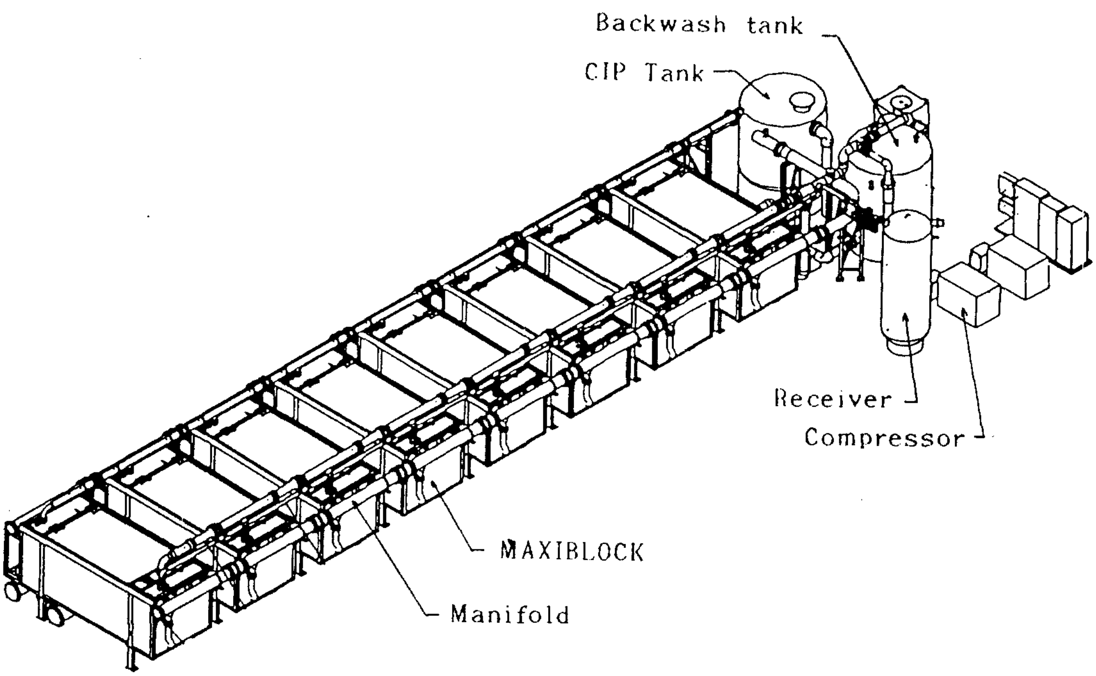
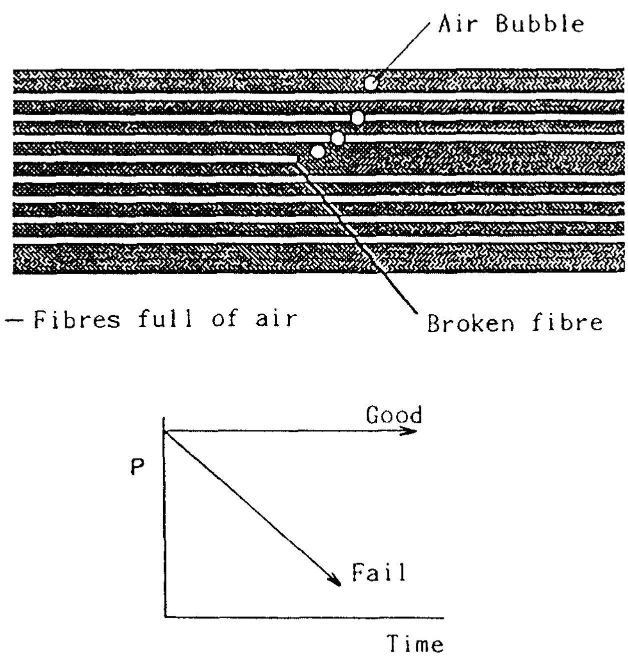


Fig.8 A Bank of CMF module blocks
MAXIBLOCK 90M)C x 8(10,800m³ membrance area)



< testing of broken fiber >
< Sonic analyser >

Fig. 9 Typical figure of pressure hold test. If a fibre is damaged, lumen pressure decay.

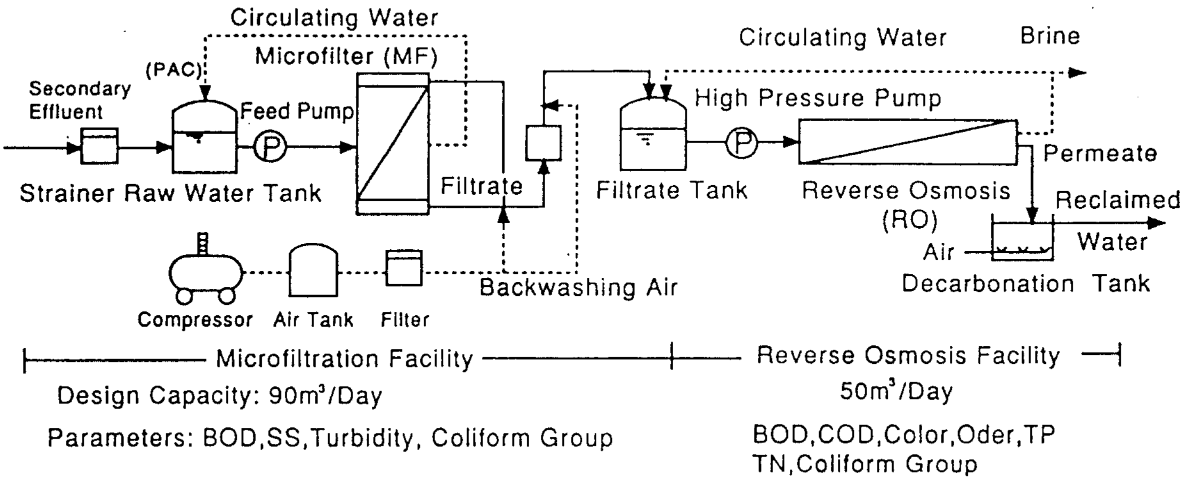


Fig. 10 Flow Diagram of the newly developed MF/RO Process

Table 2. Membrane Module Specifications

Membrane	Microfilter	Revers Osmosis (A)	Revers Osmosis (B)
Membrane Type	Hollow Fiber	Spiral-wound	Spiral-wound
Membrane Material	Polypropylene	Cross-linked polyamide	Polyvinyl alcohol
Pore size (μm)	0.2	–	–
NaCl Rejection Rate (%)	–	97 (at 15kg/cm²)	92 (at 15kg/cm²)
Membrane Area (m²)	2	7	7
Number of Elements	15	6	4

Table 3. Operating Conditions of Membrane Modules

Membrane	Microfilter	Revers Osmosis (A)	Revers Osmosis (B)
Operating Pressure(kg/cm^2)	0.5 - 2.0	12 - 18	5 - 10
Module Load(m^3/module.day)	5.0	3.5 - 4.3	3.5 - 4.3
Flux($m^3/m^2 \cdot day$)	2.5	0.5 - 0.6	0.5 - 0.6
Minimum Brine Flow (m^3/module.day)	12	29	29
Recovery Rate (%)	90 - 93	47	38
F I of Feed Water	–	< 4.0	< 4.0
Residual Chlorine(mg/l)	0.0	0.1 - 0.3	0.1 - 0.3
Air Backwash Interval(min)	12	–	–
Timing of Chemical Cleaning	T.M.P. ≤ 1.2kg/cm^2	A/Ao ≥ 0.7	A/Ao ≥ 0.7

Note

T.M.P. : Trans Membrane Pressure
Ao : Initial Value of 25°C Normalized Flux
A : 25°C Normalized Flux

Table 4. Results of Water Analysis

	Parameters	Secondry Effluent	MF Filtrate	RO (A) Permeate	RO (B) Permeate	National Guideline (proposal)
A	Appearance	light yellow	light yellow	colorless	colorless	–
	Odor	slight odor	slight odor	odorless	odorless	not offensive
	Chromaticity	38	25	< 1	< 1	<10
	Turbidity	14	< 1	< 1	< 1	< 5
B	SS (mg/l)	8	< 1	< 1	< 1	–
	TDS (mg/l)	623	637	84	271	–
C	BOD (mg/l)	4	< 1	< 1	< 1	< 3
	COD_{Mn} (mg/l)	16	10	< 1	< 1	–
	TOC (mg/l)	15	9	< 1	< 1	–
D	T-P (mg/l)	2.2	1.1	0.01	0.03	–
	T-N (mg/l)	31	30	4.2	17	–
	NH_4-N (mg/l)	28	28	3.9	15	–
E	pH	7.2	7.2	5.8	6.8	5.8 - 8.6
	EC (μS/cm)	1320	1330	145	711	–
F	Coli.(cell/100ml)	28×10^4	0	0	0	< 50
	F.Coli(cell/100ml)	49×10^3	0	0	0	–

Note :

A : Emotional Parameters B : Solid Palameters C : Organic Substance Prameters
D : Eutrophication Parameters E : Inorganic Substance Palameters
F : Hygiene Parameters
National Guideline : Guideline for Water Recreation by reclaimed water
Coli. : Coliform Group Bacteria F.Coli. : Feacal Coliform Group Bacteria

Characteristics

i. Ultra small type
ii. Advanced treatment
iii. Energy saving
iv. No man control
v. Harmonious with surroundings

Supply Quantity	2,000m³/day - 4,000 m³ day
Final effluent	SS 5 mg/litre
	BOD 5 mg/litre
Treatment Plant	Packaged type (Each facility will be cubic type)
	Space approximately 400m²

<SESERAGI PLANT SYSTEMS>

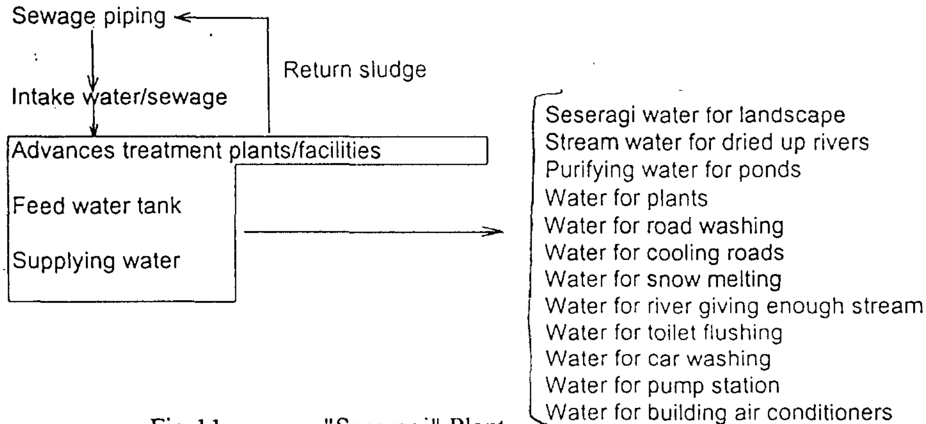
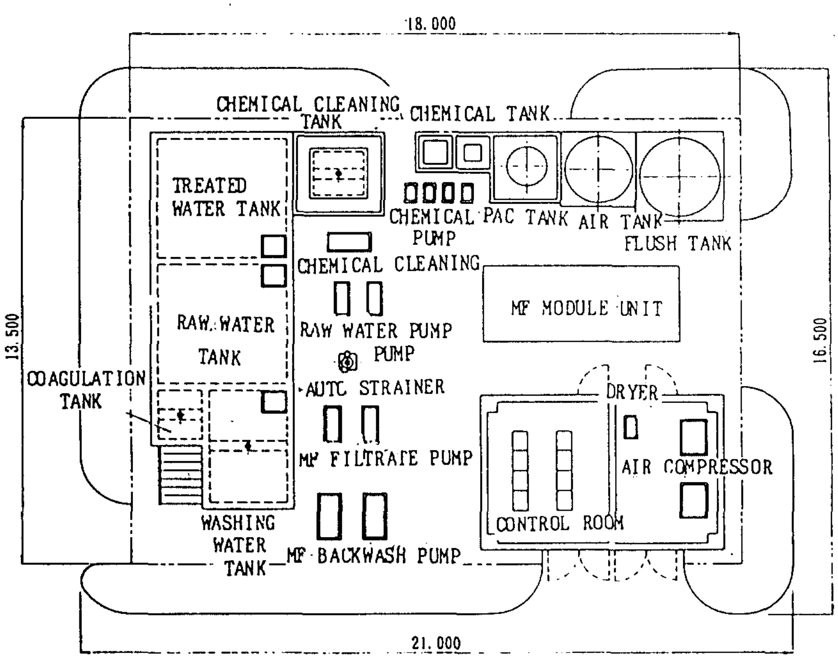


Fig. 11. "Seseragi" Plant



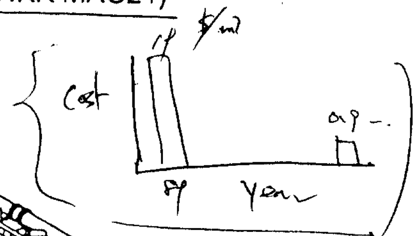
Items	¥en /m³
Power consumption	2.9
Chemicals	3.3
Membrane replacement	9.1
TOTAL	15.3

Fig. 12. A case study of CMF Plant (3,000m³/day)

Table 5. MAC 21 water quality (average)

Parameters	Unit	Period # 1		Period #3	
		Raw Sewage	Filtrate	Raw Sewage	Filtrate
Turbidity	-	16.100	0.020	10.200	0.00
Colour	-	10.000	4.000	13.000	3.000
T - Fe	mg/l	0.830	<0.01	0.640	<0.01
T - Mn	mg/l	0.049	0.010	0.044	0.016
Al	mg/l	1.100	0.030	0.470	0.030
KMnO4 consumption	mg/l	7.300	2.400	5.700	2.300
E260	-	0.174	0.151	0.139	0.112
NH4-N	mg/l	0.050	0.040	0.240	0.200
DOC: 0.4 m	mg/l	1.300	1.100	1.400	1.000
T-THMFP	mg/l	0.046	0.032	0.035	0.024
Soluble Silicate	mg/l	23.20	22.50	24.90	23.40
Bacteria	cell/100ml	31,000	6.000	21,000	1.000
F. Coli	cell/100ml	410.0	0.000	330.0	0.000

(Ref: NKK MAC21)



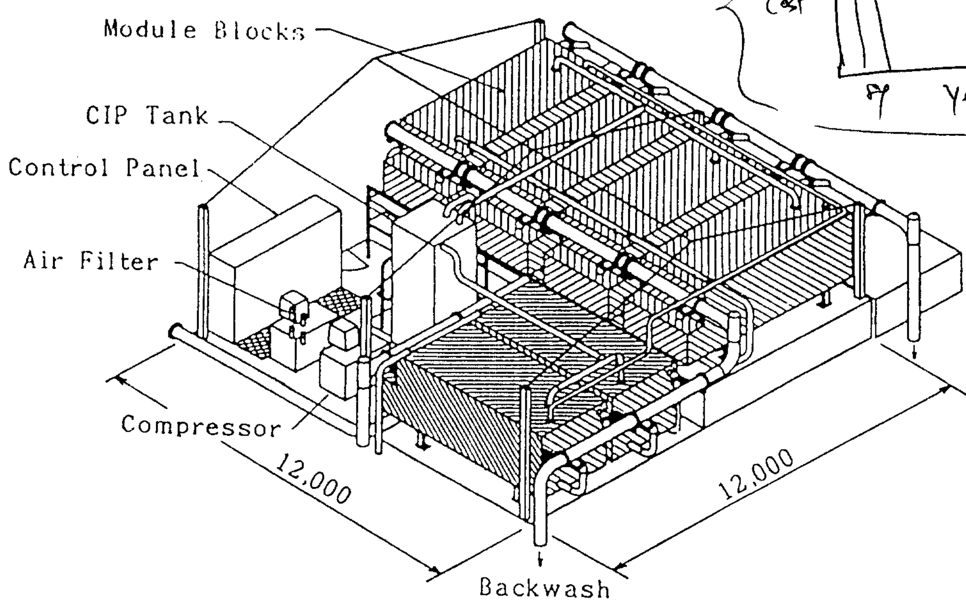


Fig 13. This figure shows the Saratoga plant in California, USA, which consists of 900M10 x 6 units (capacity 19,000m³/dav)

(new) SONY plant

for emergency, feed PAC, for AS Eff. of AS → MG 300 m³/d