7.3 Experiment with the RO Test Plant

7.3.1 Installation of RO Test Plant

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7.3.1 Installation of RO Test Plant

1. Transfer of the RO Test Plant

The RO Test Plant was transferred from SWCC Yanbu site to the SWCC R&D Center in January 1993, After the primary and secondary installation work, the unit test operation and experimental operation started at the end of August, 1994.

2. Installation of RO Test Plant

2.1 Primary Installation Work

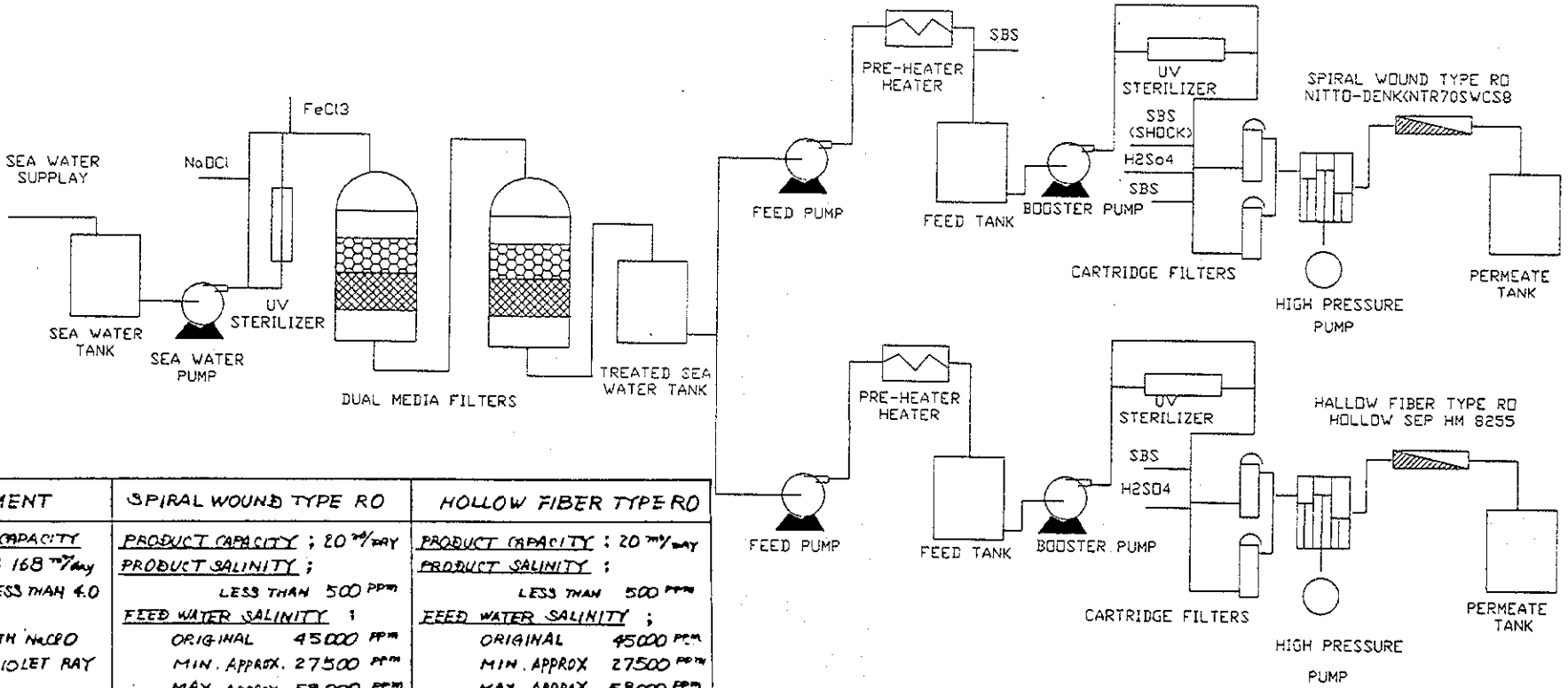
The damaged parts were repaired based on the results of the inspection conducted at the SWCC Yanbu site in September 1991. The primary installation work of the RO test plant was carried out during the period from January 30 to February 22, 1994. After an experimental water flow test, the remaining work and necessary parts required to complete the work were clarified.

2.2 Secondary Installation Work

After obtaining the necessary parts based on the results of the primary installation work, the secondary installation work of the RO Test Plant was conducted during the period from July 18 through August 20, 1994.

3. RO Test Plant

The outline of the test plant is shown in Fig. 1 to Fig. 7



PRETREATMENT	SPIRAL WOUND TYPE RO	HOLLOW FIBER TYPE RO
TREATED SEAWATER CAPACITY ; 168 m³/day FOULING INDEX ; LESS THAN 4.0 STERILIZATION CHLORINATION WITH NaClO DOSING OR ULTRA VIOLET RAY COAGULATION LINE COAGULATION WITH Fe_2Cl_3 DOSING FILTRATION DUAL MEDIA PRESSURED FILTER BACK WASHING & FLUSHING AUTOMATIC DEVICE . POLISHING FILTER.	PRODUCT CAPACITY ; 20 m³/DAY PRODUCT SALINITY ; LESS THAN 500 ppm FEED WATER SALINITY ; ORIGINAL 45000 ppm MIN. APPROX. 27500 ppm MAX. APPROX 58000 ppm FEED WATER TEMPRATURE ; 21~50 °C. FEED PREHEATER ; 50×10^3 kcal/hr FEED HEATER ; 45000 kcal/hr STERILIZATION ; SHOCK TREATMENT BY S.B.S DOSING OR ULTRA VIOLET RAY RO MODULE ; TORAY SP-120 × 6 ELEMENTS DESALINATION PASS ; SINGLE PASS APPLIED PRESSURE ; 56~70 kg/cm² RECOVERY RATIO ; 25~40 % DECHLORINATION & DEOXYEATION ; DOSING S.B.S. ($NaHSO_3$)	PRODUCT CAPACITY ; 20 m³/DAY PRODUCT SALINITY ; LESS THAN 500 ppm FEED WATER SALINITY ; ORIGINAL 45000 ppm MIN. APPROX 27500 ppm MAX APPROX. 58000 ppm FEED WATER TEMPRATURE ; 21~50°C FEED PREHEATER ; 50×10^3 kcal/hr FEED HEATER ; 45000 kcal/hr STERILIZATION ; ULTRA VIOLET RAY OR CHLORINATION WITH NaClO DOSING RO MODULE ; TOYOBO HOLLOSEP HR 8255, 8355 EACH ONE DESALINATION PASS ; SINGLE PASS APPLIED PRESSURE ; 56~65 kg/cm² RECOVERY RATIO ; 25~40 % FEED PH CONTROL ; DOSING H_2SO_4

Original Design
Spiral Wound Type RO Element: Toray SP-120 x 6
Hollow Fiber Type RO Element:Toyobo HR8355 X 1 + HM8255 X 2

New Design Base
Spiral Wound Type RO Element:Toray SU-820 X 2
Nitto Denko NTR-70SWC-S8 X 2
Hollow Fiber Type RO Element:Toyobo HR8355 X 1 + HM8255 X 2

Fig. 1 Schematic Flow Diagram of the RO Test Plant

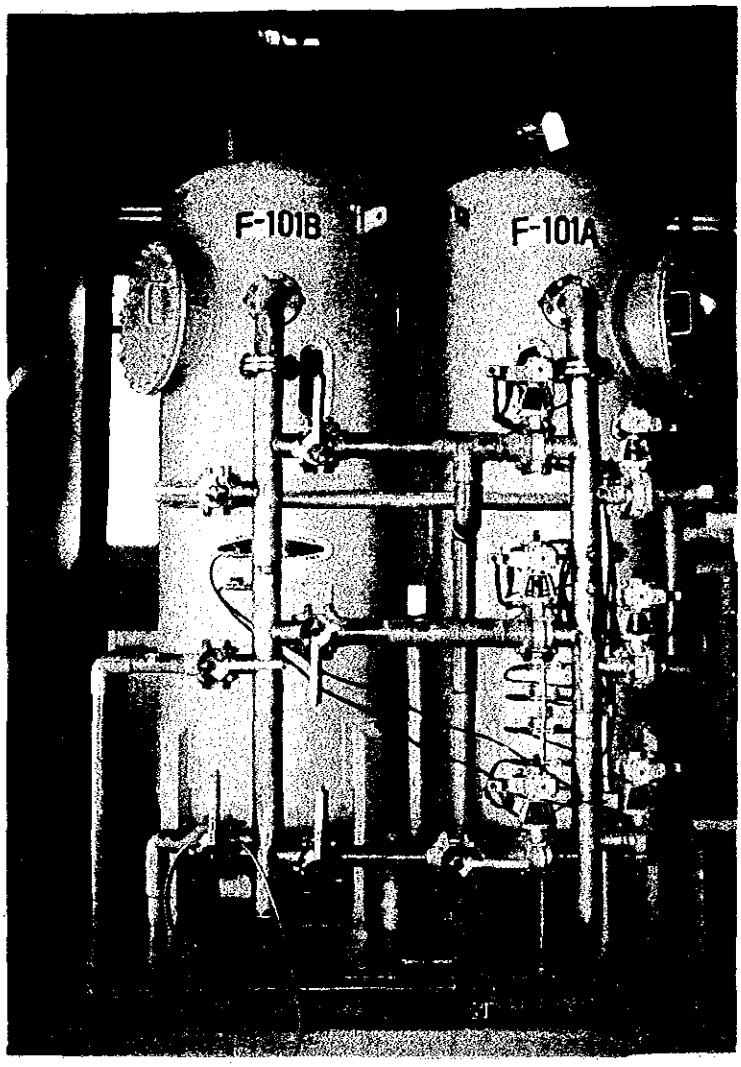


Fig. 3 F-101A,B Dual Media Filters

Fig. 2 Overall View of the RO Test Plant

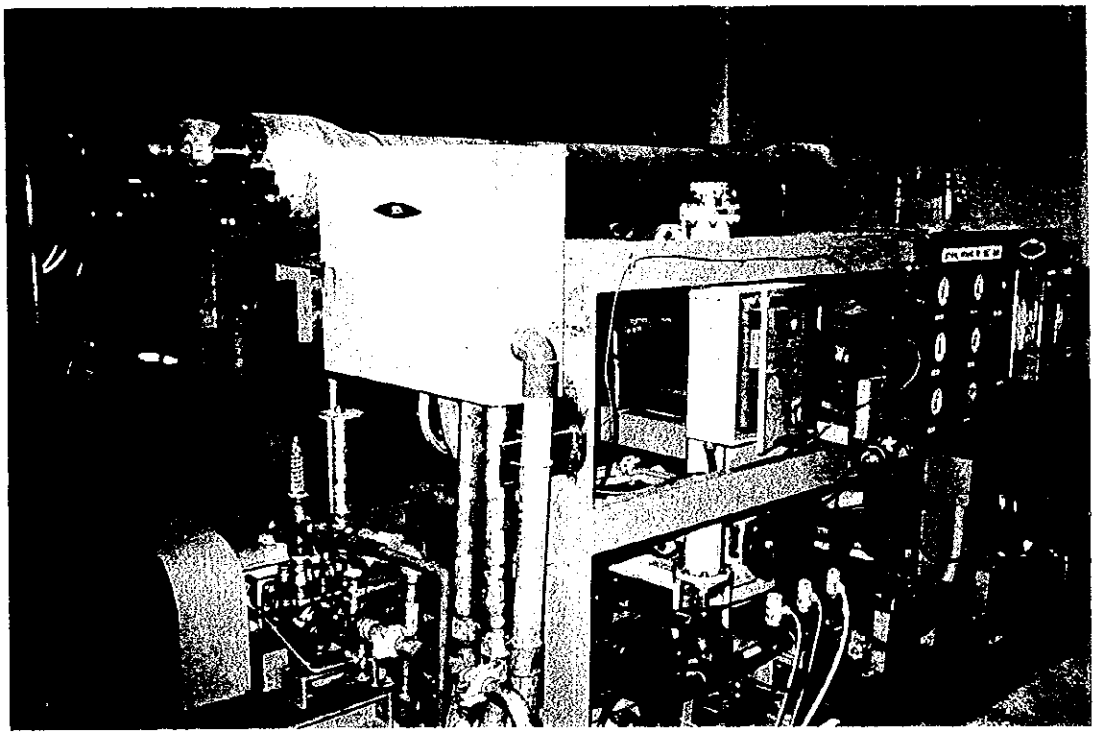


Fig. 5 RO-201 Spiral Wound Type RO Equipment

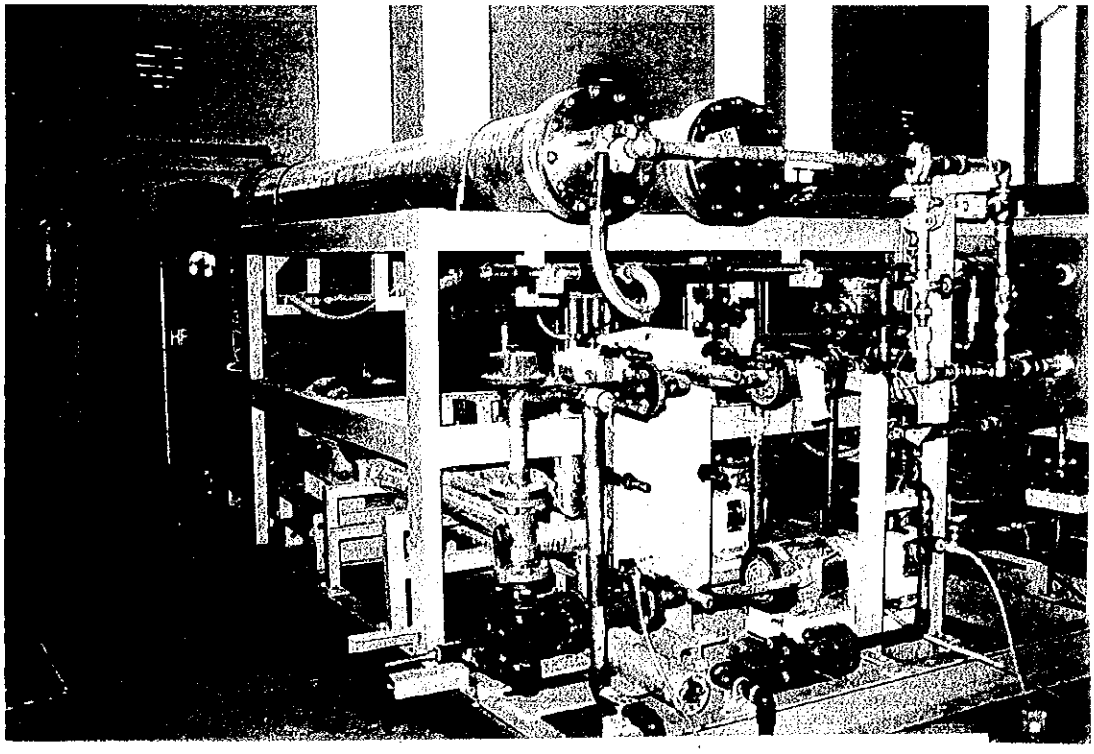


Fig. 4 RO-301 Hollow Fiber Type RO Equipment

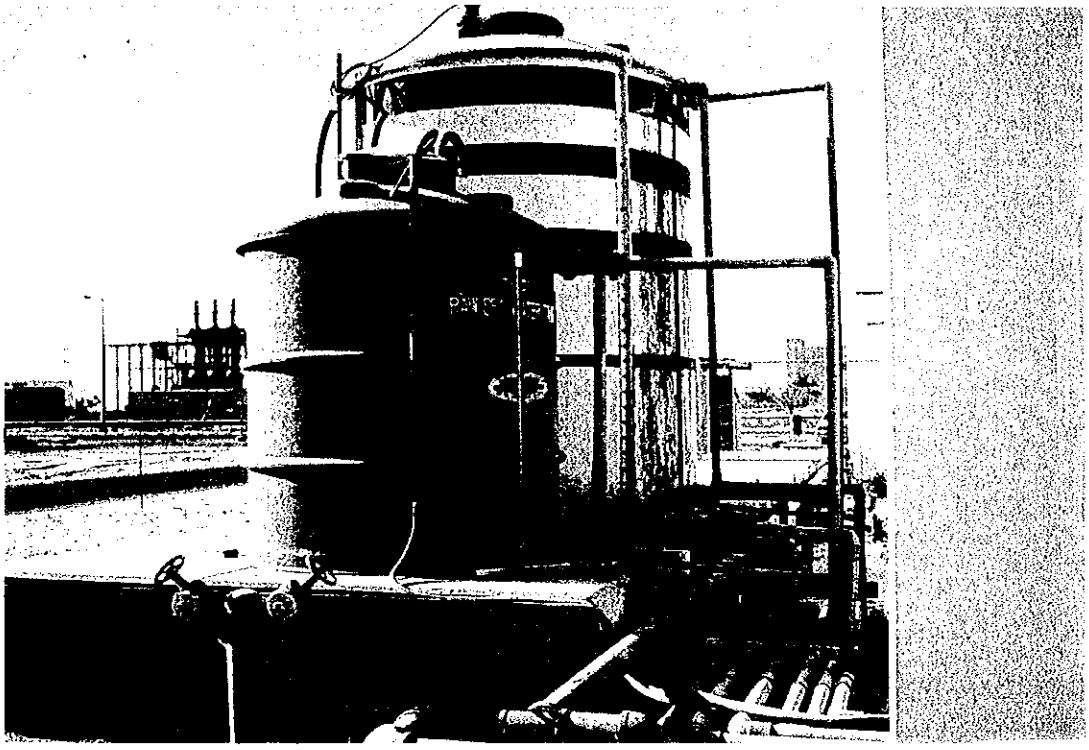


Fig. 7 Raw Seawater Tank T-101 Treated Seawater Tank T-102

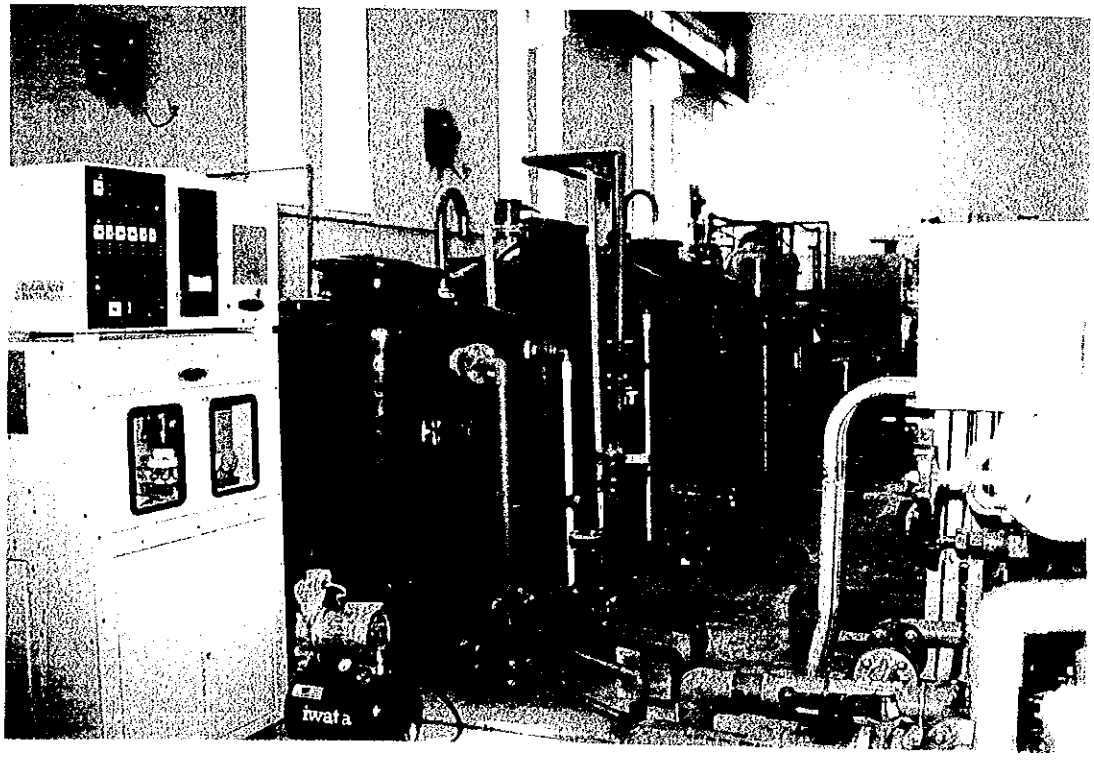


Fig. 6 Tanks(T-302,T-301,T-201,T-202),Trench and Piping

Table 1 Condition of Each Equipment before Installation and Work Performed

No.	EQUIP NO.	NAME OF EQUIPMEN	Result of inspection conducted two years ago (Note 1)	Result of inspection conducted this time (Note 2)	Measures to be taken
1	AN101	AUTO VALVE	Appearance: Defective Performance test: Good	The body has already been painted. The solenoid valve is corroded.	The operation is possible. The replacement is scheduled.
2	AN102	- do -	- do -	- do -	The operation is possible. The replacement is scheduled.
3	AN103	- do -	- do -	- do -	The operation is possible. The replacement is scheduled.
4	AN104	- do -	Appearance: Defective Performance test: The connector is broken.	The body has already been painted. The solenoid valve is broken.	The operation is not possible. The replacement is scheduled.
5	AN105	- do -	Appearance: Defective Performance test: Good	The body has already been painted. The solenoid valve is corroded.	The operation is possible. The replacement is scheduled.
6	AN106	- do -	Appearance: Defective Performance test: The joint is broken.	The body has already been painted. The joint is broken.	The operation is not possible. The replacement is scheduled.
7	AN107	- do -	Appearance: Defective Performance test: Good	The body has already been painted. The solenoid valve is corroded.	The operation is possible. The replacement is scheduled.
8	AN108	- do -	--	- do -	The operation is possible. The replacement is scheduled.

(Note 1) September, 1991; SCWW Yanbu
(Note 2) February, 1994; Jubail RD Center

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
9	F-101A	DUAL MEDIA FILTER	Appearance: Good Overhaul inspection: Good	The body has already been painted. The PDC pipe had aged deterioration and discoloration. The SGP pipe is corroded.	This item is used as it is because there seems to be no functional problem.
10	F-101B	- do -	- do -	- do -	- do -
11	FI-101	FEED INLET FLOW INDICATOR	Appearance: Good Appearance inspection: Good	A slight degree of rust was found.	There is no special problem.
12	FI-102	B/W·W INLET FLOW INDICATOR	- do -	- do -	- do -
13	FI-103	AIR BLOW FLOW INDICATOR	- do -	- do -	- do -
14	MV-105	MANUAL VALVE	Appearance: Good Overhaul inspection: Good	There is corrosion in the metal section. The drive section has already been treated with oil.	Although there is no functional problem, this item is scheduled to be replaced.
15	MV-106	- do -	- do -	- do -	- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
16	MV-107	MANUAL VALVE	Appearance: Defective Overhaul inspection: Good	There is corrosion in the metal section. The drive section has already been treated with oil.	Although there is no functional problem, this item is scheduled to be replaced.
17	MV-108	- do -	- do -	- do -	- do -
18	MV-109	- do -	- do -	- do -	- do -
19	MV-110	- do -	- do -	- do -	- do -
20	MV-111	- do -	- do -	- do -	- do -
21	P-101	SEAWATER PUMP	Appearance: (Body) Slightly defective; (Motor) Defective Overhaul inspection: Good Individual starting test of motor: Good	Both the body and the motor have already been painted. There is no problem with the appearance.	The operation is possible. This item is scheduled to be used as it is.
22	P-102	B/W PUMP	- do -	- do -	- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
23	P-103	B/W AIR BLONER	Appearance: (Body) Defective (Motor) Defective Overhaul inspection: Good Individual starting test of motor: Good Joint operation test: Good	The motor section has already been painted. The casing in the gear section has major corrosion. But the rotation is possible. There is no drive V-BELT. There is no oil in the gear section.	The operation is possible. This item is scheduled to be used after oil filling.
24	P-104	WASTE PUMP	Appearance: (Body) Slightly defective; (Motor) Defective Overhaul inspection: Good Individual starting test of motor: Good	The motor section has already been painted. There is no problem with the appearance.	The operation is possible. This pump will not be used due to the convenience of SWCC. (There is no WASTE TANK.)
25	P-401	AIR COMPRESSOR & DRYER	Appearance: (Dryer) Slightly defective Overhaul inspection: Good Performance test of dryer: The start switch rotates.	The operation has already been started. There is no problem.	This item is used as it is.
26	PI-101	SEAWATER PUMP OUTLET PRESSURE INDICATOR	Appearance: Defective Inspection: Good	Major corrosion	This item has already been replaced.
27	PI-102A	F-101A INLET PRESSURE INDICATOR	Appearance: Defective Inspection: The front glass is broken.	- do -	- do -
28	PI-103A	F-101A OUTLET PRESSURE INDICATOR	Appearance: Defective	- do -	- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
29	PI-102B	F-101B INLET PRESSURE INDICATOR	Appearance: Defective Inspection: Good	Major corrosion	This item has already been replaced.
30	PI-103B	F-101B OUTLET PRESSURE INDICATOR	Appearance: Defective Inspection: Good	- do -	- do -
31	PI-104	B/W PUMP OUTLET PRESSURE INDICATOR	Appearance: Defective Inspection: Good	- do -	- do -
32	PS-401	INSTRUMENT AIR PRESSURE SWITCH	—	The cover was very corroded. But the inside had no problem.	Although there is no functional problem, a spare is scheduled to be provided.
33	T-101	SEAWATER TANK	Appearance: Good Internal inspection: Good	The metal section of the ladder was very corroded. But it has no problem with the use. But the PVC nozzle section had serious deterioration and needs to be replaced.	The nozzle section has already been replaced.
34	T-102	TREATED SEAWATER TANK	Appearance: Slightly defective Internal inspection: Good	- do - There is no level gauge.	- do - Because there was no oil gauge, only an angle gauge was attached to the nozzle. section.

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
35	UV-101	UV STERILIZER	Appearance: Slightly defective Performance test: Good (Two pilot lamps need to be replaced.)	This item has already been painted. The stabilizing blade has corrosion, but has no problem with the actual use. The pilot lamp is not lighted.	The pilot lamp was not lighted. But the UV LAMP itself was lighted. Thus, this item is used as it is.
36	T-201	FEED TANK	Appearance: Good Internal inspection: Good	There is no problem with the appearance. But the PVC nozzle have deterioration, and needs to be replaced.	The PVC nozzle has already been replaced.
37	T-202	PROD. TANK	—	- do -	- do -
38	P-201	FEED PUMP	Appearance: (Body) Slightly defective; (Motor) Defective Individual starting test of motor: Good	The motor section has already been painted. There is no problem with the appearance.	The operation is possible. This item is scheduled to be used as it is.
39	P-202	BOOSTER PUMP	- do -	- do -	- do -
40	P-203	HIGH PRESSURE PUMP	Appearance: (Body) Slightly defective; (Crankcase) Slightly defective; (Starter) defective; (Motor) Defective Overhaul inspection: Good	- do - The spring of the relief valve is corroded.	The operation is possible. - do - This item has already been replaced.
41	HE-201	HEAT EXCHANGER	Appearance: Slightly defective	There is no problem with the appearance. But the	This item is used as it is.
42	HE-202		Appearance inspection:	PVC connecting pipe had	

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
43	UV-201	UV STERILIZER	Appearance: Good Performance test: Good	There is no special problem.	The pilot lamp is not lighted. But there is no problem with the function. Therefore, this item is used as it is.
44	F-201A B	SAFETY FILTER	Appearance: Good	There is no special problem.	A filter was installed. Then, the item was used as it is.
45	RO-201	R/O MODULE		This item was packed in the same way as it is shipped. The vessel seemed to have no problem with the appearance.	This item is scheduled to be used. - do -
46	FI-201	R/O PRODUCT FLOW INDICATPR	Appearance: Good		This item is used as it is.
47	FI-202	R/O CONCENTRATE FLOW INDICATOR	Appearance: Good	There is no special problem.	- do -
48	PI-201	FEED PUMP OUTLET PRESSURE INDICATOR	Appearance: Good	- do -	This item is used as it is.
49	PI-202	BOOSTER PUMP OUTLET PRESSURE INDICATOR	Appearance: Good	Slight corrosion	- dot -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
50	PI-203	H·P PUMP INLET PRESSURE INDICATOR	Appearance: Good	Slight corrosion	This item is used as it is.
51	PI-204	R/O FEED INLET PRESSURE INDICATOR	Appearance: Good	- do -	- do -
52	PI-205	R/O CONC PRESSURE INDICATOR	Appearance: Good	- do -	- do -
53	PI-206	HE-202 INLET PRESSURE INDICATOR	Appearance: Good	- do -	- do -
54	TC-201 & CV-201	TEMP. CONTROLLER	Appearance: Slightly defective Performance test: Good	There seemed to no problem with the appearance.	The CV-201 itself did not have a problem. But the resistance temperature sensor was defective and no control could be made. Thus, the resistance temperature sensor was replaced. The CV-201 is scheduled to be used as it is.
55	TI-201	TEMP. INDICATOR	—	There is no special problem.	There is no special problem.
56	TI-202	-do-	—		- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
57	TI-203	TEMP. INDICATOR	Appearance: Good	There is no special problem.	There is no special problem.
58	TI-204	- do -	- do -	- do -	- do -
59A	TA-201	TEMP. INDICATOR ALARM		The exterior cover is slightly corroded.	The SET POINT indicator is defective and needs to be replaced.
59B	PSA-201	PRESSURE SWITCH	Appearance: Defective Performance test: Good	The exterior cover is slightly corroded.	Although there is no problem with the function, a spare is scheduled to be provided.
60	T-301	FEED TANK	Appearance: Good Internal inspection: Good	There is no problem with the appearance. But the PCV nozzle deteriorated and needs to be replaced.	The PCV nozzle has already been replaced.
61	T-302	PROD. TANK	Appearance: Good Internal inspection: Good	- do -	- do -
62	T-301	FEED PUMP		The body has already been painted. There seemed to be no problem with the appearance.	The operation is possible. This item is scheduled to be used as it is.
63	P-302	BOOSTER PUMP	Appearance of body: Slightly defective Appearance of motor: Defective Individual starting test of motor: Good	- do -	- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
64	P-303	HIGH PRESSURE PUMP	Appearance of body: Slightly defective Appearance of crankcase: Slightly defective Appearance of motor: Defective Appearance of motor: Defective	The body has already been painted. There seemed to be no problem with the appearance. The spring of the relief valve is corroded. The plunger section have oil leakage.	The operation is possible. This item is scheduled to be used as it is. The spring has already been replaced. The oil gauge has already been replaced.
65	HE-301	HEAT EXCHANGER	Appearance: Slightly defective	These is no problem with the appearance. But the PVC connecting pipe had deterioration.	This item is used as it is.
66	HE-302		Appearance: Slightly defective		
67	UV-301	UV STERILIZATION	Appearance: Good Performance test: Good	There is no special problem.	This item is used as it is.
68	F-301A B	SAFETY FILTER		There is no special problem.	Lighted. This item is used as it is.
69	RO-301	RO MODULE	Appearance: Good	This item has already been installed in the vessel. There was an odor which was like formalin that turned into formic acid.	The MODLUE needs to be replaced at the time of commissioning. The spare is 100 % available at the site.
70	FI-301	RO PROD FLOW INDICATOR	Appearance: Good	There is no special problem.	This item is used as it is.

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
71	FI-302	RO CONC FLOW INDICATOR	Appearance: Good	There is no special problem.	This item is used as it is.
72	PI-301	FEED PUMP OUTLET PRESSURE INDICATOR	- do -	Minor corrosion	This item is used as it is.
73	PI-302	BOOSTER PUMP OUTLET PRESSURE INDICATOR	- do -	- do -	- do -
74	PI-303	H.P PUMP INLET PRESSURE INDICATOR	- do -	- do -	- do -
75	PI-304	RO FEED INLET PRESSURE INDICATOR	- do -	- do -	- do -
76	PI-305	RO CONC PRESSURE INDICATOR	- do -	- do -	- do -
77	PI-306	HE302 INLET PRESSURE INDICATOR	- do -	- do -	- do -

No.	EQUIP NO.	NAME OF EQUIPMENT	Result of inspection conducted two years ago	Result of inspection conducted this time	Measures to be taken
87	T-504	SBS TANK	Appearance: Good	There is no special problem.	This item is used.
88	P-501A	NaOCl PUMP	Appearance: Good Performance inspection: Good	- do -	This item is used.
89	P-501B	- do -	- do -	- do -	- do -
90	P-502	$FeCl_3$ PUMP	- do -	- do -	- do -
91	P-503A	H_2SO_4 PUMP	- do -	- do -	- do -
92	P-503B	- do -	- do -	- do -	- do -
93	P-504A	SBS PUMP	- do -	- do -	- do -
94	P-504B	- do -	- do -	- do -	- do -
95	P-504C	- do -	- do -	- do -	- do -
96	TSV-401	STEAM STOP VALVE	—	This item is usable in terms of appearance.	is item is scheduled to be used as it is.

Table 2 Remaining Works after the First Installation Work

UNDERTAKINGS MARK
1 : JICA SUPPY
2 : EXISTING
3 : JICA SUPPLY BUT SWCC PAY
4 : SWCC SUPPLY

PERIOD
A : '94 MAR 1st to APR 30th
B : '94 JUN 1st to JUN 10th
C : DECISION AFTER DISCUSSION ON JUN'94

NO.	WORK ITEM	UNDER TAKINGS	PERIOD
1	CLEANING FOR INSIDE TANKS	—	A
2	PIPE SUPPORT INSTALLATION	2	A
3	INSTALLATION OF TRENCH OVER PLATE	2	A
4	REPLACEMENT OF MANUAL VALVES FOR F-101B	2	A
5	REPLACEMENT OF AUTO VALVES FOR F-101A (SOLENOID VALVE)	3	B
6	OVERHAUL FOR PUMPS	2	A
7	OIL	4	B
8	REPLACEMENT OF PS-401	3	B
9	LEVEL GAGE INSTALLATION FOR T-102	4	A
10	POWER SUPPLY FOR FOULING INDEX MONITOR	2	A
11	CALIBRATION FOR - do -	1	B
12	REPLACEMENT OF TC-201	3	B
13	REPLACEMENT OF TA-201	3	B
14	REPLACEMENT OF PSA-201	3	B

NO.	WORK ITEM	UNDER TAKINGS	PERIOD
15	CALIBRATION OF ORP-201	1	B
16	INSTALLATION OF S·W RO MODULE INTO VESSEL	2	B
17	STEAM SUPPLY PIPING & POWER SUPPLY FOR TSV-401 (REF D-9)	2	C
18	REPLACEMENT OF TA-301	3	B
19	REPLACEMENT OF PSA-301	3	B
20	CALIBRATION OF PH-301	1	B
21	INSTALLATION OF H·F RO MODULE INTO VESSEL	2	B
22	CHEMICAL SUPPLY FOR TANKS AND ADJUSTMENT OF DENSITY	2, 4	B
23	ADJUSTMENT OF CHEMICAL INJECTION FOR CHEMICAL PUMPS	—	B
24	WHOLE MATERIAL CONTROL & STORAGE	—	BY 3/20
25	PORTABLE PH, DO CR METER CALIBRATION	2	B
26	REPAIR OF ELR (EARTH LEAKAGE RELAY)	1	B
27	REPLACEMENT OF H·F RO CONDUCTIVITY INDICATOR PART.	3	B
28	ADJUSTMENT OF TIMERS	—	B
29	ATTACHMENT OF 3·PC SWITCH KNOB	3	B

Table 3 Shortage of Parts for the Second Installation Work

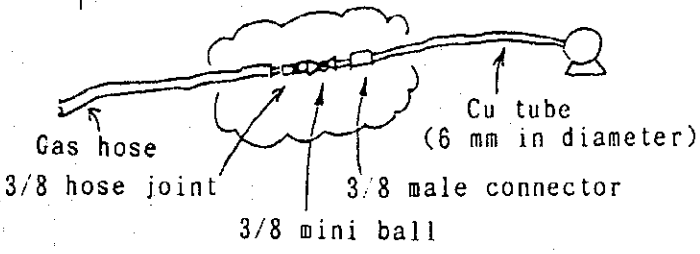
UNDERTAKINGS MARK

1 : JICA SUPPY

2 : EXISTING

3 : JICA SUPPLY BUT SWCC PAY

4 : SWCC SUPPLY

NO.	EQUIP. NO.	PART NAME	Q'TY	Description	UNDER TAKINGS
1	AN-101 to AN-108	Solenoid valve and a set of accessories for AUTO VALVE (Tomoe: Model 733S-3Y)	8 sets	1) Solenoid valve 2) Conductor (from solenoid valve to actuator) and coupling connector	1
2			1		
3	PS-401	Pressure switch	1	1) Naganokeiki CQ-20; 0 to 10 kg/cm²	3
4	F I R	FOULING INDEX MONITOR	1 set	1) A set of calibration instruments 2) Hose joint to compressor	1
				 (The parts that were shipped last time are contained in the panel.)	
5	TC-201	Resistance thermometer bulb (PT 100 Ohms)	1	1) Flexible 2 M	3
6	TA-201	Thermometer with H alarm (Naganokeiki : TL 64)	1	1) Flexible 3 M	3
7	PSA-201	Pressure switch	1	1) Naganokeiki 0 to 4 kg cm²	3

NO.	EQUIP. NO.	PART NAME	Q'TY	Description	UNDER TAKINGS
8	ORP-201	ORP MONITOR & SENSOR	1 set	1) Reagent required for calibration 2) 1 set of small hexagon wrenches (Some are located inside the panel.)	1
9	TA-301	Thermometer with H alarm (Naganokeiki : TL 64)	1	1) Flexible 3 M	3
10	PSA-301	Pressure switch	1	1) Naganokeiki 0 to 4 kg/cm²	3
11	PH-301	PH MONITOR & SENSOR	1 set	1) Reagent required for calibration (Some are located inside the panel.)	1
12		Silicone grease	2	1) This item is required for the assembly of the RO MODULE.	1
13	CR-301	CONDUCTIVITY indicator section	1	1) Indicator section only	3
14	ELR	Earth leakage sensing relay	1	1) Becasue it dit not operate, only a relay was arranged.	1
15		Switch knob: For AN valve For pump starting	 1 3	 1) White knob only 2) Red knob only	1

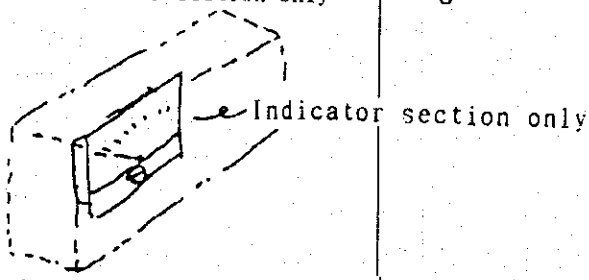


Table 4 Progress of Work and Present Status of the Equipment after the second Installation Work

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August,'94	Present status as on 20th August,'94
1	AN101	AUTO VALVE	The body has already been painted. The solenoid valve is corroded.	Replaced entire valve body and solenoid valve.	Good (Ready for Trial run.)
2	AN102	- do -	- do -	-do-	-do-
3	AN103	- do -	- do -	-do-	-do-
4	AN104	- do -	The body has already been painted.	-do-	-do-
			The solenoid valve is broken.	-do-	-do-
5	AN105	- do -	The body has already been painted.	-do-	-do-
			The solenoid valve is corroded.	-do-	-do-
6	AN106	- do -	The body has already been painted. The joint is broken.	-do-	-do-

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
7	AN107	- do -	The body has already been painted. The solenoid valve is corroded.	-do-	-do-
8	AN108	- do -	- do -	-do-	-do-
9	F-101A	DUAL MEDIA FILTER	The body has already been painted. The PDC pipe had aged deterioration and discoloration. The SGP pipe is corroded.	Replaced the SGP pipe for air-supply with new one.	Good(ready for trial run)
10	F-101B	- do -	- do -	-	-do-
11	FI-101	FEED INLET FLOW INDICATOR	A slight degree of rust was found.		
12	FI-102	B/W·W INLET FLOW INDICATOR	- do -	-	-do-
13	FI-103	AIR BLOW FLOW INDICATOR	- do -	Inside dust removed.	-do-

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
14	MV-105	MANUAL VALVE	There is corrosion in the metal parts. The drive section has already been cleaned and greased to rotate freely	replaced with a new one	good(ready for trial run)
15	MV-106	- do -	- do -	- do -	- do -
16	MV-107	MANUAL VALVE	There is corrosion in the metal section. The drive section has already been cleaned and greased to rotate freely	Replased with a new one	- do -
17	MV-108	- do -	- do -	- do -	- do -
18	MV-109	- do -	- do -	- do -	- do -
19	MV-110	- do -	- do -	- do -	- do -
20	MV-111	- do -	- do -	- do -	- do -
21	P-101	SEAWATER PUMP	Both the body and the motor have already been painted. There is no bad appearance.	-	- do -
22	P-102	B/W PUMP	- do -	-	- do-

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
23	P-103	B/W AIR BLOWER	The motor section has already been painted. The casing and the gear section has major corrosion. But the rotation is possible. There is no drive V-BELT. There is no oil in the gear section.	Blower is overhauled. Drive V-belt installed. Oil and grease for gear and bearing respectively are poured.	good(ready for trial run)
24	P-104	WASTE PUMP	The motor section has already been painted. There is no problem apparently.	-	good(Service not required.)
25	P-401	AIR COMPRESSOR & DRYER	The operation has already been started. Running well.	-	Running in good condition
26	PI-101	SEAWATER PUMP OUTLET PRESSURE INDICATOR	Major corrosion observed	Replaced with a new one	Giving acurate indication.
27	PI-102A	F-101A INLET PRESSURE INDICATOR	- do -	- do -	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
28	PI-103A	F-101A OUTLET PRESSURE INDICATOR	Major corrosion observed	Already replaced with a new one.	Giving acurate indication.
29	PI-102B	F-101B INLET PRESSURE INDICATOR	- do -	- do -	- do -
30	PI-103B	F-101B OUTLET PRESSURE INDICATOR	- do -	- do -	- do -
31	PI-104	B/W PUMP OUTLET PRESSURE INDICATOR	- do -	- do -	- do -
32	PS-401	INSTRUMENT AIR PRESSURE SWITCH	The cover was very corroded. But operate well.	Replaced with a new one.	- do -
33	T-101	SEAWATER TANK	The metal section of the ladder is corroded. But it can be used PVC nozzles are seriously deteriorated and need to be replaced.	PVC nozzles have already been replaced with new one	good(ready for trial run)
34	T-102	TREATED SEAWATER TANK	There is no level gauge.	- do - Old lavel gauge has already been installed.	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
35	UV-101	UV STERILIZER	This item has already been painted. The stabilizing blade has corrosion, but can be use. The pilot lamp is not lighted.	Replaced the unit with a new one.	good(ready for trial run)
36	T-201	FEED TANK	There is no off appearance. But the PVC nozzles are deteriorated and need to be replaced.	PVC nozzles are already replaced with new one.	- do -
37	T-202	PROD. TANK	- do -	- do -	- do -
38	P-201	FEED PUMP	The motor section has already been painted. There is no off appearance.	-	- do -
39	P-202	BOOSTER PUMP	- do -	-	- do -
40	P-203	HIGH PRESSURE PUMP	- do - The spring of the relief valve is corroded.	-	- do -
41	HE-201	HEAT EXCHANGER	Apparently there is no	-	Not connected for operation.

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
42	HE-202		problem. But the PVC connecting pipe had been deteriorated.	-	(Presently not required)
43	UV-201	UV STERILIZER	There is no problem observed.	-	good(ready for commissioning)
44	F-201A B	SAFETY FILTER	No wrongness observed.	-	- do -
45	RO-201	R/O MODULE	This remain as it was during shipment. The vessel seemed to have no probelm in operation	Two erements SP-120 loaded in a pressure vessel.	good(ready for trial run)
46	FI-201	R/O PRODUCT FLOW INDICATPR	there is no wrongness observed.	-	good(giving acurete reading)
47	FI-202	R/O CONCENTRATE FLOW INDICATOR	- do -	-	- do -
48	PI-201	FEED PUMP OUTLET PRESSURE INDICATOR	- do -	-	- do -
49	PI-202	BOOSTER PUMP OUTLET PRESSURE INDICATOR	Slight corrosion	-	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
50	PI-203	H·P PUMP INLET PRESSURE INDICATOR	Slight external corrosion obserbed.	-	giving acurate reading. (ready for trial run)
51	PI-204	R/O FEED INLET PRESSURE INDICATOR	- do -	-	- do -
52	PI-205	R/O CONC PRESSURE INDICATOR	- do -	-	- do -
53	PI-206	HE-202 INLET PRESSURE INDICATOR	- do -	-	- do -
54	TC-201 & CV-201	TEMP. CONTROLLER	There is wrongness observed.	-	Not required presently.
55	TI-201	TEMP. INDICATOR	- do -	-	giving acurate reading. (ready for trial run)
56	TI-202	-do-	- do -		- do -
57	TI-203	TEMP. INDICATOR	- do -	-	- do -
58	TI-204	- do -	- do -	-	- do -
59A	TA-201	TEMP. INDICATOR ALARM	The exterior cover is slightly corroded.	Replaced with a new one.	- do -
59B	PSA-201	PRESSURE SWITCH	The exterior cover is slightly corroded.	Replaced with a new one.	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
60	T-301	FEED TANK	There is no problem apparently. But the PVC nozzles deteriorated and needs to be replaced.	Nozzels has already been replaced.	good(ready for trial run)
61	T-302	PROD. TANK	- do -	- do -	- do -
62	T-301	FEED PUMP	The body has already been painted. There seemed to be no problem in operation.	-	- do -
63	P-302	BOOSTER PUMP	- do -	-	- do -
64	P-303	HIGH PRESSURE PUMP	The body has already been painted. There seemed to be no problem in operation. The spring of the relief valve is corroded. The plunger section has oil leakage.	-	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
65	HE-301	HEAT EXCHANGER	There may be no problem in service. But the PVC	-	Not connected for operation.
66	HE-302		connecting pipe has deterioration.	-	- do -
67	UV-301	UV STERIZATION	There is no special probelm.	-	-
68	F-301A B	SAFETY FILTER	There is no special probelm.	-	good(ready for trial run)
69	RO-301	RO MODULE	This item has already been installed in the vessel. There was an odor which was like formalin that turned into formic acid.	-	- do -
70	FI-301	RO PROD FLOW INDICATOR	There is no special problem.	-	good(giving acurate reading)
71	FI-302	RO CONC FLOW INDICATOR	There is no special problem.	-	good(ready for trial run)
72	PI-301	FEED PUMP OUTLET PRESSURE INDICATOR	Minor corrosion observed	-	- do -
73	PI-302	BOOSTER PUMP OUTLET PRESSURE INDICATOR	- do -	-	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
74	PI-303	H.P PUMP INLET PRESSURE INDICATOR	Minor corrosion observed	-	good(ready for trial run)
75	PI-304	RO FEED INLET PRESSURE INDICATOR	- do -	-	- do -
76	PI-305	RO CONC PRESSURE INDICATOR	- do -	-	- do -
77	PI-306	HE302 INLET PRESSURE INDICATOR	- do -	-	- do -
78	TC-301 & CV-301	TEMP. CONTROLLER	There seemed to be no problem with in genaraly	-	Not required presently. - do -
79	T1-301	TEMP INDICATOR	There is no special wrongness.	-	Givinng acurate reading.
80	T1-302	- do -	- do -		- do -
81	T1-303	- do -	- do -		- do -
82	T1-304	- do -	- do -		- do -
83A	TA-301	TEMP. INDICATOR ALARM	The exterior cover is slightly corroded.	Replaced with a new one.	- do -
83B	PSA-301	PRESSURE SWITCH	- do -	Replaced with a new one.	- do -

SL. No.	EQUIP. NO.	NAME OF EQUIPMENT	Result of inspection in February, '94	Work completed in July and August, 94	Present status as on 20th August, '94
84	T-501	NaOCl TANK	There is no special problem.	-	-
85	T-502	$FeCl_3$ TANK	- do -	Suction nozzle repaired.	Filled with FeCl3 soln.
86	T-503	H_2SO_4 TANK	- do -	-	-
87	T-504	SBS TANK	There is no remarkable problem.	-	-
88	P-501A	NaOCl PUMP	- do -	-	-
89	P-501B	- do -	- do -	-	
90	P-502	$FeCl_3$ PUMP	- do -	Checked operation and ajusted dosing rate.	ready for trial run.
91	P-503A	H_2SO_4 PUMP	- do -	-	-
92	P-503B	- do -	- do -	-	-
93	P-504A	SBS PUMP	- do -	-	-
94	P-504B	- do -	- do -	-	-
95	P-504C	- do -	- do -	-	-
96	TSV-401	STEAM STOP VALVE	This item is useable.	-	Not installed. (not required presently)
97	PHRA-301	pH METER	-	Electlode cracked.	Need to replace by new one.
98	ORPA-201	ORP METER	-	Electlode foulty.	Need to repair or replace with new one.
99	CR-201	EC METER	-	Unadjustable.	Need to recheck.
100	CR-301	AUTOMATIC FI MONITOR (SDI MONITOR)	-	Print circuit foulty.	Need to replace by new one.

Table 5 General Overall Status after the Installation Work

Briefly all the work of RO test plant is completed and can be described as follows:

Work	Description	Completed
Inspection		
1	Overall inspection & listing of damaged parts	C
2	Inspection of pretreatment filters	C
3	Final inspection for trial run	C
Civil		
1	Derusting, cleaning & painting of metal parts.	C
2	Anchoring of instrument air compressor with the ground.	C
3	Service water supply provision upto the units.	C
4	Pretreated water supply provision upto the units	C
5	Removal of damaged parts	C
6	Anchoring of tanks, fouling index monitor, chemical dosing skid	C
7	Connection of seawater line to feed water Tank	C
8	Installation of instrument air piping from instrument air compressor to unit skids.	C
9	Repair of damaged piping in pretreatment unit	C
10	Installation of chemical dosing piping from chemical skid to pretreatment, SWRO & HFRO units	C
11	Installation of interconnection piping from tank to unit skids.	C
12	Installation of drain, overflow & vent piping for tanks	C
13	Installation of process drain piping	C
14	Final painting	C

Work	Item	Completed
Mechanical		
1	Pumps free rotation checking, cleaning, oiling and greasing	C
2	Free rotation checking, cleaning & greasing for all control and manual values.	C
3	High pressure pumps belt tension checking, and belt reinstallation	C
4	Overhauling of heaters & preheaters	C
5	Overhauling of RO pressure vessels	C
6	Pretreatment filter vessel opening cleaning and closing (after inspection)	C
7	Maintenance checking and Reinstallation of pre-treatment blower	C
8	Insulation of steam piping	C
9	checking of bearing, speed of rotation, alignment etc. for all pumps.	C
Electrical		
1	Lighting of RO plant premises	C
2	Power cable connection from main to RO motor control panel.	C
3	Power cable connection from motor control panel to instrument air compressor.	C
4	Electrical cable connection between motor *Control Panel & Control Panel*	C
5	Cable lying and termination, at motor control panel in control room and distribution boxes mounted on the skid (outside) and level transme-ter of tanks etc.	C
6	Overhauling & testing of motors	C

Work	Item	Completed
Instrument		
1	Installation of level transmeter, level gauges for tanks as per P&I diagram	C
2	Calibration of controllers & recorders in control panel and control valves & transmeter, mounted in field and simulation of action of them between field and control panel	C
3	Sequence checking for alarm circuits	C
4	Testing of program sequences for filter control circuit, SWRO circuits, HFRO circuit, common circuit, TRC's, CR's, ORPRA, $P^{H}RA$ etc (in accordance with timer setting and also auto functioning of auto control valves).	C
5	Setting of timer depending on program chart and operation list.	C
6	Checking of interlocks for sequential action in accordance with operation list & program chart.	C
7	Installation of UV sterilizer lamp and checking of its function.	C
8	Testing of safety relieve valve & installation.	C
Final Inspection		
1	Safety inspection as a whole for the plant	C
2	Cleaning and flushing of lines.	C
3	Checking of electrical grounding	C
4	Checking the plant thoroughly for piping installation as per P & I diagram	C
5	Individual equipment checking for commissioning	C
6	System checking for commissioning	C

C = Completed

* Trial run is scheduled to be on 20/8/1994 for pretreatment unit.
27/8/1994 for desalination unit.

7.3.2 Performance Test of RO Test Plant

Contents

List of Figures

1. Objectives

1) To confirm the suitability of the RO membranes for the MSF–RO Hybrid System by performing tests with 8 inch commercial membranes

2) To establish RO membrane performance evaluation procedures and methods to achieve this objective

The work describes the performance of two commercial size Japanese made SWRO Membranes: TOYOBO cellulose triacetate hollow fine fiber (HFF), TORAY polyamide thin film composite (TFC) spiral wound (SW) and NITTO DENKO polyamide (TFC) apiral wound. Membranes were t4ested utilizing two independent skid–mounted reverse osmosis (RO) units that receive coagulated filtered water from two pressure dual media filters connected in series (See Figure 1). Plants were commissioned and filtrate SDI was maintained at less than 4.0. Figures 2 and 3 show the performance (permeate flow, percent recovery and salt rejection) of the TOYOBO and NITTO DENKO systems. Details of the work which is continuing is described in the report.

2. INTRODUCTION

Presently, reverse osmosis (RO) membrane manufacturing companies are marketing various type of membranes with special claims. Most prominent among those are made by Dupont, Filmtes, Fluid Systems, Hydranautics, all made in U.S.A. SWCC maintains a test facility for ttesting these membranes at Al–Jubail. On the other hand, major Japanese membrane manufacturing companies are TOYOBO, TORAY and NITTO DENKO. TOYOBO company utilizes cellulose triacetate hollow fine fiber (HFF) membranes and both TORAY and NITTO DENKO utilizes polyamide thin film composite (TFC), spiral wound (SW) membranes. TOYOBO membranes are being used by SWCC at Jeddah, Haqul and Duba SWRO Plant. The over 30 MGD Madinah–Yanbu Plant, now under construction, is also to use TOYOBO membranes. JICA provided a test plant which allows for the testing of 8 inch diameter commercial size membranes. This plant was at storage at Yanbu for the last ten years. Membrane evaluation is being done with the Arabian Gulf sea water

3. SWRO PILOT PLANT

Initially, the plant was to be used in evaluation of feed from the Red Sea, where all of the

operating SWCC SWRO plants (Jeddah, Haqul, Duba, Umm Lujj, Al-Birk) are located. The plant was, however, relocated for testing facility at SWCC RDC Jubail. During May 1993, the plant was transferred to Jubail, installation was completed in the first quarter of 1994 and plant was commissioned in August 1994. Since then, TOYOBO hollow fine fiber membrane unit has been operating continuously. The spiral wound membrane unit is also operating continuously, except for some period when the unit was under maintenance. The two RO units were operated first utilizing old membranes which were stored approximately for ten years and then later, were replaced by new mmembranes.

A schematic flow diagram of the pilot plant is given in Figure 1. The plant consists of a pretreatment system which provides feed to the two independent SWRO plants. The first plant employs TOYOBO cellulose triacetate hollow fine fiber membranes, while the second one utilizes TORAY and NITTO DENKO spiral wound, thin film composite membranes. Both plants utilize 8 inch commercial size membranes elements.

3.1 Pre-treatment Plant

The pretreatment unit consists of the following components: sea water feed line, sea water feed tank, feed pump, chlorination unit, U.V sterilization unit, coagulant injection system, two pressure dual media filters connected in series, pretreated water holding tanks, secondary feed pumps to the two R.O Plants, water heating system to raise the temperature, if necessary and two 10 micron cartridge filters. The unit is also equipped with a backwash system to clean the dual media filters. Moreover, the unit is furnished with the following chemical dosing systems: cholorine disinfection, coagulation using ferric chloride ($FeCl_3$), and scalant sulfuric Acid (H_2SO_4) and sodium bisulfite ($NaHSO_3$). The filter tank diameter is 900 mm and its height is 2,000 mm. The details of the filtration media is given below:

	FILTER F 101 A	FILTER F 101 B
Media Type: Anthracite		
Column Depth	400 mm	400 mm
Particle Size	0.8 mm dia	0.8 mm
Total Volume	0.6 M^3	0.6 M^3
Media Type: Sand		
Column Depth	400 mm	400 mm
Particle Size	0.55 mm dia	0.55 mm
Total Volume	0.6 M^3	0.6 M^3

Larger particles of coagulated suspended matter are removed by the first coarse filter containing sand and anthracite, while the second filter with a smaller particle size sand provides polishing of the sea water. The Silt Density Index (SDI) is maintained less than 4.0. The treated sea water is stored in the treated sea water tank. Sodium Hypochlorite is fed at the rate of 0.7 ppm for sterilization and ferric chloride at the rate of 3 to 4 ppm (Fe^{+++}= 1 to 1.3 ppm) for coagulation. The first filter is automatically operated by a programmed timer, mounted in the control panel which controls its service and regeneration. The second filter is manually operated. The SDI of the treated sea water is manually determined and was maintained at a level less than 4.0.

3.2 SWRO Desalination Plants

The sea water desalination system consists of two independent, skid-mounted desalination units which are operated in parallel. One is to operate spiral wound membrane, while the other to operate hollow fine fiber membrane. Each of the two units, is equipped with a high pressure pump, RO modules, concentrate flow control valve and product water tank. The high pressure pump is capable of providing feed pressure up to a maximum pressure of 60 Kg/cm^2 for the spiral wound unit and up to 65 Kg/cm^2 for the hollow fine fiber unit. Each unit has only one membrane module which contains two elements. Both units have their own recovery (concentrate flow) control valve. Each unit is also furnished with the following measurement devices: permeate and concentrate flow indicator, RO inlet and outlet pressure gauge, feed temperature gauge, permeate conductivity monitor, while oxidation and reduction potential (ORP) monitor is only for the spiral wound unit and pH monitor for the hollow fiber unit.

4. PROCESS DESCRIPTION

4.1 Pretreatment Plant

Non–chlorinated sea water is fed to the pressure dual media filters at the rate of 7.0 M^3/Hour by the sea water feed pump at a pressure of approximately 1.8 Kg/cm^2 from the raw sea water tank. Before its entry to dual media filters, the sea water is disinfected and coagulated. The disinfection can be done either by passing the feed through the U.V sterilization unit or by dosing 1 % sodium hypochlorite solution at the discharge of the sea water pump at a rate of 0.7 ppm to achieve the residual chlorine level of 0.1 to 0.5 ppm at filter outlet. In this experiment, both disinfection methods, i.e., chlorination and U.V sterilization were used. Ferric Chloride is used as a coagulant at the rate of 3 to 4 ppm (Fe^{+++}= 1 to 1.3 ppm). The disinfected and coagulated feed is passed through two pressure, dual media filters and the filtrate is collected in the treated sea water holding tank, from which it is transferred to the RO feed tanks by the RO feed pumps. Filtrate is further pressurized by a booster pump and is passed through a second U.V sterilization unit followed by the two cartridge safety filters.

Before its entry to the RO modules the anti–scalant is added to the pretreated feed using sulfuric acid at the rate of 50 ppm for spiral wound unit and 70 ppm for hollow fine fiber unit to givew a pH of 6.5 $\pm$ 0.5. The feed to the TORAY spiral wound membranes unit, which is secsitive to both chlorine and dissolved oxygen is further treated by adding sodium bisulfite at the rate of 10 ppm to remove both chlorine and dissolved oxygen, while additional chlorine is dosed at the rate of 0.2 ppm into the feed to the hollow fine fiber unit. NITTO DEKO spiral wound membrane, however, are not sensitive to oxygen and the sodium bisulfite was added to the pretreated feed at the rate of 10 ppm An oxidation reduction unit which is installed in the spiral wound unit to detect chlorine in the feed, measures oxidation reduction potential of the feed water to maintain its reading between –200 and +200 mv.

4.2 Spiral Wound R.O Unit

A reciprocating, variable speed, plunger type high pressure pump passes the feed water at a pressure of 56 Kg/cm^2 to the membrane where it is split into permeate which passes through membrane and the reject concentrate (brine). The concentrate flow and the corresponding permeate flow are controlled by two manual control valves to give an average recovery ratio of 27%. The permeate (product is collected in a permeate holding tank and the concentrate

(reject or brine) is discharged to a trench.

4.3 Hollow Fine Fiber R.O Unit

A reciprocating, variable speed, plunger type high pressure pump, identical to spiral wound unit passes the feed water at a pressure of 56 Kg/cm^2 to the membrane where it is split into permeate which passes through membrane and the reject concentrate. The concentrate flow and the corresponding permeate flow are controlled by two manual control valves to give an average recovery ration of 26%. The permeate is collected in a permeate holding tank and the concentrate is discharged to a trench.

The summary of process parameters at the inlet of Filters is as follows:

Pretreatment:

Feed Water Flow	:	7.0 M^3/Hour
Feed Pressure	:	1.8 Kg/cm^2
Residual Chlorine	:	0.1 to 0.5 ppm
Coagulant Dosing	:	3.0 to 4.0 ppm (Fe^{+++}=1 to 1.4 ppm)
Feed pH	:	6.5 $\pm$ 0.5
Feed Temperature	:	32 to 34 deg. C
SDI	:	3.0 to 4.0
Backwash Flow	:	25.0 M^3/Hour
Backwash Air Flow	:	36.0 M^3/Hour

Spiral Wound R.O Unit (using two elements in a vessel)
(NITTO DENKO NTR-70SWC-S8/Fully Aromatic Polyamide Thin Film Composite and TORAY 8 inch RO Elements)

Feed Flow	:	3.30 M^3/Hour
Permeate Flow	:	0.70 M^3/Hour
Concentrate Flow	:	2.6 M^3/Hour
Recovery	:	27%
Operating Pressure	:	56 Kg/cm^2
Chlorine content	:	Zero ppm

Hollow Fiber RO Unit
(TOYOBO–HOLLOSEP HM 8255/Cellulose Tri Acetate)

Feed Flow	:	**2.95 M^3/Hour**
Permeate Flow	:	**0.75 M^3/Hour**
Concentrate Flow	:	**2.3 M^3/Hour**
Recovery	:	**26%**
Operating Pressure	:	**56 Kg/cm^2**
Chlorine content	:	**0.05 ppm**

5. MEMBRANE DESCRIPTION

For the performance evaluation, three types of membranes were utilized in the investigation, two of which were of the spiral wound type and one was of the hollow fine fiber type.

5.1 Spiral Wound Membranes

The two spiral wound membranes used, were from Japanese companies TORAY and NITTO–DENKO. The description and specifications of the first membrane, as claimed by the membrane manufacturer, are as follows:

Make	:	**TORAY**
Material	:	**Composite Polyether**
Membrane Model	:	**SP–120 (PEC–1000)**
Element Model No.	:	**SP120 7307154**
	:	**SP120 7307148**
Salt Rejection	:	**99.7% (average)**
		99.5% (minimum)
Permeate Flow (average)	:	**9.0 M^3/Day (2400 GPD)**
(minimum)	:	**7.6 M^3/Day (2000 GPD)**
Element Dimensions	:	**Dia: 201 mm, Length: 1016 mm**

Recently supplied TORAY membrane–elements, which were tested, have the following specifications:

Make	:	**TORAY**

Material	:	Composite Polyether
Membrane Model	:	UTC-80S
Element Model No.	:	SU-820 40250213
	:	SU-820 40250256
Salt Rejection	:	99.4% (average)
		99.2% (minimum)
Permeate Flow (average)	:	16.0 M^3/Day (4220 GPD)
(minimum)	:	14 M^3/Day (3700 GPD)
Element Dimensions	:	Dia: 201 mm, Length: 1016 mm

Thses elements were approximately 10 years old and were loaded in the vessel in first week of February 1994 after the unit was brought from Yanbu. The two elements of the above mentioned membrane were removed, preserved and replaced by new elements from NITTO DENKO Company:

Make	:	NITTO DENKO
Material	:	Thin Film Composite Polyamide
Membrane Model	:	NTR-70SWS
Element Model	:	NTR-70SWC-S8/3100191
	:	NTR-70SWC-S8/3080155
Salt Rejection	:	99.4% (average)
		99.2% (minimum)
Permeate Flow(average)	:	16.4 M^3/Day (4330 GPD)
Element Dimensions	:	Dia: 201 mm, Length: 1016 mm

The first trial run of these membranes was carried out on August 31, 1994.

5.2 Hollow Fine Fiber Membranes

The hollow fiber R.O system was tested first using the old Toyobo Hollowsep HM 8255 membranes. The elements of this module were approximately 10 years old and were loaded in the vessel in the first week of February 1994, after the unit was brought from Yanbu. As claimed by the membrane manufacturer, membrane description is as follows:

Make	:	TOYOBO
Material	:	Cellulose Tri Acetate.

Membrane Model	:	**HOLLOSEP HM 8255**
Element Model	:	**HM 8155 406023**
	:	**HM 8155 406024**
Salt Rejection	:	**> 99.2% (average)**
Permeate Flow(average)	:	**> 25.0 M^3/Day**
Element Dimensions	:	**Dia: 305 mm, Length: 2640 mm**

On August 30, 1994, the old membrane-element were removed and new TOYOBO elements (HM 8155 312012 & HM 8155 401003) were installed:

Make	:	**TOYOBO**
Material	:	**Cellulose Tri Acetate.**
Membrane Model	:	**HOLLOSEP HM 8255**
Element Model	:	**HM 8155 312012**
	:	**HM 8155 401003**
Salt Rejection	:	**> 99.2% (average)**
Permeate Flow(average)	:	**> 25 M^3/Day (6600 GPD)**
Element Dimensions	:	**Dia: 305 mm, Length: 2640 mm**

6. RESULTS AND DISCUSSIONS

6.1 Pretreatment Plant:

Generally the coagulation and filtration system worked efficiently giving SDI less than 4.0. In some instances, the SDI was more than 4.0. To bring SDI to the desired level, the backwash frequency was increased from 24 hours to 48 hours. In one case, the ferric chloride dosing was not correct due to malfunctioning of the dosing pump. When the dosing rate was corrected to 3.5 ppm (Fe^{+++}=1.2 ppm), the SDI dropped to its normal level, less than 4.0. Presently, the system is operating using 3 ppm ferric chloride and automatic backwashing frequency once every 24 hours. Differential pressure across the filter is approximately 1.1 Kg/cm^2 indicating that the backwashing frequency can be extended to longer period.

6.2 R.O. Plant:

(1) Performance of old membranes

The performance result of the old TOYOBO hollow fine fiber R.O membrane operated for four hours at feed pressure = 56 Kg/cm^2, feed pH = 8.0 and SDI = 3.0 are as follows:

Feed Flow	:	3.27 M^3/Hour
Permeate Flow	:	1.07 M^3/Hour
Percent Recovery	:	30.01 %
Permeate Conductivity	:	1,540 μS/cm
Salt Rejection	:	97.47 %
Bundle Pressure Drop	:	0.7 Kg/cm^2

The results are satisfactory considering that the membranes were over 10 years old.

For spiral wound R.O Unit, using old TORAY SP 120 (PEC – 1000) membranes, the performance of the plant operated for four hours at feed pressure = 56 Kg/cm ^{2}, feed pH = 6.5 and SDI = 3.8 was as follow:

Feed Flow	:	3.1 M^3/Hour
Permeate Flow	:	0.6 M^3/Hour
Percent Recovery	:	14.6 %
Permeate Conductivity	:	1,810 μS/cm
Salt Rejection	:	95.39 %
Bundle Pressure Drop	:	0.9 Kg/cm^2

The conductivity was high since the membrane is over 10 years old and was rising.

(2) Performance of new TOYOBO Hollow Fine Fiber membranes

Figure 2A gives the permeate flow, and overall percent recovery while Figure 2B shows permeate conductivity and percent salt rejection for the TOYOBO hollow fine fiber membrane with operating conditions as given in Figure 2C. The sysmtem has given a steady permeate flow of 0.8 M^3/Hour at an average conductivity of 250 – 350 μS/cm, and salt rejection of 99.6 to 99.7 percent at a water recovery of 26 percent.

(3) **Performance of new NITTO DENKO Spiral Wound membranes**

Figure 3A gives the permeate flow, and overall percent recovery while Figure 3B shows permeate conductivity and percent salt rejection for the NITTO DENKO spiral wound membrane with operating conditions as given in Figure 3C. The performance of the membrane has been steady; permeate flow of 0.8 M^3/Hour at an average conductivity of 550 – 650 μS/cm, salt rejection of 99.24 to 99.36 percent at a water recovery of 27 percent.

7. CONCLUSIONS

The plant which is consisted of a pretreatment unit and two independent SWRO plants, was commissioned after lengthy time spent in fixing this 10 years old plant which was moved to SWCC/RDC from Yanbu.. Dosage of 3 to 4 ppm (Fe^{+++}=1 to 1.3 ppm) of ferric chloride produced a feed water with SDI less than 4.0 which meets the specifications required by the membrane manufacturers TOYOBO, TORAY and NITTO DENKO. For a period of four hours, old TORAY spiral wound membranes (SP–120/PEC – 100) which were loaded in the module at the time of commissioning, were tested. Permeate flow and conductivity for this membrane were: 0.6 M^3/Hour and 2,810 μS/cm, respectively. Permeate conductivity was rising as expected. Old TOYOBO hollow fine fiber membranes (Hollosep HM 8255) were tested when loaded in the module in February 1994. Permeate flow and conductivity for this membrane were: 1.07 M^3/Hour and 1,540 μS/cm, respectiviely. Permeate conductivity, however, was rising with time.

The permeate flow and conductivity for TOYOBO hollow fine fiber, cellulose triacetate Hollowsep HM 8255 membrane were: 0.8 M^3/Hour and 250 to 350 μS/cm, respectively. For the recently supplied NITTO DENKO spiral wound polyamide membranes NTR–70SWC–S 8, the permeate flow and conductivity were: 0.8 M^3/Hour and 550 to 650 μS/cm, respectively. The plant is being operated continuously using the later two membranes.

The permeate flow and conductivity for recently supplied TORAY spiral wound, fully aromatic polyamide thin film composite, membrane SU–820 were: 0.8 M^3/Hour and 500 to 750 μS/cm, respectively. The spiral wound module was operated with two elements instead of six elements, as the capacity of high pressure pump was not sufficient for the operation of six elements.

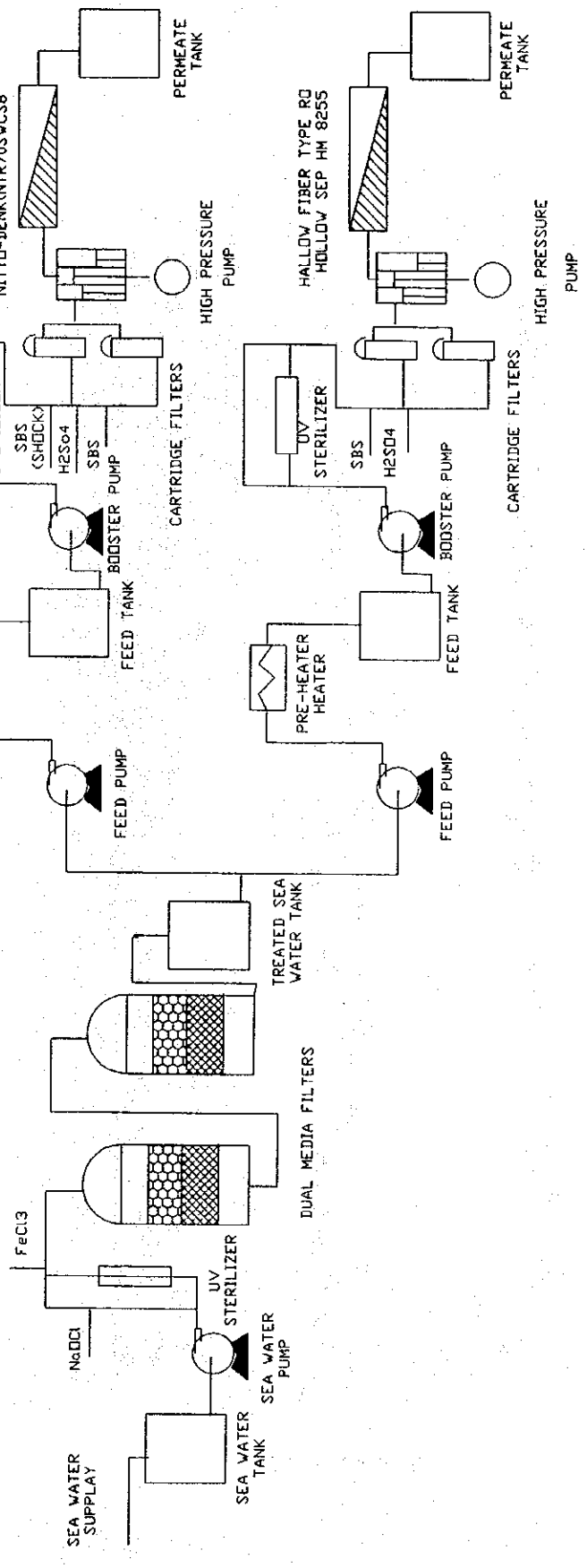


Fig. 1 Schematic Diagram of JICA Pilot Plant Design toTest Commercial Size Sea Water Membranes

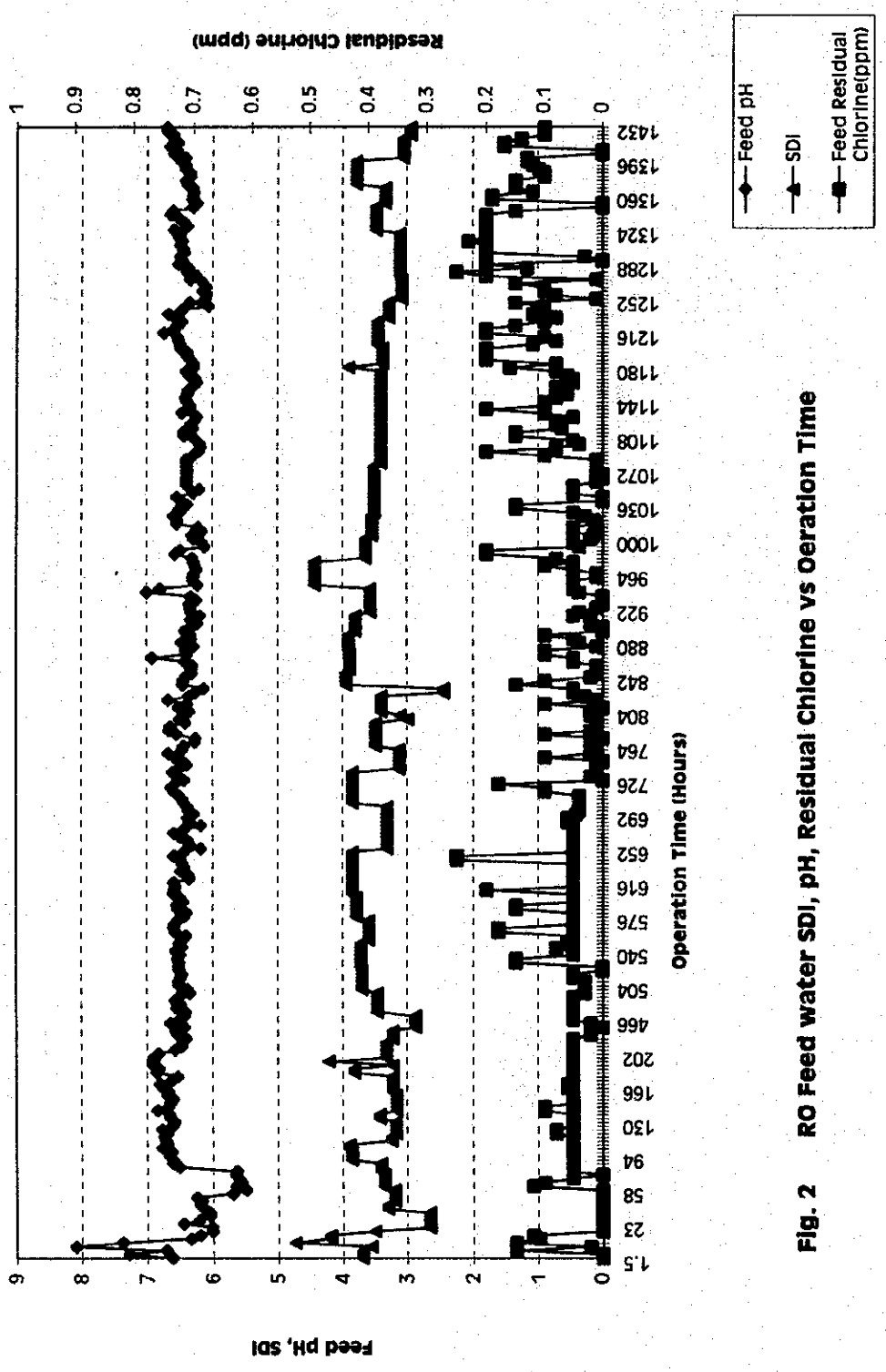


Fig. 2 RO Feed water SDI, pH, Residual Chlorine vs Oeration Time

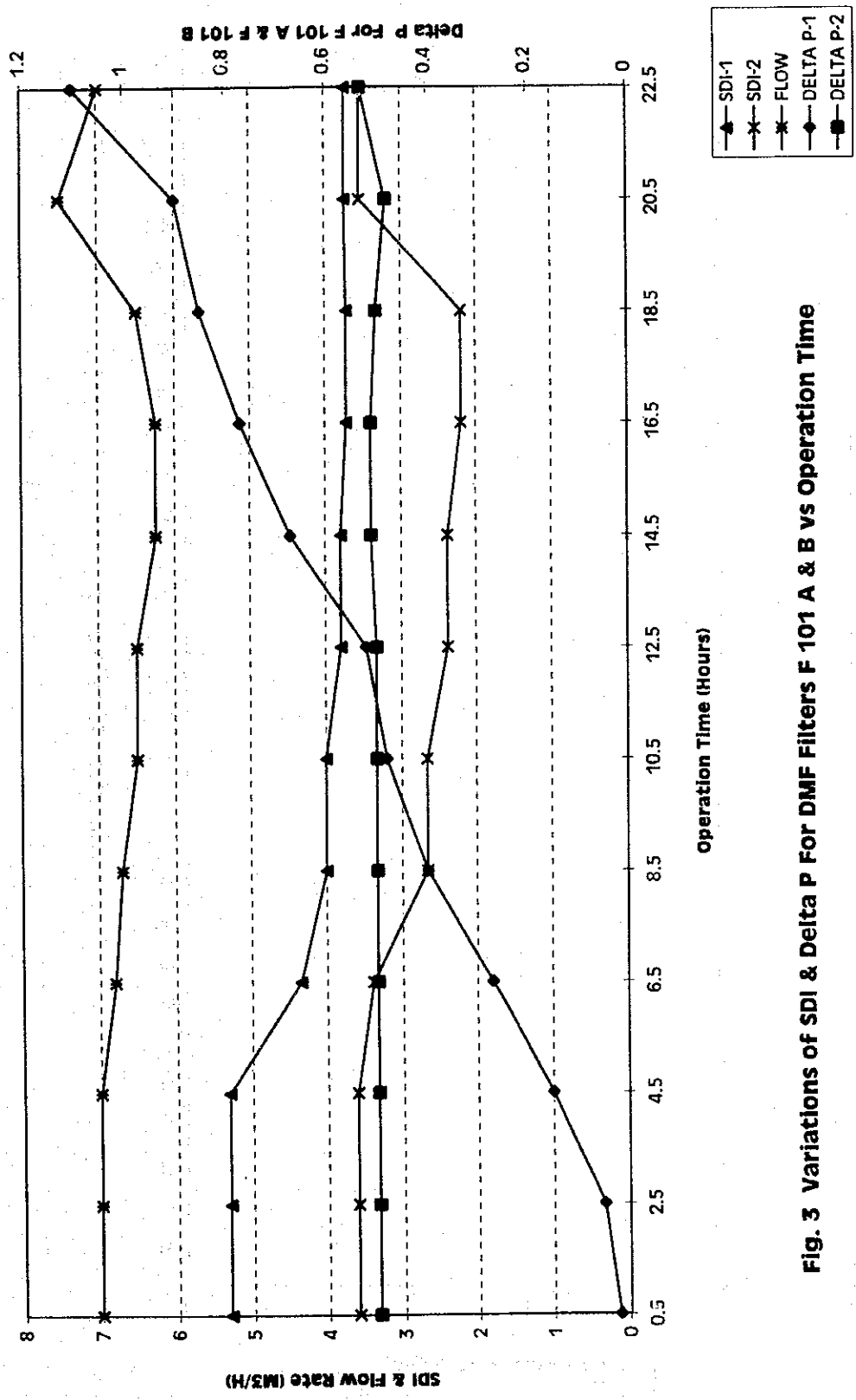


Fig. 3 Variations of SDI & Delta P For DMF Filters F 101 A & B vs Operation Time

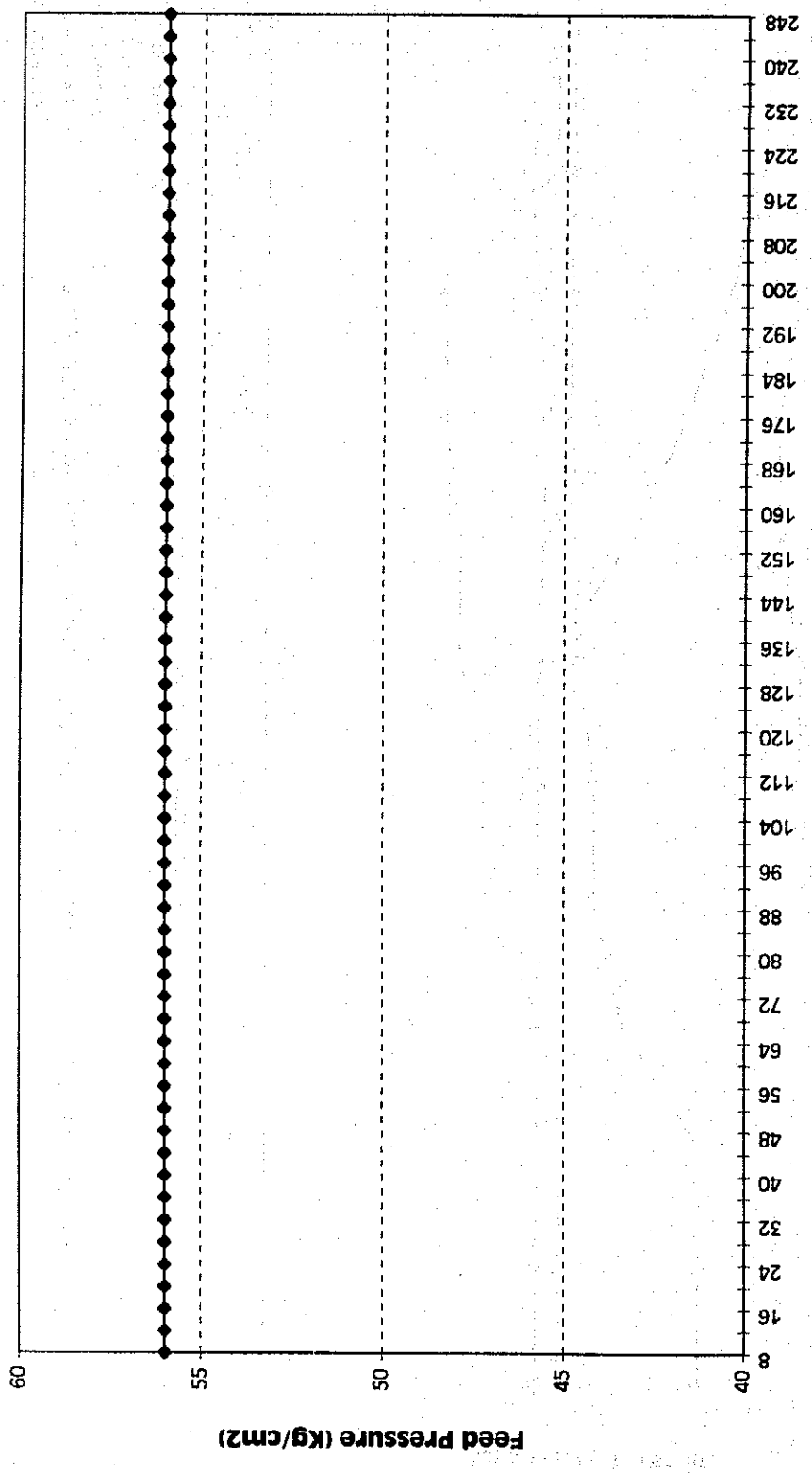


Fig. 4 Feed Pressure for Toray Spiral Wound Membrane vs Operation Time

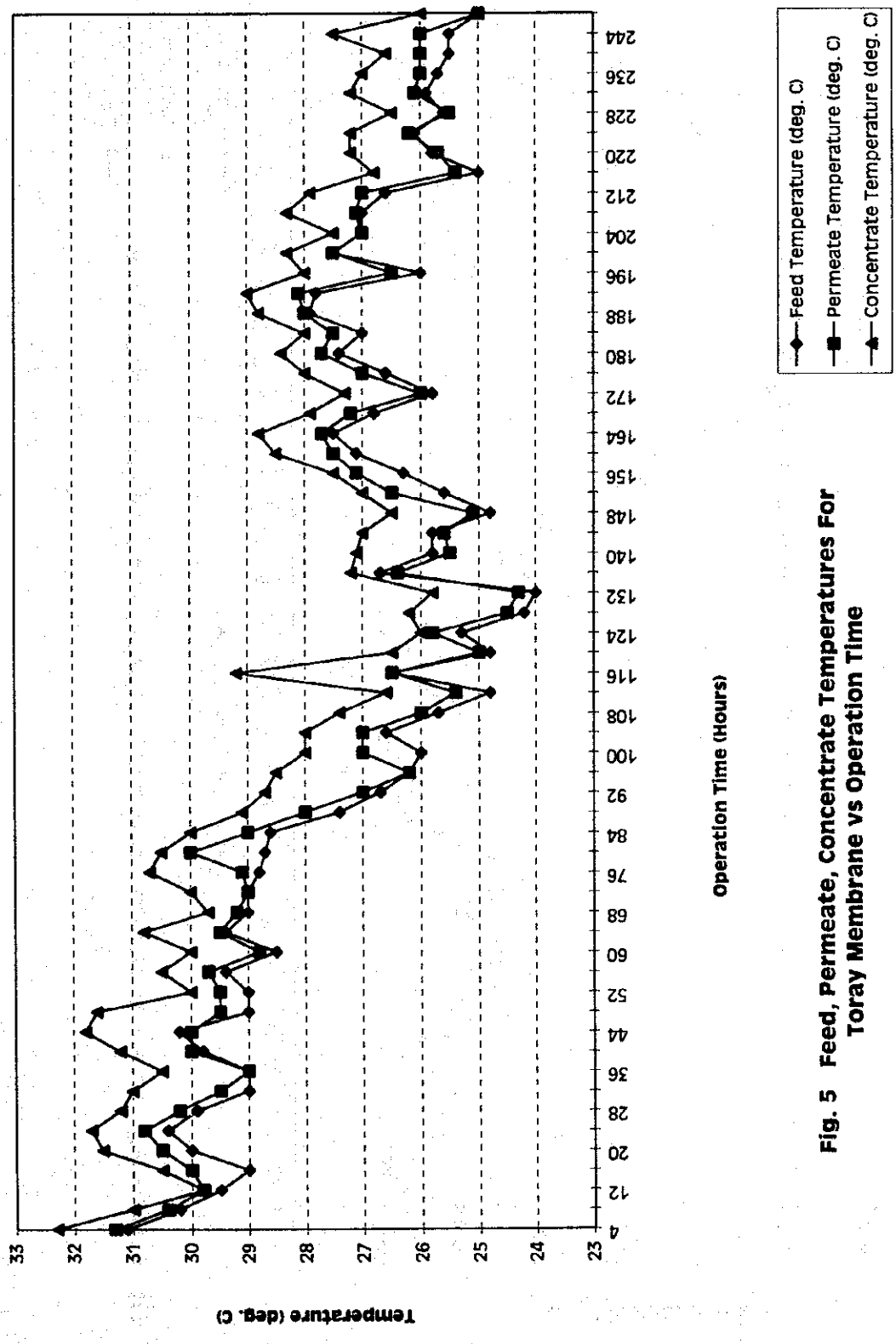


Fig. 5 Feed, Permeate, Concentrate Temperatures For Toray Membrane vs Operation Time

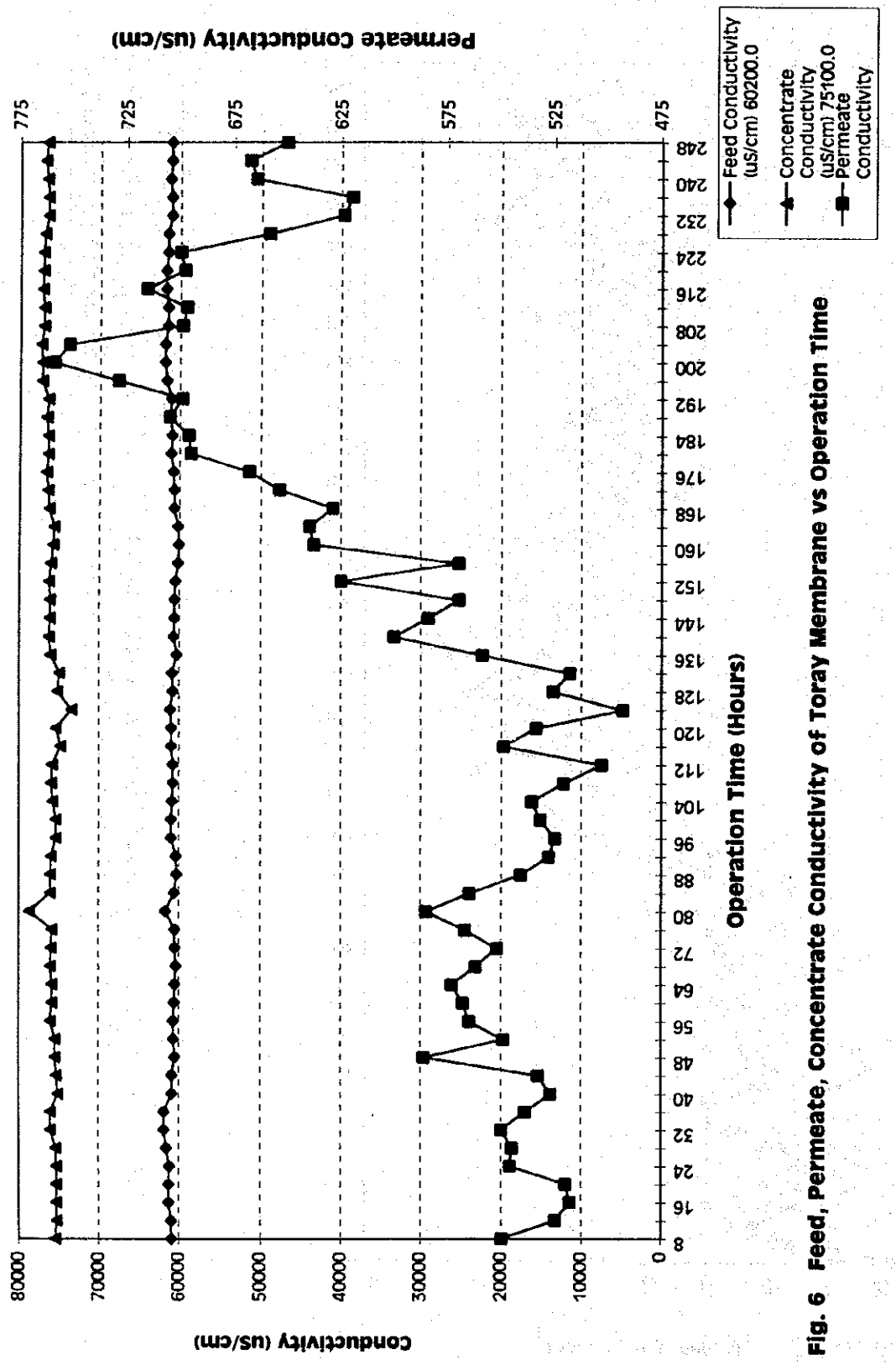


Fig. 6 Feed, Permeate, Concentrate Conductivity of Toray Membrane vs Operation Time

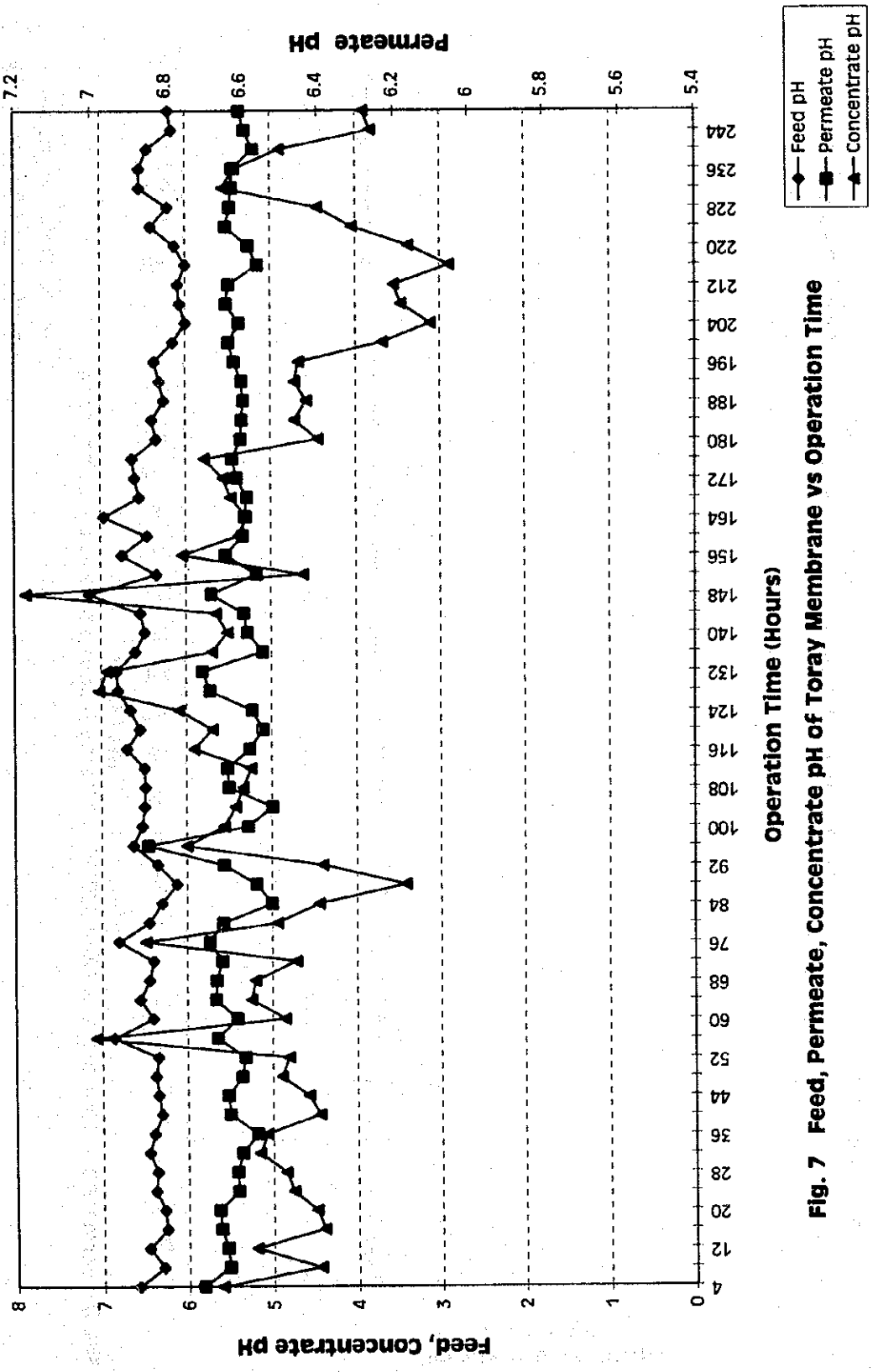


Fig. 7 Feed, Permeate, Concentrate pH of Toray Membrane vs Operation Time

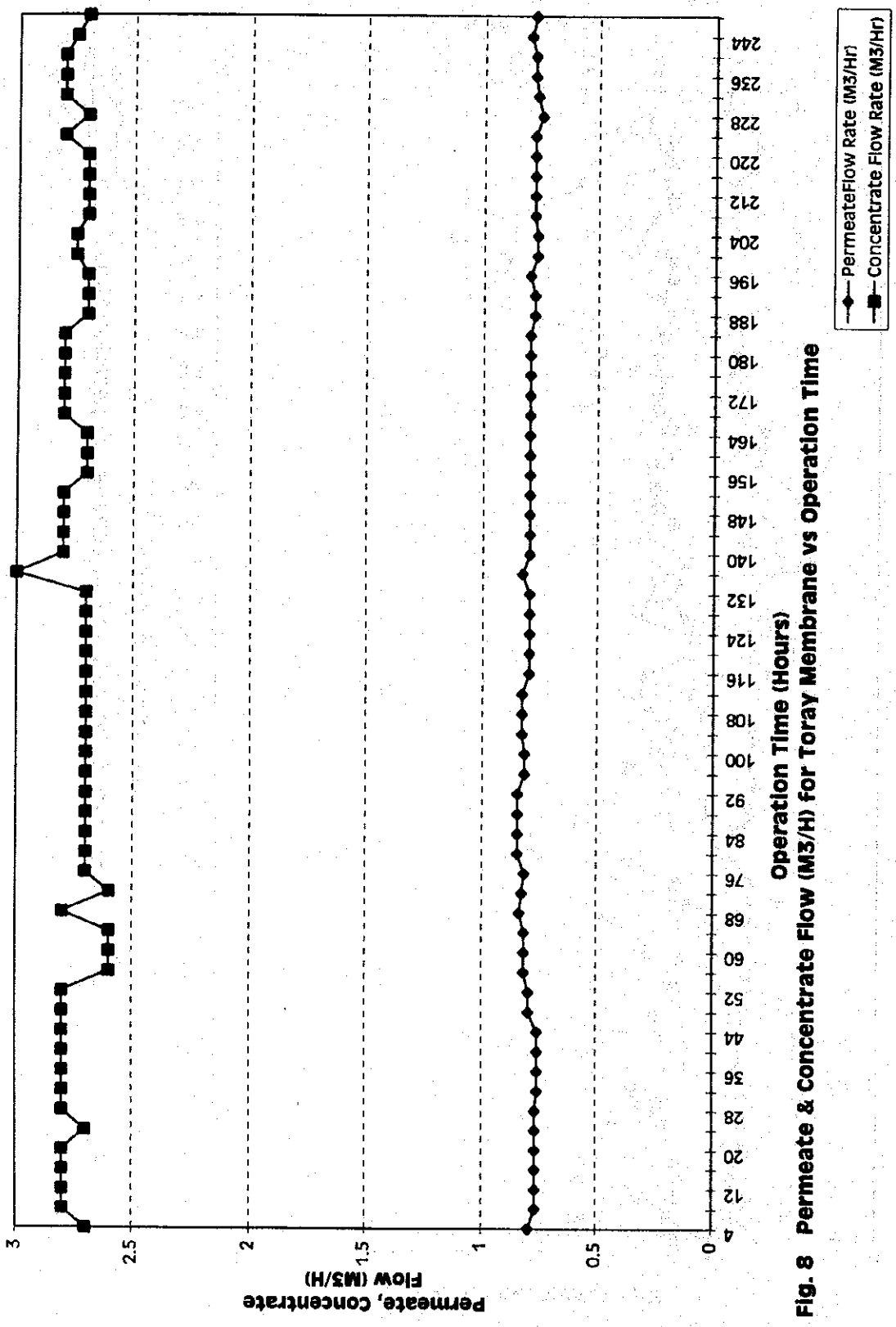


Fig. 8 Permeate & Concentrate Flow (M3/H) for Toray Membrane vs Operation Time

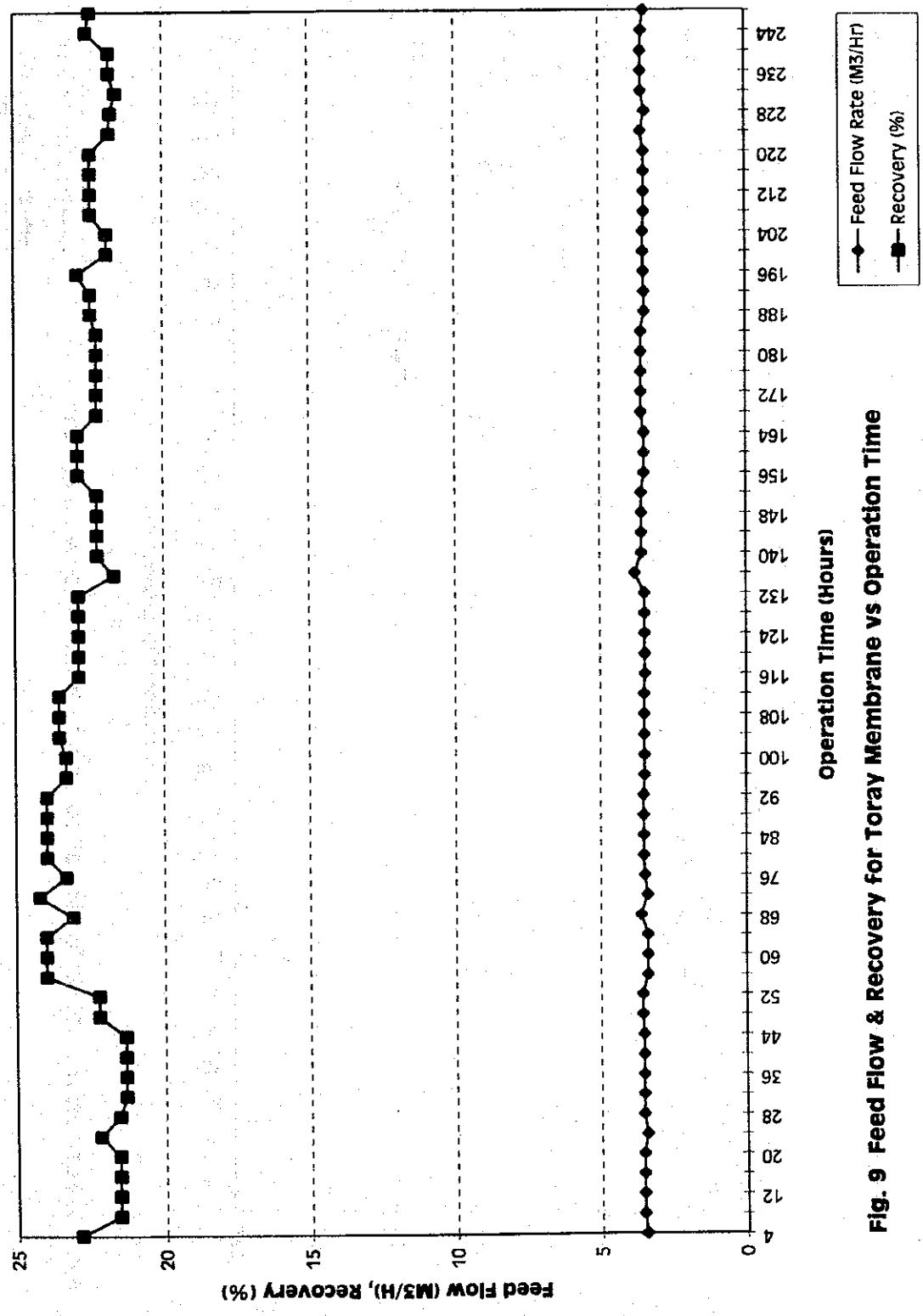


Fig. 9 Feed Flow & Recovery for Toray Membrane vs Operation Time

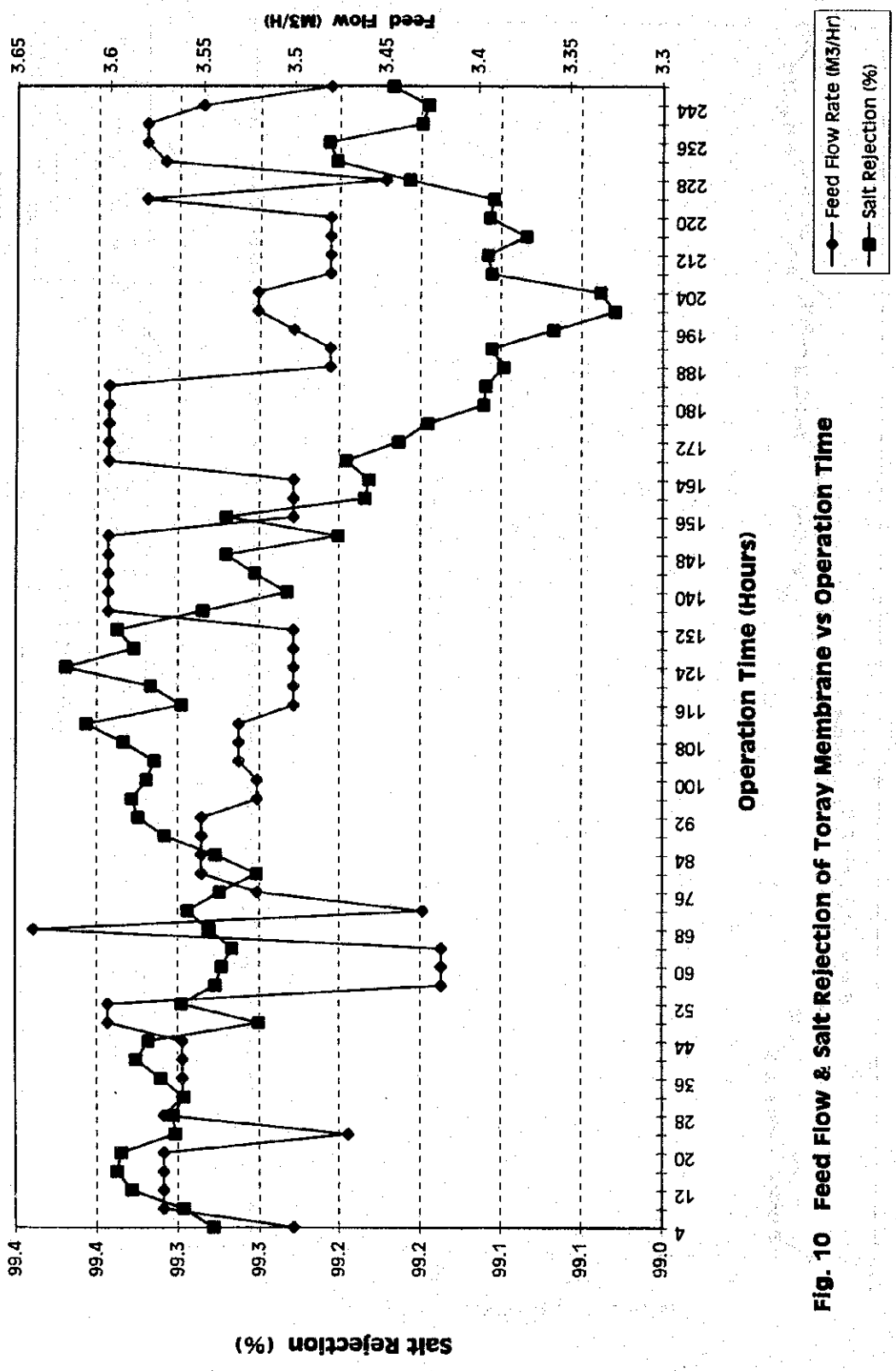


Fig. 10 Feed Flow & Salt Rejection of Toray Membrane vs Operation Time

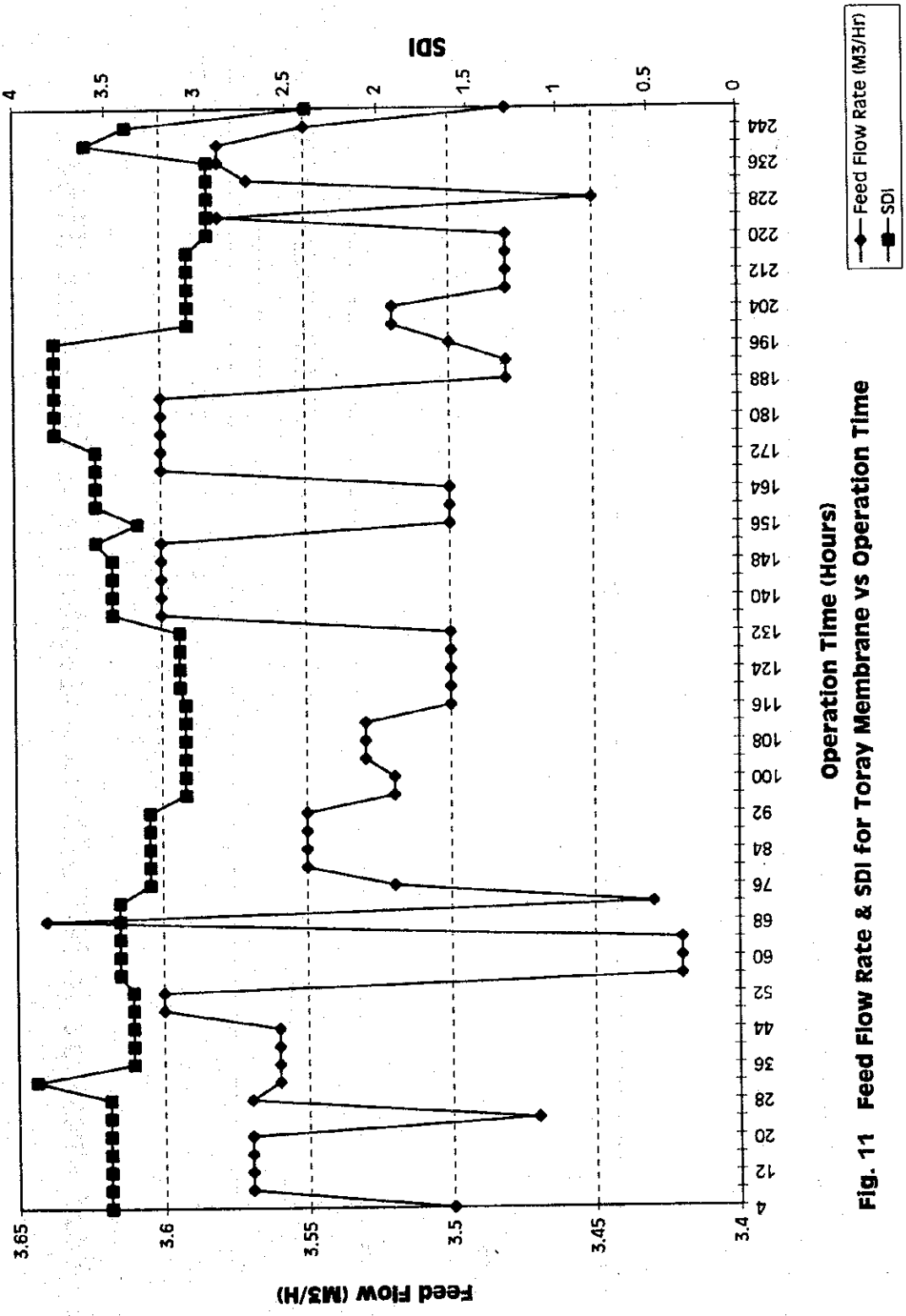


Fig. 11 Feed Flow Rate & SDI for Toray Membrane vs Operation Time

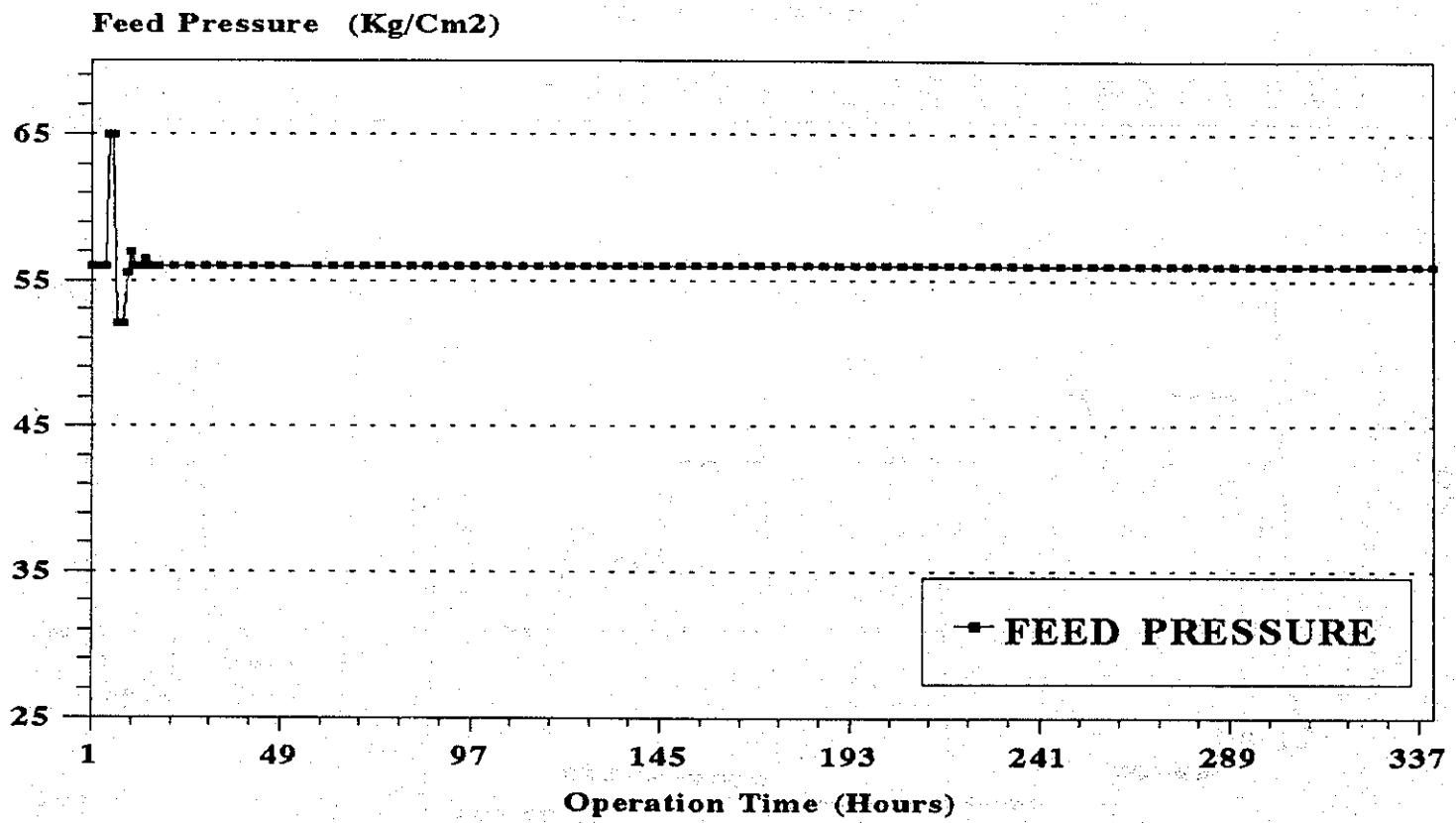


Fig. 12 Feed Pressure to Nitto Denko Membrane vs Operation Time

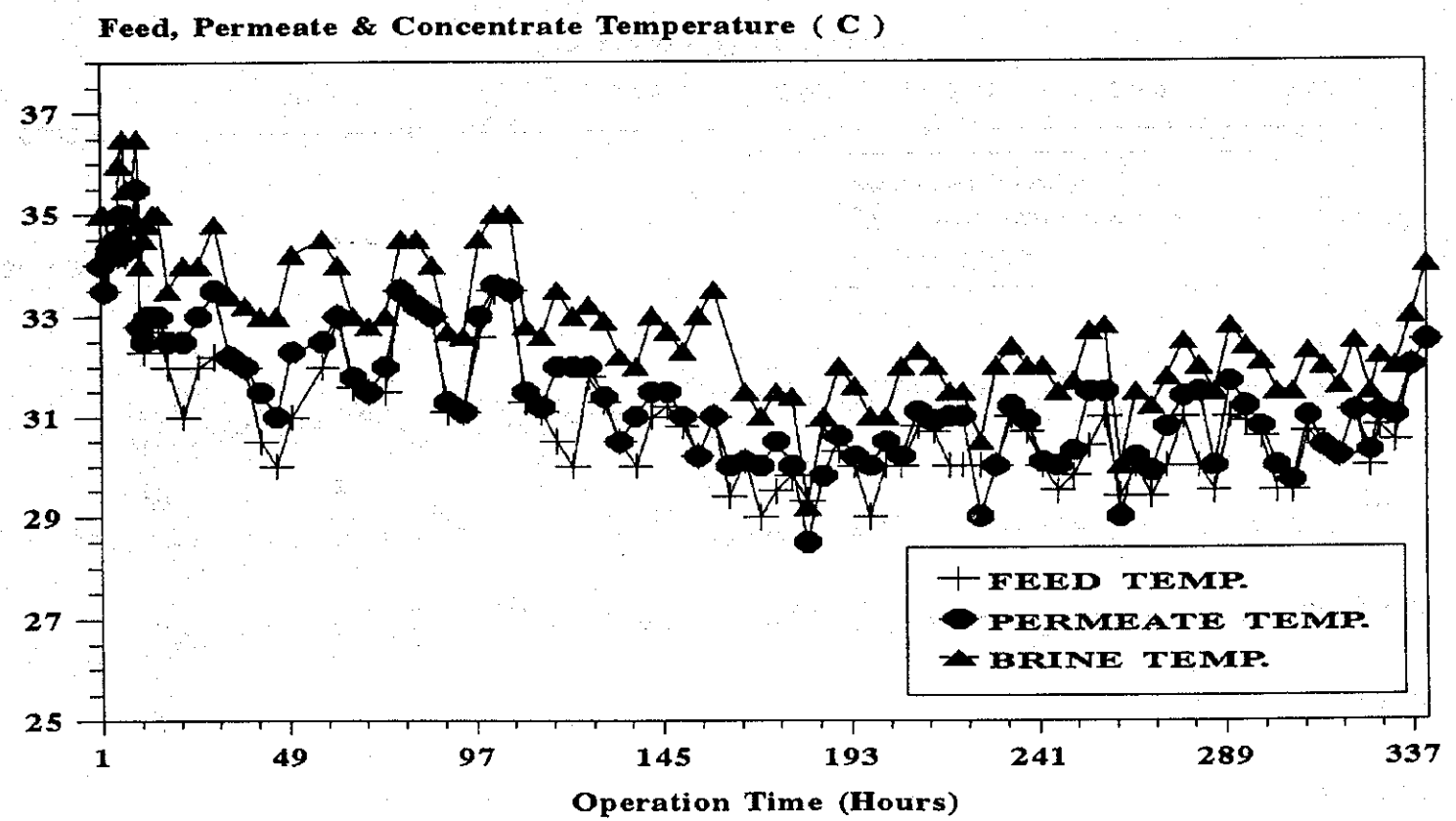


Fig. 13 Feed, Permeate & Concentrate Temperature of Nitto Denko Membrane vs Operation Time

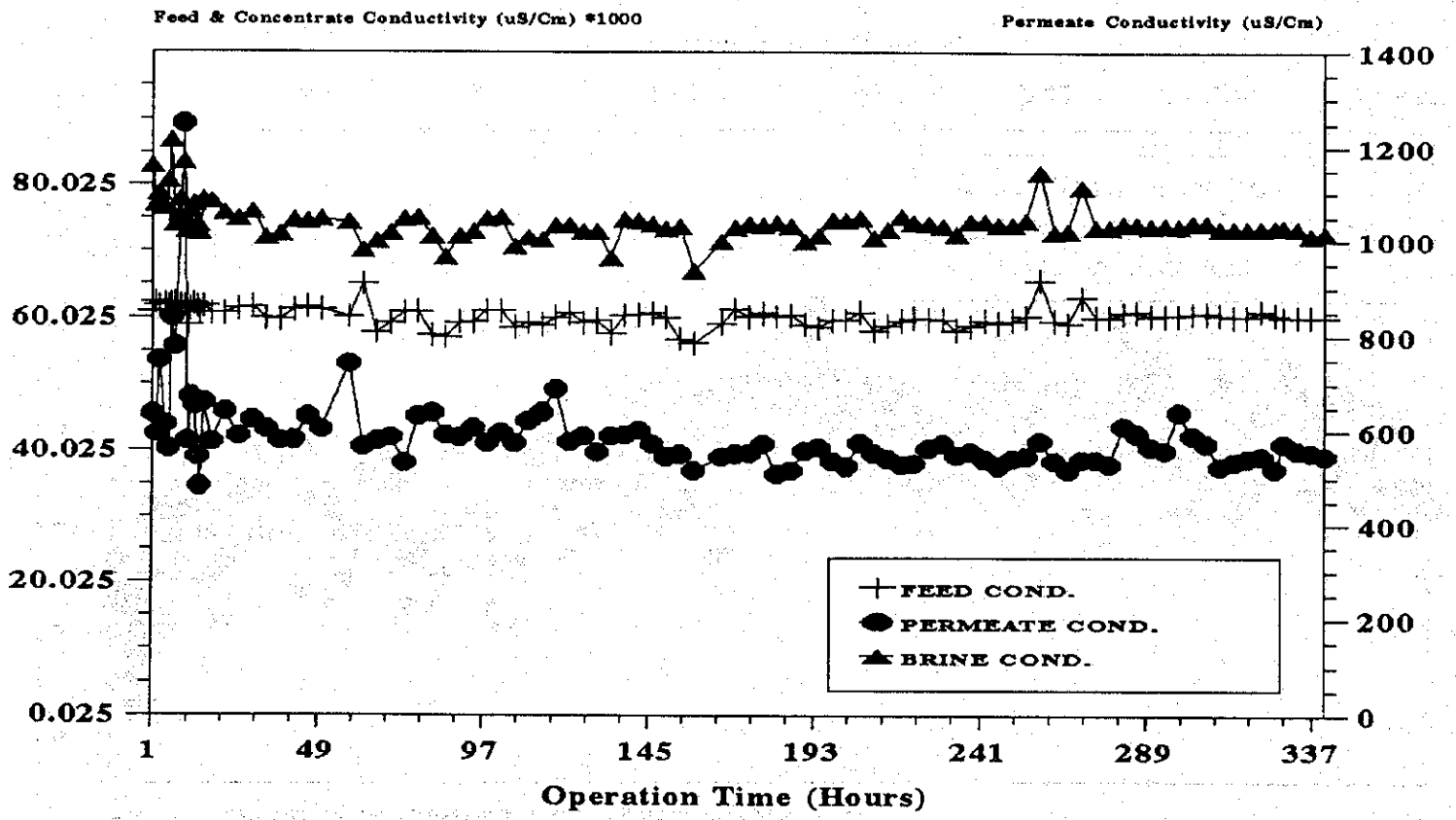


Fig. 14 Feed, Permeate & Concentrate Conductivity of Nitto Denko Membrane vs Operation Time

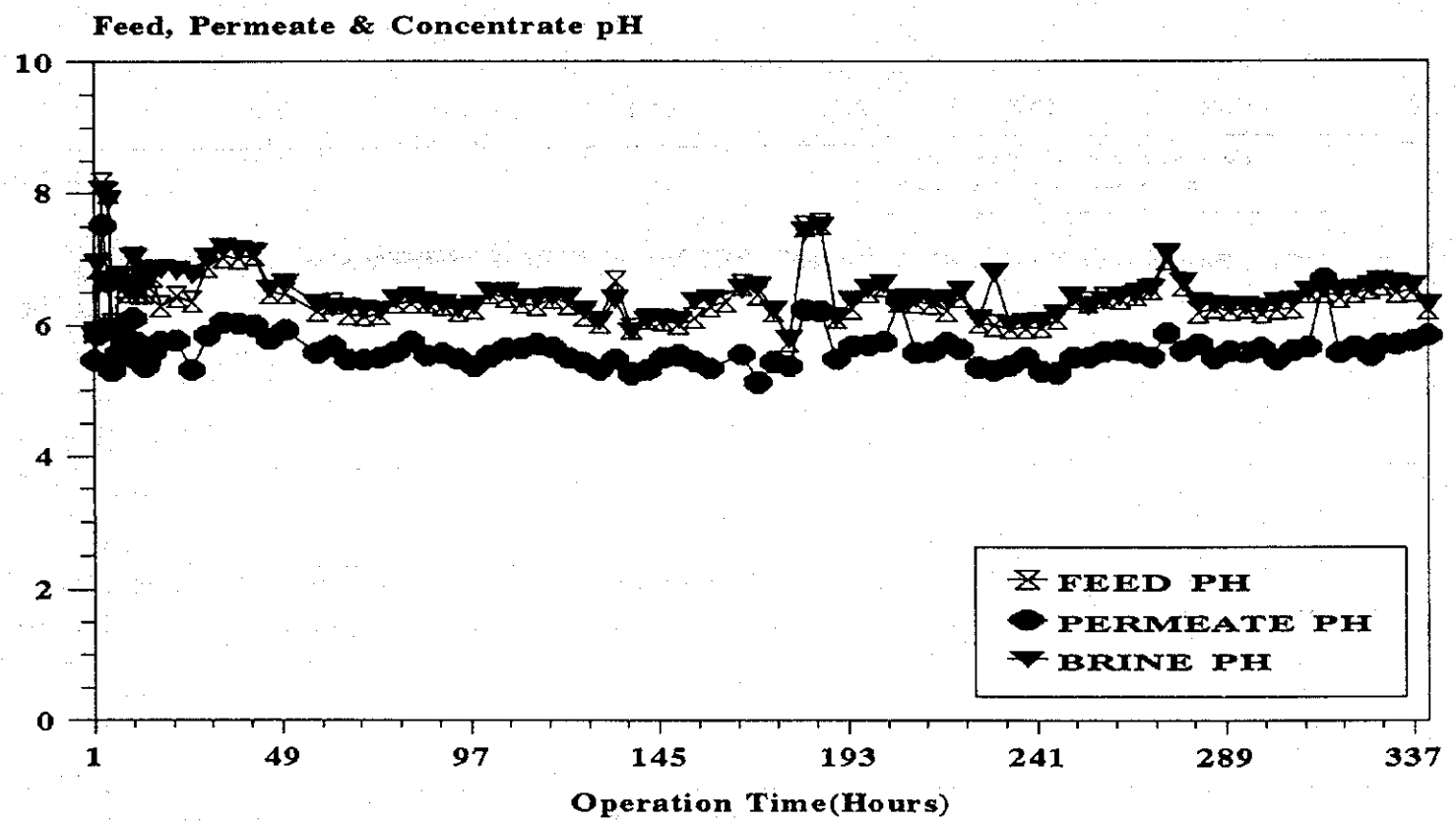


Fig. 15 Feed, Permeate & Concentrate pH OF Nitto Denko Membrane vs Operation Time

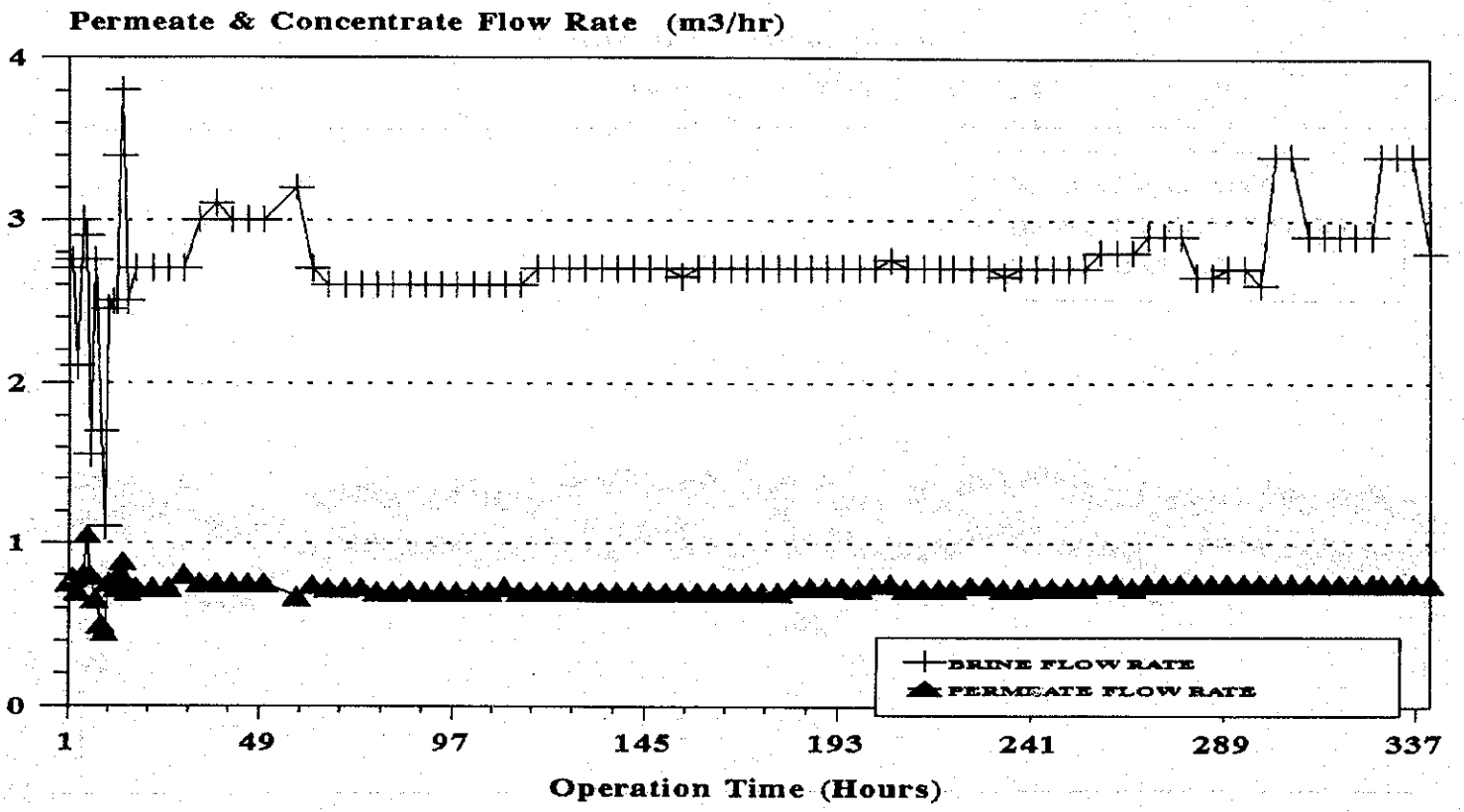


Fig. 16 Permeate & Concentrat Flow Rate of Nitto Denko Membrane vs Operation Time

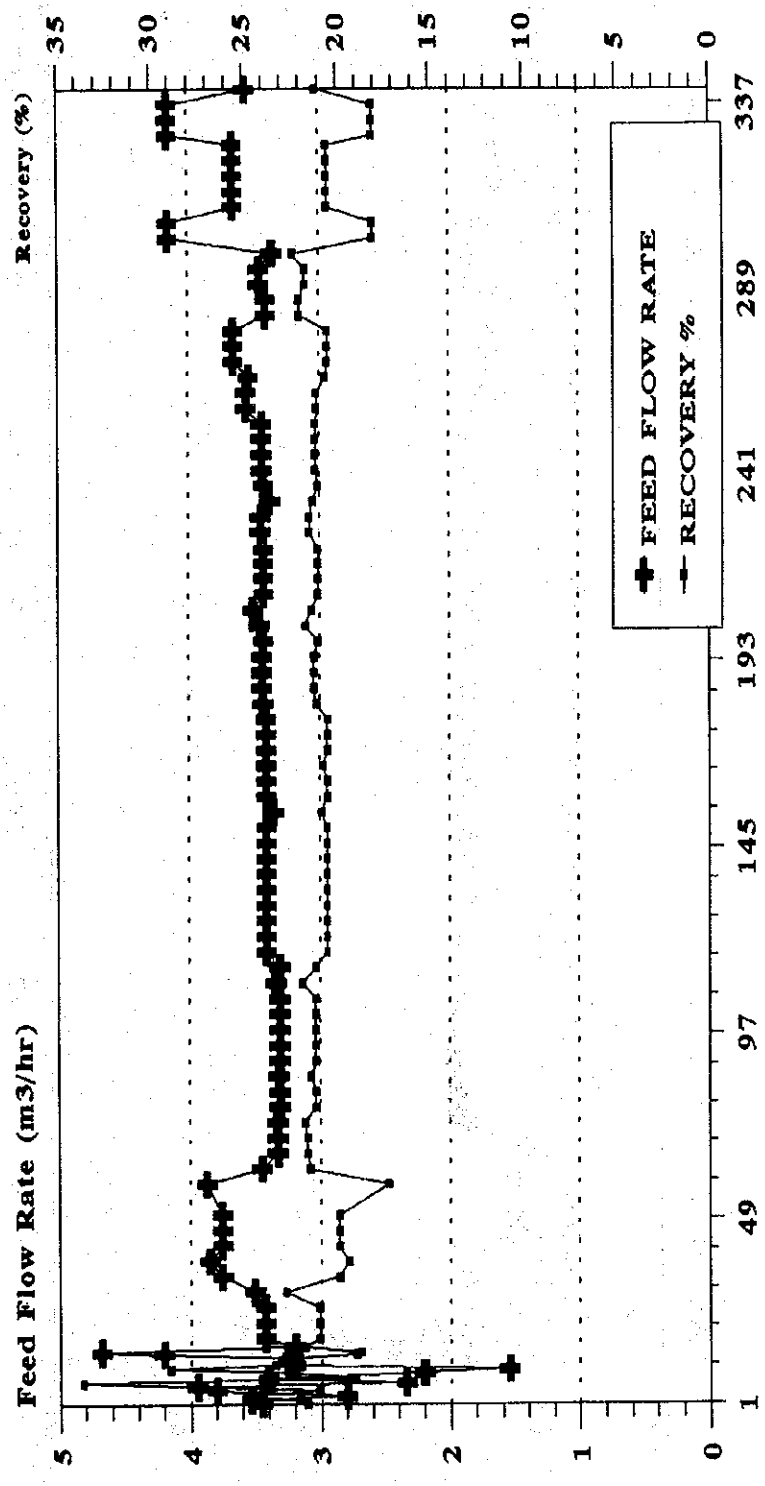


Fig. 17 Feed Flow Rate & Recovery (%) of Nitto Denko Membrane vs Operation Time

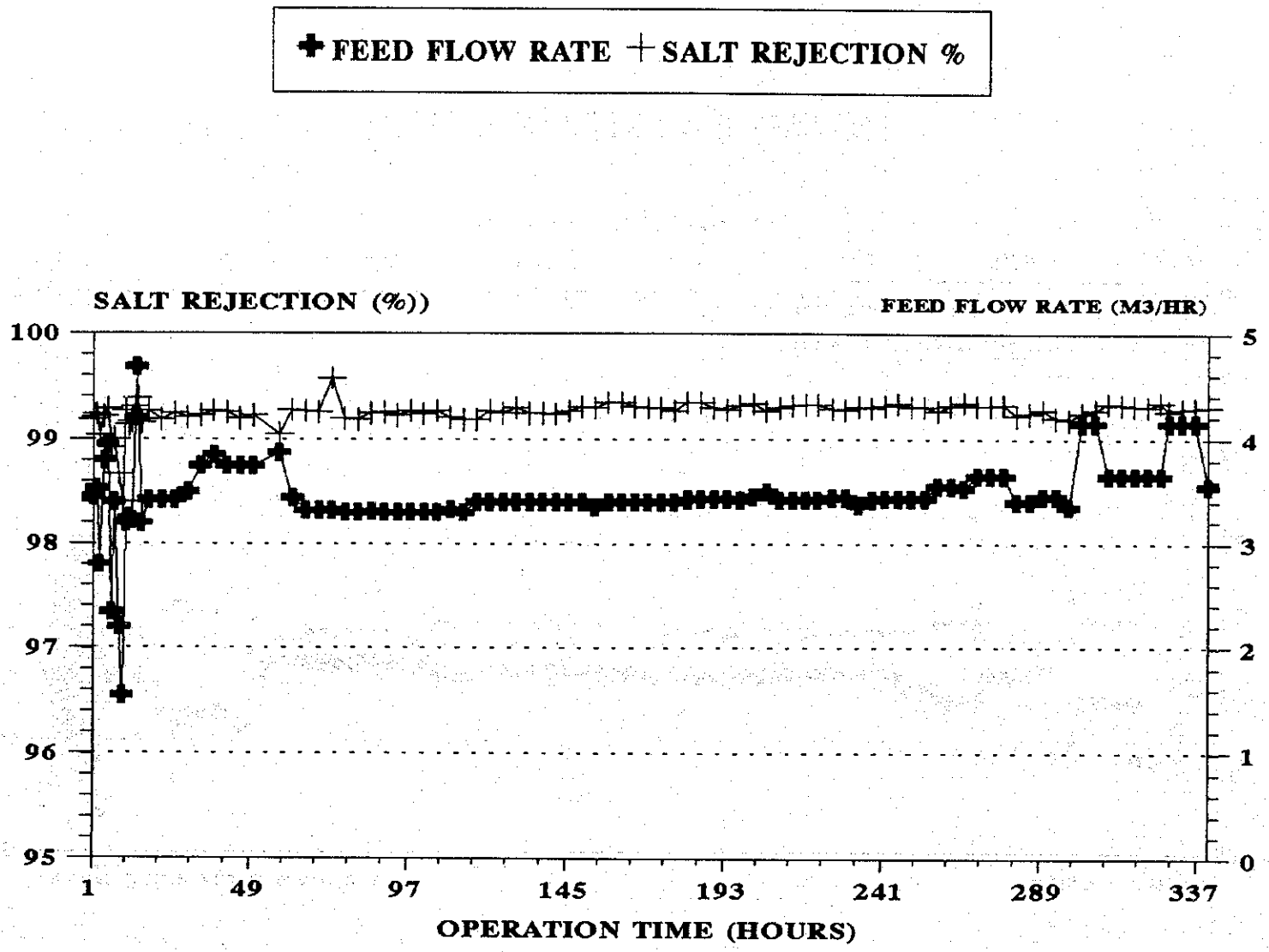


Fig.18 SALT REJ.(%) & FEED FLOW RATE FOR NITTO DENKO SPIRAL WOUND MEMBRANE VS OPERATION TIME

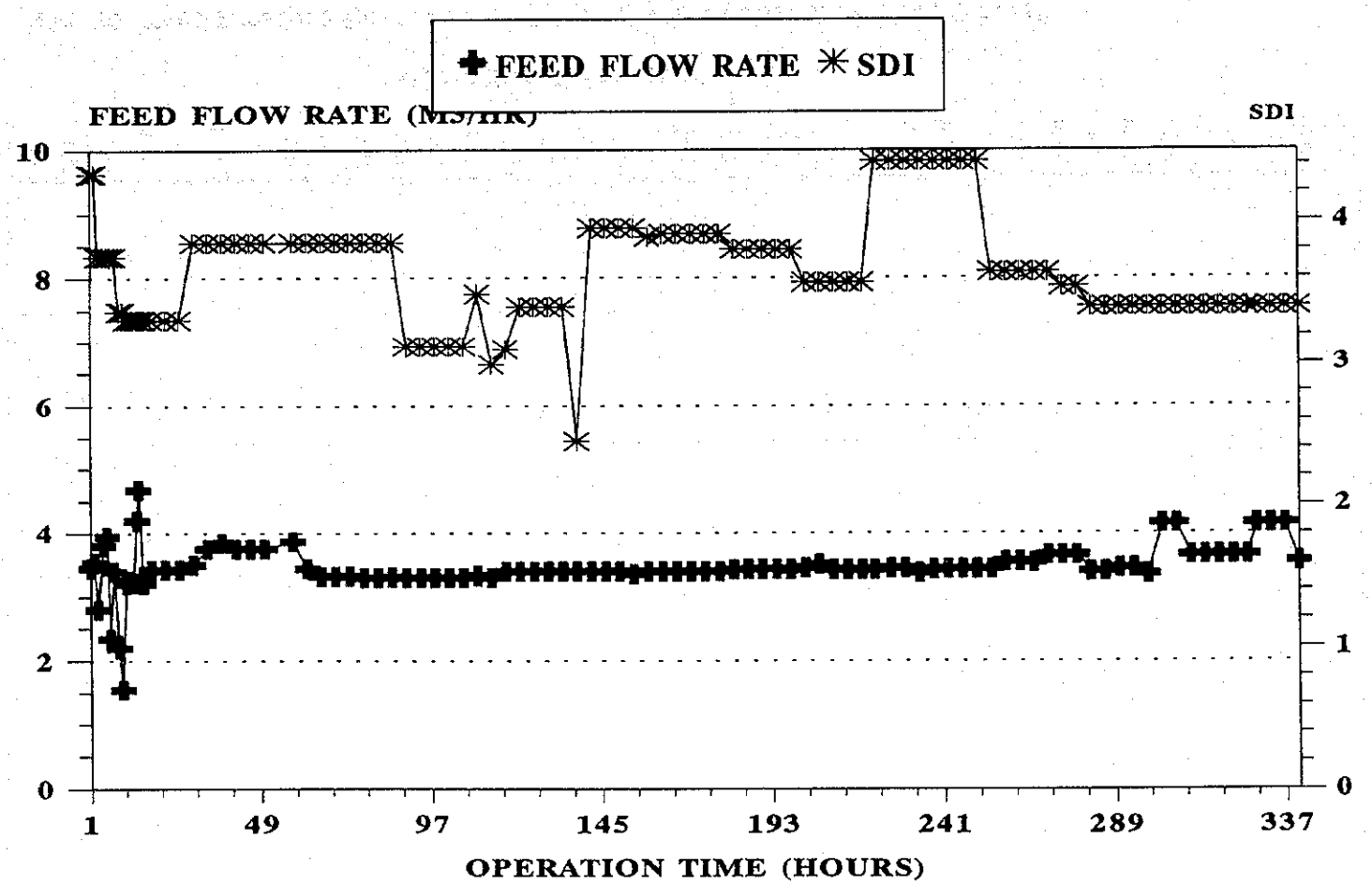


Fig.19 FEED FLOWRATE & SDI FOR NITTO DENKO SPIRAL WOUND MEMBRANE VS OPERATION TIME

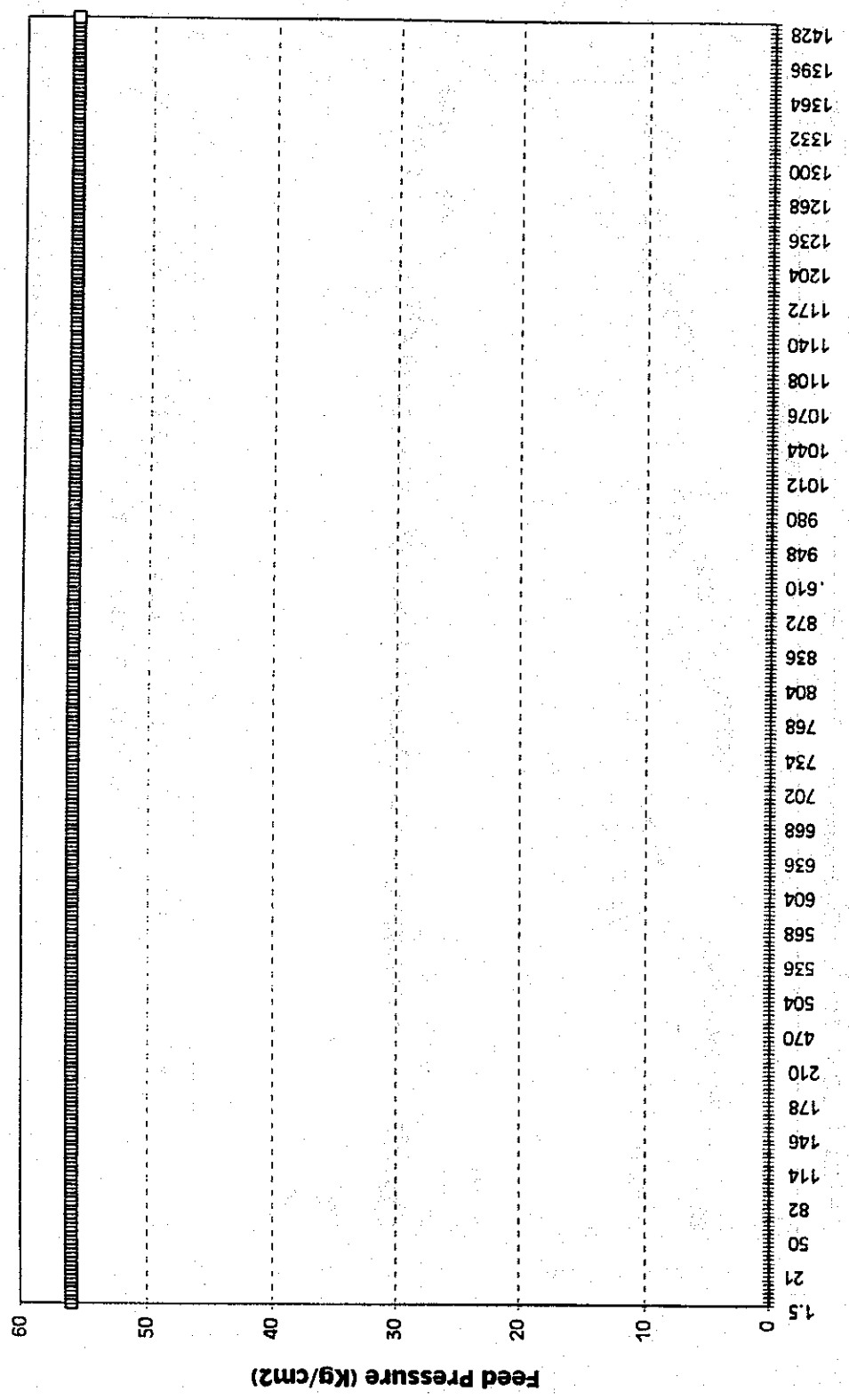


Fig. 20 Feed Pressure for Toyobo HFF Membrane vs Operation Time (Hours)

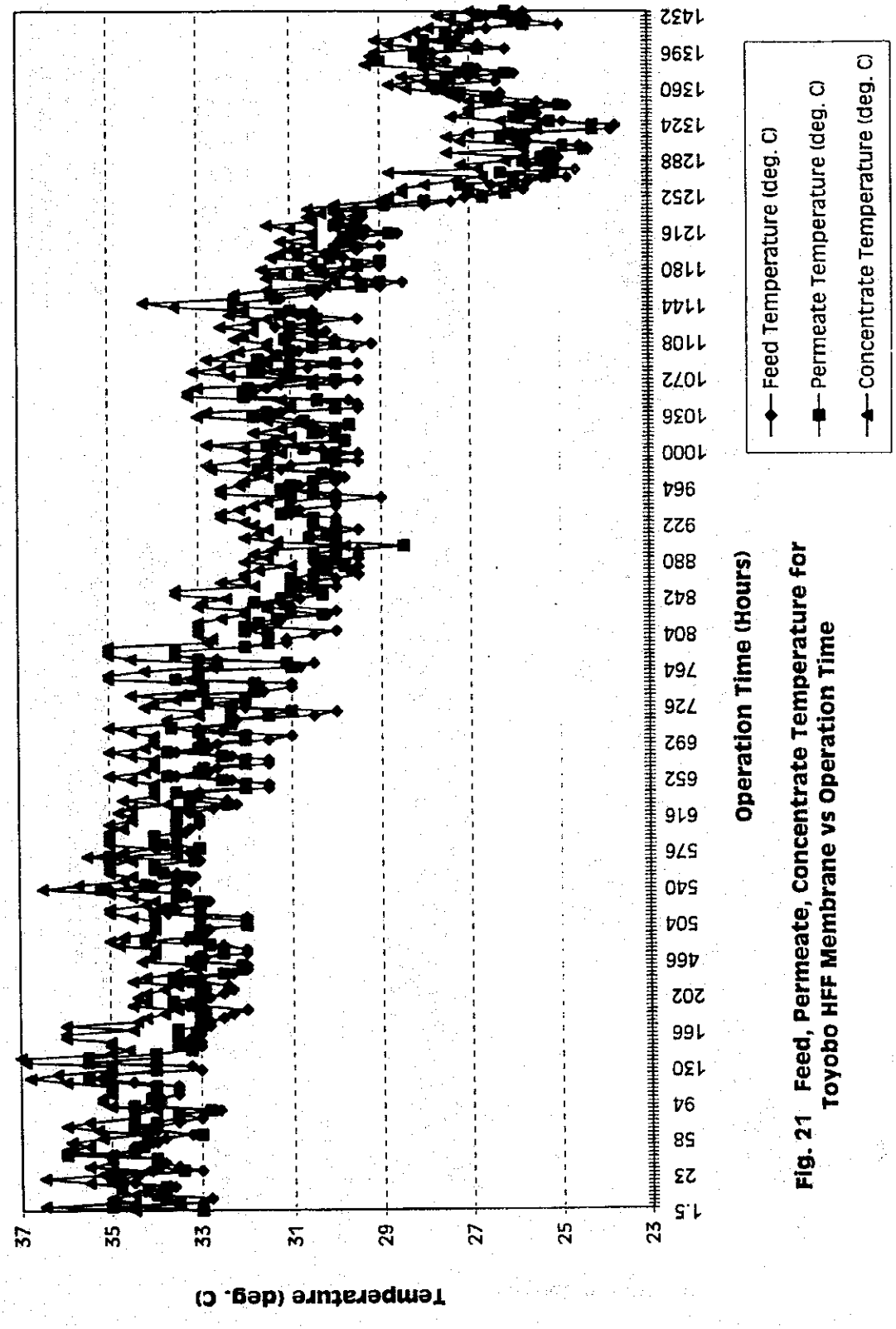


Fig. 21 Feed, Permeate, Concentrate Temperature for Toyobo HFF Membrane vs Operation Time

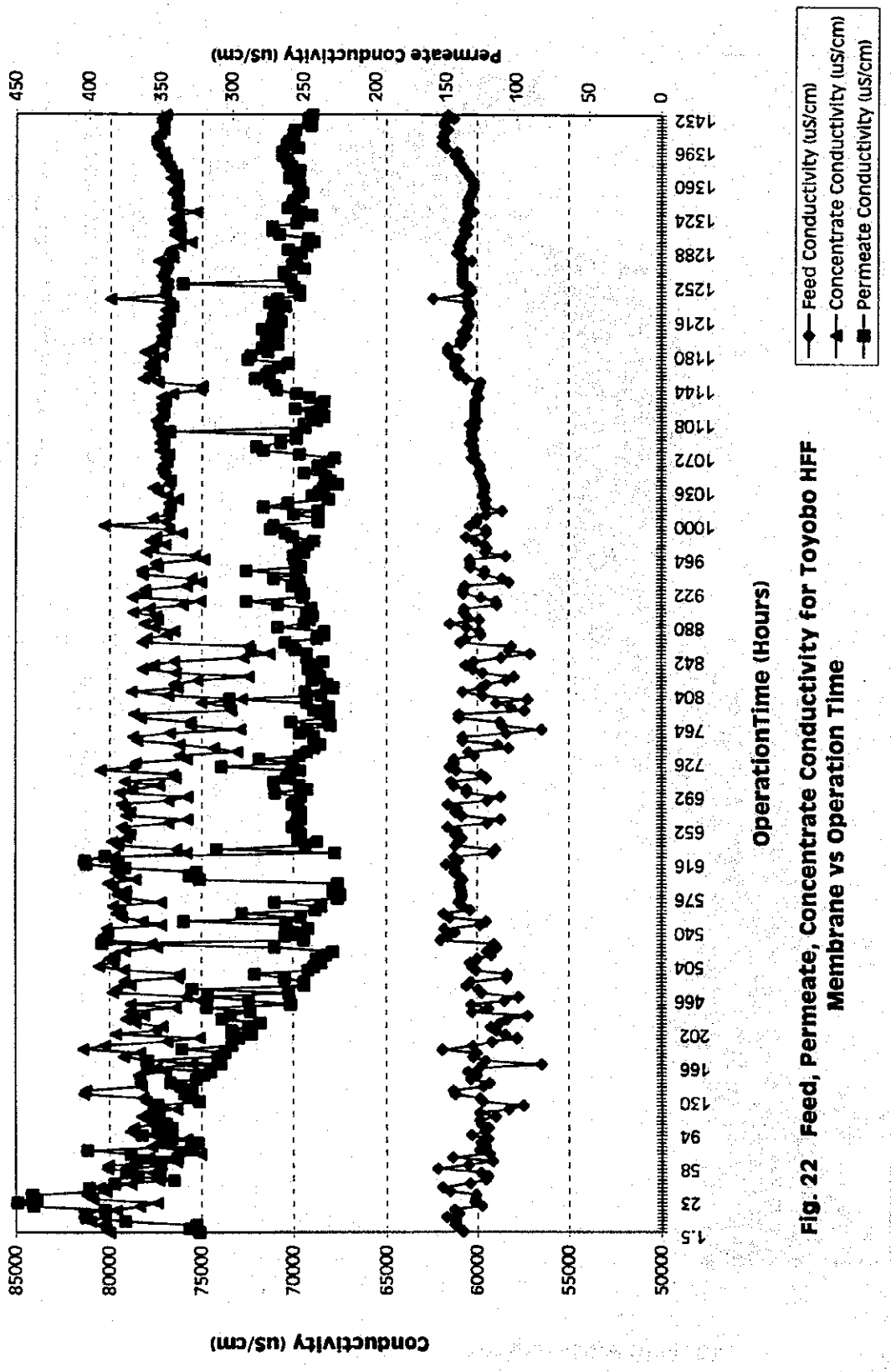


Fig. 22 Feed, Permeate, Concentrate Conductivity for Toyobo HFF Membrane vs Operation Time

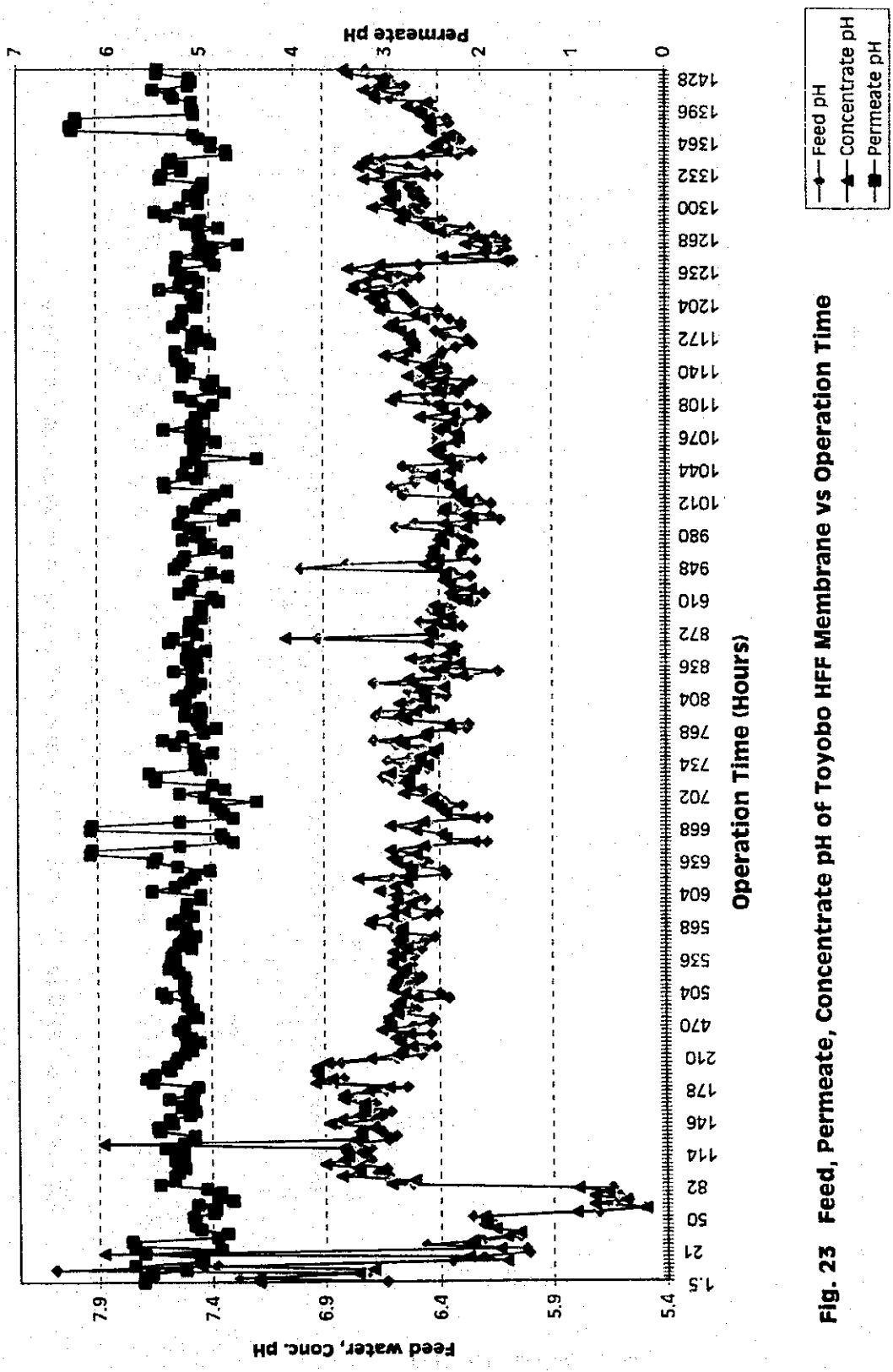


Fig. 23 Feed, Permeate, Concentrate pH of Toyobo HFF Membrane vs Operation Time

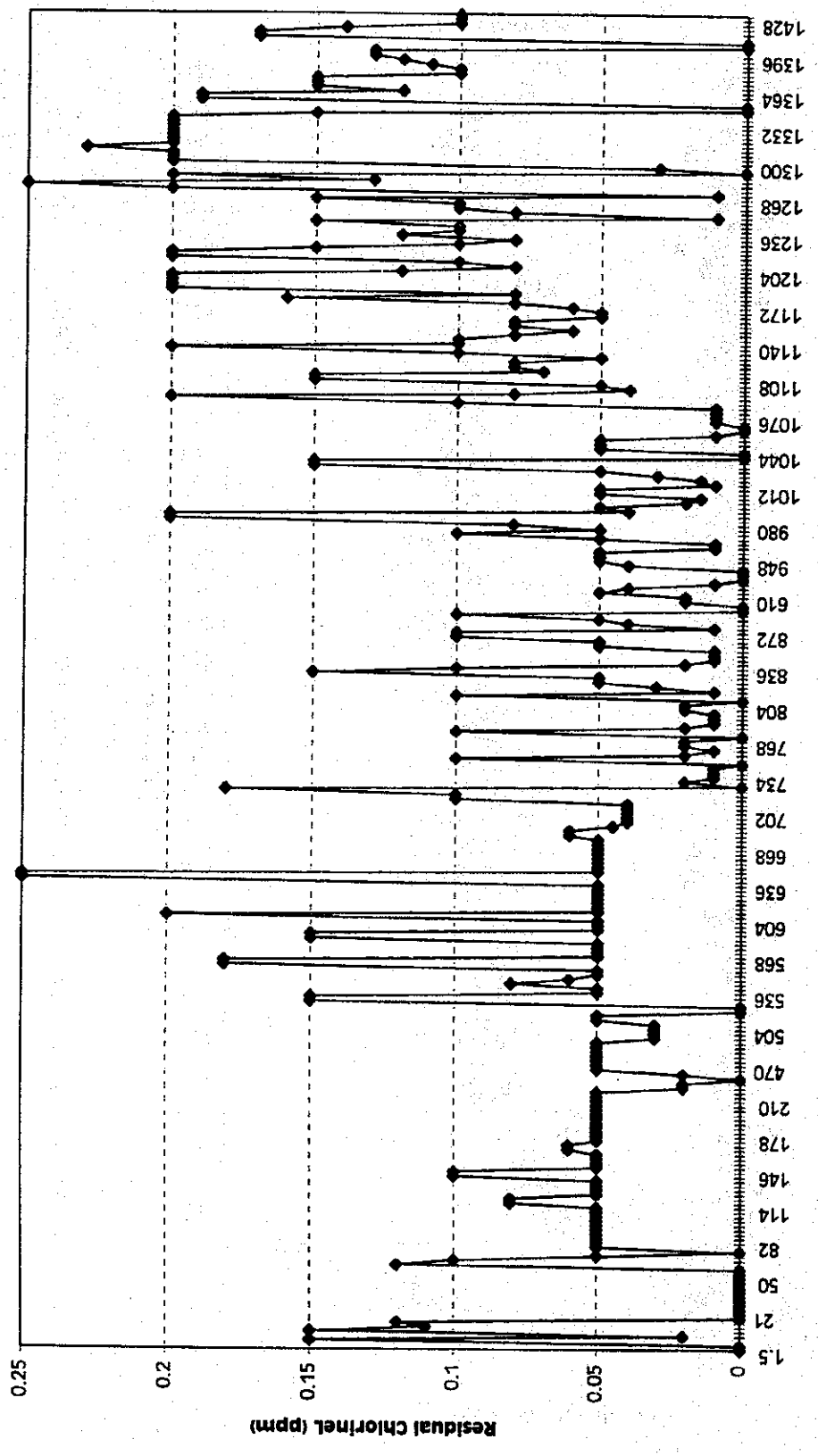


Fig. 24 Feed Residual Chlorine for Toyobo HFF Membrane vs Operation Time

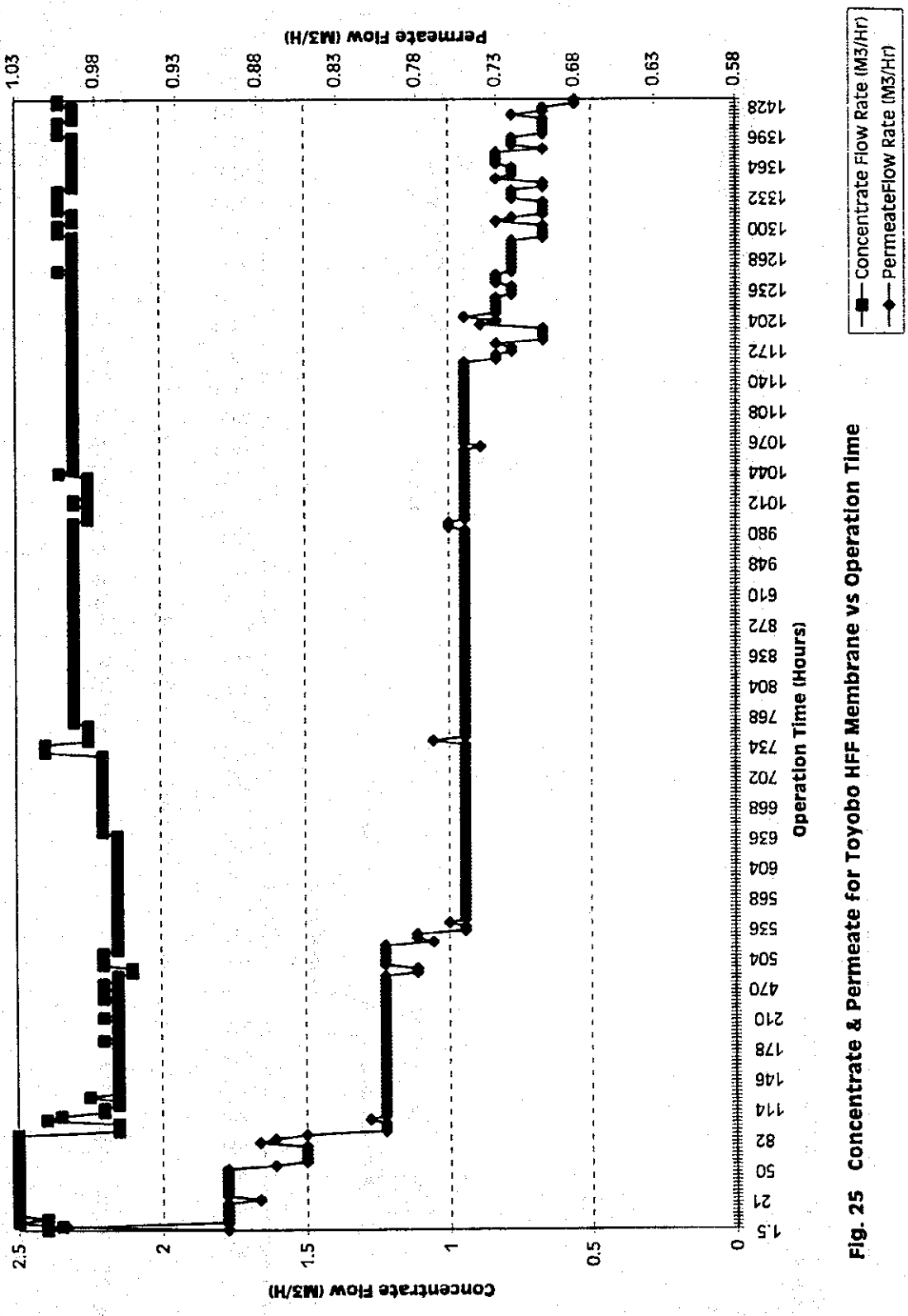


Fig. 25 Concentrate & Permeate for Toyobo HFF Membrane vs Operation Time

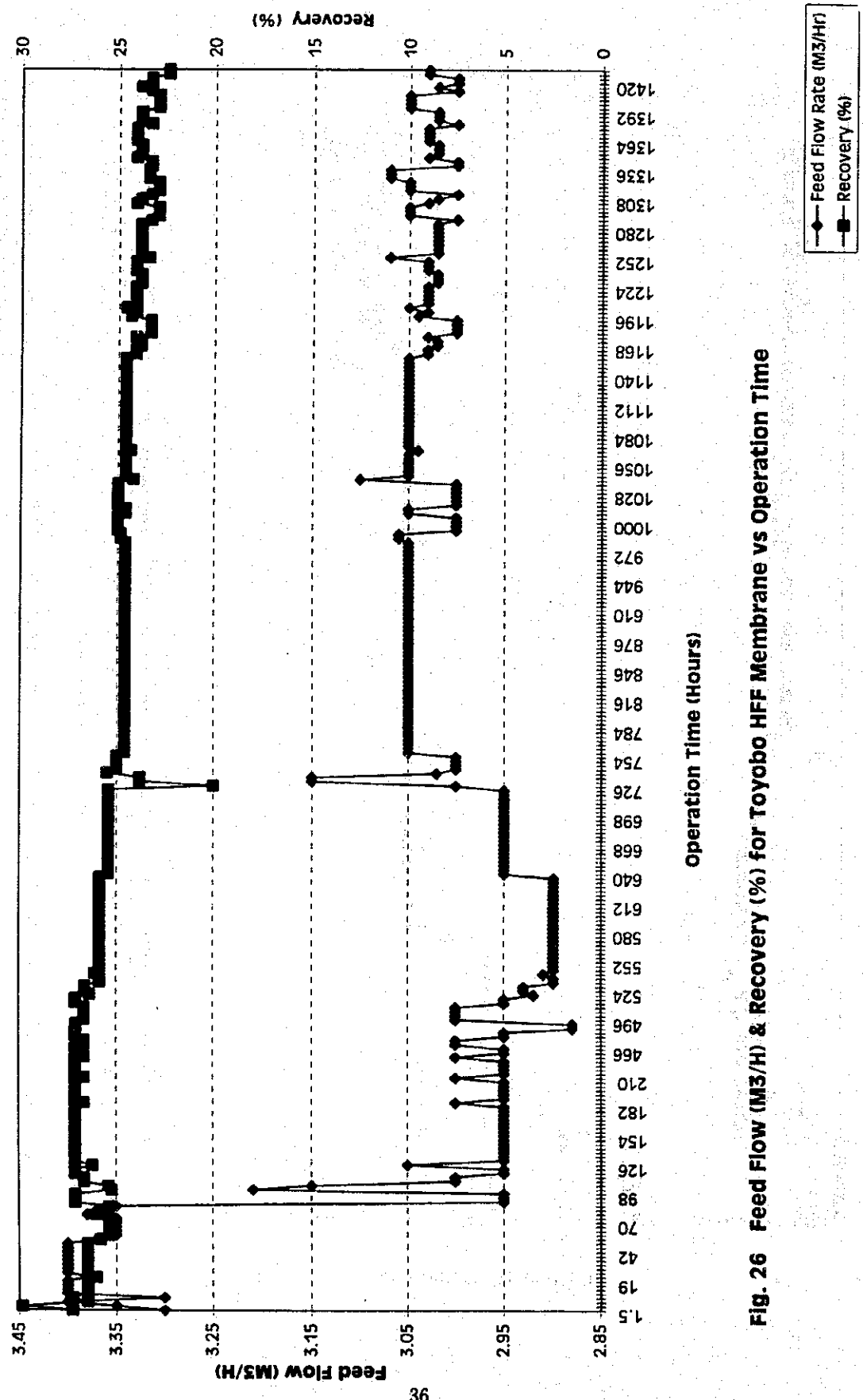


Fig. 26 Feed Flow (M3/H) & Recovery (%) for Toyobo HFF Membrane vs Operation Time

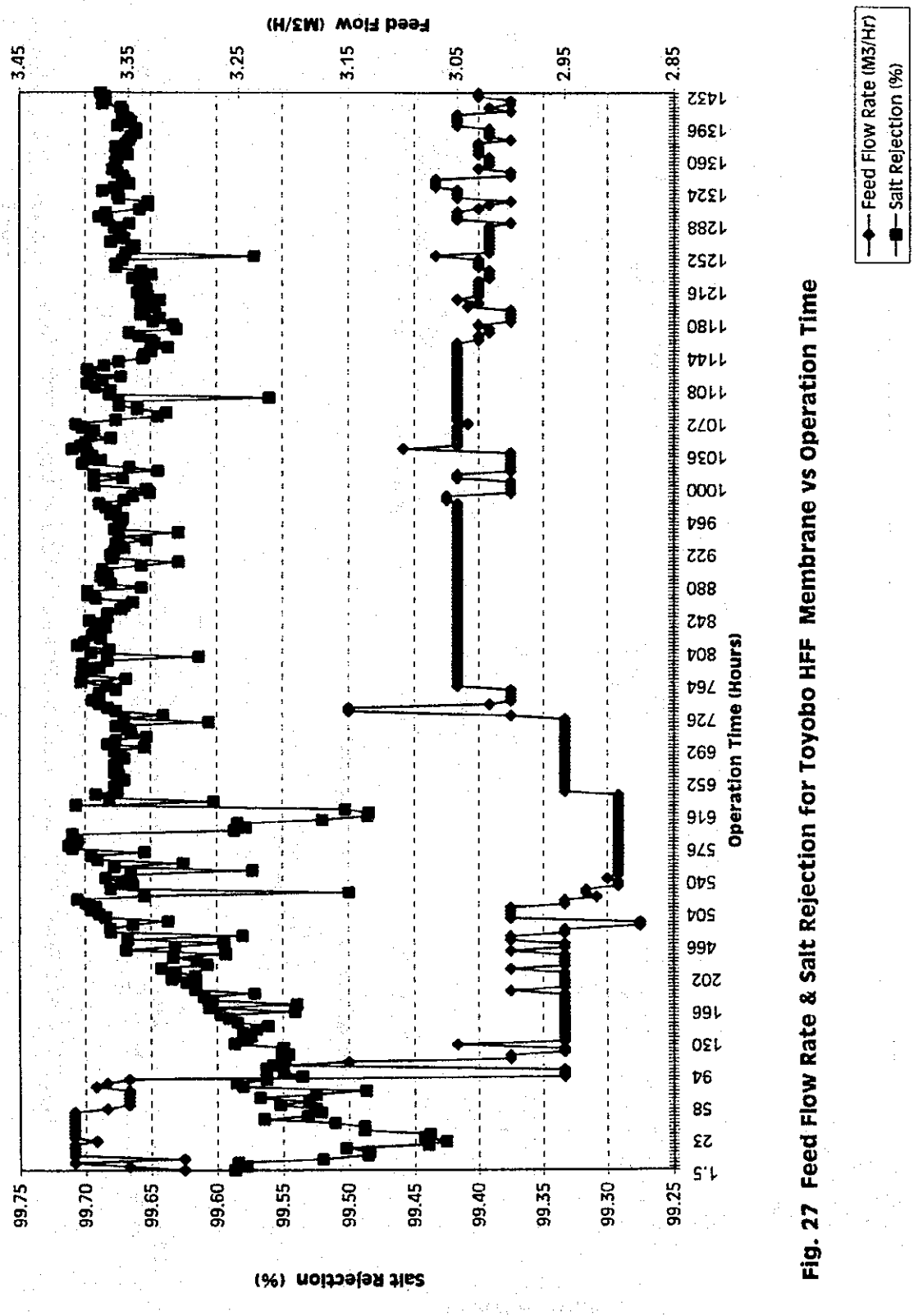


Fig. 27 Feed Flow Rate & Salt Rejection for Toyobo HFF Membrane vs Operation Time

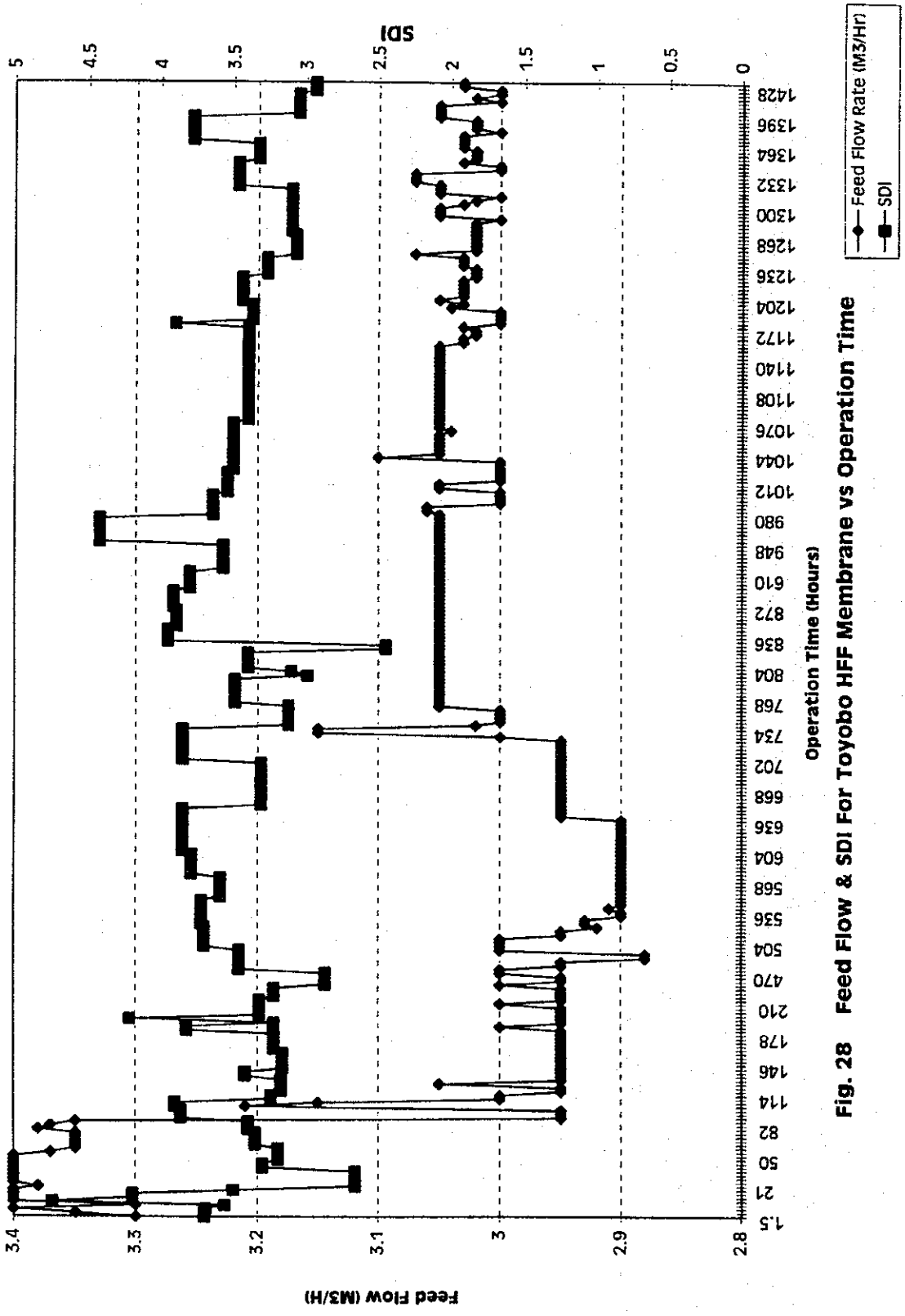


Fig. 28 Feed Flow & SDI For Toyobo HFF Membrane vs Operation Time

7.4 Transfer of Technology

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7.4 Transfer of Technology

1. Objectives

To implement transfer of technology to SWCC (especially on young Saudi researcher) through the joint research work with JICA and SWCC.

2. Method of Implementing Technology Transfer

The main technology related to this research was divided in the following technical elements and became the object of the technology transfer. The method of technology transfer was mainly effected by the implementation of joint research by both JICA and SWCC. This became firmly fixed through the processes of on the job training(OJT) and the preparation of written experiment reports and manuals and these techniques were prepared and supplied as substantial items for future use.

Main technical elements for the transfer of technology

1) RO membrane performance appraisal
2) Operation and maintenance of the RO test plant
3) General appraisal of RO membranes
4) Analyses needed for membrane appraisal
5) Operation and maintenance of test equipment for RO membrane appraisal
6) Operation and maintenance of analytical equipment
7) Analytical technology needed for membrane appraisal

Methods and Results of Technology Transfer

1) Method and result of RO membrane performance appraisal

A) On the job training on the operation of performance appraisal tests was implemented using RO flat membranes and mini-membrane modules and performance tests reports and a manual were prepared.

B) Lectures relating to RO membrane appraisal technology were delivered and technology was transferred.

2) Operation and maintenance of the RO test plant

The RO test plant was equipped with the same RO membrane modules as an actual plant and on-job training in appraisal testing technology was given. In addition to

writing performance test reports, a manual was prepared.

3) General appraisal of RO membranes

On the job training was implemented through the operation of turbidity and chlorine tolerance testing, performance test reports were written and a manual was prepared.

4) Analyses needed for membrane appraisal

Concerning the fouling of hollow fiber and spiral wound RO membrane modules, on the job training was implemented in respect of the techniques of dismantling the modules and analyzing the membrane surface contaminants. In addition to writing reports, a manual was prepared.

5) Operation and maintenance of test equipment for RO membrane appraisal

Having been provided with the following three types of equipment for testing RO membrane performance at different scales from small bench scale to full scale plant membranes, the technology for using all of this equipment for comparing the performance of deteriorated membranes and new membranes has been transferred. The technology transfer was accomplished through on the job training, report writing and the preparation of manuals, etc.

(a) Small scale, flat membrane test equipment
(b) Medium scale, mini module type test equipment
(c) RO test plant for testing actual plant size RO module performance.

Fully equipped with test equipment for measuring the performance of membranes from laboratory scale to full plant scale, the technology for using these has been established through the results of joint research in the use of these facilities. Furthermore, they are now able to implement the technical investigation of the causes of membrane fouling, the selection of new membranes and research into pre-treatment methods, etc.

6) Operation and maintenance of analytical equipment

The following analytical equipment has been provided and the technology for its operation and maintenance has been established through teaching and the provision of manuals.

Electron probe micro-analyzer
ICP emission spectrometer system
Infrared spectrophotometer
X-ray analyzer
Ion chromatography

These instruments can be used for water quality analysis, membrane contaminant analysis, fouled membrane analysis, etc.

7) Analytical technology needed for membrane appraisal

Analytical equipment which has been selected and supplied as a result of investigating methods of analyzing the content of oil, trihalomethane, etc. in seawater, has been used for analyses. The results have been collated in a report and manuals have been provided.

Using the equipment and analytical technology, it has been possible to analyze traces of oil and tri-halomethanes in sea water.

3. Results

The objectives, procedures and rusults of evaluation of technology transfer are set out in detail in Table 1.

Table 1-1 Transfer of Technology for RO-1(1)

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
EVALUATION TECHNOLOGY FOR RO MEMBRANE WITH RO TEST PLANT	To improve the evaluation technology for RO membrane with RO test plant	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)OJT training was performed experiments and results of the joint experiments are shown in the following chapter: (7.1.2.A) to (7.1.2.E) 2)Operation manual of the flat membrane is prepared(7.1.1.A) by Mr. Jamaldin and finalized by JICA team trainer after checking. 3)Lecture on fouled membrane was made by Dr. Taniguchi on February 14, 1994. 4)Manuals prepared was evaluated and finalized by JICA member.
OPERATION AND MAINTENANCE ON RO TEST PLANT	To improve the technology the methods on operation and maintenance of RO test plant	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)Performance evaluation test operation of the Test Plant was conducted jointly 2)Report of the test operation is prepared by Mr. Fayaz and Mr. Jamaldin and finalized by JICA member. 3)Seminar was held at the Monday ordinary technical meeting. 4)Report prepared was evaluated and finalized by JICA member.
OVERALL EVALUATION TECHNOLOGY FOR MEMBRANE	To improve the overall evaluation technology for RO membrane	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)Comparison test operation was operated jointly in February 1994 and the results are reported in (7.1.3) by Mr. jamaldin 2)Turbidity and chlorine tolerance tests with flat membranes and mini-module were tested jointly and report is prepared by Mr. Jamaldin in (7.1.4) and (7.2.3) then finalized by JICA member after checking. 3)Report prepared was evaluated and finalized by JICA member.

Table 1–2 Transfer of Technology for RO–1(2)

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
ANALYTICAL METHODS NECESSARY FOR MEMBRANE EVALUATION	To improve the technology on the analytical methods evaluation	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)OJT training autopsy of the spiral wound type fouled membranes, and hollow fiber type were operated on 25 July 1994 by Mr. Hirai and on 2 November 1994 by Mr. Marui. 2)Reports were prepared by Dr. Faroque in the following appendix (7.1.2-5), (7.1.2-6), (7.1.7) 3)Lecture on autopsy of the fouled membrane was made by Dr. Taniguchi on 12 November 1994 4)Lecture on autopsy of hollow fiber type fouled membranes were made on 12 November 1994. 5)Report prepared was evaluated and finalized by JICA member.
EXPERIMENTAL EQUIPMENT FOR EVALUATION ON RO MEMBRANE	To improve the technique on operation and maintenance of experimental eqipment for evaluating RO membrane	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)Operation and maintenance technologies of flat membrane performance test, mini-module membrane performance test, RO test Plant performance test were studied conducting OJT operation and seminar which was held ordinary Monay technical meeting. 2)Operation procedures for the performance test methods of flat membrane were reported in(7.1.1.A) by Mr. Jamalddin. 3)Report of the test operation is prepared by Mr. Fayaz and Mr. Jamalddin and finalized by JICA member.

Table 1-3 Transfer of Technology for RO-1(3)

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
ANALYTICAL EQUIPMENT	To improve the operation technique of following analytical equipment: 1)EPMA 2)ICP 3)INFRARED SPECTROPHOTOMETER 4)X-RAY ANALYZER 5)ION-CHROMATOGRAPH 6)etc.	1)To make experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects	1)OJT training of operation and maintenance technolog was conducted in November1994, then operation manuals and maintenance manuals were prepared as follows: ・for Electron Probe Micro Analyzer to Mr. Mausha. Asrar, T. Prakash, John O'hara, Ismail Andijani, Mohd Ismail Noor Ahmed ・for ICP, Infrared spectrometer and Spectrophotometer to Mr. S. Sulami, A. G. Javeed, Radwan ・for X-ray Diffractometer to Mr. Andi Jani, A-Fozan, Shahreer ・for Ion Chromatograph to Mr. S. Sulami, Azhar Nomani Radwan Sulaiman
EVALUATION TECHNOLOGY FOR FOULED MEMBRANE	To improve the evaluation technology for fouled membrane	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE JOB TRAINING) ・Preparation of sample ・Observation of membrane surface ・Analysis of deposited substances on the surface of membrane 2)To prepare the report or manuals jointly ・Manuals for analytical methods of fouled membrane 3)To hold seminar on the related subjects ・Evaluation of fouled membrane	1)OJT training autopsy of the spiral wound type fouled membranes, and hollow fiber type were operated on 25 July 1994 by Mr. Hiral and on 2 November 1994 by Mr. Marui. 2)Reports were prepared by Dr. Faroque in the following appendix (7.1.2-5), (7.1.2-6), (7.1.7) 3)Lecture on autopsy of the fouled membrane was made by Dr. Taniguchi on 12 November 1994 4)Lecture on autopsy of hollow fiber type fouled membranes were made on 12 November 1994. 5)Report prepared was evaluated and finalized by JICA member.

Table 1-4 Transfer of Technology for RO-1(4)

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
EVALUATION TECHNOLOGY FOR RO MEMBRANE WITH FLAT MEMBRANE TESTER	To improve the operation technique on the flat membrane tester To elevate the evaluation technology with flat membrane tester	1)To conduct experiment jointly with JICA and SWCC researchers (ON-THE OJT TRAINING) ・Operation and maintenance technique of flat membrane tester 2)To prepare the report or manuals jointly ・Operation manual for flat membrane tester 3)To hold seminar on the related subjects The trainees will participate as speakers and the trainers will check their speech.	1)Comparison test operation was operated jointly in February 1994 and the results are reported in (7.1.3) by Mr.Jamalddin 2)Operation procedures for the performance test methods of flat membrane were reported in (7.1.1.A) by Mr.Jamalddin. 3)Seminar was held at the Monday ordinary technical meeting.
EVALUATION TECHNOLOGY FOR RO MEMBRANE WITH TOLERANCE TEST IN TURBIDITY, ESPECIALLY CHLORINE AND OIL	To improve the technology the methods of tolerance test for RO membrane	1)To conduct experiment jointly with the trainees (ON-THE JOB TRAINING) For ex. ・Kind of deteriorating substances ・Analytical methods 2)To prepare the report or manuals jointly 3)To hold seminar on the related subjects The trainees will participate as speakers and the trainers will check their speech.	1)Turbidity and chlorine tolerance tests with membrane were operated jointly and report is prepared by Mr.Jamalddin in (7.1.4) and finalized by JICA member 2)Turbidity and chlorine tolerance tests with mini-modul were operated jointly and finalized by JICA members and by Mr.Jamalddin in (7.2.3) and finalized by JICA member.
EVALUATION TECHNOLOGY ON RO MEMBRANE WITH RO MODULE TESTER	To improve the technology on the methods of RO module tester and related technique	1)To conduct experiment jointly with the trainees with the RO module tester. 2)To prepare the report or manuals jointly. 3)To hold seminar on the related subjects.	1)Performance evaluation test operation of the mini-module test was conducted jointly 2)Report of the test operation is prepared by Mr.Jamalddin and after checking by JICA member(7.2.2) 3)Seminar was held at the Monday ordinary technical meeting.

Table 1-5 Transfer of Technology for RO-1(5)

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
GENERAL RESEARCH ACTIVITY	To study how to perform research activity	To conduct research activity and acquire experience by OJT method	Trainees studied the following procedure how to conduct research activity: ①to cllect information(7.1.1) ②to study information obtained (7.1.1) ③to make research plan including equipment, budget, manpower, schedule and experimental method planning (at the ordinary technical meeting held every Monday) ④to prepare materials and equipment ⑤to conduct preparative experiment (7.1.2), (7.1.2) and (7.1.3) ⑥Perform experiment (7.2), (7.3) ⑦to analyse the obtained results and data ⑧to prepare reports and operation manuals