New Design Feed Channel Spacer in Spiral Wound Elements for Pretreatment Cost Reduction

Final Technical Report

by
Peter Eriksson
Desalination Systems, Inc.
Escondido, CA

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The objective of this work was to examine whether a new type of feed channel spacer, called a parallel spacer, in spiral wound elements would decrease the pretreatment requirement, when operating RO/NF elements on municipal wastewater. The new design feed channel spacer consisted of thicker longitudinal strands, which define the spacer thickness, and thinner cross strands (perpendicular to the thicker strands), which were not in contact with the membrane surface.

RO/NF elements with the parallel spacer and the standard diamond shape spacer operated on tertiary treated municipal wastewater for six months. The elements with the standard diamond shape spacer performed better than the elements with the parallel spacer. A nominal 5 μm melt blown cartridge filter stopped the particulate material which otherwise would have increased the pressure drop over the elements, but did not stop colloidal material which caused a rapid decline in water permeability of the elements. Alkaline cleaning removed brown deposits , but did not remove a thin transparent slimy layer from the membrane surface. This slimy layer was probably the cause of the rapid decline in membrane performance after cleaning. If this slimy layer can be prevented from forming, or if it can be removed by cleaning, the permeate flux of RO/NF elements, without membrane microfiltration as pretreatment, can most likely be maintained at 10 $l/(m^2 \cdot h)$ (6 gfd) and possibly at 15 $l/(m^2 \cdot h)$ (9 gfd).

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Mission Statements

U.S. Department of the Interior

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Bureau Point of Contact

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Glossary

BOD	biological oxygen demand
Conductivity permeability	defined in Eq.(5) on page 10
gfd	US gallons per square foot and day
gpm	US gallons per minute
kgal	1000 US gallons
net driving pressure	the difference between the feed and the permeate side in hydraulic pressure minus the osmotic pressure
NF	nanofiltration
NTU	nephelometric turbidity unit
Permeate flux	permeate flow rate divided with the active membrane area
Permeate recovery	the permeate flow rate divided with the feed flow rate
Polarization modulus	the ratio (solute concentration at the membrane surface on the feed side)/(solute concentration in the bulk solution)
RO	reverse osmosis
SDI	Silt Density Index
TDS	total dissolved solids
Water permeability	the permeate flow rate per unit membrane area and net driving pressure

1. Executive Summary

Reverse osmosis (RO) and nanofiltration (NF) are presently used in a few places to purify tertiary treated municipal wastewater, and the interest for this application is growing. Spiral wound membrane elements are presently used. These elements with the standard diamond shape feed channel spacer are rather susceptible to plugging and fouling, so extensive pretreatment is required to get good membrane performance. Presently, membrane microfiltration seems to be the most cost effective method of pretreatment. The objective of this work was to examine whether a new type of feed channel spacer in spiral wound elements would decrease the pretreatment requirement. The new design feed channel spacer consisted of thicker longitudinal strands, which define the spacer thickness, and thinner cross strands (perpendicular to the thicker strands), which were not in contact with the membrane surface. This spacer is called the parallel spacer.

Two membrane units had each four spiral wound membrane elements in series. One of the membrane units had membrane elements with the standard diamond shape feed channel spacer, and the other membrane unit had membrane elements with the parallel spacer. These two membrane units operated on tertiary treated municipal wastewater for two periods of three months each, with different nominal rated (5-100 μm) cartridge prefilters. Low pressure polyamide RO membranes were used for the first three months, and polyamide NF membranes for the last three months. The permeate flux was varied between 10 and 20 l/(m^2·h) (6 and 12 gfd).

The membrane elements with the standard diamond shape spacer performed better than the elements with the new parallel spacer. The spacer design seemed not to affect the accumulation of colloidal material on the membrane surface. Alkaline cleaning easily removed brown deposits from the membrane surface, but did not remove a thin slimy layer. In order to be cost competitive when operating an RO/NF unit without membrane microfiltration as pretreatment, the minimum requirements are

(1) A cleaning method must be developed which removes the slimy layer from the membrane surface.

(2) For prefiltration, a nominal 30-100 μm screen should be used, which has either automatic backwash or other types of automatic solids removal.

(3) The RO/NF unit must be able to operate at 15 l/(m^2·h) (9 gfd) permeate flux, with only a minor decrease in the water permeability between the cleanings. Cleaning frequency should not exceed once every three weeks.

2. Introduction

Reverse Osmosis (RO) and Nanofiltration (NF) are membrane separation processes, which are used extensively for treatment of surface water and groundwater to be used for drinking water and industrial process water. For these applications, predominantly spiral wound membrane elements with a 0.71 mm (0.028") thick diamond shape feed channel spacer are used. Figure 1, skewed view portrays a diamond shaped spacer.

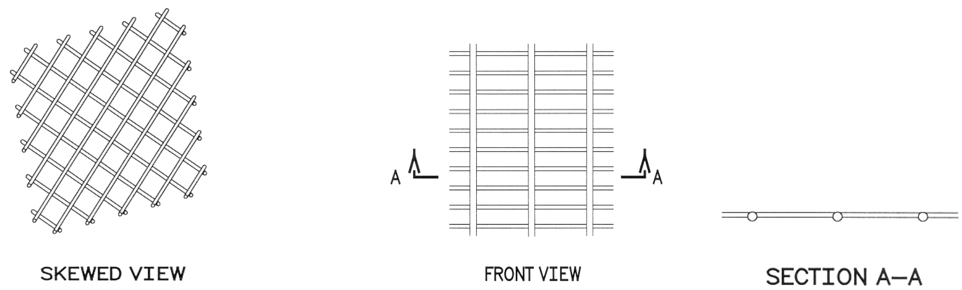


Figure 1.—Schematic of a diamond shape spacer and a parallel spacer.

The diamond shape spacer has two planes of strands, one on the top of the other. The strands are in parallel within each plane, and form an angle with the strands in the other plane. The parallel spacer has thick longitudinal strands, and thin strands in the cross direction. The thin strands do not touch the membrane surface, but they are connected off-centered to the thick strands (see side view). The strands are in contact with, or very close to, the membrane surface. Particulate materials which enter the spiral wound element typically accumulate where the strands are in close contact with the membrane surface. Deposits are typically seen on both sides of the strand, the upstream side and the downstream side (leeward side). The fluid dynamics are such that a wake is formed on the downstream side of the strand, so there is no force to remove solids which have deposited there.

The deposition of solids on the membrane surface degrades its performance. Essentially all particulate materials has to be removed from the water stream before entering the spiral wound element, to maintain a good membrane performance. This can be done in a fairly inexpensive way in most cases where the feed is groundwater or surface water with a low concentration of suspended solids. However, for many wastewaters, it becomes rather expensive to remove the particulate materials, which otherwise would cause fouling problems in spiral wound elements with diamond shape feed channel spacers. The total cost of membrane filtration and the required pretreatment might be less with another design of the feed channel spacer, which would allow for the particulate materials to easily pass from the feed end to the concentrate end of the spiral wound element.

Intuitively, a feed channel spacer as depicted in the front view of Figure 1, would allow easier passage of particulate materials. The strands which are in contact with the membrane are oriented in the flow direction, and the cross strands are thin enough to allow particles smaller than 0.15 mm (0.06 inch) to pass through on either side. The disadvantage with this type of spacer, compared to the standard diamond shape spacer, is that it promotes less mixing , which results in a higher degree of concentration polarization, and consequently a higher passage of small solutes through the membrane. However, this would only be of concern in the few wastewater applications where very low TDS (total dissolved solids) in permeate is required.

The objective with this project was to examine whether it would be cost effective to use spiral wound membrane elements with the parallel feed channel spacer as shown in Figure 1b, instead of the standard diamond shape spacer, when operating on tertiary treated municipal wastewater. The City of San Diego had already operated spiral wound RO elements with the standard diamond shape spacer on this type of water, using membrane microfiltration as pretreatment. The performance of the RO elements was stable for half a year with no need for RO membrane cleaning. The total cost for operation with membrane elements with the parallel spacer and required pretreatment was to be compared with the cost for operation with membrane elements with the standard diamond shape spacer and membrane microfiltration as pretreatment.

3. Conclusions and Recommendations

- Membrane elements with the standard diamond shape spacer gave a better performance than elements with the parallel spacer when operating on the tertiary treated municipal wastewater. The relatively poor performance of the parallel spacer was probably caused by uneven feed side flow distribution within the elements. Even if the flow distribution problem had been eliminated, these elements would not have performed better than the elements with the standard diamond shape spacer. The reason for this was that the colloidal material which fouled the membrane did easily exit the membrane element as long it was not attached to the membrane surface. Neither of the tested feed channel spacers seemed to be responsible to the accumulation of foulants in the elements.

- A nominal 5 μm melt blown cartridge prefilter prevented an increase in the pressure drop over the membrane elements. It did not, however, prevent the membrane elements from being fouled by small colloidal particles, which caused a decline in the water permeability.

- With a nominal 100 μm wound filter for prefiltration, a permeate flux of 10 $l/(m^2 \cdot h)$ (6 gfd) could be maintained fairly well, and 15 $l/(m^2 \cdot h)$ might be possible to maintain. Even with a 5 μm melt blown cartridge for prefiltration, a permeate flux of 20 $l/(m^2 \cdot h)$ caused a rapid decline in water permeability of the membrane elements.

- Alkaline (pH 11) cleaning with a surfactant at 35-40°C did easily remove the brown deposits from the membrane elements. It did not, however, remove a thin slimy layer on the membrane. This layer probably caused the rapid fouling rate upon subsequent operation on the wastewater.

- Shutting down the membrane unit for 10 minutes twice daily helped in removing the brown deposits from the membrane, and helped stabilize the performance of the membrane elements.

- In order to be cost competitive when operating an RO/NF unit without membrane microfiltration as pretreatment, the minimum requirements are

  (1) A cleaning method must be developed which removes the slimy layer from the membrane surface.

  (2) For prefiltration, a nominal 30-100 μm screen should be used, which has either automatic backwash or other types of automatic solids removal.

  (3) The RO/NF unit must be able to operate at 15 $l/(m^2 \cdot h)$ (9 gfd) permeate flux, with only a minor decrease in the water permeability between the cleanings. Cleaning frequency should not exceed once every three weeks.

4. Test Site and Feed Water

The test site was the Aqua 2000 Research Center, owned by the City of San Diego, California. The feed water was tertiary treated domestic wastewater from the Rancho Bernardo area. The tertiary treatment consisted of the following steps.

1. Mechanical bar screen and grit remover

2. Hycor Rotostrainer rotary drum screen with 6 mm (0.25 inch) openings

3. Hycor Discostrainer rotary disk filters with 250 μm openings

4. Water Hyacinth ponds

5. Coagulation with $FeCl_3$ addition followed by a plate settler

6. Single media filter with anthracite, size 1.4-1.5 mm, and 1.9 m/h (0.8 gal./(minute·ft^2)) fluid flow rate

7. Sodium hypochlorite addition to form 1-3 mg/l chloramines

The turbidity of the tertiary treated wastewater was measured continuously after the media filter, and the ferric chloride dosing in the coagulation step was controlled to give a turbidity of 2 NTU. If the turbidity after the media filter decreased below 2, the ferric chloride dose rate decreased and vice versa. The chloramine concentration in the feed water entering the membrane units was also measured continuously.

The tertiary treated wastewater was also used in other membrane tests at the Aqua 2000 Research Center. The turbidity set point was 2.0 NTU, which could be maintained all year around, to minimize the variation in the fouling tendency of the tertiary treated wastewater. The high turbidity set point was advantageous in speeding up membrane fouling. Table 1 shows other constituents in the wastewater, which were measured.

Table 1.—Typical Wastewater Pretreatment Data

	After Hyacinth pond	After media filter
BOD, mg/l	10	
Suspended solids, mg/l	10-15	
Total dissolved solids, mg/l	1100-1150	
Silt Density Index		Too high to be measurable
Osmotic pressure		67 kPa (10 psi)
pH		7.1-7.6
Ammonia		average 2.7 mg/l as Nitrogen
Nitrate		average 3.9 mg/l as Nitrogen
Absorbance at 254 nm		average 0.19

The osmotic pressure of the feed solution was estimated by plotting the permeate flow rate versus the average pressure on the feed side of the AK membrane elements, when operating on the wastewater. The result is shown in Figure 2. The average feed/concentrate conductivity at 25°C was 1780 uS/cm. The conductivity rejection was 98%.

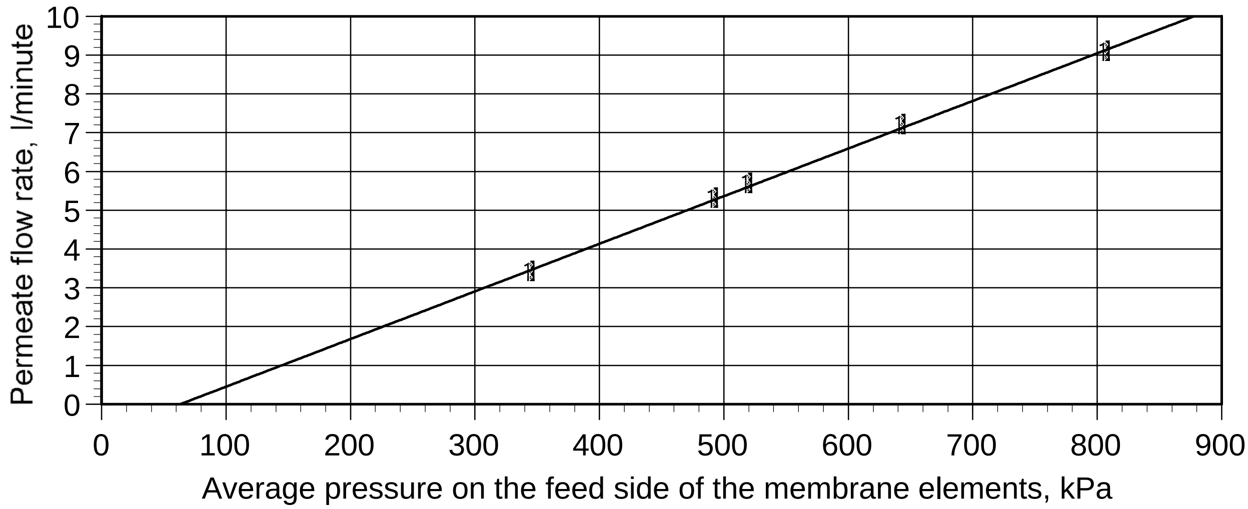


Figure 2.—The permeate flow rate versus pressure, when operating the membrane unit with AK4040 elements with the diamond shape feed channel spacer on the wastewater at 17°C.

5. Test Units and Spiral Wound Elements

For testing the spiral wound elements, two identical Osmonics RO, E4-7200-DLX, 460, 6, 50-75 units were used. They were modified by adding a throttling valve after the high pressure pump, and disconnecting the concentrate recirculation. The flow diagram of the test units is shown in Figure 3. The same Goulds NPE 1st 1F5 C4 centrifugal pump fed both test units. The valves were manually adjusted regulating valves.

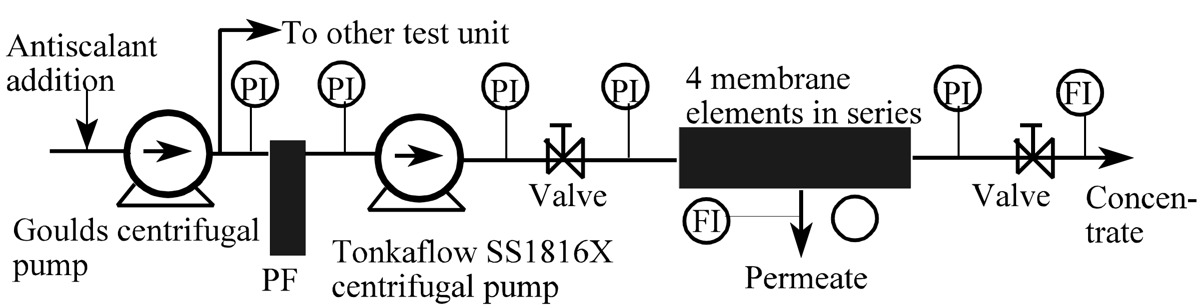


Figure 3.—Flow schematic of one of the two identical test units.

The temperature of the feed solution was measured before the Goulds centrifugal pump. About two times a day, feed and permeate samples from the membrane units were within 5 minutes of sampling brought into the laboratory for measurement of temperature, conductivity and pH.

At the beginning of the test series, the flow meters, the pressure gages just before and after the membrane element housings, and the temperature gage were checked for calibration. The result from this is shown in Appendix A.

In each test unit, there were four element housings in series, each with one membrane element with nominal size 0.1 m (4") diameter and 1 m (40") long. The feed channel spacer was a standard diamond shape one (see Figure 1a) for the membrane elements in one of the test units, and a parallel one (see Figure 1b) for the membrane elements in the other test unit. Table 2 gives some of the dimensions of the two feed channel spacers. The open space between the off-centered cross strands and the membrane surface for the parallel spacer was difficult to measure, but was estimated to be about 0.15 mm (0.006 inch) on one side and 0.43 mm (0.017 inch) on the other side of the spacer.

Table 2.—Approximate Dimensions, Two Feed Channel Spacers

Spacer thick-ness, mm		Angle between crossing strands		Strand thickness, mm			Center to center distance between parallel strands, mm		
D	P	D	P	D	P,long	P,cross	D	P,long	P,cross
0.71	0.89	85-95	90	0.36	0.89	0.25	2.9	6.6	2.0

D and P refer to the diamond shape and parallel feed channel spacer respectively. P,long and P,cross refer to the longitudinal and crossing strands respectively (seen from the perspective of the feed flow direction) of the parallel feed channel spacer. Two types of membranes were used, the AK and the DK membranes. Both of these are composite membranes with a polyamide barrier layer. The polyamide composition is different in the two membranes. The AK membrane is an RO membrane in the Desal-11 family, with a relatively high water permeability. Its sodium chloride rejection at normal operating conditions is better than 96 percent. The DK membrane is an NF membrane in the Desal-5 family. At normal operating conditions, it has above 98 percent rejection of sulfates and organics with molecular weight above 200 Dalton, and below 50 percent rejection of chlorides. The active membrane areas in the different type membrane elements are shown in Table 3.

Table 3.—Active Membrane Areas in the Membrane Elements

Element	AK4040		DK4040	
Type feed channel spacer	Diamond	Parallel	Diamond	Parallel
Active membrane area, m^2 (ft^2)	8.2 (88)	7.4 (80)	7.8 (84)	7.3 (78)

Two types of cartridge filters were used, Hytrex® melt blown filters with nominal rating 5, 10, 20 and 75 micron, and Filter-Cor WPX100R20P wound filters with nominal rating 100 micron. They were 64 (2.5 inch) mm in diameter and 0.5 m (20 inch) long.

Antiscalant was added all the time except for the first three days of operation. The antiscalant was Hypersperse AF 200 UL from Argo Scientific. The antiscalant concentration in the feed solution varied in the range 3-7 mg/l.

6. Performance Parameters of the Membrane Elements

The performances of the membrane elements during operation were monitored by calculating their water and conductivity permeabilities, and the feed side pressure drop over the four elements in series. The permeabilities were normalized for temperature, and the pressure drop was normalized for temperature and feed side flow rate. The average water and conductivity permeabilities over the four elements in the membrane unit were monitored, and not the permeabilities for the individual elements.

The measured pressure drop was that between the entrance port of the upstream element housing and the exit port of the downstream element housing. To get the pressure drop over the elements, the pressure drop over the plumbing and the entrance and exit ports of the four element housings must be deducted from the total pressure drop. However, in this study, the absolute value of the pressure drop over the elements was not important, but its change in time was important. In such a case, it is satisfactory to measure the total pressure drop over the four element housings. An increase in that normalized pressure drop indicates fouling of the membrane elements.

6.1 Calculation of the Water Permeability

The water permeability was calculated according to Eq.(1).

$$A(T_{ref}) = \frac{J_w}{TCFA \cdot (\Delta P - \pi_{fbav} + \pi_p)} \qquad (1)$$

where

$A(T_{ref})$ is the water permeability at temperature T_{ref}, m/(s·MPa)

J_w is the permeate flux, m/s or l/(m^2·h) or gfd

TCFA is the temperature correction factor for the water permeability

ΔP is the average hydraulic pressure difference between the feed and permeate sides of the membrane

π is the osmotic pressure

the subscripts fbav and p denote the average of the feed and concentrate values, and the permeate respectively.

ΔP was assumed to be the arithmetic average of the gage pressures upstream (P_{in}) and downstream (P_{out}) of the elements. The pressure drop in the permeate tubing should have been low and was neglected.

The permeate flux was the permeate flow rate divided with the active membrane area, which is listed in Table 3.

Eq.(2) was used to calculate the temperature correction factor.

$$\mathrm{TCFA} = e^{3070\cdot\left(\frac{1}{273.15 + T_{ref}} - \frac{1}{273.15 + T}\right)} \tag{2}$$

where

T is the actual temperature, and T and T_{ref} are expressed in °C.

As shown in Figure 2, the osmotic pressure of the wastewater solution with 1780 μS/cm conductivity at 25°C was estimated to 67 kPa (10 psi). The osmotic pressure of both the wastewater and the permeate was then assumed to follow Eq.(3).

$$\pi = \frac{67\cdot\kappa}{1780} \tag{3}$$

where

κ is the conductivity at 25°C in μS/cm, and π has the unit kPa.

The osmotic pressure is approximately proportional to the absolute temperature. In this study, the temperature varied between 14 and 29°C. For a solution, the osmotic pressure would increase about 5 percent for a temperature increase from 14 to 29°C. In this study, this is an increase of less than 4 kPa (1 psi), which can be neglected. The osmotic pressure was assumed to be independent of the temperature.

The conductivity of the feed and permeate solutions were measured. The concentrate conductivity was calculated from a conductivity balance according to Eq.(4).

$$\kappa_c = \frac{\kappa_f \cdot F_f - \kappa_p \cdot F_p}{F_c} \tag{4}$$

where

F is the flow rates, m^3/s or gpm

subscripts f and c refer to the feed and concentrate streams respectively

The conductivities are not linear with the solute concentrations, so Eq.(4) is not quite correct, but is good enough for the purposes of this study.

As Eq.(1) is defined, the water permeability of the element is a function of the water permeabilities of membrane and the fouling layer and also of the polarization modulus.

6.2 Calculation of the Conductivity Permeability

The conductivity permeability was calculated according to Eq.(5).

$$B(T_{ref}) = \frac{J_w \cdot \kappa_p}{TCFB \cdot (\kappa_{fbav} - \kappa_p)} \tag{5}$$

where

$B(T_{ref})$ is the conductivity permeability at temperature T_{ref} , m/s or cm/s

J_w is the permeate flux, m/s or $l/(m^2 \cdot h)$ or gfd

κ is the conductivity of the solution at 25°C, µS/cm

TCFB is the temperature correction factor for the solute permeability

The conductivity rejection, R, is defined in Eq.(6)

$$\mathbf{R = 1 - \kappa_p/\kappa_{fbav}} \qquad \mathbf{(6)}$$

The temperature correction factor for the conductivity permeability, TCFB, was assumed to be the same as that one for the water permeability, TCFA.

6.3 Calculation of the Normalized Pressure Drop

The pressure drop in a channel with a given geometry can be expressed according to Eq.(7).

$$P_{in} - P_{out} = \frac{4 \cdot L}{d_h} \cdot f \cdot \frac{1}{2} \cdot \rho \cdot v^2 \qquad (7)$$

where

P_{in} - P_{out} is the pressure drop over the channel, Pa or psi
L is the length of the channel, m or ft
d_h is a characteristic length of the channel, m or ft
f is the fanning friction factor
ρ is the density of the solution, kg/m^3
v is the velocity of the fluid in the channel, m/s or ft/s

The fanning friction factor is a function of the channel geometry and the Reynolds number, Re.

$$Re = \frac{d_h \cdot v \cdot \rho}{\mu} \qquad (8)$$

where

μ is the absolute viscosity of the solution, kg/(m·s)

For membrane elements with either of the two tested feed channel spacers, the pressure drop over the elements is approximately proportional to the feed/concentrate average flow rate to power 1.5. Eqs.(7) and (8) then imply that the fanning friction factor is proportional to the Reynolds number to the power -0.5. The pressure drop over the elements then becomes proportional to the square root of booth the viscosity and density of the solution. In the temperature interval of this study, 14-29°C, the density changes were small enough to be neglected. The pressure drop over the elements needs then only to be normalized with respect to the feed/concentrate average flow rate and its viscosity. The viscosity of the solution was assumed to be the same as for pure water, which was taken from page 3-201 of Perry (1963).

$$\mu_{w,20} = 1.005 \cdot 10^{-3}\ kg/(m \cdot s)$$

$$\mu_{w,T}/\mu_{w,20} = 99.5/[2.1482 \cdot \{(T-8.435)+(8078.4+(T-8.435)^2)^{0.5}\} -120] \qquad (9)$$

where

$\mu_{w,20}$ is the water viscosity at 20°C
$\mu_{w,T}$ is the water viscosity at T°C

The normalized pressure drop over the elements was calculated from Eq.(10).

$$(P_{in} - P_{out})_{norm} = (P_{in} - P_{out}) \cdot \left(\frac{F_{fbref}}{F_{fbav}}\right)^{1.5} \cdot \left(\frac{\mu_{T_{ref}}}{\mu_T}\right)^{0.5} \qquad (10)$$

where

$(P_{in} - P_{out})_{norm}$ is the pressure drop normalized to temperature and flow rate
$P_{in} - P_{out}$ is the measured pressure drop
F_{fbref} is a reference average feed/concentrate flow rate
F_{fbav} is the measured average feed/concentrate flow rate
μ_{Tref} is the water viscosity at a reference temperature
μ_T is the water viscosity at the measured temperature

To be accurate, only the pressure drop over the elements should be included in Eq.(10). In this work, however, the measured pressure drop also included pressure drops at entry ports and exit ports of element housings, and the tubing there between. The error in doing so was small enough, to easily see when the pressure drop over the elements increased because of fouling of the membrane elements.

7. Backwashable Cartridge Filters

According to the test plan, a backwashable cartridge filter should also had been tried as a prefilter to the membrane unit. This backwashable cartridge filter was tested on the actual tertiary treated wastewater before the membrane units were in operation. It did not perform well. The operating time between backwashes was only 4-6 hours. Cleaning chemicals were required in the backwash solution to partially restore the performance of the cartridge filter elements. The filtrate had a high Silt Density Index, above 5. The manufacturer took back the backwashable cartridge filter unit before the membrane units were put into operation.

8. Test Procedure and Results

The membrane units operated first with the AK (RO) elements for three months, followed by the DK (NF) elements for three months. During the initial three months with the AK elements, different types and nominal micron rating cartridge filters were used for prefiltration. During the last three months, only the most open of the tested cartridge filters, nominal 100 μm wound filter, was used. A cartridge filter was replaced when the pressure drop over it exceeded about 100 kPa (15 psi).

The membrane fouling rate is highly dependent on the permeate flux, which has been documented by among others Bergman (1985) and Chellam et al. (1997). At the Aqua 2000 Research Center, RO and NF spiral wound membrane elements had operated on the same feed water as used in this study, with membrane microfiltration as pretreatment. A permeate flux of 20 $l/(m^2 \cdot h)$ (12 gfd) gave stable performance for over half a year. For this reason, 20 $l/(m^2 \cdot h)$ was chosen as the initial permeate flux in this study.

The feed flow rate was also varied throughout the study. The permeate recovery for a membrane unit is defined as the permeate flow rate divided with the feed flow rate.

The membrane elements were cleaned periodically. The cleaning cycle consisted of

- Flush the membrane unit with 0.2 m^3 (50 gallons) potable water
- Recirculate the cleaning solution for about half an hour at 30-35°C for the acid cleaning, and at 35-40°C for the alkaline cleaning
- Flush the membrane unit with 0.2 m^3 potable water

The cleaning solutions were made up with RO permeate and cleaning chemicals. For acid cleanings, the cleaning chemical was 0.6 wt% citric acid to get pH in the range 2-3. For alkaline cleaning, the cleaning chemicals were 0.3 wt% sodium hydroxide, 0.06 wt% sodium dodecyl sulfate, and citric acid to get pH in the range 10.5-11.5.

The figures which show the performances of the membrane elements have the operating time for the abscissa. The operating time includes stops lasting for less than 6 hours, for example stops for cleaning, but does not include a few stops which lasted for longer times. The chosen reference temperature was 20°C, because that was close to the average operating pressure during the first three months.

Most of the time, pressures, flow rates and temperature were recorded 2-4 times a day, while the conductivities were recorded half as often. For most of the cases where conductivity data were missing, the conductivities were assumed to be the arithmetic average of the closest before and after recorded values. In a few other cases, e.g. for the first reading after a cleaning or when two readings were close together in time, the conductivities were assumed to be the same as at the closest in time recorded values.

Before each reading, if required, the two regulating valves in each membrane unit were adjusted to make the units operate with the desired permeate and concentrate flow rates. The permeate flux and permeate recovery could be slightly off these values for some time between the readings.

8.1 Performance of the AK Membrane Elements

Figure 4 shows the temperature, turbidity and chloramine concentration in the feed water to the membrane units when operating with the AK membrane elements. The time in operation refers to the membrane unit with the parallel spacer. The time scale can be up to three days off for the other membrane unit.

Figure 5 shows the water permeability of the elements during the 90 days of operation. Antiscalant was added all the time except for the first three days of operation. The membrane elements had originally, when tested on a NaCl solution, a water permeability at 20°C of about $15 \cdot 10^{-6}$ m/(s·MPa). Cleaning consisted of both acid and alkaline cleaning in every case. During the first three days, the permeate flux was 20-22 l/($m^2 \cdot h$) (12-13 gfd), the permeate recovery was 42 percent, and nominal 75 µm prefilters were used. The water permeabilities at 20°C decreased rapidly from above $10 \cdot 10^{-6}$ to below $4 \cdot 10^{-6}$ m/(s·MPa). The performance loss could have been from colloidal fouling and/or from calcium carbonate precipitation, because no antiscalant was added during these initial three days. Acid and alkaline cleaning restored some of the lost water permeability. The test continued with 20-22 l/($m^2 \cdot h$) permeate flux, but this time with antiscalant addition and nominal 5 µm prefilters. The loss in water permeability was still drastic. This must have been caused by colloidal fouling, because no inorganics should have precipitated during these conditions.

After a second cleaning, the permeate flux was lowered to 10 l/($m^2 \cdot h$) and the permeate recovery was lowered to 27 percent, and that made the water permeabilities to stay fairly stable. The elements with the diamond shape spacer had a stable water permeability at 20°C of 7 l/($m^2 \cdot h$) for 46 days, at which time the prefilter was removed. This caused the water permeability to decline. Cleanings restored the water permeability at 20°C to 8 l/($m^2 \cdot h$), but it dropped down to 6 l/($m^2 \cdot h$) in a weeks time. There was no big difference in water permeability decline whether the permeate flux was 10 or 16 l/($m^2 \cdot h$).

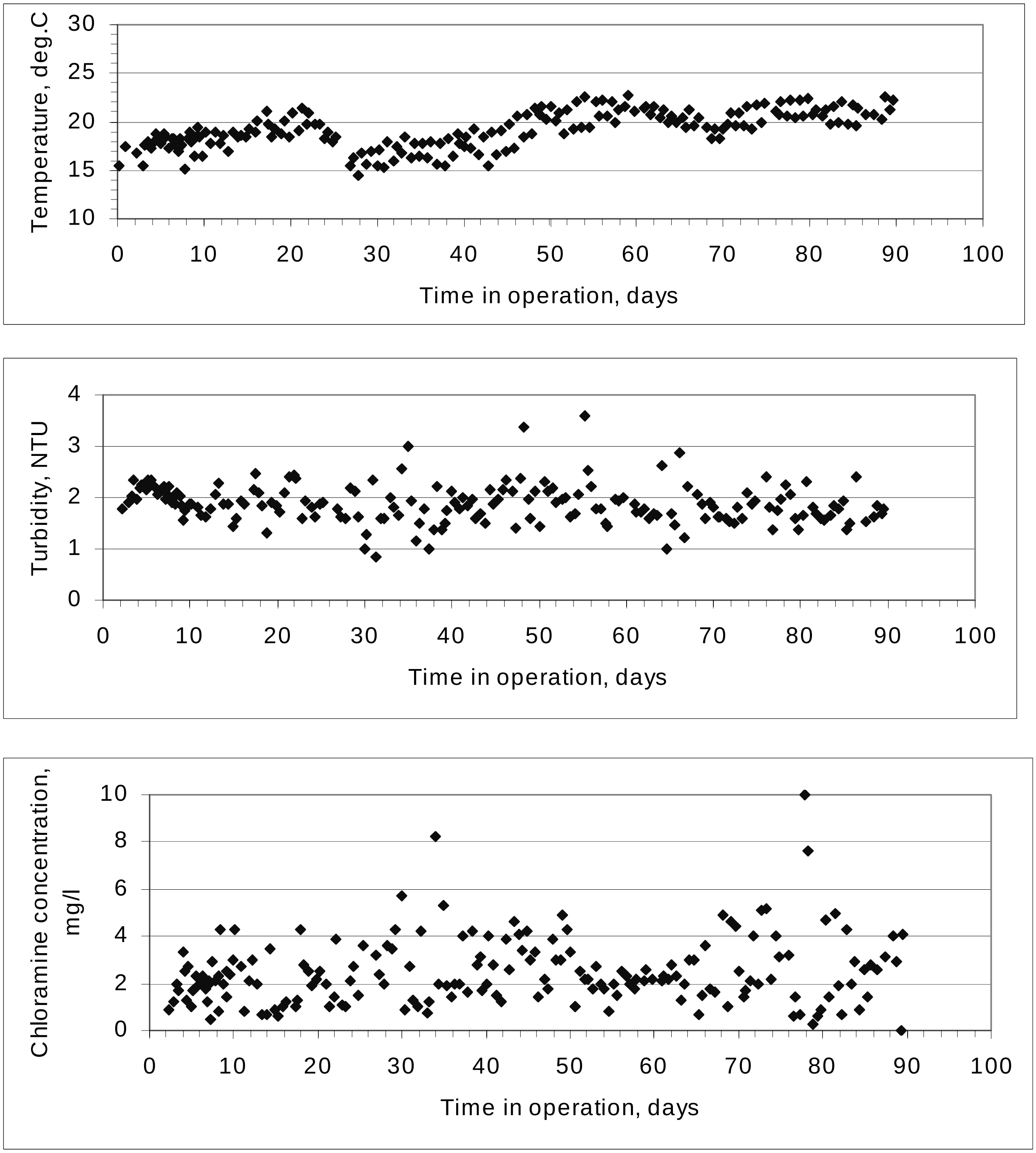
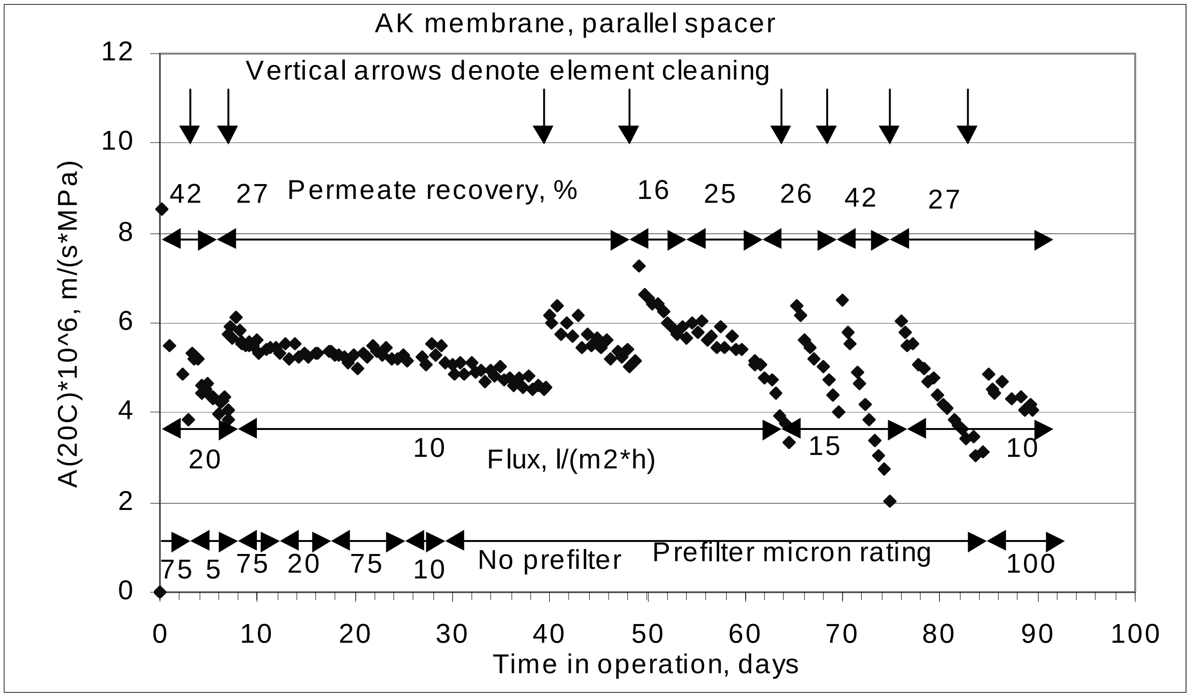


Figure 4.—Temperature, turbidity and chloramine concentration in the feed water to the membrane units when operating with the AK membrane elements.



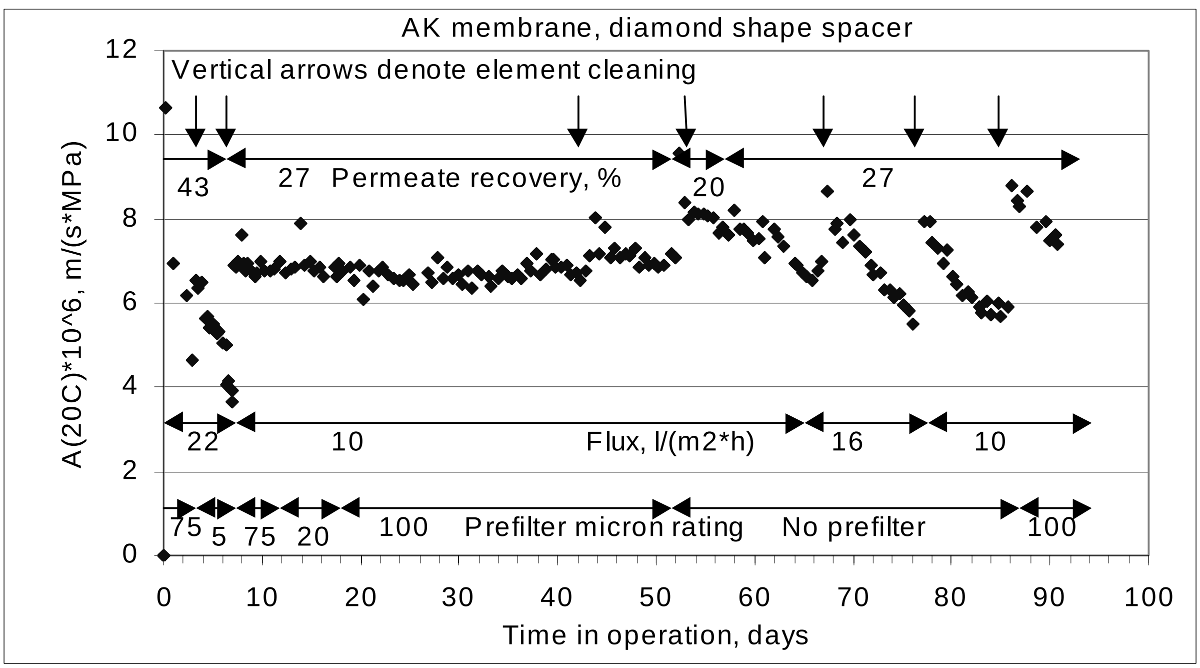


Figure 5.—Water permeabilities corrected to 20°C (A(20C) of the AK elements when operating on the wasterwater.

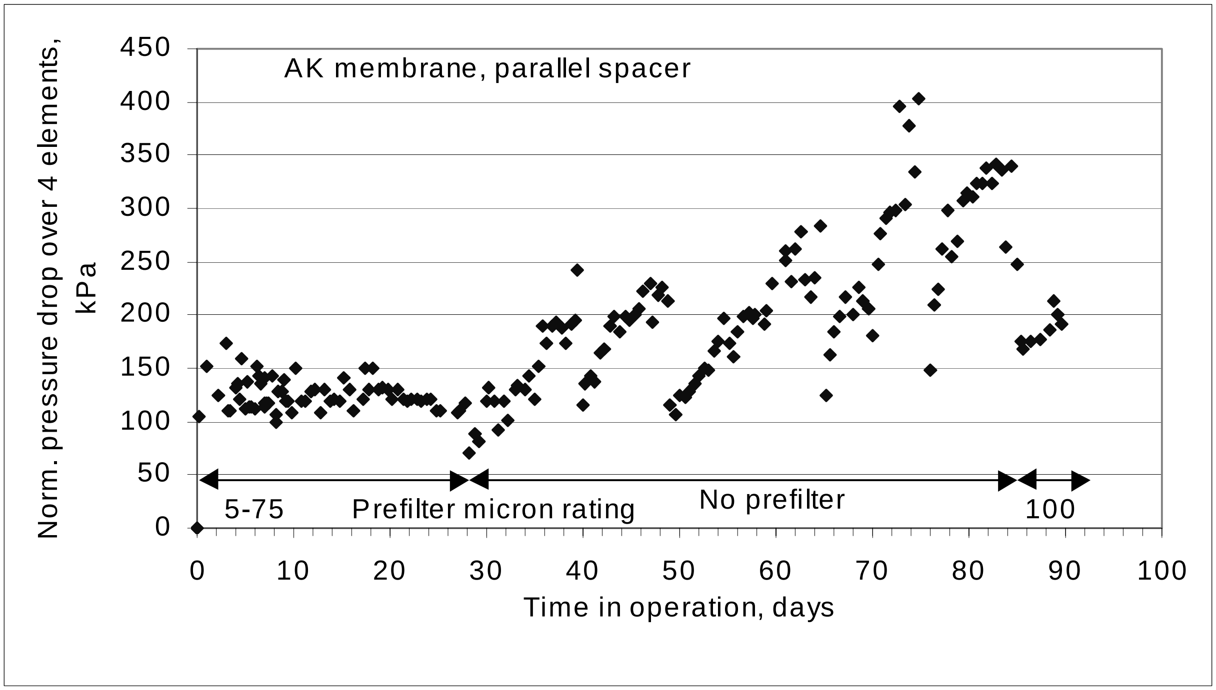
The membrane elements with the parallel spacer experienced a decrease in the water permeability at 20°C from $6 \cdot 10^{-6}$ to $5 \cdot 10^{-6}$ m/(s·MPa) during 23 days of operation with prefilters, compared to stable performance at a higher water permeability for the membrane elements with the diamond shape spacer. Thus, elements with the parallel spacer seemed to be more fouling sensitive than elements with the standard diamond shape spacer. The prefilter was removed to see if the membrane elements could operate satisfactorily without it. The decline in water permeability worsened with time. For the first 20 days without prefilter, this decline rate might have been acceptable, but it was not acceptable after that.

The membrane elements with the diamond shape spacer performed better those with the parallel spacer also when there was no prefilter installed.

At the end of the test with the AK elements, the prefilters were reinstalled, but that did not stop the decline in the water permeabilities with operating time. It seemed that the cleanings did not restore the membrane elements completely. Even though the cleanings restored the water permeability to the same level as the previous cleaning, the rate in performance loss between cleanings increased all the time at constant permeate flux and degree of prefiltration.

The normalized pressure drops over the four membrane elements are shown in Figure 6. The cleaning frequency is as shown in Figure 5. As long as melt blown Hytrex prefilters with nominal rating 5, 10, 20 or 75 μm were used, the normalized pressure drop was stable. However, these filters had to be replaced about every 5 days, during which they treated about 100 m^3 (30 kgal) of feed water. A nominal 100 μm wound prefilter treated the feed water to the unit with the diamond shape spacer for 34 days without replacement. This caused more material to accumulate inside the elements, which is evident from the rise in the pressure drop. However, it did not affect the water permeability of the elements, which is shown in Figure 5, and cleaning seemed to restore the elements completely.

The conductivity permeabilities normalized to 20°C are shown in Figure 7. The conductivity rejection varied in the range 93-99 percent. Again, the permeate flux, permeate recovery, and prefilter and cleaning frequencies are as shown in Figure 5. They were initially 0.1 μm/s, and decreased with operating time to reach 0.05 μm/s after 30 days. Later, the conductivity permeabilities increased, which coincided with the increase in the pressure drop over the elements. Most likely, the accumulation of particulate material in the membrane elements, hindered the back diffusion of rejected dissolved solids from the membrane surface. This caused an increase in the solute concentration at the membrane surface, which in turn increased the solute passage through the membrane. The conductivity permeability at 20°C increased up to 0.18 μm/s for the membrane elements with the parallel spacer, but cleaning of the membrane elements restored it back to 0.07 μm/s.



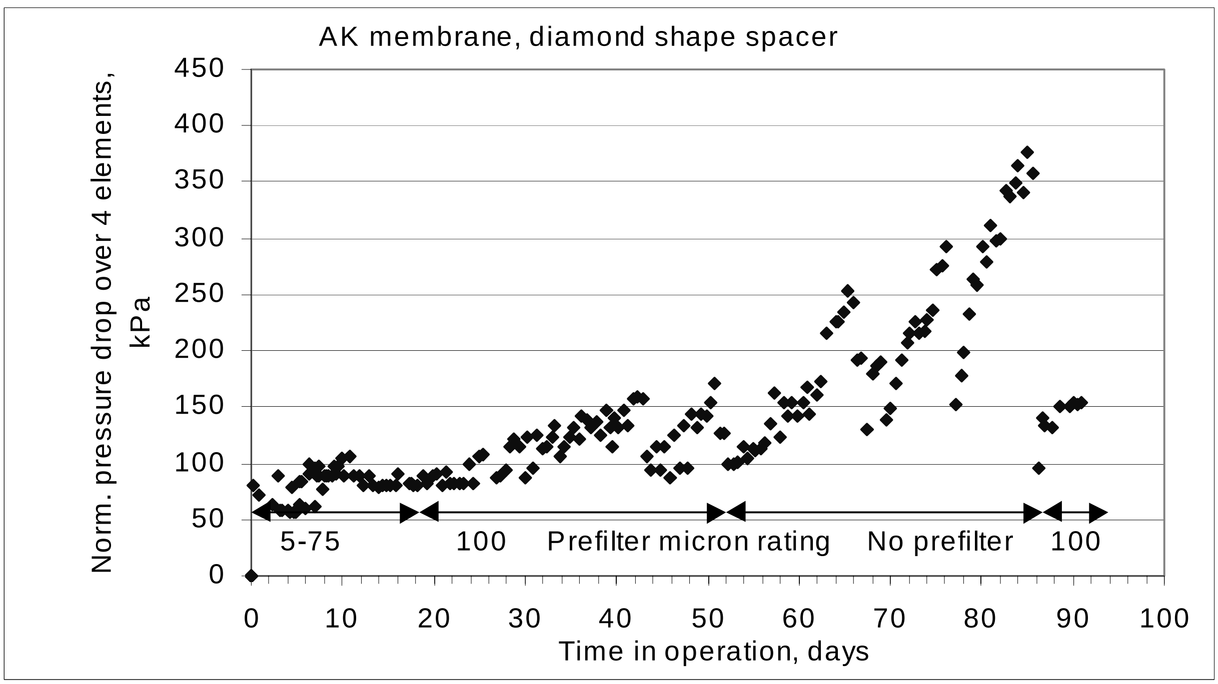
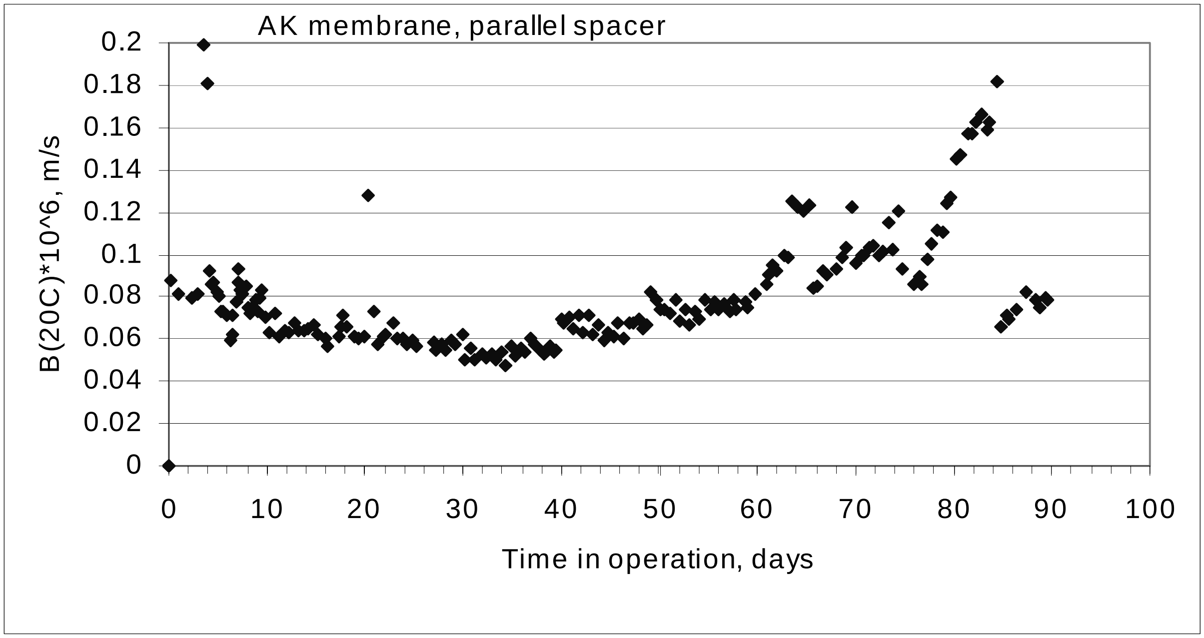


Figure 6.—Pressure drop over the four AK elements, normalized to 20°C and 1.3 m^3/h (5.7 gpm) average feed/concentrate flow rate.



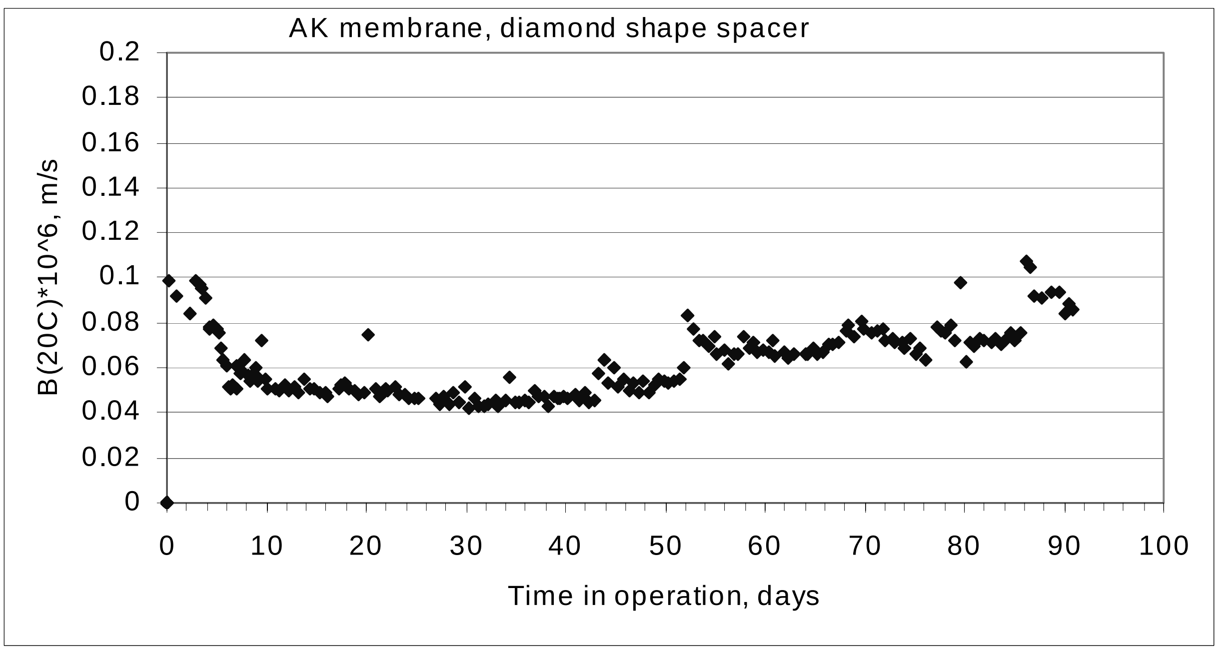


Figure 7.—Conductivity permeabilities corrected to 20°C (B(20C) of the AK elements when operating on the wastewater.

After a final cleaning, the membrane units operated for 5 days before they were shut down for removal of the elements. The two leading membrane elements and the next to the leading element with the parallel spacer were opened up for inspection. The first 0.2 m (8 inches) of membrane of both the leading elements were heavily covered by a brown slimy substance. The remaining 0.8 m length of the membrane and the membrane of the next to the leading element were only lightly covered by the same brown substance. The brown slimy substance was easily removed by gently wiping with the finger. It was evident that the brown substance first covered all the membrane lightly, and that the heavy cover was slowly spreading downstream from the upstream end of the upstream element. The brown substance was especially prevalent where the longitudinal strands were in contact with the membrane.

Six membrane samples were cut out from the most heavily fouled part of the leading element with the diamond shape spacer. Two samples were held under faucet with 45°C water coming out, which removed the foulants. Two membrane samples soaked in 0.1 M sodium hydroxide (NaOH) at 25°C for 15 minutes. The remaining two membrane samples soaked in 0.1 M hydrochloric (HCl) acid at 25°C for 15 minutes. The sodium hydroxide solution made the brown foulant to detach from the membrane and float to the surface of the solution. The acid solution seemed not to affect the brown foulant. Then the membrane samples were tested with a 0.1 wt% sodium chloride solution at 690 kPa (100 psi) gage pressure and 24°C. The test result after one hour in operation is shown in Table 4. With readings taken one hour after start of test, the presented data are the average of two values and the spread, B_{NaCl}(20C) is the sodium chloride permeability at 20°C based on wt%.

Table 4.—Test Data for Fouled AK Membrane Samples,
Which Have Been “Cleaned” With Three Different Methods

Cleaning method	45°C flush	0.1 M NaOH	0.1 M HCl
A(20C)·10^6, m/(s·MPa)	13.5±0.2	14.6±0.6	10.1±0.1
B_{NaCl}(20C)·10^6, m/s	0.16±0.05	0.21±0.01	0.074±0.008

The soak in the sodium hydroxide solution restored the water permeability of the AK membrane to its nominal value. The flush with 45°C tap water was almost as good as the soak in the sodium hydroxide solution to restore the water permeability. The soak in the hydrochloric acid solution did not affect the water permeability significantly.

8.2 Performance of the DK Membrane Elements

Figure 8 shows the temperature, turbidity and chloramine concentration in the feed water to the membrane units when operating with the DK membrane elements. The chloramine concentration was zero a few times because problems with the hypochlorite addition.

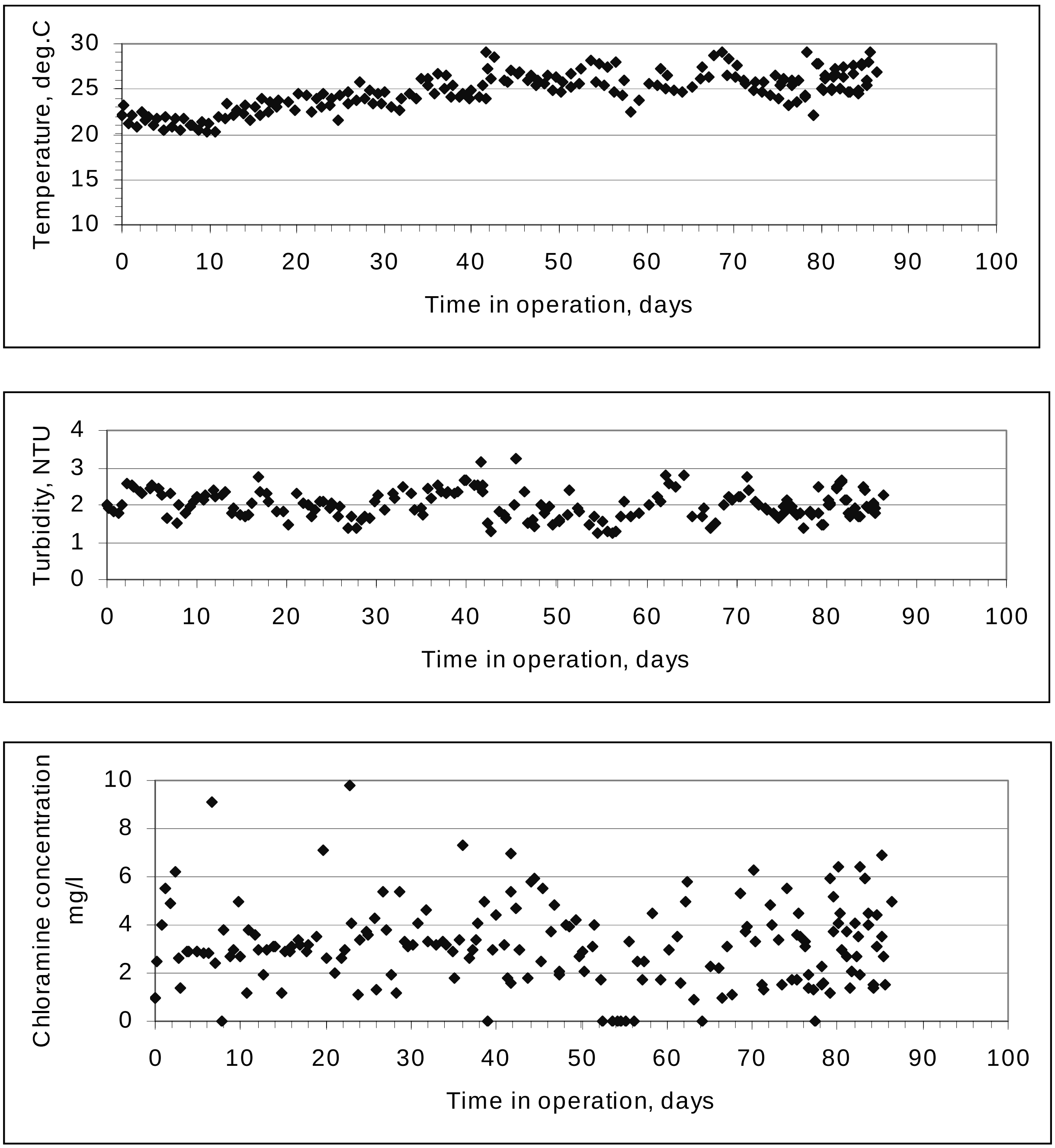


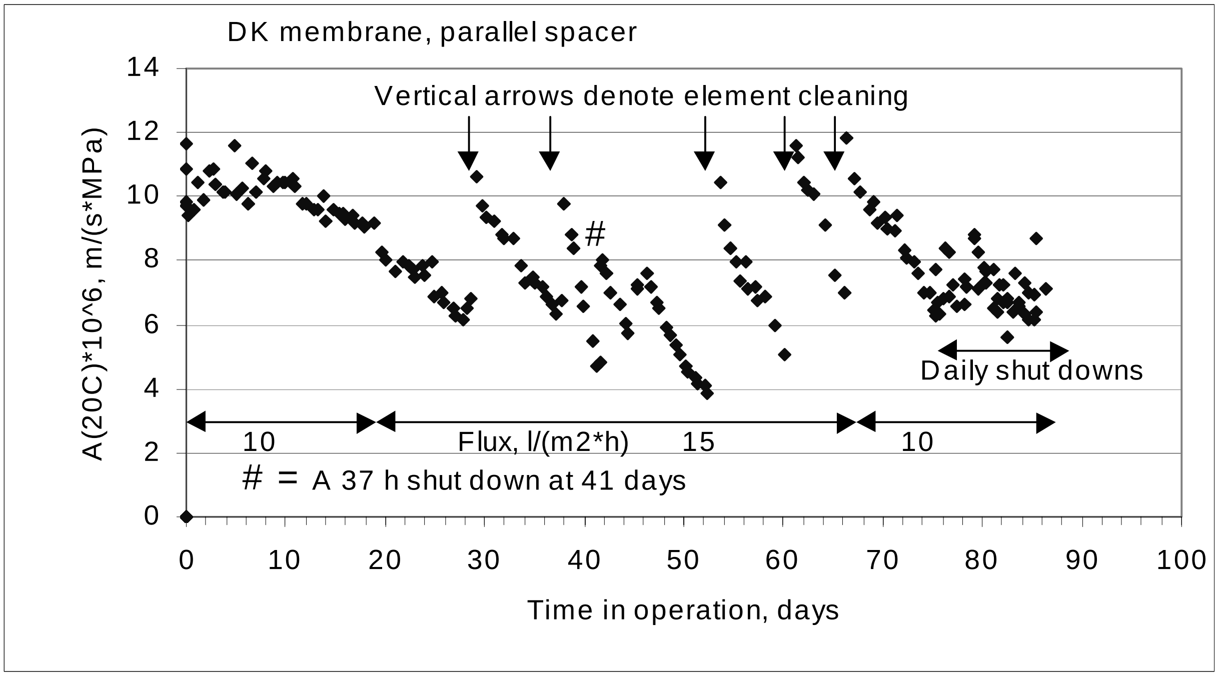
Figure 8.—Temperature, turbidity and chloramine concentration in the feed water to the membrane units when operating with the DK membrane elements.

During the whole test with the DK elements, nominal 100 μm wound cartridge filters were used for prefiltration, and the permeate recovery was about 27 percent. In the test with the AK elements, the same nominal 100 μm wound cartridge filter was used for 34 days. In the test with the DK elements, the time between prefilter replacement varied between 3 and 16 days, with an average of 8 days.

After 75 days of testing the DK elements with the diamond shape spacer, it was noticed that the downstream pressure gage of that membrane unit was stuck at about 43 psig, so it was replaced. It is not known for how long time it was unreliable, but the first suspicious value occurred after 42 days of testing. Thus, the water permeability and pressure drop data between 42 and 75 days of testing these elements are not reliable. However, the trends between changes in operating conditions in that time period should be correct.

Figure 9 shows the water permeability of the elements during the 86 days of operation. Antiscalant was added all the time. Prefiltration consisted of a nominal 100 μm wound cartridge filter. The permeate recovery was 27 percent. The membrane elements had originally, when tested on a $MgSO_4$ solution, a water permeability at 20°C of $10 \cdot 10^{-6}$ m/(s·MPa). Cleaning consisted of alkaline cleaning only. Inside the rectangle, the data are not reliable because the downstream pressure gage was stuck, but the trends are valid. During the first 19 days, the permeate flux was 10 l/($m^2 \cdot h$) (6 gfd). The water permeabilities at 20°C were stable at about $11 \cdot 10^{-6}$ m/(s·MPa) for the first 10 days and then started to decline. When the permeate flux was increased to 15 l/($m^2 \cdot h$), the rate of decline in water permeability increased somewhat. Alkaline cleanings restored the water permeabilities to their initial values or slightly higher. The rate of decline in water permeability after cleaning was rather high, however. Typically, there was a 50 percent reduction in water permeability during a week of operation. As in the case of the AK elements, also for the DK elements, the elements with the diamond shape spacer performed better than the elements with the parallel spacer.

After 41 days of operation, there was a shut down for 37 hours for general facility maintenance, including cleaning of the media filter in the pretreatment section. Upon restart, the water permeability at 20°C of the elements with the parallel spacer was $8 \cdot 10^{-6}$ m/(s·MPa), compared to $5 \cdot 10^{-6}$ m/(s·MPa) just before the shut down. The unit with the other elements was also shut down, but its downstream pressure gage was not reliable after the shut down, so it is not known how these elements reacted to the shut down. When starting up after a short stop to replace the faulty pressure gage after 75 days of operation, the concentrate was very dark brown for several minutes, which indicated that foulants had loosened from the membrane, and were flushed out.



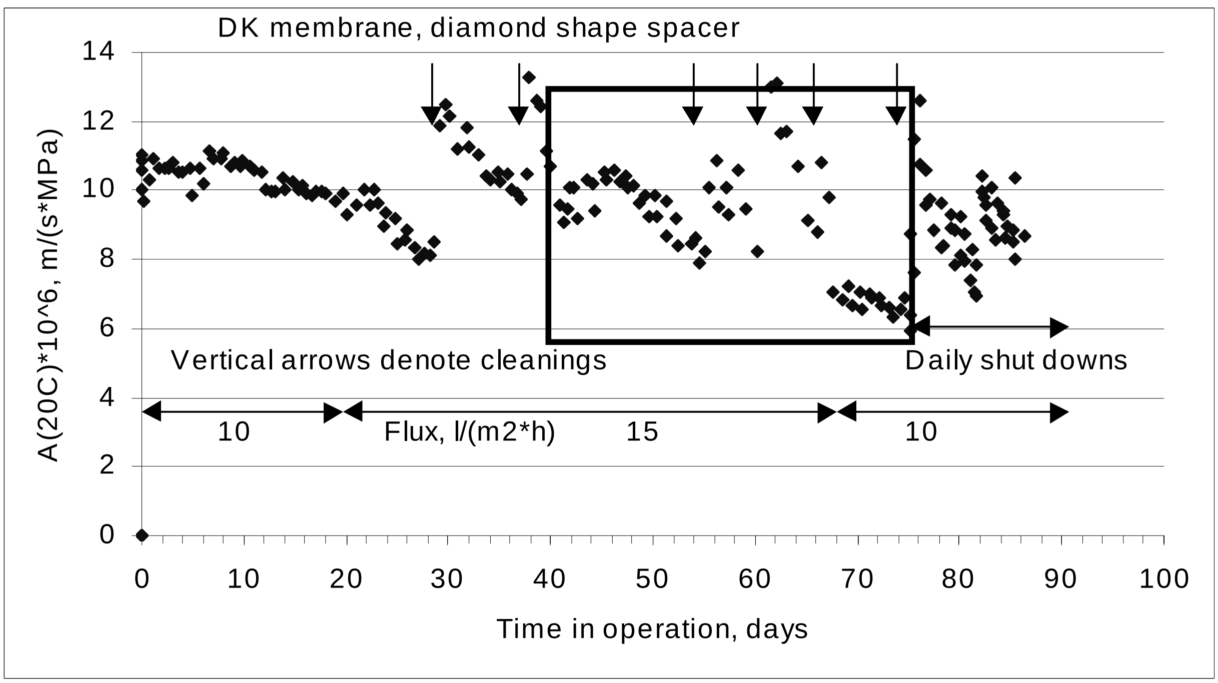


Figure 9.—Water permeabilities corrected to 20°C (A(20C) of the DK elements when operating on the wastewater.

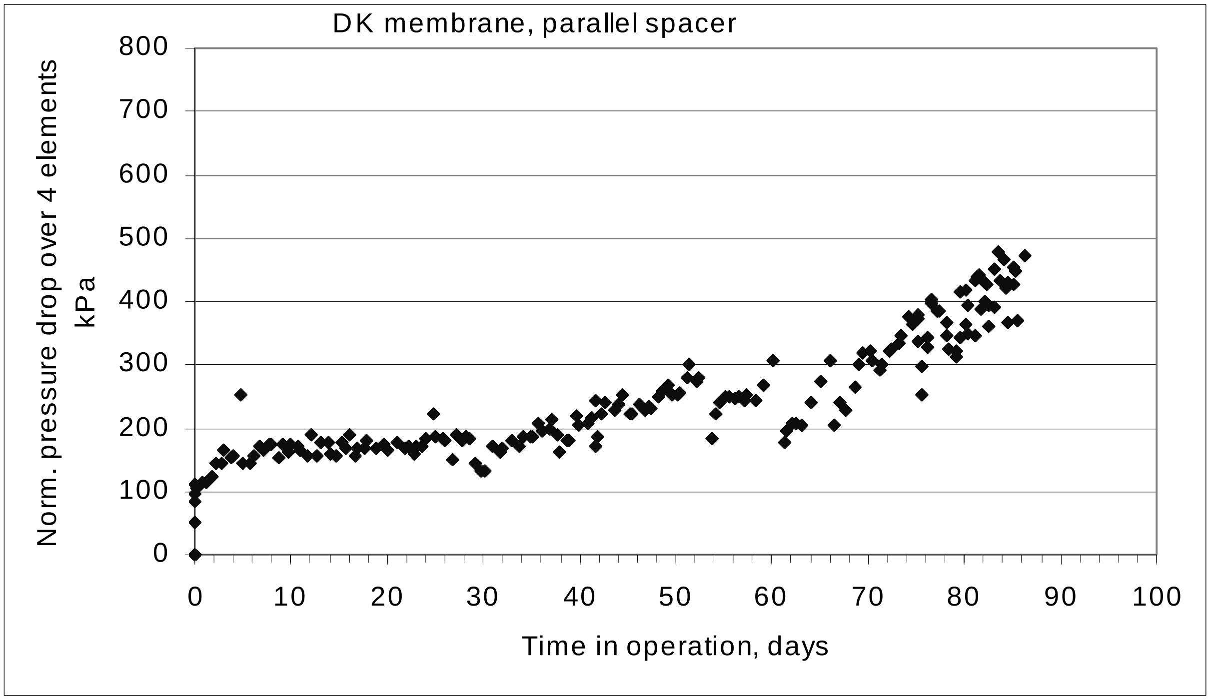
For the last 10 days, the units were shut down for about 10 minutes twice daily. This stabilized the water permeability at 20°C for the elements with the parallel spacer to be within $6 \cdot 10^{-6}$ and $8 \cdot 10^{-6}$ m/(s·MPa). For the elements with the diamond shape spacer, the water permeability at 20°C decreased during the first 6 days of twice daily shut downs to $7 \cdot 10^{-6}$ m/(s·MPa), but then suddenly jumped up to $10 \cdot 10^{-6}$ m/(s·MPa). During the remaining four days, the water permeability at 20°C decreased to $8 \cdot 10^{-6}$ m/(s·MPa). After 85 days of operation, there was a 23 hours stop, which was caused by a power outage. This stop caused the water permeabilities for the elements in both the membrane units to temporarily increase significantly.

The normalized pressure drop over the elements is shown in Figure 10. The cleaning frequency matched that as shown in Figure 9. There is no significant difference between the two types of elements, except between 76 and 82 days of operation. This was the first six days of twice daily shut downs of the units. The rectangle shows the period of time when the downstream pressure gage was suspect.

The conductivity permeabilities at 20°C of the elements are shown in Figure 11. The conductivity rejection varied in the range of 20 to 50 percent. The permeate flux, recovery and prefilter and cleaning frequencies are as shown in Figure 9. These increase steadily up to the point of the first alkaline cleaning. After the first alkaline cleaning, they seemed to have stabilized at 6-8 μm/s for the elements with the parallel spacer, and 5-7 μm/s for the elements with the diamond shape spacer. The variations within these ranges were probably caused by the variations of the amounts of foulants on the membrane surface.

At the end of the test, the upstream and downstream elements in both membrane units were removed, and the remaining membrane elements went through alkaline cleaning. The upstream element with the diamond shape spacer and the downstream element with the parallel spacer were opened up and inspected. The membrane in both elements were covered by a layer of brown deposit. For the element with the parallel spacer, the deposits where slightly thicker on the membrane surface which was closer to the cross strands than the membrane on the other side of the spacer.

Two of the cleaned membrane elements, from the second position of each membrane unit, were opened up and inspected. The element with the diamond shape spacer had all the brown deposits removed, except for linear brown stains on the membrane where it was in direct contact with the feed channel spacer, and also linear brown stains directly underneath the strands which were not in contact with the membrane. In general, the membrane was slightly darker closer to the centertube than in the outer areas. Even though almost all the membrane looked very clean, it was covered by a thin transparent slimy layer, which was easily wiped away with a finger. This slimy layer is probably what caused the high fouling rate during operation.



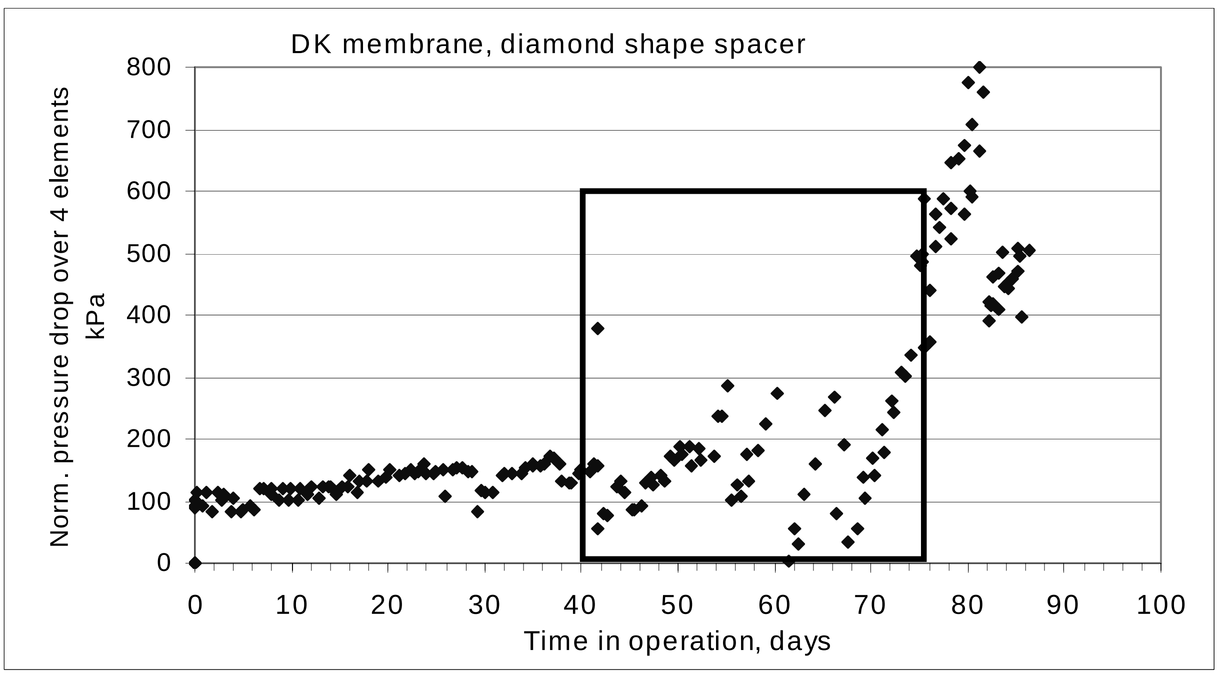
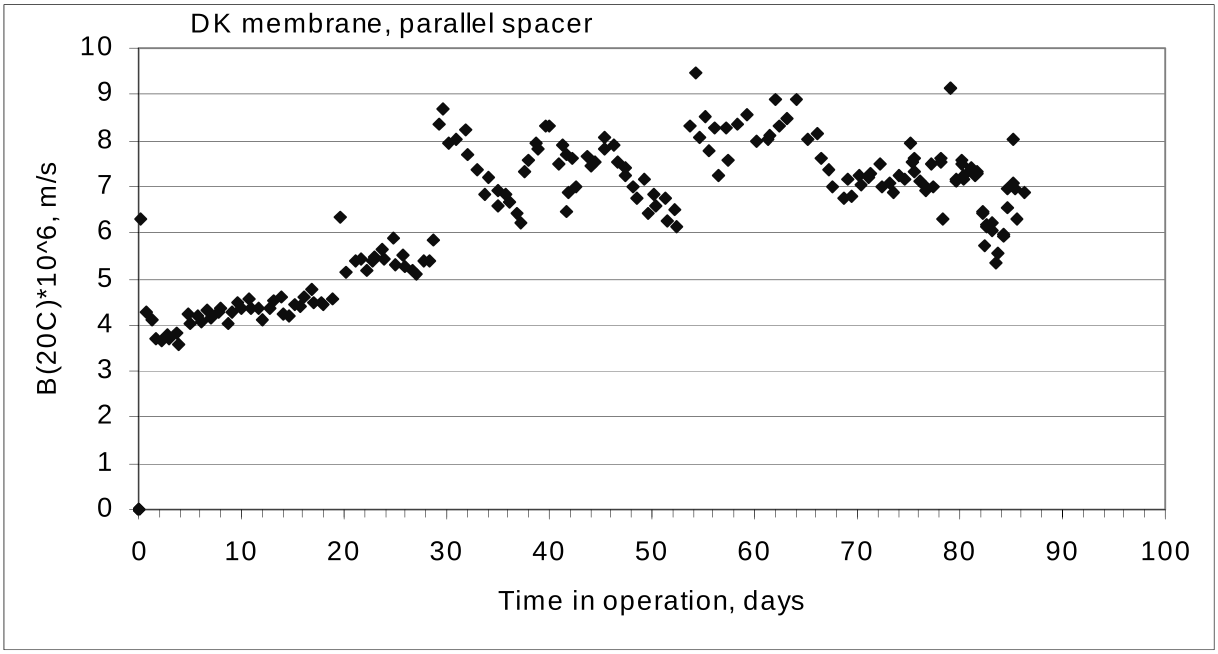


Figure 10.—Pressure drop over the four DK elements, normalized to 20°C and 1.3 m^3/h (5.7 gpm) average feed/concentrate flow rate.



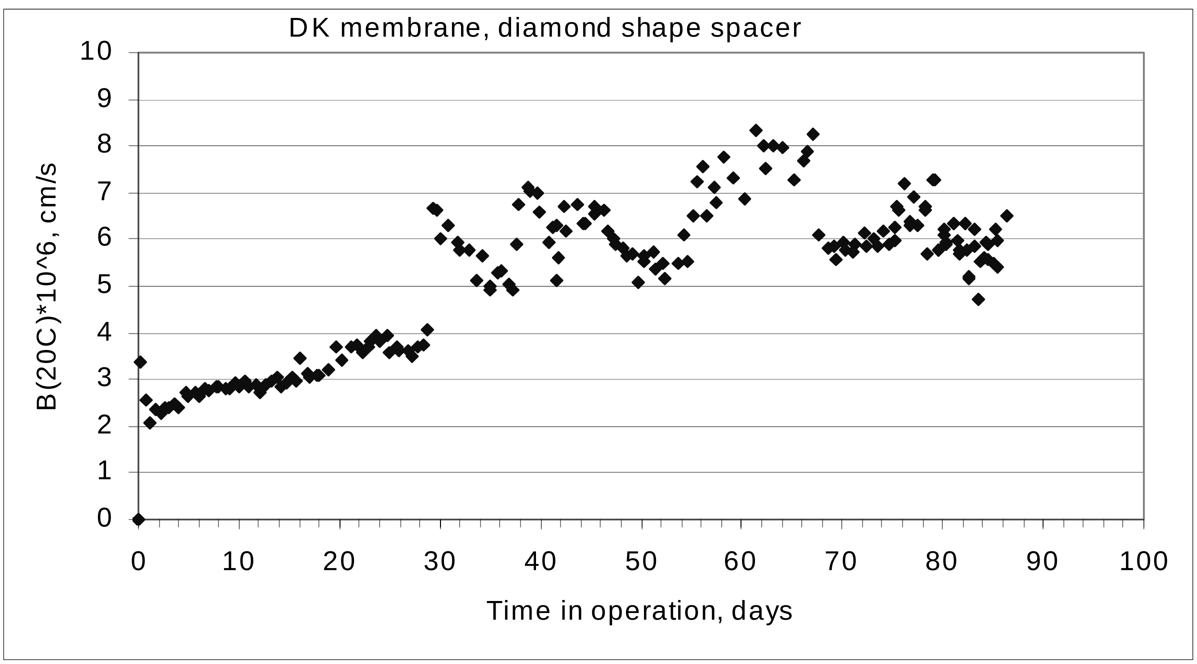


Figure 11.—Conductivity permeabilities corrected to 20°C (B(20C) of the DK elements when operating on the wastewater.

The element with the parallel spacer had still a lot of brown deposits on the membrane. There were a few 0.1 m (4 inches) wide areas in parallel with the centertube, covering the whole length of the element, which had been cleaned from the brown deposits. This indicates that there was uneven flow distribution within the element. Most of the feed flow went to a few channels, and these channels were cleaned very well. Most of the flow channels, however, must have got a very low feed flow rate, which caused them to foul heavily, and made cleaning difficult. Also in this element, there was the thin slimy transparent layer, and linear brown stains between the longitudinal strands and the membrane and where the cross strands passed over the membrane.

9. Analysis of Results

Membrane elements with the standard diamond shape feed channel spacer outperformed the elements with the parallel spacer. The main reason for this was probably uneven flow distribution on the feed side of the latter elements. The feed and exit ports of the element housings had an inner diameter of 12 mm (0.5 inch), and there was 4 cm (1.6 inches) distance between the inner end of the port and the feed channel of the element. With the typical feed flow rate of 23 l/minute (6 gpm), the feed velocity in the port was 4 m/s (13 ft/s), which corresponds to a dynamic pressure of 8 kPa (1.2 psi). The feed side pressure drop over a clean element with this feed flow rate should be between 8 and 13 kPa. Thus, the dynamic pressure was about the same as the expected pressure drop over the element. This coupled with the design of the parallel feed channel spacer, which hinders feed flow redistribution after entering the element, most likely resulted in a highly uneven flow distribution on the feed side of the membrane element.

The membrane fouling was mainly caused by small colloidal material which passed through a nominal 5 μm melt blown filter. It was deposited on the membrane surface independent on the type of feed channel spacer. It was easily removed by an alkaline cleaning, and it was enough with a 10 minutes shut down to detach some of the deposits from the membrane surface. The easiness in which the deposits could be removed, resulted in no advantage in using the parallel spacer instead of the diamond shape spacer. Even with even flow distribution, the parallel spacer would not be to any advantage in operating on the tertiary treated wastewater.

Membrane microfiltration uses short term reverse permeate flow (higher pressure on the permeate side than on the feed side) to remove deposits from the membrane surface. This method would work very well also with spiral wound elements operating on the tertiary treated municipal wastewater. However, the reverse permeate flow would probably shorten the life time of the membrane elements. Spiral wound membrane elements normally will not be damaged from up to 100 kPa (15 psi) higher pressure on the permeate side than on the feed side, but doing this repeatedly would most likely with time cause damage.

Membrane foulants were stuck between the spacer strands and the membrane where these were in contact with each other, which is as expected. More difficult to explain is why there were lines of dark material on the membrane underneath or above the strands which were half a channel height away from the membrane surface. The only plausible explanation is that these strands generate a flow pattern, which forms a wake on the membrane surface just below or above the strand. It is not likely that the accumulation of foulants in these suggested wakes contributed significantly to the overall fouling of the membrane surface.

In operation, the tested DK nanofiltration membrane elements had the same water permeabilities after cleaning as at the initial production test on a clean magnesium sulfate solution. The tested AK reverse osmosis membrane elements on the other hand, had only about half or less of their original water permeability when operating on the wastewater. The difference was most likely that the AK membrane attracted the foulants more strongly than the DK membrane. It can not be excluded, however, that the higher salt concentration at the membrane surface in the case for the AK membrane compared to the DK membrane, also had an influence on the fouling tendency. The feed temperature was higher when operating the DK elements than when operating the AK elements, which should have resulted in faster microbiological growth in the former case.

The melt blown Hytrex cartridge filters removed the particulate material which caused pressure drop over the elements, but not the small colloidal particles which caused a decline in the water permeability. Such a filter treated about 100 m^3 (30 kgal) tertiary treated wastewater before replacement. The cost for such a filter is about $4, which gives a prefilter replacement cost of $0.04 per m^3 ($0.13 per kgal) wastewater feed. To this comes the labor and disposal costs of prefilter replacement. These costs together with the frequent cleaning of the RO/NF unit make disposable cartridge prefiltration not cost competitive with membrane microfiltration as pretreatment.

Alkaline cleaning at pH 11 with a surfactant worked fine to remove the brown deposits from at least the DK membrane elements. However, there still remained a thin slimy layer on the membrane surface, which without doubt caused the membrane to foul rapidly upon start up. In order to make RO/NF without membrane microfiltration competitive with RO/NF with membrane microfiltration as pretreatment, it is imperative that a cleaning method is developed, which removes the slimy layer. Even better would be an additive to the feed solution, which prevented the formation of the slimy material.

If a cleaning method is developed, which removes the slimy layer on the membrane, the required cleaning frequency would be every 3 to 4 weeks according to the first four weeks data in Figures 6 and 9. Prefiltration could consist of a screen with nominal 30-100 μm rating. Such screens are commercially available, which have either automatic backwash or other types of automatic removal of solids from the screen. The RO/NF unit can most likely not operate at 20 $l/(m^2 \cdot h)$ (12 gfd) permeate flux, as in the case with membrane microfiltration as prefiltration, but most likely at 10 $l/(m^2 \cdot h)$ and maybe at 15 $l/(m^2 \cdot h)$.

Leslie et al. (1998) conducted a cost evaluation of using membrane microfiltration followed by reverse osmosis to treat clarified secondary effluent from municipal wastewater. Their result was that the amortized capital costs contributed to 59 percent of the total costs (about 20 percent of the total costs was for the amortized capitol costs of the MF and RO membrane units), and the operating costs for power, membranes and maintenance were about equal. The capital cost for equipment was estimated to \$240 per m^3/d (\$0.9 per gal/d) permeate for the RO unit and \$106 per m^3/d (\$0.4 per gal/d) permeate for the MF unit. If the permeate flux of the RO unit is lowered to half of the value, which can be maintained with membrane prefiltration as pretreatment, the RO membrane area to produce a given permeate flow rate would double. The pumps and instrumentation for the RO unit would remain the same in both cases, but the number of RO elements, element housings and manifold piping would double. The doubling of these component would increase the cost of the RO unit by at least 50 percent, making the capital cost of the RO to be higher than the combined cost of the alternative membrane microfiltration followed by RO. Operating at a lower permeate flux would require a lower pressure, and consequently a lower energy consumption. The RO membrane replacement cost would, however, double. It is not likely that eliminating membrane microfiltration and operating the RO unit at half the permeate flux would be economical. However, if the RO unit could operate well without membrane microfiltration at 15 $l/(m^2 \cdot h)$ with cleanings every 3-4 weeks, it might be competitive to RO with membrane microfiltration as pretreatment.

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SI Metric Conversion Table

SI Metric Unit	Multiply with	To get
m	3.28	ft
cm	0.3937	inch
μm	0.00003937	inch
m^2	10.76	ft^2
m^3	264.2	US gallons
l	0.2642	US gallons
$l/(m^2 \cdot h)$	0.5889	gfd
kPa	0.145	psi
$m/(s \cdot MPa)$	10.13	$cm/(s \cdot atm)$
$m/(s \cdot MPa)$	14621	gfd/psi

Appendix A - Result of Calibration Check

The pressure gages were checked for calibration against a master pressure gage. The master pressure gage was accurate when checked against a deadweight tester. The pressure gage readings were in psig. P_{read} was the pressure gage reading in psig. P_{real} was the real pressure in psig, which was obtained from the calibration check. One pressure gage failed, and was replaced 12 days before the end of the testing.

Pressure gages used in the membrane unit with the parallel feed channel spacer.

Just before upstream element housing: $P_{real} = 0.996 \cdot P_{read} + 2.6$

Just after downstream element housing: $P_{real} = 0.000109 \cdot P^2_{read} + 0.9437 \cdot P_{read} + 4.47$

Pressure gages used in the membrane unit with the diamond shape feed channel spacer.

Just before upstream element housing: $P_{real} = 0.986 \cdot P_{read} + 1.3$

Just after downstream element housing

All the time except after 74.5 days of operation with the DK elements:

If $P_{real} < 100$; $P_{real} = 0.96 \cdot P_{read} + 4$, If $P_{real} > 100$; $P_{real} = P_{read}$

After 74.5 days of operation with the DK elements: $P_{real} = P_{read}$

The flow meter readings were in gallons per minute, gpm. After 7 days of operating time with the AK membrane elements, the permeate flow meters were replaced with smaller ones. The flowmeters were calibrated using a bucket and a stop watch. F_{read} was the flow meter reading in gpm. F_{real} was the real flow rate in gpm, which was obtained from the calibration check.

Flow meters used in the membrane unit with the parallel feed channel spacer.

Concentrate flow meter: $F_{real} = F_{read}$

Permeate flow meter for the first 7 days in operation: $F_{real} = F_{read} + 0.2$

Permeate flow meter after the first 7 days in operation: $F_{real} = F_{read} - 0.05$

Flow meters used in the membrane unit with the diamond shape feed channel spacer.

Concentrate flow meter: $F_{real} = F_{read}$

Permeate flow meter for the first 7 days in operation: $F_{real} = F_{read} + 0.3$

Permeate flow meter after the first 7 days in operation: $F_{real} = F_{read} - 0.1$

During the first week of operation, the temperature gage readings were compared with the temperatures of the feed solutions, which were measured in the laboratory. The latter temperatures were mostly about 0.5°C higher than the former ones. It was then assumed that the real temperature was 0.5°C higher than the reading from the temperature gage.

Appendix B - Raw Data Record

The data are shown in following order

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- AK elements with parallel spacer 34
- AK elements with diamond shape spacer 38
- DK elements with parallel spacer 42
- DK elements with diamond shape spacer 46

AK membrane elements with parallel feed channel spacer

Start time=		2/23/98 11:00			Pressures, psig								
	Time in ope-		Flow rates, gpm		Prefilter		Elements		Turbidi	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
75 u PF	0.1	2/23/98 14:00	3.80	2.7	48	46	140	129			15	1580	26
	0.9	2/24/98 9:00	3.80	2.7	47	43	198	182			17	1580	26
	2.3	2/25/98 17:30	3.80	2.5	47	42	211	199	1.78	0.9	16.2	1583	26
	2.9	2/26/98 9:00	3.80	2.4	49	39	268	250	1.9	1.2	14.9	1583	26
Cleaning	3.0	2/26/98 12:00	stop										
acid + alk.		3/2/98 9:00	restart										
5 u PF	3.2	3/2/98 13:30	3.80	2.5	48	47	188	178	2.04	2	17.1	1697	71
	3.5	3/2/98 19:00	3.80	2.5	48	46	190	180	2.35	1.7	17.5	1697	71
	4.0	3/3/98 6:50	3.80	2.5	48	43	195	182	1.98	3.3	16.8	1691	63.2
	4.2	3/3/98 12:50	3.80	2.5	48	43	215	202	2.2	2.5	17.4	1716	34
	4.4	3/3/98 16:40	3.80	2.5	46	40	215	204	2.25	1.3	18.2	1704	32.4
	4.6	3/3/98 23:10	3.80	2.5	48	32	218	202	2.23	2.7	17.7	1715	32.4
5 u PF	5.0	3/4/98 7:05	3.80	2.5	49	31	212	202	2.15	1	17.2	1730	30.4
	5.2	3/4/98 12:30	3.80	2.5	48	46	222	209	2.35	1.7	17.9	1730	30.4
	5.4	3/4/98 17:00	3.80	2.5	48	46	220	210	2.31	1.8	18.3	1730	28
	5.5	3/4/98 21:00	3.80	2.5	48	48	220	210	2.33	2.3	18	1730	28
	6.0	3/5/98 7:00	3.80	2.5	48	44	250	240	2.23	2	16.8	1733	26
	6.3	3/5/98 14:45	4.00	2	48	43	190	175	2.07	2.3	17.8	1733	26
	6.4	3/5/98 18:45	4.00	2	48	42	189	175	2.09	2.1	17.7	1750	27.2
	6.6	3/5/98 22:20	4.00	2	47	39	188	175	2.11	1.8	17.2	1755	31
	7.0	3/6/98 7:10	3.90	1.8	49	35	188	175	2.21	1.2	16.4	1760	35.4
	7.0	3/6/98 8:15	3.80	2.4	48	36	248	238	2.17	2	16.7	1760	35.4
Cleaning	7.0	3/6/98 8:20	stop	store in SBS									
acid + alk.		3/9/98 11:00	restart										
75 u PF	7.1	3/9/98 13:00	3.70	1.4	47	44	94	84	1.98	2.1	17	1770	56
	7.3	3/9/98 17:45	3.70	1.4	49	48	90	80	2.06	0.5	17.8	1787	56
	7.5	3/9/98 22:05	3.70	1.4	48	47	95	85	2.21	2.9	17.1	1786	53
	7.8	3/10/98 6:50	3.70	1.4	49	49	98	85	1.9	2.1	14.6	1785	50.6
	8.1	3/10/98 13:20	3.70	1.4	48	47	91	82	2.01	2.3	17.7	1795	50.4
	8.3	3/10/98 17:35	3.70	1.4	49	48	92	84	1.89	0.8	18.5	1806	50.2
	8.5	3/10/98 22:10	3.70	1.4	50	48	96	85	2.09	4.3	17.4	1800	50
	8.8	3/11/98 7:00	3.70	1.4	50	48	102	91	2.04	2	16	1800	50
	9.1	3/11/98 12:45	3.70	1.4	49	47	95	83	1.85	2.5	18	1800	50
	9.2	3/11/98 16:00	3.70	1.4	48	46	92	82	1.56	1.4	19	1790	56
	9.5	3/11/98 22:00	3.70	1.4	50	48	95	85	1.75	2.4	18	1789	56
	9.9	3/12/98 8:00	3.70	1.4	50	48	99	90	1.89	3	16	1800	45
	10.2	3/12/98 15:00	3.70	1.4	48	44	98	85	1.86	4.3	18.4	1795	44
	10.8	3/13/98 7:00	3.70	1.4	50	44	99	89	1.81	2.7	17.2	1804	48
	11.3	3/13/98 17:30	3.70	1.4	46	41	95	85	1.67	0.8	18.4	1820	43
20 u PF	11.9	3/14/98 7:30	3.70	1.4	50	49	99	88	1.62	2.1	17.2	1842	43.6
	12.3	3/14/98 17:00	3.70	1.4	48	48	98	87	1.78	3	18.1	1835	44
	12.9	3/15/98 7:15	3.70	1.4	50	49	99	90	2.06	2	16.4	1828	44.2
	13.3	3/15/98 17:50	3.70	1.4	49	46	99	88	2.27	0.7	18.4	1815	44.7
	13.9	3/16/98 7:45	3.70	1.4	48	39	95	85	1.89	0.7	18	1815	44.3
	14.3	3/16/98 17:50	3.70	1.4	48	47	99	89	1.86	3.5	18.1	1812	44.7
	14.8	3/17/98 6:30	3.70	1.4	49	48	98	88	1.44	0.9	17.9	1815	46
	15.3	3/17/98 17:10	3.70	1.4	49	47	98	86	1.6	0.6	18.7	1825	44.1
	15.9	3/18/98 8:05	3.70	1.4	49	47	97	86	1.95	1	18.4	1823	42.3
	16.1	3/18/98 13:50	3.70	1.4	48	45	93	84	1.86	1.2	19.6	1823	42
	17.3	3/19/98 17:30	3.70	1.4	48	36	90	80	2.15	1	20.5	1809	46
75 u PF	17.5	3/19/98 22:10	3.70	1.4	50	49	95	82	2.46	1.3	19.3	1830	48
	17.8	3/20/98 7:00	3.70	1.4	48	47	99	88	2.09	4.3	18	1839	50
	18.2	3/20/98 16:15	3.70	1.4	47	46	98	85	1.83	2.8	18.7	1830	47

AK membrane elements with parallel feed channel spacer

Start time=		2/23/98 11:00			Pressures, psig								
	Time in ope-		Flow rates, gpm		Prefilter		Elements		Turbidit	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
	18.9	3/21/98 7:40	3.70	1.4	48	47	99	88	1.31	2.5	18.2	1808	42.7
	19.2	3/21/98 16:40	3.70	1.4	49	48	97	86	1.91	1.9	19.6	1797	43.5
	19.9	3/22/98 7:30	3.70	1.4	49	47	99	88	1.85	2.2	18	1801	42.2
	20.3	3/22/98 17:00	3.70	1.4	49	48	92	82	1.72	2.49	20.4	1180	61
	20.9	3/23/98 8:15	3.70	1.4	50	48	96	85	2.1	2	18.6	1770	50
	21.3	3/23/98 18:25	3.70	1.4	48	45	91	81	2.4	1	20.9	1797	43.6
	21.9	3/24/98 7:15	3.70	1.4	49	45	92	82	2.45	1.4	19.2	1797	44
	22.2	3/24/98 14:30	3.70	1.4	48	45	90	80	2.39	3.9	20.4	1779	46
	22.8	3/25/98 6:45	3.70	1.4	49	43	95	85	1.58	1.1	19.2	1816	48.5
	23.3	3/25/98 17:30	3.70	1.4	49	41	92	82	1.94	1	19.3	1776	43
	23.9	3/26/98 7:20	3.70	1.4	50	40	100	90	1.8	2.1	17.8	1750	40
	24.3	3/26/98 17:30	3.70	1.4	49	37	98	88	1.61	2.7	18.5	1711	38
	24.9	3/27/98 7:45	3.70	1.4	49	34	99	90	1.88	1.5	17.5	1730	38.3
10um PF	25.3	3/27/98 17:40	3.70	1.4	50	33	100	91	1.91	3.6	17.9	1705	37
	26.9	3/29/98 8:55	3.70	1.4	50	49	108	99	1.79	3.2	14.9	1694	34.1
	27.3	3/29/98 17:30	3.70	1.4	50	48	108	99	1.64	2.4	15.8	1648	31.9
	27.8	3/30/98 6:15	3.70	1.4	50	46	108	98	1.59	2	13.9	1799	34
	28.3	3/30/98 17:30	3.70	1.4	49	43	101	96	2.18	3.6	16.3	1692	33.4
	28.8	3/31/98 6:30	3.70	1.4	49	39	102	95	2.14	3.5	15.1	1669	34
No prefilte	29.3	3/31/98 17:30	3.70	1.4	48	48	104	98	1.62	4.3	16.4	1729	35.7
	30.0	4/1/98 9:50	3.70	1.4	50	49	111	101	1.01	5.7	15	1649	35
	30.3	4/1/98 17:00	3.70	1.4	49	48	110	99	1.27	0.9	16.6	1635	30
	30.8	4/2/98 7:00	3.70	1.4	48	48	111	101	2.33	2.7	14.8	1619	30.7
	31.2	4/2/98 16:10	3.70	1.4	49	48	105	98	0.84	1.3	17.4	1636	31
	31.9	4/3/98 8:00	3.70	1.4	49	48	109	99	1.59	1	15.5	1664	31.1
	32.3	4/3/98 17:00	3.70	1.4	48	48	107	99	1.59	4.2	16.9	1624	30.8
	32.9	4/4/98 9:00	3.70	1.4	50	49	110	99	2.01	0.78	16.2	1659	31.8
	33.3	4/4/98 17:30	3.70	1.4	48	48	109	98	1.82	1.2	17.9	1659	31.8
	33.9	4/5/98 9:00	3.70	1.4	50	49	112	101	1.67	8.2	15.7	1648	31.3
	34.3	4/5/98 18:45	3.70	1.4	48	47	110	98	2.55	2	17.2	1704	30
	34.9	4/6/98 8:20	3.70	1.4	49	48	109	99	3	5.3	16	1707	34.6
	35.3	4/6/98 18:10	3.70	1.4	48	47	112	99	1.94	1.9	17.2	1704	32.8
	35.9	4/7/98 7:25	3.70	1.4	49	49	118	101	1.16	1.4	15.8	1720	34
	36.2	4/7/98 16:40	3.70	1.4	48	48	115	100	1.51	2	17.4	1753	35.4
	36.9	4/8/98 7:10	3.70	1.4	50	50	121	104	1.78	2	15.2	1760	36.6
	37.3	4/8/98 17:49	3.70	1.4	46	46	118	101	1	4	17.3	1766	37.8
	37.8	4/9/98 7:00	3.70	1.4	49	48	120	103	1.38	1.6	15	1685	31.5
	38.3	4/9/98 17:25	3.70	1.4	46	46	115	100	2.23	4.2	17.8	1717	34.3
	38.8	4/10/98 7:00	3.70	1.4	51	50	122	105	1.38	2.8	15.9	1704	34.2
	39.3	4/10/98 17:45	3.70	1.4	47	47	115	98	1.5	3.1	18.2	1692	34.9
	39.5	4/10/98 22:40	3.70	1.4	50	49	120	98	1.76	1.7	17.3	1700	35
		4/11/98 6:50											
		4/11/98 17:15											
		4/12/98 8:17											
		4/12/98 18:00											
Cleaning		4/13/98 7:40											
acid + alk.	40.0	4/13/98 11:10	3.70	1.4	48	48	88	78	2.11	2	17	1690	43
	40.2	4/13/98 17:00	3.70	1.4	48	48	89	77	1.9	4	17.9	1678	43
	40.8	4/14/98 7:15	3.70	1.4	48	47	88	75	1.77	2.8	16.7	1719	44.1
	41.2	4/14/98 16:25	3.70	1.4	50	48	90	78	2	1.5	18.7	1664	42.2
	41.8	4/15/98 6:40	3.70	1.4	48	48	95	80	1.84	1.2	16.1	1664	42.2

AK membrane elements with parallel feed channel spacer

Start time= 2/23/98 11:00

	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Flow rates, gpm Perm.	Pressures, psig Prefilter In	Pressures, psig Prefilter Out	Pressures, psig Elements In	Pressures, psig Elements Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Cond., uS/cm Perm.
	42.3	4/15/98 17:45	3.70	1.4	48	47	94	79	1.98	3.9	18	1692	40.8
	42.8	4/16/98 6:30	3.70	1.4	48	47	98	80	1.58	2.6	14.9	1692	40.8
	43.3	4/16/98 17:32	3.70	1.4	48	47	98	80	1.69	4.6	18.4	1724	41.4
	43.8	4/17/98 7:03	3.70	1.4	50	49	100	83	1.5	4.1	16.1	1707	40.4
	44.3	4/17/98 19:00	3.70	1.4	48	48	97	79	2.16	3.4	18.6	1703	39.5
	44.8	4/18/98 7:15	3.70	1.4	49	48	101	83	1.87	4.2	16.4	1699	38.6
	45.3	4/18/98 18:30	3.70	1.4	48	48	96	78	1.97	3	19.2	1707	41.8
	45.8	4/19/98 7:00	3.70	1.4	50	49	101	82	2.17	3.3	16.7	1713	41.8
	46.3	4/19/98 17:30	3.70	1.4	46	46	98	78	2.33	1.4	20.1	1715	42.4
	46.9	4/20/98 8:50	3.70	1.4	48	48	102	81	2.12	2.2	18	1693	43.7
	47.3	4/20/98 18:00	3.70	1.4	49	48	95	78	1.4	1.8	20.3	1718	47.8
	47.9	4/21/98 7:50	3.70	1.4	50	49	100	80	2.39	3.9	18.3	1713	45.4
	48.2	4/21/98 16:50	3.70	1.4	48	47	99	79	3.36	3	20.9	1771	48.7
media filte	48.8	4/22/98 6:25	3.70	1.4	48	48	98	79	1.96	3	20.3	1771	48.7
cleaned		4/22/98 21:48											
Cleaning		4/23/98 7:40											
acid + alk.	49.1	4/23/98 17:20	7.00	1.4	47	46	75	50	1.6	4.9	21.1	1774	56.9
	49.6	4/24/98 6:50	7.00	1.4	48	47	82	59	2.11	4.3	19.8	1724	50.9
	50.1	4/24/98 18:00	7.00	1.4	48	47	82	55	1.45	3.3	21.1	1729	50
	50.6	4/25/98 6:00	7.20	1.4	48	47	87	59	2.31	1	19.6	1705	47
	51.1	4/25/98 17:30	7.00	1.4	48	46	85	57	2.11	2.5	20.4	1718	47.3
	51.6	4/26/98 7:25	7.00	1.4	48	47	93	63	2.19	2.2	18.3	1721	47.9
	52.0	4/26/98 16:15	7.00	1.4	48	46	90	59	1.91	2.2	20.8	1723	46
	52.6	4/27/98 7:35	7.00	1.4	48	46	98	65	1.98	1.8	18.7	1744	46.9
	53.1	4/27/98 17:50	7.00	1.4	48	47	92	60	1.99	2.7	21.5	1733	46
	53.6	4/28/98 6:40	7.00	1.4	48	46	99	62	1.61	2	18.9	1731	45.9
	54.1	4/28/98 17:20	4.00	1.4	48	47	85	68	1.7	1.8	22.1	1740	52.6
	54.6	4/29/98 6:30	4.00	1.4	50	49	90	70	2.07	0.8	19	1765	54
	55.2	4/29/98 21:11	4.00	1.4	48	47	85	68	3.6	2	21.5	1791	55.9
	55.6	4/30/98 6:40	4.00	1.4	50	49	85	69	2.54	1.5	20	1739	54
	56.0	4/30/98 17:11	4.00	1.4	48	47	87	69	2.21	2.5	21.7	1753	55.1
	56.6	5/1/98 7:00	4.00	1.4	49	48	91	71	1.79	2.3	20	1742	54
	57.1	5/1/98 19:40	4.00	1.4	49	48	90	70	1.78	2	21.6	1742	53.8
	57.6	5/2/98 6:10	4.00	1.4	48	48	90	70	1.51	1.8	19.5	1742	53.8
	57.8	5/2/98 11:40	4.00	1.4	48	47	89	69	1.45	2.2	20.7	1162	35.6
	58.7	5/3/98 9:15	4.00	1.4	48	47	88	69	1.96	2.1	21	1751	56.6
	59.1	5/3/98 17:21	4.00	1.4	47	46	90	70	1.93	2.6	22.2	1810	58.8
	59.7	5/4/98 8:11	4.00	1.4	49	48	95	72	2.01	2.2	20.5	1746	57.8
	60.9	5/5/98 14:10	4.00	1.4	48	48	100	75	1.86	2.1	20.9	1748	61.8
	61.1	5/5/98 18:00	4.00	1.4	48	47	99	73	1.73	2.3	21	1751	65.8
	61.6	5/6/98 7:10	4.00	1.4	48	47	101	78	1.71	2.2	20.2	1758	66.8
	62.0	5/6/98 16:05	4.00	1.4	48	47	105	79	1.77	2.8	21	1766	67.5
	62.7	5/7/98 8:15	4.00	1.4	48	47	110	82	1.59	2.3	19.9	1744	69
	63.1	5/7/98 18:15	5.55	2.05	46	45	163	125	1.7	1.29	20.8	1767	49.3
	63.6	5/8/98 6:25	5.55	2.05	46	45	185	150	1.67	2	19.5	1745	58.4
	64.1	5/8/98 18:19	5.55	2.05	49	48	190	152	2.64	3	20.1	1745	58.4
Cleaning	64.6	5/9/98 6:30	4.50	2.05	48	47	215	180	1	3	19.4	1745	58.4
acid + alk.	65.3	5/9/98 22:45	5.55	2.05	45	45	115	95	1.68	0.7	19.9	1745	58.4
	65.6	5/10/98 6:40	5.55	2.05	48	47	125	98	1.48	1.5	19	1711	38.4
	66.1	5/10/98 17:45	5.55	2.05	48	47	130	100	2.89	3.6	20.8	1742	42.1
	66.6	5/11/98 7:18	5.55	2.05	49	48	142	109	1.23	1.79	19.1	1747	43.2
	67.1	5/11/98 19:00	5.55	2.05	49	48	145	109	2.22	1.6	19.9	1736	43
	68.1	5/12/98 18:20	5.55	2.05	49	48	152	119	2.07	4.9	19	1726	42.9

AK membrane elements with parallel feed channel spacer

Start time=		2/23/98 11:00			**Pressures, psig**								
	Time in ope-		**Flow rates, gpm**		**Prefilter**		**Elements**		**Turbidit**	**NH2Cl**	**Feed Te**	**Cond., uS/cm**	
	ration, d	Date&Time	**Conc.**	**Perm.**	**In**	**Out**	**In**	**Out**	**NTU**	**mg/l**	**deg.C**	**Feed**	**Perm.**
	68.7	5/13/98 7:45	5.55	2.05	48	47	168	130	1.88	1	17.8	1715	43.1
	69.0	5/13/98 16:10	5.55	2.05	46	46	173	138	1.6	4.6	18.7	1692	45.9
Cleaning	69.7	5/14/98 7:48	5.55	2.05	49	48	192	158	1.92	4.4	17.7	1684	52
acid + alk.	70.0	5/14/98 22:55	2.80	2.05	49	48	115	103	1.82	2.5	18.7	1691	48.9
	70.5	5/15/98 12:20	2.80	2.05	48	48	127	110	1.63	1.4	19.3	1683	51.7
	70.8	5/15/98 18:00	2.80	2.05	47	47	129	110	1.63	1.7	20.4	1689	53.7
	71.5	5/16/98 10:15	2.80	2.05	48	48	149	129	1.58	2.1	19.1	1661	52.2
	71.8	5/16/98 18:10	2.80	2.05	47	46	151	131	1.54	4	20.4	1698	56.3
	72.4	5/17/98 9:05	2.80	2.05	49	48	172	152	1.5	2	19.1	1664	50.4
	72.8	5/17/98 17:38	2.80	2.05	48	47	178	151	1.82	5.1	21	1704	56.3
	73.3	5/18/98 7:25	2.80	2.05	49	48	210	190	1.6	5.2	18.7	1695	58.5
	73.8	5/18/98 17:50	2.80	2.05	48	47	215	190	2.1	2.2	21.3	1685	56.6
	74.3	5/19/98 7:19	2.80	2.05	49	48	250	228	1.88	4	19.4	1680	62.2
	74.8	5/19/98 18:10	2.80	1.61	47	47	245	221	1.94	3.1	21.4	1680	62.2
Cleaning	76.0	5/20/98 22:40	3.70	1.4	48	48	82	69	2.42	3.2	20.5	1705	60.1
acid + alk.	76.5	5/21/98 10:31	3.70	1.4	48	47	89	70	1.8	0.6	20.2	1723	62.8
	76.7	5/21/98 16:10	3.70	1.4	48	46	90	70	1.39	1.4	21.5	1723	62.8
	77.3	5/22/98 6:15	3.70	1.4	49	49	95	71	1.74	0.7	20	1700	67
	77.8	5/22/98 18:32	3.70	1.4	48	47	99	72	1.96	10	21.7	1729	77.3
	78.3	5/23/98 6:25	3.70	1.4	50	49	103	80	2.26	7.6	19.9	1710	76
	78.8	5/23/98 18:50	3.70	1.4	48	47	103	79	2.06	0.3	21.7	1667	78.5
	79.3	5/24/98 6:30	3.70	1.4	48	47	109	81	1.6	0.6	20	1670	83
	79.7	5/24/98 16:42	3.70	1.4	49	48	110	82	1.38	0.9	21.9	1702	91.6
	80.3	5/25/98 7:00	3.70	1.4	48	48	120	92	1.66	4.7	20.3	1679	97.2
	80.7	5/25/98 17:00	3.70	1.4	49	48	121	92	2.32	1.4	20.8	1646	98.2
	81.5	5/26/98 10:40	3.70	1.4	48	48	130	101	1.81	5	20.1	1680	104.3
	81.8	5/26/98 18:20	3.70	1.4	49	48	131	101	1.7	1.9	20.8	1612	102.3
	82.3	5/27/98 7:22	3.70	1.4	49	48	139	110	1.59	0.7	19.3	1665	104
	82.7	5/27/98 17:10	3.70	1.4	49	48	139	109	1.56	4.3	21	1662	112
	83.4	5/28/98 8:10	3.70	1.4	49	48	145	115	1.66	2	19.4	1686	103.2
	83.7	5/28/98 16:35	3.70	1.4	47	46	148	126	1.83	2.9	21.5	1650	110.7
Cleaning	84.4	5/29/98 7:45	3.70	1.4	48	48	159	129	1.79	0.9	19.3	1641	113.7
acid + alk.	84.9	5/29/98 21:00	3.70	1.4	48	47	101	79	1.94	2.6	21.2	1633	45.6
100 u PF	85.3	5/30/98 7:15	3.70	1.4	48	47	110	95	1.38	1.4	19.1	1583	44.3
	85.6	5/30/98 13:50	3.70	1.4	47	46	105	91	1.51	2.8	20.9	1570	46
	86.4	5/31/98 9:30	3.70	1.4	48	46	103	88	2.4	2.6	20.2	1554	47
	87.4	6/1/98 8:50	3.70	1.4	49	46	110	95	1.52	3.1	20.2	1475	49.4
	88.3	6/2/98 6:50	3.70	1.4	49	44	111	95	1.63	4	19.8	1523	48.3
	88.7	6/2/98 16:30	3.70	1.4	49	43	111	93	1.85	2.9	22	1512	49.2
	89.3	6/3/98 6:15	3.70	1.4	49	42	112	95	1.68	0	20.8	1494	49.7
	89.5	6/3/98 12:00	3.70	1.4	48	41	111	95	1.78	4.1	21.7	1476	50.1

AK membrane elements with diamond shape feed channel spacer

Start time= 2/23/98 11:00

	Time in ope-		Flow rates, gpm		Pressures, psig Prefilter		Elements		Turbidit	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
75 u PF	0.1	2/23/98 14:00	4.20	2.9	48	48	118	105			15	1580	29
	0.9	2/24/98 9:00	4.20	2.9	44	43	160	148			17	1580	29
	2.3	2/25/98 17:30	4.20	2.9	47	44	181	170	1.78	0.9	16.2	1583	26
Cleaning	2.9	2/26/98 9:00	4.20	2.9	48	41	248	232	1.9	1.2	14.9	1583	29
acid + alk.	3.0	2/26/98 12:00	stop										
		3/2/98 9:00	restart										
5 u PF	3.2	3/2/98 13:30	4.20	2.9	49	47	168	158	2.04	2	17.1	1697	33
	3.5	3/2/98 19:00	4.20	2.9	48	46	170	160	2.35	1.7	17.5	1697	33
	4.0	3/3/98 6:50	4.20	2.9	48	42	170	160	1.98	3.3	16.8	1691	30.7
	4.2	3/3/98 12:50	4.20	2.9	49	38	190	180	2.2	2.5	17.4	1716	27
	4.4	3/3/98 16:40	4.20	2.9	47	28	185	172	2.25	1.3	18.2	1704	28
	4.6	3/3/98 23:10	4.20	2.9	48	24	195	185	2.23	2.7	17.7	1715	28
5 u PF	5.0	3/4/98 7:05	4.20	2.9	48	23	196	186	2.15	1	17.2	1730	27.2
	5.2	3/4/98 12:30	4.20	2.9	48	46	197	186	2.35	1.7	17.9	1730	27
	5.4	3/4/98 17:00	4.20	2.9	48	47	199	185	2.31	1.8	18.3	1730	25
	5.5	3/4/98 21:00	4.20	2.9	47	45	199	185	2.33	2.3	18	1730	23
	6.0	3/5/98 7:00	4.20	2.9	50	45	216	205	2.23	2	16.8	1733	21
	6.3	3/5/98 14:45	4.00	2.3	48	43	175	162	2.07	2.3	17.8	1733	22
	6.4	3/5/98 18:45	4.00	2	48	42	189	175	2.09	2.1	17.7	1750	23.6
	6.6	3/5/98 22:20	4.00	2	47	39	188	175	2.11	1.8	17.2	1755	24
	7.0	3/6/98 7:10	3.90	1.8	49	35	188	175	2.21	1.2	16.4	1760	24.6
	7.0	3/6/98 8:15	3.80	2.4	48	36	248	238	2.17	2	16.7	1760	25
Cleaning	7.0	3/6/98 8:20	stop	a sodium bisulfite solution									
acid + alk.		3/9/98 11:00	restart										
75 u PF	7.1	3/9/98 13:00	4.00	1.6	48	47	83	72	1.98	2.1	17	1770	39.2
	7.3	3/9/98 17:45	4.00	1.6	49	48	82	70	2.06	0.5	17.8	1787	39
	7.5	3/9/98 22:05	4.00	1.6	49	49	82	71	2.21	2.9	17.1	1786	39
	7.8	3/10/98 6:50	4.00	1.6	49	50	82	72	1.9	2.1	14.6	1785	38.3
	8.1	3/10/98 13:20	4.00	1.6	48	48	81	70	2.01	2.3	17.7	1795	38.2
	8.3	3/10/98 17:35	4.00	1.6	48	48	81	70	1.89	0.8	18.5	1806	38
	8.5	3/10/98 22:10	4.00	1.6	50	50	82	71	2.09	4.3	17.4	1800	38
	8.8	3/11/98 7:00	4.00	1.6	50	50	87	76	2.04	2	16	1800	38
	9.1	3/11/98 12:45	4.00	1.6	48	47	83	71	1.85	2.5	18	1800	38
	9.2	3/11/98 16:00	4.00	1.6	47	47	81	70	1.56	1.4	19	1790	38
	9.5	3/11/98 22:00	4.00	1.6	49	48	83	71	1.75	2.4	18	1789	49
	9.9	3/12/98 8:00	4.00	1.6	50	48	86	73	1.89	3	16	1800	35
	10.2	3/12/98 15:00	4.00	1.6	48	46	81	70	1.86	4.3	18.4	1795	35
	10.8	3/13/98 7:00	4.00	1.6	50	47	85	72	1.81	2.7	17.2	1804	34
	11.3	3/13/98 17:30	4.00	1.6	48	44	81	70	1.67	0.8	18.4	1820	35
20 u PF	11.9	3/14/98 7:30	4.00	1.6	50	50	82	71	1.62	2.1	17.2	1842	35.6
	12.3	3/14/98 17:00	4.00	1.6	48	48	82	72	1.78	3	18.1	1835	35
	12.9	3/15/98 7:15	4.00	1.6	50	49	86	75	2.06	2	16.4	1828	34.1
	13.3	3/15/98 17:50	4.00	1.6	49	46	80	70	2.27	0.7	18.4	1815	34.5
	13.9	3/16/98 7:45	4.00	1.6	48	36	72	62	1.89	0.7	18	1815	38.1
	14.3	3/16/98 17:50	4.00	1.6	48	48	80	70	1.86	3.5	18.1	1812	34.8
	14.8	3/17/98 6:30	4.00	1.6	49	49	80	70	1.44	0.9	17.9	1815	35
	15.3	3/17/98 17:10	4.00	1.6	49	49	80	70	1.6	0.6	18.7	1825	35.1
	15.9	3/18/98 8:05	4.00	1.6	48	47	80	70	1.95	1	18.4	1823	34.4
	16.1	3/18/98 13:50	4.00	1.6	48	46	80	69	1.86	1.2	19.6	1823	35
	17.3	3/19/98 17:30	4.00	1.6	48	35	75	65	2.15	1	20.5	1809	38
100 u PF	17.5	3/19/98 22:10	4.00	1.6	49	50	80	70	2.46	1.3	19.3	1830	38
	17.8	3/20/98 7:00	4.00	1.6	48	48	80	70	2.09	4.3	18	1839	37
	18.2	3/20/98 16:15	4.00	1.6	48	48	80	70	1.83	2.8	18.7	1830	36

AK membrane elements with diamond shape feed channel spacer

Start time= 2/23/98 11:00

	Time in ope-		Flow rates, gpm		Pressures, psig Prefilter		Elements		Turbidit	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
	18.9	3/21/98 7:40	4.00	1.6	48	48	81	70	1.31	2.5	18.2	1808	34.8
	19.2	3/21/98 16:40	4.00	1.6	49	48	80	70	1.91	1.9	19.6	1797	35
	19.9	3/22/98 7:30	4.00	1.6	48	48	81	70	1.85	22	18	1801	33.5
	20.3	3/22/98 17:00	4.00	1.6	48	48	79	68	1.72	2.49	20.4	1180	36
	20.9	3/23/98 8:15	4.00	1.6	49	48	80	70	2.1	2	18.6	1770	35
	21.3	3/23/98 18:25	4.00	1.6	48	47	79	68	2.4	1	20.9	1797	35.9
	21.9	3/24/98 7:15	4.00	1.6	49	48	79	69	2.45	1.4	19.2	1797	36
	22.2	3/24/98 14:30	4.00	1.6	48	47	75	65	2.39	3.9	20.4	1779	37
	22.8	3/25/98 6:45	4.00	1.6	50	48	80	70	1.58	1.1	19.2	1816	37.4
	23.3	3/25/98 17:30	4.00	1.6	49	47	80	70	1.94	1	19.3	1776	34
	23.9	3/26/98 7:20	4.00	1.6	49	47	85	73	1.8	2.1	17.8	1750	32
	24.3	3/26/98 17:30	4.00	1.6	49	46	82	72	1.61	2.7	18.5	1711	31
	24.9	3/27/98 7:45	4.00	1.6	49	45	85	72	1.88	1.5	17.5	1730	30
	25.3	3/27/98 17:40	4.00	1.6	49	46	86	73	1.91	3.6	17.9	1705	30
			4.00	0.1									
			4.00	0.1									
	26.9	3/29/98 8:55	4.00	1.6	50	45	90	79	1.79	3.2	14.9	1694	26.6
	27.3	3/29/98 17:30	4.00	1.6	50	45	90	79	1.64	2.4	15.8	1648	25.5
	27.8	3/30/98 6:15	4.00	1.6	49	45	90	78	1.59	2	13.9	1799	28
	28.3	3/30/98 17:30	4.00	1.6	48	43	89	75	2.18	3.6	16.3	1692	26.8
	28.8	3/31/98 6:30	4.00	1.6	49	43	90	75	2.14	3.5	15.1	1669	28
	29.3	3/31/98 17:30	4.00	1.6	50	43	89	75	1.62	4.3	16.4	1729	27.9
	30.0	4/1/98 9:50	4.00	1.6	49	43	90	79	1.01	5.7	15	1649	28.9
	30.3	4/1/98 17:00	4.00	1.6	49	43	90	75	1.27	0.9	16.6	1635	25
	30.8	4/2/98 7:00	4.00	1.6	48	42	90	78	2.33	2.7	14.8	1619	25.7
	31.2	4/2/98 16:10	4.00	1.6	48	42	89	74	0.84	1.3	17.4	1636	26
	31.9	4/3/98 8:00	4.00	1.6	50	43	89	75	1.59	1	15.5	1664	25.1
	32.3	4/3/98 17:00	4.00	1.6	48	42	86	72	1.59	4.2	16.9	1624	25.9
	32.9	4/4/98 9:00	4.00	1.6	50	42	89	74	2.01	0.78	16.2	1659	27
	33.3	4/4/98 17:30	4.00	1.6	49	41	88	72	1.82	1.2	17.9	1659	27
	33.9	4/5/98 9:00	4.00	1.6	49	41	90	77	1.67	8.2	15.7	1648	26.5
	34.3	4/5/98 18:45	4.00	1.6	48	40	85	71	2.55	2	17.2	1704	35
	34.9	4/6/98 8:20	4.00	1.6	48	40	90	75	3	5.3	16	1707	27.3
	35.3	4/6/98 18:10	4.00	1.6	48	39	88	72	1.94	1.9	17.2	1704	28
	35.9	4/7/98 7:25	4.00	1.6	50	41	90	75	1.16	1.4	15.8	1720	27.8
	36.2	4/7/98 16:40	4.00	1.6	48	40	88	71	1.51	2	17.4	1753	29.5
	36.9	4/8/98 7:10	4.00	1.6	50	40	90	73	1.78	2	15.2	1760	30.2
	37.3	4/8/98 17:49	4.00	1.6	46	37	86	70	1	4	17.3	1766	30.9
	37.8	4/9/98 7:00	4.00	1.6	49	39	88	71	1.38	1.6	15	1685	27.4
	38.3	4/9/98 17:25	4.00	1.6	46	37	85	70	2.23	4.2	17.8	1717	28.1
	38.8	4/10/98 7:00	4.00	1.6	50	41	90	72	1.38	2.8	15.9	1704	28.3
	39.3	4/10/98 17:45	4.00	1.6	48	38	81	65	1.5	3.1	18.2	1692	30
	39.5	4/10/98 22:40	4.00	1.6	50	40	82	68	1.76	1.7	17.3	1700	29.5
	39.8	4/11/98 6:50	4.00	1.6	50	39	87	70	2.35	1.4	16.7	1711	29.5
	40.3	4/11/98 17:15	4.00	1.6	50	40	85	69	1.81	1.4	17.2	1692	29
	40.9	4/12/98 8:17	4.00	1.6	48	38	88	70	1	4.1	16.2	1680	28.8
	41.3	4/12/98 18:00	4.00	1.6	48	37	85	69	2.03	4.1	17.8	1669	28.8
	41.9	4/13/98 7:40	4.00	1.6	50	38	90	71	2.69	6.4	16.5	1731	30.7
	42.0	4/13/98 11:10											
	42.3	4/13/98 17:00	4.00	1.6	48	36	88	69	1.9	4	17.9	1678	28.6
	42.9	4/14/98 7:15	4.00	1.6	48	35	89	70	1.77	2.8	16.7	1719	28.7
Cleaning	43.2	4/14/98 16:25	4.00	1.6	48	42	77	64	2	1.5	18.7	1664	37.5
acid + alk.	43.8	4/15/98 6:40	4.00	1.6	49	41	75	63	1.84	1.2	16.1	1664	37.5

AK membrane elements with diamond shape feed channel spacer

Start time= 2/23/98 11:00

	Time in ope-ration, d	Date&Time	Flow rates, gpm Conc.	Perm.	Pressures, psig Prefilter In	Out	Elements In	Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Perm.
	44.3	4/15/98 17:45	4.00	1.6	49	40	79	65	1.98	3.9	18	1692	34.4
	44.8	4/16/98 6:30	4.00	1.6	48	38	80	68	1.58	2.6	14.9	1692	34.4
	45.3	4/16/98 17:32	4.00	1.6	48	39	79	65	1.69	4.6	18.4	1724	34.1
	45.8	4/17/98 7:03	4.00	1.6	49	40	81	70	1.5	4.1	16.1	1707	33.5
	46.3	4/17/98 19:00	4.00	1.6	48	38	79	64	2.16	3.4	18.6	1703	33
	46.9	4/18/98 7:15	4.00	1.6	50	40	82	70	1.87	4.2	16.4	1699	32.6
	47.3	4/18/98 18:30	4.00	1.6	48	38	78	62	1.97	3	19.2	1707	33
	47.8	4/19/98 7:00	4.00	1.6	50	39	80	68	2.17	3.3	16.7	1713	33.8
	48.3	4/19/98 17:30	4.00	1.6	46	36	79	62	2.33	1.4	20.1	1715	34.7
	48.9	4/20/98 8:50	4.00	1.6	48	36	81	65	2.12	2.2	18	1693	34
	49.3	4/20/98 18:00	4.00	1.6	48	38	78	61	1.4	1.8	20.3	1718	38.9
	49.9	4/21/98 7:50	4.00	1.6	50	39	82	65	2.39	3.9	18.3	1713	35.5
	50.3	4/21/98 16:50	4.00	1.6	47	35	78	60	3.36	3	20.9	1771	39.6
	50.8	4/22/98 6:25	4.00	1.6	48	36	80	60	1.96	3	20.3	1771	39.6
	51.5	4/22/98 21:48	4.00	1.6	50	42	75	60	2.66	2	20.6	1847	42.2
Cleaning	51.9	4/23/98 7:40	4.00	1.6	50	41	75	60	1.84	1.1	20.8	1810	45.5
acid + alk.	52.3	4/23/98 17:20	6.00	1.6	47	47	61	41	1.6	4.9	21.1	1774	58.8
no prefilter	52.8	4/24/98 6:50	6.00	1.6	48	48	69	49	2.11	4.3	19.8	1724	50.8
	53.3	4/24/98 18:00	6.00	1.6	48	48	69	49	1.45	3.3	21.1	1729	50
	53.8	4/25/98 6:00	6.00	1.6	48	48	72	49	2.31	1	19.6	1705	46.5
	54.3	4/25/98 17:30	6.00	1.6	48	48	70	49	2.11	2.5	20.4	1718	46.7
	54.9	4/26/98 7:25	6.00	1.6	48	48	75	52	2.19	2.2	18.3	1721	46.1
	55.2	4/26/98 16:15	6.00	1.6	48	48	70	48	1.91	2.2	20.8	1723	45.2
	55.9	4/27/98 7:35	6.00	1.6	48	48	75	52	1.98	1.8	18.7	1744	43.3
	56.3	4/27/98 17:50	6.00	1.6	48	48	72	49	1.99	2.7	21.5	1733	43.3
	56.8	4/28/98 6:40	6.00	1.6	47	47	78	51	1.61	2	18.9	1731	42.4
	57.3	4/28/98 17:20	4.00	1.6	48	48	70	51	1.7	1.8	22.1	1740	50.4
	57.8	4/29/98 6:30	4.00	1.6	50	50	70	55	2.07	0.8	19	1765	51
	58.4	4/29/98 21:11	4.00	1.6	48	48	70	52	3.6	2	21.5	1791	52.3
	58.8	4/30/98 6:40	4.00	1.6	50	50	72	55	2.54	1.5	20	1739	50.1
	59.3	4/30/98 17:11	4.00	1.6	49	49	70	52	2.21	2.5	21.7	1753	50.7
	59.8	5/1/98 7:00	4.00	1.6	50	50	74	57	1.79	2.3	20	1742	47.9
	60.4	5/1/98 19:40	4.00	1.6	48	48	71	53	1.78	2	21.6	1742	50.1
	60.8	5/2/98 6:10	4.00	1.6	48	48	73	53	1.51	1.8	19.5	1742	50.1
	61.0	5/2/98 11:40	4.00	1.6	48	48	72	55	1.45	2.2	20.7	1162	31.6
	61.9	5/3/98 9:15	4.00	1.6	48	48	71	52	1.96	2.1	21	1751	49
	62.3	5/3/98 17:21	4.00	1.6	47	47	71	51	1.93	2.6	22.2	1810	50.8
	62.9	5/4/98 8:11	4.00	1.6	49	49	78	53	2.01	2.2	20.5	1746	47.4
	64.1	5/5/98 14:10	4.00	1.6	50	50	81	55	1.86	2.1	20.9	1748	48.5
	64.3	5/5/98 18:00	4.00	1.6	49	49	81	55	1.73	2.3	21	1751	48.5
	64.9	5/6/98 7:10	4.00	1.6	49	49	85	58	1.71	2.2	20.2	1758	49
	65.2	5/6/98 16:05	4.00	1.6	48	48	85	56	1.77	2.8	21	1766	49
	65.9	5/7/98 8:15	4.00	1.6	47	47	88	60	1.59	2.3	19.9	1744	47.3
	66.3	5/7/98 18:15	6.10	2.35	46	46	120	80	1.7	1.29	20.8	1767	34.7
Cleaning	66.8	5/8/98 6:25	6.10	2.35	46	46	122	81	1.67	2	19.5	1745	33
acid + alk.		5/8/98 18:19											
	67.4	5/9/98 6:30	6.10	2.35	48	48	98	70	1	3	19.4	1745	33
	68.1	5/9/98 22:45	6.10	2.35	46	46	110	72	1.68	0.7	19.9	1745	36.1
	68.4	5/10/98 6:40	6.10	2.35	48	48	112	72	1.48	1.5	19	1711	35.3
	68.9	5/10/98 17:45	6.10	2.35	48	48	112	72	2.89	36	20.8	1742	35.9
		5/11/98 7:18											
		5/11/98 19:00											
		5/12/98 18:20											

AK membrane elements with diamond shape feed channel spacer

Start time= 2/23/98 11:00

	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Flow rates, gpm Perm.	Pressures, psig Prefilter In	Pressures, psig Prefilter Out	Pressures, psig Elements In	Pressures, psig Elements Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Cond., uS/cm Perm.
	69.6	5/13/98 7:45	6.10	2.35	47	47	110	80	1.88	1	17.8	1715	34.6
	70.0	5/13/98 16:10	6.10	2.35	46	46	112	80	1.6	4.6	18.7	1692	34
	70.6	5/14/98 7:48	6.10	2.35	49	49	121	84	1.92	4.4	17.7	1684	32
	71.3	5/14/98 22:55	6.10	2.35	48	48	121	80	1.82	2.5	18.7	1691	33.4
	71.8	5/15/98 12:20	6.10	2.35	48	48	125	81	1.63	1.4	19.3	1683	34.5
	72.1	5/15/98 18:00	6.10	2.35	48	48	125	80	1.63	1.7	20.4	1689	33.4
	72.7	5/16/98 10:15	6.10	2.35	48	47	130	82	1.58	2.1	19.1	1661	32.1
	73.1	5/16/98 18:10	6.10	2.35	47	47	130	85	1.54	4	20.4	1698	33.5
	73.7	5/17/98 9:05	6.10	2.35	48	48	135	89	1.5	2	19.1	1664	31.3
	74.1	5/17/98 17:38	6.10	2.35	47	47	132	85	1.82	5.1	21	1704	33
	74.6	5/18/98 7:25	6.10	2.35	48	48	140	90	1.6	5.2	18.7	1695	32.2
	75.1	5/18/98 17:50	6.10	2.35	47	47	138	82	2.1	2.2	21.3	1685	31.6
	75.6	5/19/98 7:19	6.10	2.35	48	48	149	91	1.88	4	19.4	1680	30.6
	76.1	5/19/98 18:10	6.10	2.35	47	47	148	88	1.94	3.1	21.4	1680	30.6
Cleaning	77.3	5/20/98 22:40	4.00	1.6	48	48	70	52	2.42	3.2	20.5	1705	54.7
acid + alk.	77.8	5/21/98 10:31	4.00	1.6	49	49	72	51	1.8	0.6	20.2	1723	53.5
	78.0	5/21/98 16:10	4.00	1.6	48	48	74	51	1.39	1.4	21.5	1723	55.6
	78.6	5/22/98 6:15	4.00	1.6	48	49	80	53	1.74	0.7	20	1700	54
	79.1	5/22/98 18:32	4.00	1.6	48	48	81	51	1.96	10	21.7	1729	53.8
	79.6	5/23/98 6:25	4.00	1.6	50	50	82	52	2.26	7.6	19.9	1710	67
	80.1	5/23/98 18:50	4.00	1.6	49	49	85	52	2.06	0.3	21.7	1667	45.3
	80.6	5/24/98 6:30	4.00	1.6	49	49	90	58	1.6	0.6	20	1670	48
	81.0	5/24/98 16:42	4.00	1.6	49	49	90	55	1.38	0.9	21.9	1702	51
	81.6	5/25/98 7:00	4.00	1.6	49	50	92	58	1.66	4.7	20.3	1679	50.3
	82.0	5/25/98 17:00	4.00	1.6	49	49	92	58	2.32	1.4	20.8	1646	49.4
	82.8	5/26/98 10:40	4.00	1.6	48	48	99	60	1.81	5	20.1	1680	48.7
	83.1	5/26/98 18:20	4.00	1.6	49	50	98	60	1.7	1.9	20.8	1612	48.9
	83.6	5/27/98 7:22	4.00	1.6	49	49	100	60	1.59	0.7	19.3	1665	46.4
	84.0	5/27/98 17:10	4.00	1.6	48	49	100	59	1.56	4.3	21	1662	50.1
	84.7	5/28/98 8:10	4.00	1.6	48	48	100	61	1.66	2	19.4	1686	50.3
	85.0	5/28/98 16:35	4.00	1.6	47	47	100	58	1.83	2.9	21.5	1650	50.5
	85.6	5/29/98 7:45	4.00	1.6	49	49	102	61	1.79	0.9	19.3	1641	49
Cleaning	86.2	5/29/98 21:00	4.00	1.6	47	47	60	48	1.94	2.6	21.2	1633	73
acid + alk.	86.6	5/30/98 7:15	4.00	1.6	49	49	68	51	1.38	1.4	19.1	1583	64
100 u PF	86.9	5/30/98 13:50	4.00	1.6	48	48	65	49	1.51	2.8	20.9	1570	60
	87.7	5/31/98 9:30	4.00	1.6	48	46	64	48	2.4	2.6	20.2	1554	57
	88.7	6/1/98 8:50	4.00	1.6	49	46	70	52	1.52	3.1	20.2	1475	56
	89.6	6/2/98 6:50	4.00	1.6	49	44	70	52	1.63	4	19.8	1523	57
	90.0	6/2/98 16:30	4.00	1.6	48	42	69	51	1.85	2.9	22	1512	55.1
	90.6	6/3/98 6:15	4.00	1.6	49	42	70	52	1.68	0	20.8	1494	54.7
	90.8	6/3/98 12:00	4.00	1.6	46	41	70	52	1.78	4.1	21.7	1476	54.2

DK membrane elements with parallel feed channel spacer

Start time=		6/3/98 14:25			Pressures, psig								
	Time in ope-		Flow rates, gpm		Prefilter		Elements		Turbidit	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
100 u PF	0.0	6/3/98 14:32	4.40	0.82	48	43	30	20	2	1	21.7	1580	800
	0.0	6/3/98 14:36	3.90	1.3	47	43	41	31	2	1	21.7	1580	800
	0.0	6/3/98 14:38	5.90	1.75	48	41	58	49	2	1	21.7	1583	800
	0.0	6/3/98 14:45	3.70	1.4	49	44	42	31	2	1	21.7	1583	800
	0.1	6/3/98 18:00	3.70	1.4	48	40	45	35	1.93	2.5	22.7	1161	858
	0.7	6/4/98 7:33	3.70	1.4	49	40	49	38	1.84	4	20.7	1402	900
	1.2	6/4/98 19:30	3.70	1.4	49	41	45	34	1.78	5.5	21.6	1716	1100
	1.7	6/5/98 8:16	3.70	1.4	48	37	50	38	2	4.9	20.3	1714	1035
	2.3	6/5/98 21:00	3.70	1.4	49	39	45	31	2.6	6.2	22	1729	1064
	2.7	6/6/98 7:00	3.70	1.4	48	37	46	32	2.54	2.6	21	1721	1059
	3.0	6/6/98 13:30	3.70	1.4	49	35	48	32	2.5	1.4	21.5	1726	1062
	3.7	6/7/98 6:45	3.70	1.4	50	34	50	35	2.37	2.9	20.5	1731	1064
	4.0	6/7/98 13:20	3.70	1.4	48	32	49	34	2.33	2.9	21.3	1753	1063
	4.8	6/8/98 9:40	3.70	1.4	48	28	50	25	2.45	2.9	20	1675	1062
New PF	5.0	6/8/98 13:40	3.70	1.4	49	48	48	34	2.55	2.9	21.5	1697	1078
	5.7	6/9/98 6:30	3.70	1.4	49	48	49	35	2.46	2.8	20.3	1697	1078
	6.1	6/9/98 17:51	3.70	1.4	49	47	50	35	2.25	2.8	21.3	1732	1100
	6.7	6/10/98 6:20	3.70	1.4	47	45	48	31	1.63	9.1	20	1712	1092
	7.1	6/10/98 15:45	3.70	1.4	48	45	49	33	2.3	2.4	21.2	1693	1084
	7.8	6/11/98 10:05	3.70	1.4	47	44	49	32	1.5	0	20.5	1693	1084
	8.0	6/11/98 14:15	3.70	1.4	48	44	48	31	1.99	3.8	20.5	1691	1092
	8.7	6/12/98 7:55	3.70	1.4	48	45	50	35	1.78	2.7	19.9	1706	1059
	9.2	6/12/98 18:10	3.70	1.4	49	43	49	32	1.97	3	20.8	1686	1085
	9.7	6/13/98 6:10	3.70	1.4	49	45	50	34	2.11	5	19.8	1692	1091
	9.9	6/13/98 13:00	3.70	1.4	48	43	49	32	2.24	2.7	20.7	1699	1097
	10.7	6/14/98 6:30	3.70	1.4	49	44	50	33	2.15	1.2	19.7	1697	1102
	11.0	6/14/98 13:20	3.70	1.4	48	43	48	32	2.27	3.8	21.4	1702	1109
	11.8	6/15/98 8:30	3.70	1.4	48	42	50	35	2.39	3.6	21.2	1702	1109
	12.0	6/15/98 15:30	3.70	1.4	48	42	49	31	2.22	3	22.9	1702	1109
	12.8	6/16/98 8:37	3.70	1.4	48	40	50	35	2.27	1.9	21.7	1707	1116
	13.1	6/16/98 18:00	3.70	1.4	47	39	50	33	2.36	3	22.2	1699	1134
	13.9	6/17/98 11:45	3.70	1.4	48	39	49	32	1.78	3.1	21.8	1705	1138
	14.1	6/17/98 16:40	3.70	1.4	47	36	50	35	1.89	3.1	22.7	1677	1102
	14.7	6/18/98 7:45	3.70	1.4	48	38	51	36	1.74	1.2	21.1	1650	1058
	15.3	6/18/98 21:00	3.70	1.4	49	36	50	33	1.7	2.9	22.6	1659	1105
	15.7	6/19/98 8:00	3.70	1.4	48	36	51	35	1.74	2.9	21.7	1665	1095
	16.0	6/19/98 15:30	3.70	1.4	47	35	50	32	2.05	3.1	23.4	1678	1142
Clean PF	16.8	6/20/98 8:40	3.70	1.4	48	38	50	35	2.74	3.4	22	1644	1113
	17.0	6/20/98 13:20	3.70	1.4	48	38	50	34	2.37	3.2	23.1	1669	1121
	17.7	6/21/98 7:20	3.70	1.4	48	36	51	35	2.32	2.9	22.5	1694	1129
	17.9	6/21/98 12:30	3.70	1.4	48	38	51	34	2.09	3.2	23.3	1687	1132
	18.9	6/22/98 12:35	3.70	1.4	48	32	50	34	1.84	3.5	23.1	1681	1135
New PF	19.7	6/23/98 6:50	5.50	2.1	47	42	88	59	1.83	7.1	22.1	1680	1090
	20.1	6/23/98 17:41	5.50	2.1	47	42	85	58	1.45	2.6	24	1696	1045
	21.1	6/24/98 16:25	5.50	2.1	48	40	89	60	2.3	2	23.9	1685	1055
	21.8	6/25/98 8:30	5.50	2.1	48	37	91	63	2.04	2.6	22	1672	1022
	22.3	6/25/98 21:10	5.50	2.1	48	41	88	60	2	3	23.5	1698	1041
	22.8	6/26/98 9:20	5.50	2.1	45	35	91	65	1.68	9.8	22.6	1724	1060
	23.1	6/26/98 15:40	5.50	2.1	47	37	90	62	1.88	4.1	24	1693	1067
	23.7	6/27/98 7:00	5.50	2.1	47	32	90	62	2.11	1.1	22.8	1687	1058
New PF	23.9	6/27/98 13:00	5.50	2.1	46	45	92	62	2.1	3.4	23.4	1681	1049
	24.8	6/28/98 8:30	5.50	2.1	47	44	98	60	1.89	3.7	21.1	1692	1054
	24.9	6/28/98 12:55	5.50	2.1	48	44	98	68	2.04	3.6	23.9	1692	1054

DK membrane elements with parallel feed channel spacer

Start time= 6/3/98 14:25

	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Flow rates, gpm Perm.	Pressures, psig Prefilter In	Pressures, psig Prefilter Out	Pressures, psig Elements In	Pressures, psig Elements Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Cond., uS/cm Perm.
	25.8	6/29/98 8:50	5.50	2.1	48	44	100	70	1.7	4.3	22.9	1692	1054
	25.9	6/29/98 12:00	5.50	2.1	47	42	99	70	1.96	1.3	24.2	1707	1062
	26.8	6/30/98 8:30	5.50	2.1	48	41	102	78	1.36	5.36	23.3	1687	1033
	27.1	6/30/98 17:30	5.50	2.1	48	41	102	72	1.69	3.8	25.3	1688	1054
	27.7	7/1/98 8:10	5.50	2.1	48	40	109	80	1.38	1.9	23.4	1714	1064
	28.3	7/1/98 20:45	5.50	2.1	48	40	102	72	1.6	1.2	24.3	1722	1083
	28.7	7/2/98 6:15	5.50	2.1	48	39	102	72	1.71	5.4	22.9	1730	1102
Cleaned	29.3	7/2/98 20:38	5.50	2.1	46	40	65	41	1.64	3.3	24	1760	1271
	29.7	7/3/98 7:45	5.50	2.1	48	40	71	49	2.11	3.1	22.9	1716	1240
	30.1	7/3/98 17:15	5.50	2.1	46	35	71	49	2.25	3.2	24.1	1733	1234
	30.9	7/4/98 11:25	5.50	2.1	48	46	79	50	1.88	4.1	22.5	1702	1197
	31.8	7/5/98 8:50	5.50	2.1	48	33	82	55	2.3	4.6	22.1	1718	1213
wash PF	32.0	7/5/98 13:20	5.50	2.1	48	38	80	52	2.19	3.3	23.5	1705	1196
	32.9	7/6/98 12:00	5.50	2.1	47	32	80	50	2.5	3.2	24	1693	1179
	33.7	7/7/98 8:10	5.50	2.1	46	43	88	60	2.3	3.3	23.4	1731	1170
	34.1	7/7/98 17:35	5.50	2.1	48	44	88	58	1.85	3.2	25.7	1709	1202
	34.9	7/8/98 12:20	5.50	2.1	47	41	88	58	1.91	2.9	25	1696	1171
	35.0	7/8/98 15:30	5.50	2.1	48	41	88	58	1.74	1.8	25.7	1683	1153
	35.7	7/9/98 8:04	5.50	2.1	48	40	96	62	2.44	3.4	24	1669	1135
	36.1	7/9/98 17:30	5.50	2.1	46	37	92	61	2.18	7.3	26.2	1701	1176
	36.8	7/10/98 10:00	5.50	2.1	47	36	100	68	2.52	2.6	24.5	1692	1134
	37.2	7/10/98 18:24	5.50	2.1	47	35	100	66	2.35	3	26.1	1707	1153
Cleaning	37.7	7/11/98 6:40	5.50	2.1	48	34	100	69	2.31	3.4	23.6	1697	1174
New PF	37.9	7/11/98 11:40	5.50	2.1	47	46	69	42	2.34	4.1	25	1695	1202
	38.7	7/12/98 6:50	5.50	2.1	49	47	80	50	2.3	5	23.6	1695	1202
	38.9	7/12/98 12:45	5.50	2.1	48	45	82	52	2.35	0	24	1695	1202
	39.7	7/13/98 6:15	5.50	2.1	48	44	98	62	2.67	3	23.4	1687	1209
	39.9	7/13/98 12:50	5.50	2.1	47	43	101	68	2.65	4.4	24.4	1679	1215
	40.9	7/14/98 11:05	5.50	2.1	47	41	121	88	2.54	3.2	23.7	1728	1206
	41.3	7/14/98 21:00	5.50	2.1	47	40	132	98	2.53	1.8	25	1704	1224
Shut down	41.7	7/15/98 6:33	5.50	2.1	49	41	139	100	3.14	5.4	23.4	1705	1196
New PF	41.7	7/16/98 19:47	5.50	2.1	48	46	75	48	2.53	1.6	28.6	1705	1196
	41.8	7/16/98 22:05	5.50	2.1	48	47	79	49	2.37	7	26.7	1705	1196
	42.3	7/17/98 10:35	5.50	2.1	48	46	88	52	1.5	4.7	25.7	1736	1241
	42.6	7/17/98 18:17	5.50	2.1	48	46	89	51	1.31	3	28.1	1736	1241
	43.6	7/18/98 18:50	5.50	2.1	48	46	99	62	1.81	1.8	25.5	1736	1241
	44.1	7/19/98 6:50	5.50	2.1	49	45	108	70	1.72	5.8	25.3	1739	1231
	44.4	7/19/98 12:50	5.50	2.1	48	44	110	70	1.64	5.9	26.6	1743	1253
	45.3	7/20/98 10:12	5.50	2.1	48	44	90	54	2.01	2.5	26.2	1747	1275
	45.4	7/20/98 13:15	5.50	2.1	48	44	91	55	3.26	5.5	26.3	1754	1272
	46.3	7/21/98 10:45	5.50	2.1	48	44	90	51	2.37	3.7	25.4	1761	1269
	46.7	7/21/98 21:00	5.50	2.1	48	44	92	55	1.51	4.8	26	1733	1240
	47.3	7/22/98 11:00	5.50	2.1	48	42	100	62	1.61	1.9	25	1720	1211
	47.5	7/22/98 14:15	5.50	2.1	48	42	101	64	1.44	2.1	25.5	1720	1211
	48.2	7/23/98 8:05	5.50	2.1	48	42	112	72	2.01	4	25.1	1711	1187
	48.6	7/23/98 17:54	5.50	2.1	48	41	113	72	1.78	3.9	26.1	1733	1200
	49.2	7/24/98 9:00	5.50	2.1	49	40	125	82	1.95	4.2	24.4	1699	1177
	49.6	7/24/98 18:27	5.50	2.1	48	40	125	85	1.45	2.7	25.9	1740	1184
	50.2	7/25/98 8:05	5.50	2.1	49	40	139	99	1.59	2.9	24.2	1704	1161
	50.4	7/25/98 12:13	5.50	2.1	48	39	139	99	1.57	2.1	25.3	1711	1167
	51.2	7/26/98 9:17	5.50	2.1	49	39	149	105	1.73	3.1	24.7	1718	1173
	51.4	7/26/98 13:18	5.50	2.1	47	37	149	102	2.4	4	26.2	1719	1165
	52.2	7/27/98 8:56	5.50	2.1	49	38	155	112	1.9	1.7	25.1	1719	1165
	52.4	7/27/98 13:22	5.50	2.1	47	37	155	112	1.82	0	26.8	1719	1165

DK membrane elements with parallel feed channel spacer

Start time= 6/3/98 14:25

	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Flow rates, gpm Perm.	Pressures, psig Prefilter In	Pressures, psig Prefilter Out	Pressures, psig Elements In	Pressures, psig Elements Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Cond., uS/cm Perm.
Cleaned	53.7	7/28/98 20:05	5.50	2.1	47	46	62	32	1.47	0	27.7	1721	1284
New PF	54.2	7/29/98 7:30	5.50	2.1	49	47	77	40	1.68	0	25.3	1696	1280
	54.6	7/29/98 18:00	5.50	2.1	48	46	79	40	1.23	0	27.3	1720	1268
	55.2	7/30/98 7:10	5.50	2.1	49	45	89	48	1.56	0	24.9	1726	1263
	55.6	7/30/98 16:50	5.50	2.1	48	43	89	49	1.31	3.3	27	1734	1263
	56.2	7/31/98 7:50	5.50	2.1	49	45	91	50	1.24	0	24.1	1744	1257
	56.5	7/31/98 15:15	5.50	2.1	48	42	90	50	1.27	2.5	27.5	1746	1252
	57.2	8/1/98 8:25	5.50	2.1	49	44	99	59	1.71	1.7	23.8	1743	1253
	57.4	8/1/98 12:55	5.50	2.1	48	42	100	59	2.07	2.5	25.5	1758	1253
	58.3	8/2/98 9:30	5.50	2.1	49	42	109	68	1.7	4.5	21.9	1772	1253
	59.2	8/3/98 7:40	5.50	2.1	49	41	119	75	1.79	1.7	23.2	1760	1270
	60.2	8/4/98 8:20	5.50	2.1	48	38	132	83	2.02	3	25.1	1749	1260
Cleaned	61.2	8/5/98 9:20	5.50	2.1	50	38	62	32	2.2	3.5	24.9	1749	1260
	61.5	8/5/98 15:48	5.30	2.1	48	36	61	30	2.09	1.6	26.7	1758	1293
	62.1	8/6/98 6:30	5.50	2.1	49	34	70	35	2.8	5	24.6	1761	1301
	62.4	8/6/98 13:20	5.70	2.1	48	36	69	33	2.58	5.8	26.1	1745	1281
	63.1	8/7/98 6:35	5.50	2.1	49	32	72	38	2.47	0.9	24.4	1729	1259
New PF	64.1	8/8/98 6:50	5.50	2.1	49	46	81	41	2.79	0	24.2	1744	1283
	65.2	8/9/98 7:10	5.50	2.1	48	36	95	50	1.7	2.3	24.8	1800	1295
	66.2	8/10/98 7:15	5.50	2.1	49	35	101	51	1.69	2.2	25.6	1765	1286
Cleaned	66.4	8/10/98 13:15	5.20	2.2	49	47	61	29	1.89	1	27	1772	1273
New PF	67.1	8/11/98 7:00	5.50	2.1	48	46	70	30	1.38	3.1	25.9	1780	1264
	67.7	8/11/98 19:25	3.70	1.4	49	47	41	20	1.52	1.1	28.3	1760	1394
	68.6	8/12/98 18:45	3.70	1.4	49	46	44	20	2.02	5.3	28.5	1740	1370
	69.1	8/13/98 6:30	3.70	1.4	48	46	48	20	2.2	3.7	26.1	1726	1352
	69.4	8/13/98 13:45	3.70	1.4	48	43	49	20	2.14	3.9	27.8	1720	1350
	70.2	8/14/98 8:30	3.70	1.4	49	45	51	21	2.2	6.3	25.9	1720	1350
	70.4	8/14/98 12:35	3.70	1.4	49	45	50	22	2.2	3.3	27.1	1713	1347
	71.1	8/15/98 6:50	3.70	1.4	50	45	52	25	2.74	1.5	25.4	1730	1350
	71.3	8/15/98 11:48	3.70	1.4	49	44	51	23	2.42	1.3	25.1	1717	1340
	72.2	8/16/98 7:25	3.70	1.4	50	43	58	28	2.08	4.8	24.3	1703	1330
	72.4	8/16/98 13:05	3.70	1.4	49	42	58	28	2	4	25.3	1705	1322
	73.2	8/17/98 7:45	3.70	1.4	49	42	61	30	1.9	3.4	24.2	1708	1315
	73.4	8/17/98 14:05	3.70	1.4	49	41	62	30	1.85	1.5	25.2	1724	1330
	74.2	8/18/98 7:12	3.70	1.4	49	40	70	35	1.79	5.5	23.9	1740	1345
	74.6	8/18/98 18:25	3.70	1.4	49	41	65	32	1.65	1.7	26	1748	1369
	75.1	8/19/98 7:00	3.70	1.4	50	40	75	40	1.77	3.6	23.5	1733	1362
	75.3	8/19/98 10:05	3.70	1.4	49	39	73	39	1.97	1.7	25	1733	1362
	75.3	8/19/98 10:15	3.70	1.4	49	39	61	30	1.97	1.7	25	1733	1362
	75.5	8/19/98 15:25	3.70	1.4	47	38	64	41	2.02	4.5	25.2	1745	1376
	75.6	8/19/98 17:30	3.70	1.4	49	40	68	41	2.14	3.5	25.6	1745	1370
Start twice	76.2	8/20/98 7:20	3.70	1.4	49	40	72	40	1.88	3.3	22.8	1710	1305
daily shut-	76.2	8/20/98 7:45	3.70	1.4	49	40	61	30	1.95	3.1	22.8	1710	1305
downs for	76.7	8/20/98 19:15	3.70	1.4	48	38	69	32	1.73	1.9	25.4	1717	1328
10 min	76.7	8/20/98 19:45	3.70	1.4	49	40	61	24	1.75	1.4	25	1717	1328
	77.1	8/21/98 6:40	3.70	1.4	49	38	70	34	1.76	1.3	23.1	1717	1328
	77.5	8/21/98 14:28	3.70	1.4	48	37	70	35	1.37	0	25.5	1712	1329
	78.2	8/22/98 7:40	3.70	1.4	50	38	73	39	1.79	1.5	23.6	1707	1330
	78.2	8/22/98 8:05	3.60	1.4	49	40	65	34	1.81	2.3	23.8	1707	1330
	78.4	8/22/98 12:00	3.30	1.4	45	37	56	31	1.73	1.6	28.5	1707	1330
	79.1	8/23/98 5:45	3.70	1.4	50	37	60	30	2.51	5.9	21.7	1707	1364
	79.1	8/23/98 6:30	3.70	1.4	48	40	60	29	1.78	1.2	21.7	1707	1364
	79.6	8/23/98 16:50	3.50	1.4	48	37	63	28	1.46	5.2	27.3	1710	1354
	79.6	8/23/98 17:50	3.40	1.4	48	40	53	25	1.48	3.7	27.3	1710	1354

DK membrane elements with parallel feed channel spacer

Start time=		6/3/98 14:25			Pressures, psig								
	Time in ope-		Flow rates, gpm		Prefilter		Elements		Turbidit	NH2Cl	Feed Te	Cond., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
	80.1	8/24/98 6:35	3.50	1.4	49	38	67	31	1.99	4.1	24.5	1714	1343
	80.2	8/24/98 7:20	3.70	1.4	49	39	63	29	2.12	6.4	24.4	1714	1343
	80.4	8/24/98 13:00	3.70	1.4	48	36	65	29	1.98	4.5	25.7	1714	1343
	80.4	8/24/98 13:40	3.70	1.4	49	39	60	28	2.06	3	26	1714	1343
	81.1	8/25/98 7:00	3.70	1.4	49	36	75	35	2.5	3.7	24.4	1686	1315
	81.2	8/25/98 7:20	3.70	1.4	49	40	62	30	2.46	2.7	24.6	1686	1315
	81.4	8/25/98 13:45	3.70	1.4	48	35	70	30	2.64	1.4	25.8	1715	1345
	81.6	8/25/98 18:05	3.70	1.4	48	36	72	32	2.64	2.1	26.7	1743	1377
	81.6	8/25/98 19:00	3.50	1.4	49	38	63	30	2.65	2.1	26.2	1743	1377
	82.2	8/26/98 7:10	3.50	1.4	49	35	72	35	2.12	4.1	24.6	1718	1300
	82.2	8/26/98 7:30	3.70	1.4	49	37	68	31	2.15	2.7	24.6	1718	1300
	82.4	8/26/98 13:25	3.70	1.4	49	35	71	32	1.79	3.5	25.8	1770	1312
	82.6	8/26/98 16:45	3.60	1.4	48	34	75	44	1.74	6.4	26.9	1823	1392
	82.6	8/26/98 17:15	3.50	1.4	48	36	65	32	1.7	1.9	27	1823	1392
	83.1	8/27/98 6:45	3.60	1.35	49	34	75	35	1.89	5.9	24.1	1737	1298
	83.2	8/27/98 8:20	3.50	1.4	49	38	65	31	1.89	5.9	24.1	1737	1298
	83.6	8/27/98 18:00	3.50	1.4	48	34	70	30	1.68	4.5	27.1	1730	1278
	83.7	8/27/98 20:38	3.60	1.4	48	36	70	32	1.67	4	26.2	1730	1278
	84.2	8/28/98 8:00	3.50	1.4	49	33	78	38	2.5	1.38	24	1730	1278
	84.3	8/28/98 9:30	3.70	1.4	48	36	69	30	2.4	1.51	24.4	1730	1278
	84.5	8/28/98 16:35	3.70	1.3	48	34	68	30	1.94	3.1	27.2	1724	1354
	84.6	8/28/98 17:20	3.70	1.4	48	36	63	30	1.9	4.4	27.3	1724	1354
	85.1	8/29/98 7:00	3.60	1.2	50	33	68	29	2.05	6.9	25	1701	1359
	85.2	8/29/98 8:10	3.70	1.4	49	35	69	30	1.98	3.5	25.5	1701	1359
New PF	85.4	8/29/98 12:30	3.50	1.3	48	32	65	28	1.89	2.7	27.5	1701	1359
	85.5	8/30/98 11:30	3.30	1.4	48	48	50	21	1.76	1.5	28.5	1705	1328
	86.4	8/31/98 8:50	3.50	1.4	48	46	67	27	2.27	5	26.3	1705	1328

DK membrane elements with diamond shape feed channel spacer

	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Flow rates, gpm Perm.	Pressures, psig Prefilter In	Pressures, psig Prefilter Out	Pressures, psig Elements In	Pressures, psig Elements Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Cond., uS/cm Perm.
Start time=		6/3/98 14:25											
100 u PF	0.0	6/3/98 14:32	4.70	1.19	47	44	40	25	2	1	21.7	1580	800
	0.0	6/3/98 14:36	4.20	1.6	48	43	48	36	2	1	21.7	1580	800
	0.0	6/3/98 14:38	5.80	2.28	48	41	68	49	2	1	21.7	1583	800
	0.0	6/3/98 14:45	4.00	1.6	48	44	47	34	2	1	21.7	1583	800
	0.1	6/3/98 18:00	4.00	1.6	48	39	49	35	1.93	2.5	22.7	1161	694
	0.7	6/4/98 7:33	4.00	1.6	48	38	50	38	1.84	4	20.7	1402	718
	1.2	6/4/98 19:30	4.00	1.6	49	39	49	35	1.78	5.5	21.6	1716	800
	1.7	6/5/98 8:16	4.00	1.6	48	35	50	39	2	4.9	20.3	1714	833
	2.3	6/5/98 21:00	4.00	1.6	49	38	49	35	2.6	6.2	22	1729	854
	2.7	6/6/98 7:00	4.00	1.6	49	35	50	37	2.54	2.6	21	1721	856
	3.0	6/6/98 13:30	4.00	1.6	48	32	49	35	2.5	1.4	21.5	1726	864
	3.7	6/7/98 6:45	4.00	1.6	48	29	50	39	2.37	2.9	20.5	1731	871
	4.0	6/7/98 13:20	4.00	1.6	48	27	50	37	2.33	2.9	21.3	1753	873
	4.8	6/8/98 9:40	4.00	1.6	48	20	50	39	2.45	2.9	20	1675	874
New PF	5.0	6/8/98 13:40	4.00	1.6	48	48	51	40	2.55	2.9	21.5	1697	890
	5.7	6/9/98 6:30	4.00	1.6	48	46	50	38	2.46	2.8	20.3	1697	890
	6.1	6/9/98 17:51	4.00	1.6	49	47	50	39	2.25	2.8	21.3	1732	906
	6.7	6/10/98 6:20	4.00	1.6	47	45	50	35	1.63	9.1	20	1712	905
	7.1	6/10/98 15:45	4.00	1.6	48	47	49	34	2.3	2.4	21.2	1693	904
	7.8	6/11/98 10:05	4.00	1.6	47	45	50	35	1.5	0	20.5	1693	904
	8.0	6/11/98 14:15	4.00	1.6	48	44	49	35	1.99	3.8	20.5	1691	908
	8.7	6/12/98 7:55	4.00	1.6	49	45	51	38	1.78	2.7	19.9	1706	896
	9.2	6/12/98 18:10	4.00	1.6	49	45	50	35	1.97	3	20.8	1686	899
	9.7	6/13/98 6:10	4.00	1.6	49	45	51	38	2.11	5	19.8	1692	908
	9.9	6/13/98 13:00	4.00	1.6	48	43	50	35	2.24	2.7	20.7	1699	916
	10.7	6/14/98 6:30	4.00	1.6	49	44	51	38	2.15	1.2	19.7	1697	912
	11.0	6/14/98 13:20	4.00	1.6	48	42	50	35	2.27	3.8	21.4	1702	927
	11.8	6/15/98 8:30	4.00	1.6	48	41	50	36	2.39	3.6	21.2	1702	927
	12.0	6/15/98 15:30	4.00	1.6	47	41	50	35	2.22	3	22.9	1702	927
	12.8	6/16/98 8:37	4.00	1.6	48	39	51	38	2.27	1.9	21.7	1707	941
	13.1	6/16/98 18:00	4.00	1.6	47	38	51	36	2.36	3	22.2	1699	954
	13.9	6/17/98 11:45	4.00	1.6	47	37	50	35	1.78	3.1	21.8	1705	959
	14.1	6/17/98 16:40	4.00	1.6	44	38	50	35	1.89	3.1	22.7	1677	933
	14.7	6/18/98 7:45	4.00	1.6	48	36	51	37	1.74	1.2	21.1	1650	905
	15.3	6/18/98 21:00	4.00	1.6	46	35	50	35	1.7	2.9	22.6	1659	949
	15.7	6/19/98 8:00	4.00	1.6	49	35	51	36	1.74	2.9	21.7	1665	925
	16.0	6/19/98 15:30	4.00	1.6	47	33	50	33	2.05	3.1	23.4	1678	1018
Clean PF	16.8	6/20/98 8:40	4.00	1.6	49	36	51	37	2.74	3.4	22	1644	943
	17.0	6/20/98 13:20	4.00	1.6	48	34	50	34	2.37	3.2	23.1	1669	958
	17.7	6/21/98 7:20	4.00	1.6	48	32	51	35	2.32	2.9	22.5	1694	972
New PF	17.9	6/21/98 12:30	4.00	1.6	48	48	51	33	2.09	3.2	23.3	1687	979
	18.9	6/22/98 12:35	4.00	1.6	47	46	51	35	1.84	3.5	23.1	1681	987
	19.7	6/23/98 6:50	6.00	2.4	48	41	81	52	1.83	7.1	22.1	1680	858
	20.1	6/23/98 17:41	6.00	2.4	47	40	82	51	1.45	2.6	24	1696	860
	21.1	6/24/98 16:25	6.00	2.4	48	38	79	50	2.3	2	23.9	1685	883
	21.8	6/25/98 8:30	6.00	2.4	48	36	81	51	2.04	2.6	22	1672	854
	22.3	6/25/98 21:10	6.00	2.4	48	41	81	50	2	3	23.5	1698	870
	22.8	6/26/98 9:20	6.00	2.4	45	34	80	50	1.68	9.8	22.6	1724	888
	23.1	6/26/98 15:40	6.00	2.4	47	34	79	49	1.88	4.1	24	1693	904
	23.7	6/27/98 7:00	6.00	2.4	47	30	88	55	2.11	1.1	22.8	1687	897
New PF	23.9	6/27/98 13:00	6.00	2.4	46	45	82	52	2.1	3.4	23.4	1681	890
	24.8	6/28/98 8:30	6.00	2.4	47	44	89	59	1.89	3.7	21.1	1692	872
	24.9	6/28/98 12:55	6.00	2.4	48	44	88	58	2.04	3.6	23.9	1692	872

DK membrane elements with diamond shape feed channel spacer

					Pressures, psig								
Start time=		6/3/98 14:25											
	Time in operation, d	Date&Time	Flow rates, gpm Conc.	Perm.	Prefilter In	Out	Elements In	Out	Turbidit NTU	NH2Cl mg/l	Feed Te deg.C	Cond., uS/cm Feed	Perm.
	25.8	6/29/98 8:50	6.00	2.4	48	44	90	59	1.7	4.3	22.9	1692	872
	25.9	6/29/98 12:00	6.00	2.4	47	42	80	58	1.96	1.3	24.2	1707	893
	26.8	6/30/98 8:30	6.00	2.4	48	41	91	60	1.36	5.36	23.3	1687	867
	27.1	6/30/98 17:30	6.00	2.4	48	40	89	58	1.69	3.8	25.3	1688	884
	27.7	7/1/98 8:10	6.00	2.4	48	38	92	61	1.38	1.9	23.4	1714	893
	28.3	7/1/98 20:45	6.00	2.4	47	37	90	60	1.6	1.2	24.3	1722	913
	28.7	7/2/98 6:15	6.00	2.4	48	36	90	60	1.71	5.4	22.9	1730	934
Cleaned	29.3	7/2/98 20:38	6.00	2.4	46	38	60	42	1.64	3.3	24	1760	1173
	29.7	7/3/98 7:45	6.00	2.4	47	34	63	38	2.11	3.1	22.9	1716	1127
New PF	30.1	7/3/98 17:15	6.00	2.4	45	45	62	38	2.25	3.2	24.1	1733	1117
	30.9	7/4/98 11:25	6.00	2.4	48	46	69	45	1.88	4.1	22.5	1702	1093
	31.8	7/5/98 8:50	6.00	2.4	48	44	70	40	2.3	4.6	22.1	1718	1074
	32.0	7/5/98 13:20	6.00	2.4	48	44	70	40	2.19	3.3	23.5	1705	1074
	32.9	7/6/98 12:00	6.00	2.4	46	41	70	40	2.5	3.2	24	1693	1073
	33.7	7/7/98 8:10	6.00	2.4	47	38	75	45	2.3	3.3	23.4	1731	1039
	34.1	7/7/98 17:35	6.00	2.4	48	38	71	40	1.85	3.2	25.7	1709	1099
	34.9	7/8/98 12:20	6.00	2.4	47	33	72	40	1.91	2.9	25	1696	1030
	35.0	7/8/98 15:30	6.00	2.4	48	33	72	40	1.74	1.8	25.7	1683	1027
New PF	35.7	7/9/98 8:04	6.00	2.4	47	46	74	42	2.44	3.4	24	1669	1024
	36.1	7/9/98 17:30	6.00	2.4	46	43	72	40	2.18	7.3	26.2	1701	1075
	36.8	7/10/98 10:00	6.00	2.4	47	43	78	43	2.52	2.6	24.5	1692	1026
	37.2	7/10/98 18:24	6.00	2.4	48	43	75	41	2.35	3	26.1	1707	1046
Cleaned	37.7	7/11/98 6:40	6.00	2.4	47	42	75	42	2.31	3.4	23.6	1697	1079
New PF	37.9	7/11/98 11:40	5.70	2.4	47	46	57	31	2.34	4.1	25	1695	1150
	38.7	7/12/98 6:50	6.00	2.4	49	47	62	35	2.3	5	23.6	1695	1150
	38.9	7/12/98 12:45	6.00	2.4	48	45	62	35	2.35	0	24	1695	1150
	39.7	7/13/98 6:15	6.00	2.4	48	42	70	40	2.67	3	23.4	1687	1135
	39.9	7/13/98 12:50	6.00	2.4	47	39	71	40	2.65	4.4	24.4	1679	1119
	40.9	7/14/98 11:05	6.00	2.4	46	36	79	49	2.54	3.2	23.7	1728	1102
	41.3	7/14/98 21:00	6.00	2.4	47	34	80	48	2.53	1.8	25	1704	1126
	41.7	7/15/98 6:33	6.00	2.4	49	34	81	49	3.14	5.4	23.4	1705	1106
New PF	41.7	7/16/98 19:47	5.10	2.4	48	48	60	0	2.53	1.6	28.6	1705	1106
Cleaned	41.8	7/16/98 22:05	6.00	2.4	48	48	61	49	2.37	7	26.7	1705	1106
	42.3	7/17/98 10:35	6.00	2.4	48	47	65	48	1.5	4.7	25.7	1736	1182
	42.6	7/17/98 18:17	6.00	2.4	48	46	65	49	1.31	3	28.1	1736	1182
	43.6	7/18/98 18:50	6.00	2.4	48	46	68	43	1.81	1.8	25.5	1736	1182
	44.1	7/19/98 6:50	6.00	2.4	49	44	70	43	1.72	5.8	25.3	1739	1157
	44.4	7/19/98 12:50	6.00	2.4	48	44	70	47	1.64	5.9	26.6	1743	1177
	45.3	7/20/98 10:12	6.00	2.4	48	44	62	44	2.01	2.5	26.2	1747	1195
	45.4	7/20/98 13:15	6.00	2.4	48	44	63	45	3.26	5.5	26.3	1754	1193
	46.3	7/21/98 10:45	6.00	2.4	48	44	64	45	2.37	3.7	25.4	1761	1191
	46.7	7/21/98 21:00	6.00	2.4	48	43	68	42	1.51	4.8	26	1733	1153
	47.3	7/22/98 11:00	6.00	2.4	48	42	70	42	1.61	1.9	25	1720	1119
	47.5	7/22/98 14:15	6.00	2.4	48	42	70	44	1.44	2.1	25.5	1720	1119
	48.2	7/23/98 8:05	6.00	2.4	48	41	72	43	2.01	4	25.1	1711	1102
	48.6	7/23/98 17:54	6.00	2.4	49	40	72	45	1.78	3.9	26.1	1733	1120
	49.2	7/24/98 9:00	6.00	2.4	49	40	78	43	1.95	4.2	24.4	1699	1076
	49.6	7/24/98 18:27	6.00	2.4	49	39	78	45	1.45	2.7	25.9	1740	1079
	50.2	7/25/98 8:05	6.00	2.4	49	38	80	42	1.59	2.9	24.2	1704	1075
	50.4	7/25/98 12:13	6.00	2.4	48	37	80	45	1.57	2.1	25.3	1711	1086
	51.2	7/26/98 9:17	6.00	2.4	49	37	80	42	1.73	3.1	24.7	1718	1097
	51.4	7/26/98 13:18	6.00	2.4	47	35	80	49	2.4	4	26.2	1719	1090
	52.2	7/27/98 8:56	6.00	2.4	48	35	82	45	1.9	1.7	25.1	1719	1084
	52.4	7/27/98 13:22	6.00	2.4	48	35	82	49	1.82	0	26.8	1719	1084

DK membrane elements with diamond shape feed channel spacer

	Start time=	6/3/98 14:25			Pressures, psig								
	Time in ope-		Flow rates, gpm		Prefilter		Elements		Turbidit	NH2Cl	eed Tem	d., uS/cm	
	ration, d	Date&Time	Conc.	Perm.	In	Out	In	Out	NTU	mg/l	deg.C	Feed	Perm.
New PF	53.7	7/28/98 20:05	6.00	2.4	47	45	80	46	1.47	0	27.7	1721	1121
	54.2	7/29/98 7:30	6.00	2.4	48	46	90	43	1.68	0	25.3	1696	1114
	54.6	7/29/98 18:00	6.00	2.4	48	45	91	45	1.23	0	27.3	1720	1118
	55.2	7/30/98 7:10	6.00	2.4	49	44	99	42	1.56	0	24.9	1726	1153
Cleaned	55.6	7/30/98 16:50	6.00	2.4	48	46	64	43	1.31	3.3	27	1734	1224
	56.2	7/31/98 7:50	6.00	2.4	49	45	68	42	1.24	0	24.1	1744	1212
	56.5	7/31/98 15:15	6.00	2.4	48	42	67	45	1.27	2.5	27.5	1746	1201
	57.2	8/1/98 8:25	6.00	2.4	49	43	78	42	1.71	1.7	23.8	1743	1185
	57.4	8/1/98 12:55	6.00	2.4	48	42	75	48	2.07	2.5	25.5	1758	1199
	58.3	8/2/98 9:30	6.00	2.4	49	42	80	42	1.7	4.5	21.9	1772	1212
	59.2	8/3/98 7:40	6.00	2.4	49	40	88	42	1.79	1.7	23.2	1760	1198
	60.2	8/4/98 9:00	6.00	2.4	48	36	97	43	2.02	3	25.1	1749	1193
Cleaned	61.5	8/5/98 15:48	5.00	2.4	48	44	43	41	2.09	1.6	26.7	1758	1299
New PF	62.1	8/6/98 6:30	4.90	2.4	49	41	50	40	2.8	5	24.6	1761	1263
	62.4	8/6/98 13:20	4.90	2.4	48	42	51	45	2.58	5.8	26.1	1745	1249
	63.1	8/7/98 6:35	5.10	2.4	48	38	60	41	2.47	0.9	24.4	1729	1235
	64.1	8/8/98 6:50	5.40	2.4	49	35	70	41	2.79	0	24.2	1744	1239
	65.2	8/9/98 7:10	5.50	2.4	48	17	86	42	1.7	2.3	24.8	1800	1250
New PF	66.2	8/10/98 7:15	5.70	2.5	49	47	92	42	1.69	2.2	25.6	1765	1241
	66.5	8/10/98 15:00	4.80	2.6	49	49	61	48	1.89	1	27	1772	1273
	67.1	8/11/98 7:00	4.90	2.4	48	47	72	42	1.38	3.1	25.9	1780	1304
	67.7	8/11/98 19:25	4.00	1.6	49	47	50	45	1.52	1.1	28.3	1760	1345
	68.6	8/12/98 18:45	4.00	1.6	49	46	52	45	2.02	5.3	28.5	1740	1317
	69.1	8/13/98 6:30	4.00	1.6	48	46	58	42	2.2	3.7	26.1	1726	1281
	69.4	8/13/98 13:45	4.00	1.6	48	45	57	45	2.14	3.9	27.8	1720	1280
	70.2	8/14/98 8:30	4.00	1.6	49	45	61	42	2.2	6.3	25.9	1720	1280
	70.4	8/14/98 12:35	4.00	1.6	48	44	61	45	2.2	3.3	27.1	1713	1278
	71.1	8/15/98 6:50	4.00	1.6	50	45	65	41	2.74	1.5	25.4	1730	1270
	71.3	8/15/98 11:48	4.00	1.6	49	43	64	44	2.42	1.3	25.1	1717	1265
	72.2	8/16/98 7:25	4.00	1.6	49	43	70	41	2.08	4.8	24.3	1703	1260
	72.4	8/16/98 13:05	4.00	1.6	49	42	69	42	2	4	25.3	1705	1258
	73.2	8/17/98 7:45	4.00	1.6	49	41	75	41	1.9	3.4	24.2	1708	1256
	73.4	8/17/98 14:05	4.00	1.6	49	41	75	42	1.85	1.5	25.2	1724	1270
	74.2	8/18/98 7:12	4.00	1.6	49	40	78	41	1.79	5.5	23.9	1740	1285
	74.6	8/18/98 18:25	4.00	1.6	49	40	79	29	1.65	1.7	26	1748	1300
	75.1	8/19/98 7:00	4.00	1.6	50	40	88	38	1.77	3.6	23.5	1733	1280
	75.3	8/19/98 9:40	4.00	1.6	49	39	89	39	1.97	1.7	25	1733	1280
	75.3	8/19/98 10:00	4.00	1.6	49	39	70	19	1.97	1.7	25	1733	1280
	75.5	8/19/98 15:25	4.00	1.6	47	37	80	20	2.02	4.5	25.2	1745	1330
Cleaning	75.6	8/19/98 17:30	4.00	1.6	49	44	51	16	2.14	3.5	25.6	1745	1330
Start twice	76.2	8/20/98 7:20	4.00	1.6	49	40	62	16	1.88	3.3	22.8	1710	1300
daily shut-	76.2	8/20/98 7:45	4.00	1.6	49	43	52	15	1.95	3.1	22.8	1710	1300
downs for	76.7	8/20/98 19:15	3.60	1.6	49	40	65	15	1.73	1.9	25.4	1717	1297
10 min	76.7	8/20/98 19:45	3.50	1.6	49	42	59	15	1.75	1.4	25	1717	1297
	77.1	8/21/98 6:40	3.80	1.6	49	39	69	16	1.76	1.3	23.1	1717	1297
	77.5	8/21/98 14:28	3.70	1.6	48	38	70	16	1.37	0	25.5	1712	1292
	78.2	8/22/98 7:40	3.80	1.6	49	38	80	17	1.79	1.5	23.6	1707	1287
	78.2	8/22/98 8:05	3.60	1.6	49	41	68	16	1.81	2.3	23.8	1707	1287
	78.4	8/22/98 12:00	3.80	1.6	46	38	65	17	1.73	1.6	28.5	1707	1287
	79.1	8/23/98 5:45	3.70	1.6	50	37	80	17	2.51	5.9	21.7	1707	1293
	79.1	8/23/98 6:30	3.70	1.6	50	38	78	15	1.78	1.2	21.7	1707	1293
	79.6	8/23/98 16:50	3.60	1.6	48	37	75	16	1.46	5.2	27.3	1710	1285
	79.6	8/23/98 17:50	3.60	1.6	48	40	65	16	1.48	3.7	27.3	1710	1285
	80.1	8/24/98 6:35	3.30	1.6	50	37	80	17	1.99	4.1	24.5	1714	1278

DK membrane elements with diamond **shape feed channel spacer**

Start time=	6/3/98 14:25		**Pressures, psig**									
Time in ope-		**Flow rates, gpm**		**Prefilter**		**Elements**		**Turbidit**	**NH2Cl**	**eed Tem**	**d., uS/cm**	
ration, d	Date&Time	**Conc.**	**Perm.**	**In**	**Out**	**In**	**Out**	**NTU**	**mg/l**	**deg.C**	**Feed**	**Perm.**
80.2	8/24/98 7:20	3.60	1.6	49	40	70	16	2.12	6.4	24.4	1714	1278
80.4	8/24/98 13:00	3.60	1.6	48	38	79	16	1.98	4.5	25.7	1714	1278
80.4	8/24/98 13:40	3.70	1.6	48	39	70	16	2.06	3	26	1714	1278
81.1	8/25/98 7:00	3.50	1.6	49	36	88	18	2.5	3.7	24.4	1686	1265
81.2	8/25/98 7:20	3.70	1.6	49	39	78	16	2.46	2.7	24.6	1686	1265
81.4	8/25/98 13:45	3.70	1.6	49	35	90	16	2.64	1.4	25.8	1715	1281
81.6	8/25/98 18:05	3.70	1.6	49	36	90	15	2.64	2.1	26.7	1743	1297
81.6	8/25/98 19:00	3.50	1.6	49	37	80	15	2.65	2.1	26.2	1743	1297
82.2	8/26/98 7:10	4.00	1.6	49	34	61	18	2.12	4.1	24.6	1718	1285
82.2	8/26/98 7:30	4.00	1.6	49	38	58	18	2.15	2.7	24.6	1718	1285
82.4	8/26/98 13:25	4.00	1.6	49	35	60	18	1.79	3.5	25.8	1770	1305
82.6	8/26/98 16:45	3.80	1.6	48	34	62	19	1.74	6.4	26.9	1823	1324
82.6	8/26/98 17:15	3.80	1.6	48	37	58	19	1.7	1.9	27	1823	1324
83.1	8/27/98 6:45	3.90	1.5	49	34	65	19	1.89	5.9	24.1	1737	1288
83.2	8/27/98 8:20	4.00	1.6	49	39	61	19	1.89	5.9	24.1	1737	1288
83.6	8/27/98 18:00	3.60	1.4	48	34	58	16	1.68	4.5	27.1	1730	1269
83.7	8/27/98 20:38	3.80	1.6	49	35	60	18	1.67	4	26.2	1730	1269
84.2	8/28/98 8:00	3.80	1.5	49	34	62	19.2	2.5	1.38	24	1730	1269
84.3	8/28/98 9:30	4.00	1.6	49	36	65	19.5	2.4	1.51	24.4	1730	1269
84.5	8/28/98 16:35	3.80	1.5	48	34	60	18	1.94	3.1	27.2	1724	1297
84.6	8/28/98 17:20	3.90	1.6	48	36	62	18	1.9	4.4	27.3	1724	1297
85.1	8/29/98 7:00	3.60	1.3	49	34	58	15	2.05	6.9	25	1701	1296
85.2	8/29/98 8:10	3.80	1.5	49	36	62	18	1.98	3.5	25.5	1701	1296
85.4	8/29/98 12:30	3.70	1.4	48	34	60	17	1.89	2.7	27.5	1701	1296
85.5	8/30/98 11:30	3.70	1.6	48	49	51	16	1.76	1.5	28.5	1705	1302
86.4	8/31/98 8:50	3.90	1.6	48	47	67	18	2.27	5	26.3	1705	1302