Jørgen Wagner

Ericavej 168
DK-2820 Gentofte
Denmark

Tel +45 3511 2515
Cell +45 2015 6432
jorgen@wagnerdk.dk

Membrane Filtration Definitions Handbook

by

Jørgen Wagner

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Definitions handbook

Introduction.

There are many special words used in membrane filtration literature. Some words are easy to understand, some are impossible to understand and some are - worst of all - seemingly easy to understand, but used in a way which makes it all too easy to misunderstand

Lists of words used in membrane filtration have been issued. This is an attempt to add a few more items and to clarify the definitions, which the author have found hard to understand or found that others find confusing or hard to understand.

Some of the definitions refer to each other. In order to fully understand a word you may have to look up several words.

Several of the definitions is taking for granted that the reader has some knowledge about chemistry. Comments from readers tell me that a degree in chemical engineering helps a lot. Some of the definitions may not be understood by non-chemical engineers, since none of the basic chemical subjects are explained in this paper.

There are personal remarks in several of the definitions. This may not be very scientific. However, the colorful words have been added when they help the understanding.

The list does by no means cover all the membrane filtration buzzword. However, I believe that it covers the most common plus a few of the more rare.

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Comment on numbering of loops.

The stages in multistage recycle systems are numbered after two conflicting methods.

1. The method of TetraPak Filtration System (TPFS)
2. The method used by the rest of the world.

	Loop with most dilute product	Loop with most concentrated product
Most common	Loop #1	Highest number
TPFS	Highest number	Loop #1

Definitions

A-value	A very peculiar, but standardized unit for pure water flux. Unit: g/(cm^2*sec*bar) at 25 deg C. Multiply with 0,36 to get LMH at 1 bar NDP 1,02 to get GFD at 70 PSI NDP 1 to get approx. GFD at 70 PSI NDP (2% error)
Alfa. Alpha α	1 The first Greek letter. 2 Percent water recovery in water desalination systems.
Array	A row of housings operating in parallel.
Ash	Whatever is left after heating a sample to 550 °C until constant weight.
ATD	Anti-Telescoping Device which prevents the leaves in a spiral wound elements from moving downstream due to the force of the flow of liquid.
Back flush	Process where flow of permeate is opposite of normal operation. The permeate side is pressurized and flow will lift dirt and deposits from the membrane surface. Backflush can be done with permeate, clean water or water with addition of miscellaneous chemicals. Back flush can last seconds or minutes.
Back pulse	Back flush for a very short time (seconds or milliseconds). Typically done very often.
Base line pressure	See: Pressure, feed
B-value	Salt flux. Similar to A-value. Unit may be g/(h*m^2)

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Beta value	Concentration polarization factor. Multiply the salt concentration in the bulk solution to get the concentration at the membrane surface.
Blister	*(Specific for spiral wound elements).* Under special conditions water filled bubbles can be formed in the glue line in a spiral wound module. It is due to OSMOSIS. It is decidedly unwanted but very hard to avoid and is considered a nuisance rather than a real problem.
Booster flow = FlowB	Water The flow leaving a pump which increases pressure before next array. See Figure 3. Process The flow from the pump recirculation liquid into an array of housings an a loop. See Figure 4.
Booster pump	The term has two meanings. See figure 3 and 4. In water desalination it means a pump which increase the pressure somewhere in a single pass system. See Figure 3. In a multistage recirculation plant it refers to the pump ensuring the right cross flow over membrane housings in a recirculation loop. See Figure 4.
Brine	The word means water with high salt content. It is used as synonym for concentrate (water desalination terminology)
Buckling	*(Specific for spiral wound elements).* Take a sheet of paper and roll it into a cylinder, which has two flat ends. Squeeze the ends of the cylinder between your hands. The folds in the collapsing cylinder are the buckles. Typical phenomenon in an spiral wound element which is subjected to a pressure drop / flow which is larger than in can support.
Central tube	*(Specific for spiral wound elements).* The perforated tube around which a spiral wound element is rolled. Also called a permeate tube.
Channeling	*(Specific for spiral wound elements).* Open flow channels in spirals. They do not exist in new elements. They may appear after some time of operation when an element is subjected to frequently changing pressure and temperature. It is a highly unwanted defect which it is very hard to avoid completely. Channeling results in poor flow conditions and poor cleaning and may result in premature element failure. Main reason for channeling is that the element is rolled too loosely.
CIP	Cleaning In Place. Cleaning a system without dismantling it.

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Concentrate flow = FlowC	Several different meanings. However, it is always the liquid which did not go through the membranes. See Figure 1. · The flow leaving an element. · The flow leaving a housing. · The flow leaving an array or loop. · The flow leaving a membrane plant (final concentrate). Also known as retentate.
Concentration, unit	Many units are used. **mg/l and g/l** is common. **Percent** is also used and it is quite troublesome unless clearly defined. For very dilute solutions it is acceptable. For more concentrated solutions it is essential to know whether it is W/W%, V/V% or a combination. Be very careful if there is a non-water soluble component in the liquid, e.g. fat, oil, grease or suspended solids. That can totally distort the mass balance unless you make calculations on the non-water phase and the water phase individually.
Concentration ratio	The definition may refer to volume or to a particular solute in the concentrate. Volume: FlowF / FlowC = VolF / VolC Solute: (Conc. of solute X in concentrate) / (conc of solute X in feed) When the permeability of a solute is zero then Solute Concentration Ratio is equal to Volumetric Concentration Ratio. When the permeability is >0 and conc. ratio refers to a solute then Solute Concentration Ratio is < Volumetric Concentration Ratio.
Core tube	*(Specific for spiral wound elements).* see Central tube
Cross flow	The volume of liquid (raw product) flowing tangential to the membrane surface with the objective to reduce concentration polarization and deposits. The opposite operation of dead-ended flow operation.
Dalton	Used synonymous for Molecular Weight
Dead ended operation	Raw water permeates perpendicular to the membrane surface. The same flow as in cartridge filters (and a Melitta filter). Typically pressure driven. Product, which cannot permeate, accumulates on the membrane surface and must be removed. Dead ended operation is only useful when the about of non-permeable matter is quite small. The opposite operation of cross flow operation.
DEP Dead end plug	*(Specific for spiral wound elements).* Device which closes one end of the permeate tube of a spiral wound element. Typically at the inlet end of a housing.

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Diafiltration FlowD	Addition of water with the objective to move some of a low MW solute from the feed side to the permeate side. Either because it is unwanted or because it is the product. Examples: Unwanted Lactose in whey Product Cephalosporin in fermentation broth Diafiltration can be done by RO, NF, UF, MF and even more course filtration The volume of water added during diafiltration
ESA	Energy Saving ATD. Device made by DDS/DSS/TetraPak with the objective to reduce bypass around the elemetn in a sanitary way.
Fast forward flush	Cleaning mode of a system operated dead-ended. The concentrate valve is opened and raw water will flow very rapidly, flushing concentrate and deposits out for a short period of time. Used in tubular and inside-out fibre systems
Feed & bleed	Another name for a multistage recycle system.
Filtrate	The same as permeate
Flow, feed = FlowF	The water fed to a membrane plant for treatment. Also known as raw water. Feed flow has two meanings. · The flow coming to a plant · The flow entering a plant. (Do not confuse with booster flow)
Flow, booster = FlowB	This term is used almost exclusively in a multistage recirculation plant. It refers to the flow out of a booster pump. See figure 1. In a single pass system pressure is in rare occasions increased. See figure 3.
Flow, recirculation = FlowR	FlowR is the volume of concentrate returned to suction side of the feed pump (single pass system) or the recirculation pump (multistage recirculation plant). See figures 1 and 6.
Flux instantaneous average	The instantaneous flux is the flux at any given moment. (It is equivalent to the speed shown in a speedometer.) Average flux is the average flux from the process is started until it ends. (It is equivalent to the average speed you can calculate once you have reached your goal.) The instantaneous flux can be measured. The average flux must be calculated. You need to know the average flux in order to design a system.
Flux unit	Mostly Volume of permeate per unit area and time (see A-value) lmh = liter per m^2 and hour liter/(hour*m^2) gfd = US GALLONS per ft^2 and day US Gallon/(day*ft^2) lmh = gfd * 1.7 Flux is sometimes used as synonym for flow of permeate.

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Flux, water	The flow of water under well-defined conditions. Water flux has a definite meaning in reverse osmosis and nanofiltration, is indicative for UF and of little use for MF It is commonly used to verify that a membrane system is clean and performing well.
Formula mass	See Molecular Weight
Fouling	Membranes get dirty during operation: they foul. Dirt is anything that precipitate on the membrane surface and which disturbs (reduces) flux and/or cross flow. (See Scaling)
GFD	see Flux, unit
Glue line	*(Specific for spiral wound elements).* In a spiral the membranes are glued together to form closed spaces (leaves) where only permeate can get in. The area, where there is glue, is called the glue line. Leaves have glue lines on three sides. The fourth side is connected to the central tube. Side glue line is the glue line which can be observed in each end of an element. It is perpendicular to the central tube. The end glue line is parallel to the central tube. It is usually hard to see.
H-value	The resistance of permeate flow in the permeate carrier. Rare definition. Unit can be [BAR]*[Second]/[ml]. Typical value is 0,15 [BAR]*[Second]/[ml]. H = 0 when there is no resistance. H = infinite, when no permeate can flow.
HF	See Hyperfiltration
Housing	The part of the membrane filtration equipment holding spiral wound elements or other types of membrane elements. It is also referred to as pressure vessel, which is a somewhat misleading name. A housing holds so little water that it shall not be designed according to any norms. A housing is for all practical purposes a pipe/tube with membrane elements inside.
Hyperfiltration	Another (and better word) for Reverse Osmosis
IC Inter Connector	*(Specific for spiral wound elements).* The part which is the connector between two spiral wound elements. Permeate flow from one element to the other through the interior of the inter connector.

Definitions handbook

Inside-out	*(Mostly used about fibres.)* Operation where the raw water is on the inside of the fibres (lumen) and the permeate on the outside of the fibres. Operation is typically done by pressure, but can be performed with vacuum. Product, which cannot permeate, accumulates inside the fibres. Discharge from the lumen can be done in two ways: 1. by Fast Forward Flush. 2. Backflush
Kjelddahl nitrogen	The content of N determined according to the Kjelddahl method. N*6,25 is used to get the protein content in most industries. N*6,38 is used to get the protein content in the dairy industry. It is always an approximation to multiply N with a constant.
Langelier index	Index for the tendency of $CaCO_3$ to precipitate and create scaling. If positive $CaCO_3$ scaling is likely. If negative $CaCO_3$ scaling is unlikely. See also SDSI.
Leaf	*(Specific for spiral wound elements).* Two membranes glued together in a spiral wound element.
LMH	See Flux, unit
Loop	See figure 1. Building block in a feed and bleed system. It consists as minimum of one pump, one housings and some tubing.
mil	US and UK unit of length. 1 mil = 1/1000 inch = 0,0254 mm.
Molecular weight	A more modern wording is “Formula Mass” Sometimes referred to as Dalton.
Multistage recycle system	The same as feed and bleed system.
MW	See Molecular Weight
MWCO	Molecular Weight Cut Off. Defined as the MW of a solute which is rejected 90% at test conditions. · Well defined for RO and NF. · Poorly defined for UF. · No meaning for MF.
Nanofiltration	Process similar to RO. However, a true NF membrane will have a very high rejection of di- and polyvalent negative ions, while monovalent ions have a high permeability.

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NDP	See: Pressure, net driving.
NF	See Nanofiltration
NPN	Non Protein Nitrogen. Common abbreviation in the dairy industry. It is the N-containing solutes which do not precipitate with trichloroacetic acid. Often used about low MW peptides.
Outside-in	*(Mostly used about fibres.)* Operation where the raw water is on the outside of the fibres (lumen) and the permeate on the inside of the fibres. Operation is typically done by vacuum, but can be performed with pressure. Product, which cannot permeate, accumulates in the volume outside the fibres (concentrate). Discharge of concentrate removes the products which cannot permeate.
PEA	*(Specific for spiral wound elements).* Product End Adapter. The device which connects the stack of element to the end cap and allow permeate to flow out. NOTE: there are many different types of PEA. Ask the housing producer to supply one in the correct dimensions and material.
Permeability, apparent. P_{app}	100 * (mg/l solute in average permeate)/(mg solute in feed flow). Salt content in average permeate = Papp * TSF. Can be calculated from Membrane Permeability and Recovery.
Permeability, membrane	It is most common that the permeability is related to a specific solute, e.g. NaCl. In special cases it can mean water flux. A typical RO membrane will have between 0,5 and 2% NaCl permeability. Example with NaCl. Permeability = 100 * (mg/l NaCl in FlowP)/(mg NaCl in feed flow) when the recovery is <10%. Rejection = 100 - Permeability Permeability can be measured. Rejection must be calculated.
Permeate flow FlowP	The liquid which passes through the membranes. Also called FILTRATE. By water desalination known as PRODUCT.
Permeate carrier	Also called permeate support. The drainage placed between or under membranes. It conducts permeate with a minimum of resistance to the permeate outlet.
Permeate tube	*(Specific for spiral wound elements).* See Central tube
pi Π	See: Pressure, osmotic Greek letter

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ppm	parts per million. Strictly speaking, mg solute per 1000 gram solution. Used as the equivalent for mg per liter.
Pressure drop	Several different pressure drops can be measured. Pressure difference from inlet to outlet of · one spiral wound element. · one housing with several spiral wound elements. · one complete single pass system. · one membrane module of any design Rarely and incorrectly used for the trans membrane pressure (TMP)
Pressure, feed = PresF	Several meanings, so use it with care. Make sure that both parties agree about the meaning. · Pressure of raw feed coming to a membrane plant. · Pressure out of pre-feed pump. · Pressure out of high pressure pump. · Pressure in common line in multistage recirculation plant. · Pressure into a housing.
Pressure, net driving	Net driving pressure = TMP_{av} -$\Pi_{conc.,av}$ + $\Pi_{perm.,av}$ NDP may refer to 1 the average in a plant 2 the average in a housing 3 the average in an element.
Pressure, osmotic	A theoretical value which highly impacts reality. The osmotic pressure is a function of the content of salt and other low MW solutes. High MW solutes can theoretically not contribute to osmotic pressure, but in reality a phenomena is experienced which resembles osmotic pressure. Osmotic pressure is sometimes written with the Greek letter Π (Pi) Π = f* i * m * R * T where f is activity factor. For dilute solutions it is 1. i = number of ions by dissociation m = molality R = gas constant T = degree Kelvin
Pressure, trans membrane or differential = TMP	Trans Membrane Pressure. The difference between the pressure on the feed side and the permeate side. TMP may refer to the average in a plant, in a housing and in an element. Housing example: (housing inlet pres. + housing outlet pres.) / 2- permeate pres.) Permeate pressure is usually zero.
Pressure vessel PV	See Housing PV is a much used word, but not a good one. Housing is better. PV more than hints that special safety is needed, like in boilers. In reality a PV is nothing but a large pipe.

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Product	A word with many and conflicting meanings. Product can refer to the permeate, the concentrate or a component in either of the two streams. Examples: RO of water — the permeate UF of carrageenan — the carrageenan in the concentrate NF of Glucose-sucrose — the Glucose in the permeate
Product end adapter	See PEA
Product spacer	See Spacer
Recovery	Water terminology Percent of feed which becomes permeate. Process terminology Percent of a particular solute which is recovered (in concentrate or permeate).
Reject	The same as concentrate.
Rejection	In water desalination the rejection of NaCl is used as a standard number to characterize a membrane. Permeability is a much better number. Permeability is calculated directly. Rejection = 100 - Permeability.
Retentate	The same as concentrate
Salt	In everyday language it means table salt, NaCl. More widely it means very many inorganic and organic solutes which dissolve as ions. E.g. K_2SO_4, Ca-acetate, NH_4Cl
SDI	Silt Density Index. Standard unit for characterizing the amount of suspended solids in water.
Scaling	Deposits on the membranes of inorganic salts. See fouling
SDSI index	Stiff and Davis Saturation Index. It is similar to the Langelier index, but can be used in high salinity water. See Langelier index.
Spacer	*(Specific for spiral wound elements).* Also called product spacer. The netting between membranes. The objective of the product spacer is to form a well defined flow channel and to create some turbulence. A rigid spacer helps to maintain element stability at extreme conditions. A diamond spacer is most common. A parallel spacer is more rare. A corrugated spacer is very rare.

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Spacer height	*(Specific for spiral wound elements).* Spacers are delivered in many dimensions. 30 mil (+/- 3) is most common and standard for water treatment. 47 mil (+/- 3) is less common. Mainly for processes. Higher spacers exist but are rare, e.g. 60, 80, 100 and 120 mil.
Spacer migration	*(Specific for spiral wound elements).* Movement of the spacer in the direction of the flow. A little movement is normal. Too much (whatever that is) will cause the flow to be uneven and may cause element failure. Most commonly due to partial or complete blocking of the flow channels (poor cleaning) or a too high load of dirt..
Telescoping	*(Specific for spiral wound elements).* Movement of the membrane leaves in the direction of the flow. The movement can get so severe that the element eventually fail.
TFC, TFM	Acronyms for Thin Film Composite Membranes.
TMP	See Pressure, trans Membrane.
TRP	True Protein. Common abbreviation in the dairy industry. Protein which precipitate with trichloroacetic acid.
TS, TDS	TS = Total Solids TDS = Total Dissolved Solids. The two words will usually mean the same thing. An exception is ED-paint where the amount of suspended solids is very high. This means that for ED-paint is TDS<<TS. TSC TS or TDS in the concentrate TSF TS or TDS in the Feed to the plant TSP TS or TDS in the permeate
UF	Ultrafiltration
Ultra osmosis UO	Another word for nanofiltration. Used by Filtration Engineering, Inc
VCR VCF	Volumetric Concentration Ratio. Volumetric Concentration Factor. See Concentration ratio. 1/VCR = volume fraction concentrate.
Vexar	Trade name. Do not use it. (It has been used for feed spacer)
Vol	Commonly used by the author for VOLUME , relating to a batch process
VolC	Volume Concentrate in a batch process

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VolF	Volume of liquid to be treated in a batch process
VolP	Volume Permeate in a batch process
Volume Fraction Concentrate	Volume of concentrate divided by volume of feed. Often called X. 0 < X<=1. Volume percent concentrate = X * 100 VCF = 1/X
Volumetric Concentration ratio	See Concentration ratio VolF/VolC or FlowF/FlowC
Water recovery	See Recovery and Yield
X	Abbreviation for Volume fraction concentrate
Yield	See: Recovery.

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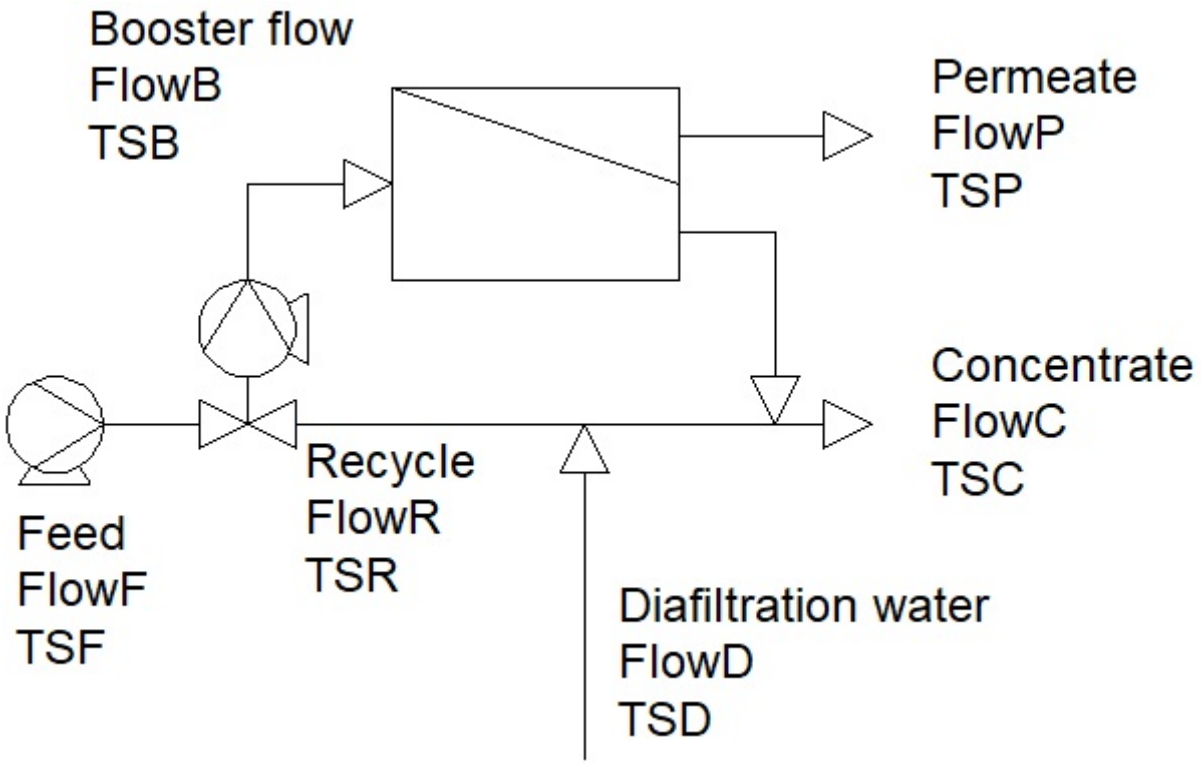
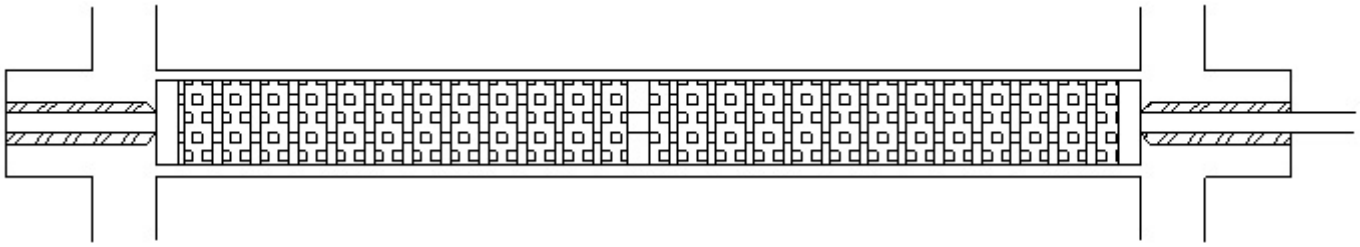
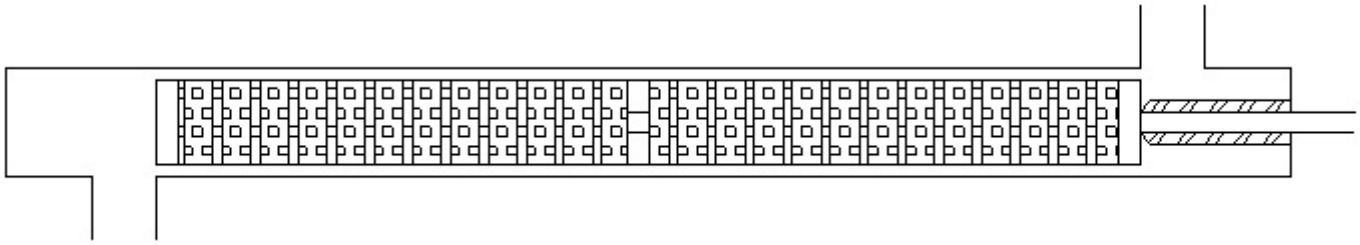
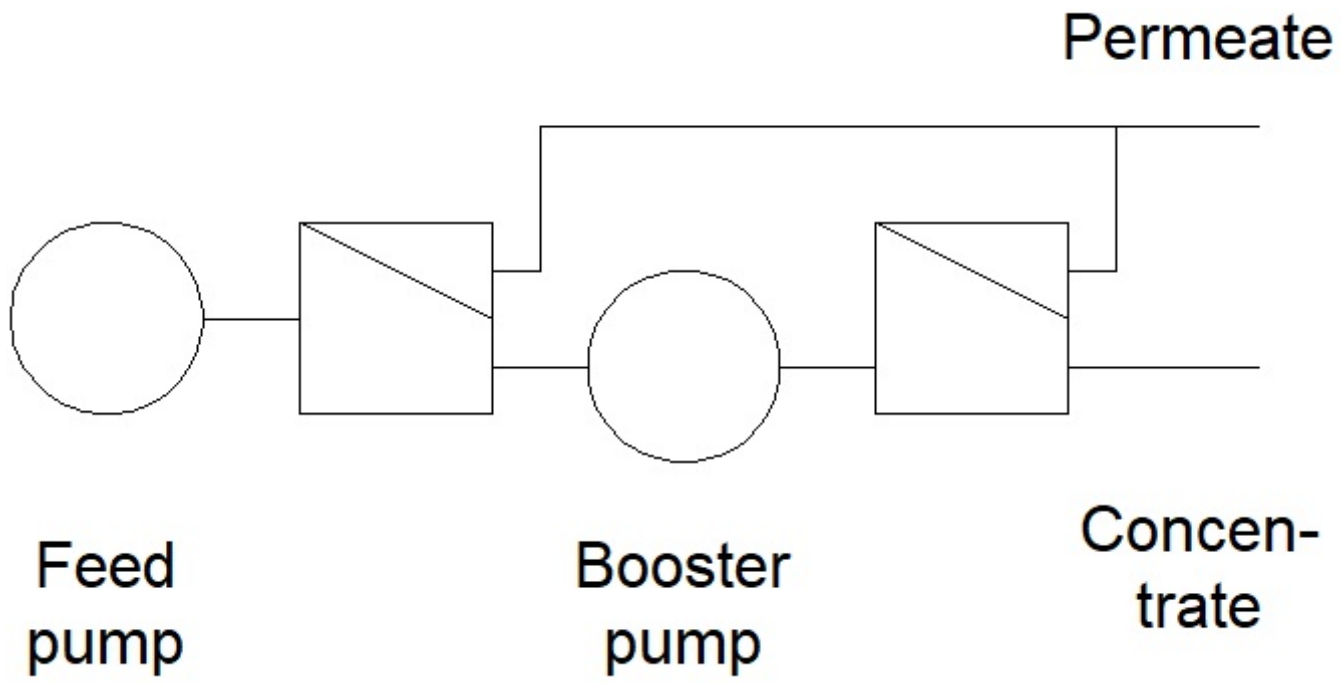
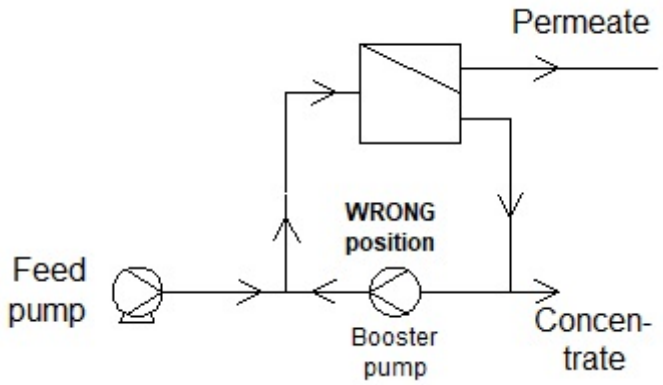
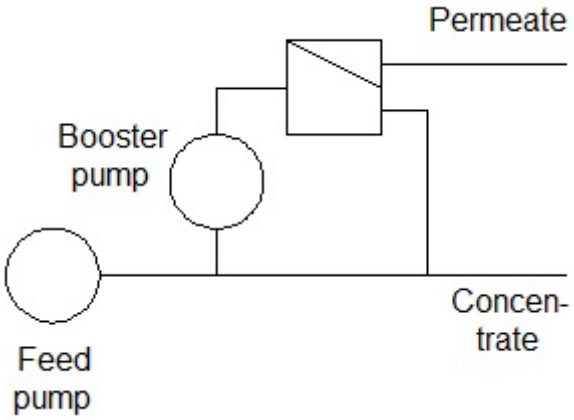







Permeate
Feed pump
Booster pump
Concen-trate


Permeate
WRONG position
Feed pump
Booster pump
Concen-trate


Permeate
Booster pump
Concen-trate
Feed pump

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