Volume 1 : Edition 10 – Handyman : Best Friend of Service Technician at Site *Oct 24, 2021*

Water & Wastewater, now referred as Waughter is an interesting engineering encompassing Civil, Mechanical, Electrical, Instrumentation and automation engineering and prolific use of basic chemistry, physics, and electricity.

'Handyman' is dedicated to the engineers and technicians in field, often alone and at remote sites but expected to solve their day-to-day issues. We have tried to be comprehensive and cover formulas, calculations, and basics well in Version 1 of Handyman.

Please feel free to share this and feedback to us for inclusion of any point, idea or correction.

Happy Waughtering!
Best Regards

Nidhi Jain
Editor Waughter

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Important Do's

- This is Handybook and not the entire knowledge on the subject. Please continue to read, manual, textbook etc.
- If in doubt, please ask and do not experiment.
- While at site the SHE compliance take top priority.
- If you are not certified electrician, do not touch an electrical devise while in commission phase.

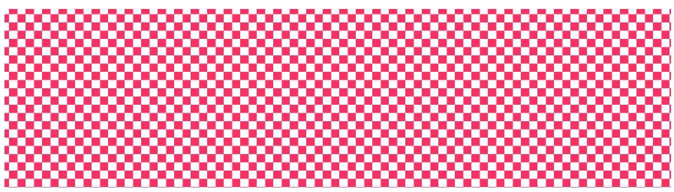
Important Definitions

Absorption
To draw in or drink in like a sponge / porous material takes in water. A phenomenon that can be reversed.

Adsorption
A natural phenomenon of a gas, liquid vapour or fine particles being attracted and held on to the molecular surface structure of a material. Not normally a reversible phenomenon.

Asymmetrical membrane
A membrane whose structure is graded throughout its depth from coarse /open to fine/tight.

Basket
The filter element used in basket strainer. A device normally using a screen / mesh as it is filtering medium. Used for the removal of coarse bulk solids.



Blind Spots
An area of the filter media where no filtration takes place as strainers in that area may be blocked.

Capillary
A very thin tube, in filtration, is used as an example to describe pores in a membrane.

Clarity
Cleanness of a liquid measured by the amount of contaminants remaining.

Clogging
The process of solids being removed by filter, block the filter for increasing the differential pressure.

Cold Sterilization
The Sterilization of liquid with filtration, neither heat nor irradiation.

Colloid
A non-crystalline substance held in suspension or dispersed in a fluid. Contamination impurities in fluid.

0rganic Matter
Grouped under this are all substances susceptible to oxidation and expressed by various indices given below.

Dead End Filters
A mode of filtration where the fluid contacts the filters materials at 90 degrees. All the fluids must pass through the filter material to reach the downstream side. Most cartridge filtration works in this mode.

Differential Pressure
The difference in pressure between the upstream and downstream sides of a filter.

Direction of Flow
Direction in which products flow through a filter; may be from inside to outside, from outside to inside. Or end to end depending on the design of elements

Effective filtration Area-EFA
The surface area of filter membrane available for filtration, not the total area used to make the cartridge-some is taken up in seals, joints etc.

Efficiency
Degree to which a filter cartridge will perform in removing solids and/or liquid.

Filaments
A single continuous strand of indefinite length, such as rayon, silk, or nylon. Compared to staples fibres such as cotton and nylon.

Fluid
A general term for a substance which can flow, it can be a liquid or gas.

Flux
The unit of rate of filtration.

Food and Drug Administration
The United States regulatory authority to ensure that the drugs produced for USA consumption are of high quality.

Hydrophilic
Having an affinity for water - the filter wet easily.

In-Situ
A test or procedure carried out with a filter in position in the pipeline e.g., RO Plant CIP is done while membranes are in-situ

Integrity Test
A test carried out to ensure that a filter is not damaged and will perform the duty it was intended.

Ion
An electrically charged atom or group of atoms, formed by the gains or loss of electron.

Medium
A term used generally describe filter material

Membrane
A relatively thin sheet of materials normally a synthetic polymer used for filtration of fine particles. Also, the outer layer of micro-organism

Mesh
Number of openings in a linear of wire cloth

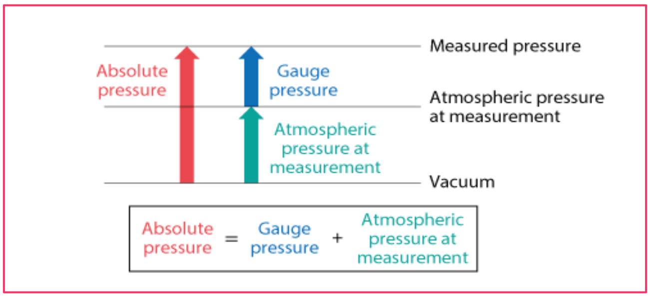
Micro-filtration
Filtration of particles between approximately 10 and 0.1 micron

Pores
A term used to describe the opening in a filter material normally membrane.

Porosity
A term used to describe a filter materials structure sometimes known as a void volume.

Atmospheric Pressure
The force exerted by the atmosphere at sea level which is equivalent to 1 Kg/Cm^2.

Pressure Drop
Loss in applied pressure across a filter system or process see delta P and difference pressure.



Voids
The operating in the medium. Also referred to as interstices or pores.

Colour
Colour may be due to some mineral impurities. Iron and manganese colour the water as they precipitate when the water is brought into contact with air.

Ultrafiltration UF
UF is a pressure driven membrane filtration system operating on cross flow mode. Used to separate macromolecules such as proteins and organic compounds of 300 molecular weight and over. UF operates at pressure between 1 and 8 atm and is generally separating coarser materials than an RO system

Ultraviolet
High Frequency light beyond the purple end of the spectrum. Used as an effective sterilization system.

Volumetric Flow Rate
Unit for measuring quantities of a substance by the volume they take up–usually at standard atmospheric (cubic feet, cubic meters).

Wettability
The extent to which a solid wetted by a liquid

Density
Pure water has a density of 1.0 kg/l at 4^0C and atmospheric pressure. The density decreases at other temperature. In practice the numerical value of the density of pure water is considered as unity.

Viscosity
The ability of a liquid to resist movements such as flow. It is the basic cause of head loss and therefore plays an important part in water treatment

Surface Tension
This is a property peculiar to boundary surfaces of two phases. It is a tensile force which is exerted at the surface of the liquid and which tends to reduce the area of this surface to the greatest possible extent.

Odor and Taste
The bad taste and smell of water is generally caused by the presence of bacteria, germs and various microorganisms and their secretions and excretions in water. It is due to organic matter and gases such as hydrogen sulphide dissolved in water.

What is **PureOx**?

PureOx chlorine dioxide is a **very powerful disinfectant** with various applications in **water treatment.** As a chlorine dioxide solution, **it's concentration is at 5000 ppm** and **i**t is extremely effective against **all kinds of microorganisms and impurities** found in water. It is a **perfect substitute to harmful biocides such as general chlorine and sodium hypochlorite**, due to its non-toxic nature.

Why **PureOx**?

- Leaves no hazardous residues
- Broader pH spectrum
- Lower dosage rate
- Destroys biofilm at source
- Shorter contact time
- Destroys all microorganisms

INDUSTRY APPLICATIONS

FOOD & BEVERAGES

COOLING TOWERS

BIOFILM REMOVAL

PAPER & PULP

WASTEWATER TREATMENT

POULTRY

DAIRY

MEMBRANE CLEANING

PACKAGED DRINKING WATER

SHRIMP & AQUACULTURE

ODOUR REMOVAL

SANITIZATION

www.purewaterent.net +91 7021292182 info@purewaterent.net

Water Chemistry

The water chemistry is the most important subject for you to learn before visiting a customer. We give here below some of the important formula that shall be useful:

pH = 6.3 + log [(HCO_3 as $CaCO_3$)/ (CO_2 as CO_2)]

1ppm = 1 mg per liter = 1 gm per m^3

All the ionic impurities need to be converted to $CaCO_3$ before they are added:

ppm as $CaCO_3$ = 50 ppm as such / Equivalent Weight of element

(Where 50 is the equivalent weight of $CaCO_3$)

Total hardness = Ca Hardness + Mg Hardness

Equivalent Mineral Acidity (EMA) = Chlorine +Sulphate + Nitrate (All expressed as CaCO3)

Total Anion = EMA + M-alk

Total Cation = Total Anion

Temp Hardness = M-alk if TH> M-alk, TH if TH< M-alk Hardness

Perm. Hardness = Total Hardness – Temp Hardness

Sodium alkalinity = M alkalinity-Hardness, If M alk > Hardness

Alkalinity indicates the quantities of Bicarbonates, Carbonate and Hydroxides in water.

The alkalinity of water is determined using two indicators. Phenolphthalein indicator given the P alkalinity (End point 8.3 pH) and Methyl Orange Indicator yield the M alkalinity (End point 4.2 pH) M alkalinity is also called total alkalinity.

The type of alkaline species is then determined based on the value of P alkalinity and M alkalinity.

M alkalinity = $HCO_3 + CO_3 + OH$
P alkalinity = $1/2CO_3 + OH$

Alkalinity Relationship			
Relation	Bicarbonate HCO_3^-	CarbonateCO_3^-	Hydroxyl OH^-
P = 0	M	0	0
M = P	0	0	M
M = 2P	0	M	0
M < 2P	0	2 (M- P)	2P - M
M > 2P	M - 2P	2P	0

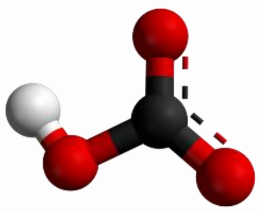
Very Important:

Na = Total Cation – TH

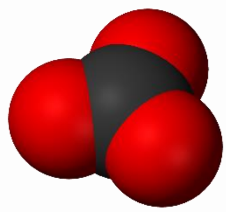
In case the calculated Na is Negative, then there is some mistake in your water analysis.

The basis and equivalence of various degrees' used in water treatment, is given below:

1 English degree	= 1 grain/gal	:	14.38 ppm as CaCO3
1 German degree	= 10 mg CaO/l	:	17.86 ppm as CaCO3
1 French degree	= N/5000	:	10 ppm CaCO3



HCO_3^-



CO_3^-

OH^-

Clarifiers

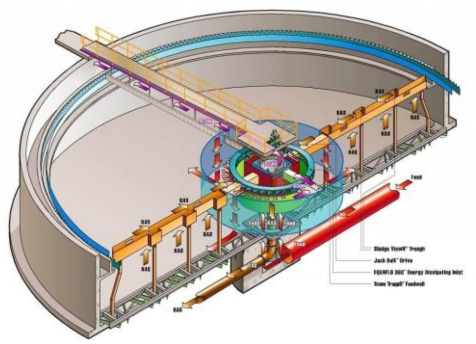
If a Clarifier is 12 m diameter, 3 m HOS, Flocculation Tank is 1.4 m, we need to check what's Rise rate and detention Time. How we do that?

Let's Calculate,

First, we need to identify Flow rate that is say 120 m^3/h in this case. Next:

Description	Unit	Formula /Symbo	Result
Outer Dia Available	m	D_o	12.00
Inner Dia Available	m	D_i	1.20
HOS Available	m	H	3.00
Flow Rate	m3/h	Q	120.00
Area based on Above	m2	A_o=¶D_o^2/4	113.14
Area based on Above	m2	A_i=¶D_i^2/4	1.13
Nett Area to Rise	m2	A_o - A_i	112.01
Rise rate	m3/h.m2	RR = Q/(Ao - Ai)	1.07
Volume Total	V	V=A_o * H	339.43
Detention Time	h	t = V/Q	2.83
		Input Data by Designer	

Now imagine we need to dose Alum, Lime, and NaOCl & Poly. So, let's work out requirement:



Description	Unit	Formula /Symbol	Result
Alum Dose	mg/l ppm	AlumDose	60.00
Lime Dose	mg/l ppm	LimeDose	25.00
NaOCl Dose	m	NaOClDose	3.00
Polyelectrolyte Dose	m	PolyDose	1.00
Flow Rate	m3/h	Q	120.00
Alum Quantity Required	gm/h	WAlum	7200.00
Lime Quantity Required	gm/h	Wlime	3000.00
NaOCl Quantity Required	gm/h	WNaOCl	360.00
Poly Quantity Required	gm/h	Wpoly	120.00
Alum Solution Strength	%w/v	(5 - 10%)Alum%	10.00
Lime Solution Strength	%w/v	(5-6%)Lime%	6.00
NaOCl Solution Strength	%w/v	(Market 9 -12%) NaOCl%	11.00
Poly Solution Strength	%w/v	(0.5 - 1%)Poly%	1.00
Alum Dosing Rate	l/h	=WAlum/(Alum% * 10)	72.00
Lime Dosing Rate	l/h	=WLime/(Lime% * 10)	50.00
NaOCl Dosing Rate	l/h	=WNaOCl/(NaOCl% * 10)	3.27
Poly Dosing Rate	l/h	=WPoly/(Poly% * 10)	12.00
		Input Data by Designer	

In some plants, we have plate clarifier, so rise rate need to be calculated based on PESA a term used for Projected effective surface area.

Imagine at a site you have a plate clarifier with 110 plates of dimensions 1.2 m width and 2.5 m long. These plates are inclined at an angle of 65o. So how to calculate Rise rate?

For Plate Clarifier: First, we need to calculate PESA that is equal to

= n (No of Plates) * L * W * CosΦ

= 100 * 2.5 * 1.2 * Cos 65

= 126.7 m^2

For Plate Clarifier Alum, Lime etc. Can be calculated on the same basis as conventional Clarification.

The next important handy calculation is estimate of Sludge quantity from clarifier. So what all we need as input?

Inlet TSS mg/l = 3000

Outlet TSS mg/l = 50

Sludge Conc. = (0.8–2%) depends On design
= 1% (Assumed)

TSS Removed every hour = (3000-50) * 120
= 354000 gm/h
= 354 kg/h

Sludge Volume for Sludge = 354 ÷ (1% * 10) m3/h
= 35.4 m3/h

So in our case customer need to feed (120+35.4) 155.4 m3/h water to get 120 m3/h clear water and manage 35.4 m3/h of 1% sludge.

Sludge dewatering can be applied if we need to reduce the feed volume. Filter press can give 20-28% Sludge and the recovered water can be subtracted from feed water. Let's calculate sludge if Filter press can raise consistency to 20%.

Solids in 1% Sludge in kg/h = 354

Solids in 20% Sludge in kg/h = 354 😊

Hence Sludge Volume = 35.4 ÷20

= 1.77 m3/h

The above assumes no loss of solid in filter press clean water.

Filter & Carbon Filter

At a site we see some GRP Filter and need to calculate media quantity to commission the plant. Media is available with Client, and he can give provided we tell quantity. Let's Calculate, For Sand Filter:

Parameter	Unit	Symbol	Value
Flow rate	m^3/h	Q_S	6
Diameter of Vessel, Vailable	mm	Ø	626
Area of the Vessel, selected	m^2	A = ¶Ø^2/4	0.308
Rate of Filtration,	$m^3/h.m2$	Sp.V=Q_S/A	19.48668364
Backwash Velocity	$m^3/h.m2$	V_{BW}	36
Unit Stregith Height	mm	HOS	1291.00
Total Volume (Streight)	m3	V=A*HOS	398
Free Board for B/W	Fr	FB_{Fr}	0.50
Height for Media (Sand)	mm	H_{Media} = (1*HOS/(1+FB_{Fr})	861
Volume of Sand Required	m^3	V_{Sand}	0.27
Bulk Debnsity of Sand	kg/m3	BD_{Sand}	1750
Quantity of Sand Required	kg	W_{Sand}	463.75

Input Data by Designer

And for Carbon Filter:

Parameter	Unit	Symbol	Value
Flow rate	m^3/h	Q_S	6
Diameter of Vessel, Vailable	mm	Ø	636
Area of the Vessel, selected	m^2	A = ¶Ø^2/4	0.318
Rate of Filtration,	$m^3/h.m2$	Sp.V=Q_S/A	18.87871236
Backwash Velocity	$m^3/h.m2$	V_{BW}	9
Unit Stregith Height	mm	HOS	1112.00
Total Volume (Streight)	m3	V=A*HOS	353
Free Board for B/W	Fr	FB_{Fr}	0.75
Height for Media (Carbon)	mm	H_{Media} = (1*HOS/(1+FB_{Fr})	635
Volume of Carbon Required	m^3	V_{Carbon}	0.201950819
Bulk Debnsity of Carbon	kg/m3	BD_{Carbon}	600
Quantity of Carbon Required	kg	W_{carbon}	121.17

Input Data by Designer

STD GRP vessels are as here under:

Tank OC	Tank Ø	Tank Height	Tank HOS
Unit	mm	mm	mm
FRP	334	1400	1081
FRP	363	1674	1312
FRP	413	1671	1312
FRP	486	1681	1199
FRP	555	1670	1158
FRP	626	1868	1291
FRP	780	1804	1154
FRP	938	1805	1100
FRP	1089	2072	1281
FRP	1233	2065	1216

So be aware that use Tank HOS and not over all HOS while designing.

At some sites a Multiport valve is available for doing all functions such as service, backwash, rinse etc. One must not operate this valve (Shift Position from say service to Backwash without stopping the feed pump.

If Pump is on, you may damage the Valve lever. The valves available are:

Back Wash Flow	BW Veloci	Valve Size	Valve Mounting
m^3/h	$m^3/h.m2$	Inch	Position
3.15	36.00	3/4"	Multiport Top
3.72	36.00	1"	Multiport Side
4.82	36.00	1 1/2"	Multiport Side
6.67	36.00	1 1/2"	Multiport Side
8.70	36.00	2"	Multiport Side
11.07	36.00	2"	Multiport Side

For larger flow rate plants, individual valves may be more comfortable as 3" valve is quite expensive. For selecting manual ball valve, follow table below:

Valves	BW Flow	Inlet	Outlet	BW In	BW Out	Air Release	Rinse	Drain
Ball Valve	m3/h	mm	mm	mm	mm	mm	mm	mm
Set 1	17.19	40	40	50	50	25	40	25
Set 2	24.86	50	50	63	63	25	50	25
Set 3	33.51	63	63	75	75	25	63	25
Set 4	42.96	75	75	75	75	25	75	25

Sr. No.	Multi Port Valve Size	Maximum Feed Flow (m^3/hr)
1	3/4"	2
2	1"	5
3	1 1/2"	12
4	2"	29
5	2 1/2"	35
6	3"	40
7	4"	60

Ion – Exchange Resin

Resins are Key to Demineralization; Resins are classified based on the type of functional group they contain and their % of cross-linkages

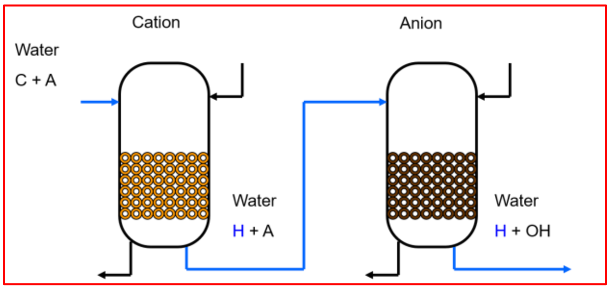
Let's understand Resin from basics:

H Cl + Na OH → Na Cl + H OH

Is a simple acid and base reaction. Both HCl and NaOH above are liquid. Imagine we have them as Solids.

R H → Is Cation Exchange Resin where H is free to reactor and R is an inert Solid.

R OH → Is Anion Exchange Resin where OH is free to react.



If they come in contact with water that has cation or anion "willing" to react, the EXCHANGE takes place. See below:

R H + Na Cl → R Na + H Cl (Service)

In above reaction the Na present in water has replaced H ion of Resin, it's possible because R loves Na more than H. This is selectivity of Resin.

Each resin has certain liking and disliking SAC (Strong Acid Cation) resin love Ca most, Mg next and Na least. This is the reason when we apply SAC resin in DM plant, Na Slips and governs the termination of service cycle.

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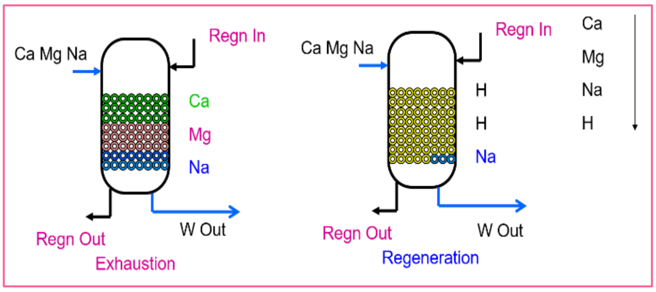
Regeneration

During Water Softening the resin has trapped all the hardness minerals it possibly can, a saltwater solution (brine) needs to flush through the system to clean it out.

HCl/H_2SO_4 for Cation and NaOH for Anion is usually employed as the chemicals for regeneration. If the REGENERANT is flowing in the same direction as that of service water, it's called Co-Current Regeneration.



The reaction during regeneration of cation are

CaR_2	+	2HCl	→	2HR	+	$CaCl_2$
MgR_2	+	2HCl	→	2HR	+	$MgCl_2$
NaR	+	2HCl	→	HR	+	NaCl

The reaction during regeneration of anion are:

R_2SO_4	+	2NaOH	→	2ROH	+	Na_2SO_4
RCl	+	NaOH	→	ROH	+	NaCl
$RHCO_3$	+	NaOH	→	ROH	+	$NaHCO_3$
RHSiO	+	NaOH	→	ROH	+	$NaHSiO_4$

Load considered fro various units

Softner	=	Total Hardness
Strong Acid Cation	=	Na + Ca + Mg
Strong Base Cation	=	EMA + M-alk + SiO_2
weak Base Cation	=	Tem Hardness
Weak Base Cation	=	EMA

Resin Selection

Resin ion selectivity is based on two factors
Valence (Ionic Charge)

- IX resin has a greater affinity for ions with greater charge
- resin is more selective for Mg^{+2} than for Na^{+1}

Molecular Weight

- IX resin has a greater affinity for ions with higher molecular weight
- Resin is more selective for Ca^{+2} (40.1) than for Mg^{+2} (24.3)

Overall Selectivity

- Ra+2>Ba+2>Ca+2>Mg+2>K+1>NH4+1>Na+1>Li+1>H+1

Exchanges Capacities for Various Resins

User is advised to follow the instruction written in the operation manual or go through the Resins characteristics curve. For quick calculation the exchanges capacities as mentioned here may be used:

Softener Resin	=	54 ppm $CaCO_3$
Cation Strongly Acid	=	45-50 ppm $CaCO_3$
Cation Weak Acid	=	80 ppm $CaCO_3$
Anion Strong Base	=	22-26 ppm $CaCO_3$
Anionic Strongly Basic Type l	=	32-34 ppm $CaCO_3$
Anion weakly Basic Type ll	=	50-55 ppm $CaCO_3$
Cation for MB	=	40 ppm $CaCO_3$
Anion for MB	=	3.0 ppm $CaCO_3$

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Calculation of Regenerates

Regeneration level (RL) means they amount of acid-alkali required per m^3

Cation Volume m^3	= 2 m^3
Regn. Level kg/m^3 (100%HCl)	= 60
HCl required 100% HCl	= Resin Vol. x RL = 120 Kgs
(30% HCl)	= 120 x 100/30 = 400 l

For Anion

Resins required 5% solution for regeneration that goes through 5.1 ejector. In case 1:1 ejector is used (as in softener), final concentration will be half of original.

Anion Volume, m^3	= 1 m3
Regn. Level kg/m^3 (100%NaOH)	= 40
NaOH required 100% NaOH	= Resin Vol. x RL = 40 Kgs
(30% NaOH)	= (40 x 100)/30 = 133

Softeners

Water hardness decrease the life of our equipment so it's necessary to reduce the hardness of water feed, done with a piece of equipment known as a water softener, where the ion exchange process occurs.

The reaction takes place in softener are;

$CaCl_2 + 2NaR \rightarrow CaR_2 + 2NaCl$

$MgSO_4 + 2NaR \rightarrow MgR_2 + Na_2SO_4$

The reaction during regeneration are;

$CaR_2 + 2NaCl \rightarrow 2NaR + CaCl_2$

$MgR_2 + 2NaCl \rightarrow 2NaR + MgCl_3$

Calculation for resin volume:

Load: means the impurity that needs to be removed.

OBR: means output between two successive regenerations.

Resin quantity (l)	=	{Load (Total Hardness in ppm)*OBR (m^3)/Exchange capacity kg/m^3
OBR (m^3)	=	[Resin Quantity (l) * Exchange capacity (m^3)/Load (ppm)

Resins are Key to Demineralization, We have the following Categories:

Strong Acid Cation (SAC) Resin - R. SO3. H

Weak Acid Cation (WAC) Resin) - R.COO.H

Strong Base Anion (SBA) Resin - R. Amine. OH

Weak Base Anion (WBA) Resin - R.Amine

Demineralization Plant

It is the process of removing mineral salts from Water by using the ion exchange process and water produced by this process is completely free of dissolved minerals. This process is also known as Deionized water. During Deionization, Reaction takes place:

The reactions that takes place in cation colutmn are :

$$Ca(HCO_3)_2 + 2RH \rightarrow CaR_2 + 2H_2CO_3$$
$$MgCl_2 + 2RH \rightarrow MgR_2 + 2HCl$$
$$Na_2SO_4 + 2RH \rightarrow 2NaR + H_2SO_4$$

Carbonic acid is unstable and dissociate in to CO_2 and H_2O

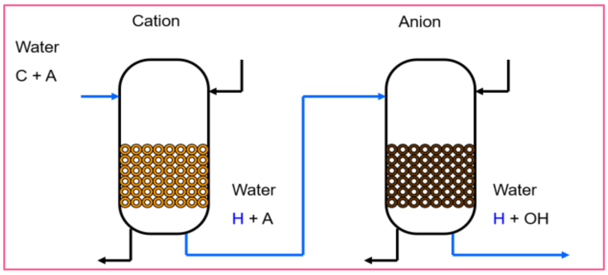
$$H_2CO_3 \rightarrow H_2O + CO_2$$

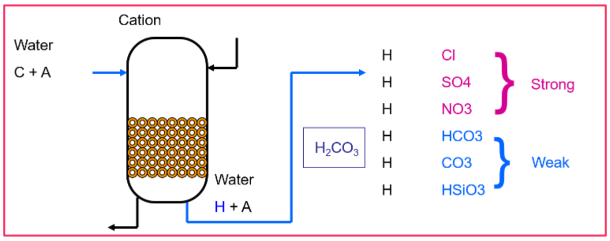
The reaction that takes placer in an anion column are:

$$H_2SO_4 + 2ROH \rightarrow R_2SO_4 + 2H_2O$$
$$HCl + ROH \rightarrow MgR_2 + H_2O$$

$$CO_2 + ROH \rightarrow RHCO_3$$
$$SiO_2 + ROH \rightarrow RHSiO_3$$
$$NaCl + ROH \rightarrow RCl + NaOH$$

DM plant has a Cation & Anion Exchanger as below





Ultrafiltration

Ultra-filtration is a separation process using membranes with pore sizes in the range of 0.1 to 0.001 micron.

Ultra-Filtration (UF) aims at full or partial removal of impurities in comparison to NF & RO as shown below.

Parameter	Unit	Feed	UF	NF	RO
pH		7			~7
TSS	mg/l	35	1	0	0
Turbidity	NTU	104	1	0	0
Oil & Gas	mg/l	12	1	0	0
Colloids	SDI	>7	1	0	0
Color-Soluble	Pt Co	83	40	35	150
Color- Pigments	Pt Co	45	1	0	0
Fe	mg/l	6	1	0	0
Pb	mg/l	2	1	0	0
Zn	mg/l	1	1	0	0
Ca& Mg	mg/l	120		1	0
SO4 CO3	mg/l	125		1	0
Na ,K	mg/l	170		170	0
Cl, NO3 HCO3	mg/l	310		310	0
SiO2	mg/l	22		11	0
CO2	mg/l	6	6	6	6
COD - Organic Soluble	mg/l	120	60	35	0
COD - Organic Particulte	mg/l	10	1	0	0
Pathogens- Bacteria, Virus	TBS/1000ml	10^5	1	0	0
Endotoxins- Bacteeria Dead Body	EU/100ml	200	1	0	0

0 – means it will remove but Foul

Gases: Will not be removed by any process

COD Removal: MWCO Dependent

MF/UF process is a batch process. We need Feed Tank, Product Tank. Since batch could be just 30 or 60 min, UF is always 100% Auto operation.

The crossflow stream has contaminants and thus cannot be looped back to Feed Tank. The backwash water should be pure permeate, and post backwash it shall be discarded.

Terminologies:

Cartridge - a sealed module unit with hollow fiber membranes. Constructed somewhat like a shell and tube heat exchanger.

Flux - $\frac{\text{Flow rate (l/h)}}{m^2 \text{ of membrane}}$

$= l/m^2.h$

Flow = Area x Velocity

Flux increases with increase in temp & pressure and Flux decreases over time.

Permeate - Clean water that has passed through the membrane wall, also known as filtrate.

Retentate - The water with undesirable material in it that has been retained by the membrane. Also known as concentrate, sometimes referred to as the reject or bleed because a portion or % of this is sent to drain.

TMP - This is the amount of force or pressure that is required to push the water through the membrane wall to the permeate side.

Trans Membrane Pressure (TMP) shall be observed during UF operation.

To calculate TMP one must have facility to read: -

Feed Pressure P_f
Reject Pressure P_r
Product Pressure P_p
Formula: -

$$P_{TMP} = \frac{(P_f + P_c)}{2} - P_p$$

Note: For Ultra Filtration, TMP should always be less than 2.3 kg/cm^2

In UF Application what is the role of CEB?

The Chemical is added with permeate to help in CUTTING the deposits.

Hydrophilicity thus is of paramount importance in membrane selection as Water and Chemical must reach all pores to CUT.

CEB: NaOH Cleaning

If feed contains O&G or any oleophilic substances, it's recommended to conduct alkaline backwash.

Use ~ 500 ppm NaOH during backwash.

Actual dose depends upon pH achieved and dose may be reduced to achieve pH ~ 10.5

CEB: NaOCl during Backwash

If feed has plenty of microorganisms and they form layer on membrane surface, they may reduce permeability.

Use ~ 2000 ppm NaOCl during backwash to kill film

Time Scale, h (24 Backwash)																							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
B	B	B	HCl	B	B	B	NaOCl	B	B	B	HCl	B	B	B	NaOH	B	B	B	HCl	B	B	B	NaOH
IfCycle is 30 Min, Still follow above																							
The challenge is now the BW waste is chemical laden, so think whereto take																							

Use alkaline and Acidic & Alkaline CEB as well to remove debris.

Role of LSI

LSI is the measure of Scaling Potential of the water.

If membranes are blocked due to scale:

ΔP will ↑ and Flux would ↓

To avoid above one need to either:

Adjust Feed pH

Use CEB as maintenance step and design Citric Acid or HCl injection during backwash. Typical dose ~ 500 ppm.

LSI	Indication
Positive LSI	Scale Forming Water
Negative LSI	No Potential To Scale
LSI Close to Zero	Non Scaling

What is LSI?

LSI is estimated as the difference between the current pH of the water (pH) and the pH at which calcium carbonate reaches saturation (pH LSI)

LSI = pH – pH LSI

Where
pH LSI = (9.3 + A + B) – (C + D)

where:

A = (log (TDS) – 1)/10

B = -13.12 * log(Temp(0C) + 273) + 34.55

C = log [Ca as CaCO3] – 0.4

D = log [Alk as CaCO3]

LSI Chart

Total Solids	A
50 - 300	0
400 - 1000	0
Temperature	**B**
Deg °c	
0.0 - 1.1	3
2.2 - 5.5	3
2.2 - 5.6	2
10.0 - 13.3	2
14.4 - 16.7	2
17.8 - 21.1	2
22.2 - 26.7	2.0
27.8 - 31.1	2
32.2 - 36.7	2
37.8 - 43.3	2
44.4 - 50.0	2
51.1 - 55.6	2
56.7 - 63.3	1
64.4 - 71.1	1
72.2 - 81.1	1

Calcium Hardness			C
10	-	11	0.6
12	-	13	0.7
14	-	17	0.8
18	-	22	0.9
23	-	27	1.0
28	-	34	1.1
35	-	43	1.2
44	-	55	1.3
56	-	69	1.4
70	-	87	1.5
88	-	110	1.6
111	-	138	1.7
139	-	174	1.8
175	-	220	1.9
230	-	270	2.0
280	-	340	2.1
350	-	430	2.2
440	-	550	2.3
560	-	690	2.4
700	-	870	2.5

M Alkalinity			D
10	-	11	1.0
12	-	13	1.1
14	-	17	1.2
18	-	22	1.3
23	-	27	1.4
28	-	35	1.5
36	-	44	1.6
45	-	55	1.7
56	-	69	1.8
70	-	88	1.9
89	-	110	2.0
111	-	139	2.1
140	-	176	2.2
177	-	220	2.3
230	-	270	2.4
280	-	350	2.5
360	-	440	2.6
450	-	550	2.7
560	-	690	2.8
700	-	800	2.9

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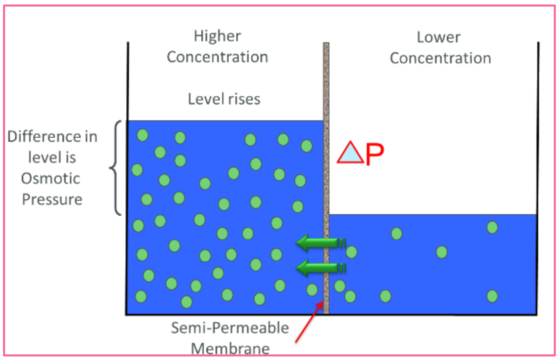
Reverse Osmosis

For RO, recovery relates to water (quantity) and passage and rejection relates to salt (Quality). Engineer must understand this important relation and basic calculation.



RO Recovery

= (Permeate Flow/ Feed Flow) x 100

Salt Balance

Feed Load = Permeate Load + Concentration load

Salt Rejection%:

= 100 - % Salt Passage

Salt Passage%

= (Permeate TDS / Feed TDS) x 100

Pressure Drop

= Feed Pressure – Reject Pressure

Osmotic Pressure

As a thumb rule 1 psi / 86 ppm NaCl

Solution and Material Behaviour

Allows Water	Allows Salt	Example	Called
yes	Yes	Paper	Permeable
No	No	Plastic	Non - Permeable
Yes	No	RO Membrane	Semi - Permeable
No	Yes	EDI Membrane	Semi - Permeable

Brine

Another name for reject. Also Called Concentrate

NDP (Net Driving Force)

In RO Plant since the salt are rejected the brine in TDS. The increase in TDS is understood by the term concentration factor.

= Average feed pressure - Average osmotic pressure

= [(Feed Pressure + Reject Pressure)/2 - Product Pressure] - Average Osmotic Pressure

Concentration Factor

In RO Plant since the salt are rejected the brine in TDS. The increase in TDS is understood by the term concentration factor.

Concentration Factor = Reject TDS / Feed TDS

CF = 1 / (1 – R)
Where R is recovery

Let's Calculate concentration factor and then calculate reject silica for recovery of 80% and feed silica of 25 ppm

CF = 1/ (1-0.8) = 1/0.2 = 5

CF = Reject Silica / Feed Silica

5 = Reject Silica/25

Reject Silica = 5 x 25

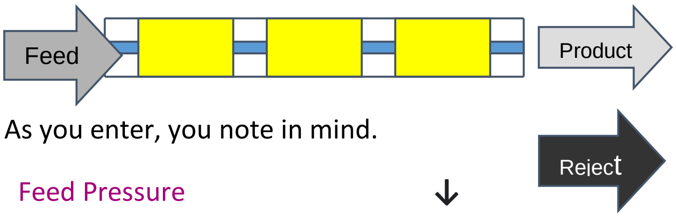
Reject Silica = 125 ppm

At Higher recoveries CF increase at a faster rate w.r.t lower recoveries

% Recovery	CF
40	1.67
50	2
60	2.5
70	4
80	5
90	10

Let’s Enter an RO Plant

A good engineer imagines him / her to be Waughter and feels whats happening by entering and assuming a parameter.



As you enter, you note in mind.

Feed Pressure	$\downarrow$
Feed Flow	$\downarrow$
Feed TDS	$\uparrow$
Feed Osmotic Press	$\uparrow$
Permeate flow/area	$\downarrow$
Reject Flow	$\downarrow$
Permeate Quality	$\downarrow$
Sweeping Velocity	$\downarrow$
% Salt Passage	Unchanged
Reject TDS	$\uparrow$
Flux	$\downarrow$

Your RO plant shall behave the way it is above.

Antiscalant Dose Calculation

$A_{feed} = A_{reject}\,(1\text{-}R)$

Where,
A_{feed} = Antiscalant dose
A_{reject} = Antiscalant residual in reject
R = Recovery (Say 80%)

Antiscalant dose depends on LSI value and normally engineer shall use computer projection to estimate the correct dose. In case of high silica in feed special antiscalant may be required for silica control.

For Example:

If LSI is 1.3 approx. A_{reject} value is 15. For feed flow18m^3 /h the antiscalant dose will be calculated as:-

A feed = A reject (1-R) = 18*(1 – 0.8)= 3.6ppm
100% dose of antiscalant = Flow rate x A feed

= 18m3/h x 3.6ppm

= 64.8 gm/h

For Example:

If LSI is 1.3 approx. A_{reject} value is 15. For feed flow18m^3 /h the antiscalant dose will be calculated as:-
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100% dose of antiscalant = Flow rate x A feed

= 18m3/h x 3.6ppm

= 64.8 gm/h

Caution: One most use polymeric antiscalant in consultant in consultation with the superior and after referring to the RO rejection.

Alum is never used in pretreatment plants in case the water is used for RO application.

SDI Measurement: -

SDI is the measure of all those materials which hooks the surface of the membrane.

If SDI<5 ………………… (Worst feed)

If SDI<1 …………………… (Best Feed)

Note: If SDI > 5, it should never be used for the RO

Formula: -

$$SDI = \frac{[1-(T_i/T_f)]}{T_t}$$

Where,

T_i = Time in seconds for collection of first (Initial) 500 ml sample.

T_f = Time in seconds for collection of final 500 ml sample

T_t = Total time selected for the test in minutes. (Normally it is taken as 15 minutes)

Calibration

Why & When is it important?

Minimise any measurement uncertainty by ensuring the accuracy of test equipment

- When a specified time has been elapsed
- When operating hours has been elapsed
- When instrument has shock or vibration
- Sudden change in weather
- When observations are questionable

Note:

A good engineer should not touch the instrument without having operating and instruction manual and calibration procedure with him/her.

Before you calibrate, answer?

- Do you have a calibration procedure?
- Do you have operating, and installation manual

  People who do not have above answers should not work or they will spoil it.

Calibration of pH

Calibration of pH meter is a very important function that should be performed every day before performing any test on the pH meter.

Operate the pH meter and electrode system according to the manufacturer's instructions or according to the applicable SOPs. All measurements should be made at the same temperature of 20° to 25°.

The apparatus is calibrated with the buffer solution of potassium hydrogen phthalate (primary standard) (buffer pH 4.0) and one other buffer solution of different pH, preferably buffer pH 9.2. The measured pH of a third buffer pH 7.0 must not differ by more than 0.05.

Calibration Procedure:

- Set temperature knob at 25° C
- Wash the DM water and wipe the probe with tissue paper
- Put the probe in to pH 7.00 calibration standard solution
- Set 7.00 using the knob provide in the front of pH meter.
- Wash and wipe the probe and then put it into pH 4.00 calibration standard solution
- Set 4.00 using the knob provide at the back of the pH meter
- Wash the probe and put it back in to DM water.

Preparing calibration standard solution

- Take a respective capsule, open and its salt to 100 ml distilled water
- Mix the solution until the salt dissolved completely

Conductivity Meter

Measuring conductivity in a solution is an important parameter used to determine the quality of that solution. Conductivity can be affected by temperature, pollution and organic materials.

Conductivity meters should be calibrated to a standard solution to ensure accurate measurements. Standard solutions should have a conductivity close to that of the samples to be measured.

Calibration procedure

- Set temperature knob at 25 °C.
- Wash with DM water and wipe the probe with tissue paper
- Put the p[robe in to 1 N KCl standard solution
- Set the range to , 20 mS/cm
- Switch the knob at 'check' and adjust 1.00 using the knob provided at the back of conductivity meter.
- Switch the knob at 'cell constant 'and adjust to the cell constant of the probe using the cell constant knob provided in the front of the meter
- Switch the knob to 'Cond' and the conductivity of 1N KCl solution should be 1413µS/cm.
- Wash the probe and put it back in to DM water.

Preparing Calibration Standard Solution

- Weight 7.45g KCl and add to 100 ml distilled water.
- Mix the solution until the salt dissolved completely.

Note:

- Conductivity meter should be calibrated every morning without fail.
- Calibration standard should be prepared be prepared every 15 days.
- Conductivity probe should always store in D.M water and should be changed every morning.
- After use, conductivity probe should be wash and cleaned thoroughly in in separate beaker and after it should should be put in to D.M. water.

Ionic Conversion Table

Species	Chemical Name	Atomic Wt.	Equivalent Wt.	Multiplication Factors	
				As CaCO3	As such
Ca	Calcium	40.1	20.1	2.5	0.4
$Ca(HCO_3)_2$	Calcium Hydrogen Carbonate	162.1	81.1	0.6	1.6
$CaCO_3$	Calcium Carbonate	100.1	50.1	1.0	1.0
$CaCl_2$	Calcium Chloride	111.0	55.5	0.9	1.1
$Ca(OH)_2$	Calcium Hydroxide	74.0	37.1	1.4	0.7
CaO	Calcium Oxide	56.0	28.0	1.8	0.6
$CaSO_4$	Calcium Sulfate	136.1	68.1	0.7	1.4
$Ca(NO_3)_2$	Calcium Nitrate	164.1	82.1	0.6	1.6
Mg	Magnesium	24.3	12.2	4.1	0.2
$Mg(HCO_3)_2$	Magnesium Hydrogen Carbonate	146.3	73.0	38.0	1.5
$MgCO_3$	Magnesium Carbonate	84.3	47.2	1.2	0.8
$MgCl_2$	Magnesium Chloride	95.2	47.2	1.1	1.0
MgO	Magnesium Oxide	40.3	20.2	2.5	0.4
$MgSO_4$	Magnesium Sulfate	120.4	60.2	0.8	1.2
$Mg(No_3)_2$	Magnesium Nitrate	148.3	74.2	0.7	1.5
Na	Sodium	23.0	23.0	2.2	0.5
$NaHCO_3$	Sodium Hydrogen Carbonate	84.0	84.0	0.6	1.7
Na_2CO_3	Sodium Carbonate	106.0	53.0	0.9	1.1
NaCl	Sodium Chloride	58.5	58.5	0.9	1.2
NaOH	Sodium Hydroxide	40.0	40.0	1.3	0.8
$NaNO_3$	Sodium Nitrate	85.0	85.0	0.5	1.7
Na_2SO_4	Sodium Sulfate	142.1	71.0	0.7	1.4
HCO_3	Bicarbonate	61.0	61.0	0.8	1.2
CO_3	Carbon trioxide	60.0	30.0	1.7	0.6
CO_2	Carbon dioxide	44.0	44.0	1.1	0.9
Cl	Chloride	35.5	35.5	1.1	0.7
NO_3	Nitrate	62.0	62.0	0.8	1.2
SO_4	Sulafate	96.1	48.0	1.0	1.0
SiO_2	Silicon dioxide	60.0	60.0	0.8	1.2

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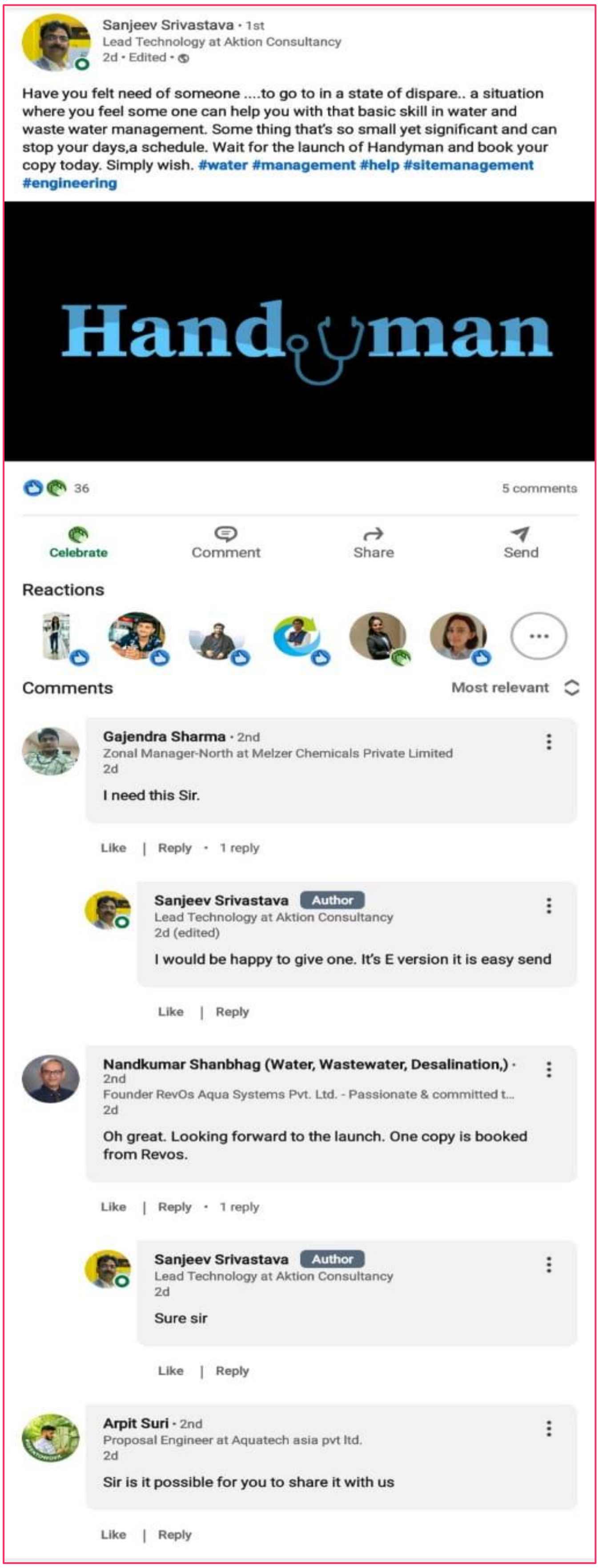
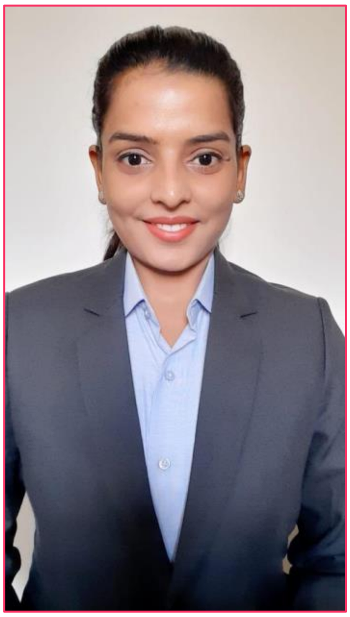


जल जीवन जननी !!

As an intern, I learned a lot of technical things. Even then, I used to think that how big the industry would have been, how the equipment would look like. Will everyone know like I know technical?

The answer is 'NO'



So, I thought that something like Handyman should be created that will help a fresher and technician to understand the technical things and equipment working.

I am delighted to get this chance and have tried to cover small to small concept. If you think something needs to be CHANGED or ADD in this, then contact us.

Vaishali Singh – Technical Associate

Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead. Our next edition focuses on:

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