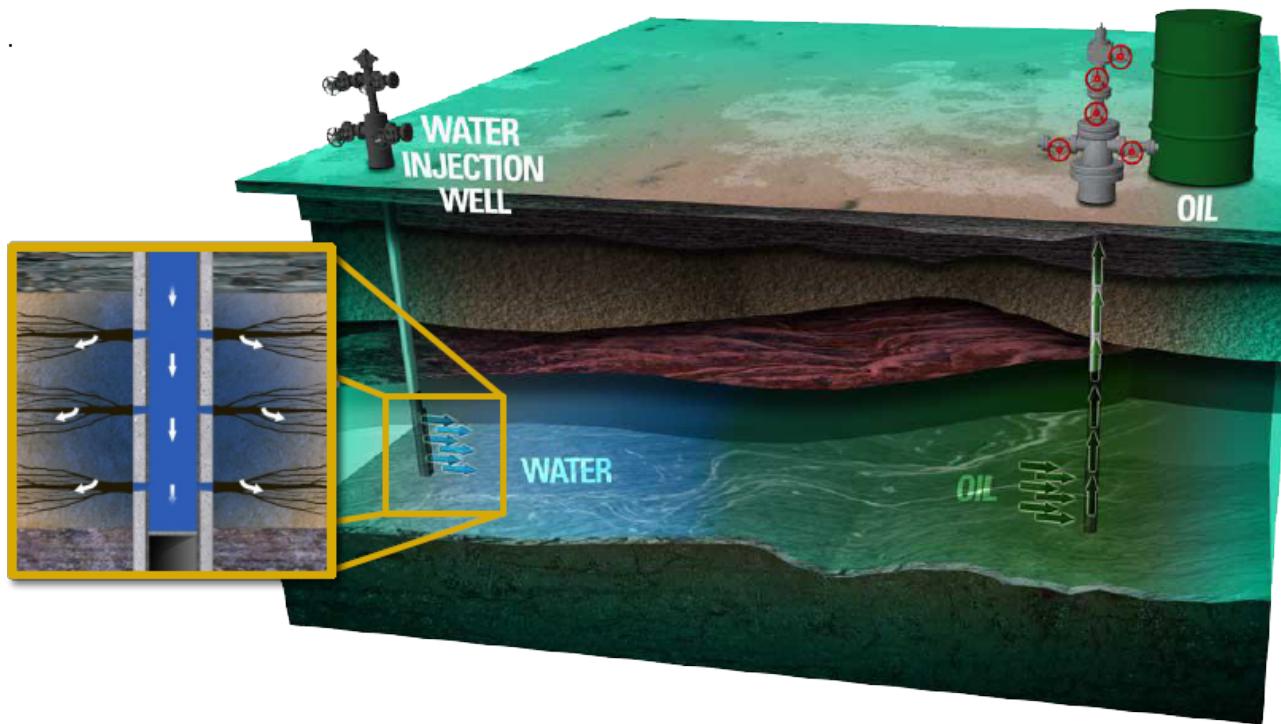

Upstream Process Engineering Course

6. Water Injection

Water Injection

1. Reservoir Pressure Support
2. To avoid dumping produced water to sea

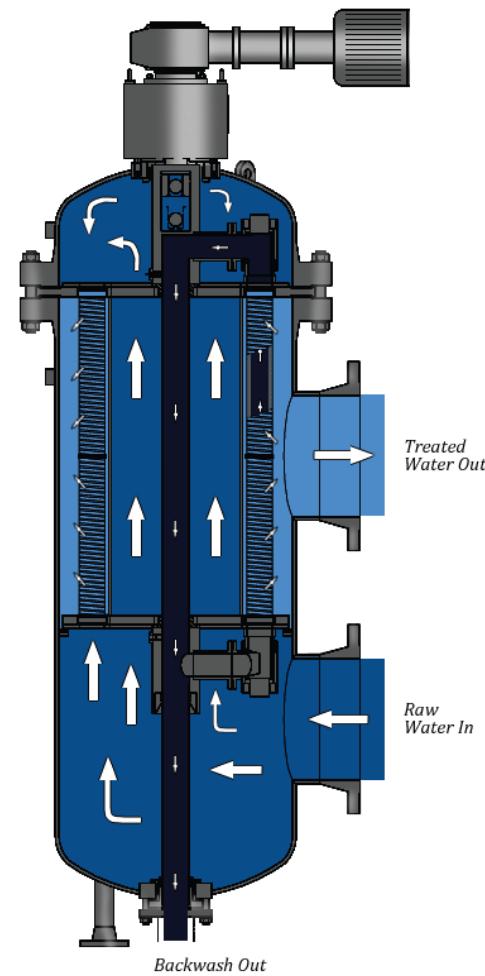
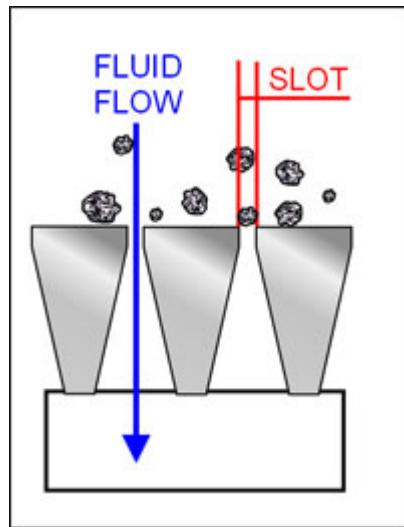


Seawater Coarse Filtration

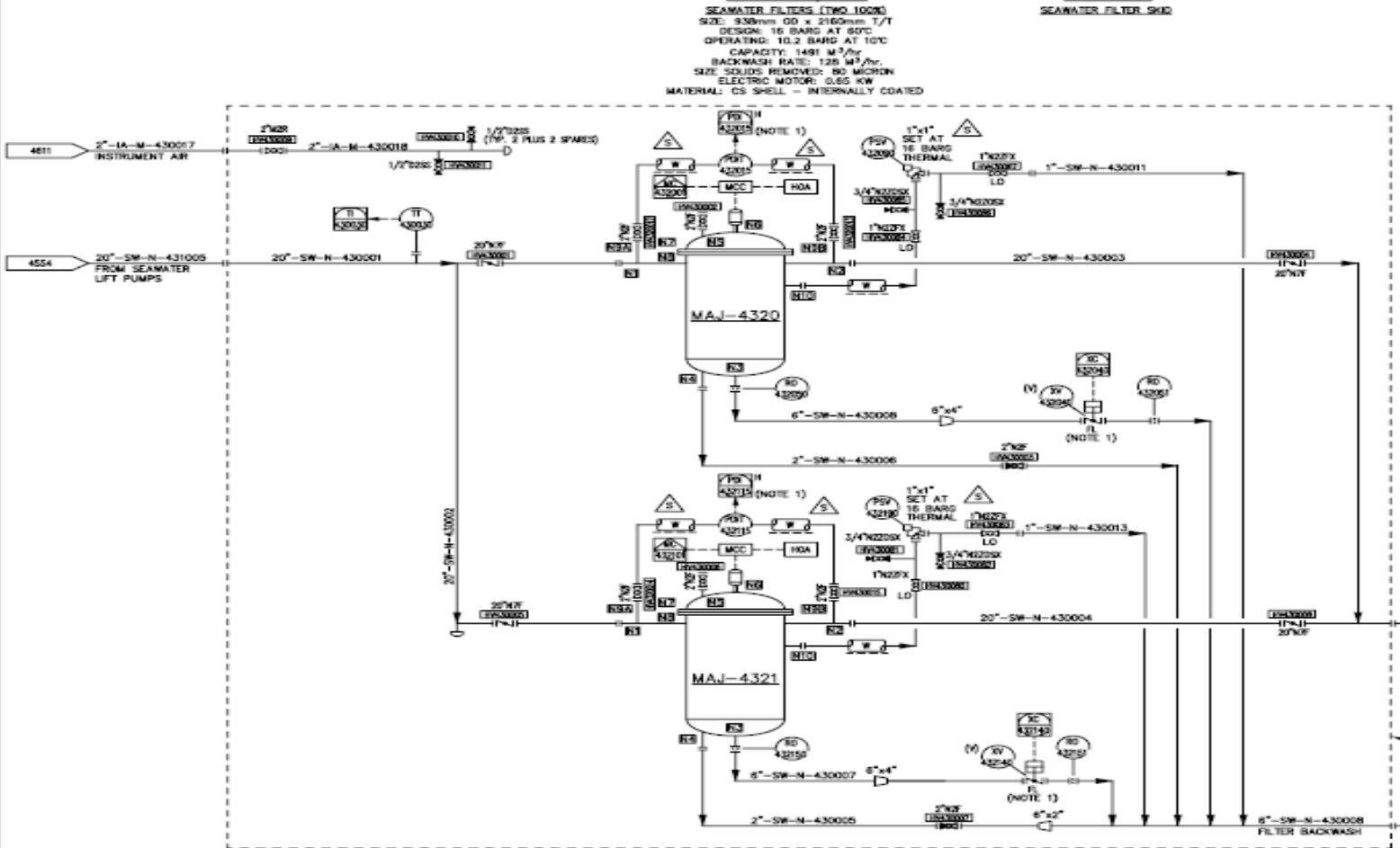
Seawater pumped to a facility requires filtration prior to use. The seawater passes through a coarse filter which will typically remove 95% of particle over 50 microns.

Operation

In the design shown, the seawater enters the base of the strainer basket, passing radially outwards through wire wedge strainers. A portion of the filtered seawater is used to flush the wedges in the opposite direction to dislodge the trapped solids.

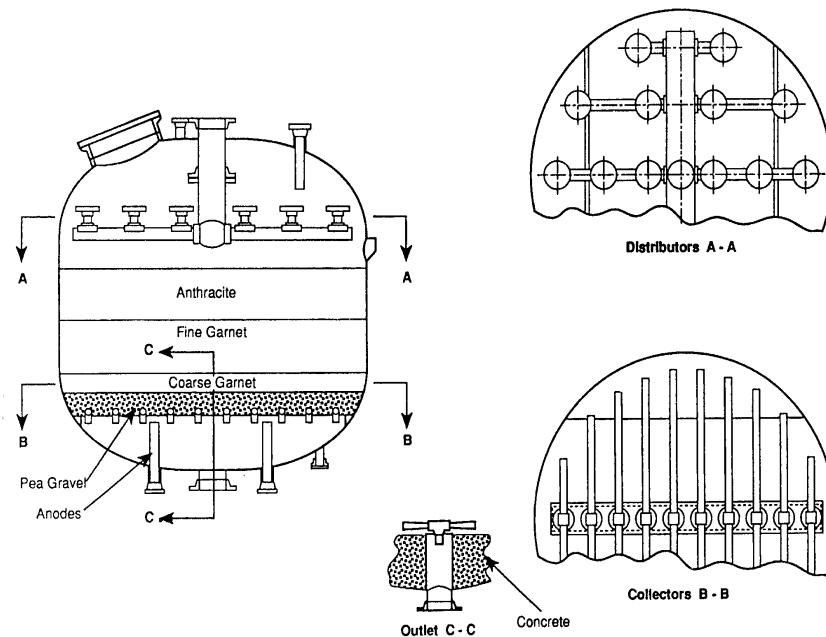


Seawater Coarse Filtration P&ID



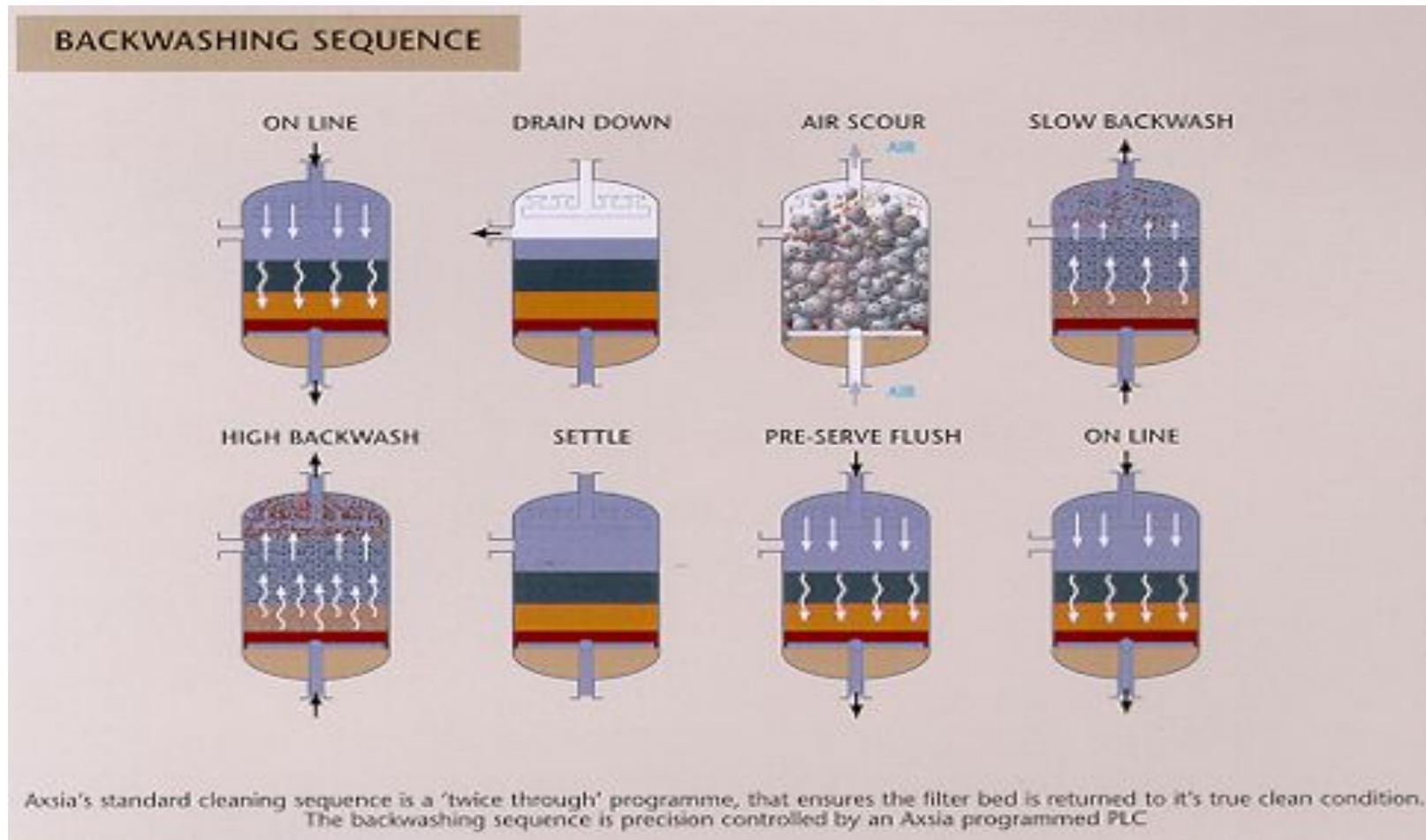
Fine Filtration

To prevent reservoir rock blockage due to injected solids, the seawater is filtered to remove typically 98% of 2 micron particles.



Sand filters

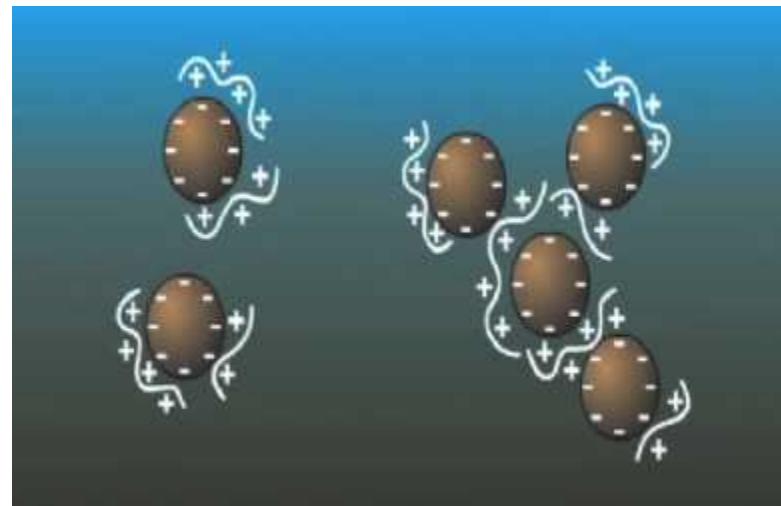
Fine Filtration - Back Washing



Coagulation and Flocculation

Media filter performance is therefore enhanced by use of chemicals.

- Coagulant - ferric chloride
- Affects negative charged cloud around small particles
- Flocculant - polyelectrolyte
- Long chain polymer which bridges particles and attaches them to the filter media.



Fine Filtration

Investigation of various reservoirs has indicated that the removal of fine filtration has negligible impact on injectivity. As a result Fine Filtration facilities have been mothballed on various platforms such as Magnus and Miller and is not considered for many green field applications.

For oil fields where the formation rock has low permeability, sand filters may still be utilised.

Deaeration

The removal of oxygen from seawater is an established means of corrosion control and allows the use of carbon steel material for flowlines and downhole tubulars in place of corrosion resistant alloys. An injection water oxygen-in-water specification is typically < 5 ppb, often 2-3 ppb mol fraction.

There are various methods for the deaeration of seawater:

- Chemical Injection
- Gas Stripping
- Vacuum

Deaeration – Vacuum System

System equipment

Deaeration tower
Vacuum Package

Vacuum system are capable of reducing the oxygen content to 20 - 50 ppb mechanically with further reduction to 5-10 ppb achieved via the injection of scavenger chemicals.

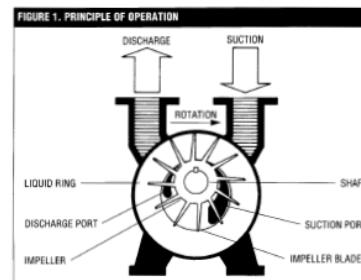
Packed bed, two stage deoxygenation systems are commonly used. 90% of the dissolved gases are typically removed in first stage.

Single stage liquid ring vacuum pump and air ejector provide required vacuum levels.

Liquid seal provided between both stages.

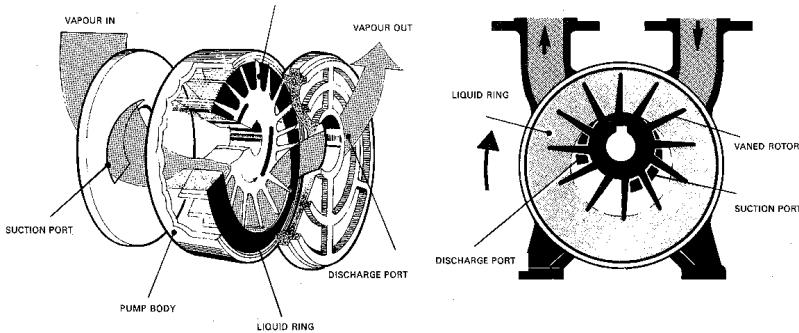
Deaerator sump provides

- reaction time for oxygen scavenger
- Suction head for booster pumps
- pump rundown reservoir
- flow buffer

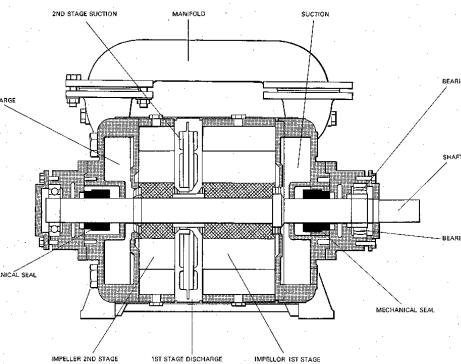


Vacuum Pumps

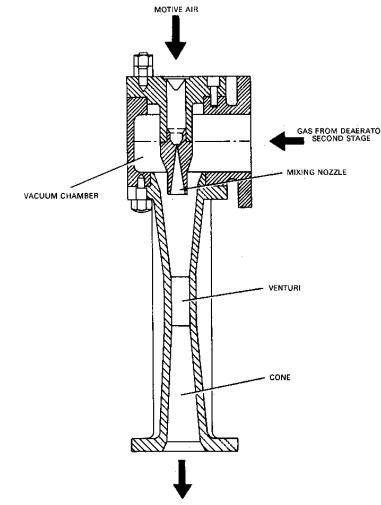
- Vacuum pumps are used to draw vacuum in the deaeration (deoxygenation) tower
- Vacuum is created by either:
 - Directly acting vacuum pumps (liquid ring type) or
 - Vacuum ejectors using HP separator gas as motive gas



Vacuum Pump Operation

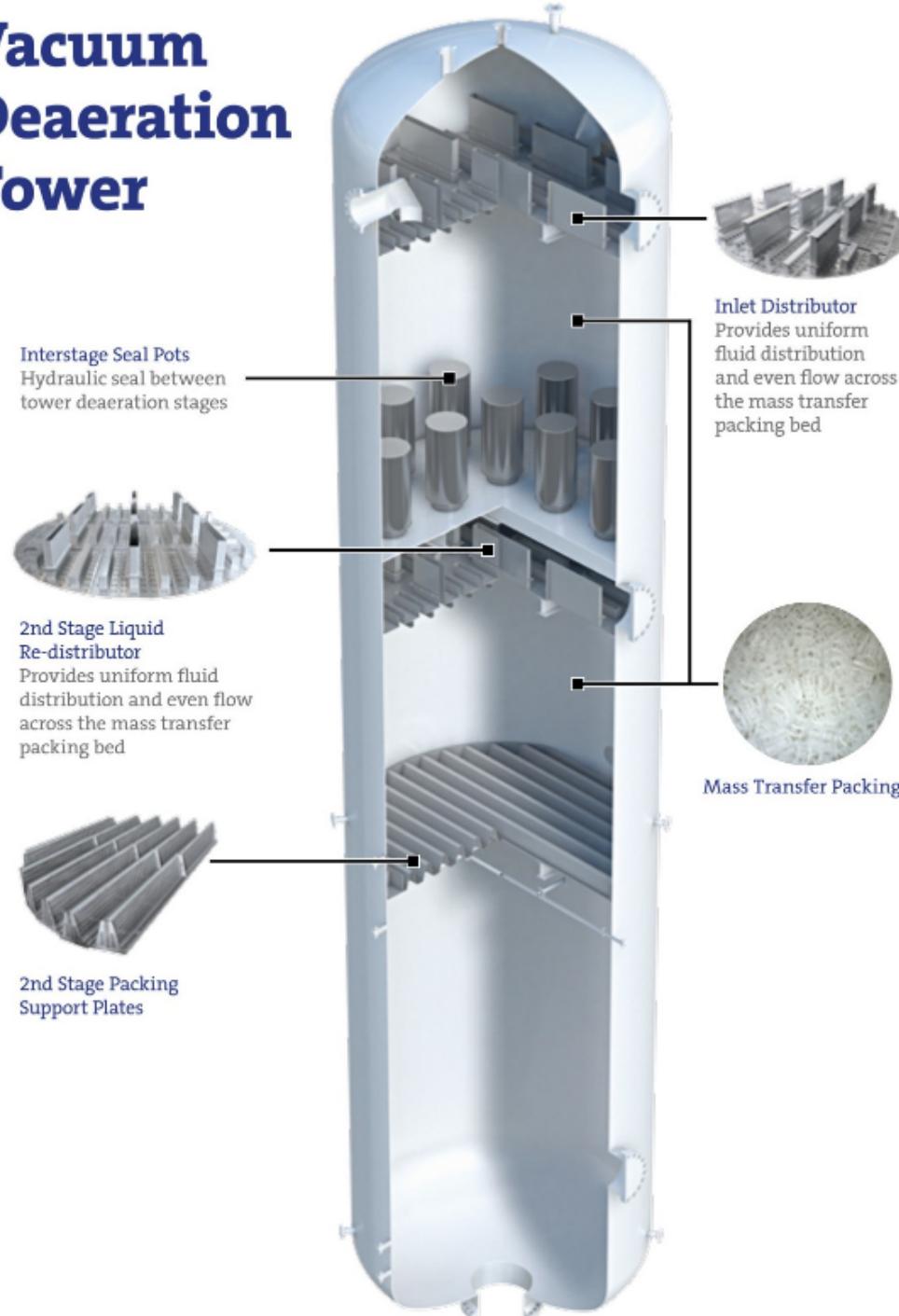


Vacuum Pump section



Vacuum Ejector

Vacuum Deaeration Tower



Number of Stages

Deaerator Stages	2	1
Total Oxygen Load	1 kg/h	1 kg/h
<u>Stage 1</u>		
Operating Pressure	40 Torr	-
Oxygen Load	0.93 kg/h	-
Water Vapour Load	0.558 kg/h	-
<u>Stage 2</u>		
Operating Pressure	10 Torr	10 Torr
Oxygen Load	0.07 kg/h	1.0 kg/h
Water Vapour Load	0.56 kg/h	8.0 kg/h
Total Vacuum Pump Load	180 m ³ /h @ 40 Torr	1100 m ³ /h @ 40 Torr
Pump Power	22 kW	75 kW

VACUUM DEAERATOR DESIGN - Design Principles

HENRY'S LAW :

The partial pressure of the contaminant above the liquid

$$pp = H \cdot x$$

H – Henry's constant

x – mol fraction of component in liquid phase

The partial pressure of the contaminant in the vapour phase

$$pp = y \cdot P_T$$

P_T – system pressure

y – mol fraction of component in vapour phase

Perry 7th Edition (Pure Water)

T(°C) Units	VP H ₂ O Torr	H _{N2} × 10 ⁻⁴ atm/mole fraction	H _{O2} × 10 ⁻⁴	H _{N2}	H _{O2}
0	4.58	5.29	2.55	52,900	25,500
5	6.54	5.97	2.91	59,700	29,100
10	9.21	6.68	3.27	66,800	32,700
15	12.79	7.38	3.64	73,800	36,400
20	17.54	8.04	4.01	80,400	40,100
25	23.76	8.65	4.38	86,500	43,800
30	31.82	9.24	4.75	92,400	47,500
35	42.18	9.85	5.07	98,500	50,700
40	55.32	10.40	5.35	104,000	53,500
45	71.88	10.90	5.63	109,000	56,300
50	92.51	11.30	5.88	113,000	58,800
60	149.38	12.00	6.29	120,000	62,900
70	233.70	12.50	6.63	125,000	66,300
80	355.10	12.60	6.87	126,000	68,700
90	525.76	12.60	6.99	126,000	69,900
100	760.00	12.60	7.01	126,000	70,100

Deaeration system vendors have corrections for salinity.

Oxygen in water

Calculate the concentration of oxygen in water for an air water system in equilibrium at 15 DegC? Oxygen concentration of air is 20.95 mol%.

$$H = 36400 \text{ atm/mf} \text{ at } 15 \text{ DegC}$$

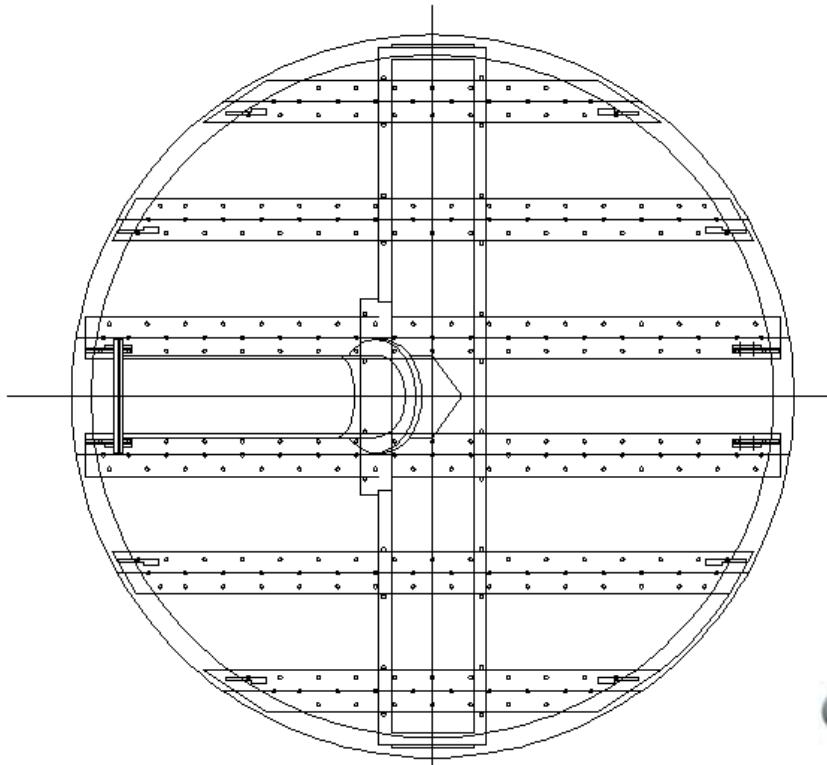
$$ppO_2 = 0.2095 \text{ atm}$$

$$x_{O_2} = 0.2095/36400 = 5.7 \times 10^{-6} = 5.7 \text{ ppm}$$

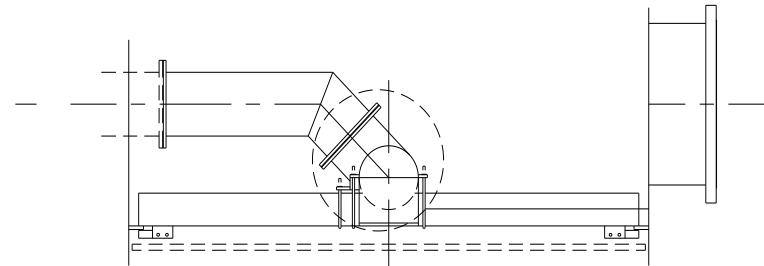
Perry 7th Edition (Pure Water)

T(°C) Units	VP H ₂ O Torr	H _{N2} × 10 ⁻⁴ atm/mole fraction	H _{O2} × 10 ⁻⁴	H _{N2}	H _{O2}
0	4.58	5.29	2.55	52,900	25,500
5	6.54	5.97	2.91	59,700	29,100
10	9.21	6.68	3.27	66,800	32,700
15	12.79	7.38	3.64	73,800	36,400
20	17.54	8.04	4.01	80,400	40,100
25	23.76	8.65	4.38	86,500	43,800
30	31.82	9.24	4.75	92,400	47,500
35	42.18	9.85	5.07	98,500	50,700
40	55.32	10.40	5.35	104,000	53,500
45	71.88	10.90	5.63	109,000	56,300
50	92.51	11.30	5.88	113,000	58,800
60	149.38	12.00	6.29	120,000	62,900
70	233.70	12.50	6.63	125,000	66,300
80	355.10	12.60	6.87	126,000	68,700
90	525.76	12.60	6.99	126,000	69,900
100	760.00	12.60	7.01	126,000	70,100

Deaerator Internals



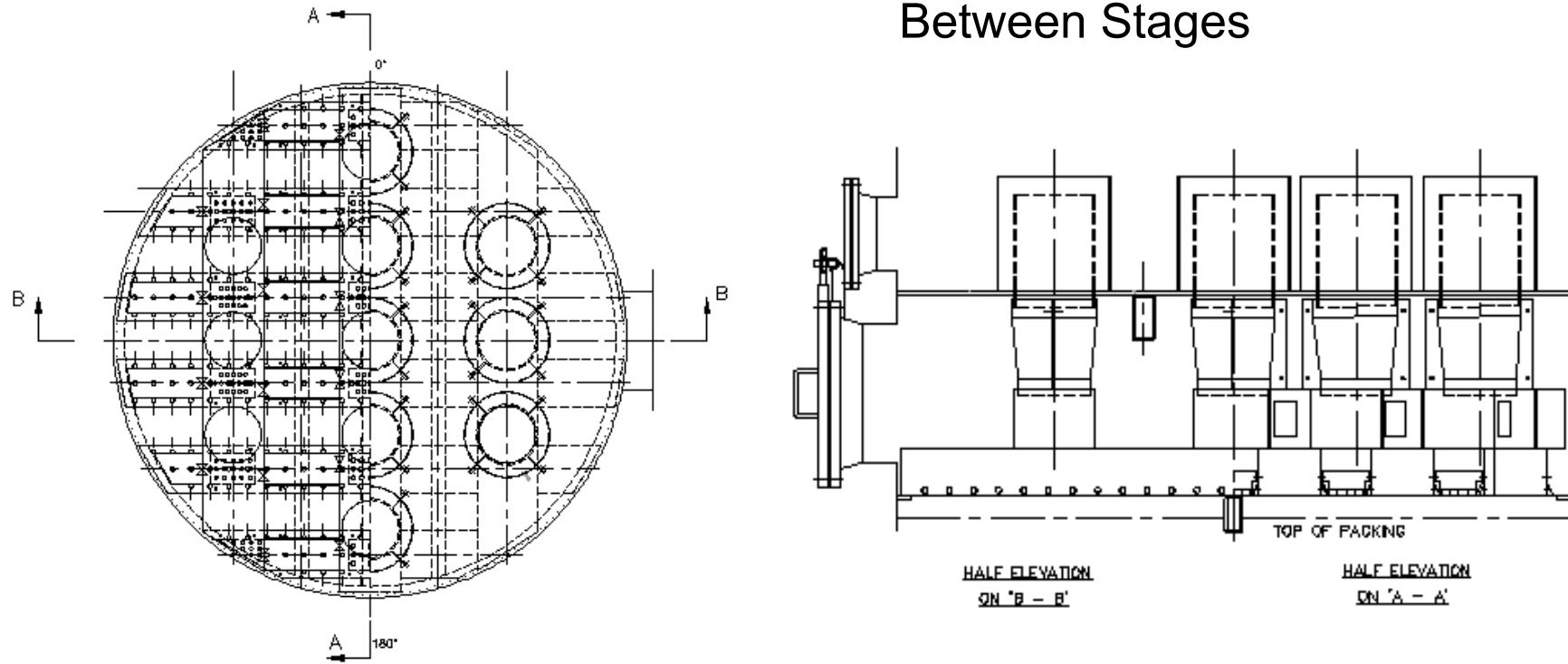
Top Distributor



Deaerator Internals

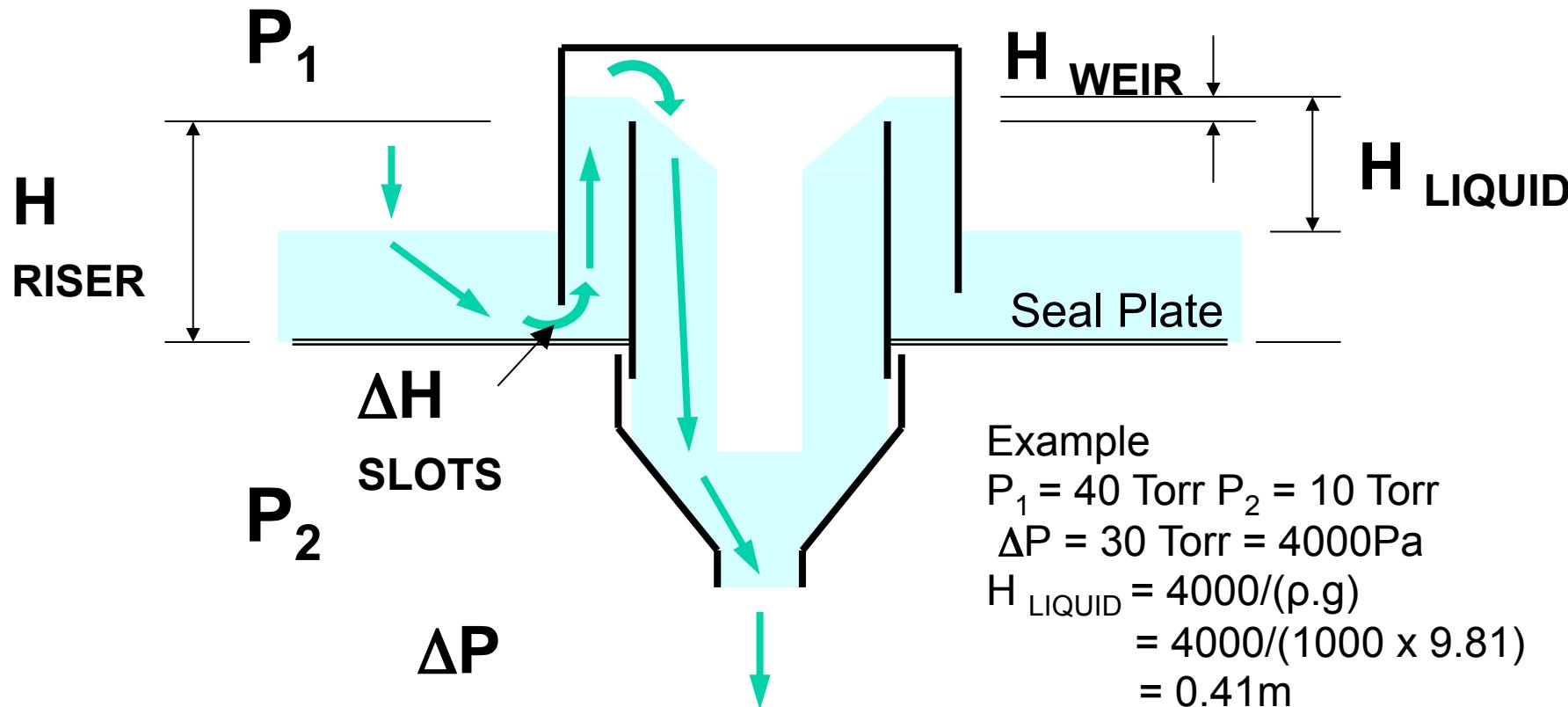
For a multi-stage vacuum column a sealing system is required to allow operation at differing vacuums

**Seal Plate/Redistributor
Between Stages**



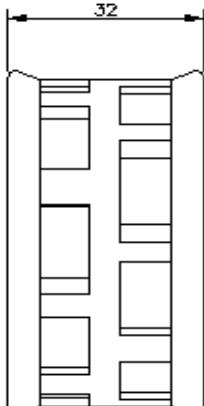
Packing

$$H_{RISER} = H_{LIQUID} + (P_1 - P_2) - \Delta H_{SLOTS} - H_{WEIR}$$

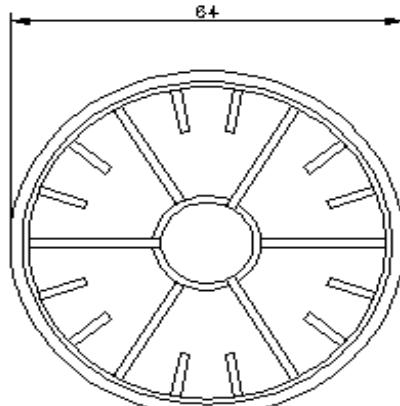


Deaerator Internals

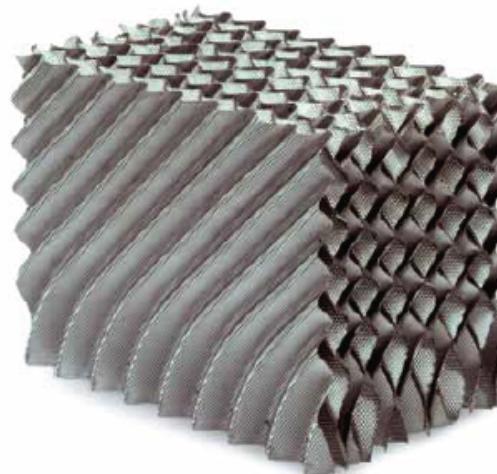
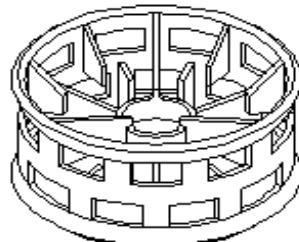
Packing – typically Beta Rings or Structured packing



ELEVATION



PLAN VIEW



Structure of the
Montz-Pak Type M / MN

The new Type MN-series gives 30% more separation efficiency along with higher throughput capacity when compared to standard packing crimps. Higher purities, small column heights and simple tower debottlenecking are now possible.

The Type M-series allows throughput increases of 30% compared to columns equipped with standard packing types due to the reduced pressure drop. This packing only offers the same efficiency as standard packing types.

Both packing types are patented in the USA and Europe. Layer height depends upon crimp shape which prevents liquid hold-up at the lower end of the packing layer at high gas loads.

Type M and Type MN packing are ideal for new columns or tower revamps. Revamps from standard packed columns to the new high performance packing types consistently deliver outstanding performances.

Applications

- vacuum columns
- normal-pressure and high pressure columns
- absorption
- natural gas drying with glycols refinery columns
- revamping existing packing, random rings or tray columns

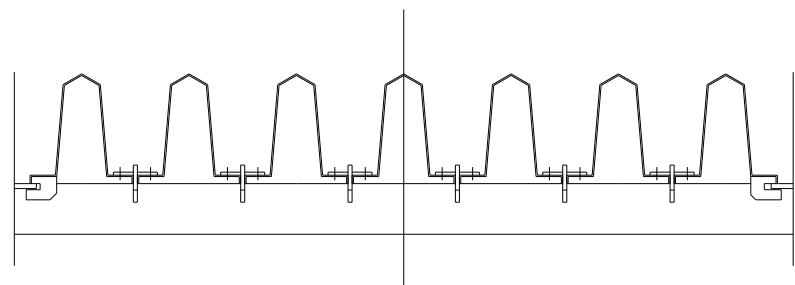
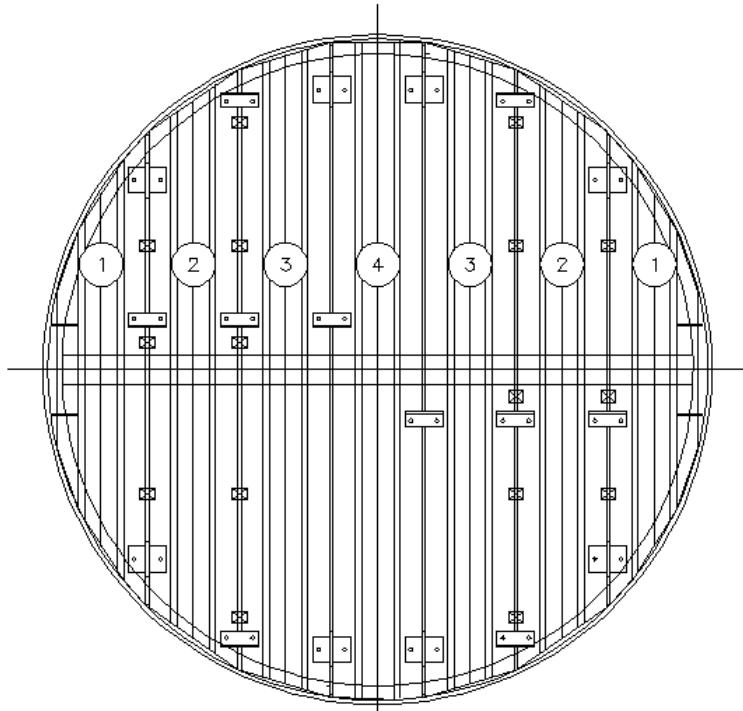
Characteristics Type M

- maximized capacity
- lowest pressure drop
- same separation efficiency compared to standard packing types

Characteristics Type MN

- higher capacity
- lower pressure drop
- highest separation efficiency

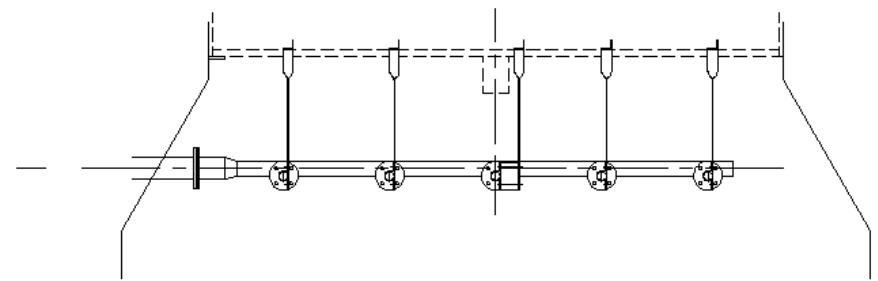
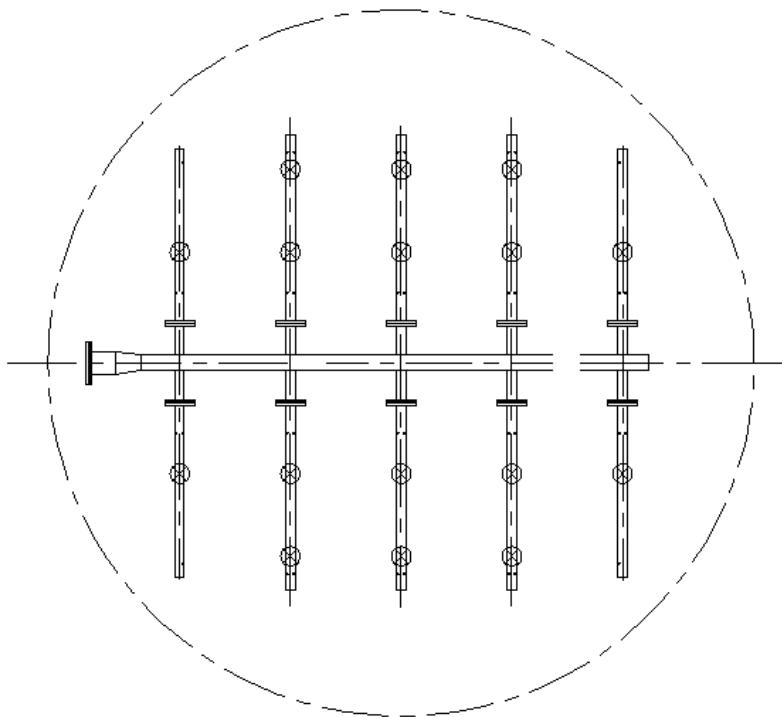
Deaerator Internals



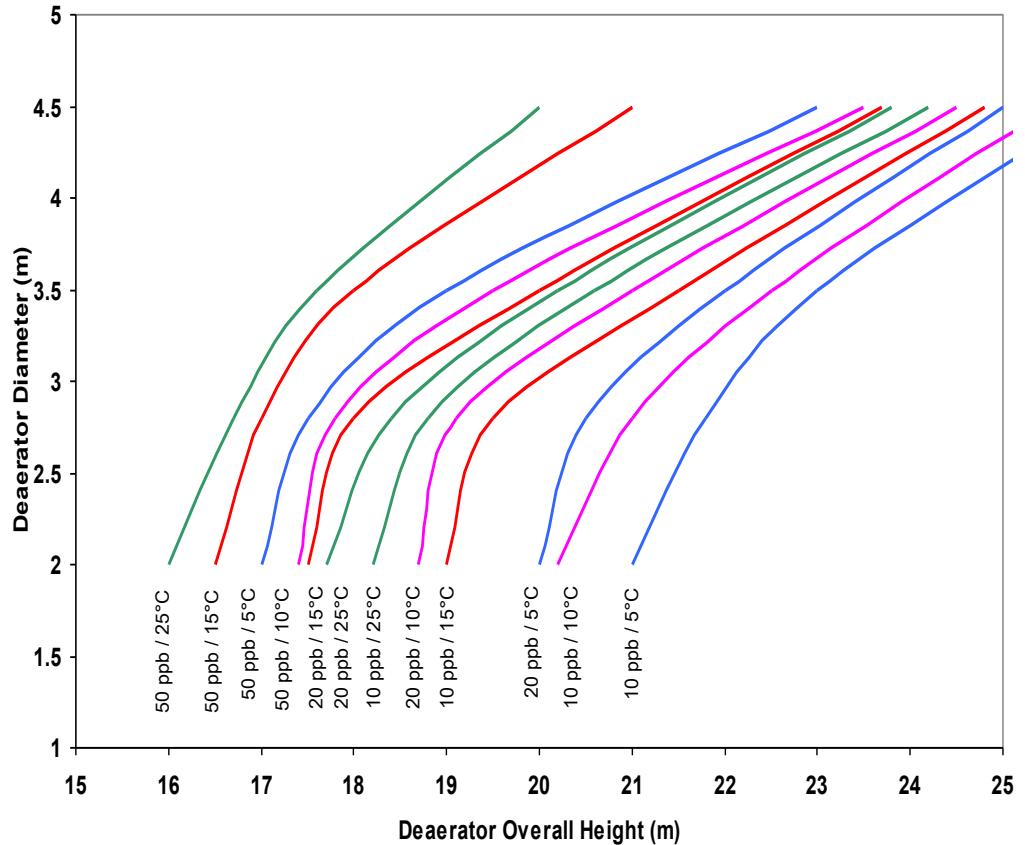
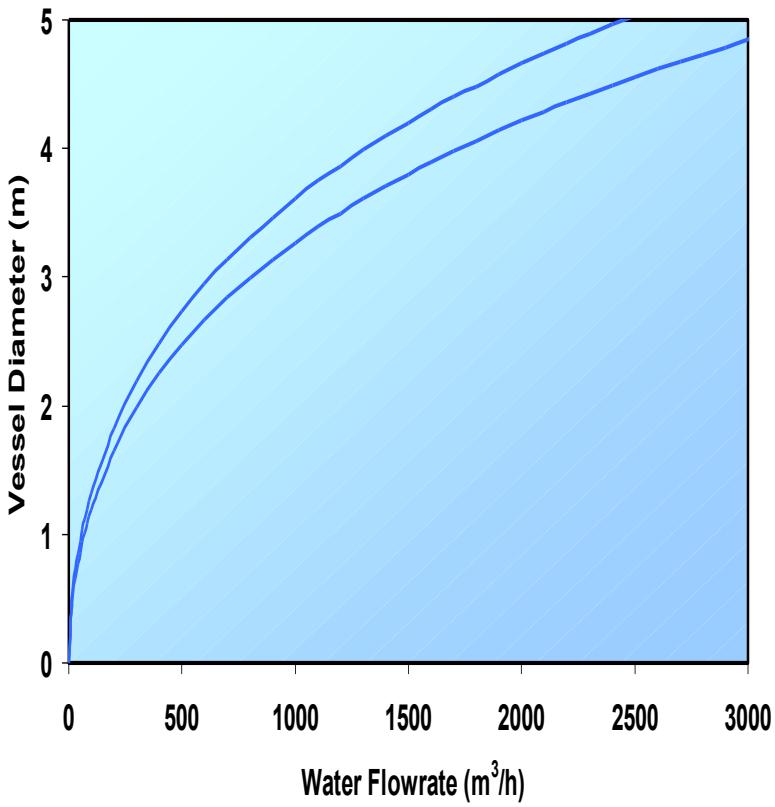
Support Plate

Deaerator Internals

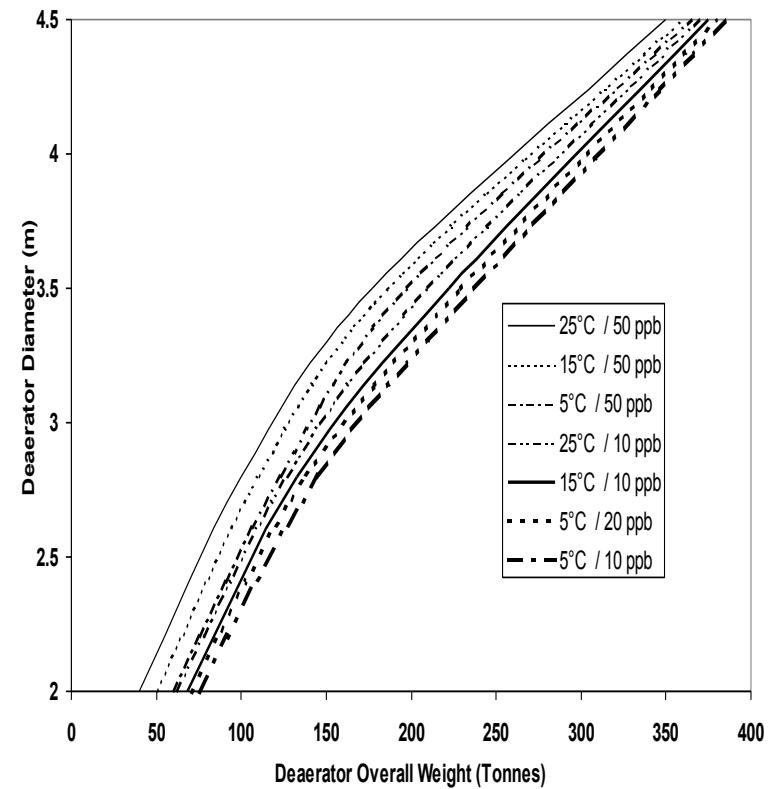
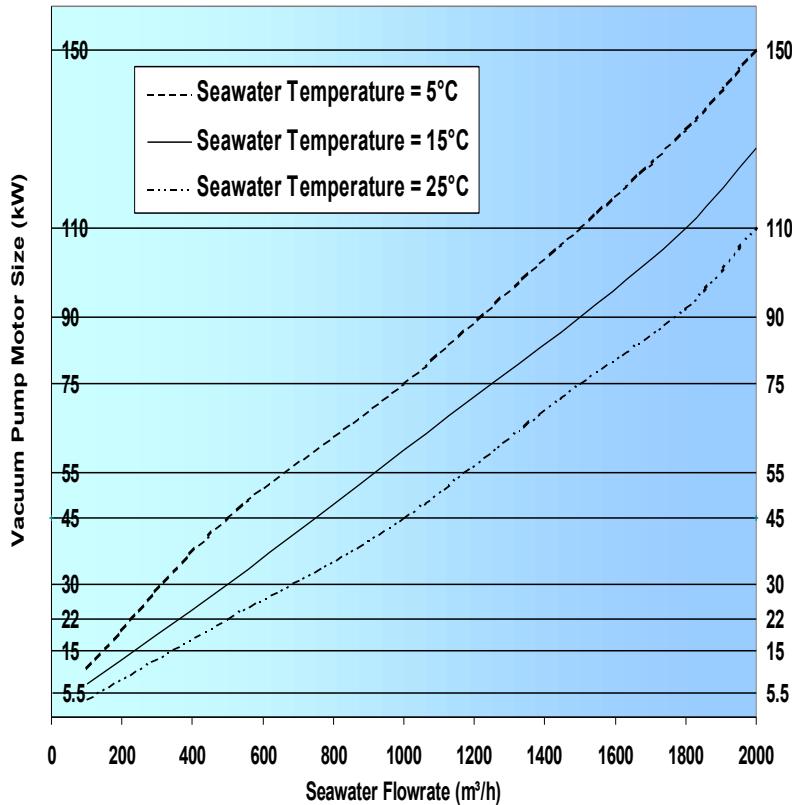
Oxygen Scavenger
Distributor



Conceptual Sizing



Conceptual Sizing



Chemical Injection

A number of chemicals are required for the Water Treatment system :-

Oxygen Scavenger-Irrespective of the oxygen levels attainable by the deaeration equipment, oxygen scavenger will be provided to supplement and provide back-up to the deaeration system. Oxygen scavenger reaction requires residence time hence use of deaerator sump - 2 mins typical. Sodium and ammonium bisulphite commonly used. It should be noted that the scavenger reacts with free chlorine hence preventing further biofouling control. This is usually dosed into the recycled carrier water flow from the booster pumps, back to the tower (approximately 1% of the tower throughput) to give good distribution into the sump. Based on ammonium bisulphite as the scavenging chemical, dose rates;

1. 8 ppm Scavenger per 1 ppm oxygen
2. 2.4 ppm Scavenger per 1 ppm chlorine
3. 1-2 ppm Scavenger to drive the reaction

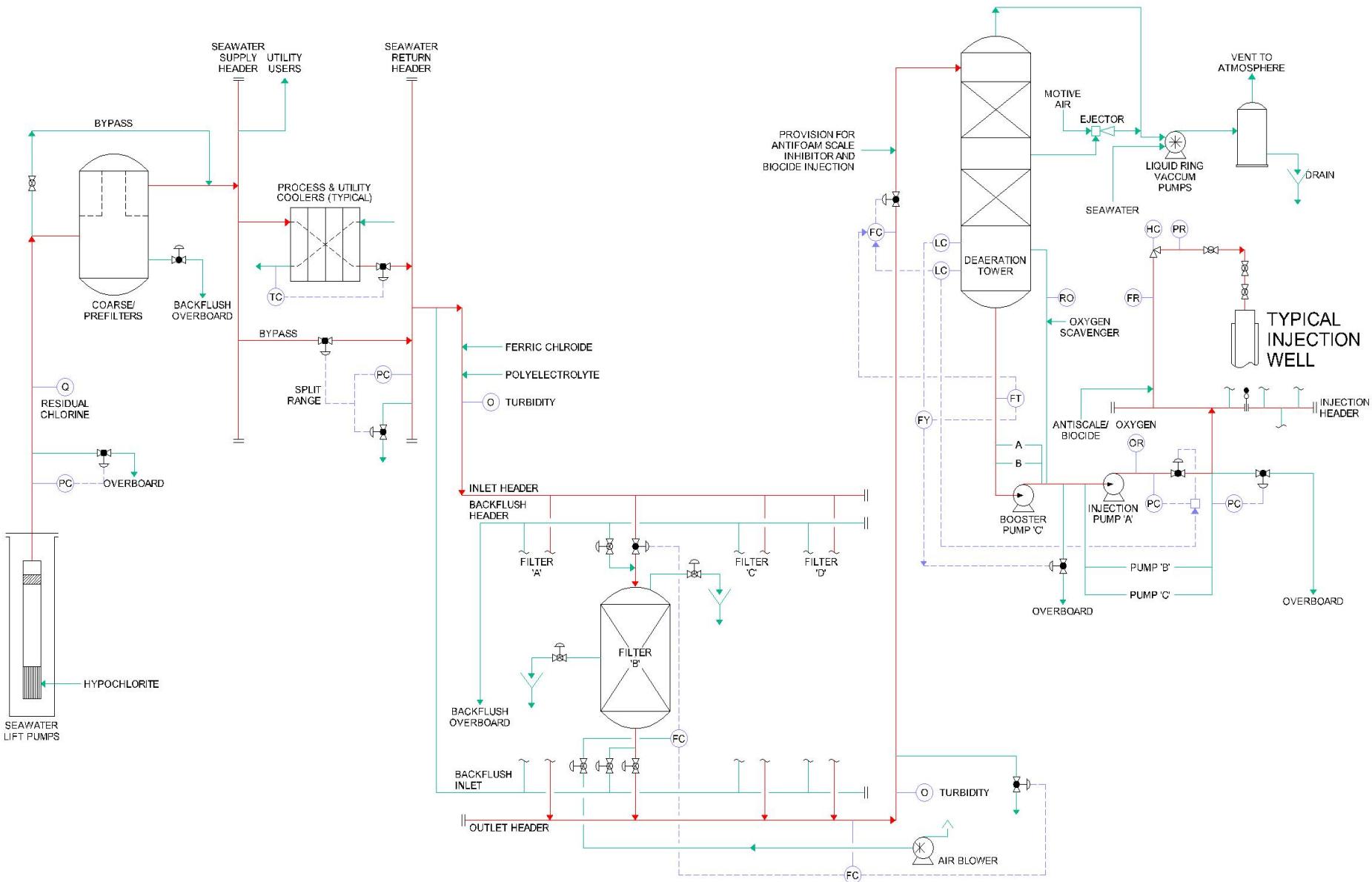
At temperatures $<15^{\circ}\text{C}$, the reaction time is $\leq 1\frac{1}{2}$ minutes.

At temperatures $>15^{\circ}\text{C}$, the reaction time is ≤ 1 minute.

Biocide-Biocide injection points are provided downstream of the deaeration equipment. Biocide is normally injected periodically as required to kill any bacterial growth in topsides and downhole equipment.

Anti-foam-Anti-foaming agents will be injected upstream of the deaerator if and when foaming within the deaerator impacts the outlet water specification. Does rate typically 1ppm.

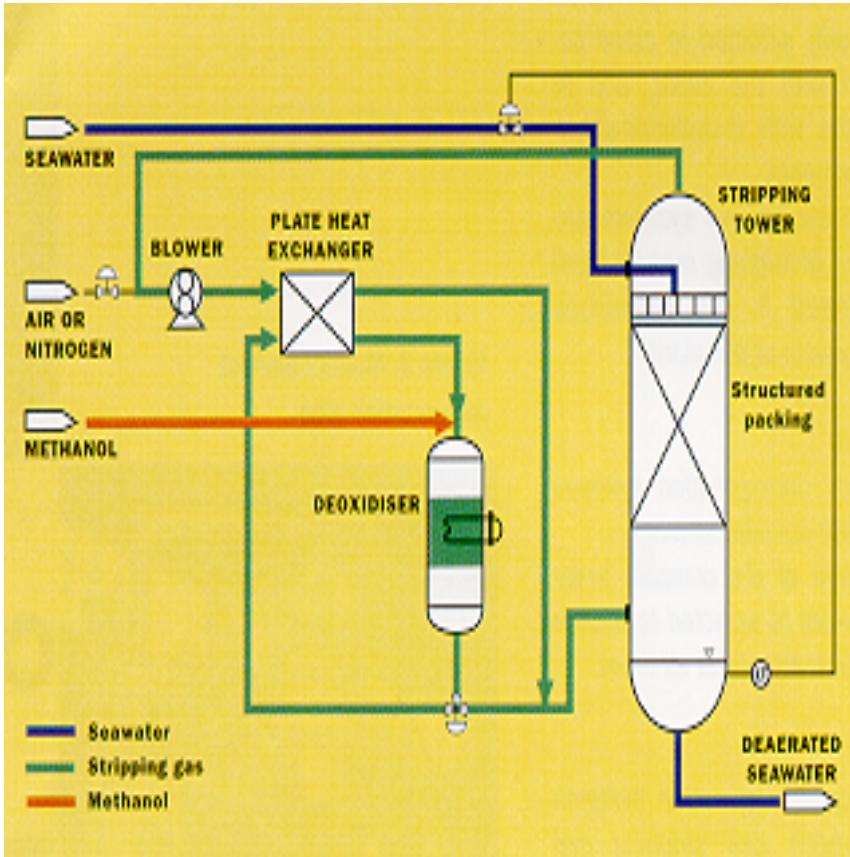
Nitrate Addition - biogenic formation of hydrogen sulfide has, and will, occur in most oil and gas reservoirs - particularly those flooded with sea water. Hydrogen sulfide causes high costs and serious operational problems, including reservoir souring, sulfide corrosion, iron sulfide plugging, reduced product value, and health and environmental hazards. Historically, the sulfide problem has been treated with toxic biocides, which have proven to be costly and mostly ineffective. Trials are underway with a nitrate-based microbial treatment technology for both the prevention and removal of sulfide from reservoirs, produced water, surface facilities, pipelines and gas storage reservoirs, as well as increasing oil recovery.



TYPICAL SEAWATER LIFT & INJECTION ARRANGEMENT

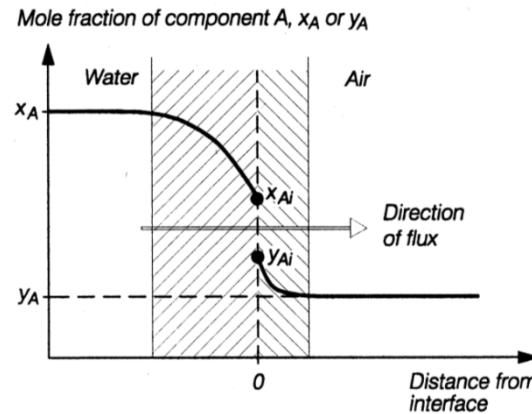
Deaeration – Gas Stripping

Minox System.



DEAERATOR DESIGN – Stripping Gas Design Principles

Most techniques for designing packed columns for stripping (and absorption) are based upon the Whitman two-film theory concept.



Steady mass transfer equates the mass rate through the liquid film to that through the gas film.

$$\text{Mass flux} = K_{La} \cdot (x_A - x_{Ai}) = K_{Ga} \cdot (y_{Ai} - y_A)$$

The overall stripping mass transfer coefficients K_{Ga} and K_{La} are based upon the driving force between the liquid and the gas.

This concept has been developed for the analysis of packed column using the method of transfer units.

DEAERATOR DESIGN – Number Transfer Units

In this method, height of packing required can be evaluated either based on the gas-phase or the liquid-phase. The packed height (z) is calculated using the following:

$$Z = L_m / (\rho_m \cdot K_l) \cdot \int dx / (x_e - x)$$

L_m is the molar velocity, mol/hr.m²

K_l is the mass transfer coefficient

ρ_m is the molar density, kgmol/m³

x is the mole fraction of the solute in the main body of liquid

x_e is the mole fraction of the solute in equilibrium with the main body of gas

DEAERATOR DESIGN – Number Transfer Units

If the equilibrium and operating lines are straight, as is the case for O₂ stripping, then the integral may be replaced with the following;

$$(x_1 - x_2) / \Delta x_{lm}$$

$$\Delta x_{lm} = ((x - x_e)_1 - (x - x_e)_2) / \ln((x - x_e)_1 / (x - x_e)_2)$$

1 and 2 are top and bottom of column.

This is simplified to;

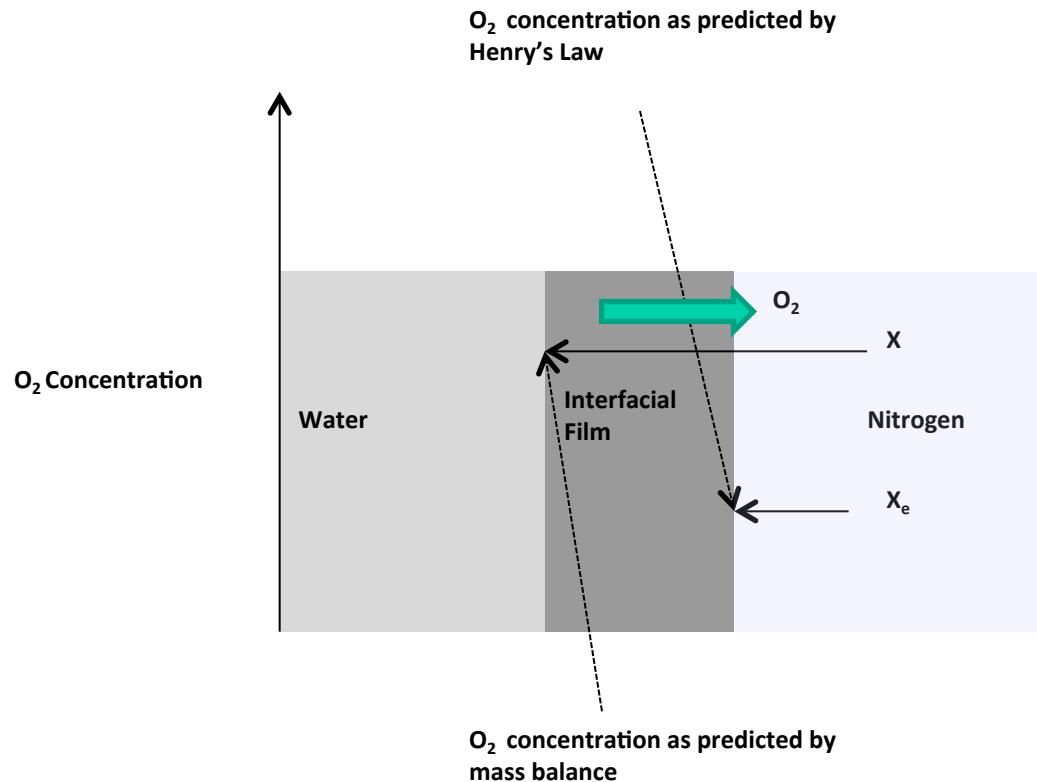
$$Z = N \times H$$

where ;

$$N = \text{number of transfer units (NTU)} - \text{dimensionless} = (x_1 - x_2) / \Delta x_{lm}$$

$$H = \text{height of transfer units (HTU)} - \text{dimension of length} = L_m / (\rho_m \cdot K_l).$$

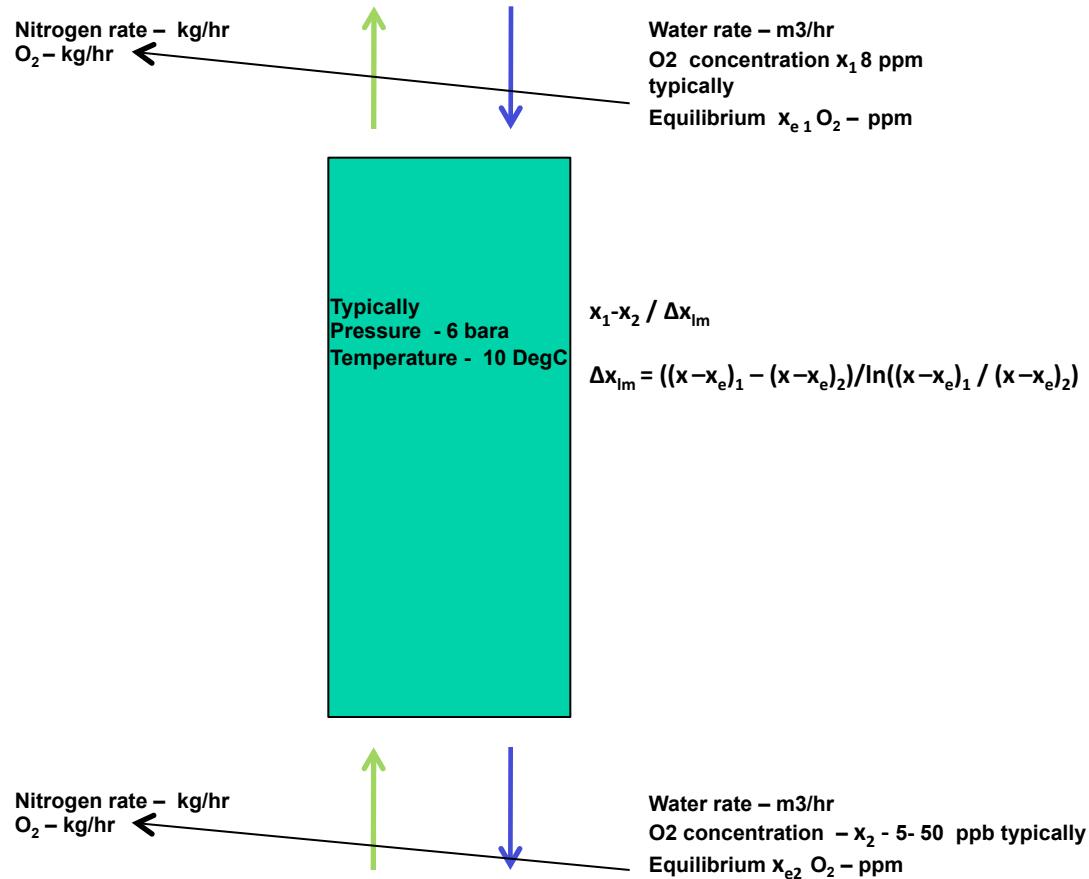
DEAERATOR DESIGN – Stripping Gas Design Principles



DEAERATOR DESIGN – Stripping Gas Design Principles

The number of transfer units (NTU) required is a measure of the difficulty of the separation. A single transfer unit gives the change of composition of one of the phases equal to the average driving force producing the change. The NTU is similar to the number of theoretical trays required for trayed column. Hence, a larger number of transfer units will be required for a very high purity product.

The height of a transfer unit (HTU) is a measure of the separation effectiveness of the particular packing for a particular separation process. As such, it incorporates the mass transfer coefficient . The more efficient the mass transfer (i.e. larger mass transfer coefficient), the smaller the value of HTU. HTU is generally supplied by the mass transfer equipment vendors. The values of HTU can be estimated from empirical correlations or pilot plant tests, but the applications are rather restricted.



DEAERATOR DESIGN – Height of Transfer Unit

Onda, Takeuchi, and Okumoto(1968) published useful correlations for the film mass-transfer coefficients kG and kL and the effective wetted area of the packing a_w , which can be used to calculate the HTU.

Their correlations were based on a large amount of data on gas absorption and distillation, with a variety of packings that included Pall rings and Berl saddles. Their method for estimating the effective area of packing can also be used with experimentally determined values of the mass-transfer coefficients, and values predicted using other correlations.

The equation for the effective area is shown:

$$\frac{a_w}{a} = 1 - \exp \left[-1.45 \left(\frac{\sigma_c}{\sigma_L} \right)^{0.75} \left(\frac{L_w^*}{a\mu_L} \right)^{0.1} \left(\frac{L_w^{*2} a}{\rho_L^2 g} \right)^{-0.05} \left(\frac{L_w^{*2}}{\rho_L \sigma_L a} \right)^{0.2} \right]$$

The mass transfer coefficient is calculated from:

$$k_L \left(\frac{\rho_L}{\mu_L g} \right)^{1/3} = 0.0051 \left(\frac{L_w^*}{a_w \mu_L} \right)^{2/3} \left(\frac{\mu_L}{\rho_L D_L} \right)^{-1/2} (ad_p)^{0.4}$$

$$\frac{k_G}{a} \frac{RT}{D_v} = K_5 \left(\frac{V_w^*}{a \mu_v} \right)^{0.7} \left(\frac{\mu_v}{\rho_v D_v} \right)^{1/3} (ad_p)^{-2.0}$$

where $K_5 = 5.23$ for packing sizes above 15 mm, and 2.00 for sizes below 15 mm

L_w^* = liquid mass flow rate per unit cross-sectional area, kg/m²s

V_w^* = gas mass flow rate per unit column cross-sectional area, kg/m²s

DEAERATOR DESIGN – Height of Transfer Unit

The mass transfer coefficient is calculated from:

$$k_L \left(\frac{\rho_L}{\mu_L g} \right)^{1/3} = 0.0051 \left(\frac{L_w^*}{a_w \mu_L} \right)^{2/3} \left(\frac{\mu_L}{\rho_L D_L} \right)^{-1/2} (ad_p)^{0.4}$$

$$\frac{k_G}{a} \frac{RT}{D_v} = K_5 \left(\frac{V_w^*}{a \mu_v} \right)^{0.7} \left(\frac{\mu_v}{\rho_v D_v} \right)^{1/3} (ad_p)^{-2.0}$$

where $K_5 = 5.23$ for packing sizes above 15 mm, and 2.00 for sizes below 15 mm

L_w^* = liquid mass flow rate per unit cross-sectional area, kg/m²s

V_w^* = gas mass flow rate per unit column cross-sectional area, kg/m²s

a_w = effective interfacial area of packing per unit volume, m²/m³

a = actual area of packing per unit volume (see Table), m²/m³

d_p = packing size, m

σ_c = critical surface tension for the particular packing material given below:

Material	σ_c mN/m
Ceramic	61
Metal (steel)	75
Plastic (polyethylene)	33
Carbon	56

σ_L = liquid surface tension, N/m

k_G = gas film mass-transfer coefficient, kmol/m²s atm or kmol/m²s bar

k_L = liquid film mass-transfer coefficient, kmol/m²s (kmol/m³) = m/s

DEAERATOR DESIGN – Height of Transfer Unit

Table 17.2 Design Data for Various Packings

	Size		Bulk Density (kg/m ³)	Surface (m ² /m ³)	Packing Factor F_p m ⁻¹
	in	mm			
Raschig rings ceramic	0.50	13	881	368	2100
	1.0	25	673	190	525
	1.5	38	689	128	310
	2.0	51	651	95	210
	3.0	76	561	69	120
Metal (density for carbon steel)	0.5	13	1201	417	980
	1.0	25	625	207	375
	1.5	38	785	141	270
	2.0	51	593	102	190
	3.0	76	400	72	105
Pall rings metal (density for carbon steel)	0.625	16	593	341	230
	1.0	25	481	210	160
	1.25	32	385	128	92
	2.0	51	353	102	66
	3.5	76	273	66	52
Plastics (density for polypropylene)	0.625	16	112	341	320
	1.0	25	88	207	170
	1.5	38	76	128	130
	2.0	51	68	102	82
	3.5	89	64	85	52
INTALOX® saddles ceramic	0.5	13	737	480	660
	1.0	25	673	253	300
	1.5	38	625	194	170
	2.0	51	609	108	130
	3.0	76	577		72

DEAERATOR DESIGN – Height of Transfer Unit

The units for k_G will depend on the units used for the gas constant:

$$R = 0.08206 \text{ atm m}^3/\text{kmol K} \text{ or}$$

$$0.08314 \text{ bar m}^3/\text{kmol K}$$

The film transfer unit heights are given by

$$\mathbf{H}_G = \frac{G_m}{k_G a_w P}$$

$$\mathbf{H}_L = \frac{L_m}{k_L a_w C_t}$$

where P = column operating pressure, atm or bar

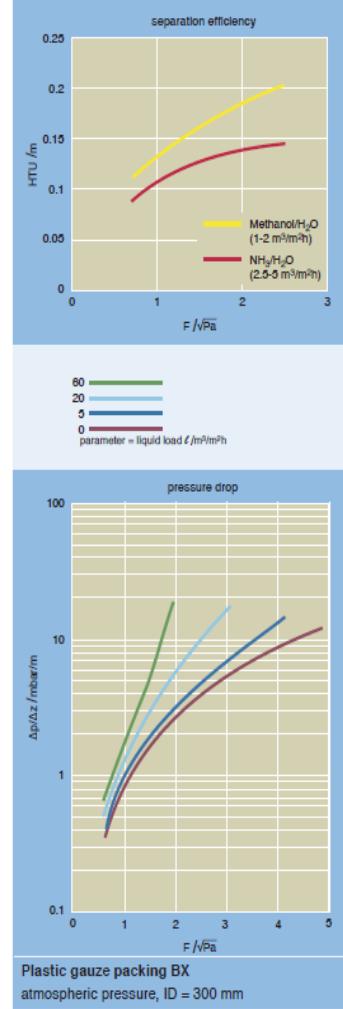
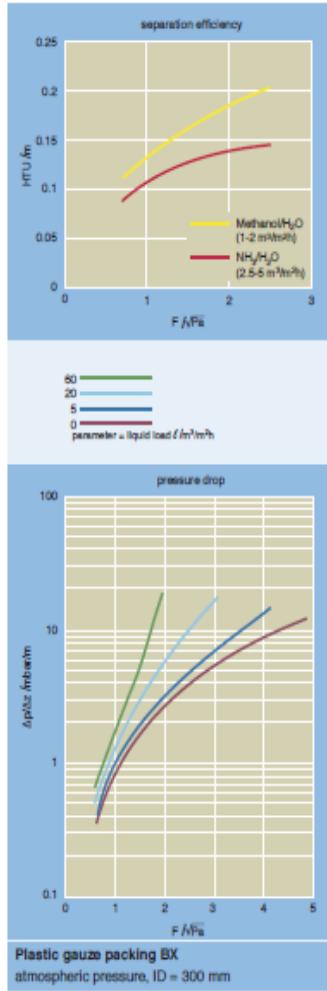
C_t = total concentration, $\text{kmol/m}^3 = \rho_L / \text{molecular weight solvent}$

G_m = molar gas flow rate per unit cross-sectional area, $\text{kmol/m}^2\text{s}$

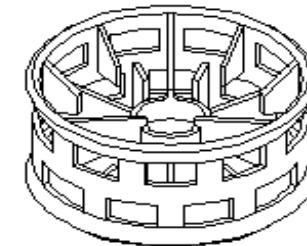
L_m = molar liquid flow rate per unit cross-sectional area, $\text{kmol/m}^2\text{s}$

Typical HTU values for a gas stripping unit are 0.6 – 1.0 m

HTU Vendor Data

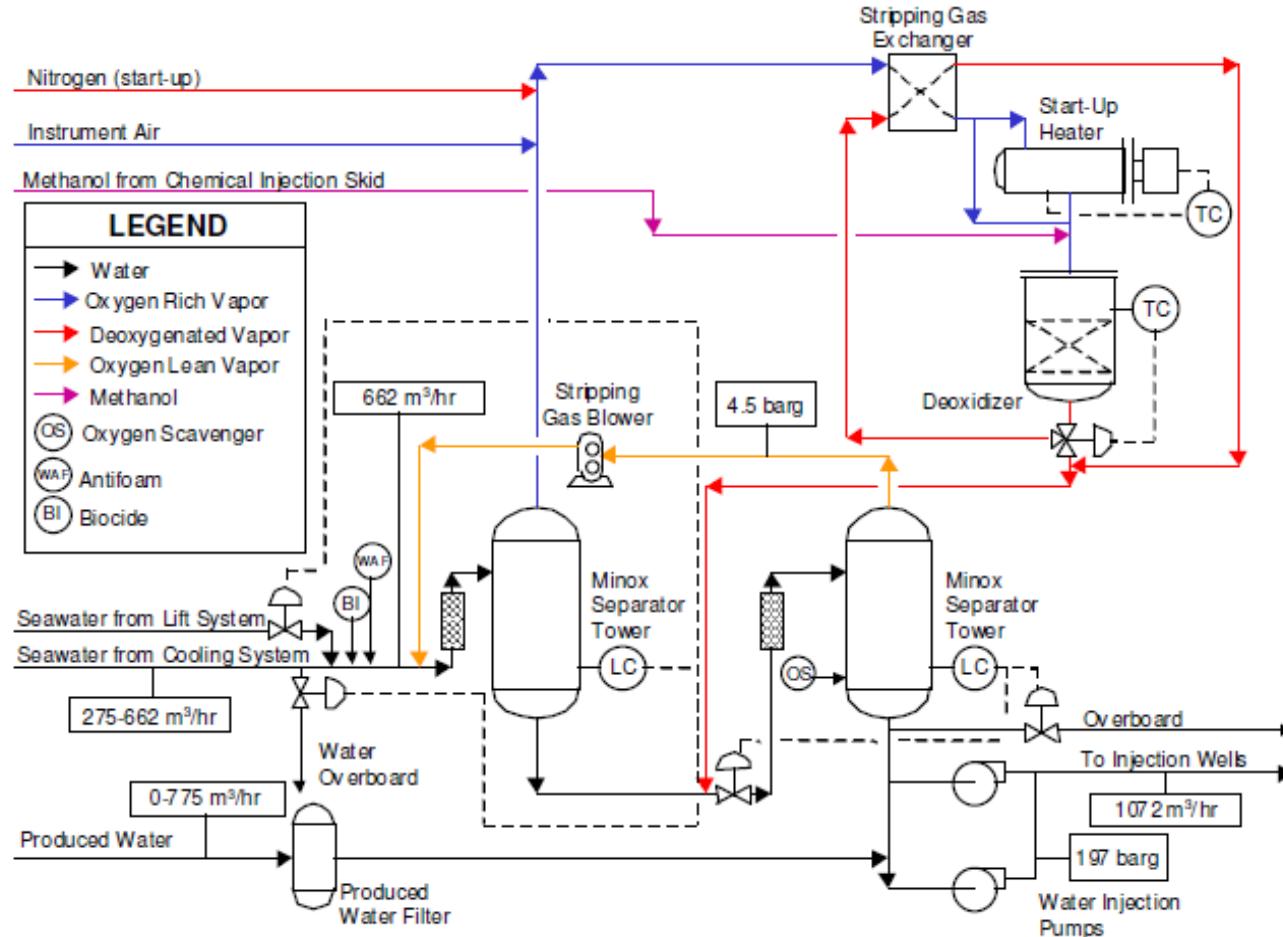


Typical height of a transfer unit for Beta Rings is 1m.



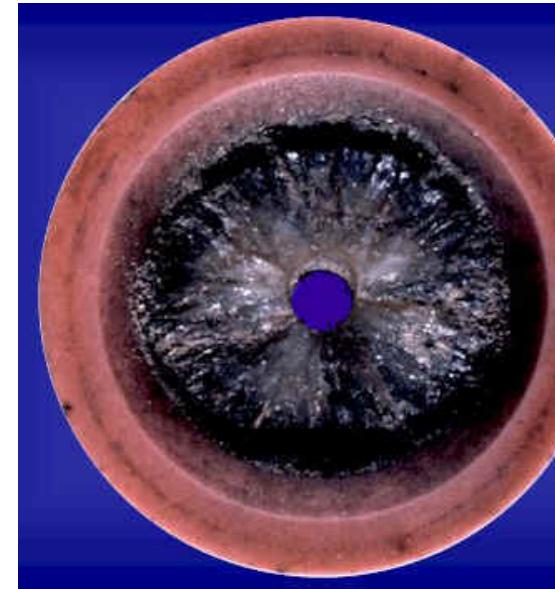
F	$F \text{ factor} = W_G \cdot \sqrt{\rho_G}$	$\text{m/s} \sqrt{\text{kg/m}^3} = \sqrt{\text{Pa}}$	0.8197	$\text{ft/s} \sqrt{\text{lbm/ft}^3}$
W_G	Superficial gas velocity (related to empty column)	m/s	3.281	ft/s

Two Stage Minox Unit



Chemical formulas and common names

<u>Chemical formula</u>	<u>Common name</u>
NaCl	halite
BaCO ₃	witherite
SrSO ₄	celestite
BaSO ₄	barite
CaSO ₄ 2H ₂ O	gypsum
CaSO ₄ H ₂ O	hemihydrate
CaSO ₄	anhydrite
CaCO ₃	calcite



Scale Inhibitors

Scale inhibitors are chemicals which stop or interfere with the nucleation, precipitation and/or adherence of solid scale. Scale inhibitors have been used for over 50 years. It is estimated that there are more than 2000 chemical scale inhibitors commercially available, but modern, oilfield scale inhibitors fall into four main classes. Typical inhibitor concentrations for oilfield production are in the 10 - 100 ppm range.

Inorganic phosphates

- cheap and easily prepared
- readily soluble in water and non-toxic
- effective at low treatment level (0.5-20 ppm)
- main use is control of calcium carbonate scale
- limited for oilfield use since they hydrolyse to orthophosphates which have little scale inhibitor activity

Organic phosphate esters

- similar to inorganic phosphates
- also hydrolyse to a form that has limited activity

Organophosphonates

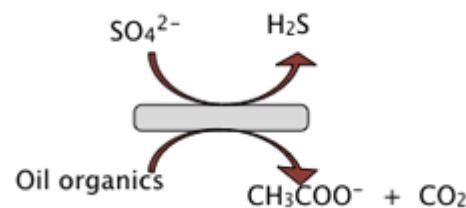
- these compounds are more stable than inorganic or organic phosphonates
- commonly used as oilfield scale inhibitors for calcium, strontium and barium ions

Organic Polymers

- becoming very commonly used
- excellent thermal and hydrolytic stabilities

Reservoir Souring

Souring in oil field systems is most commonly due to the action of sulphate-reducing bacteria, a diverse group of anaerobic microorganisms that respire sulphate and produce hydrogen sulphide. Such biological sulphide production is a detrimental, widespread phenomenon in the petroleum industry, occurring within oil reservoirs or in topside processing facilities, under low- and high-temperature conditions, and in onshore or offshore operations. Sulphate reducers can exist either indigenously in deep subsurface reservoirs or can be "inoculated" into a reservoir system during oil field development (e.g., via drilling operations) or during the oil production phase. In the latter, souring most commonly occurs during water flooding, a secondary recovery strategy wherein water is injected to re-pressurize the reservoir and sweep the oil towards production wells to extend the production life of an oil field. The water source and type of production operation can provide multiple components such as sulphate, labile carbon sources, and sulphate-reducing communities that influence whether oil field souring occurs. Souring can be controlled by biocides, which can non-specifically suppress microbial populations, and by the addition of nitrate (and/or nitrite) that directly impacts the sulphate-reducing population by numerous competitive or inhibitory mechanisms.



Sulphate Removal

When seawater, generally high in sulphate, is injected for reservoir pressure control it mixes with formation water which in some oilfields can be high in barium and strontium. In this instance a supersaturated solution of barium and strontium sulphate can occur. Under high pressure this solution is relatively stable, but as pressure is reduced around the production well the solution becomes unstable and precipitation can occur resulting in scale formation in production tubing or the formation rock around the well. Production can be severely affected. Removal of sulphate from injection water reduces the potential for scaling. Second, removal of sulphate significantly reduces the likelihood of reservoir souring.

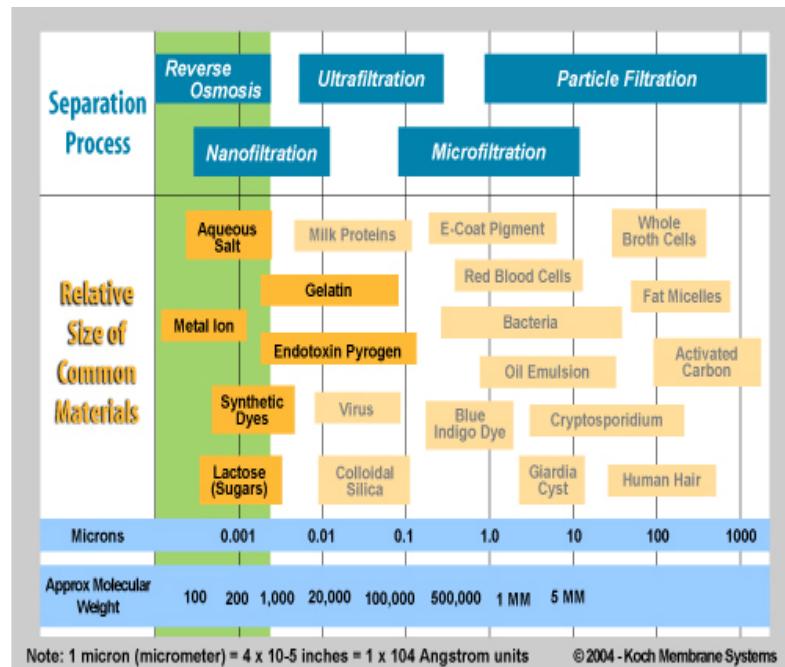


	Seawater Feed (mg/l)	Predicted Low Sulfate Water (mg/l)
Sodium	11200	10690
Potassium	370	320
Calcium	400	330
Magnesium	1400	330
Chloride	19750	19000
Sulfate	2650	40
Bicarbonate	140	20
Total	35910	30730

Membranes Reverse Osmosis (RO)

- Retains salts and organics
- Passes essentially only water
- Passes molecules in the range of 5 Angstroms (0.0005 micron)

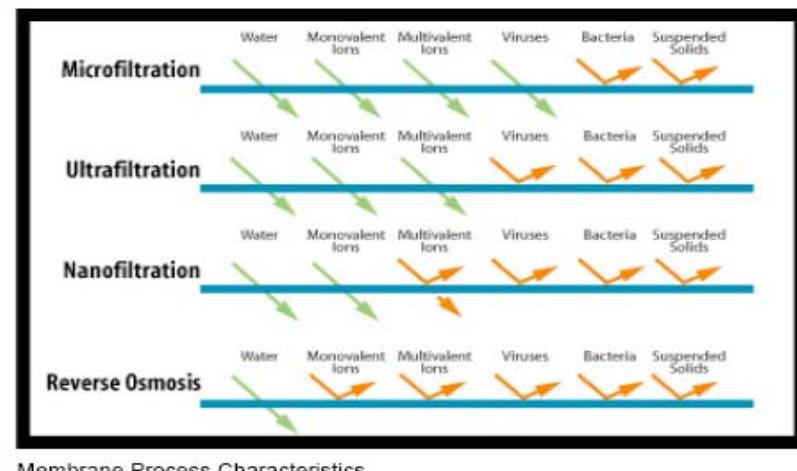
RO membranes will reject dissolved and suspended materials including monovalent salts. Since essentially all dissolved and suspended material is rejected by the membrane, the RO permeate is pure water.



Membranes – Nanofiltration (NF)

- Retains divalent salts and organics
- Passes monovalent salts, water, acid and alkaline compounds
- Pore sizes ranging between UF and RO

Nanofiltration is a low to moderately high pressure (typically 5 - 30 bara) process in which monovalent ions will pass freely through the membrane but highly charged, multivalent salts and low molecular weight organics will be rejected to a much greater degree. Typical NF applications include water softening, desalination of dyestuffs, acid and caustic recovery and color removal.



Ultrafiltration and Microfiltration

Ultrafiltration

- UF is a low pressure (0.3 – 10 bara) process for separating larger size solutes from aqueous solutions by means of a semi-permeable membrane.
- Retains oils, particulate matter, bacteria and suspended solids large macromolecules and proteins
- Passes most surfactants, water, acid and alkaline compounds
- Pore sizes ranging from 0.005 – 0.1 micron
- Permeate is clear (non-turbid) solution void of suspended solids

Microfiltration

MF is a low pressure (0.5- 8 bara) process for separating larger size solutes from aqueous solutions by means of a semi-permeable membrane. This process is carried out by having a process solution flow along a membrane surface under pressure. Retained solutes (such as particulate matter) leave with the flowing process stream and do not accumulate on the membrane surface.

- Retains large suspended solids
- Passes some suspended solids and all dissolved material
- Pore ranges from 0.1 micron to 3 micron

Low Salinity Water Injection Improved Oil Recovery

Significant portion of oil remains unrecovered after a waterflood

New understanding of chemistry behind oil wettability

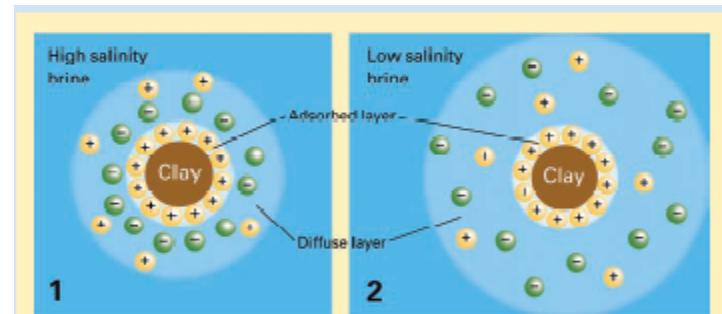
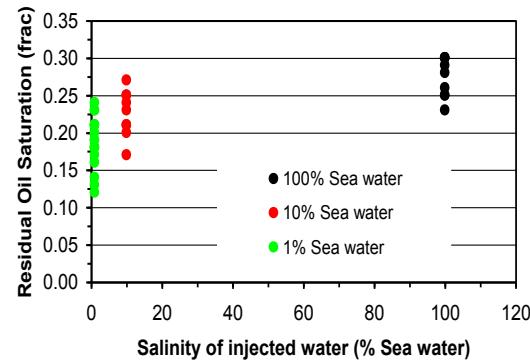
Most sandstones are a mixture of sand and clay containing oil and water

Oil molecules are held to the surface of the negatively charged clay by divalent cations – Ca++ and Mg++

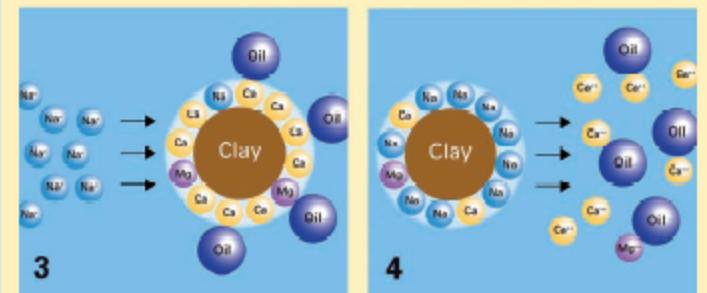
When flooded with a lower salinity water than the reservoir's formation water , free monovalent cations in the flood water, e.g. Na+, exchange with the divalent cations and release the oil molecules.

Low salinity water is usually in the range 500 – 1000ppm.

Low salinity water can be produced using membrane processes.



When a negatively charged clay particle in the porous rock structure of an oil-bearing reservoir is immersed in water, an electrical 'double layer' forms around it. The double layer consists of an inner adsorbed layer of positive ions, and an outer diffuse layer of mainly negative ions. The thickness of the double layer depends on the ion concentration in the surrounding water. In the case of high salinity water containing more ions, the double layer is more compact (1), but when low salinity water is introduced, the double layer expands (2).



The adsorbed layer of positive ions contains divalent calcium (Ca) or magnesium (Mg) ions, which act as tethers between the clay and oil droplets. Injecting reduced salinity water opens up the diffuse layer, enabling monovalent ions such as sodium (Na), carried in the injection water, to penetrate into the double layer (3). Here, the monovalent ions displace the divalent ions, breaking the tethers between oil and clay particles, thus allowing the oil to be swept out of the reservoir (4).

Key learnings

1. Purpose of water Injection and treatment requirements
2. Sand filter principles
3. Henry's law
4. Principles of Oxygen Removal by Chemicals Vacuum and Gas Stripping
5. NTU and HTU as applied to absorption/desorption operations $Z = NTU \times HTU$
6. Scaling
7. Reservoir Souring, sulphate removal and membrane principles