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Anexo I

Calibração da Bomba de Diafragma de Alta Pressão Omel NSP-2
27/05   Calibração da Bomba NSP2 - Omel

Q (L/h) = 60/t1L
Q (m3/s) = 2.8x10-7 Q (L/h)
Q (gpd) = 6.3 Q (L/h)
Vcf (m/s) = Q (m3/s)/A (m2)

Módulo PAMp
Dimensões do canal de alimentação da célula retangular pequena de aço inox:
largura do canal = c = 42.0 mm = 0.04200 m
altura do canal = h = 1.65 mm = 0.00165 m
área da seção perpendicular ao fluxo cruzado = Acf = c.h = 7.0x10-5

| | | | | | | Acf | |
| | | | | | | 7.00E-05 | |

no. visor	t1L (min)	Q (L/h)	Q (gpd)	Q (m3/s)	Vcf (m/s)	Re (p.v.dh/u)	regime de fluxo
3	22	2.7	17	7.56E-07	1.10E-02	3.96E+01	laminar
4	8	7.5	47.3	2.10E-06	3.00E-02	1.08E+02	laminar
5	5.2	11.4	71.8	3.19E-06	4.60E-02	1.65E+02	laminar
6	3.5	17.1	107.7	4.79E-06	6.80E-02	2.44E+02	laminar
7	2.7	22.5	141.8	6.30E-06	9.00E-02	3.24E+02	laminar
8	2	30	189	8.40E-06	1.20E-01	4.31E+02	laminar
9	1.7	36	226.8	1.01E-05	1.40E-01	5.03E+02	laminar
10	1.5	40	252	1.12E-05	1.60E-01	5.75E+02	laminar

Anexo II

Calibração do Condutivímetro Quimis modelo Q-450

Estabilização/Compactação Membrana TFC SR (FluidSystems-Koch)

Testes de Rejeição

Solução padrão KCl 0,01M (1412 mmho/cm)

NaCl (g/L)	Co (mmho/cm)
0,25	0,542
0,5	1,063
0,75	1,55
1	1,98
2	3,78
3	5,52
4	8,07
5	9,99
6	11,8
7	13,58
8	15,36
9	17,15
10	18,86

curva de calibração NaCl

$y = 1,9032x + 0,1318$
$R^2 = 0,9989$
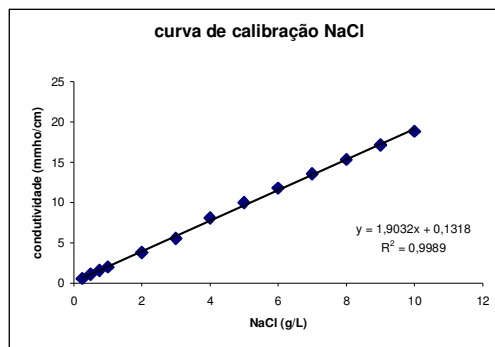
TFC SR NaCl 1000 ppm

$R\% = 100*(Co - Cp)/Co$

t operação	Co (mmho)	NaCl (g/L)	Cp (mmho)	NaCl (g/L)	R%
	1,708	0,828	1,312	0,620	**25,123715**
	1,818	0,886	1,394	0,663	**25,145297**
	1,850	0,903	1,415	0,674	**25,317192**
				R% média	**25**

Solução padrão KCl 0,01M (1412 mmho/cm)

Na2SO4 (mg/L)	Co (mmho/cm)
50	0,11
100	0,17
150	0,29
200	0,37
400	0,69
600	0,97
800	1,3
1000	1,55

curva de calibração Na2SO4

$y = 0,0015x + 0,0487$
$R^2 = 0,998$
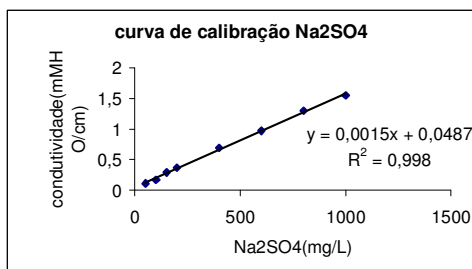
Na2SO4 1000 ppm

Co (mmho)	NaCl (g/L)	Cp (mmho)	NaCl (g/L)	R%
1,689	1,069	0,085	0,000	**100**
1,667	1,055	0,085	0,000	**100**
1,654	1,046	0,085	0,000	**100**
			R% média	**100,0**

TFC SR NaCl 2000 ppm

Co (mmho)	NaCl (g/L)	Cp (mmho)	NaCl (g/L)	R%
3,700	1,875	2,790	1,397	25,503055
3,350	1,691	2,640	1,318	22,062022
3,390	1,712	2,780	1,391	18,721994
3,500	1,770	3,090	1,554	12,172674
3,370	1,701	2,800	1,402	17,602372
3,320	1,675	2,760	1,381	17,56477
3,290	1,659	2,720	1,360	18,048255
3,350	1,691	2,790	1,397	17,401032
3,370	1,701	2,820	1,412	16,984745
3,850	1,954	3,200	1,612	17,481577
3,820	1,938	3,320	1,675	13,556749
3,930	1,996	3,370	1,701	14,743826
3,950	2,006	3,460	1,749	12,833272
			R% média	14,7

TFC SR Na2SO4 2000 ppm

Co (mmho)	NaCl (g/L)	Cp (mmho)	NaCl (g/L)	R%
2,650	1,710	0,085	0,000	100,0
3,320	2,157	0,086	0,001	100,0
3,120	2,023	0,100	0,010	99,5
3,470	2,257	0,110	0,017	99,3
3,260	2,117	0,110	0,017	99,2
2,920	1,890	0,110	0,017	99,1
			R% média	99,3

Anexo III

Determinação do Fluxo Limite ou em Estado Estacionário
CaSO4 puro

t (h)	Jp (L/m2.h)	t (min)	ln t	Q (mL/min)
0,0001	19,36	0,0000	1,000000	2,500
0,5	18,73	30,0	3,401	2,419
1,0	17,14	60,0	4,094	2,214
2,0	12,19	120,0	4,787	1,575
2,5	10,35	150,0	5,011	1,336
3,0	8,68	180,0	5,193	1,122
3,5	7,55	210,0	5,347	0,976
4,0	6,14	240,0	5,481	0,793
4,5	5,35	270,0	5,598	0,690
5,0	4,51	300,0	5,704	0,583
5,5	3,83	330,0	5,799	0,494
6,0	3,25	360,0	5,886	0,420

$y = 21,856e^{-0,313x}$
$R^2 = 0,994$
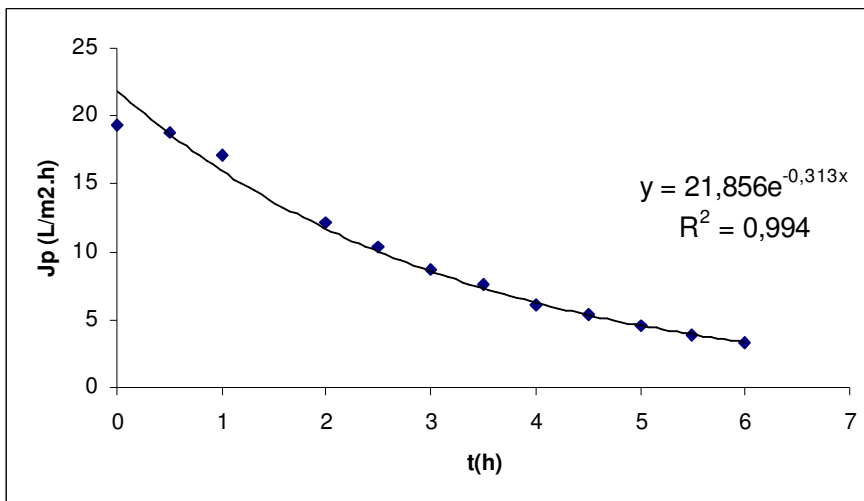
J ss   fluxo de estado estacionário ou terminal ou limite; para longos períodos

T. C. Arnot; Journal of Membrane Science 169 (2000) 1-15;
T. V. Knyazkova, A. A. Maynarovich; Desalination 126 (1999) 163-169;

Jss (L/m2.h)
3,83

Anexo IV

Cálculos dos Estudos dos Mecanismos de Formação das Incrustações

Modelo de Hermia:

	modelos filtração direta
Ko	0,0074
K1	0,0053
K1,5	0,0032
K2	0,0049

Modelo de Field:

	Modelos cross-flow (Field et al. 1995) *paper Knyazkova	gráfico 7.5 (até 1800 min)	gráfico 7.7 (até 650 min)	gráfico planilha CF ORIGIN 2 (360 min)
	Qp		F(x)	
complete (n=2) F1	Qs+(Qo-Qs)*EXP(-K1*t)	2.6204+2.5977* EXP(-0.000379*X)	3.871+1.3020* EXP(-0.000379*X)	0,4947+2,0056*EXP(-0,0022*X)
intermediate/ incomplete (n=1) F8	Qs/{1-[(Qo-Qs)/Qs]*EXP(-K2*Qs*t)}	2.6204/(1-0.9913* EXP(-0.000262*X))	3.871/(1-0.3363* EXP(-0.000387*X))	0,4947/(1-4,0542* EXP(-0,0006*X))
standard (n=1,5) F5	Qs*{[(Qo^0,5+Qs^0,5)/(Qo^0,5-Qs^0,5)*EXP(-K3*Qs*t)+1]^2 * [(Qo^0,5+Qs^0,5)/(Qo^0,5-Qs^0,5)*EXP(-K3*Qs^0,5*t)-1]^2}	5.218/(1+0.000198*X)^2	5.173/(1+0.000197*X)^2	2,5003/(1+0,0015*X)^2
standard (n=1,5) F5	Qo/(1+0.5*K1,5*Qo*X)^2			
cake (n=0) F6	Qs/{1-[(Qo-Qs)/Qo]*EXP(-Qs[Qs*K4*t+(Qo-Qp)/Qp*Qo]}	5.173/(1+0.001070*X)^0.5	5.173/(1+0.001070*X)^0.5	2,5003/(1+0,0075*X)^0,5
cake (n=0) F6	Qo/(1+2Ko*Qo^2*X)^0.5			

Modelo de Koltuniewicz:

t (h)	Jp (L/m2.h)	t (min)	t (min)	R	dR/dt1
0,0001	19,36	0,01	0,0	1,5498	
0,5	18,73	30,0	30,0	1,6014	1,722E-03
1,0	17,14	60,0	60,0	1,7500	3,336E-03
2,0	12,19	120,0	120,0	2,4603	7,587E-03
2,5	10,35	150,0	150,0	2,8994	8,997E-03
3,0	8,68	180,0	180,0	3,4547	1,058E-02
3,5	7,55	210,0	210,0	3,9713	1,153E-02
4,0	6,14	240,0	240,0	4,8883	1,391E-02
4,5	5,35	270,0	270,0	5,6115	1,504E-02
5,0	4,51	300,0	300,0	6,6512	1,700E-02
5,5	3,83	330,0	330,0	7,8393	1,906E-02
6,0	3,25	360,0	360,0	9,2212	2,131E-02

Anexo V

Cálculos dos Indicadores do Processo

parâmetro	fórmula	unidades
rejeição (rejection)	**R=1-Cp/Cf**	
recuperação ou conversão (recovery or conversion)	**Rec=Qp/Qf**	
velocidade de fluxo cruzado (crossflow velocity)	Vcf=Qf/A	m/s
vazão (flow rate)	Q	m3/s ou L/h ou gpd
fluxo permeado (permeate flux)	J=Q/Am	kg/m2.s ou L/m2.h ou gfd
permeabilidade (permeability)	Lp	
fator de concentração (concentration factor)	**cf=Cc/Cf**	
área perpendicular ao fluxo	Ap=c.h	m2
fluxo solvente permeado	Js=Lp.(dP-dpi)	
rejeição aparente ou observada	**Robs = (Cf-Cp)/Cf**	
rejeição verdadeira	**Rt = (Cm-Cp)/Cm**	
concentração na membrana	Cm	
coeficiente de transferência de massa (k)	**exp(Js/k)=(Cm-Cp)/(Cf-Cp)**	
número de Reynolds	Re = p.v.dh/u	
densidade	p	kg/m3
viscosidade	u	Pa.s
diâmetro hidráulico	dh = 2.Ap/(c+h) =~2.h	Pa.s
supersaturação	**ss = Cm/s = CP.Cf/s**	
módulo de polarização de concentração	**CP = (Cm-Cp)/(Cf-Cp)=exp(Js/k)**	
fluxo limite	Jl = k.ln(Cm/Cf)	
taxa de operação	toperação = toperação/tlimpeza	
recuperação de fluxo	**RF = Jcw1/Jcw2**	
eficiência do processo	EP = (Vp-Vlavagem)/Vp	
produtividade(Vp produzido)	Vpp = J.A .t	
pressão osmótica	pi = f . C . RT/M	
índice de densidade de sedimentos ou de fouling	SDI = IF = experimental	
índice de saturação de Langelier	ISL = pHef - pHs	

k = J / ln{[dP/(dpi)].[1- (J/Jw)]}

p = concentração do soluto permeado
Cf = concentração do soluto alimentação
Cc = concentração do soluto concentrado

Amostra	Cond (uMHO/cm)	Na (mg/L)	Ca (mg/L)	Cl (mg/L)	SO4 (mg/L)
CaSO4 09/12 A0	7870	1390	790	2354	2199
CaSO4 09/12 A3	8420	1340	800		
CaSO4 09/12 A6	8470	1380	800	2259	2202
CaSO4 09/12 P0	1790	410	9	1141	8
CaSO4 09/12 P3	3420	760	18		
CaSO4 09/12 P6	3660	810	19	1237	15

Amostra	Cond (uMHO/cm)	Na (mg/L)	Ca (mg/L)
CaSO4 SHMP 2 A0	7630	4980	830
CaSO4 SHMP A3	8290	880	1340
CaSO4 SHMP A6	7690	1390	1180
CaSO4 SHMP P0	2200	1400	15
CaSO4 SHMP P3	3980	810	30
CaSO4 SHMP P6	3630	870	30

Amostra	Cond (uMHO/cm)	Na (mg/L)	Ca (mg/L)	Cl (mg/L)	SO4 (mg/L)
CaSO4 SHMP 3 (07/01) A0	7860	1370	940		
CaSO4 SHMP(07/01) A1	7870			2188	2439
CaSO4 SHMP(07/01) A4	9130	1450	810		
CaSO4 SHMP(07/01) A7	10090			2427	2197
CaSO4 SHMP (07/01) A8	10350	1500	790		
CaSO4 SHMP (07/01) P0	2360	570	12		
CaSO4 SHMP(07/01) P1	3560			1444	22
CaSO4 SHMP(07/01) P4	3870	960	30		
CaSO4 SHMP(07/01) P7	4640			1493	20
CaSO4 SHMP (07/01) P8	4890	1030	57		

Amostra	Cond (uMHO/cm)	Na (mg/L)	Ca (mg/L)
CaSO4 EDTA A0	7330	1370	830
CaSO4 EDTA A3	7720	1300	820
CaSO4 EDTA A6	8810	2040	1140
CaSO4 EDTA P0	2000	460	15
CaSO4 EDTA P3	3760	850	22
CaSO4 EDTA P6	3380	840	9

Amostra	Cond (uMHO/cm)	Na (mg/L)	Ca (mg/L)	Cl (mg/L)	SO4 (mg/L)
CaSO4 EDTA 06/01 A0	9510	1700	1150		
CaSO4 EDTA 06/01 A1	9800			2319	3155
CaSO4 EDTA 06/01 A3	11010	2040	1020		
CaSO4 EDTA 06/01 A4,5	12100			2796	2687
CaSO4 EDTA 06/01 A5	12370	2200	980		
CaSO4 EDTA 06/01 P0	3150	690	7		
CaSO4 EDTA 06/01 P1	4320			1306	396
CaSO4 EDTA 06/01 P3	4770	1080	12		
CaSO4 EDTA 06/01 P4,5	5080			1519	470
CaSO4 EDTA 06/01 P5	5140	1150	16		

PROTOCOLO PADRÃO DE CÁLCULOS DE PC CaSO4.2H2O

Cálculo de Pressão Osmótica (pi) [TDS](g/L)=cond(mMHO/cm)*0.70 Langelier/Russell(0.64)/Standard Methods(0.60-0.80)
pi = f . C . RT/M **AAS / IC**

data	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
09/12-12:15 pHo= 5.0	0,0	240	0	7,87	1,79	7,66	5,5090	1,2530	5,3620	2	1,586	0,361	1,2255	0,0917	23,95	6,65E-06
	1,0	271	0	7,45	2,87	7,47	5,2150	2,0090	5,2290	2	1,502	0,578	0,9232	0,0917	13,68	3,80E-06
	2,0	381	0	7,9	3,31	xxx	5,5300	2,3170	xxx	2	1,592	0,667	0,9252	0,0917	9,28	2,58E-06
	3,0	535	0	8,42	3,42	xxx	5,8940	2,3940	xxx	2	1,697	0,689	1,0078	0,0917	4,79	1,33E-06
	4,0	757	0	8,43	3,49	xxx	5,9010	2,4430	xxx	2	1,699	0,703	0,9957	0,0917	3,78	1,05E-06
	5,0	1030	0	8,44	3,58	xxx	5,9080	2,5060	xxx	2	1,701	0,722	0,9796	0,0917	3,00	8,32E-07
pH6=	6,0	1428	0	8,47	3,66	8,48	5,9290	2,5620	5,9360	2	1,707	0,738	0,9695	0,0917	2,52	7,01E-07

Membrana NF TFC SR **Módulo PAM retangular pequeno/ bomba NSP2.**

Após 2L para remoção de impurezas a 1bar

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)		Re	dP bar	dP kPa			Jlim
09/12 11h	0,0				reciclo total; 30 bar; v = 3	108	30	3000	**Rm**		19,36
12:00	4,0	218	21,8	**21,31**	*Após h de compactação: **fluxo de água limpa Jo=Jw**				1407,72		17,14317

CaSO4 - Polarização/Incrustação **AAS**

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb TDS mg/L	Cp TDS mg/L	PC	Cm TDS mg/L	Rej obs TDS %	Rej real TDS %	SS superf	Rf	Rt
09/12-12:15	0,0	240	24,0	19,36	27,91	0,0917	23,95	5.509	1.253	2,2	12.362	77,3	89,9	5,9	142	1550
	0,5	248	24,8	18,73	30,23	0,1210									194	1601
	1,0	271	27,1	17,14	36,15	0,1956	9,27	5.215	2.009	6,4	33.144	61,5	93,9	15,9	342	1750
	2,0	381	38,1	12,19	54,59	0,4278	4,64	5.530	2.317	13,9	76.715	58,1	97,0	36,7	1053	2460
	2,5	449	44,9	10,35	61,46	0,5145									1492	2899
	3,0	535	53,5	8,68	67,66	0,5925	3,03	5.894	2.394	17,6	103.956	59,4	97,7	49,7	2047	3455
	3,5	615	61,5	7,55	71,87	0,6455									2564	3971
	4,0	757	75,7	6,14	77,14	0,7120	2,00	5.901	2.443	21,5	126.589	58,6	98,1	60,6	3481	4888
	4,5	869	86,9	5,35	80,09	0,7491									4204	5612
	5,0	1030	103,0	4,51	83,20	0,7883	1,42	5.908	2.506	24,1	142.635	57,6	98,2	68,2	5243	6651
	5,5	1214	121,4	3,83	85,75	0,8204									6432	7839
	6,0	1428	142,8	3,25	87,88	0,8473	1,00	5.929	2.562	26,2	155.453	56,8	98,4	74,4	7814	9221
	6,5															
	7,0															

*considerando u(viscosidade da água a 20oC) =1cP = 0.001 kg/m.s

Blanpain,1996
Lei de Darcy **Rm+Rf=dP/u.Js** Js=fluxo no steady-state 1atm=1kgf/cm2=15psi=20lbf/cm2=1,01bar=100kPa
Rm=dP/u.Jw Jw=fluxo de água limpa

* f = fator de correção de Van't Hoff ou coeficiente de Van't Hoff = 1+ α (q-1)

onde: α = grau de ionização; q = número total de íons liberados na ionização de um composto.

PROTOCOLO PADRÃO DE CÁLCULOS DE | CaSO4 + SHMP 50 ppm (antes)

Cálculo de Pressão Osmótica ([TDS](mg/L)=cond*0.70)   Langelier/Russell(0.64)/Standard Methods(0.60-0.80)

$$\pi = f \cdot C \cdot RT/M$$

data	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
13/12-13:15 pHo= 5.0	0,0	304	0	8,62	2,14	xxx	6,0340	1,4980	xxx	2	5,109	1,268	3,8403	0,0987	-58,74	-1,63E-05
	1,0	294	0	8,42	3,82	xxx	5,8940	2,6740	xxx	2	4,990	2,264	2,7261	0,0000	#NÚM!	#NÚM!
	2,0	292	0	8,48	3,92	xxx	5,9360	2,7440	xxx	2	4,983	2,323	2,6598	0,0680	-59,65	-1,66E-05
	3,0	292	0	8,56	3,95	xxx	5,9920	2,7650	xxx	2	5,030	2,341	2,6891	0,0616	-42,50	-1,18E-05
	4,0	294	0	8,57	3,98	xxx	5,9990	2,7860	xxx	2	5,036	2,359	2,6772	0,0000	#NÚM!	#NÚM!
	5,0	292	0	8,63	4,02	xxx	6,0410	2,8140	xxx	2	5,071	2,382	2,6887	0,0616	-42,51	-1,18E-05
pH6=	6,0	292	0			xxx										

Compactação   Membrana NF TFC SR   Módulo PAM retangular pequeno/ bomba NSP2.

Após 2L para remoção de impurezas a 1bar   reciclo total; 30 bar; v = 4   Área efetiva da membrana 0.775x10-2m2

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	Re	dP bar		Jlim
09/12 11h	0,0				108	30	Rm	15,28
12:00	4,0	274	27,4	16,96	*fluxo de água limpa Jo=	1.769,34		

$$k = J / \ln\{[dP/(dpi)].[1- (J/Jw)]\}$$

CaSO4 - Polarização/Incrustação

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb mg/L	Cp mg/L	CP	Cm mg/L	Robs %	R %	SS	Rf	Rt
13/12 - 13:15	0,0	304	30,4	15,28	0,00	0,09868	-58,74	6034	1498	0,7709	4651,7	75,2	67,8	2,2257	194	1963
	0,5	318	31,8	14,61	4,40										284	2053
	1,0	294	29,4	15,80	-3,40	0,06803	-54,58	5894	2674	0,7486	4412,3	54,6	39,4	2,1112	129	1898
	2,0	292	29,2	15,91	-4,11	0,06164	-43,78	5936	2744	0,6953	4127,1	53,8	33,5	1,9747	116	1886
	2,5	300	30,0	15,49	-1,33										168	1937
	3,0	292	29,2	15,91	-4,11	0,06164	-42,50	5992	2765	0,6877	4120,8	53,9	32,9	1,9717	116	1886
	3,5	292	29,2	15,91	-4,11										116	1886
	4,0	294	29,4	15,80	-3,40	0,06803	-58,22	5999	2786	0,7623	4573,1	53,6	39,1	2,1881	129	1898
	4,5	294	29,4	15,80	-3,40										129	1898
	5,0	292	29,2	15,91	-4,11	0,06164	-42,51	6041	2814	0,6878	4155,0	53,4	32,3	1,9881	116	1886
	5,5	293	29,3	15,86	-3,75										123	1892
	6,0	294	29,4	15,80	-3,40	0,06803									129	1898

PROTOCOLO PADRÃO DE CÁLCULOS DE PC   CaSO4 + SHMP 20 ppm (4h)

Cálculo de Pressão Osmótica (pi)   [TDS](mg/L)=cond*0.70   Langelier/Russell(0.64)/Standard Methods(0.60-0.80)

$$\pi = f \cdot C \cdot RT/M$$

data	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
09/12-12:15 pHo= 5.0	0,0	292	0	7,63	2,2	6,37	5,3410	1,5400	4,4590	2	1,538	0,341	1,1969	0,1370	12,90	3,58E-06
	1,0	282	0	7,53	3,58	xxx	5,2710	2,5060		2	1,518	0,548	0,9702	0,1064	13,84	3,84E-06
	2,0	296	0	8,31	3,59	xxx	5,8170	2,5130		2	1,675	0,606	1,0690	0,1127	14,21	3,95E-06
	3,0	360	0	8,29	3,98	xxx	5,8030	2,7860		2	1,671	0,670	1,0007	0,1486	10,50	2,92E-06
add SHMP	4,0	522	0	8,07	3,91	xxx	5,6490	2,7370		2	1,627	0,641	0,9856	0,1923	8,43	2,34E-06
	5,0	466	0	7,78	3,61	xxx	5,4460	2,5270		2	1,568	0,571	0,9976	0,3000	5,87	1,63E-06
pH6=	6,0	442	0	7,69	3,63	7,7	5,3830	2,5410	5,3900	2	1,550	0,567	0,9830	0,4220	4,17	1,16E-06

Compactação   Membrana NF TFC SR   Módulo PAM retangular pequeno/ bomba NSP2.

Após 2L para remoção de impurezas a 1bar   Área efetiva da membrana 0.775x10-2m2

data	t (h)	(s)	t1mL (s)	Jp (L/m2.h)	reciclo total; 30 bar; v = 4	Re	dP bar		Jlim
13-14/12 11:00	0,0					108	30	Rm	15,91027
12:00	4,0	252	25,2	18,44	*fluxo de água limpa Jo=Jw			1627,28	

CaSO4 - Polarização/Incrustação

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb mg/L	Cp mg/L	CP	Cm mg/L	Robs %	R %	SS	Rf	Rt
14/12 - 14:35	0,0	292	29,2	15,91	0,00	0,1370	12,90	5341	1540	3,4334	18338	71,2	91,6	8,77	258	1886
	1,0	282	28,2	16,47	-3,55	0,1064	13,84	5271	2506	3,2896	17340	52,5	85,5	8,30	194	1821
	1,5	284	28,4	16,36	-2,82	0,1127									207	1834
	2,0	296	29,6	15,70	1,35	0,1486	10,99	5817	2513	4,1717	24267	56,8	89,6	11,61	284	1911
	2,5	312	31,2	14,89	6,41	0,1923									387	2015
	3,0	360	36,0	12,91	18,89	0,3000	5,88	5803	2786	8,9935	52189	52,0	94,7	24,97	697	2325
	3,5	436	43,6	10,66	33,03	0,4220									1188	2815
add SHMP	4,0	522	52,2	8,90	44,06	0,5172	3,23	5649	2737	15,7433	88934	51,5	96,9	42,55	1744	3371
	4,5	512	51,2	9,07	42,97	0,5078									1679	3306
	5,0	466	46,6	9,97	37,34	0,4592	3,80	5446	2527	13,8095	75206	53,6	96,6	35,98	1382	3009
	5,5	450	45,0	10,32	35,11	0,4400									1279	2906
	6,0	442	44,2	10,51	33,94	0,4299	4,08	5383	2541	13,1193	70621	52,8	96,4	33,79	1227	2854

$$k = J / \ln\{[dP/(dpi)].[1- (J/Jw)]\}$$ $$CP = (Cm - Cp) / (Cb - Cp) = \exp (J / k)$$ Modelo do Filme

PROTOCOLO PADRÃO DE CÁLCULOS DE PC   ■   CaSO4 + SHMP 5 ppm (antes)

Cálculo de Pressão Osmótica (pi)   [TDS](mg/L)=cond*0.70   Langelier/Russell(0.64)/Standard Methods(0.60-0.80)

pi = f . C . RT/M

data	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
10:55 pHo= 5.0	0,0	428		7,86	2,36	xxx	5,5020	1,6520	xxx	2	4,66	1,40	3,26	0,08	58,14	1,62E-05
	0,5	432		7,8	3,44	xxx	5,4600	2,4080	xxx	2	4,62	2,04	2,58	0,09	47,37	1,32E-05
	1,0	424		7,87	3,56	xxx	5,5090	2,4920	xxx	2	4,66	2,11	2,55	0,08	58,93	1,64E-05
	1,5	420		7,92	3,61	xxx	5,5440	2,5270	xxx	2	4,69	2,14	2,55	0,07	67,35	1,87E-05
	2,0	416		7,95	3,65	xxx	5,5650	2,5550	xxx	2	4,71	2,16	2,55	0,06	78,51	2,18E-05
	2,5	408		8,14	3,67	xxx	5,6980	2,5690	xxx	2	4,82	2,17	2,65	0,04	119,64	3,32E-05
	3,0	396		8,27	3,71	xxx	5,7890	2,5970	xxx	2	4,90	2,20	2,70	0,02	241,26	6,70E-05
	3,5	400		8,34	3,75	xxx	5,8380	2,6250	xxx	2	4,94	2,22	2,72	0,02	241,92	6,72E-05
	4,0	396		8,45	3,87	xxx	5,9150	2,7090	xxx	2	5,01	2,29	2,71	0,02	241,70	6,71E-05
	4,5	400		8,56	3,93	xxx	5,9920	2,7510	xxx	2	5,07	2,33	2,74	0,02	242,80	6,74E-05
	5	400		9,55	4,41	xxx	6,6850	3,0870	xxx	2	5,66	2,61	3,05	0,02	253,89	7,05E-05
	5,5	400		9,75	4,46	xxx	6,8250	3,1220	xxx	2	5,78	2,64	3,14	0,02	257,12	7,14E-05
	6,0	400		9,9	4,53	xxx	6,9300	3,1710	xxx	2	5,87	2,68	3,18	0,02	258,84	7,19E-05
	6,5	408		9,92	4,57	xxx	6,9440	3,1990	xxx	2	5,88	2,71	3,17	0,04	129,21	3,59E-05
	7,0	432		10,09	4,64	xxx	7,0630	3,2480	xxx	2	5,98	2,75	3,23	0,09	#REF!	#REF!
	7,5	484		10,25	4,78	xxx	7,1750	3,3460	xxx	2	6,07	2,83	3,24	0,19	25,43	7,06E-06
	8,0	668		10,35	4,89	xxx	7,2450	3,4230	xxx	2	6,13	2,90	3,24	0,41	#REF!	#REF!

Compactação   **Membrana NF TFC SR**   **Módulo PAM retangular pequeno/ bomba NSP2.**

Após 2L para remoção de impurezas a 1bar   reciclo total; 30 bar; v = 4   Área efetiva da membrana 0.775x10-2m2   t(s)

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	Re	dP bar				Jlim	2.5 mL	10 mL	
	0,0	392	39,2	11,85	108	30	Rm 2531,31861			10,854673	197	788	0,1866971

k = J / ln[[dP/(dpi)].[1- (J/Jw)]]

CaSO₄ - Polarização/Incrustação

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb mg/L	Cp mg/L	CP	Cm mg/L	Robs %	R real %	SS	Rf	Rt
	0,00	428	42,8	10,85	0	0,084	58,14	5502	1652	1,2053	6631,4	70,0	75,1	3,1729	232	2764
	0,50	432	43,2	10,75	1	0,093	47,37	5460	2408	1,2549	6851,6	55,9	64,9	3,2783	258	2790
	1,00	424	42,4	10,96	-1	0,075	58,93	5509	2492	1,2043	6634,6	54,8	62,4	3,1745	207	2738
	1,50	420	42,0	11,06	-2	0,067	67,35	5544	2527	1,1785	6533,5	54,4	61,3	3,1261	181	2712
	2,00	416	41,6	11,17	-3	0,058	78,51	5565	2555	1,1529	6415,7	54,1	60,2	3,0697	155	2686
	2,50	408	40,8	11,39	-5	0,039	119,64	5698	2569	1,0999	6267,0	54,9	59,0	2,9985	103	2635
	3,00	400	40,0	11,61	-7	0,020	241,26	5789	2597	1,0493	6074,5	55,1	57,2	2,9065	52	2583
	3,50	400	40,0	11,61	-7	0,020	241,92	5838	2625	1,0492	6125,1	55,0	57,1	2,9307	52	2583
	4,00	400	40,0	11,61	-7	0,020	241,70	5915	2709		54,2				52	2583
	4,50	400	40,0	11,61	-7	0,020	242,80	5992	2751	1,0490	6285,6	54,1	56,2	3,0075	52	2583
	5,00	400	40,0	11,61	-7	0,020	253,89	6685	3087	1,0468	6997,9	53,8	55,9	3,3483	52	2583
	5,50	400	40,0	11,61	-7	0,020	257,12	6825	3122	1,0462	7140,4	54,3	56,3	3,4164	52	2583
	6,00	400	40,0	11,61	-7	0,020	258,84	6930	3171	1,0459	7248,0	54,2	56,3	3,4680	52	2583
	6,50	408	40,8	11,39	-5	0,039	129,21	6944	3199	1,0921	7583,7	53,9	57,8	3,6286	103	2635
	7,00	432	43,2	10,75	1	0,093	52,11	7063	3248	1,2292	8681,9	54,0	62,6	4,1540	258	2790
	7,50	484	48,4	9,60	12	0,190	22,69	7175	3346	1,5265	10952,3	53,4	69,4	5,2404	594	3125
	8,00	668	66,8	6,95	36	0,413	7,56	7245	3423	2,5096	18181,7	52,8	81,2	8,6994	1782	4314

PROTOCOLO PADRÃO DE CÁLCULOS DE PC   CaSO4 + EDTA 0.5% (4:45h)

Cálculo de Pressão Osmótica (pi)   [TDS](mg/L)=cond*0.70   Langelier/Russell(0.64)/Standard Methods(0.60-0.80)

pi = f . C . RT/M

data	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
15/12-12:15 pHo= 5.0	0,0	216	0	7,33	2	5,02	5,1310	1,4000	3,5140	2	1,477	0,403	1,0743	0,2037	12,37	3,44E-06
	1,0	246	0	7,16	3,41	7,19	5,0120	2,3870	5,0330	2	1,443	0,687	0,7559	0,2037	10,29	2,86E-06
	2,0	312	0	8	3,43	xxx	5,6000	2,4010		2	1,613	0,691	0,9212	0,3008	8,28	2,30E-06
	3,0	458	0	7,72	3,76	xxx	5,4040	2,6320		2	1,556	0,758	0,7982	0,3986	6,00	1,67E-06
add EDTA	4,0	692	0	8,1	3,79	xxx	5,6700	2,6530		2	1,633	0,764	0,8687	0,4487	5,43	1,51E-06
	5,0	706	0	9,53	3,7	9,56	6,6710	2,5900	6,6920	2	1,921	0,746	1,1751	0,5351	4,80	1,33E-06
pH6=	6,0	700	0	8,81	3,38	8,84	6,1670	2,3660	6,1880	2	1,776	0,681	1,0945	0,6245	3,57	9,92E-07

Compactação   **Membrana NF TFC SR**   **Módulo PAM retangular pequeno/ bomba NSP2.**

Após 2L para remoção de impurezas a 1bar   Área efetiva da membrana 0.775x10-2m2

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	reciclo total; 30 bar; v = 4	Re	dP bar		Jlim	
13-14/12 11:00	0,0					108	30	Rm		
12:00	4,0	172	17,2	27,01	*fluxo de água limpa Jo=Jw			1110,68	18,357	

CaSO4 - Polarização/Incrustação

data	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb mg/L	Cp mg/L	CP	Cm mg/L	Robs %	R %	SS	Rf	Rt
15/12-12:15	0,0	216	21,6	21,51	0,00	0,2037	12,37	5131	1400	5,6882	22622,7	72,7	93,8	10,8243	284	1395
	0,5	216	21,6	21,51	0,00	0,2037									284	1395
	1,0	246	24,6	18,89	12,20	0,3008	7,62	5012	2387	11,9390	33727,0	52,4	92,9	16,1373	478	1589
	1,5	286	28,6	16,24	24,48	0,3986									736	1847
	2,0	312	31,2	14,89	30,77	0,4487	5,55	5600	2401	14,6137	49150,4	57,1	95,1	23,5169	904	2015
	2,5	370	37,0	12,56	41,62	0,5351									1279	2389
	3,0	458	45,8	10,14	52,84	0,6245	3,21	5404	2632	23,4698	67690,3	51,3	96,1	32,3877	1847	2958
	3,5	650	65,0	7,15	66,77	0,7354									3087	4197
	4,0	692	69,2	6,71	68,79	0,7514	2,06	5670	2653	25,9492	80941,8	53,2	96,7	38,7281	3358	4469
add EDTA	4,5	916	91,6	5,07	76,42	0,8122									4804	5915
	5,0	706	70,6	6,58	69,41	0,7564	2,22	6671	2590	19,3096	81392,3	61,2	96,8	38,9437	3448	4559
	6,0	700	70,0	6,64	69,14	0,7543	2,19	6167	2366	20,6748	80950,8	61,6	97,1	38,7324	3410	4520
	6,5	786	78,6	5,91	72,52	0,7812									3965	5076
	7,0	772	77,2	6,02	72,02	0,7772									3874	4985

PROTOCOLO PADRÃO DE CÁLCULOS DE PC   **CaSO4 + EDTA 0.5% (0:00h)**

Cálculo de Pressão Osmótica (pi)

[TDS](mg/L)=cond*0.70		Langelier/Russell(0.64)/Standard Methods(0.60-0.80)
pi = f . C . RT/M		

data (dia-hora)	t (h)	t10mL (s)	[Ca] (mg/L)	cond a (mMHO/cm)	cond p (mMHO/cm)	cond c (mMHO/cm)	[TDS]a (g/L)	[TDS]p (g/L)	[TDS]c (g/L)	f	pi a (atm)	pi p (atm)	dpi a-p (bar)	1-(J/Jw)	k L/m2.h	k m/s
06/01-11:30 pHo= 3.5	0,0	0	0	9,51	3,15	x	6,6570	2,2050	x	2	5,6	1,9	3,8	0,1273	1634,77	4,54E-04
	0,5	0	0	9,63	4,2	x	6,7410	2,9400	x	2	5,7	2,5	3,2	0,1273	113,44	3,15E-05
	1,0	0	0	9,8	4,32	x	6,8600	3,0240	x	2	5,8	2,6	3,2	0,1273	119,23	3,31E-05
	1,5	0	0	10,04	4,43	x	7,0280	3,1010	x	2	5,9	2,6	3,3	0,1273	137,41	3,82E-05
	2,0	0	0	10,34	4,52	x	7,2380	3,1640	x	2	6,1	2,7	3,4	0,1111	-1132,90	-3,15E-04
	2,5	0	0	10,68	4,66	x	7,4760	3,2620	x	2	6,3	2,8	3,5	0,1111	-407,40	-1,13E-04
	3,0	0	0	11,01	4,77	x	7,7070	3,3390	x	2	6,5	2,8	3,6	0,1111	-242,29	-6,73E-05
	3,5	0	0	11,28	4,88	x	7,8960	3,4160	x	2	6,6	2,9	3,7	0,1111	-188,50	-5,24E-05
	4,0	0	0	11,65	5	x	8,1550	3,5000	x	2	6,8	3,0	3,9	0,1273	-1263,51	-3,51E-04
	4,5	0	0	12,1	5,08	x	8,4700	3,5560	x	2	7,1	3,0	4,1	0,2615	27,53	7,65E-06
pH5= 3,5	5,0	0	0	12,37	5,14	x	8,6590	3,5980	x	2	7,3	3,0	4,2	0,4353	12,10	3,36E-06

Compactação   **Membrana NF TFC SR**   **Módulo PAM retangular pequeno/ bomba NSP2.**

Após 2L para remoção de impurezas a 1bar   Área efetiva da membrana 0.775x10-2m2   Área de seção cruzada de fluxo Acf = c.h =

obs. data (dia-hora)	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)			
06/01/2005 11:00	0,0				reciclo total; 30 bar; v = 4		
						Re	dP bar
							30
			0	#DIV/0!		108	Rm
11:15	0,3	192	19,2	24,20	Após compactação: fluxo de água		1239,83

Jlim 14,15

CaSO4 - Polarização/Incrustação

obs. data (dia-hora)	t (h)	t10mL (s)	t1mL (s)	Jp (L/m2.h)	dJp (%)	1-(J/Jw)	k L/m2.h	Cb mg/L	Cp mg/L	CP	Cm mg/L	Robs %	R %	SS	Rf	Rt
início:06/01 - 11:3	0,0	220	22,0	21,12	0,00	0,13	1.635	6657,0	2205,0	1,0	6714,9	66,9	67,2	3,2129	181	1421
	0,5	220	22,0	21,12	0,00	0,13	113	6741,0	2940,0	1,2	7518,7	56,4	60,9	3,5975	181	1421
	1,0	220	22,0	21,12	0,00	0,13	119	6860,0	3024,0	1,2	7603,3	55,9	60,2	3,6379	181	1421
	1,5	220	22,0	21,12	0,00	0,13	137	7028,0	3101,0	1,2	7680,3	55,9	59,6	3,6748	181	1421
	2,0	216	21,6	21,51	-1,85	0,11	-1.133	7238,0	3164,0	1,0	7161,4	56,3	55,8	3,4265	155	1395
	2,5	216	21,6	21,51	-1,85	0,11	-407	7476,0	3262,0	0,9	7259,3	56,4	55,1	3,4733	155	1395
	3,0	216	21,6	21,51	-1,85	0,11	-242	7707,0	3339,0	0,9	7336,0	56,7	54,5	3,5100	155	1395
	3,5	216	21,6	21,51	-1,85	0,11	-188	7896,0	3416,0	0,9	7412,9	56,7	53,9	3,5468	155	1395
	4,0	220	22,0	21,12	0,00	0,13	-1.264	8155,0	3500,0	1,0	8077,8	57,1	56,7	3,8650	181	1421
	4,5	260	26,0	17,87	15,38	0,26	28	8470,0	3556,0	1,9	12960,9	58,0	72,6	6,2014	439	1679
	5,0	340	34,0	13,66	35,29	0,44	12	8659,0	3598,0	3,1	19249,5	58,4	81,3	9,2103	956	2196
	5,5	520	52,0	8,93	57,69	0,63	x	x	x	x	x	x	x	x	2118	3358
	6,0	754	75,4	6,16	70,82	0,75	x	x	x	x	x	x	x	x	3629	4869