

13-Apr

Slurry Density ( $\rho$ )	1000
Diameter (m)	0,070

Dynamic viscosity, $\eta$	
(Pa.s)	0,000932 @ 23 deg

<https://wiki.anton-paar.com/za-en/water/>

Water Mas	3
g	9,81

3L Water Test 1							
Time	1000	1100	1200	1300	1400	1500	
01:00	160	151	165	170	179	188	
01:30	158	158	158	172	174	200	
02:00	158	160	165	172	183	188	
02:30	158	158	163	170	181	186	
03:00	160	158	163	167	181	183	
03:30	154	156	160	170	181	186	
04:00	165	156	163	170	181	188	
04:30	156	158	163	172	179	190	
05:00	156	158	160	170	179	188	
Average	158,3	157,0	162,2	170,3	179,8	188,6	
Consumed	14,6	12,0	15,1	15,7	21,8	24,1	

Out of water							
Time	1000	1100	1200	1300	1400	1500	
01:00	144	144	147	154	160	163	
01:30	147	147	149	154	158	165	
02:00	149	147	151	154	160	160	
02:30	144	147	147	154	156	165	
03:00	142	144	149	154	160	165	
03:30	144	144	149	149	158	163	
04:00	142	144	144	163	158	167	
04:30	140	144	144	156	158	167	
05:00	142	144	144	154	154	165	
	143,8	145,0	147,1	154,7	158,0	164,4	

3L Water Test 2							
Time	1000	1100	1200	1300	1400	1500	
01:00	147	151	156	167	172	186	
01:30	144	149	154	165	172	183	
02:00	147	149	158	163	172	181	
02:30	144	147	156	160	172	183	
03:00	144	149	156	163	174	183	
03:30	144	149	156	165	170	186	
04:00	142	151	156	163	177	183	
04:30	144	147	156	165	174	183	
05:00	142	149	158	163	172	183	
Average	144,2	149,0	156,2	163,8	172,8	183,4	
Consumed	12,3	13,7	16,2	19,4	21,6	26,8	

Out of water							
Time	1000	1100	1200	1300	1400	1500	
01:00	137	137	144	147	154	158	
01:30	133	133	137	144	149	156	
02:00	131	135	140	144	151	156	
02:30	131	137	142	142	151	154	
03:00	131	140	140	142	149	156	
03:30	131	133	140	142	151	156	
04:00	131	133	140	144	154	156	
04:30	131	135	137	147	151	158	
05:00	131	135	140	147	151	160	
	131,9	135,3	140,0	144,3	151,2	156,7	

Hertz	16,67	18,33	20	21,67	23,33	25
RPM	1000	1100	1200	1300	1400	1500
Consumed	13,4	12,8	15,7	17,6	21,7	25,4
Np	1,68	1,21	1,13	1,00	0,99	0,94
Re	88638	97464	106344	115224	124050	132930
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation	0,56	0,40	0,38	0,33	0,33	0,31
Nq (Pumping)			0,0897			
Neu (Euler)			13			
Pressure (Pa)			25030			
Pressure (kPa)			25			

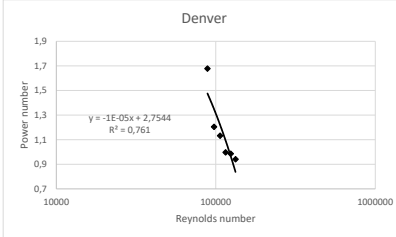
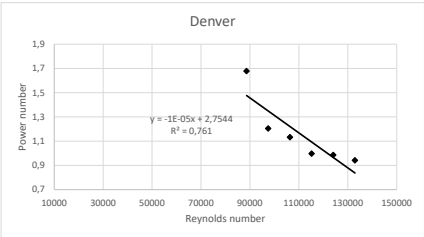
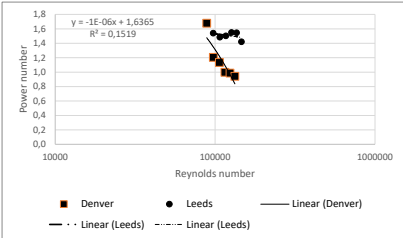


TABLE 5 Dimensionless numbers used to characterize flotation cell hydrodynamics

Group	Definition	Range
Reynolds number	$Re = \frac{\rho_f \cdot N \cdot D^2}{\mu}$	(1-7) $10^6$
Froude number	$Fr = \frac{D \cdot N^2}{g}$	0.1-5
Power number	$Np = \frac{Po}{\rho_f \cdot N^3 \cdot D^5}$	0.5-5
Airflow number	$Q_L = \frac{Q}{N \cdot D^3}$	0.01-0.2

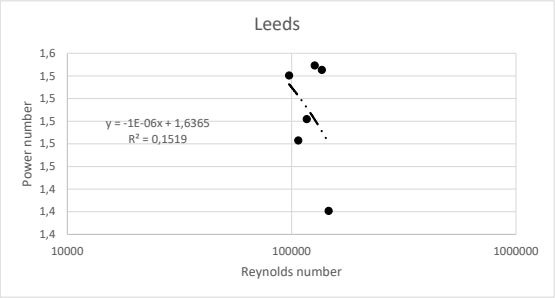
Notes: N = Impeller speed, D = Impeller diameter, Q = airflow rate, Po = net power input,  $\rho_f$  = slurry density,  $\mu$  = slurry viscosity, g = gravitational constant.



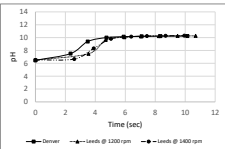
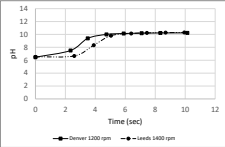
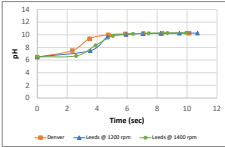
07-Apr

Slurry Density (kg)	1000	Dynamic viscosity, $\eta$				<a href="https://wiki.anton-paar.com/za-en/water/">https://wiki.anton-paar.com/za-en/water/</a>		Water Mas	3			
Diameter (m)	0,074	(Pa.s)		0,000932		@ 23 deg		g	9,81			
Leeds empty (W)							started here					
Impeller speed (r)	1000	1100	1200	1300	1400	1500	Leeds with water (W) 3L					
Time (min)	cell empty						1000	1100	1200	1300	1400	1500
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
1	59	62	62	64	62	64	75	82	89	98	105	114
2	59	59	62	62	62	62	75	82	87	98	105	112
3	59	62	62	64	62	62	75	80	89	96	105	112
4	59	59	62	64	62	64						
5	59	64	62	64	62	64						
Ave. Test 2	59	61	62	64	62	63	75	81	88	97	105	113
Ave. Test 1	58	61	63	62	62	64	73	81	89	97	105	112
Ave. T1 & T2	59	61	63	63	62	64	74	81	89	97	105	112

Hertz	16,67	18,33	20	21,67	23,33	25	19,58333
RPM	1000	1100	1200	1300	1400	1500	1175
Consumed	15,6	20,0	26,3	34,5	42,9	48,5	
Np	1,54	1,48	1,50	1,55	1,55	1,42	
Re	97353	107048	116801	126553	136248	146001	
Fr	2,09	2,53	3,01	3,53	4,09	4,70	2,88
Mean energy dissipation	0,51	0,49	0,50	0,52	0,52	0,47	
Nq (Pumping)			0,0681		0,0550		
Neu (Euler)			22		28		
Pressure (Pa)			47991		83274		
Pressure (kPa)			48		83		



### 3. Let water



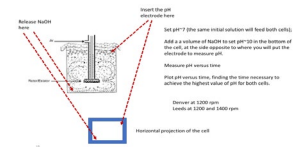
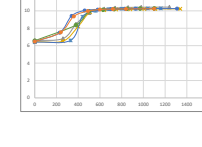
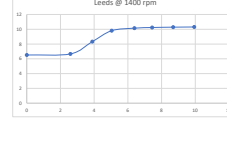
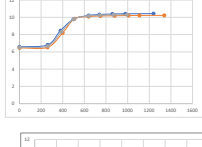
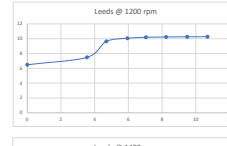
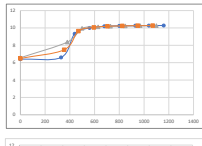
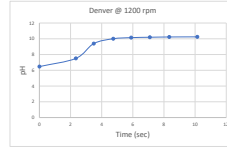
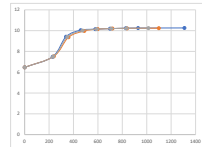
Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52



Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Time	1200	1400
0	6.52	6.52
10	10.52	10.52

Variables	Unit (SI)	Denver
Impeller diameter (D)		0,070
Tank diameter (T)		0,161
Width of impeller's blades (W) =R-S		0,0072
Distance between the center of the impeller and the bottom of the tank © = (R-S)/2 + S		0,0184
Level of the pulp in the cell (Z)	m	0,165
Slurry specific gravity ()	kg/m <sup>3</sup>	1000
Slurry dynamic viscosity ()	Pa.s	0,0010
Surface tension of flotation solution ()	N/m	0,072
Acceleration due to gravity (g)	m/s <sup>2</sup>	9,81
Impeller rotational speed (N)	s <sup>-1</sup>	15
Power drawn by the impeller (P)	W	13,44
Slurry flowrate discharged by the impeller (Q <sub>d</sub> )	m <sup>3</sup> /s	0,0006
Air flowrate feeding the cell (Q <sub>G</sub> )	m <sup>3</sup> /s	3,3E-05
Pressure difference promoted by the movement of j	Pa	?

# Code

Red letters means I used the closest value measured

Data from Lima et al (2019)

Other data, approximated from my cell test conditions

Light blue (additional variables)

water  
@ 20 deg  
@20 deg

I used the closest value measured

water

$$N_P = \left( \frac{\rho Q_G}{N D^3} \right) \left( \frac{\rho Q_d}{N D^3} \right) \left( \frac{\Delta p}{N^2 D^2 \rho} \right) \left( \frac{N^2 D^3 \rho}{\mu_L} \right) \left( \frac{N^2 D^3 \rho}{\gamma} \right) \left( \frac{P}{g} \right) \left( \frac{Z}{D} \right) \left( \frac{W}{D} \right) \left( \frac{C}{D} \right) \quad (17)$$

I assigned an alphabet letter to each term in brackets

$$N_P = a * b * c * \dots * j$$

Terms

a		6E-03
b		0,12
c		?
d		7E+04
e		1E+03
f		1,61
g		2,36
h		0,10
i		0,26
j		2,30
a to j product without c		1E+04
Pressure difference promoted by the movement of j	Pa	0,13

$$N_P = \left( \frac{Q_G}{N D^3} \right) \left( \frac{Q_d}{N D^3} \right) \left( \frac{\Delta p}{N^2 D^2 \rho} \right) \left( \frac{N^2 D^3 \rho}{\mu_L} \right) \left( \frac{N^2 D^3 \rho}{\gamma} \right) \left( \frac{P}{g} \right) \left( \frac{Z}{D} \right) \left( \frac{W}{D} \right) \left( \frac{C}{D} \right) \quad (17)$$

		Denver	1200	1400	Leeds	1200	Range
Water density (kg)	1000						
Water (m/s)	0.003						
Diameter (m)	0.070	0.070	0.074				
Impeller speed	20						
Dynamic viscosity	0.13E-04						Pa.s @ 23 deg
g	9.81						m/s²
Air rate	3.3E-05						m³/s
Power consumed		15.67	43.3		26.3		W
Average time pH 10		4.79	1.82		5.48		
Q (m³/s)		0.0006	0.0005		0.0005		
Average time pH 10		4.79	1.82		5.48		
Re (Reynolds number)		1.05E+05	1.36E+05		3.17E+05	5.51E+04 - 2.51E+06	
Fr (Froude number)		2.87	4.09		3.01	0.1 - 5	
Ng (Power number)		2.23	1.53		1.50	0.1 - 5	
Ng (Air flow number)		4.8E-03	3.6E-03		4.1E-03	0.01 - 0.2	
Ng (Pumping)		0.09	0.05		0.07		
Meu (Euler)		15.6	25.1		22.0	0.5 - 2	
Pressure (Pa)		25000	83024		47991		
Pressure (kPa)		25	83		48		
Energy/power input (W/kg or h)		0.88	0.52		0.50	0.015 - 0.6	
Superficial gas velocity (kg/cm)		0.22	0.27		0.21	0.5 - 1.5	

lit of Lead2me

Changunda et al, 2008

Seed stress

Table 1

Dimensionless numbers used in flotation hydrodynamics characterizations

Parameters	Symbol	Equation	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho N D^2}{\mu}$	Reynolds number	$10^4 - 10^6$	(Morris, 1993)
Power number	$N_p$	$N_p = \frac{P}{\rho N^3 D^5}$	Power number	0.5 - 5	(Garcia et al., 1993; Morris, 1993)
Ng (Power number)	$N_g$	$N_g = \frac{P}{\rho N^3 D^5}$	Ng (Power number)	0.000 - 0.2	(Garcia et al., 1993)
Froude number	$Fr$	$Fr = \frac{N^2 D}{g}$	Froude number	0.1 - 5	(Garcia et al., 1993; Rodriguez et al., 2003)
Water number	$Wn$	$Wn = \frac{N D}{\sqrt{g}}$	Water number	-	(Rodriguez et al., 2003)
Capillary number	$Ca$	$Ca = \frac{\mu N D}{\sigma}$	Capillary number	-	(Garcia et al., 1993)
Stokes number	$St$	$St = \frac{1}{2} \left( \frac{D_p}{D} \right)^2 \frac{\rho N^2}{\mu}$	Stokes number	-	(Garcia et al., 1993)

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m³) and  $\mu$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_g$  is the volumetric gas flowrate (m³/s),  $g$  is the gravitational acceleration (m/s²),  $\sigma$  is the surface tension of air-liquid interface (N/m),  $\nu$  is the kinematic viscosity of the fluid (m²/s),  $\tau$  is the shear rate (s⁻¹) and  $D_p$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_b$  and  $\mu_b$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.

Mavros, P., 1992. Mixing and hydrodynamics in flotation cells, Innovations in Flotation Technology. Springer, pp. 211-234.

Impeller speed	rpm	1000	1000	1200	1400	1200
Variables	Unit (SI)	Denver	Leeds	Denver	Leeds	Leeds
Impeller diameter (D)		0.070	0.074	0.070	0.074	0.074
Tank diameter (T)		0.161	0.158	0.160	0.158	0.158
Width of impeller's blades (W)		0.0072	0.0076	0.0072	0.0076	0.0076
Distance between the center of the impeller and the bottom of the tank (z)	m	0.0184	0.0099	0.0184	0.0099	0.0099
Level of the pulp in the cell (Z)	m	0.148	0.150	0.148	0.150	0.150
Slurry specific gravity (i)	kg/m³	1000	1000	1000	1000	1000
Slurry dynamic viscosity (i)	Pa.s	0.0009	0.0009	0.0009	0.0009	0.0009
Surface tension of flotation solution (i)	N/m	0.012	0.012	0.012	0.012	0.012
Acceleration due to gravity (g)	m/s²	9.81	9.81	9.81	9.81	9.81
Impeller rotational speed (N)	s⁻¹	16.67	16.67	20	23.3	20
Power drawn by the impeller (P)	W	11	11	15.00	27	20
Slurry flowrate discharged by the impeller	m³/s	2.8E-04	2.6E-04	2.0E-04	1.8E-04	2.2E-04
Air flowrate feeding the cell (Q <sub>g</sub> )	m³/s	3.3E-05	3.3E-05	3.3E-05	3.3E-05	3.3E-05
Ng (Power number)		1.37	1.09	1.08	0.97	1.14

cell On the note book

@ 23 deg

@ 22 deg

water - No air

Terms						
a		6E-03	5E-03	5E-03	4E-03	4E-03
b		8E-02	4E-02	3E-02	2E-02	3E-02
c						
d		9E+04	1E+05	1E+05	1E+05	1E+05
e		2617.2	3012.6	3708.8	5004.6	4338.3
f		1.95	2.09	2.87	4.09	2.73
g		2.12	2.03	2.12	2.03	2.03
h		0.10	0.10	0.10	0.10	0.10
i		0.26	0.13	0.26	0.13	0.13
j		2.20	2.14	2.29	2.14	2.14
Pressure difference promoted by the m	Pa	1.7E+04	7.8E+03	2.0E+04	1.4E+04	9.3E+03
		0.31	0.23	0.31	0.21	0.27

Solids %	2.65
Percentage	15.7
Slurry Density	1316

$$N_q = \frac{\text{Flow rate}}{ND^3}$$

¶

N = Impeller rotational speed (s-1)¶

D = Impeller diameter (m)¶

$$N_{eu} = \frac{\Delta p}{\rho N^2 D^2}$$

¶

$$N_p = \left( \frac{Q_g}{ND^3} \right) \left( \frac{Q_g}{ND^3} \right) \left( \frac{\Delta p}{N^2 D^3 P} \right) \left( \frac{ND^2 \rho}{\mu} \right) \left( \frac{N^2 D^3 \rho}{\mu} \right) \left( \frac{D^3 \rho}{N^2} \right) \left( \frac{D^3}{N^2} \right) \left( \frac{D^3}{N^2} \right) \quad (17)$$

$$N_p = a * b * c * \dots * j$$

14-Oct

Water Density (kg)	1000	Step 2	Dynamic viscosity, $\eta$			
Diameter (m)	0,070		(Pa.s)		0,001024 @ 23 deg	
Leeds empty (W)						
Impeller speed (r)	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
Averages	121	128	134	141	148	155

<https://wiki.anton-paar.com/za-en/water/>

Step 1

Water Mas	3
g	9,81

Step 3

Solids SG	2,65
Percentag	16,7
Slurry Den	1116

Denver with water (W) 2.87L & 5/75g SiO2 @ 2 LPM					
1000	1100	1200	1300	1400	1500
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
128	137	146	156	167	178

With water only						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,0	12,0	15,0	17,0	19,0	23,0
Np	1,37	1,13	1,08	0,97	0,86	0,85
Re	80640	88704	96768	104832	112896	120960
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
	0,46	0,38	0,36	0,32	0,29	0,28
Qd (m3/s)	0,0002					
Nq (Pumping)	0,0281 = Qd/(ND^3)					
Neu (Euler)	39 = Np/Nq					
Pressure (Pa)	76583 $\Delta p = Neu*(N^2 D^2 \rho)$					
Pressure (kPa)	77					

0,001024

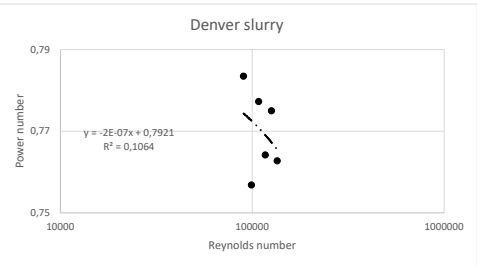
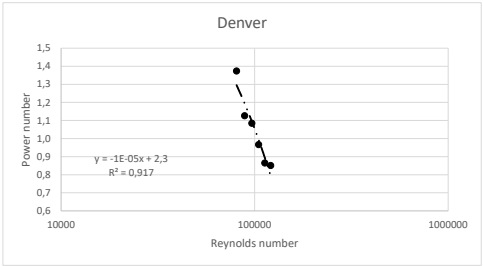
With solids Dynamic viscosity, $\eta$ (Pa.s) = 0,00102						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	7,0	9,0	12,0	15,0	19,0	23,0
Np	0,78	0,76	0,78	0,76	0,78	0,76
Re	89992	98992	107991	116990	125989	134989
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
n	0,26	0,25	0,26	0,25	0,26	0,25
Q (m3/s)	0,0003					
Nq (Pumping)	0,0477 = Qd/(ND^3)					
Neu (Euler)	16 = Np/Nq					
Pressure (Pa)	36040 $\Delta p = Neu*(N^2 D^2 \rho)$					
Pressure (kPa)	36					

Table 1

Dimensionless numbers used in flotation hydrodynamics characterization.

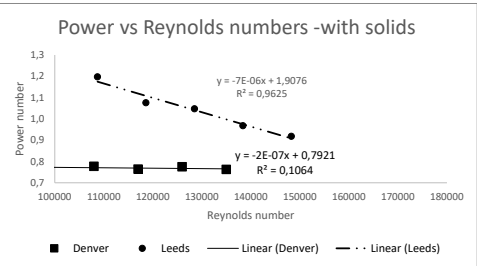
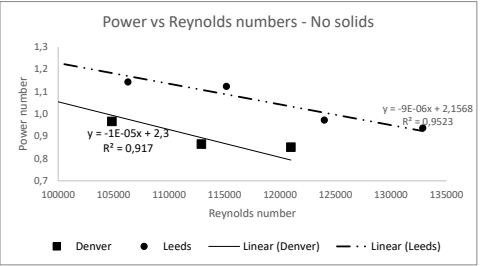
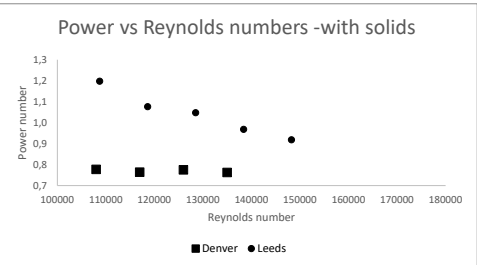
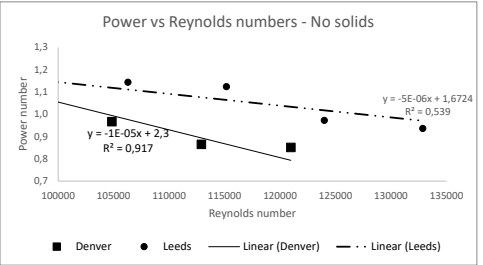
Parameters	Symbol	Equations	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho ND^2}{\eta}$ (6)	inertial force	$5 \times 10^4 - 2 \times 10^5$	(Mavros, 1992)
Power number	$N_p$	$N_p = \frac{P}{\rho N^3 D^5}$ (7)	viscous force resistance force	0.5-5	(Bates et al., 1963; Harris, 1974)
Air flow number	$N_a$	$N_a = \frac{Q_a}{N D^3}$ (8)	inertial force air flowrate	0.002-0.2	(Archiver et al., 1976)
Froude number	$Fr$	$Fr = \frac{N^2 D}{g}$ (9)	impeller velocity inertial force gravity force	0.1-5	(Kramers et al., 1953; Rodrigues et al., 2001)
Weber number	$We$	$We = \frac{\rho N^2 D^3}{\sigma}$ (10)	surface tension viscous shear force	-	(Rodrigues et al., 2001)
Capillary number	$Ca$	$Ca = \frac{\eta R_b}{\sigma}$ (11)	surface tension inertial force	-	(Chu et al., 2019)
Stokes number	$St$	$St = \frac{1}{2} \frac{\rho_p}{\rho} \left( \frac{d_p}{d_b} \right)^2 Re_b$ (12)	drag force	-	(Mietzen et al., 2010)

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m<sup>3</sup>) and  $\mu_p$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_a$  is the volumetric gas flowrate (m<sup>3</sup>/s).  $g$  is the gravitational acceleration (m/s<sup>2</sup>).  $\sigma$  is the surface tension of air/solution interface (N/m).  $\nu$  is the kinematic viscosity of the fluid (m<sup>2</sup>/s),  $\gamma$  is the shear rate (s<sup>-1</sup>) and  $R_b$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_p$  and  $\rho_l$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.



0,78349 0,756832 0,777271 0,764181 0,775005 0,762762

0,78349  
0,756832  
0,777271  
0,764181  
0,775005  
0,762762



14-Oct

Water Density (kg)	1000	Step 3		Dynamic viscosity, $\eta$		
Diameter (m)	0,074			(Pa.s)	0,001024	@ 27 deg
Leeds empty (W)						
Impeller speed (r	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
Averages (W)	63	64	67	68	71	72

<https://wiki.anton-paar.com/za-en/water/>

Step 1

Water Mass	3
g	9,81

Solids SG	2,65
Percentage	16,7
Slurry Den	1116

Leeds with water (W) 3L @ 2 LPM					
1000	1100	1200	1300	1400	1500
74	81	87	93	98	104

Leeds with water (W) 2.87L & 575g SiO2 @ 2 LPM					
1000	1100	1200	1300	1400	1500
74	82	88	94	101	107

With water only

Hertz	16,67	18,33	20	21,67	23,33	25
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,0	17,0	20,0	25,0	27,0	32,0
Np	1,09	1,26	1,14	1,12	0,97	0,94
Re	88587	97408	106283	115158	123979	132854
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation	0,36	0,42	0,38	0,37	0,32	0,31
Q (m3/s)			0,0002			0,0002
Nq (Pumping)			0,03			0,02
Neu (Euler)			42			50
Pressure (Pa)			92433			148650
Pressure (kPa)			92			149

$$= Qd/(ND^3)$$

$$= Np/Nq$$

$$\Delta p = Neu \cdot (N^2 D^2 \rho)$$

With solids Dynamic viscosity,  $\eta$  (Pa.s) = 0,00102

Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,0	18,0	21,0	26,0	30,0	35,0
Np	0,97	1,20	1,08	1,05	0,97	0,92
Re	98841	108725	118609	128493	138378	148262
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation	0,32	0,40	0,36	0,35	0,32	0,31
Q (m3/s)			0,0003			0,0002
Nq (Pumping)			0,04			0,03
Neu (Euler)			30			37
Pressure (Pa)			71855			121933
Pressure (kPa)			72			122

$$= Qd/(ND^3)$$

$$= Np/Nq$$

$$\Delta p = Neu \cdot (N^2 D^2 \rho)$$

0,973863 1,197291 1,075922 1,047728 0,9679265 0,91812

0,973863

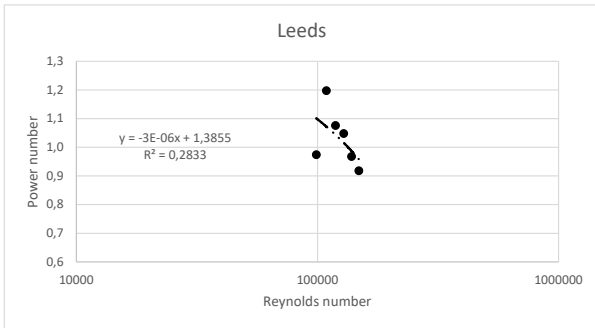
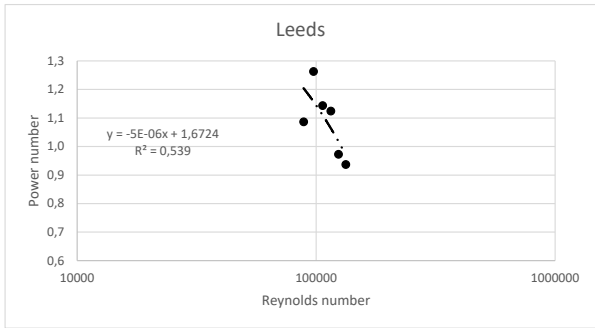
1,197291

1,075922

1,047728

0,967927

0,91812



Water (No Air)

Impeller speed	rpm	1000	1000	1200	1400	1200
Variables	Unit (SI)	Denver	Leeds	Denver	Leeds	Leeds
Impeller diameter (D)		0,070	0,074	0,070	0,074	0,074
Tank diameter (T)		0,161	0,158	0,161	0,158	0,158
Width of impeller's blades (W)		0,0072	0,0076	0,0072	0,0076	0,0076
Distance between the center of the impeller and the bottom of the tank (C)						
Level of the pulp in the cell (Z)	m	0,0184	0,0099	0,0184	0,0099	0,0099
Water specific gravity (γ)	kg/m <sup>3</sup>	1000	1000	1000	1000	1000
Water dynamic viscosity (η)	Pa.s	0,0010	0,0010	0,0010	0,0010	0,0010
Surface tension of flotation solution (γ)	N/m	0,038	0,038	0,038	0,038	0,038
Acceleration due to gravity (g)	m/s <sup>2</sup>	9,81	9,81	9,81	9,81	9,81
Impeller rotational speed (N)	s <sup>-1</sup>	16,67	16,67	20	23,3	20
Power drawn by the impeller (P)	W	11	11	15,00	27	20
Slurry flowrate discharged by the impeller (Q <sub>dis</sub> )	m <sup>3</sup> /s	2,8E-04	2,6E-04	2,0E-04	1,8E-04	2,2E-04
Air flowrate feeding the cell (Q <sub>a</sub> )	m <sup>3</sup> /s	3,3E-05	3,3E-05	3,3E-05	3,3E-05	3,3E-05
Np (Power number)		1,37	1,09	1,08	0,97	1,14

cal. On the note book

@ 22 deg  
Modified 23 Nov 2022  
Modified 23 Nov 2023

water - No air

Terms					
a		6E-03	5E-03	5E-03	4E-03
b		5E-02	4E-02	3E-02	2E-02
c		?	?	?	?
d		9E+04	1E+05	1E+05	1E+05
e		2555,9	2942,0	3680,5	5766,4
f		1,99	2,09	2,87	4,09
g		2,12	2,03	2,12	2,03
h		0,10	0,10	0,10	0,10
i		0,26	0,13	0,26	0,13
j		2,29	2,14	2,29	2,14
All terms multiplied		1,6E+04	6,9E+03	1,9E+04	1,3E+04
Pressure difference promoted by the mPa		0,12	0,24	0,11	0,22
		0,25			

Average time pH 11		10,57	11,33	15,32	16,52	13,87	No Air
Re (Reynolds number)		8,65E+04	9,51E+04	1,04E+05	1,33E+05	1,14E+05	5E10 <sup>04</sup> - 2E11
Fr (Froude number)		1,99	2,09	2,87	4,09	3,01	0.1 - 5
Np (Power number)		1,37	1,09	1,08	0,97	1,14	0.5 - 5
Na (Air flow number)		5,7E-03	5,0E-03	4,8E-03	3,6E-03	4,1E-03	0.01 - 0.2
Nq (Pumping)		0,05	0,04	0,03	0,02	0,03	
Neu (Euler)		8,59E-05	1,57E-04	5,69E-05	7,46E-05	1,17E-04	0.5 - 2
Energy/power input (W/kg or kW/m3)		0,46	0,36	0,36	0,32	0,38	0.015 - 0,6
Superficial gas velocity (Ug) (cm/s)				0,21	0,22	0,21	0.6-1.5
Np = Nq * Neu		4,19E-06	6,20E-06	1,60E-06	1,45E-06	3,15E-06	

$$N_p = \left( \frac{Q_{dis}}{ND^3} \right) \left( \frac{Q_{a}}{ND^3} \right) \left( \frac{\Delta p}{N^2 D^5 \rho} \right) \left( \frac{ND^2 \rho}{\mu_L} \right) \left( \frac{ND^3 \rho}{\gamma_{L/G}} \right) \left( \frac{DN^2}{g} \right)^2 \left( \frac{W}{\eta} \right) \left( \frac{\gamma}{\eta} \right) \left( \frac{f}{\eta} \right) \quad (17)$$
$$N_p = a * b^c * c * \dots * j$$

Table 1

Dimensionless numbers used in flotation hydrodynamics characterization

Parameters	Symbols	Equations	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho ND^2}{\mu_L}$ (6)	inertial force	$5 \times 10^4 - 2 \times 10^6$	(Merriss, 1980)
Power number	$N_p$	$N_p = \frac{P}{\rho ND^5}$ (7)	viscous force	0.5-5	(Baker et al., 1960; Hertz, 1974)
Air flow number	$N_a$	$N_a = \frac{Q_a}{ND^3}$ (8)	viscosity force	0.002-0.2	(Ashwin et al., 1976)
Froude number	$Fr$	$Fr = \frac{ND^3}{g}$ (9)	inertial force	0.1-5	(Kraemer et al., 1993; Rodriguez et al., 2001)
Weber number	$We$	$We = \frac{\rho ND^3}{\sigma}$ (10)	gravity force	-	(Rodriguez et al., 2001)
Capillary number	$Ca$	$Ca = \frac{\rho ND^3}{\sigma}$ (11)	surface tension	-	(Chu et al., 2019)
Stokes number	$St$	$St = \frac{\rho ND^3}{\mu_L} \left( \frac{d_p}{d_b} \right)^2$ (12)	viscous shear force	-	(Munitions et al., 2010)
			drag force	-	

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m<sup>3</sup>) and  $\mu_L$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_a$  is the volumetric gas flowrate (m<sup>3</sup>/s).  $g$  is the gravitational acceleration (m/s<sup>2</sup>).  $\sigma$  is the surface tension of air-liquid interface (N/m).  $\nu$  is the kinematic viscosity of the fluid (m<sup>2</sup>/s),  $\tau$  is the shear rate (s<sup>-1</sup>) and  $R_0$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_p$  and  $\rho_L$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.

Lit of Leal2me  
Changunda et al, 2008  
Saeed thesis

$$N_q = \frac{\text{Flow rate}}{ND^3}$$

N = Impeller rotational speed (s-1)

eller diameter (m)

$$N_{eu} = \frac{\Delta p}{\rho N^2 D^2}$$



Slurry data (with 2LPM air)

Impeller speed	rpm	1000	1000	1200	1400	1200
Variables	Unit (SI)	Denver	Leeds	Denver	Leeds	Leeds
Impeller diameter (D)		0,070	0,074	0,070	0,074	0,074
Tank diameter (T)		0,161	0,158	0,161	0,158	0,158
Width of impeller's blades (W)		0,0072	0,0076	0,0072	0,0076	0,0076
Distance between the center of the impeller and the bottom of the tank (c)		0,0184	0,0099	0,0184	0,0099	0,0099
Level of the pulp in the cell (Z)	m	0,149	0,150	0,149	0,150	0,150
Slurry specific gravity (ρ)	kg/m <sup>3</sup>	1116	1116	1116	1116	1116
Slurry dynamic viscosity (η)	Pa.s	0,0011	0,0011	0,0011	0,0011	0,0011
Surface tension of flotation solution (γ)	N/m	0,037	0,037	0,037	0,037	0,037
Acceleration due to gravity (g)	m/s <sup>2</sup>	9,81	9,81	9,81	9,81	9,81
Impeller rotational speed (N)	s <sup>-1</sup>	16,67	16,67	20	23,3	20
Power drawn by the impeller (P)	W	7	11	12,00	30	21
Slurry flowrate discharged by the impeller	m <sup>3</sup> /s	2,6E-04	2,6E-04	2,3E-04	2,6E-04	2,4E-04
Air flowrate feeding the cell (Q <sub>a</sub> )	m <sup>3</sup> /s	3,3E-05	3,3E-05	3,3E-05	3,3E-05	3,3E-05
Np (Power number) - Hydrodynamic test		0,78	0,97	0,78	0,97	1,08

Solids SG	2,65
Percentage S	16,7
Slurry Density	1116

cal. On the note book

$$N_q = \frac{\text{Flow rate}}{ND^3}$$

¶

N = Impeller rotational speed (s<sup>-1</sup>)¶

D = Impeller diameter (m)¶

@ 22 deg

@22 deg

water - Air

$$N_P = \left( \frac{Q_d}{ND^3} \right) \left( \frac{Q_d}{ND^3} \right) \left( \frac{\Delta p}{N^2 D^2 \rho} \right) \left( \frac{ND^2 \rho}{\mu_L} \right) \left( \frac{N^2 D^3 \rho}{\gamma_{L/G}} \right) \left( \frac{DN^2}{g} \right) \left( \frac{Z}{n} \right) \left( \frac{W}{n} \right) \left( \frac{c}{n} \right) \quad (17)$$

Np = a \* b\* c .....\* j

Terms					
Qg/(ND^3 )		6E-03	5E-03	5E-03	4E-03
Qd/(ND^3 )		4E-02	4E-02	3E-02	3E-02
Δp/(N^2 D^2 ρ)		?	?	?	?
(ND^2 ρ)/μL		8E+04	9E+04	1E+05	1E+05
(N^2 D^3 ρ)/(γL/G)		2920,7	3362,0	4305,9	6589,4
(DN^2)/g		1,99	2,09	2,87	4,09
Z/D		2,12	2,03	2,12	2,03
W/D		0,10	0,10	0,10	0,10
c/D		0,26	0,13	0,26	0,13
T/D		2,29	2,14	2,29	2,14
All terms multiplied		1,6E+04	7,1E+03	2,4E+04	2,0E+04
Pressure difference promoted by the moven	Pa	0,08	0,23	0,07	0,16

Average time pH 11		11,52	11,66	12,88	11,63	12,28	Ranges	Air
Re (Reynolds number)		80233	88122	96280	123371	105747	5E10^4 - 2E10^6	
Fr (Froude number)		1,99	2,09	2,87	4,09	3,01	0.1 - 5	
Np (Power number)		0,78	0,97	0,78	0,97	1,08	0.5 - 5	
Na (air flow number)		5,7E-03	5,0E-03	4,8E-03	3,6E-03	4,1E-03	0,01 - 0,2	
Nq (Pumping)		0,04	0,04	0,03	0,03			
Neu (Euler)		5,04E-05	1,37E-04	3,24E-05	4,93E-05	9,19E-05	0,5 - 2	Lit of Lea12me
Energy/power input (W/kg or kW/m3)		0,26	0,32	0,26	0,32	0,36	0,015 - 0,6	Changunda et al, 2008
Superficial gas velocity (Ug) (cm/s)				0,21	0,22	0,21	0,6-1.5	Saeed thesis
Nq * Neu		2,26E-06	5,25E-06	1,08E-06	1,36E-06	2,80E-06		

Impeller speed	rpm	1000	1000	1200	1400	1200
Variables	Unit (SI)	Denver	Leeds	Denver	Leeds	Leeds
Impeller diameter (D)		0,070	0,074	0,070	0,074	0,074
Tank diameter (T)		0,161	0,158	0,161	0,158	0,158
Width of impeller's blades (W)		0,0072	0,0076	0,0072	0,0076	0,0076
Distance between the center of the impeller and the bottom of the tank (c)		0,0184	0,0099	0,0184	0,0099	0,0099
Level of the pulp in the cell (Z)	m	0,149	0,150	0,149	0,150	0,150
Slurry specific gravity (ρ)	kg/m <sup>3</sup>	1116	1116	1116	1116	1116
Slurry dynamic viscosity (η)	Pa.s	0,0009	0,0009	0,0009	0,0009	0,0009
Surface tension of flotation solution (γ)	N/m	0,037	0,037	0,037	0,037	0,037
Acceleration due to gravity (g)	m/s <sup>2</sup>	9,81	9,81	9,81	9,81	9,81
Impeller rotational speed (N)	s <sup>-1</sup>	16,67	16,67	20	23,3	20
Power drawn by the impeller (P)	W	7	11	12,00	30	21
Slurry flowrate discharged by the impeller	m <sup>3</sup> /s	2,8E-04	2,6E-04	3,3E-04	2,5E-04	2,9E-04
Air flowrate feeding the cell (Q <sub>a</sub> )	m <sup>3</sup> /s	3,3E-05	3,3E-05	3,3E-05	3,3E-05	3,3E-05
Np (Power number)		0,78	0,97	0,78	0,97	1,08

@ 23 deg

@22 deg

water - Air

Terms					
a		6E-03	5E-03	5E-03	4E-03
b		5E-02	4E-02	5E-02	3E-02
c					
d		1E+05	1E+05	1E+05	2E+05
e		2920,7	3362,0	4305,9	6589,4
f		1,99	2,09	2,87	4,09
g		2,12	2,03	2,12	2,03
h		0,10	0,10	0,10	0,10
i		0,26	0,13	0,26	0,13
j		2,29	2,14	2,29	2,14
Pressure difference promoted by the mpe		0,08	0,34	0,06	0,14

Average time pH 11		10,70	11,42	9,01	12,19	10,27	Air
Re (Reynolds number)		9,80E+04	1,08E+05	1,33E+05	1,33E+05	1,30E+05	5E10^4 - 2E1
Fr (Froude number)		1,99	2,09	2,87	4,09	3,01	0.1 - 5
Np (Power number)		0,78	0,97	0,78	0,97	1,08	0.5 - 5
Na (air flow number)		5,7E-03	5,0E-03	4,8E-03	3,6E-03	4,1E-03	0,01 - 0,2
Nq (Pumping)		0,03	0,04	0,03	0,03	0,04	
Neu (Euler)		3,80E-05	1,08E-04	1,84E-05	4,20E-05	6,24E-05	0,5 - 2
Energy/power input (W/kg or kW/m3)		0,26	0,32	0,26	0,32	0,36	0,015 - 0,6
Superficial gas velocity (Ug) (cm/s)				0,21	0,22	0,21	0,6-1.5
Nq * Neu		1,83E-06	4,26E-06	8,79E-07	1,33E-06	2,27E-06	



14-Oct

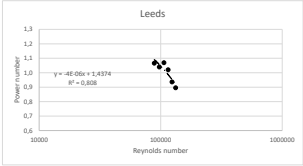
Slurry Density (kg/m <sup>3</sup> )	1000		Step 3		Dynamic viscosity, $\eta$ (Pa.s)		0.00102 @ 27 deg	
	0.074							
Impeller speed (r/min)	1000		1100		Leads empty (W)		1400 1500	
	Time (min)							
0.5	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	55	57	59	62	64	64	64	64
1	55	57	59	62	64	64	64	64
1.5	55	57	59	62	64	64	64	64
2	55	57	59	62	64	64	64	64
2.5	55	57	59	62	64	64	64	64
3	55	57	62	62	64	64	64	64
3.5	55	57	59	62	64	64	64	64
4	55	57	59	62	64	64	64	64
4.5	55	57	59	62	64	64	64	64
5	55	57	59	62	64	64	64	62
Ave. Test 2	55	57	59	62	64	64	64	64
Ave. Test 1	55	57	59	62	64	64	64	64
Ave. T1 & T2	55	57	59	62	64	64	64	64

Step 1					
Leads empty (W)					
Impeller speed (r/min)	1000	1100	1200	1300	1400
Time (min)	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	68	73	80	87	94
1	68	73	80	87	94
1.5	68	73	82	89	96
2	68	73	80	87	96
2.5	71	73	80	87	96
3	68	73	80	87	94
3.5	68	73	82	87	96
4	68	73	82	87	96
4.5	68	73	82	89	94
5	68	73	82	89	94
Ave. Test 2	68	73	81	88	95
Ave. Test 1	68	73	81	88	95
Ave. T1 & T2	68	73	81	88	95

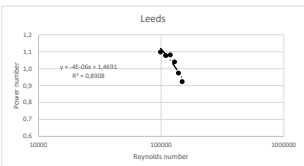
Step 2					
Leads empty (W)					
Impeller speed (r/min)	1000	1100	1200	1300	1400
Time (min)	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	64	71	78	85	94
1	66	71	78	85	94
1.5	66	71	78	85	94
2	64	71	78	85	94
2.5	68	71	78	85	94
3	66	71	78	85	94
3.5	66	71	78	85	94
4	66	71	78	85	94
4.5	66	71	78	85	94
5	66	71	78	85	94
Ave. Test 2	66	71	78	85	94
Ave. Test 1	66	71	78	85	94
Ave. T1 & T2	66	71	78	85	94

Step 4					
Leads empty (W)					
Impeller speed (r/min)	1000	1100	1200	1300	1400
Time (min)	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	68	73	80	87	94
1	66	75	80	89	96
1.5	68	73	80	89	96
2	66	73	82	87	94
2.5	66	73	80	87	94
3	68	73	80	87	94
3.5	68	73	82	87	94
4	68	73	80	89	94
4.5	68	73	80	89	94
5	68	73	80	87	94
Ave. Test 2	67	73	80	88	94
Ave. Test 1	67	73	80	88	94
Ave. T1 & T2	67	73	80	88	94

With water only					
Hertz	16.67	18.33	20	21.67	23.33
RPM	1000	1100	1200	1300	1400
Consumed	10.8	14.0	18.7	22.7	26.0
Np	1.07	1.04	1.07	1.02	0.94
Re	88587	97408	106283	115158	123979
Fr	2.09	2.53	3.01	3.53	4.09
Mean energy dissipation	0.36	0.35	0.36	0.34	0.31
Nq (Pumping)	0.0681		0.0550		
Nu (Euler)	16		17		
Pressure (Pa)	34166		50469		
Pressure (kPa)	34		50		



With solids					
Hertz	16.7	18.3	20.0	21.7	23.3
RPM	1000	1100	1200	1300	1400
Consumed	12.4	16.2	21.1	25.8	30.2
Np	1.0978	1.0776	1.0810	1.0397	0.9744
Re	98841	108725	118609	128493	138378
Fr	2.09	2.53	3.01	3.53	4.09
Mean energy dissipation	0.37	0.36	0.36	0.35	0.32
Nq (Pumping)	0.0681		0.0550		
Nu (Euler)	16		16		
Pressure (Pa)	38551		58613		
Pressure (kPa)	39		59		



1.09715	1.07815	1.08105	1.03919	0.974797	0.92337	1.066408754	1.03979	1.0692	1.02037	0.93656	0.89579
98841.1	108725	118609	128493	138377.5	148262	106643.497	117263	127947	138630	149250	159933
98841.1	1.09715										
108725	1.07815										
118609	1.08105					1.066408754	1.24414	1.00716	0.12333		
128493	1.03919					117263	1.03979419	1.30717	1.18834	0.13396	
138378	0.9748					127947	1.06919856	1.2007	1.06348	0.07763	
148262	0.92337					138630	1.020365741	1.14173	1.04284	0.06457	
						149250	0.936560586	1.08065	0.92936	0.08534	
						159933	0.895793993	1.06559	0.87823	0.10347	
0.97386	1.09715	1.00867	0.97328	0.0638	1.02637						
1.15729	1.07815	1.18463	1.15801	0.05542	1.14027	0.055416					
1.07592	1.08105	1.09642	1.03493	0.032	1.0708	0.031996					
1.04773	1.03919	1.06336	1.02308	0.02027	1.04187	0.020273					
0.96793	0.9748	1.04581	0.92961	0.05868	0.9834	0.058777					
0.91812	0.92337	1.00206	0.86566	0.06847	0.93036	0.068472					
98841.1	89992.3	119012	14873.2	101615							
108725	89991.6	130863	16333	112860							
118609	107991	142785	17832.1	123129							
128493	116990	154708	19331.2	133397							
138378	125989	166559	20791	141642							
148262	134989	178482	22290.2	153911							

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Water Density (kg)		Step 2		Dynamic viscosity, $\eta$			
Diameter (m)		0.070		(Pa.s)		0.001024 @ 23 deg	
				Leads empty (W)			
Impeller speed (r	1000	1100	1200	1300	1400	1500	
Time (min)							
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	114	126	131	140	144	146	150
1	117	124	128	135	147	147	156
1.5	114	121	131	137	144	156	
2	114	124	128	135	142	156	
2.5	117	124	131	135	147	156	
3	117	121	128	137	142	151	
3.5	117	124	133	137	147	156	
4	117	121	133	135	147	154	
4.5	114	124	133	135	147	154	
5	114	126	131	137	147	154	
Ave. Test 2	116	124	131	136	145	155	
Ave. Test 1							
Ave. T1 & T2	116	124	131	136	145	155	

<https://wiki.anton-paar.com/en/water/>

Water Mat				Step 1	
Water Mat				9.61	
started here then move					
1000	1100	1200	1300	1400	1500
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
126	133	144	156	167	172
128	135	142	156	163	172
126	133	144	156	165	174
124	131	144	156	167	174
124	131	144	158	163	172
126	133	144	154	165	174
126	137	144	154	170	177
126	133	144	156	167	177
124	133	144	156	167	174
124	133	144	156	167	170
125	133	144	156	166	173
125	133	144	156	166	173

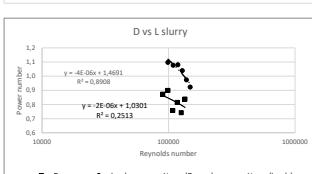
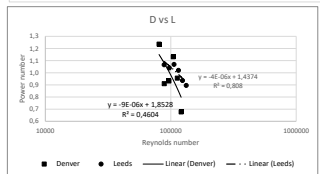
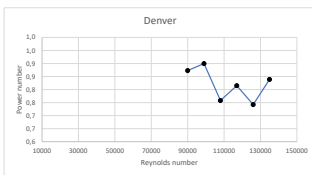
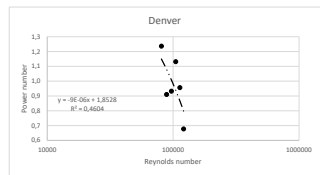
started here then move backwards

Solids %	
2.65	
Percentage	
16.7	
Slurry Den	
1316	

Leads with water (W) 2.3% @ 5754 (100 @ 1.1M)					
Impeller speed (r	1000	1100	1200	1300	1400
Time (min)					
0.1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
0.5	121	135	140	154	165
1	124	135	144	149	160
1.5	124	135	144	151	161
2	121	133	144	156	165
2.5	124	135	144	154	165
3	126	133	142	151	160
3.5	124	133	140	151	165
4	121	135	140	149	165
4.5	124	133	144	154	165
5	124	135	142	154	160
Ave. Test 2	123	134	142	152	163
Ave. Test 1					
Ave. T1 & T2	123	134	142	152	163

With water only							
Hertz	16.7	18.3	20.0	21.7	23.3	25.0	19.58333
RPM	1000	1100	1200	1300	1400	1500	1175
Consumed	9.9	9.7	12.5	19.9	21.0	18.3	
Re	80640	88704	96768	104832	112896	120960	
Fr	1.99	2.41	2.87	3.37	3.91	4.49	2.75
Mean energy dissipation							
n	0.41	0.30	0.31	0.38	0.32	0.23	
Ne (Pumping)			0.0897				
Ne (Euler)			10				
Pressure (Pa)			20610				
Pressure (kPa)			21				

With solids							
Hertz	16.7	18.3	20.0	21.7	23.3	25.0	19.58333
RPM	1000	1100	1200	1300	1400	1500	1175
Consumed	7.8	10.7	11.7	16.0	18.2	25.3	
Re	89992	98992	107991	116990	125989	134989	
Fr	1.99	2.41	2.87	3.37	3.91	4.49	2.75
Mean energy dissipation							
n	0.29	0.30	0.25	0.27	0.25	0.28	
Ne (Pumping)			0.0897				
Ne (Euler)			8				
Pressure (Pa)			18693				
Pressure (kPa)			19				



108335.5	119169.1	130002.6	140836.2	151669.7	162503.3	1.235848	0.910796	0.912473	1.130871	0.956339	0.677279
0.872508	0.90028	0.75784	0.814751	0.742692	0.839039	97076.82	106784.5	116492.2	126199.9	135907.5	145615.2
89992.35	0.872508					97076.82	1.235848	1.573842	1.324025	0.17532	
89991.58	0.90028					106784.5	0.910796	1.126142	1.238758	0.166641	
107990.8	0.75784					116492.2	0.932473	1.088728	1.069814	0.088825	
116990	0.814751					126199.9	1.130871	0.943775	0.966517	0.10209	
125989.3	0.742692					135907.5	0.956339	0.746535	0.728127	0.126714	
134988.5	0.839039					145615.2	0.677279	0.866028	0.740196	0.096107	
std dev Average											
0.872508	0.83826	0.78349	0.873031	0.042729	0.83026	0.025699					
0.90028	0.756832	0.756832	0.941836	0.096322	0.8185	0.097066					
0.75784	0.751362	0.777271	1.023407	0.131088	0.85068	0.155229					
0.814751	0.764181	0.764181	0.753992	0.027407	0.760785	0.032539					
0.742692	0.726058	0.775005	0.750531	0.030364	0.750531	0.012488					
0.839039	0.759526	0.762762	0.722966	0.049292	0.760551	0.058672					

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Water Density (kg)	1000	Step 2	Dynamic viscosity, $\eta$			
Diameter (m)	0,070		(Pa.s)	0,001024	@ 27 deg	
Leeds empty (W)						
Impeller speed (r	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
Averages	119	126	131	137	146	152

<https://wiki.anton-paar.com/za-en/water/>

Step 1

Water Mas	3
g	9,81

Step 3

Solids SG	2,65
Percentag	16,7
Slurry Den	1116

Denver with water (W) 2.87L & 575g SiO2 @ 2 LPM					
1000	1100	1200	1300	1400	1500
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
131	139	148	158	167	177

With water only

Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	15,6	17,8	21,0	22,6	25,4	27,0
Np	1,95	1,67	1,52	1,28	1,16	1,00
Re	80640	88704	96768	104832	112896	120960
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
	0,65	0,56	0,51	0,43	0,39	0,33
Qd (m3/s)	0,0002					
Nq (Pumping)	0,0281					
Neu (Euler)	54					
Pressure (Pa)	107217					
Pressure (kPa)	107					

With solids

Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,2	12,8	16,8	20,4	21,2	25,6
Np	1,25	1,08	1,09	1,04	0,86	0,85
Re	89992	98992	107991	116990	125989	134989
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
	0,42	0,36	0,36	0,35	0,29	0,28
Q (m3/s)	0,0003					
Nq (Pumping)	0,0477					
Neu (Euler)	23					
Pressure (Pa)	50456					
Pressure (kPa)	50					

Table 1

Dimensionless numbers used in flotation hydrodynamics characterization.

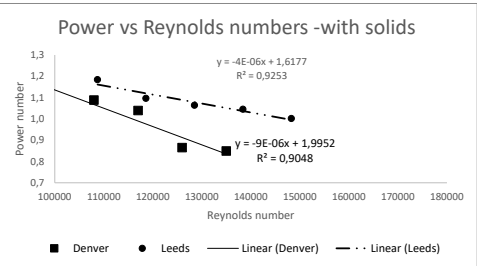
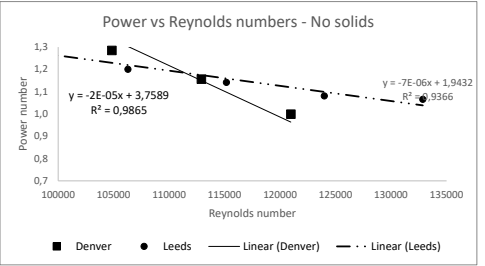
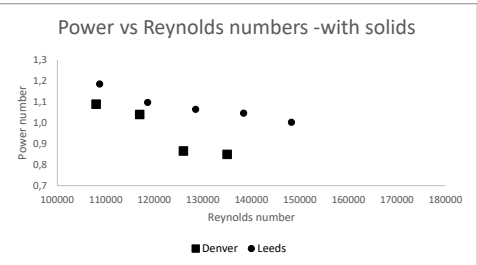
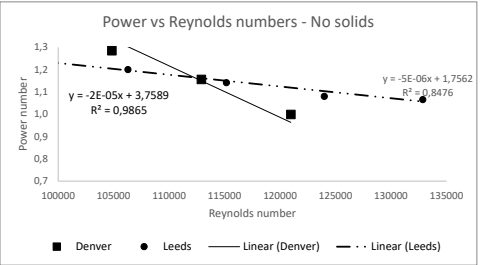
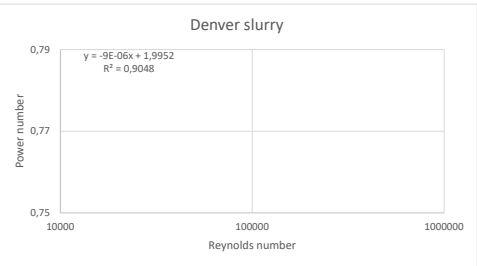
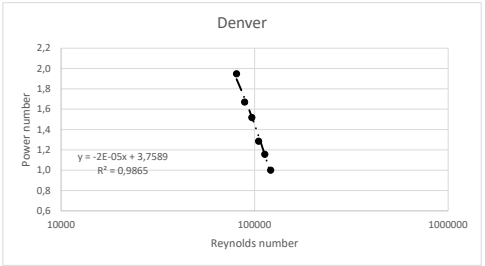
Parameters	Symbol	Equations	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho N D^2}{\mu}$ (6)	inertial force	$5 \times 10^4 - 2 \times 10^5$	(Mavros, 1992)
Power number	$N_p$	$N_p = \frac{P}{\rho N^3 D^5}$ (7)	viscous force resistance force	0.5-5	(Bates et al., 1963; Harris, 1974)
Air flow number	$N_a$	$N_a = \frac{Q_a}{N D^3}$ (8)	inertial force air flowrate	0.002-0.2	(Archibler et al., 1976)
Froude number	$Fr$	$Fr = \frac{N^2 D}{g}$ (9)	impeller velocity inertial force	0.1-5	(Kramers et al., 1953; Rodrigues et al., 2001)
Weber number	$We$	$We = \frac{\rho N^2 D^3}{\sigma}$ (10)	gravity force inertial force	-	(Rodrigues et al., 2001)
Capillary number	$Ca$	$Ca = \frac{\mu R_0}{\sigma}$ (11)	surface tension viscous shear force	-	(Chu et al., 2019)
Stokes number	$Str$	$Str = \frac{1}{2} \frac{\rho_p}{\rho_l} \left( \frac{d_p}{d_b} \right)^2 Re_b$ (12)	inertial force drag force	-	(Mientzen et al., 2010)

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m<sup>3</sup>) and  $\mu$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_a$  is the volumetric gas flowrate (m<sup>3</sup>/s).  $g$  is the gravitational acceleration (m/s<sup>2</sup>).  $\sigma$  is the surface tension of air/solution interface (N/m).  $\nu$  is the kinematic viscosity of the fluid (m<sup>2</sup>/s),  $\gamma$  is the shear rate (s<sup>-1</sup>) and  $R_0$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_b$  and  $\rho_l$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.

89992,35	98991,58	107990,8	116990	125989,3	134988,5
1,253583	1,076384	1,08818	1,039287	0,864743	0,848988
89992,35	1,253583				
98991,58	1,076384				
107990,8	1,08818				
116990	1,039287				
125989,3	0,864743				
134988,5	0,848988				

1,95	1,67	1,52	1,28	1,16	1,00
97077	106785	116492	126200	135908	145615

97077	1,95
106785	1,67
116492	1,52
126200	1,28
135908	1,16
145615	1,00



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Water Density (kg)	1000	Step 3		Dynamic viscosity, $\eta$		
Diameter (m)	0,074			(Pa.s)	0,001024	@ 27 deg
Leeds empty (W)						
Impeller speed (r	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
Averages (W)	62	64	67	68	69	69

<https://wiki.anton-paar.com/za-en/water/>

Water Mass	3
g	9,81

Solids SG	2,65
Percentage	16,7
Slurry Den	1116

Leeds with water (W) 3L @ 2 LPM						
1000	1100	1200	1300	1400	1500	
75	81,6	87,8	93,4	98,6	105	

Leeds with water (W) 2.87L & 575g SiO2 @ 2 LPM						
1000	1100	1200	1300	1400	1500	
74	82	88	94	101	107	

With water only

Hertz	16,67	18,33	20	21,67	23,33	25
RPM	1000	1100	1200	1300	1400	1500
Consumed	12,6	17,6	21,0	25,4	30,0	36,4
Np	1,24	1,31	1,20	1,14	1,08	1,07
Re	88587	97408	106283	115158	123979	132854
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation						
	0,41	0,44	0,40	0,38	0,36	0,36
Q (m3/s)			0,0002			0,0002
Nq (Pumping)			0,03			0,02
Neu (Euler)			45			56
Pressure (Pa)			97055			165167
Pressure (kPa)			97			165

$= Qd/(ND^3)$

$= Np/Nq$

$\Delta p = Neu^*(N^2 D^2 p)$

With solids

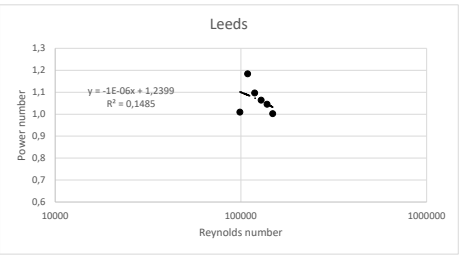
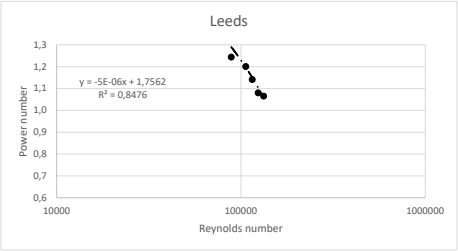
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,4	17,8	21,4	26,4	32,4	38,2
Np	1,01	1,18	1,10	1,06	1,05	1,00
Re	98841	108725	118609	128493	138378	148262
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation						
n	0,34	0,39	0,37	0,35	0,35	0,33
Q (m3/s)			0,0003			0,0002
Nq (Pumping)			0,04			0,03
Neu (Euler)			30			40
Pressure (Pa)			73224			131688
Pressure (kPa)			73			132

$= Qd/(ND^3)$

$= Np/Nq$

$\Delta p = Neu^*(N^2 D^2 p)$

1,008671	1,184634	1,096416	1,063356	1,0458088	1,002063	1,244143547	1,30717	1,200704	1,141731	1,080647	1,065585
98841,1	108725,2	118609,3	128493,4	138377,54	148261,6	106643,497	117263,1	127946,6	138630,1	149249,7	159933,3
98841,1	1,008671										
108725,2	1,184634					106643,5	1,244143547				
118609,3	1,096416					117263,1	1,307169839				
128493,4	1,063356					127946,6	1,200704265				
138377,5	1,045809					138630,1	1,141730829				
148261,6	1,002063					149249,7	1,08064683				
						159933,3	1,065585012				



14-Oct

Water Density (kg/m <sup>3</sup> )	1000	Step 2		Dynamic viscosity, $\eta$ (Pa.s)	0,001024	@ 27 deg
Diameter (m)	0,070	Leeds empty (W)				
Impeller speed (rpm)	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
Averages	118,6	126,4	133	140,2	148,6	155,2

<https://wiki.anton-paar.com/za-en/water/>

Water Mass (g)	3
g	9,81

Step 1

Denver with water (W) 3L @ 2 LPM					
1000	1100	1200	1300	1400	1500
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
131	138,4	148,2	156,8	165	178,6

Step 3

Solids SG	2,65
Percentage	16,7
Slurry Den	1116

Denver with water (W) 2.87L & 575g SiO <sub>2</sub> @ 2 LPM					
1000	1100	1200	1300	1400	1500
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
126	135,4	144,6	155,2	166,4	179,2

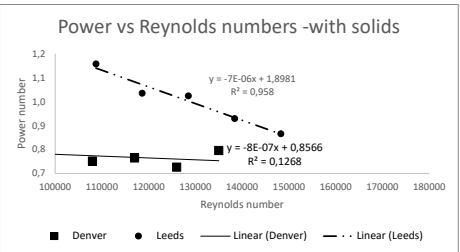
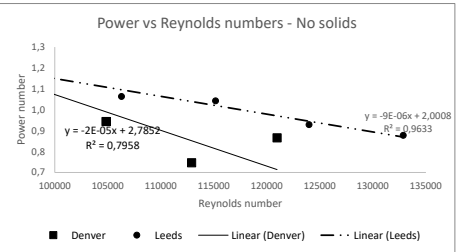
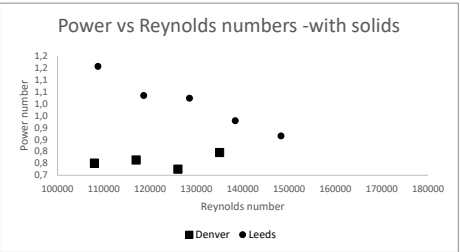
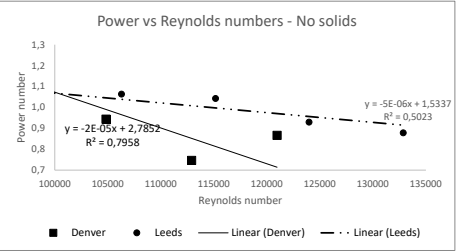
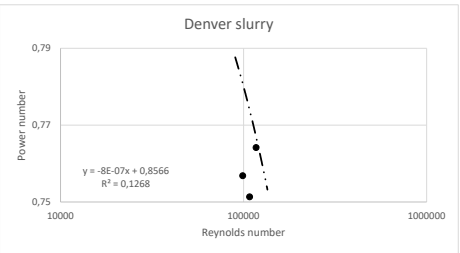
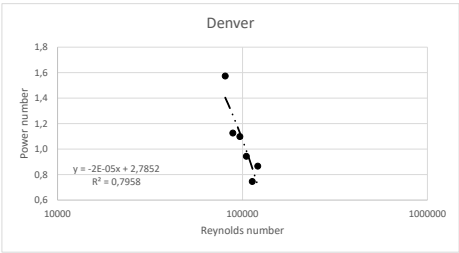
With water only						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	12,6	12,0	15,2	16,6	16,4	23,4
Np	1,57	1,13	1,10	0,94	0,75	0,87
Re	80640	88704	96768	104832	112896	120960
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation	0,52	0,38	0,37	0,31	0,25	0,29
Qd (m3/s)			0,0002			
Nq (Pumping)			0,0281	= Qd/(ND <sup>3</sup> )		
Neu (Euler)			39	= Np/Nq		
Pressure (Pa)			77604	$\Delta p = Neu^2(N^2 D^2 \rho)$		
Pressure (kPa)			78			

With solids						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	7,4	9,0	11,6	15,0	17,8	24,0
Np	0,83	0,76	0,75	0,76	0,73	0,80
Re	89992	98992	107991	116990	125989	134989
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation			0,25	0,25	0,24	0,27
Q (m3/s)			0,0003			
Nq (Pumping)			0,0477	= Qd/(ND <sup>3</sup> )		
Neu (Euler)			16	= Np/Nq		
Pressure (Pa)			34839	$\Delta p = Neu^2(N^2 D^2 \rho)$		
Pressure (kPa)			35			

Table 1  
Dimensionless numbers used in flotation hydrodynamics characterization.

Parameters	Symbol	Equations	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho ND^2}{\mu_p}$ (6)	inertial force	$5 \times 10^4 - 2 \times 10^6$	(Mavros, 1992)
Power number	$N_p$	$N_p = \frac{P}{\rho N^3 D^5}$ (7)	viscous force	0.5-5	(Bates et al., 1963; Hanzli, 1974)
Air flow number	$N_L$	$N_L = \frac{Q_g}{N^2 D^3}$ (8)	inertial force	0.002-0.2	(Arbiter et al., 1976)
Froude number	$Fr$	$Fr = \frac{N^2 D}{g}$ (9)	impeller velocity	0.1-5	(Kramers et al., 1953; Rodrigues et al., 2001)
Weber number	$We$	$We = \frac{\rho N^2 D^3}{\sigma}$ (10)	inertial force	-	(Rodrigues et al., 2001)
Capillary number	$Ca$	$Ca = \frac{\eta R_0}{\sigma}$ (11)	surface tension	-	(Chu et al., 2019)
Stokes number	$St$	$St = \frac{1}{9} \frac{\rho_p}{\rho} \left( \frac{d_p}{d_b} \right)^2 Re_b$ (12)	inertial force	-	(Miettinen et al., 2010)

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m<sup>3</sup>) and  $\mu_p$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_g$  is the volumetric gas flowrate (m<sup>3</sup>/s),  $g$  is the gravitational acceleration (m/s<sup>2</sup>),  $\sigma$  is the surface tension of air/solution interface (N/m).  $v$  is the kinematic viscosity of the fluid (m<sup>2</sup>/s),  $\gamma$  is the shear rate (s<sup>-1</sup>) and  $R_0$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_p$  and  $\rho_b$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.



0,82826	0,756832	0,751362	0,764181	0,726058	0,795926	1,573842	1,126143	1,098728	0,943775	0,746535	0,866029
108335,5	119169,1	130002,6	140836,2	151669,7	162503,3	97076,82	106784,5	116492,2	126199,9	135907,5	145615,2
108335,5	0,82826										
	0,756832					97076,82	1,573842				
	0,751362					106784,5	1,126143				
	0,764181					116492,2	1,098728				
	0,726058					126199,9	0,943775				
	0,795926					135907,5	0,746535				
						145615,2	0,866029				

14-Oct

Water Density (kg/m³)	1000	Step 3		Dynamic viscosity, η (Pa.s)		
Diameter (m)	0,074					
Leeds empty (W)						
Impeller speed (rpm)	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
Averages (W)	63	64,4	68	69	72,2	73,8

<https://wiki.anton-paar.com/za-en/water/>

Step 1

Water Mass (g)	3
g	9,81

Solids SG	2,65
Percentage	16,7
Slurry Den	1116

Leeds with water (W) 3L @ 2 LPM						
1000	1100	1200	1300	1400	1500	
73	80	87	92	98	104	

Leeds with water (W) 2.87L & 575g SiO2 @ 2 LPM						
1000	1100	1200	1300	1400	1500	
74	82	88	94	101	107	

With water only

Hertz	16,67	18,33	20	21,67	23,33	25
RPM	1000	1100	1200	1300	1400	1500
Consumed	10,2	16,0	18,6	23,2	25,8	30,0
Np	1,01	1,19	1,06	1,04	0,93	0,88
Re	88587	97408	106283	115158	123979	132854
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation	0,34	0,40	0,35	0,35	0,31	0,29
Q (m³/s)			0,0002		0,0002	
Nq (Pumping)			0,03		0,02	
Neu (Euler)			39		48	
Pressure (Pa)			85963		142043	
Pressure (kPa)			86		142	

= Qd/(ND³)

= Np/Nq

Δp = Neu\*(N² D² ρ)

With solids

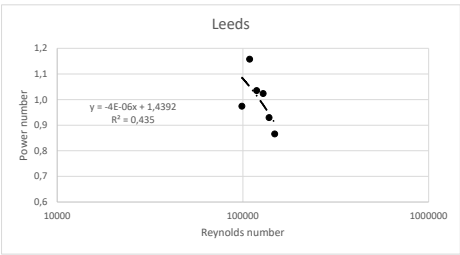
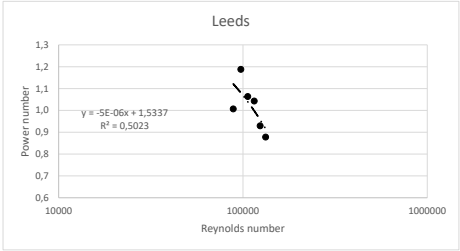
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	11,0	17,4	20,2	25,4	28,8	33,0
Np	0,97	1,16	1,03	1,02	0,93	0,87
Re	98841	108725	118609	128493	138378	148262
Fr	2,09	2,53	3,01	3,53	4,09	4,70
Mean energy dissipation	0,32	0,39	0,34	0,34	0,31	0,29
Q (m³/s)			0,0003		0,0002	
Nq (Pumping)			0,04		0,03	
Neu (Euler)			28		35	
Pressure (Pa)			69118		117056	
Pressure (kPa)			69		117	

= Qd/(ND³)

= Np/Nq

Δp = Neu\*(N² D² ρ)

0,973279	1,158013	1,034935	1,023077	0,9296078	0,865656	1,007163823	1,188336	1,063481	1,042841	0,929356	0,878229
119011,7	130862,9	142785,5	154708,1	166559,25	178481,8	106643,497	117263,1	127946,6	138630,1	149249,7	159933,3
119011,7	0,973279					106643,5	1,007163823				
130862,9	1,158013					117263,1	1,188336217				
142785,5	1,034935					127946,6	1,06348092				
154708,1	1,023077					138630,1	1,042840758				
166559,3	0,929608					149249,7	0,929356274				
178481,8	0,865656					159933,3	0,878229405				





14-Oct

Water Density (kg/m <sup>3</sup> )	1000	Step 2	Dynamic viscosity, $\eta$ (Pa.s)			
Diameter (m)	0,070		0,001024		@ 27 deg	
Leeds empty (W)						
Impeller speed (r/min)	1000	1100	1200	1300	1400	1500
Time (min)	cell empty					
0-1	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise
Averages	119	125,6	131	141,2	147,8	156,4

<https://wiki.anton-paar.com/za-en/water/>

Water Mass (g)	3
g	9,81

Step 1

Denver with water (W) 3L @ 2 LPM						
1000	1100	1200	1300	1400	1500	
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	
130	138,8	145,8	158,2	163,8	176,4	

Step 3

Solids SG	2,65
Percentage	16,7
Slurry Den	1116

Denver with water (W) 2.87L & 575g SiO <sub>2</sub> @ 2 LPM						
1000	1100	1200	1300	1400	1500	
Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	Stabilise	
126,8	136,8	146,8	156	166,2	178,2	

With water only						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	10,6	13,2	14,8	17,0	16,0	20,0
Np	1,32	1,24	1,07	0,97	0,73	0,74
Re	80640	88704	96768	104832	112896	120960
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
	0,44	0,41	0,36	0,32	0,24	0,25
Qd (m3/s)			0,0002			
Nq (Pumping)			0,0281	= Qd/(ND <sup>3</sup> )		
Neu (Euler)			38	= Np/Nq		
Pressure (Pa)			75562	$\Delta p = Neu^*(N^*2 D^*2 \rho)$		
Pressure (kPa)			76			

With solids						
Hertz	16,7	18,3	20,0	21,7	23,3	25,0
RPM	1000	1100	1200	1300	1400	1500
Consumed	7,8	11,2	15,8	14,8	18,4	21,8
Np	0,87	0,94	1,02	0,75	0,75	0,72
Re	89992	98992	107991	116990	125989	134989
Fr	1,99	2,41	2,87	3,37	3,91	4,49
Mean energy dissipation						
	0,29	0,31	0,34	0,25	0,25	0,24
Q (m3/s)			0,0003			
Nq (Pumping)			0,0477	= Qd/(ND <sup>3</sup> )		
Neu (Euler)			21	= Np/Nq		
Pressure (Pa)			47453	$\Delta p = Neu^*(N^*2 D^*2 \rho)$		
Pressure (kPa)			47			

Table 1  
Dimensionless numbers used in flotation hydrodynamics characterization.

Parameters	Symbol	Equations	Interpretation	Range	Reference
Reynolds number	$Re$	$Re = \frac{\rho ND^2}{\mu}$ (6)	inertial force	$5 \times 10^4 - 2 \times 10^6$	(Mavros, 1992)
Power number	$N_p$	$N_p = \frac{P}{\rho N^3 D^5}$ (7)	viscous force	0.5-5	(Bates et al., 1963; Hanzli, 1974)
Air flow number	$N_L$	$N_L = \frac{Q_g}{N^2 D^3}$ (8)	inertial force	0.002-0.2	(Arbiter et al., 1976)
Froude number	$Fr$	$Fr = \frac{N^2 D}{g}$ (9)	impeller velocity	0.1-5	(Kramers et al., 1953; Rodrigues et al., 2001)
Weber number	$We$	$We = \frac{\rho N^2 D^3}{\sigma}$ (10)	inertial force	-	(Rodrigues et al., 2001)
Capillary number	$Ca$	$Ca = \frac{\eta R_b}{\sigma}$ (11)	viscous shear force	-	(Chu et al., 2019)
Stokes number	$St$	$St = \frac{1}{9} \frac{\rho_p}{\rho_l} \left( \frac{d_p}{d_b} \right)^2 Re_b$ (12)	surface tension	-	(Miettinen et al., 2010)
			inertial force	-	
			drag force	-	

$N$  is the impeller rotation speed (rpm),  $D$  is the impeller diameter (m),  $\rho$  is the pulp density (kg/m<sup>3</sup>) and  $\mu$  is the pulp dynamic viscosity (kg/m.s).  $P$  is the net power consumption by impeller (W).  $Q_g$  is the volumetric gas flowrate (m<sup>3</sup>/s),  $g$  is the gravitational acceleration (m/s<sup>2</sup>),  $\sigma$  is the surface tension of air/solution interface (N/m).  $v$  is the kinematic viscosity of the fluid (m<sup>2</sup>/s),  $\gamma$  is the shear rate (s<sup>-1</sup>) and  $R_b$  is the initial radius of fluid particle (m).  $Re_b$  is the Reynolds number of the bubble,  $\rho_p$  and  $\rho_l$  are densities of the particle and the liquid, respectively, and  $d_p$  and  $d_b$  are diameters of the particle and the bubble, respectively.

0,873031	0,941836	1,023407	0,753992	0,750531	0,722966	1,324025	1,238758	1,069814	0,966517	0,728327	0,740196
108335,5	119169,1	130002,6	140836,2	151669,7	162503,3	97076,82	106784,5	116492,2	126199,9	135907,5	145615,2

108335,5	0,873031	97076,82	1,324025
119169,1	0,941836	106784,5	1,238758
130002,6	1,023407	116492,2	1,069814
140836,2	0,753992	126199,9	0,966517
151669,7	0,750531	135907,5	0,728327
162503,3	0,722966	145615,2	0,740196

