NIKKELVERK
A GLENCORE COMPANY

Hydromet-seminar at Glencore
Lecture 3: **Leaching and Filtration**

Separation

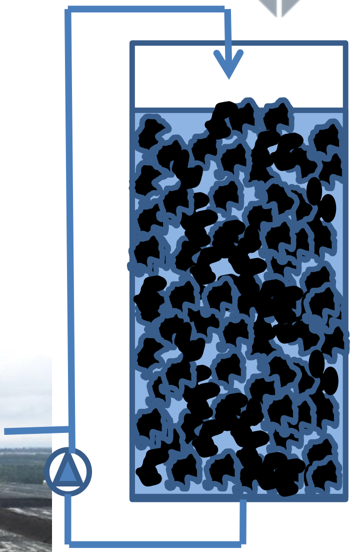
- Industrial processes are to separate mixtures
  - Divide into two product stream
  - Remove impurities from the main stream
  - Recover your main product from the main stream

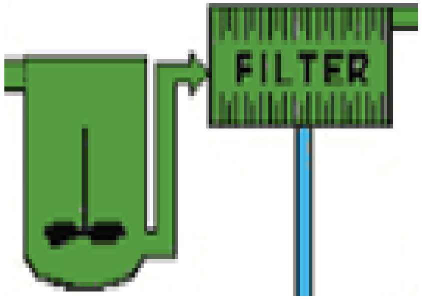
- Leaching/Dissolve solids ↔
  - *Complete: not very interesting*
  - *Partly/selective: Separation*

- Crystallization

Leaching

- Static leaching
- Heap leaching
- Stirred tank reactor (slurry)

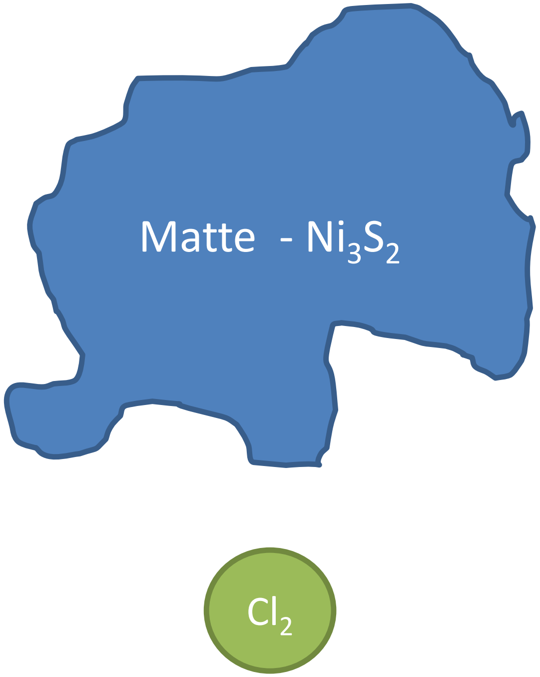




Leaching / Dissolution

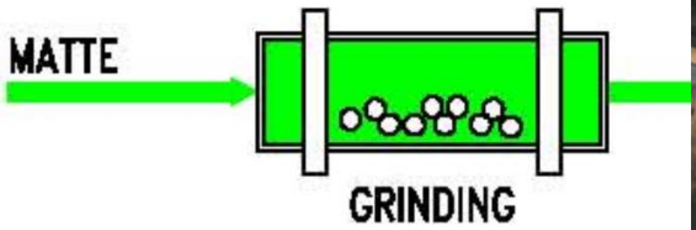
- Soluble in the media (our case water)

- Some kind of reaction
  - Acid – base
  - Red –ox
  - Biological - pure chemical
  - Electrochemical reaction
  - Complexes
  - Fast or slow -> temperature/pressure
  - Unwanted reactions

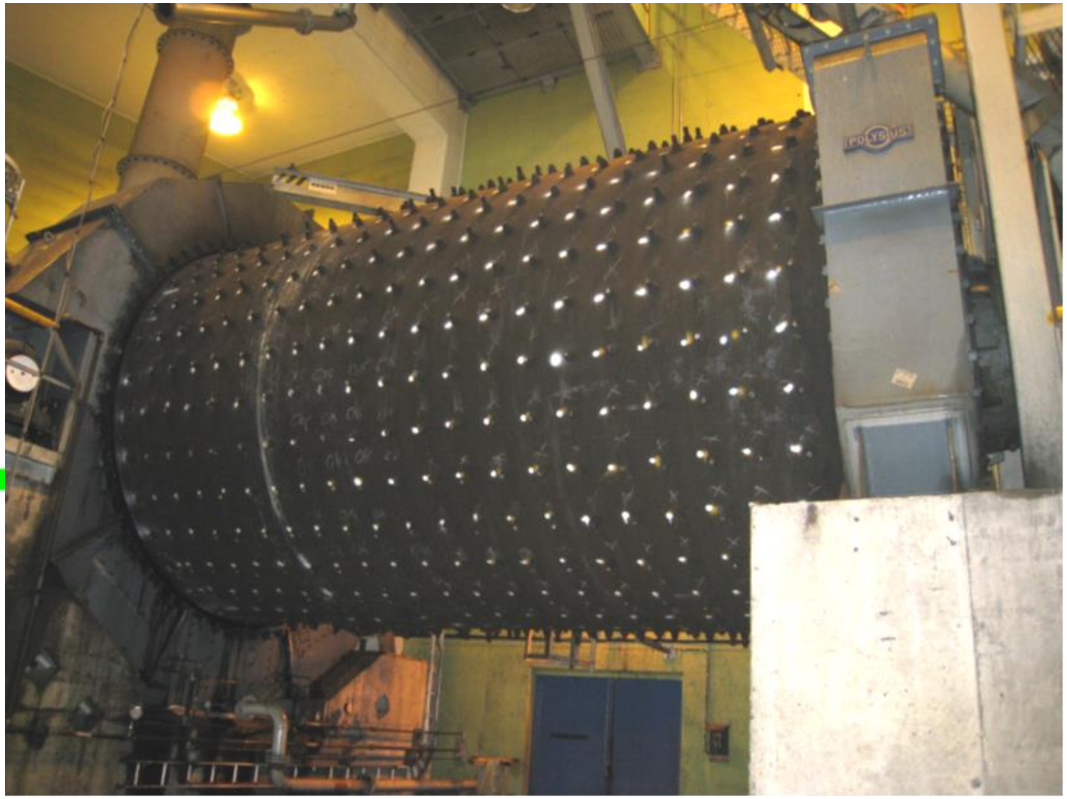


- Heterogeneous
  - Happens on a surface
  - Conditions on the surface might be different from bulk
  - Surfaces might be blocked by something

Matte Grinding

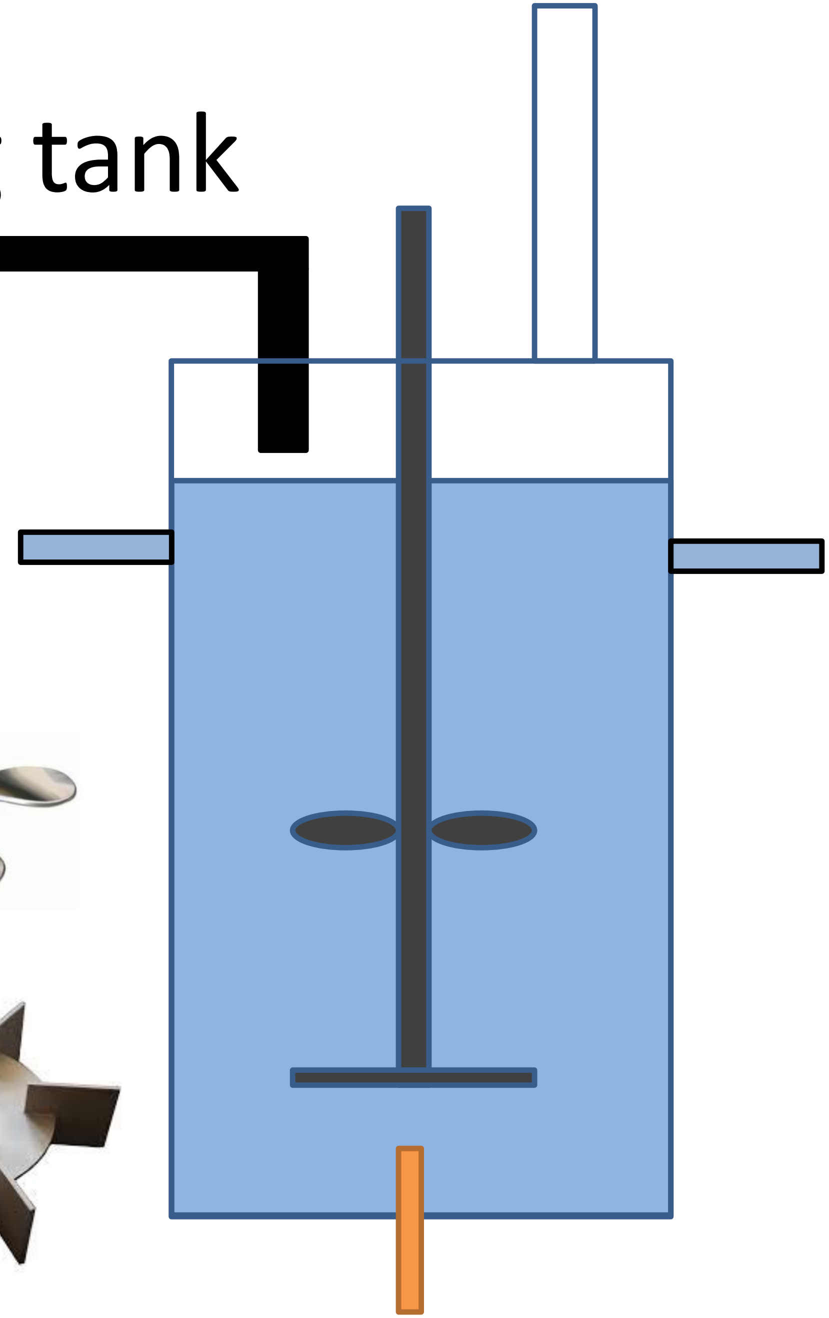


<175 µm

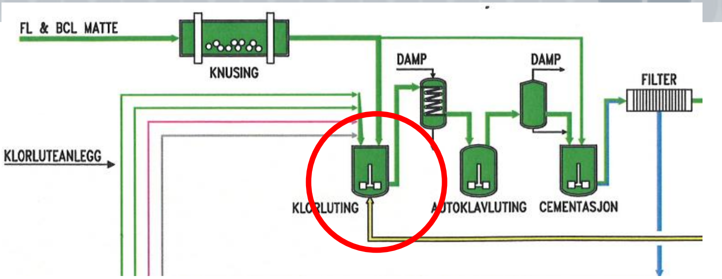


Leaching tank

- Tank
- Solution feed (in/out)
- Ground matte feed
- Chlorine gas
- Turbine impeller
  - To make small bobbles
- Pump impeller
  - Avoid settling
- Offgas to scrubber



Chlorine leach of Ni_3S_2



- $2\ CuCl + Cl_2(g) = 2\ CuCl_2$
  - Alternatively: $CuCl + 4\ HCl + O_2(g) = 4\ CuCl_2 + 2\ H_2O$

- $Ni_3S_2(s) + 2\ CuCl_2 = 2\ NiS(s) + 2\ CuCl + NiCl_2$
- $NiS(s) + 2\ CuCl_2 = 2\ CuCl + NiCl_2 + S°(s)$ (similar for other sulphides)

Net reaction : $Ni_3S_2 + 3Cl_2 \rightarrow 3\ Ni^{2+} + 6\ Cl^- + 2\ S°$

Other reaction:

- $Ni°(s) + 2\ HCl = NiCl_2 + H_2(g)$ ($Ni_3S_2 \approx Ni° + 2\ NiS$)
- $S°(s) + 4\ H_2O + 6\ CuCl_2 = H_2SO_4 + 6\ HCl$ (S-oxidation to SO4)
- $Me(OH)_n(s) + n\ HCl = MeCl_n + n\ H_2O$ (we also feed some metal hydroxides)

Chlorine leach of Ni_3S_2

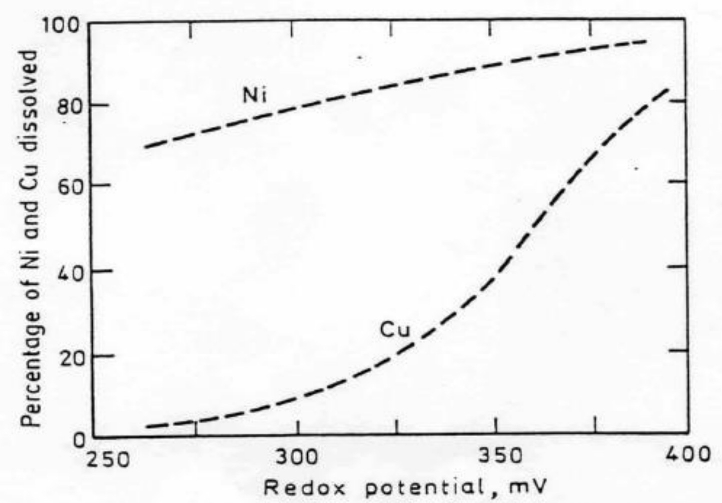
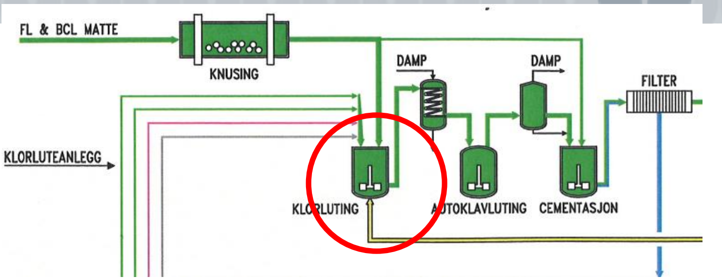


Fig. 3 Dissolution of Ni and Cu as function of redox potential

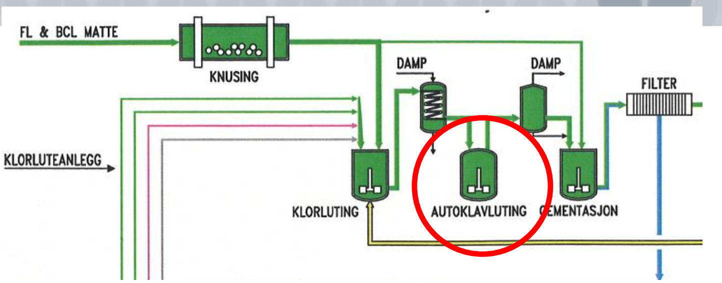


- Control
  - Conc of Cu
  - Control orp (Cu^+/Cu^{2+})
  - Temp

- Optimize with respect to
  - Ni, Co, Cu
  - PGMs
  - Impurities like Fe

- $2\ CuCl + Cl_2(g) = 2\ CuCl_2$
- $Ni_3S_{2(s)} + 2\ CuCl_2 = 2\ NiS(s) + 2\ CuCl + NiCl_2$
- $MeS_{(s)} + 2\ CuCl_2 = 2\ CuCl + MeCl_2 + S°_{(s)}$

Autoclave



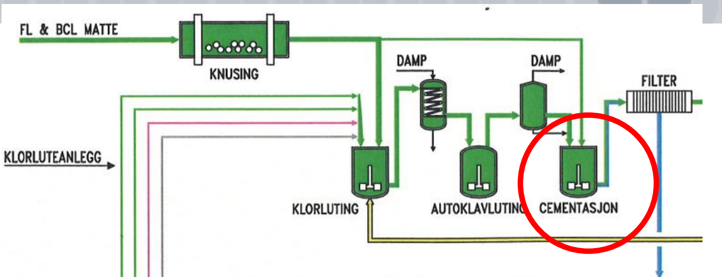
- Higher temperature
- No chemicals added
  - Temp. drives thermodynamics towards better Cu-precipitation
  - Better Ni:Cu selectivity

- $NiS(s) + 2\ CuCl_2 = 2\ CuCl + NiCl_2 + S°(l)$
- Cementations
  - $NiS(s) + 2\ CuCl = Cu_2S(s) + NiCl_2$
  - $NiS(s) + 2\ AgCl = Ag_2S(s) + NiCl_2$
- $Cu_2S(s) + S°(l) = 2\ CuS(s)$

Side reaction: S-oxidation to SO4

Cementation

- Control of pH & ORP
  - $NiCO_3(s) + 2\ HCl = NiCl_2 + CO_2(g) + H_2O$
  - $Me°(s) + 2\ HCl = MeCl_2 + H_2(g)$



- Cementations
  - $Ni_3S_2(s) + 2\ CuCl + S°(s) = 2\ NiS(s) + NiCl_2 + 2\ Cu_2S(s)$
  - $Ni°(s) + 2\ CuCl + S°(s) = NiCl_2 + Cu_2S(s)$

- $Cu_2S(s) + S°(S) = 2\ CuS(s)$

Filtration

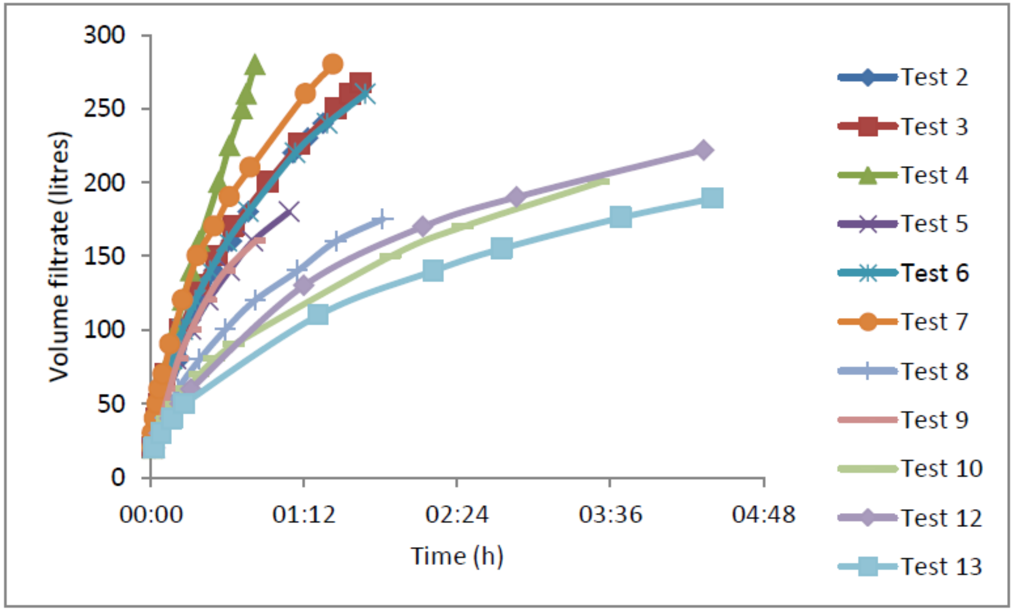
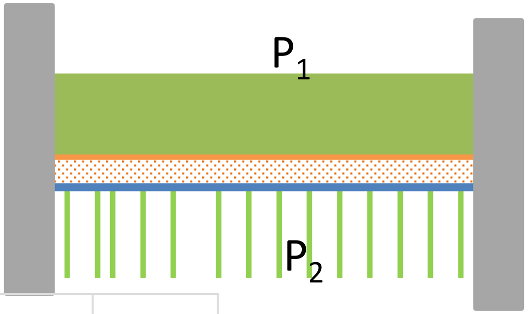


Figure 2: Increase in volume of filtrate with time

- The chemical reactions are of limited value if the separation is difficult
- Filtration is very common in hydrometallurgy.

Alpha (α) - Filtercake resistance



Low - easy (fast) filtration

High - difficult (slow) filtration

<u>BEREGNING AV FILTERKAKEMOTASTAND - TEORI</u>

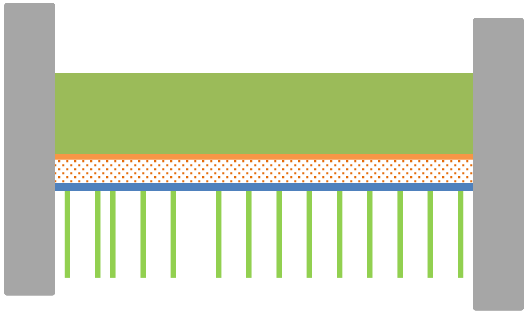
REF: Perry, Chemical Engeneering Handbook, s. 19-66, 6. utgave

Poiseulle's ligning, massebalanse over et batch filter,
konstant trykkfiltrering:

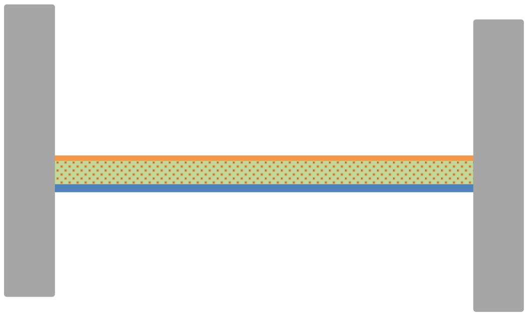
$$\frac{dt}{d(V/A)} = \text{alfa}\,\frac{\mu\, c}{\Delta P}\,(V/A) + r\,\frac{\mu}{\Delta P}$$

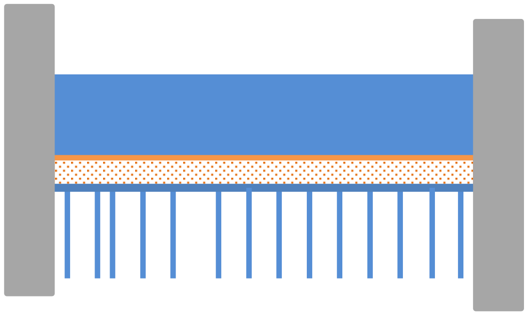
Hvor:	t	=	Filtreringstid [sek]
	V	=	Volum filtrat [m3]
	A	=	Filterareal [m2]
	μ	=	Viskositet for filtrat [kg/m,s = 1000 cp]
	c	=	Slamvekt (Tørr vekt slam pr. vol. filtrat) [kg/m3 = gram/liter]
	ΔP	=	Trykkdifferanse over filterkake (egentlig filterkake + duk) [N/m2 = kg/m,s2]
	alfa	=	Filterkakemotstand [m/kg]
	r	=	Dukmotstand [1/m]

α - Filtercake resistance



Solution left
in the filtercake

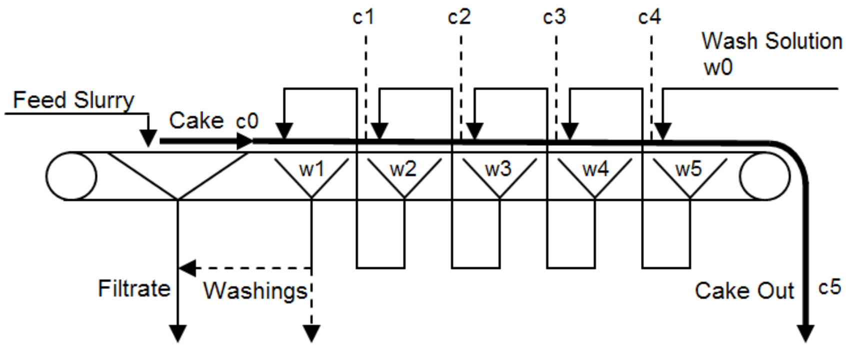




- Wash – several stages
- Blow

- Takes also time

Belt filters

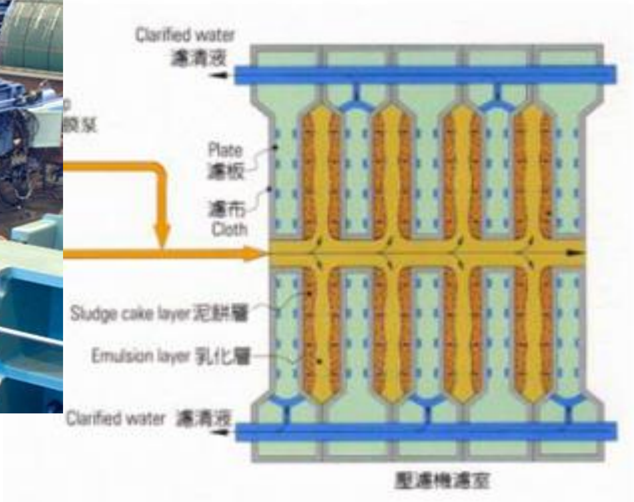


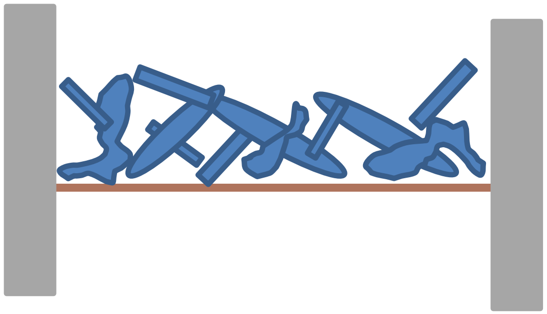
- “easy” to filter – low pressure drop
- Continuous - automatic

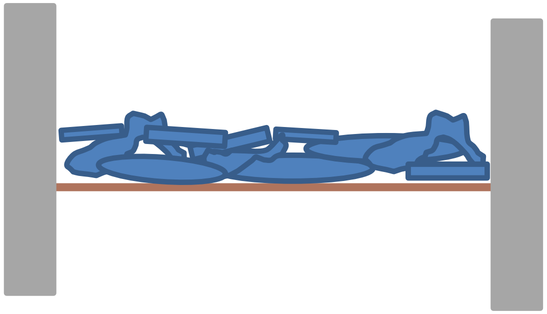
$$\frac{dt}{d(V/A)} = \text{alfa}\,\frac{\mu\, c}{\Delta P}\,(V/A) + r\,\frac{\mu}{\Delta P}$$

Hvor:	t	=	Filtreringstid [sek]
	V	=	Volum filtrat [m3]
	A	=	Filterareal [m2]
	µ	=	Viskositet for filtrat [kg/m,s = 1000 cp]
	c	=	Slamvekt (Tørr vekt slam pr. vol. filtrat) [kg/m3 = gram/liter]
	ΔP	=	Trykkdifferanse over filterkake (egentlig filterkake + duk) [N/m2 = kg/m,s2]
	alfa	=	Filterkakemotstand [m/kg]
	r	=	Dukmotstand [1/m]

Filter presses







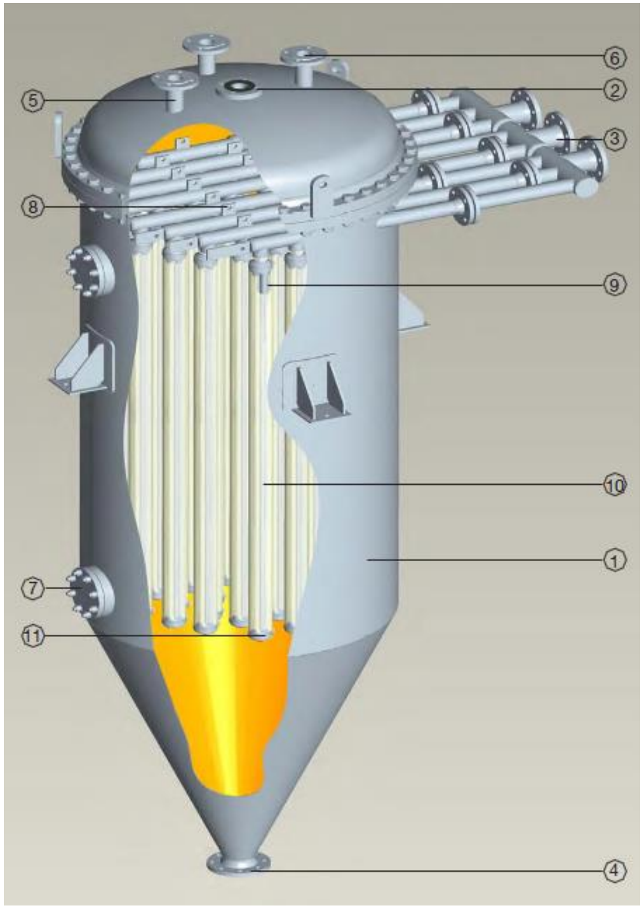
- Slow filtration
  - Increase pressure (typically 1-5 bar)
  - Increase filter area
- Semi-batch -> manual or automatic

$$\frac{dt}{d(V/A)} = \text{alfa}\,\frac{\mu\, c}{\Delta P}\,(V/A) + r\,\frac{\mu}{\Delta P}$$

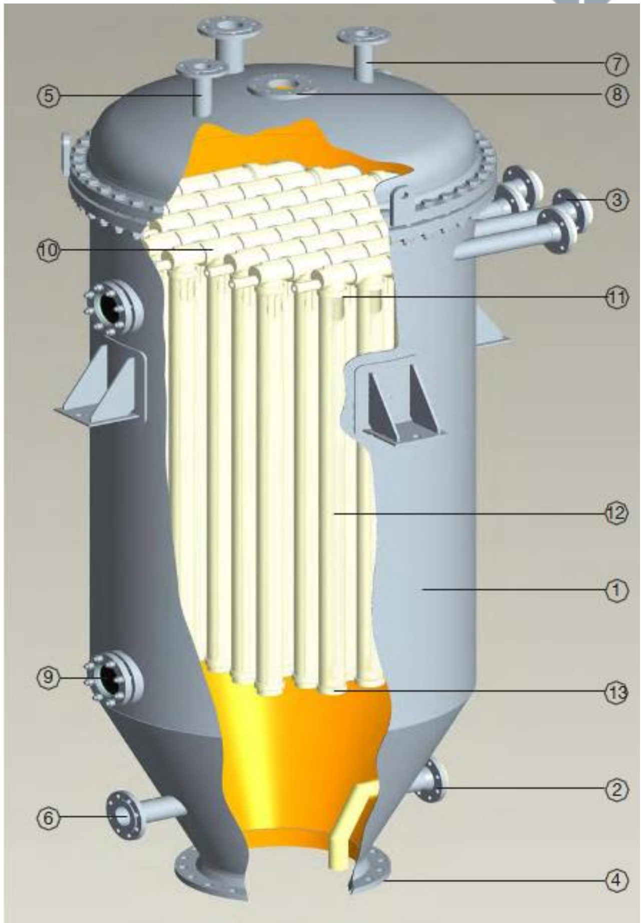
Hvor:	t =	Filtreringstid [sek]
	V =	Volum filtrat [m3]
	A =	Filterareal [m2]
	μ =	Viskositet for filtrat [kg/m,s = 1000 cp]
	c =	Slamvekt (Tørr vekt slam pr. vol. filtrat) [kg/m3 = gram/liter]
	ΔP =	Trykkdifferanse over filterkake (egentlig filterkake + duk) [N/m2 = kg/m,s2]
	alfa =	Filterkakemotstand [m/kg]
	r =	Dukmotstand [1/m]

Tømming av filterpresser i Cu-luting

Candle filters (automatic)

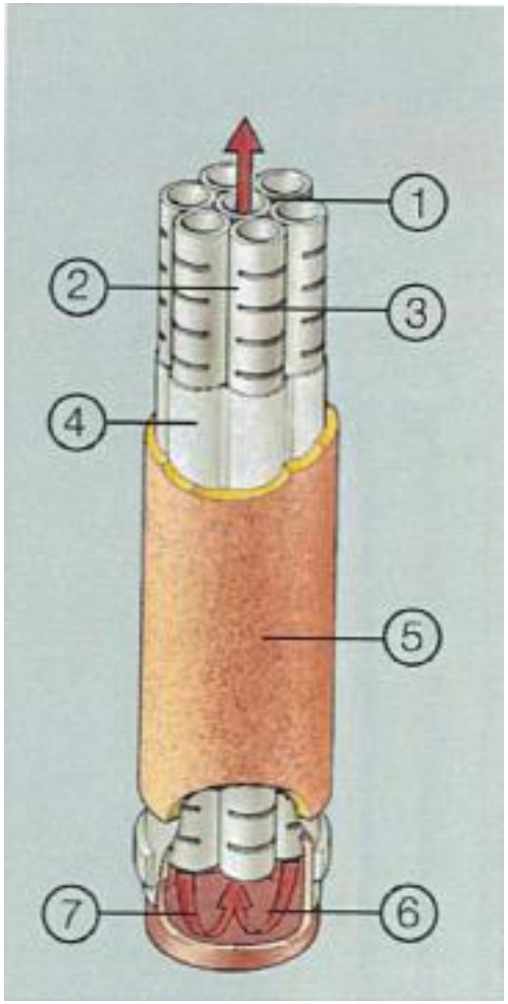


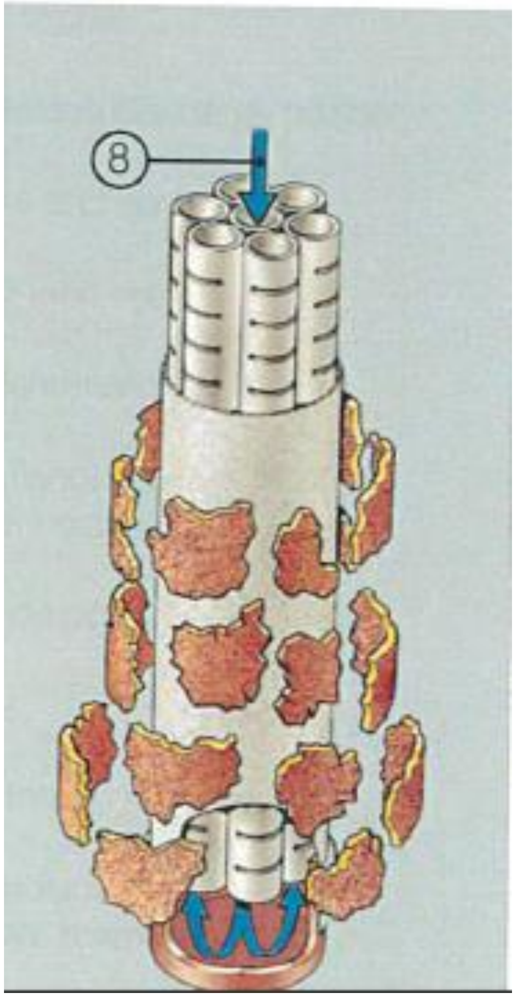
Slurry discharge

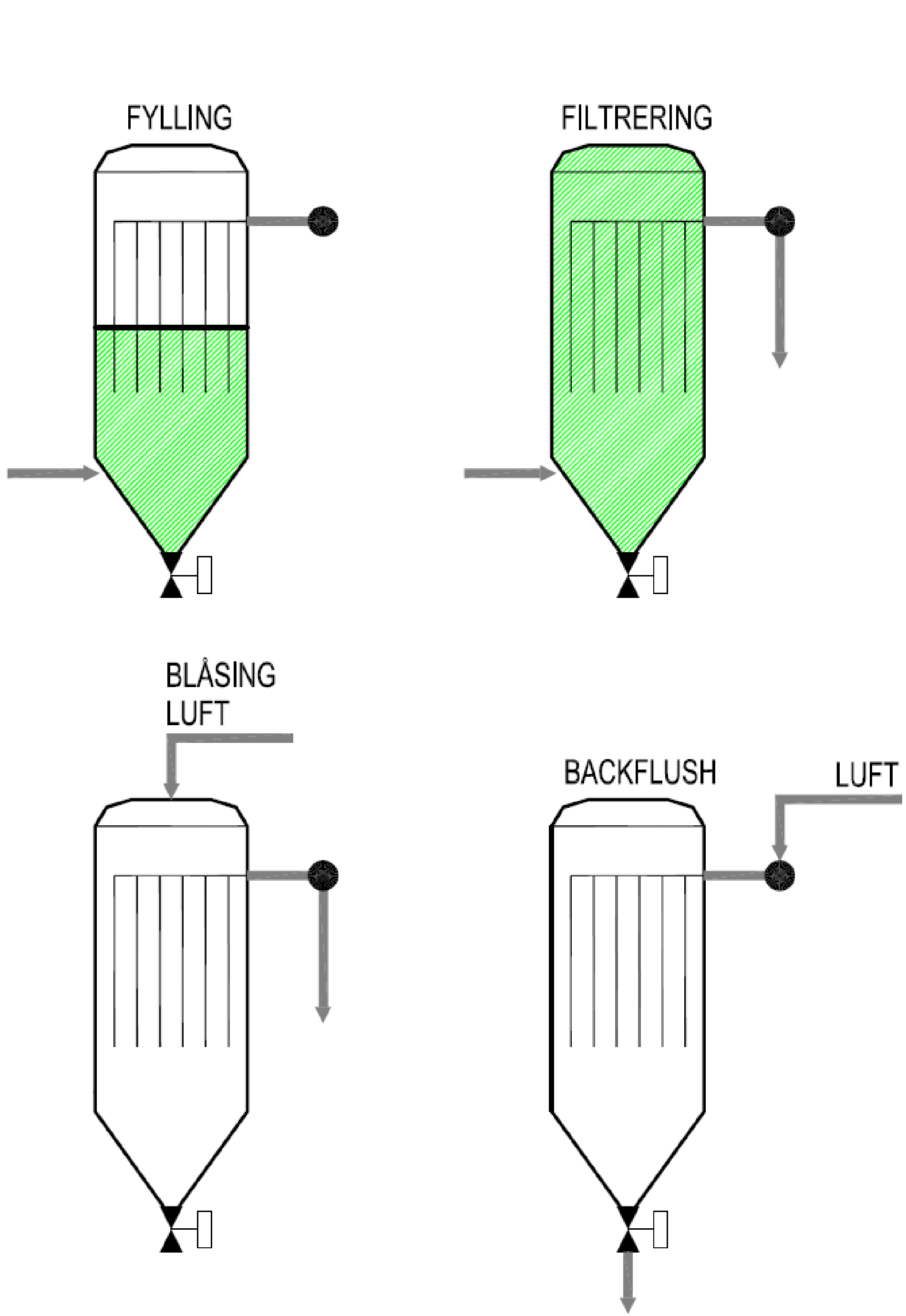


«dry» filtercake discharge

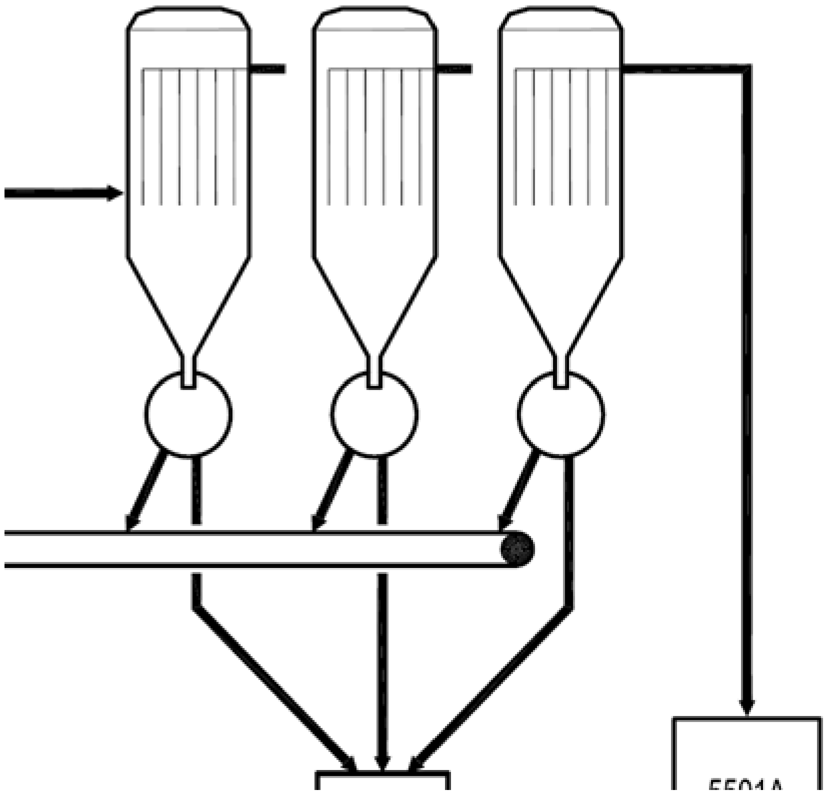
Candle filters



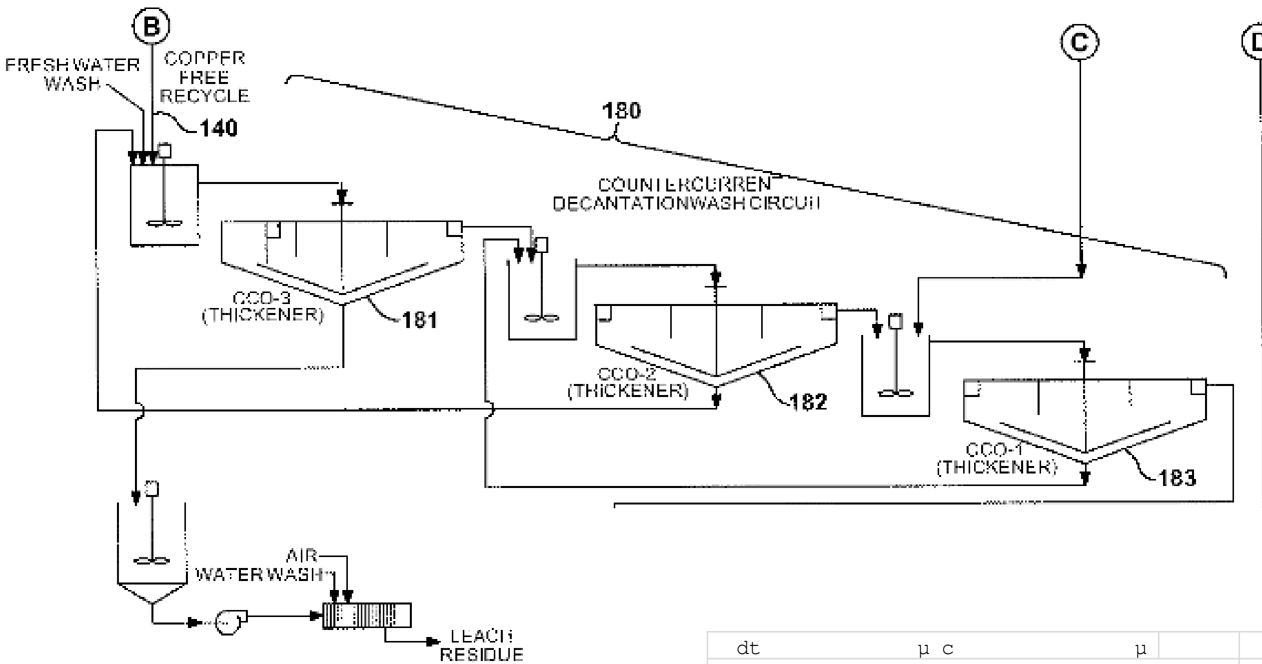




NIKKELVERK
A GLENCORE COMPANY



Counter Current Decantation (CCD) (settlers + filter)



- Reduce volume
  - preferred final separation technology
- CCD - Automatic

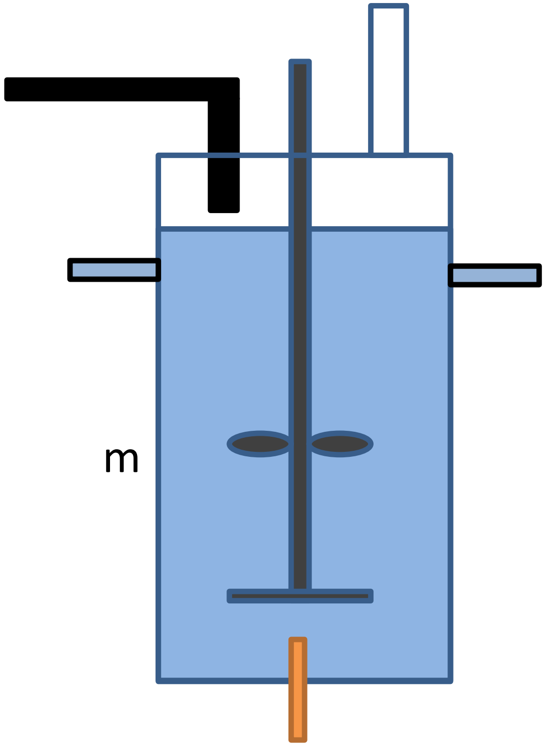
$$\frac{dt}{d(V/A)} = \text{alfa}\,\frac{\mu\, c}{\Delta P}\,(V/A) + r\,\frac{\mu}{\Delta P}$$

Hvor:	t	=	Filtreringstid [sek]
	V	=	Volum filtrat [m3]
	A	=	Filterareal [m2]
	μ	=	Viskositet for filtrat [kg/m,s = 1000 cp]
	c	=	Slamvekt (Tørr vekt slam pr. vol. filtrat) [kg/m3 = gram/liter]
	ΔP	=	Trykkdifferanse over filterkake (egentlig filterkake + duk) [N/m2 = kg/m,s2]
	alfa	=	Filterkakemotstand [m/kg]
	r	=	Dukmotstand [1/m]

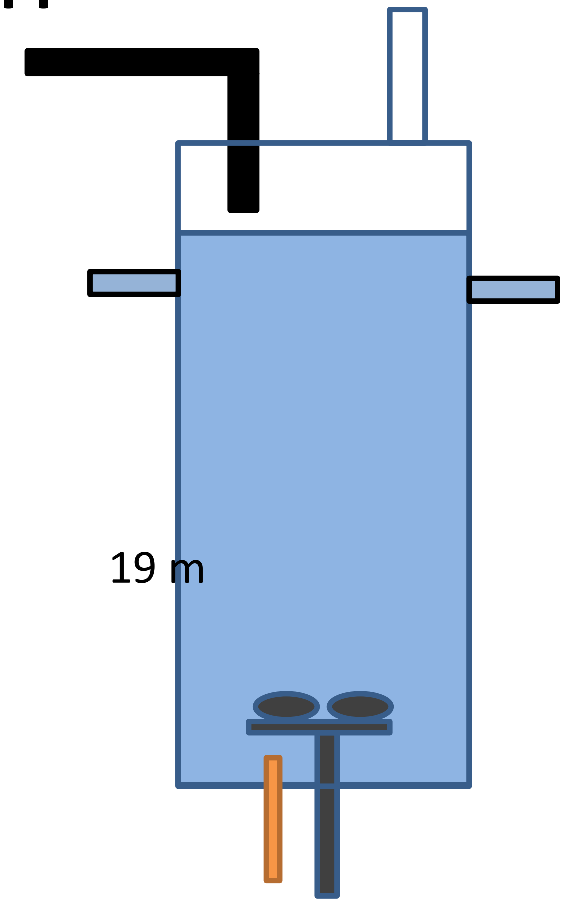
Conclusion

- Leaching (or crystallization) must fit with the chosen filtration technology
  - Particle size/shape
  - Flow
  - Hazards (closed vs open)
  - Temperature
  - Materials (corrosion)
- Conditions in factory is not stable
  - Your process should work good enough

Nikkelverk vs Boliden



$Ni_3S_2 + 3Cl_2(g) \rightarrow 3\,Ni^{2+} + 6\,Cl^- + 2\,S°$



$ZnS + 2H^+ + \frac{1}{2}O_2(g) \rightarrow Zn^{2+} + H_2O + S°$

Both plants have:

Leaching

Cementations

Crystallisations/precipitations

Filtration (belt filter, filterpresses)

Electrowinning

Roasters