SLUDGE DEWATERING

SNF FLOERGER®

Today, the treatment of water is a well-known process and is executed by state of the art techniques. The sludge resulting from this process represents the next challenge for the water treatment industry, in particular the minimizing of its volume.
This Sludge Dewatering handbook will present the key parameters to take into account in order to optimize sludge treatment with SNF Floerger's organic polymers.

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1 Sludge characterisation

There are several types of sludge that have specific characteristics that will influence:

- The choice in conditioning chemical (cationic flocculant, ferric chloride, lime...)
- The choice in the dewatering equipment to be used (filtration, centrifuge...)
  These choices will also depend on the final use of the sludge (incineration, agricultural spreading...)

1.1. Origin of the sludge:

During the course of the water treatment, products coming from the pollution are extracted while the treated water is released in the environment.

Amongst these products coming from the pollution one can distinguish:

- Particles that decant naturally or that come from the physico-chemical treatment
- Excess micro-organisms coming from the dissolved organic matter treatment
- Mineral matter that is non biodegradable

All these products are suspended in more or less concentrated forms and the resulting liquid is called **sludge**.

1.2. The different types of sludge:

1.2.1. Primary sludge:

Primary sludge **comes from the settling process**. It is therefore made of easily decantable suspended particles: large and/or dense particles.
It has a low level of **V**olatile **S**olids content (**VS** around 55% to 60%) and its **dewatering ability** is **excellent**.
It is also very easy to concentrate this type of sludge with a static thickening step just before dewatering. The drawback is that this sludge **ferments very easily**.

1.2.2. Biological sludge:

Biological sludge **comes from the biological treatment** of the wastewater. It is made of a mixture of microorganisms. These microorganisms, mainly bacteria, amalgamate in **bacterial flocs** through the synthesis of exo-polymers. A simple decantation in the clarifier will easily separate the bacterial flocs from the treated water.
Only part of this settled sludge is sent to dewatering: the **excess biological sludge**; part of it is recirculated to maintain the bacterial population in the reactor.

To simplify, we will not differentiate between the different qualities of biological sludge (prolonged aeration, low charge, high charge...); their main properties are:

- A high **V**olatile **S**olids content: **VS** around 70% to 80%.
- A low dry solids content: 7 g/l to 10 g/l. It is often necessary to introduce a dynamic thickening step by flotation or gravity belt.
- The dewatering ability is medium. It depends partially on the VS. The higher the VS the harder it is to extract the water from the sludge.

1.2.3. Mixed sludge:

Mixed sludge is a **blend of primary and biological sludges**. The blending ratio is often as follows:

- 35% to 45% of primary sludge.
- 65% to 55% of biological sludge.

This blending will permit an easier dewatering as the intrinsic properties of this sludge are between the other two types.

1.2.4. Digested sludge:

Digested sludge **comes from a biological stabilizing** step in the process called digestion. This stabilization is performed on biological or mixed sludge. It can be done under different temperatures (mesophilic or thermophilic) and with or without the presence of oxygen (aerobic or anaerobic). Following this stabilization step the properties of the sludge are:

- A **lower V**olatile **S**olids content: **VS** around 50%. A mineralisation of the sludge occurs during digestion
- A dry solids content around 20 g/l to 40 g/l
- A **good dewatering ability**.

1.2.5. Physico-chemical sludge:

This type of sludge is the **result of a physico-chemical treatment of the wastewater** (see brochure **"Coagulation Flocculation"**). It is composed of flocs produced by the chemical treatment (coagulants and/or flocculants).
The characteristics of this sludge is the direct result of the chemicals used (mineral or organic coagulants) and of course of the pollutants in the water.

1.2.6. Mineral sludge:

This name is given to sludge **produced during mineral processes** such as quarries or mining beneficiation processes. Their nature is essentially mineral particles of various sizes (including clays). They have a very good aptitude to settle by gravity and very high concentrations are frequently obtained.

1.3. Parameters that influence the dewatering abilities of sludge:

Several parameters concerning the sludge will influence its ability to dewater easily. Amongst these, the main ones are:

1.3.1. Concentration (g/l):

Measured in g/l, the concentration of the sludge will influence:

- **The incorporation of the flocculant**. The higher the concentration of the sludge, the harder it is to mix in a viscous solution of flocculant (even at low flocculant concentrations). Solutions to this problem are: post-dilution of the flocculant, injecting the flocculant upstream, multiple injection points of the flocculant, use an on-line mixer.

- **The consumption of flocculant**. The higher the concentration of the sludge, the lower the consumption of flocculant. This is true only if the incorporation is correctly done.

1.3.2. The organic matter content (%):

The organic matter content is comparable to the **V**olatile **S**olids content (**VS**).

The higher the VS, the more difficult the dewatering. The dryness achieved will be low, the mechanical properties will be low and the flocculant consumption will be high.

When the VS of the sludge is high, it is **recommended** to **add a thickening step** in the process in order to achieve a better dewatering.

1.3.3. The colloidal nature of the sludge:

This characteristic has a very important effect on the dewatering performance. **The higher the colloidal nature, the more difficult it is to dewater.**
Four factors will affect the colloidal nature of the sludge:

- The origin of the sludge:

Primary → Digested primary → Fresh mixed → Digested mixed → Biological
Low colloidal nature → **High** colloidal nature

- The freshness of the sludge: the colloidal nature of the sludge will increase with its level of fermentation (septic sludge).
- The origin of the wastewater: a dairy or brewery origin will increase the colloidal nature of the sludge.
- The sludge return: a badly controlled return of the sludge will increase its colloidal nature.

❷ Dewatering aids

Sludge is generally conditioned before thickening and dewatering. Two types of conditioning chemicals are used to enhance the treatability of the sludge:

- **Mineral** chemicals such as iron salts and lime. These chemicals are frequently found in filter press applications.
- **Organic** chemicals such as coagulants and flocculants. The most common type of flocculants encountered are **cationic** in nature.

2.1. Mineral chemicals:

2.1.1. Iron salts:

Ferric Chloride and **Iron Chloro-Sulfate** are mainly used in conjunction with lime to condition the sludge before a **filter press**.
They allow a better filterability by coagulating the colloids (thus lowering the content of linked water) and by micro-flocculation of the precipitates (hydroxides).
The dosages for iron salts are between **3% and 15% of the dry content**, depending on the quality of the sludge.

There is a trend to **associate iron salts with organic flocculants** (cationic) in order to lower the volume of the sludge produced compared to a classic iron salts + lime process.

2.1.2. Lime:

Lime as a conditioning agent is only used in conjunction with iron salts on filter press applications. It brings a mineral nature to the sludge and strengthens its mechanical properties (higher specific resistance to filtration).
The **dosages** for lime are between **15% and 40%** of the dry content.

Remarks:

- Lime is also used after dewatering to **stabilize** the sludge.
- **The specific resistance to filtration** (r) depends on the size, shape and degree of agglomeration of the solid particles that make-up the cake from a filter-press. It is independent of the sludge concentration.

2.2. Organic chemicals:

Cationic flocculants represent the large majority of the chemicals used in sludge dewatering.

2.2.1. Flocculation mechanism:

Flocculation of sludge is the step in the process where destabilized particles are agglomerated in aggregates called flocs.

Flocculants, with their very high molecular weights (long chains of monomers) and their varied ionic charge, fix the destabilized particles on their chain. Therefore the **particle size** in the aqueous phase **will increase** throughout the **flocculation** step with the formation of **flocs**.
The formation of flocs induces a **release of the water**. This water will thus be easily eliminated during the dewatering step.

2.2.2. Destabilized particles:

The origin of destabilized particles varies a lot and essentially depends on the nature of the sludge.
The **charge** that the flocculant brings will be selected according to the type of destabilized particles present in the sludge to be treated. It will therefore depend on the **type of sludge** (biological, digested, physico-chemical, mineral... see paragraph n°1).
The charge to be brought often follows the pattern below:

- **Low to medium anionic for mineral sludge.**
- **Low anionic to low cationic for physico-chemical sludge.**
- **Low cationic for digested and primary sludge.**
- **Medium cationic for mixed sludge.**
- **High cationic for biological sludge.**

2.3. Parameters of the organic chemicals that will influence dewatering:

Organic flocculants are characterised by five main parameters:

- **The type of charge**
- **The charge density**
- **The molecular weight**
- **The molecular structure**
- **The type of monomer**

These will influence the quality of the flocculation and thus the quality of the dewatering.

2.3.1. The type of charge (+ or -):

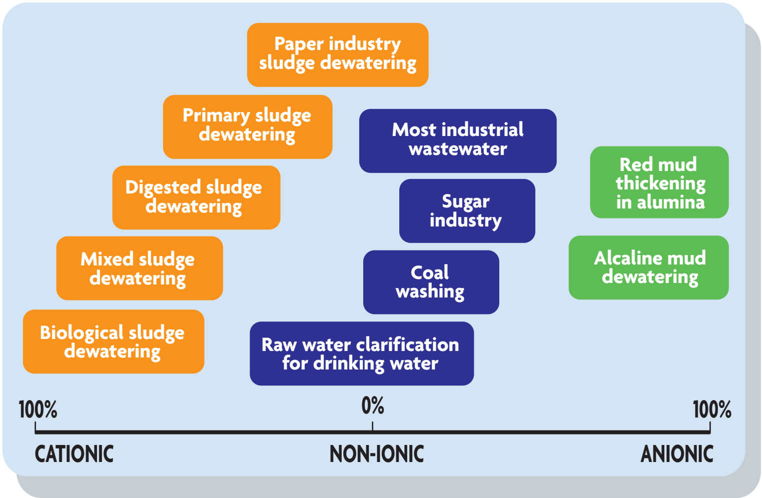
The type of charge of a flocculant is selected according to the type of particles. Generally the choice follows the pattern below:

- An **anionic (-)** flocculant to catch **mineral** particles.
- A **cationic (+)** flocculant to catch **organic** particles.

As usual, only a laboratory test can really determine which charge is well adapted.

2.3.2. The charge density (%):

The charge density represents the quantity of + or – charge necessary to obtain the best flocculation at the lowest dosage. The charge density depends on the **type of sludge** to treat. For **municipal sludge**, this charge density is mainly a function of the **O**rganic **M**atter content (**OM**) in the sludge. The OM is generally assimilated to the **V**olatile **S**olids content (**VS**). **The higher the VS, the higher the cationic charge needed**.



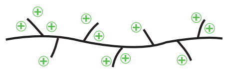
2.3.3. The molecular weight (MW):

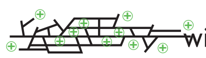
The choice of molecular weight, which is the length of the polymer chain, depends on the type of equipment used for dewatering.
For **centrifuge**: A high to **very high molecular weight** is best adapted due to the high shearing applied to the flocs.
For **filtration:** A **low to medium molecular weight** will be best adapted to obtain a good drainage.

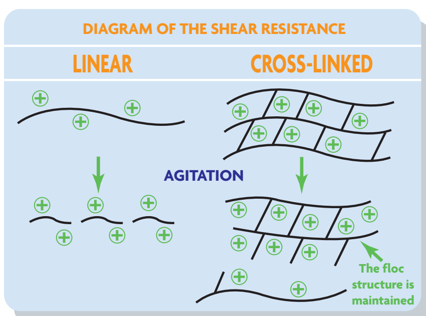
2.3.4. The molecular structure:

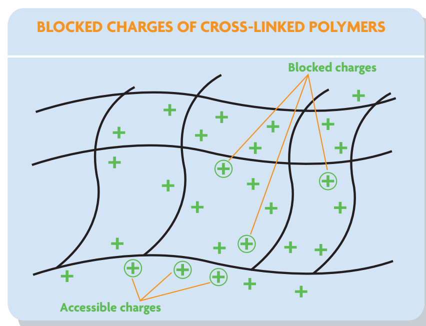
The molecular structure of the flocculant depends on the dewatering performances required.
For cationic flocculants there are:

- **Linear** structures:  with **low dosage** and **good performance** when the correct molecular weight is chosen.

- **Branched** structures:  with **medium dosage** and **excellent drainage** performance.

- **Cross-linked** structures:  with **high dosage** and **exceptional drainage performance** and **shear resistance.**





LINEAR OR CROSS-LINKED STRUCTURE ?

LINEAR	CROSS-LINKED
ADVANTAGES	
• Low dosage • Large range of MW	• Very strong flocs • Excellent drainage • Higher cake dryness
DRAWBACKS	
• Low strenght of the flocs • Possibility of overdosing	• High dosage

2.3.5. The type of monomer:

The type of monomer used to synthesize the flocculants also influence flocculation. Two different cationic monomers are commonly used:

- ADAM-MeCl: see brochure “**Preparation of organic polymers**”.
- APTAC: insensitive to hydrolysis of the cationic charges, they sometimes react better on deinking sludge from the paper industry.

The most frequent anionic monomer is sodium acrylate.

3 Dynamic thickening

Dynamic thickening of sludge is not systematic. When implemented, it is done:

- **Before dewatering**, in order to increase the Dry Solids Content and facilitate the dewatering step (less equipment, less reagents...)
- **Before farm spreading**, to lower the volume thus lowering the number of truckloads.

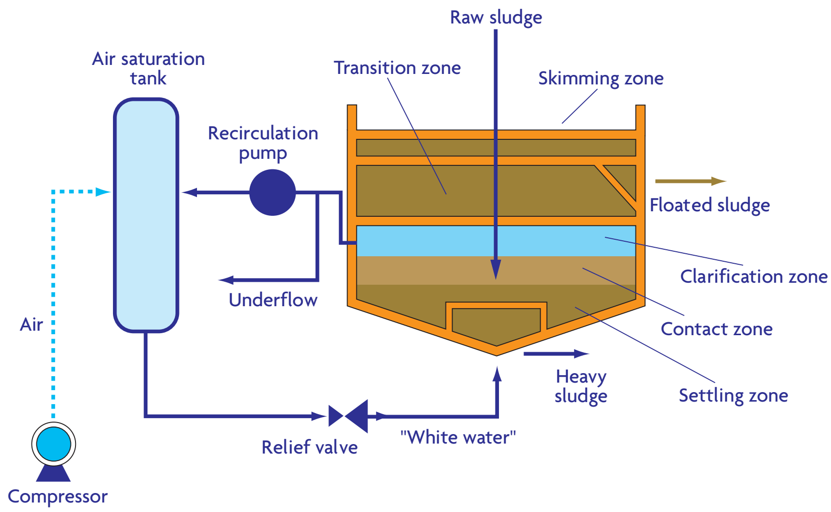
Four types of equipment are used to thicken sludge dynamically: flotation, gravity belt, drum filter and centrifuge.

3.1. Flotation:

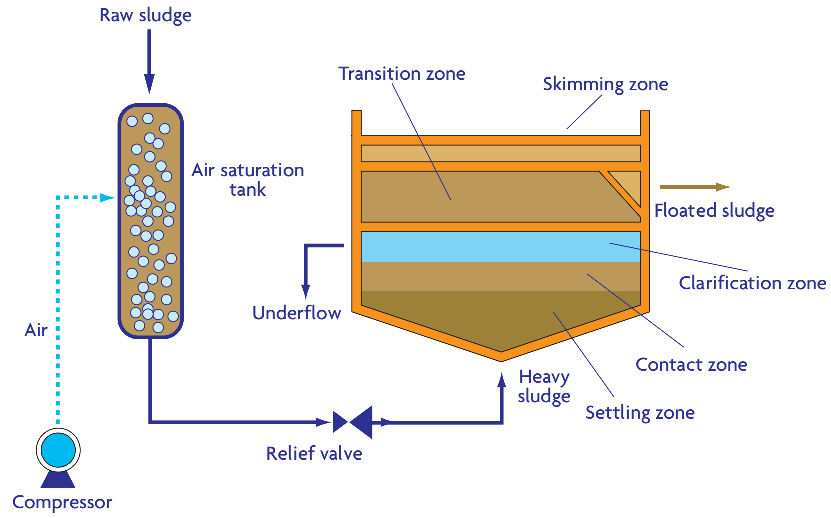
Flotation is mainly used to thicken biological sludge that comes from the clarifier.
The principle is to attach **micro-bubbles** to the particles in the sludge. Air injection and pressurisation create these micro-bubbles. The pressurisation can be applied on:

- The water underflow that is mixed to the sludge when depressurised (**indirect flotation**). With micro-bubbles fixed to the particles, these have then a lower density and float to the surface. The thickened sludge is then evacuated in the overflow and the underflow water is recycled at the beginning of the plant.
- The raw sludge (**direct flotation**)

3.1.1. Indirect flotation:



3.1.2. Direct flotation:



3.1.3. Sludge conditioning before flotation:

Sludge conditioning before flotation with an organic polymer is not essential but is strongly recommended to get a better underflow by enhancing of the capture rate.

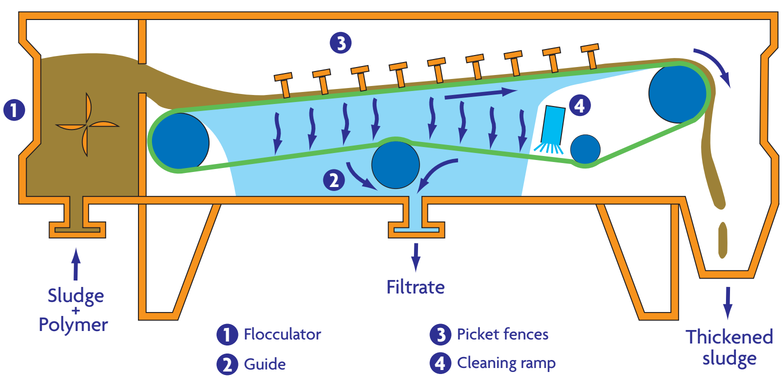
	LAB TESTS		PLANT TRIALS	
KEY PARAMETERS	• Floc size • Overflow quality • Floc formation speed • Shear resistance of the flocs		• Sludge flow • Polymer flow • Injection point • **Capture rate** • Floating sludge concentration • Pressure	
LAB PROCEDURE/ SPREADSHEET	Jar test method	Laboratory trials - Coagulation Flocculation	/	/
RECOMMENDATIONS	• Select the best **charge density** for the sludge. • Select several molecular weights to be tested industrially. Use a high molecular weight for direct flotation.		• Polymer dosage should be between **0.2 and 1.0 kg/dry solids tonne (0,4 and 2 lbs/DT)**. • The **injection point** of the polymer is a key element and the capture rate will depend on it.	

3.2. Gravity belt:

It is essential to use an organic flocculant on gravity belt. The flocculant will accelerate the drainage of water and allow it to flow through the sludge and the filtration belt.

The flocculated sludge flows over a filtration belt that is conveyed at a certain speed.
The water freed by the flocculation step is drained through the pores of the belt.
This elimination of water (the filtrate) leads to a thickening of the sludge at the end of the conveyer belt. Picket fences resting on the belt are often used to enhance the gravity drainage.
Continuous pressure cleaning of the belt is necessary to prevent pore plugging.
The filtrate is returned to the beginning of the process while the thickened sludge is sent to a temporary storage tank before dewatering.

3.2.1. Functionning principle:



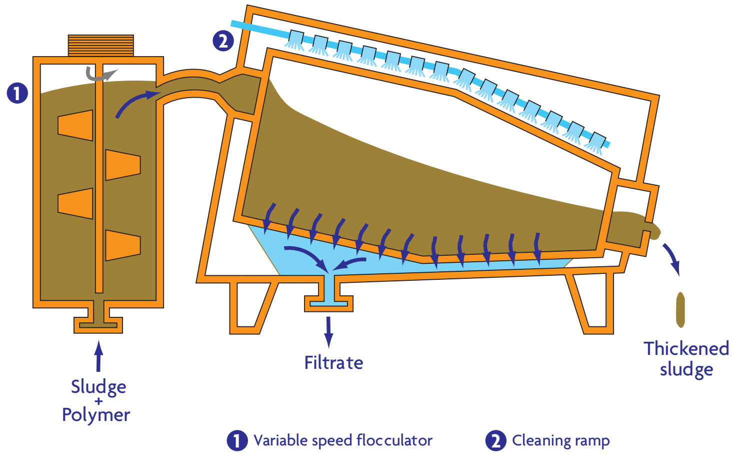
3.2.2. Sludge conditioning before gravity belt:

	LAB TESTS		PLANT TRIALS	
KEY PARAMETERS	• Drainage speed • Filtrate quality • Floc formation speed		• Sludge flow • Polymer flow • Injection points • Belt speed • Belt cleaning • Flocculator speed • Thickened sludge concentration • Filtrate quality	
LAB PROCEDURE/ SPREADSHEET	Laboratory evaluation for belt press and gravity belt	Laboratory trials - Gravity belt & Belt filter	/	Gravity belt & Belt filter performance sheet
RECOMMENDATIONS	• Select the best **charge density** for the sludge. • Select the molecular weight best suited for drainage.		• Polymer dosage should be between **3.0 and 10.0 kg/Dry Solids Tonne (6 and 20 lbs/DT)**. • The **injection point** of the polymer is a key element and the drainage speed will depend on it. • Check carefully the water line.	

3.3. Thickening drum, screw drum:

The principle is identical to the gravity belt: sludge conditioning with a flocculant, liberation of intersticial water in the sludge, gravity drainage of the free water through a grid. In the case of the screw drum, the only difference is that the sludge conveying is done with an Archimedean screw.

3.3.1. operating principle:



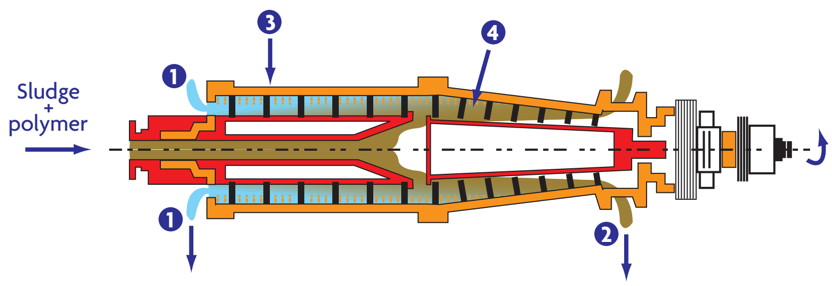
3.3.2. Sludge conditionning before thickening drum:

	LAB TESTS		PLANT TRIALS	
KEY PARAMETERS	• Drainage speed • Shear resistance • Filtrate quality • Floc formation speed		• Sludge flow • Polymer flow • Injection points • Screw speed • Grid cleaning • Thickened sludge concentration • Filtrate quality	
LAB PROCEDURE/ SPREADSHEET	Laboratory evaluation for belt press and gravity belt + Laboratory evaluation for centrifuges	Laboratory trials - Gravity belt & Belt filter + Laboratory trials - Centrifuge	/	Gravity belt & Belt filter performance sheet
RECOMMENDATIONS	• Select the best **charge density** for the sludge. • Select the molecular weight best suited for drainage.		• Polymer dosage should be between **3.0 and 10.0 kg/Dry Solids Tonne (6 and 20 lbs/DT)**. • Check the thickened sludge quality.	

3.4. Centrifuge:

The centrifuge principle is completely different (from previous methods). With centrifugation it is the **centrifugal force** instead of gravity that is used to force the solid/liquid separation. This force is created in a conical-cylinder bowl that rotates at high speed (2500-3500 rpm). The sludge particles are pressed against the bowl and conveyed out of the centrifuge by a screw that rotates at a slightly different speed than the bowl (a few rpms).

3.4.1. Operating principle :



1 Filtrate or centrate
2 Thickened sludge
3 Bowl
4 Screw

3.4.2. Sludge conditioning before centrifuge:

	LAB TESTS		PLANT TRIALS	
KEY PARAMETERS	• Shear resistance • Filtrate quality • Floc formation speed		• Sludge flow • Polymer flow • Injection points • Relative speed of the screw and/or torque • Thickened sludge concentration • Filtrate quality	
LAB PROCEDURE/ SPREADSHEET	Laboratory evaluation for centrifuge	Laboratory trials - Centrifuge	/	Centrifuge performance sheet
RECOMMENDATIONS	• Select the best **charge density** for the sludge. • Select the molecular weight best suited for shear resistance of the flocs.		• Polymer dosage should be between **3.0 and 8.0 kg/Dry Solids Tonne (6 and 16 lbs/DT)**. • Check the thickened sludge quality.	

4 Belt filter dewatering

Belt Filters (Belt Filter Presses, BFP) allow for a continuous sludge dewatering between two filter belts.

4.1. Equipment description and operating principle:

There are many variations in belt filters, but all of them have the following characteristics:

- **A flocculator:** The sludge is conditioned before arriving in the drainage zone. The sludge-flocculant blend is done in the flocculator and the flocculated sludge is distributed evenly on the filter belt. At this level the sludge is in the form of flocs with the free water in between the flocs.

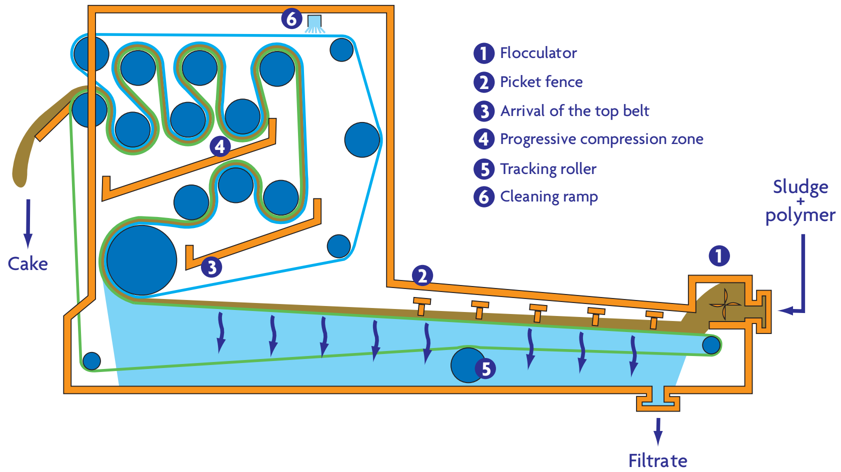
- **A gravity drainage zone:** The flocculated sludge is drained on a first belt (lower belt) by simple gravity. The drainage is helped by picket fences that lay freely on the belt. In this zone a **water line** is created that corresponds roughly to the moment where the majority of the water freed by flocculation is eliminated.

- **A progressive compression zone:** The sludge, after drainage of the water freed by flocculation, is then pressed between two filter belts. With the arrival of the top belt, a progressive pressurization takes place:

- Up to 4 bars for low-pressure belt filters.
- Up to 5 bars for medium pressure belt filters.
- Up to 7 bars for high-pressure belt filters.

- **A cake scraping zone:** Once pressed, the sludge has a more solid aspect. It is called a sludge cake or simply cake. This cake is then scraped off from the surface of the two belts that seperate at this level.

- **A high pressure washing station:** A bank of nozzles under 7 to 8 bars (100 to 120 PSI) continuously cleans each belt.



4.2. Lab tests:

4.2.1. Sampling:

Of the solution to be treated.

A **representative sample** of the sludge must be taken.
In order to achieve this, the sample will be taken just before the polymer injection point and the lab tests will be executed rapidly after sampling (the sludge condition may change over time).
An analysis of the **D**ry **S**olids content (**DS**) of the sludge must be made since the polymer dosage is a function of the DS.

Of the polymer.

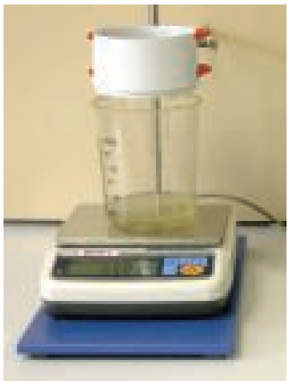
It is not necessary to test all the products available (more than 200 for dewatering applications), a primary screening will do. Select the ionic charge by testing a range of products with the same molecular weight: FLOPAM™ AN 900 SH Series for the anionic powders and FLOPAM™ FO 4000 SH for the cationic powders.

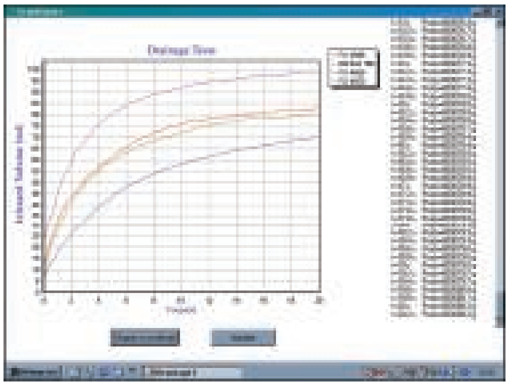
4.2.2. Laboratory equipment:

In order to analyse the volume of drained water in function of time, the minimum equipment necessary is as follows:

- 400 ml beakers
- 90 mm diameter buchner funnel.
- 90 mm diameter belt filter cloth
- 250 ml graduated cylinder
- Stopwatch

A repeatable drainage control can be done via a computer-linked scale that weighs the drained filtrate. This computer recording of the drainage test is recommended since the first 10 seconds of the drainage are the most crucial.





Note:

See the brochure « **Preparation of Organic Polymers** » to have a list of the necessary equipment to prepare polymer solutions.

4.2.3. Test procedures:

The aim of this chapter is not to impose a testing procedure but to describe the key elements that are essential and common to all the existing procedures. The selection of the polymer(s) best adapted to belt filter dewatering is done in two steps.

● **Selection of the ionic charge:**
Polymers having the **same molecular weight and different ionic charges** are compared at different dosing levels (low, optimal, and high).

The **determination of the optimal polymer dosage** must first be made. To do so, a medium range polymer is tested on the sludge by beaker to beaker pouring. The initial dosage is function of the sludge concentration (ie: 5ml of a 3g/l solution in 200ml of 30g/l sludge). If a good flocculation occurs at this dosage, the test is repeated at a lower dosage (ie: - 1ml). If the flocculation is bad or doesn't occur, increase the initial dosage (+ 1ml). The minimal dosage is the lowest dosage that still flocculates.

Then other polymers are tested starting with the minimal dosage determined above and the same number of beaker to beaker pours.

The interpretation of the results can be based on two criteria:
- The best flocculant is the one that frees the most water in minimum time.
- The quality of the filtrate has also to be taken into account.

● **Selection of the molecular weight:**
Flocculants having the same ionic charge but of different molecular weights are then tested using the same method. The number of beaker to beaker pours is indicative of the capacity of the polymer to mix with the sludge.

4.2.4. Parameters to check and analysis of the results:

The key parameters to check are:

- **The drainage speed during the first 10 seconds**
- **The filtrate quality**
- **The efficiency of the polymer at low, optimum and high dosages**
- **The mixing ability of the polymer in the sludge.**

All these data are then compiled in a spreadsheet in order to analyse the results in view of the selection criteria chosen.

4.3. Plant trials:

Industrial trials are used to **confirm the lab test** selection.

4.3.1. Setting up a trial:

During the trial period the quality and flow of the effluent must be as typical as possible. The making up of the reagents must be thorough (See the brochure **« Preparation of Organic Polymers »**). The concentration of the reagents, the injection points... must be selected based on the lab results.

4.3.2. Parameters to follow and analysis of results:

The main parameters to follow depend on the results targeted by the operator. Nevertheless the most frequent are:

- **Flocculant Mass Flow (kg/h, lbs/HR)**
- **Sludge Mass Flow (kg/h, lbs/HR)**
- **Sludge Concentration (g/l, %)**
- **Injection points**
- **Equipment parameters: belt speeds, flocculator speed, pressure**
- **Floc Size**
- **Drainage**
- **Dryness of the cake (%)**
- **Filtrate quality (g/l, mg/l of Suspended Solids)**

To analyse these results, it is usefull to compile all the data in a spreadsheet in order to calculate the chemical consumption rates per volume treated or per dry solids tonne (DST). This spreadsheet also allows the calculation of perfomance costs.

4.4. Optimizing belt filters:

The quality of the sludge flocculation plays a major role in the end results: sludge flow, filtrate quality, cake dryness. On belt filters, it is easy to check the quality of the flocculation in the drainage zone.
The three main operating problems are:

- **Bad drainage:** The sludge reaches the progressive compression zone without being fully drained.
- **Sludge creep:** In the compression zone, the sludge has a tendency to run away on the sides of the belt.
- **Low cake dryness:** The sludge cake's Dry Solids content is too low.

4.4.1. Bad drainage:

When the drainage is insufficient, the following parameters must be checked:

→ **Mixing conditions:** The mixing of the sludge with the flocculant solution must be optimal to obtain the best floc size. To achieve this, it is necessary:

- To have a good mixing intensity: speed of the flocculator.
- To determine the best injection point: before or after the sludge pump or in the flocculator or having several injection points...
- To check the sludge distribution on the belt.

→ **Belt cleaning:** If the belts themselves are not perfectly clean, it is impossible to have a good drainage since the pores are plugged. So the following parameters have to be checked:

- The cleaning water flow may be too low
- The cleaning water pressure may be too low
- The cleaning nozzle may be blocked

The belt pressure can also influence pore plugging. The higher the pressure the more sludge goes through the belt and dirties it.

→ **Flow:** If the flocculation quality is not optimal, drainage will be low. Adjusting the sludge flow and the flocculant flow must be done. The flocculant post-dilution is also an important step; it allows for a better dispersion in the sludge.

4.4.2. Sludge creep:

Sludge creep (squeeze out) happens frequently on biological sludge which are difficult to dewater and sensitive to pressure. Three parameters must then be modified:

→ **Flocculation:** Optimal dosage is necessary for the best results. In order to determine the optimal dosage, lower to the minimal dosage and slightly increase it. Structured polymers can be used to obtain a better drainage and a better floc structure.

→ **Drainage:** The faster water is released, the dryer the sludge is when reaching the compression zone. Checking the initial drainage in order to obtain a maximum water release and checking the cleaning of the belts should resolve this problem.

→ **Sludge feeding:** A high Solids Content can induce creep. Lowering of the sludge flow, reducing the width of the drainage zone and optimizing the cake thickness are the parameters to check.

4.4.3. Low cake dryness:

It is sometimes possible to have a better dryness when modifying the following parameters:

- Mixing conditions
- Belt speed and tension
- Polymer selection

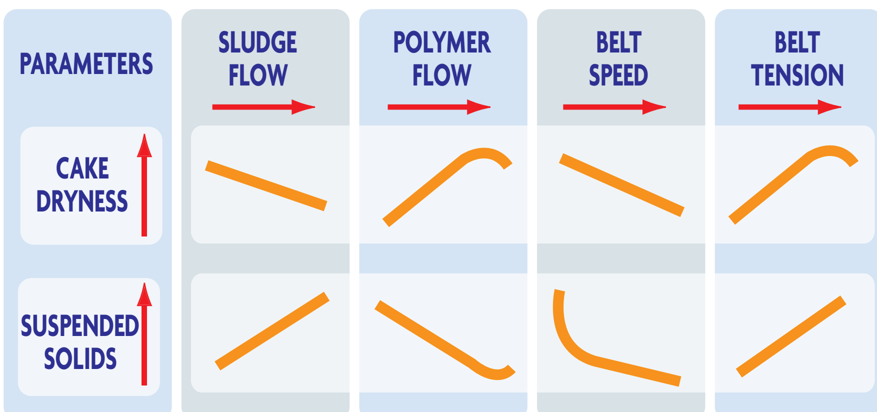
↳ **Mixing conditions:** If mixing is not good, dryness may be low. Rearrange the mixing conditions and the injection points.

↳ **Belt speed and tension:** If the belt speed is high, the drainage time is short. By reducing the speed, the drainage time is longer and therefore the drainage is better. The belt pressure is an important factor to get a good dryness. By increasing the belt pressure a better dewatering is obtained.

↳ **Polymer selection:** An accurate polymer selection will give the best results. Changing the molecular weight, the structure of the polymer and its dosage; all these parameters, although preselected in the lab tests, can be optimized on a plant scale.

↳ **Cake thickness:** The cake thickness should be adjusted taking into account the intrinsic characteristics of the sludge.

4.4.4. Summary of the adjustable parameters:



Note:
shows an increase of the parameter and indicates the trend in dryness or in Suspended Solids. For example, when the sludge flow increases, the dryness decreases and the Suspended Solids in the filtrate increase .

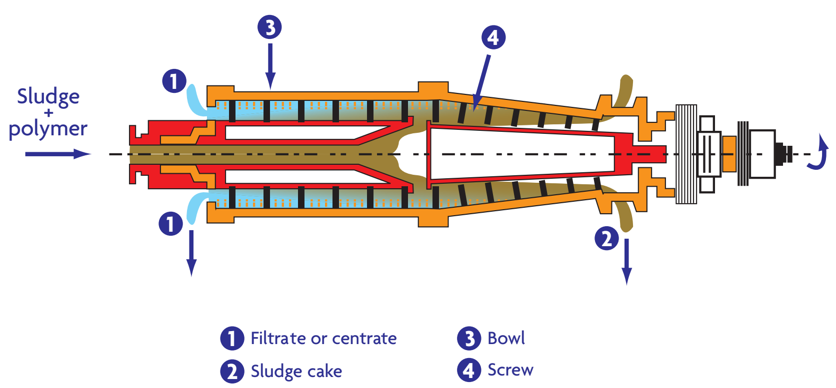
5 Centrifuge dewatering

Centrifuges dewater continuously using **centrifugal forces** of several thousand gs.

5.1. Equipment description and operating principle:

The principle of a centrifuge, also known as centrifugal decantor, is to use centrifugal force to accelerate solid-liquid seperation.
To simplify, it can be assumed that a centrifuge is a conical cylinder decantor that turns horizontally on its axis with a clarified water overflow, the dewatered sludge being removed by an Archimedean screw. The rotation applies a centrifugal force on the solid particles that then move a lot more quickly.

In practice, the flocculated sludge is injected inside the centrifuge bowl through an injection pipe. The bowl has a high rotation speed (3500 rpm) and the particles are flattened against the bowl's sides in the **clarification zone**. The particles are then pushed by an Archimedean screw towards the end of the bowl's cone in the **sludge spin-dry zone**. The clarified liquid called, **centrate**, is evacuated at the other end of the bowl by overflow.



Several parameters, specific to centrifuge dewatering, should be considered since they affect on the polymer selection during lab tests and industrial trials.

● **Diaphragm diameter:**

This parameter corresponds to the diameter of the centrate exit hole. It is controlled by a series of plates that can be adjusted in height. Inside the bowl a **liquid ring** is created, its thickness is equal to the distance between the bowl's surface and the edge of the plate.
The smaller the diaphragm diameter, the thicker the liquid ring.
The diaphragm diameter is selected to obtain the best compromise between centrate clarification and sludge dryness.

● **Relative speed:**

The relative speed is the difference in rotation speeds between the bowl and the central Archimedean screw. The higher the relative speed, the faster the sludge is extracted.

● **Torque:**

The torque measures the pressure of the sludge on the screw. This pressure creates torsion on the screw axis. This torsion is measured to give the torque. The higher the sludge pressure on the screw, the higher the torque.

Note: This is only one example of torque measurement.

Torque and relative speed are linked. An increase of the relative speed will lower the torque and the sludge is extracted more quickly.

High Performance Centrifuges increase sludge dryness. They have a different structure for the conveying screw that allows for a longer residence time in the centrifuge.

5.2. Lab tests:

5.2.1. Sampling:

Of the solution to be treated:

A **representative sample** of the sludge must be taken. In order to achieve this, the sample will be taken just before the polymer injection point and the lab tests will be executed rapidly after sampling (the sludge condition may change over time).
An analysis of the **D**ry **S**olids content (**DS**) of the sludge must be made since the polymer dosage is a function of the DS.

Of the polymer:

It is not necessary to test all the products available (more than 200 for dewatering applications), a primary screening will do. Select the ionic charge by testing a range of products with the same molecular weight: FLOPAM™ AN 900 SH Series for the anionic powders and FLOPAM™ FO 4000 SH for the cationic powders.

5.2.2. Laboratory equipment:

In order to analyse the volume of drained water in function of time, the minimum equipment necessary is as follows:

- 400ml beakers
- Mechanical mixer with blade
- Stopwatch

Note:
See the brochure **"Preparation of Organic Polymers"** to have a list of the necessary equipment to prepare polymer solutions.

5.2.3. Test procedures:

The aim of this chapter is not to impose a testing procedure but to describe the key elements that are essential and common to all the existing procedures. The selection of the polymer(s) best adapted to centrifuge dewatering is done in two steps.

- **Selection of the ionic charge.**

Polymers having the **same molecular weight** and **different ionic charges** are compared at different dosing levels (low, optimal, and high).
The **determination of the optimal polymer dosage** must first be made. To do so, a medium range polymer is mixed with the sludge by the mechanical mixer. The initial dosage is a function of the sludge concentration (ie: 5ml of a 3g/l solution in 200ml of 30g/l sludge). If a good flocculation occurs at this initial dosage, the test is repeated at a lower dosage (ie: - 1ml). If the flocculation is bad or doesn't occur, increase the initial dosage (+ 1ml). The minimal dosage is the lowest dosage that still flocculates.
Then other polymers are tested starting with the minimal dosage determined above +15%.

The interpretation of the results can be based on two criteria:
- The best flocculant is the one that gives the biggest flocs after the longest mixing time.
- The best flocculant must reflocculate the best (add 20% of the initial dosage after completely breaking the flocs).

- **Selection of the molecular weight.**

Flocculants having the same ionic charge but of different molecular weights are then tested using the same method.

5.2.4. Parameters to check and analysis of the results:

The key parameters to check are:

- **Floc shear resistance**
- **Reflocculation**
- **Centrate quality**
- **Incorporation**

All this data is then compiled in a spreadsheet in order to analyse the results in view of the selection criteria chosen.

5.3. Plant trials:

Industrial trials are used to **confirm the lab test** selection.

5.3.1. Setting up a trial:

During the trial period, the quality and flow of the effluent must be as typical as possible. The making up of the reagents must be thorough (See the brochure **"Preparation of Organic Polymers"**). The concentration of the reagents, the injection points... must be selected based on the lab results.

5.3.2. Parameters to follow and analysis of results:

The main parameters to follow depend on the results targeted by the operator. Nevertheless the most frequent are:

- **Flocculant mass flow (kg/h, lbs/HR)**
- **Sludge mass flow (kg/h, lbs/HR)**
- **Concentration of the sludge (g/l, %)**
- **Injection point**
- **Equipment parameters: torque, relative speed**
- **Dryness (%)**
- **Centrate quality (g/l, mg/l of Suspended Solids)**

To analyse these results, it is useful to compile all the data in a spreadsheet in order to calculate the chemical consumption rates per volume treated and per Dry Solids Tonne (DST). This spreadsheet also allows the calculation of perfomance costs.

5.4. Optimizing centrifuges:

It is a lot more difficult to control the flocculation quality on a centrifuge than on a belt filter since everything takes place inside pipes or inside the machine. Within the centrifuge, the flocs are submitted to an important force (2000g to 4000g). The flocs can be quickly destroyed if the polymer has not been well chosen or dosed.
The three main operating problems are:

- **Black centrate:** The centrate has an unusual dark color. This color is due to the presence of numerous particles that are evacuated with the diaphragm overflow and are going back to the start of the process.
- **Gray, foaming centrate:** Only an excessive foaming is indicative of a problem. Slight foaming is a normal occurrence due to the high agitation level inside the centrifuge. Degasing eliminates this foam.
- **Low dryness:** The sludge cake has a lower than expected solids content.

5.4.1. Black centrate:

When the centrate has too many solids, the following points must be checked:

↳ **Solids flow:** Each centrifuge is designed for a specific solids flow load. If it is overloaded, the centrifuge will never work well.

↳ **Relative speed:** The lower the relative speeds, the longer the residence time of the sludge in the centrifuge. The pressure applied to the flocs will have time to destroy them and the fine particles will exit with the centrate. Increasing the relative speed should clarify the centrate.

↳ **Polymer flow:** The flocs have to be solid enough to resist the shearing generated inside the centrifuge by the pressure and the screw. The dosage of the polymer should be high enough to reflocculate the particles if there is a destruction inside the centrifuge.
In any case, the dosages of polymer for a centrifuge application is always higher than for belt filters.

5.4.2. Gray, foaming centrate:

In this case it is necessary to adjust:

↳ **The mass flow:** A lack of solids forces the centrifuge to reduce its relative speed in order to maintain a sufficient torque. It is then necessary to adjust the polymer dosage to the quality of sludge.

↳ **The torque:** If the torque is unstable, the centrifuge cannot work correctly and particles will appear in the centrate during the changes in relative speed.

The polymer flow : The presence of foam may indicate polymer overdosing. Furthermore, polymer overdosing redisperses the particles. Reducing the polymer dosage must be tested.

Note :
A gray color may indicate that the polymer is not well adapted to the sludge, due to a wrong polymer selection and/or a bad mixing of the polymer with the sludge.

5.4.3. Low cake dryness :

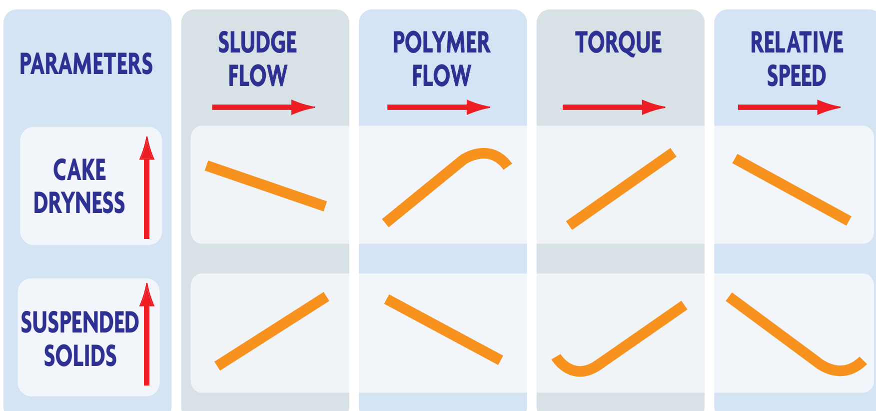
Adjusting the following parameters may enhance the cake dryness:

Torque : Adjusting the torque and/or the relative speed to the sludge concentration must be systematic.

Liquid ring : A smaller liquid ring diameter ensures a better drying of the sludge since the water height in the conical part of the centrifuge is lower.

Floc stability : Floc stability is a key parameter in the performance of a centrifuge because of the high shear forces involved. SNF has developed a range of emulsion cationic flocculants in order to provide the best stability and an optimum reflocculation.

5.4.4. Summary of the adjustable parameters :



Note:
shows an increase of the parameter and indicates the trend in Cake Dryness or in Suspended Solids. For example, when the sludge flow increases, the Cake Dryness decreases and the Suspended Solids in the filtrate increases

6 Frame filter press dewatering

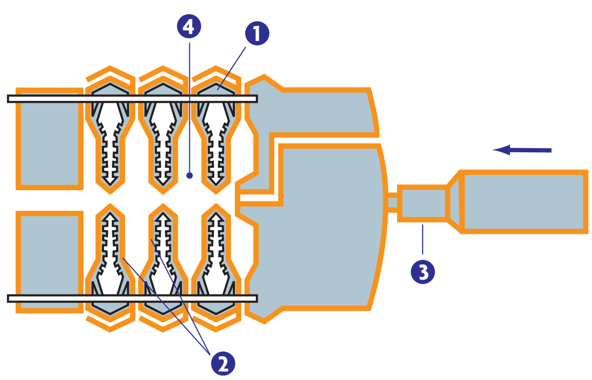
Frame filter presses will dewater sludge at a higher level of dryness than the previous techniques reviewed above. It is a discontinuous process that works in batch cycles.

6.1. Equipment description and operating principle:

With a frame filter press, also called a filter press, the operating principle is **filtration**. A filter press is composed of a series of hollow vertical frames with filter cloths stretched on both sides. These frames are hung next to each other and pressed together with a hydraulic jack. A **filter chamber** is formed bewteen the plates.

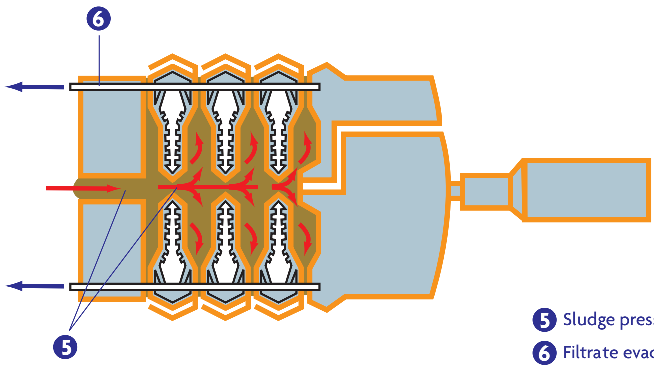
Each cycle can be split into three phases:

↳ **Filling phase:** At the start of the cycle, the conditioned sludge is injected in the filtration chambers by a high-pressure pump. The sludge fills each chamber and the water starts to seep out.



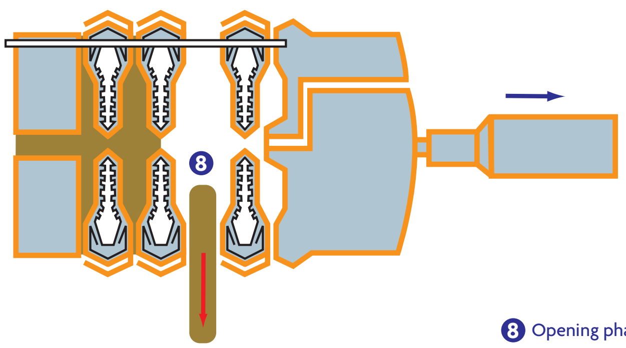
1 Vertical hollow plates
2 Filter cloth
3 Jack
4 Filtration chamber

Filtration phase: Once all the chambers are filled, the sludge continues to be pumped in and the pressure increases to reach up to 15 bars. The filtrate flows into the chanels placed in each frame and is evacuated in a main pipe. The sludge injection flow reduce when the pressure increases. Very often, two seperate off-centre-screw pumps are used: a high flow/low pressure pump for the beginning of the cycle and a low flow/high pressure pump for the end.



5 Sludge pressure injection
6 Filtrate evacuation
7 Compressed air

Opening phase: Several parameters may be used to signal the end of the cycle (stopping the injection pump): maximum pressure, filtration time, filtrate volume. Once the press has stopped, the central core is purged of the liquid sludge inside. The jack that presses the frames together is released. The chambers are opened sequentially and the cake falls below into a skip or on to a conveyor.



8 Opening phase and cake falling

Membrane Filter Presses have been recently developed to obtain higher cake dryness than on regular Frame Filter Press. Every second plate is made of a membrane that can be shaped by air or water pressure (7-10 bars). This **extra pressure** is applied at the end of the injection phase, once the cake is formed.

6.2. Lab tests:

6.2.1. Sampling:

Of the solution to be treated.

A **representative sample** of the sludge must be taken. In order to achieve this, the sample will be taken just before the polymer injection point and the lab tests will be executed rapidly after sampling since the sludge condition may change over time.
An analysis of the **D**ry **S**olids content (**DS**)of the sludge must be made since the polymer dosage is a function of the DS.

Of the polymer:

For Frame Filter Press several combinations may be envisaged:

- Combination of iron salts and lime (the most frequent). This method significantly increases the volume of sludge to be treated (30%-50% of extra mineral matter).
- Combination of iron salts and cationic flocculant
- Organic coagulant alone
- Organic flocculant alone

6.2.2. Laboratory equipment:

In order to control the floc resistance under pressure, the minimum equipment necessary is as follows:

- 400ml beakers
- Mechanical mixer with blade
- Stopwatch
- Capillary Suction Time (CST) meter

Note:
See the brochure **"Preparation of Organic Polymers"** to have a list of the necessary equipment to prepare polymer solutions.

6.2.3. Test procedures:

The aim of this chapter is not to impose a testing procedure but to describe the key elements that are essential and common to all the existing procedures. The selection of the polymer(s) best adapted to frame filter press dewatering depends on the conditioning method employed.
In the case of an **organic flocculant alone**: the method will be similar to Belt Filters and Centrifuges.

Selection of the ionic charge.

Polymers having the **same molecular weight** and **different ionic charges** are compared at different dosing levels (low, optimal, and high).

The **determination of the optimal polymer dosage** must first be made. To do so, a medium range polymer is mixed with the sludge by the mechanical mixer. The initial dosage is a function of the sludge concentration (ie: 5ml of a 3g/l solution in 200ml of 30g/l sludge). If a good flocculation occurs at this initial dosage, the test is repeated at a lower dosage (ie: - 1ml). If the flocculation is bad or doesn't occur, increase the initial dosage (+ 1ml). The minimal dosage is the lowest dosage that still flocculates.

Using **C**apillary **S**uction **T**ime (**CST**) allows to evaluate the size of the flocs versus mixing time. The best flocculant is the one that gives the shortest CST times after the longest mixing time.

Note: Never do a CST on flocs that are too big or on suspensions that are not homogenous (solid-liquid separation in the beaker).

Selection of the molecular weight.

Flocculants having the same ionic charge but of different molecular weights are then tested using the same method.

When a **combination of mineral/organic coagulant and an organic flocculant** is used, it is necessary to first determine the optimum coagulant dosage using the CST and then to select the optimum flocculant using the method described above.

6.2.4. Parameters to check and analysis of the results:

The key parameters to check are:

- **Floc size and floc resistance measured with the CST**
- **Filtrate quality**
- **Incorporation**

All this data is then compiled in a spreadsheet in order to analyse the results in view of the selection criteria chosen.

6.3. Plant trials:

Industrial trials are used to **confirm the lab test** selection.

6.3.1. Setting up a trial:

During the trial period the quality and flow of the effluent must be as close to the average as possible. The making up of the reagents must be thorough (See the brochure **"Preparation of Organic Polymers"**). The concentration of the reagents, the injection points... must be selected based on the lab results.

6.3.2. Parameters to follow and analysis of results:

The main parameters to follow depend on the results targeted by the operator. Nevertheless the most frequent are:

- **Reagent mass flow (kg/h, lbs/HR)**
- **Sludge mass flow (kg/h, lbs/HR)**
- **Concentration of the sludge (g/l, %)**
- **Pressure build-up**
- **Filtration cycle time**
- **Cake aspect**
- **Cake dryness (%)**

To analyse these results, it is useful to compile all the data in a spreadsheet in order to calculate the chemical consumption rates per volume treated and per Dry Solids Tonne (DST). This spreadsheet also allows the calculation of perfomance costs.

6.4. Optimizing frame filter press:

For a frame filter press, the most frequent conditioning by far was the combination of $FeCl_3$ and lime. Today, due to the ever-increasing volume of sludge to be disposed of, any unnecessary increase in sludge volume leads to unacceptable operating costs (too many operating cycles and too much sludge volume). That is the reason behind the **new organic polymer conditioning processes** that have been developed.

The three main operating problems in an organic polymer conditioning process are:

- **Sticky cakes:** This is the main problem when using organic polymers. Instead of falling off by gravity, the cake sticks to the filter cloth and an operator has to intervene during the opening phase.
- **Cloth plugging:** Pores get plugged, preventing the filtrate from passing through the cloth.
- **Polymer efficiency loss:** This phenomenon is often observed when the liquid sludge has been previously treated with lime. It results in a degradation of the flocs with time.

6.4.1. Sticky cakes:

When the cake starts to stick the following parameters must be checked:

Dosage of the chemicals.
When a cationic flocculant is used, the sticky cakes may be due either to an overdosing or to an underdosing. The association of $FeCl_3$ and a flocculant is best suited to remedy this problem, especially on sludge with a high VSS. The addition of $FeCl_3$ allows a lower the flocculant dosage.

Cloth cleanliness.
If the cloth is clogged, it is impossible to get a good dewatering. Regular cleaning of the cloth (every 10-30 cycles) is necessary.

Polymer selection.
If the flocculant is not well adapted (cationicity, molecular weight, dosage), the cake may stick. It is necessary to check in the lab the dosage and the molecular weight.

6.4.2. Cloth plugging:

This problem is signaled by a rapid increase in pressure. The pressure increase during the cycle must be slow and regular. This parameter is used to check the degree of advancement of the cycle.
A regular sampling between the sludge pump and the filter plates will permit a check with the CST meter of the strength of the flocs submitted to pressure.

Other parameters also to consider:

- **Cloth cleanliness.** The more the pores are plugged, the faster the cloth will clog. Cleaning the cloth with high-pressure water must be done.
- **Floc size:** Optimum filtration is obtained with small pressure-resistant flocs. To get these type of flocs, the best flocculants are often medium to low molecular weights and structured (branched and cross-linked).

6.4.3. Polymer efficiency loss:

In this case the following parameters must be checked:

Polymer preparation.

Degradation in time of a cationic polymer is a normal phenomenon (see paragraph on hydrolysis in the brochure **"Preparation of Organic Polymers"**); there is a loss in viscosity and in performance of the polymer. Checking the polymer solution (age, concentration, pH...) is recommended.

Sludge pH.

If the sludge to be dewatered has a high pH (10/11), as is likely with the addition of lime, the cationic flocculant will hydrolyse very quickly. This hydrolysis can be easily observed since the flocs will break at the slightest movement. There are two ways to solve this problem: change the sludge pH or choose a polymer less sensistive to hydrolysis like the FLOPAM™ CB Series or polyDADMACs.

Sludge-polymer contact time.

Under difficult operating conditions such as a high pH, the cationic polymer is not stable for a long time. Selecting the injection point will become an important factor to the performance. The best conditions are always in-line injection with the polymer dosing regulated by the sludge flow.

Notes :

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