Molasses Filtration with Automatic Discharge of Dry Solids

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ABSTRACT

Molasses contains approx. 60% of sugar. In order to extract this sugar and to increase the overall yield of a sugar mill, the molasses is processed in a chromatographic process into three phases. Whereas the natural betaine fraction is sold to third parties and the raffinate is added to sweeten animal feed, the sucrose extract is recirculated to the crystallization to recover additional sugar.

This three phase separation happens in a chromatographic process, which needs to be protected through proper filtration as the resin bed of the columns is rather sensitive and very costly to exchange.
Due to these facts precoat filtration using filter aid is the state of the art technology. As the sticky molasses is rather difficult to clean of the filter cloths usually a slurry discharge was used for regeneration, with the effect of efficient cleaning, but loss of product, respectively molasses.

In order to be able to process 100% of the molasses the Lenzing Technik GmbH has gone through an intensive trial phase together with the customer for more than a year to optimize the settings, parameters and consumables used at the Lenzing CakeFil equipment. These trials resulted in a dry solids discharge, molasses filtration process without product losses and additional recovery steps.

KEYWORDS

Cake filtration, precoat, molasses filtration, filter aid, filtration efficiency, molasses, dry discharge, efficiency improvement, increasing yield

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1. INTRODUCTION

Closing the loops and increasing yields are only two phrases which are often used, but need to be followed to be able to survive in a more and more competitive environment. These very general phrases also count for the sugar industry especially in regards of the changing market.

Thinking about closed loops and increased yields in sugar industry automatically Molasses comes into one's mind. Although it is almost everywhere already used in a sensible way, as e.g. addition to sweeten animal feed, it could be used to produce more sugar per beet and to gain higher margin from betaine fraction.
Therefore the molasses is processed in a chromatographic process into three phases. Whereas the natural betaine fraction is sold to third parties and the raffinate is added to sweeten animal feed, the sucrose extract is recirculated to the crystallization to recover additional sugar.

This three phase separation happens in a chromatographic process, which needs to be protected through proper filtration as the resin bed of the columns is rather sensitive and very costly to exchange.
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2. STATUS QUO

In the specific case this paper is targeting, a sugar mill is operating a Simulated-Moving-Bed (SMB) Chromatography for 70 000 tons of Molasses per year which the operator wants to increase to 100 000 tons with the parameters shown in Table 1.

The task of molasses filtration can be seen as an example only because chromatographic equipment always requires efficient filtration to provide a feed with a maximum of 5ppm suspended solids and a maximum particle size of 5µm. Within sugar refineries e.g. the recovery house can be replaced by chromatographic columns.[i]

Table 1: Operation Parameter for the described case

Molasses amount	70 000 T/a
Sugar Content	60 brix
Static viscosity	3800 cm/s
Dynamic viscosity	4.77 mPas
Operating Temperature	84 °C

During this capacity expansion project it turned out that filtration is the bottleneck and need to be increased in capacity.

2.1. Existing Filtration

Actually the molasses is filtered through two units plate type precoat filters with slurry discharge. One of these two units is always in operation the other one in regeneration. The slurry is recovered through a decanter unit to minimize product losses.

Figure 1: Left: existing plate type precoat filters / Right: Slurry decanter

As the performance of the plate type precoat filters is, additionally to the capacity problems, also unsatisfying in terms of filtrate quality an automatic Lenzing OptiFi® operated with 5µm woven screen is used for polishing afterwards.

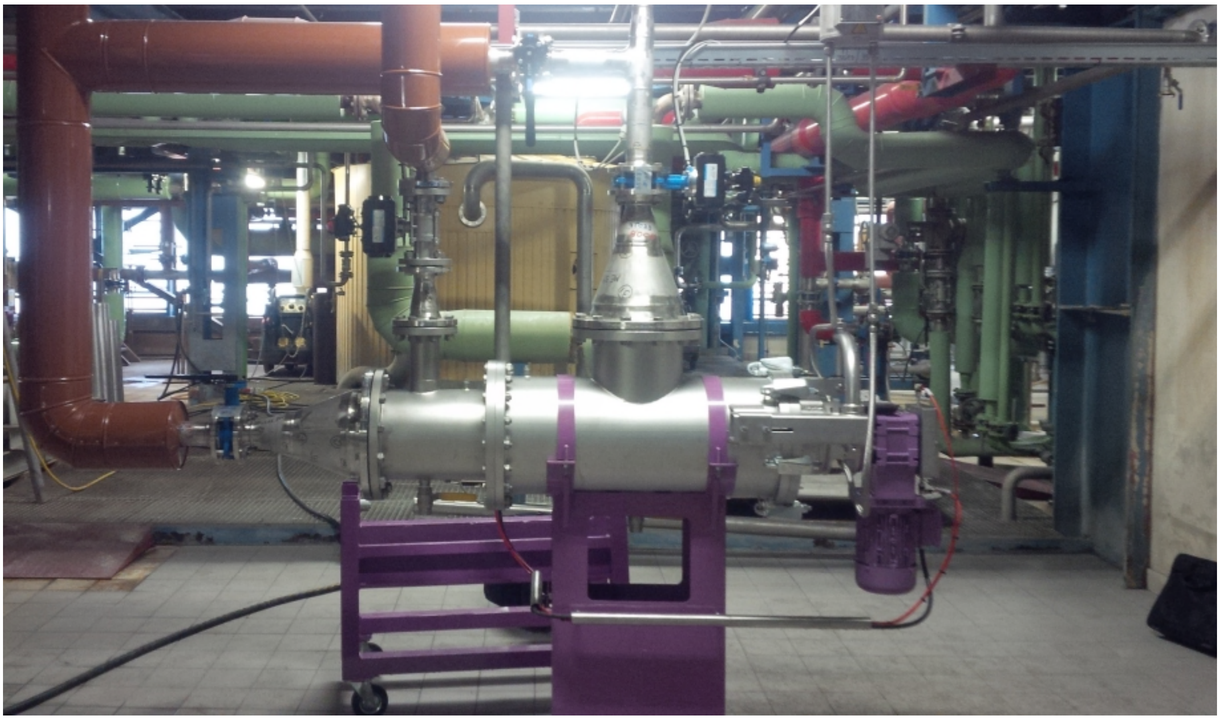

Figure 2: Lenzing OptiFil® for downstream polishing

3. THEORETICAL BACKGROUND AND DEFINITIONS

3.1. Filtration Mechanism[ii]

In theory the retention of particles from fluids can be described in four idealized mechanisms, which are surface, depth, cake and precoat filtration. In the following lines these theoretical approaches are described. Although in reality always a mixture of these mechanisms appears.

- Surface Filtration

Surface or blockage filtration describes the mechanism, how solids block the pores of a filter media. This mechanism is most descriptive when soft and formable particles are filtered on a sieve. In this case the differential pressure over the sieve rises exponentially after the solids blocked the last free pore of the sieve, as shown in Figure 3.

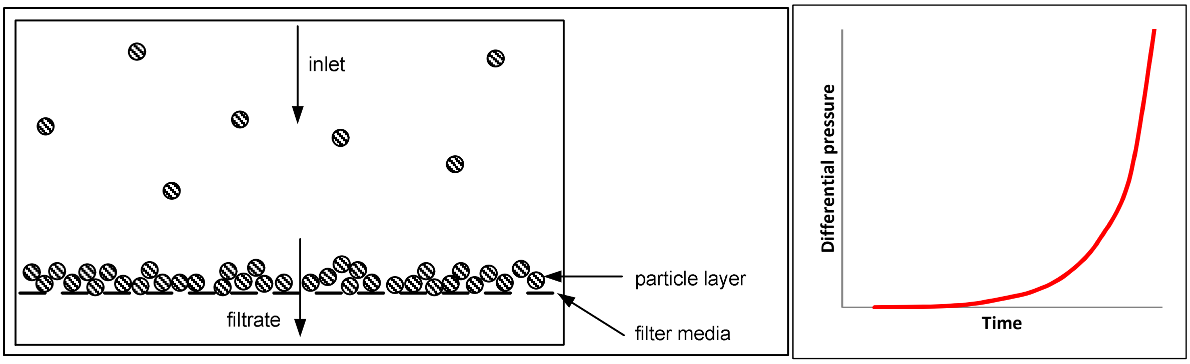

Figure 3: Principle of Sieve Filtration

- Depth Filtration

Figure 4 shows the principle of depth filtration, where solids are kept in the inside of a permeable multilayer filter media until the filter media has reached its absorption capacity. After that, the differential pressure increases either exponentially as already described above or the critical differential pressure leads to a break-through of the impurities into the filtrate.

Although the same principle applies for both, the single layers of the filter material as well as for the surface or blockage filtration, the dirt holding capacity is significantly higher.

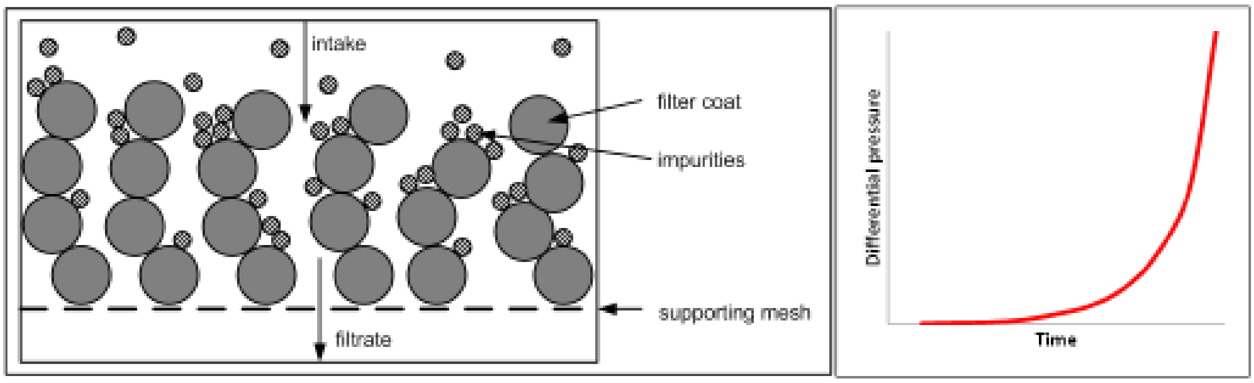

Figure 4: Principle of Depth Filtration

- Cake Filtration

During cake filtration the solid particles settle on the filter media and build up a filter cake of growing thickness. In the best case the resistance of the filter cake rises proportionally to its thickness. At a continuous flow rate, the differential pressure rises proportionally to the filtered volume.

As shown in Figure 5, typically the pores of the filter media have a bigger diameter than the solid particles. However the particles tend to form solid bridges above the pores. Until this happens it is possible that solid particles migrate into the filtrate.

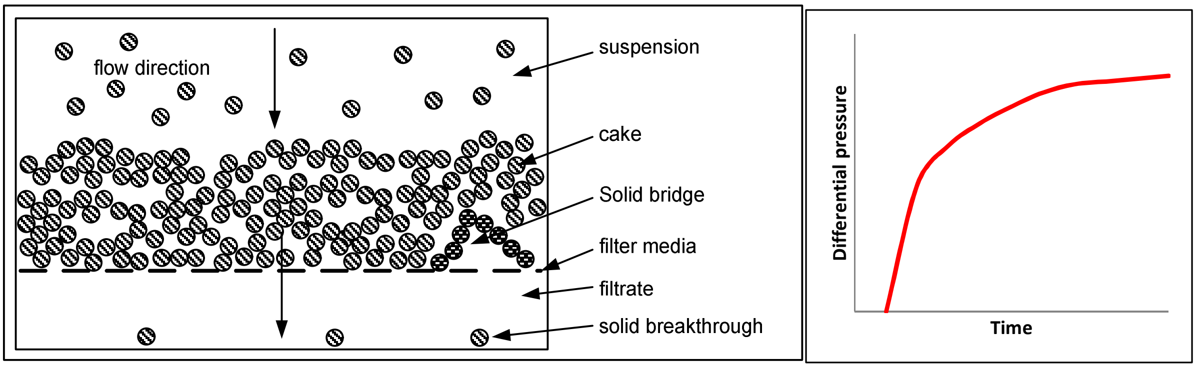

Figure 5: Principle of Cake Filtration

- Precoat Filtration

The theoretical background of precoat filtration is a kind of cake filtration. The only difference is that filter aid (typically Perlite, Diatomaceous earth or Cellulose) is added to the suspension to form a permeable filter cake.

This can be done as precoat and / or bodyfeed depending on the requirements of the filtration process and the characteristics of the particles.

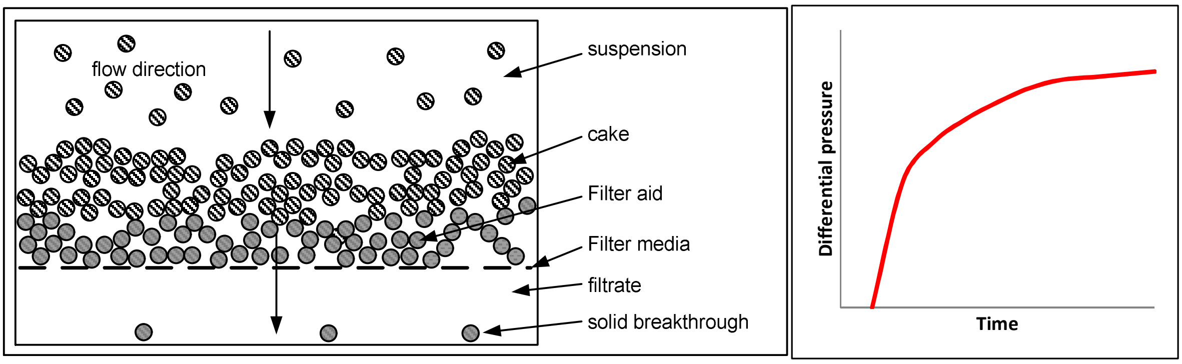

Figure 6: Principle of Precoat Filtration

3.2. Filter aids

As the impurities contained within the molasses, do not form a permeable filter cake it is necessary to add filter aids for proper filter cake formation. For Molasses Filtration the filter aid of choice is Perlite, but for varying filtration tasks varying filter aids are required. In the following lines the most prevalent ones are described.

- Perlite

Perlite is a naturally occurring volcanic glass which thermally expands upon processing. Perlite is chemically a sodium potassium aluminum silicate. After milling, a porous, complicated structure is present, but because its structure is not as intricate (or tortuous) as that of diatomite, perlite is better suited to the separation of coarse microparticulates from liquids having high solids loading. Perlite is lower in wet cake density than diatomite and this enables using less filter aid (by weight).[iii]

- Cellulosic

Cellulose filter media is produced by the sulphite or sulphate processing of hard woods. Cellulose is characterized by its high aspect ratio, which enables it to precoat a septum very easily. It is most often used in that capacity in combination with diatomite. Like perlite, cellulose possesses a less intricate structure than diatomite. Attempts have been made to add structure. These include fibrillating the strands. Cellulose also has the ability to operate in elevated pH environments above 10, making it frequently used in the chlorine-caustic industry to filter the brine feed to electrolysis membrane separators. Another application of cellulose is in treating machining oils and cutting fluids, to break the emulsion or to trap metal fines. Cellulose can be burned out after the filtration to recover the metal particles.

- Diatomite

Diatomite is obtained from diatomaceous earth, a sediment greatly enriched in biogenic silica in the form of the siliceous frustules of diatoms, a diverse array of microscopic, single-cell algae of the class Bacillariophyceae. These frustules are sufficiently durable to retain much of their structure through long periods of geologic time and through thermal processing. Diatomite products are characterized by an inherently intricate and highly porous structure composed primarily of silica, along with impurities of alumina, iron oxide, and alkaline earth oxides.

- Activated Carbon

Activated carbon's range of applications extends from removal of various impurities, e.g. flavours and odours, to removal of disinfectants and their decomposition products from water. In addition, it maintains long-term colour stability. The structure and concentration of the impurities to be removed determines subsequent treatment. To ensure efficient absorption, the pore size should be almost equal to the size of the molecules which are to be processed. A broad range of grinding degrees is available and the user-specific activated carbon grades determine the purity of the liquid's components, such as water, carbon dioxide, and sugar. This approach ensures all quality criteria can be met.*iv*

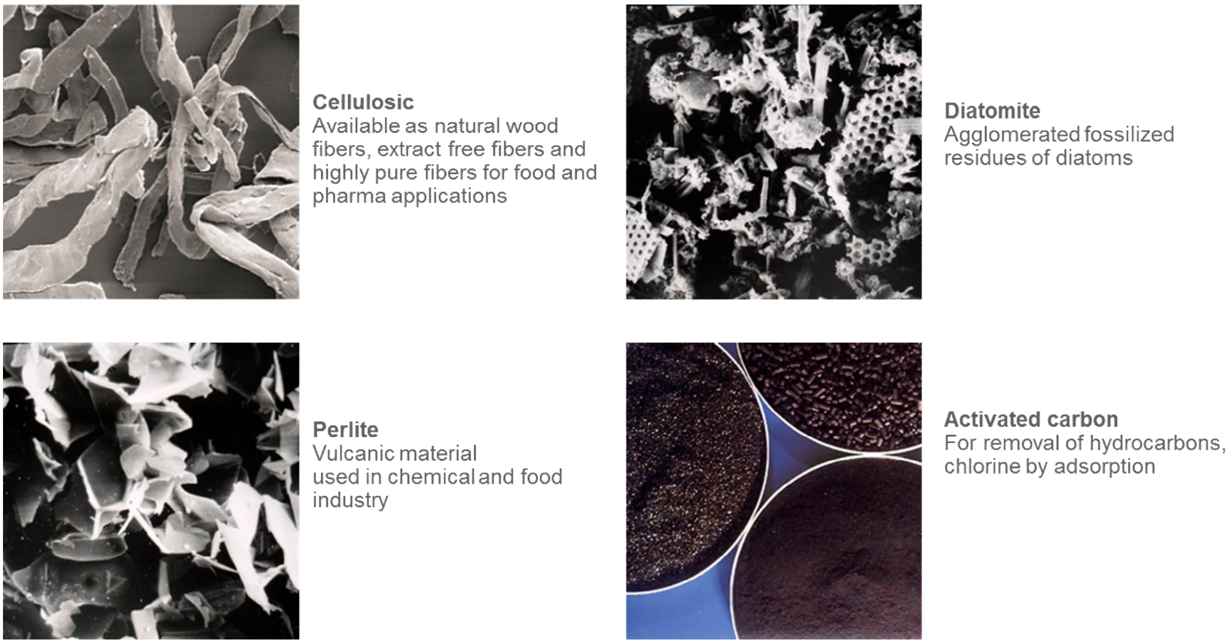

Figure 7: Overview on Filter aids available

Figure 7 shows microscopic photographs of different filter aids where e.g. it is visible that Perlite has a higher specific surface then Cellulosic, but less then Diatomite filter aids.

3.3. Filter Material/ Cloth

Besides a wide range of filter aids available also numerous options of filter materials can be applied. Figure 8 gives an overview on those. Varying applications require varying attributes of the filter cloths. Choosing the best one for each task required experience and knowledge.

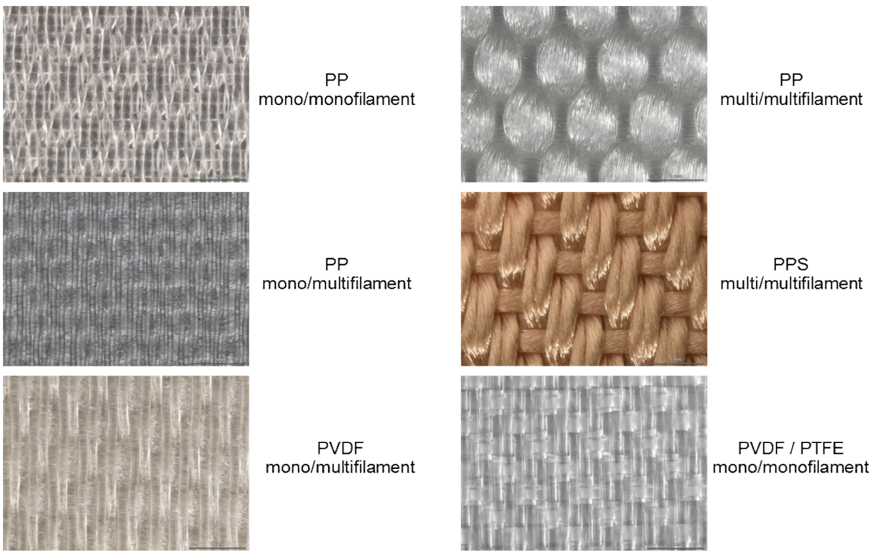

Figure 8: Range of filter material available Lenzing CakeFil

4. LENZING CakeFil

4.1. Function and Design

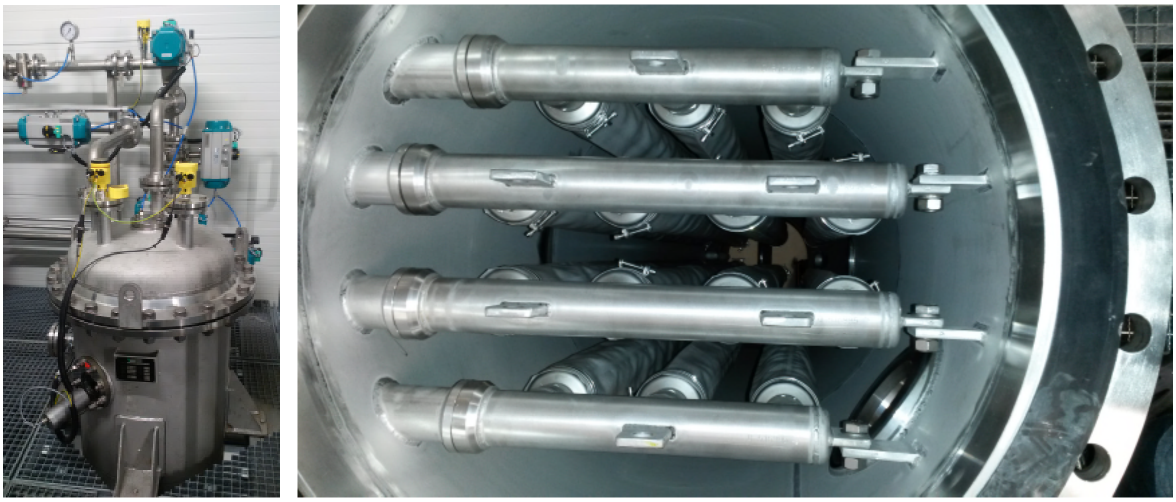

Figure 9: Left: outside of filter vessel CakeFil / Right: inside of filter vessel CakeFil

During the filtration, which takes place in a pressure vessel, as shown in example above in Figure 9, the liquid is pressed from the outside through the filter medium. Solids collect on its surface and form a uniform cake, which remains on the filter elements due to a continually maintained pressure differential across the filter candles.

Besides earlier mentioned parameters like filter aid, filter material and the vessel design, one of the keys for an economic candle filter is the choice of the correct candle design. According to the characteristics of the filter cake the type of discharge (slurry or dry) the candle design has to be adjusted accordingly. Figure 10 shows an excerpt of the candle range of Lenzing Technik GmbH as an example.

Figure 10: Excerpt of available candle variations

4.2. Step Sequence

With this kind of equipment the filtration is divided into multiple phases.

Starting from a clean filter material, in our case a filter cloth, as shown in Figure 11 one filtration cycle can be divided in different sequences.

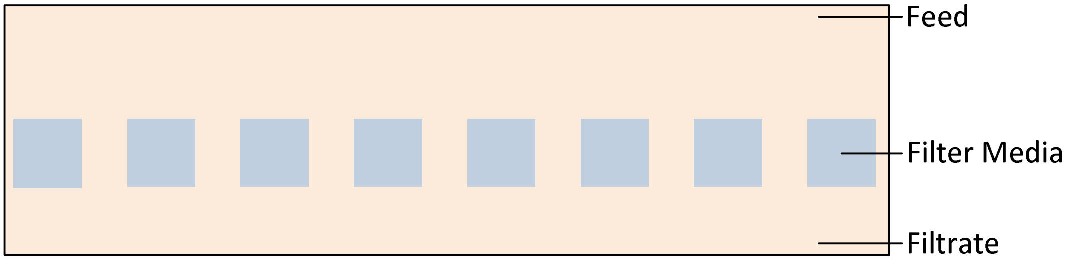

Figure 11: Clean filter material

- Precoat

During precoating the filter vessel is filled with a mixture of filtered fluid or water and a comparably coarse filter aid which is in this case a Perlite. The precoat layer is necessary to provide the support and depth for the fine filter cake created during filtration sequence. Figure 12 shows the bridge formation through a relatively coarse filter aid above the pores of the filter cloth.

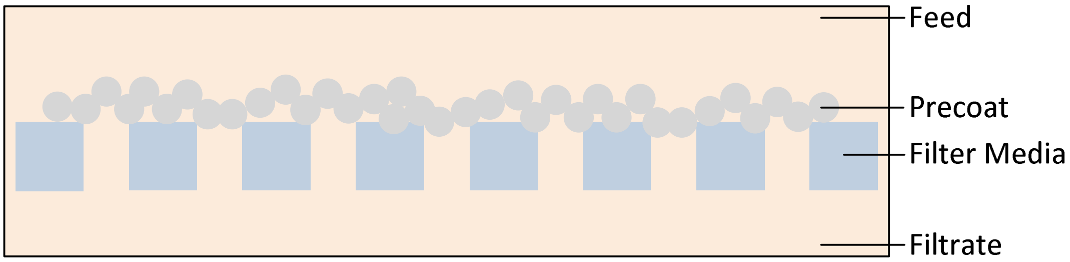

Figure 12: Precoat phase

During the formation of the precoat layer the fluid is recirculated to the feed line to prevent the migration of particles into the filtrate line.

- Filtration

Whilst the first step was only the preparation of the filter media, at this stage the main filtration starts. A mixture of suspension containing impurities and sometimes a finer filter aid dosed as a bodyfeed is fed onto the precoated filter material. Whilst the clean liquid is passing the filter cake, the impurities and the filter aid particles are kept on or in the depth of the precoat layer.

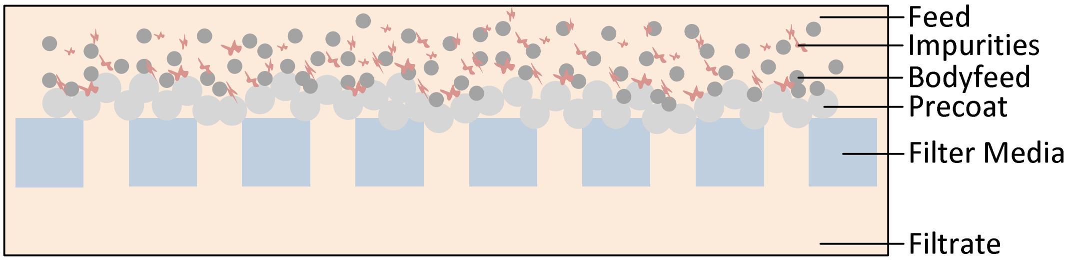

Figure 13: Filtration phase

- Cake washing

As soon as the end of a filtration sequence is reached the filter vessel gets emptied (filling volume is recirculated to the feed tank). To maximize the sugar yield the cake afterwards gets washed with water through spray nozzles. This washing water is afterwards also recirculated to the feed tank and used for dilution of the molasses.

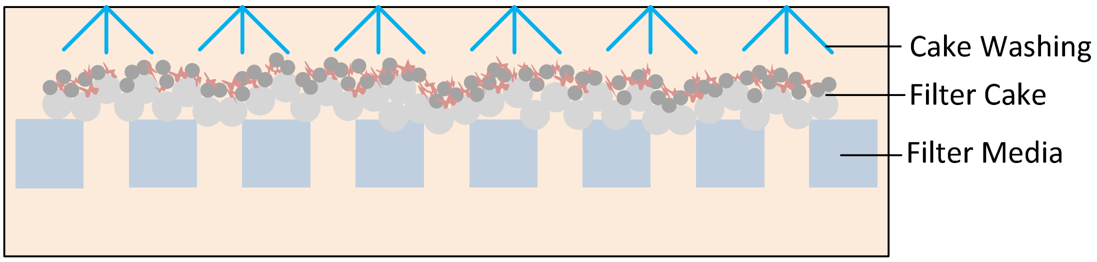

Figure 14: Cake Washing phase

- Cake drying

The washed cake is then dried with pressurized air to prepare it for the blow off. This step makes the filter cake more brittle.

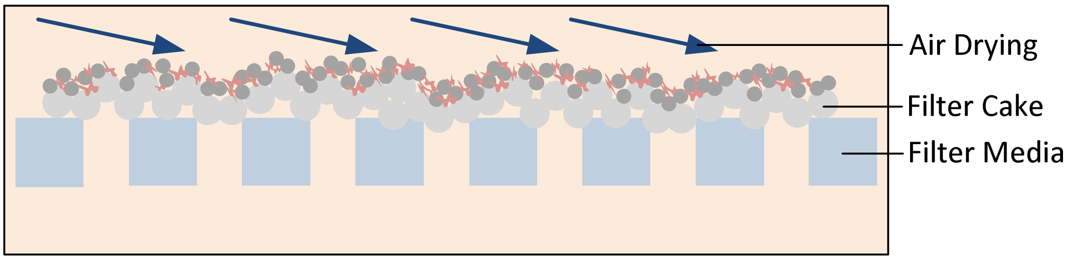

Figure 15: Cake drying

- Cake discharge

Afterwards the filter cake is blown off in reverse filtration direction by a strong pressurized air impulse which breaks the brittle filter cake and allows for the gravity driven discharge of the dry filter cake through the bottom.

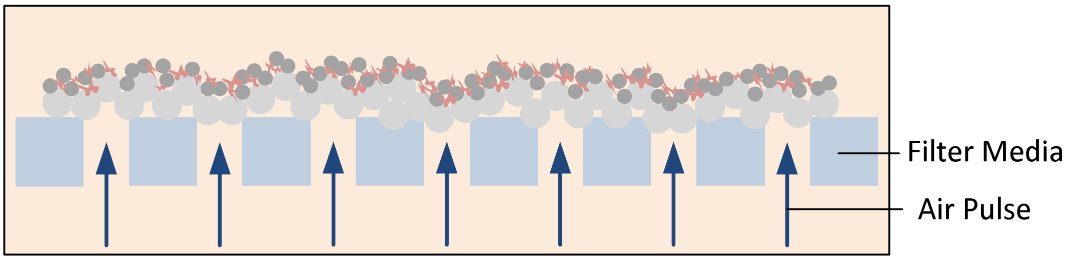

Figure 16: Cake discharge

Optionally after the discharge there can be a sequence of cloth washing before the sequence starts from the beginning.

5. Test execution and Results

5.1. Test execution

The test have been executed in a bypass stream of the molasses feed of the existing plate type precoat filters. Therefore a plug and play pilot unit shown in Figure 17 was integrated with hose connections into that line.

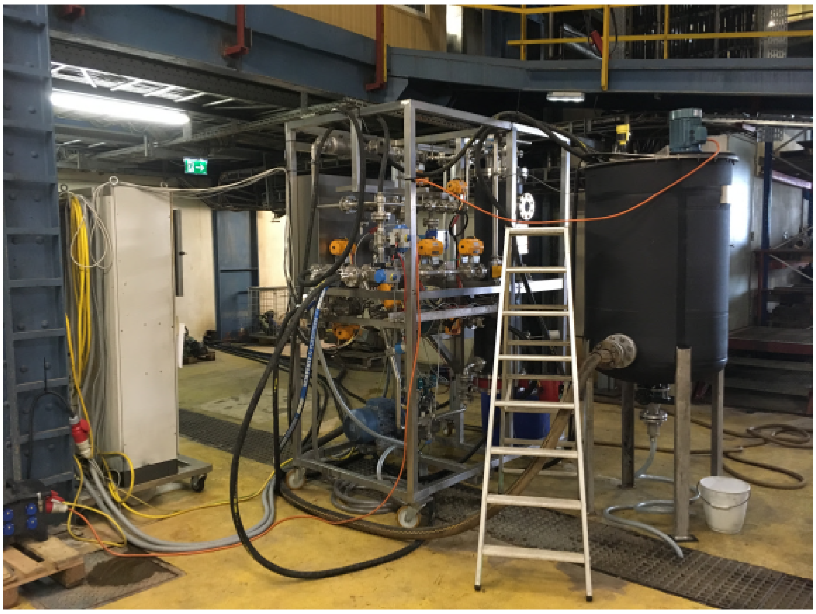

Figure 17: Pilot unit Lenzing CakeFil in operation

The setup allowed an independent operation with varying filter aid concentrations and the full range of step sequences to try the best configuration. Table 2 shows the configuration of the three most promising trials.

Table 2: Configuration of most promising trials

Trial	Filter material	Precoat [kg/m²]	Bodyfeed [g/L]	Cake washing	Cloth washing
01	LT-FM-02-13-03-007	0,83	1	No	No
02				No	Yes
03				Yes	Yes

5.2. Results

To sum up the executed trials only the three above mentioned trials will be thematised in the following lines as the full range of trials would be too extensive.

- Trial 01

This trial has shown that the quality parameter can easily achieved with these concentrations and filter material set up. Furthermore it has shown that a cyclical cloth washing is required to enhance the performance of the filter material.

- Trial 02

The trial has shown that the sequence of cloth washing had the desired effect in terms of an enhanced cloth performance and life time. As a next parameter the rest sugar content within the filter cake was observed and it showed that without cake washing the rest sugar content was 41.9 which was not acceptable for the customer and led to an additional test round.

- Trial 03

With the cake washing the rest sugar content of the dried filter cake could be minimized to a level of 2.4 which is not only acceptable, but an improvement to the actual situation.

6. Conclusion

The outcome of the tests showed that 2 units of Lenzing CakeFil each having 29m² of filter area can replace the actual setup of two times plate type precoat filters plus automatic filter for polishing as well as the decanter for the slurry recovery.
Figure 18 shows the existing filtration compared to the Lenzing CakeFil concept in a simplified form.

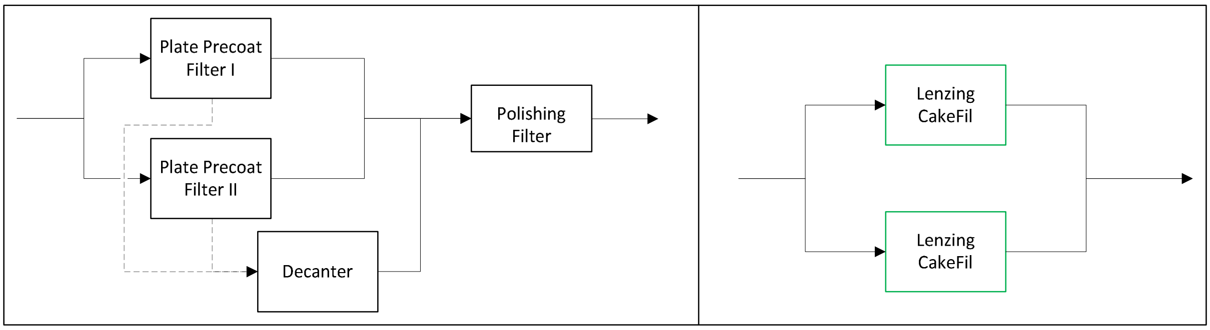

Figure 18: Left: Existing Filtration / Right: Lenzing CakeFil concept

In fact the tests have proven that an existing three stage filtration could be replaced with a single stage. Whilst achieving same levels in terms of quality and even slightly less filter aid consumption and therefore operating cost.

In Table 3 the average time per sequence is shown. One total step sequence takes 155 to 229 minutes whereas the filtration lasts for 120 to 180 minutes. This is a typical plant design with roughly 75% effective filtration and redundant filter vessels to provide reserves in terms of quality as well as capacity.

Table 3: Average time for one step sequence

Sequence	Average Time
Filling	5’
Precoating	15-20’
Filtration	120-180’
Emptying	5’
Cake Washing	3-5’
Cake Drying	2-5’
Cake Discharge	2-5’
Cloth Cleaning (cyclic)	3-4’

i M. Kearney, T. Pryor, L. Velasquez, A. Hieb, B.-C. Schulze; 71st SIT: **A Novel Approach to Raw Cane Sugar Refining using Ion Exchange and Chromatography**

ii S.Schöpf; SIT2015; **Efficiency improvement through unique automatic backwash filter**

iii Thomas E. Sulpizio; 1999; **ADVANCES IN FILTER AID AND PRECOAT FILTRATION TECHNOLOGY**

iv https://www.vulcascot.at/activatedcarbon