From a 10 kg Tailing Sample to Over 10 Years of Disc Filter Operation in a Backfill Plant

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Abstract
The paper describes the design, realization and 10 years of operation of the filtration part of a mine backfill project/operation in Europe. It begins with the first step, the filter sizing based on a sample provided by the customer, followed by the commissioning of the filter units and reports on the development of the filter performance during the following 10 years of operation.

The paper first describes the physical properties of the sample and the process targets of the client for the backfill plant. It shows the logic steps taken in the laboratory to first determine the pressure difference (vacuum) and the filter setting required to reach the moisture target. It further describes how the filtration area gets optimized using flocculant and filter rotational speed while still keeping the moisture below target level. In the last sizing step, the ancillary units such as vacuum pumps were sized based on the test results and finally the performance guarantee was given as well based on these lab test results.

After supply and installation of the filter, the commissioning started. The paper discusses some issues with filter operation during the commissioning phase, possible solutions discussed at that time and final measures that have been taken. Finally, the paper concludes by highlighting the gradual change of the filter feed observed over the more than 10 years of operation and how this change affected filter performance and operating costs.

Key words: CAPEX, OPEX, tailing filtration, vacuum disc filters, backfill, high performance, operation experience

Introduction

The dewatering of tailings has become an increasing focus in the discussion of proper mining operation as well as the decision-making for new operations. Safety hazards, environmental risks and a significant consumption of fresh water are the main topics to be considered. However, most, if not all, of these issues are solved, if tailings are able to be filtered and dry stacked in a TSF (Inci et al., 2023), or backfilled. In case of mine backfill, the main driver for this still-expensive solution is the extra portion of valuable ore to be mined with this technology and not the safety and well-being of the local communities and the environment. Generally, the earnings with the extra ore are far more than the extra cost for the backfill. However, if the life cycle cost of a mine is considered including cost for water, land, carbon tax and mine closure, then the option with tailing filtration become in many cases the option with the lowest cost (Carneiro & Fourie, 2019).

Regardless, the filtration option requires a proper sizing of the backfill plant and its major components as well as the flexibility of these components as the mine operation is expected to last for decades. Figure 1 shows the general design of the backfill plant.

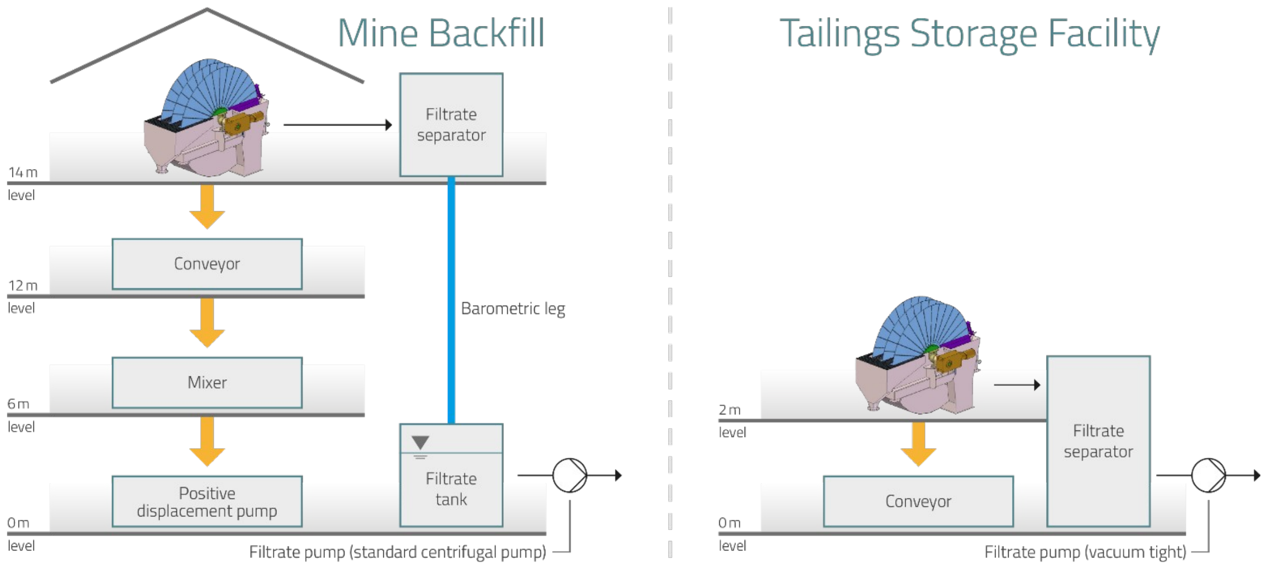

Figure 1. Tailings filtration building requirements.

At the ground level of the building is the positive displacement pump which, if required, is feeding the pipeline that goes to the underground. Above this pump sites the mixer which mixes the filtered solids with cement. The amount of cement required depends on the mineralogy and the particle size of the tailing solids. In most cases some water is added as well to get the right viscosity for pumping. On top is the filter which is fed from the tailing thickener with feed solids, typically in the range of 50–65 %w/w. The duty of the filter is to increase the solids content of the tailings to a good level for mixing in cement and pumping this slurry to the underground. Therefore, the project typically sets a maximum permitted moisture.

Project Data

The first step is the selection and sizing of the filter which has to consider the major project parameters which are as follows:

- Plant location: Eastern Europe
- Type of plant: Gold and copper mine
- Plant elevation: about 500 masl
- Ambient pressure: about 95 kPa
- Total solids throughput: 170 t/h
- Max permitted moisture: 23 %w/w.

The key for a proper sizing of the filtration equipment is a representative sample of the tailings. In many cases the operations are taking samples over a period of several weeks or months and pick three samples, representing the:

- best case for filtration
- nominal case for filtration
- worst case for filtration.

Other plants are taking samples already from areas that will be mined in the next few years and simulate the processing in the lab. This is a good way to prepare for the conditions of tailing filtration in the next few years.

The gold and copper plant provided two samples: nominal and worst case, with worst case expected about 25 % of the time. Therefore, the decision was made to size the filter on the worst case scenario. If the time for worst case filter feed would be ≤ 5 %, it would be valuable to discuss the opportunity to accept higher moisture, less solids throughput or higher amount of flocculant dosage during this limited period of time. But with 25 % of the operation time, such a discussion did not make any sense.

The properties of the sample representing the worst case scenario was as follows:

- d_{20} = 3,6 µm
- d_{50} = 23,1 µm
- d_{80} = 92,4 µm
- solids density: 3,1 t/m³
- pH = 9 …10
- feed solids content: 50 %w/w
- Temperature: ambient

Basic Filter Sizing
All data were available for lab testing. The lab tests were carried out with the BoFilTest rig (Figure 2). A slurry sample was filled into the cylinder and either compressed air was applied to the cylinder (pressure filtration) or vacuum was applied to the outlet of the bayonet bottom. The time required for cake formation was visually detected and the time for drying the cake was varied. Both filtrate flow and air flow were detected and recorded with the computer of the test rig. Testing different amounts of slurry result in a variation of cake thicknesses and was related to different rotational speeds of the filter.

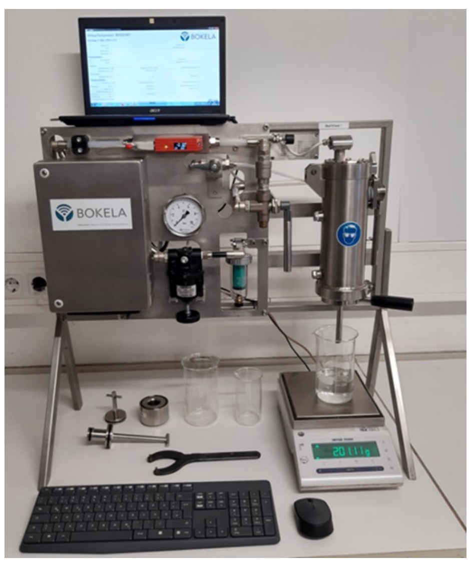

Figure 2. Lab filtration test rig BoFilTest from BOKELA GmbH

The first step in the lab was to confirm whether the target moisture, which was 23 %w/w in this case, could be reached with vacuum or if it required pressure filtration.

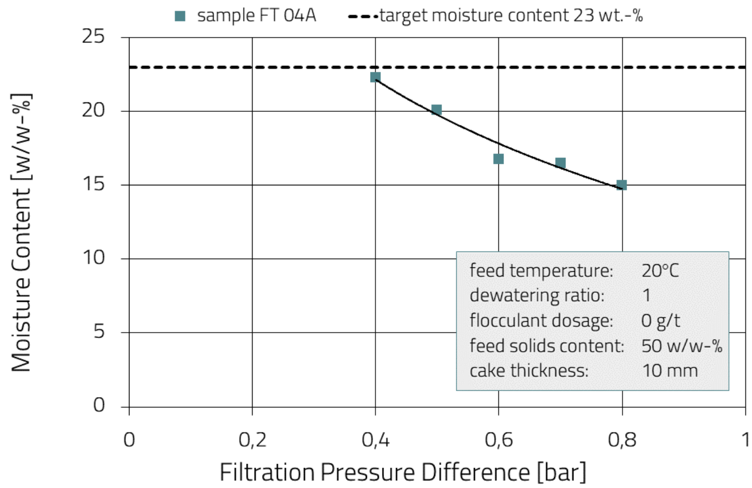

Figure 3. Moisture of filter cake vs filtration pressure difference

Figure 3 shows the moisture of the filter cake plotted vs the filtration pressure difference. Already, 40 kPa were enough to get a moisture better than the maximum permitted moisture of 23 %w/w. Therefore, vacuum filtration was a suitable method to filter the tailings prior to mixing with cement as the following calculation shows:

- Ambient pressure at the plant site is: 95 kPa
- Suction pressure of a standard vacuum pump is: 20 kPa
- Resulting maximum pressure difference of: 75 kPa
- Pressure loss of a modern vacuum disc filter is: 10–20 kPa
- Resulting available pressure difference of: 55–65 kPa

Subsequently, 60 kPa was chosen as the pressure difference (-60 kPa vacuum) for further laboratory testing. Different types of vacuum filters and different suppliers use different filter settings. In order to be able to compare these settings, Figure 4 shows the cake moisture plotted versus the dewatering ratio which is defined as the quotient of the dry time divided by the form time.

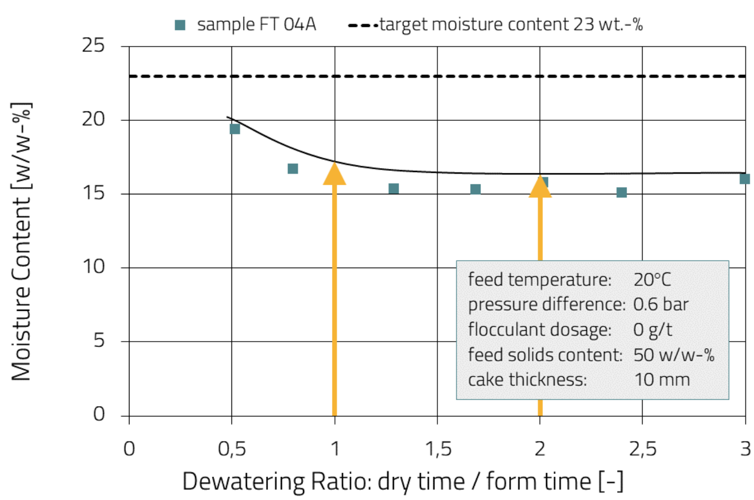

Figure 4. Moisture of filter cake vs dewatering ratio.

Modern vacuum disc filters are designed for maximum solids throughput and run with slurry levels of up to 50 % (Hahn, 2023). This means that half of the filtration area is used for cake formation and the other half for cake drying. This results in a dewatering ratio of 1. Standard vacuum disc filters are designed to minimize manufacturing cost and run with slurry levels of ≤ 35 %. This means that only a quarter of the filtration area is used for cake formation and about half for cake drying. This results in a dewatering ratio of 2. Figure 4 shows that any dewatering ratio > 0.5 will be suitable to achieve the < 23 %w/w moisture.

The final step to filter sizing is the specific solids throughput (Figure 5).

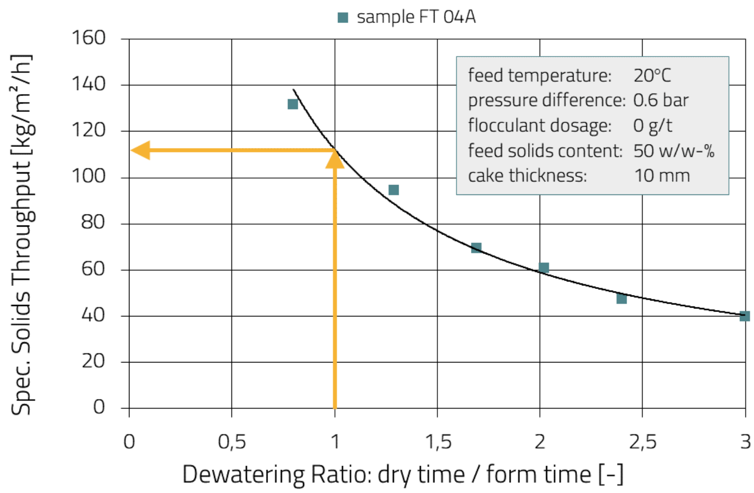

Figure 5. Specific solids throughput vs dewatering ratio.

Figure 5 shows the benefit of modern vacuum disc filters with high slurry level and a dewatering ratio of 1 versus the standard vacuum disc filters with low slurry level and a dewatering ratio of 2. The standard design reaches a specific solids throughput of 60 kg/m²/h while the modern design can obtain up to 110 kg/m²/h. However, for a total of 170 t/h this would result in a requirement of filtration area of 1545 m².

Improved Filter Sizing

To accommodate the filtration area, 9 modern vacuum disc filters with 176 m² each would be required. However, the moisture would be 17.5 %w/w. This leads directly into the optimization of the sizing which can be done by increasing the feed solids (no option as the thickener selection is fixed) or addition of flocculant which normally has a negative impact on moisture.

Figure 6 shows the cake moisture with increasing amount of flocculant added. The results show that with increasing amount of flocculant, the moisture increases. The maximum permitted moisture is 23 %w/w which will be reached at a flocculant dosage of about 90 g/t (based on dry solids). However, later on a safety margin is required with regard to the requirement of a process guarantee. This is why a moisture of 22 %w/w was chosen as the design line. This limited the flocculant dosage to a maximum of 65 g/t.

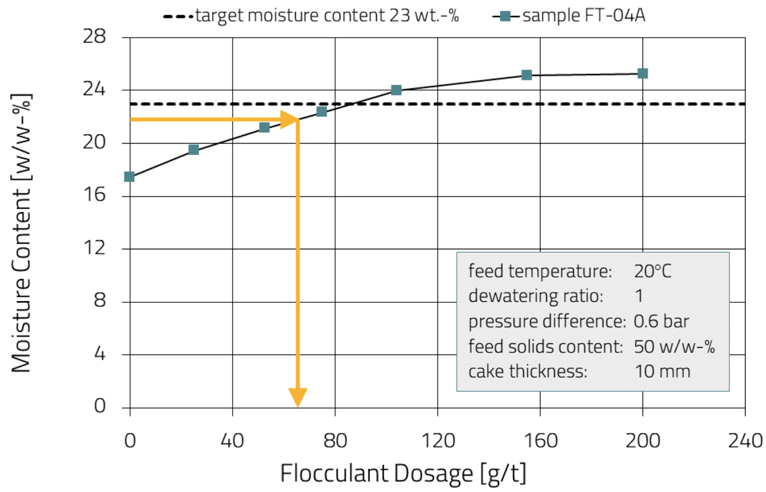

Figure 6. Moisture of filter vs flocculant dosage.

The flocculant addition increased the specific solids throughput from 110 kg/m²/h with 0 g/t flocculant dosage to 520 kg/m²/h with 65 g/t flocculant dosage as shown in Figure 7. For a total solids throughput of 170 t/h this would result in a requirement of filtration area of 327 m² which would require 2 modern vacuum disc filters with 176 m² each, resulting in a very significant reduction in number of filters.

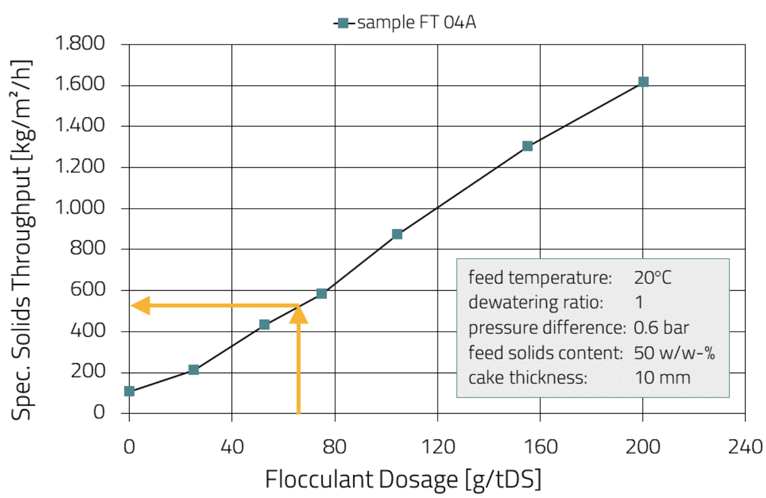

Figure 7. Specific solids throughput vs flocculant dosage

Filter Operation Window

Now the question is what can be guaranteed? For the moisture, the design flocculant dosage was already limited to 65 g/t in order to reach a moisture of 22 %w/w and maintain the 1 %w/w safety margin. Modern vacuum disc filters safely discharge cake with thicknesses down to 7 mm (Kern & Stahl 1986). Figure 8 shows the specific solids throughput plotted versus the square root of the rotation speed. The previous sizing was done on the 10 mm cake thickness. If the filter rotation speed is increased to maintain a 7 mm cake thickness at a speed of about 1.3 rpm (sqrt = 1.14), the specific solids throughput increases to 680 kg/m²/h. The increase in speed provides an additional 30 % more capacity than required for the 170 t/h total solids throughput.

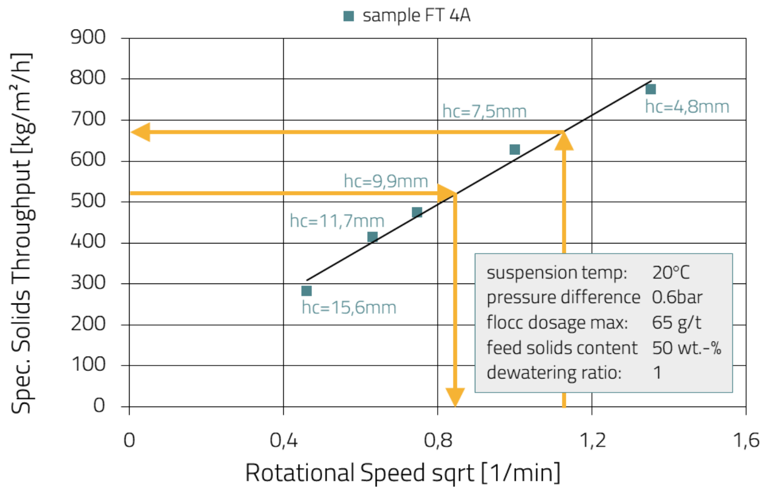

Figure 8. Specific solids throughput vs square root of rotational speed

Process Guarantee Figures
Based on the above, a process guarantee could be given for:

- two modern vacuum disc filters,
- reaching a moisture of 23%w/w or less, and
- at a solids throughput of 170 t/h (on dry basis).

The lab testing was done with the 'worst case' sample and the filter sizing considered a safety margin for moisture as well as for solids throughput which resulted in a very strong and reliable process guarantee.

Ancillary equipment
Finally, it is important to size the auxiliary units vacuum pump and blower. The blow air requirement is dependent on the filter design and the maximum speed only. Therefore, this is independent from the sample. However, the amount of air passing through the cake within the operation window of the filter is important to know.

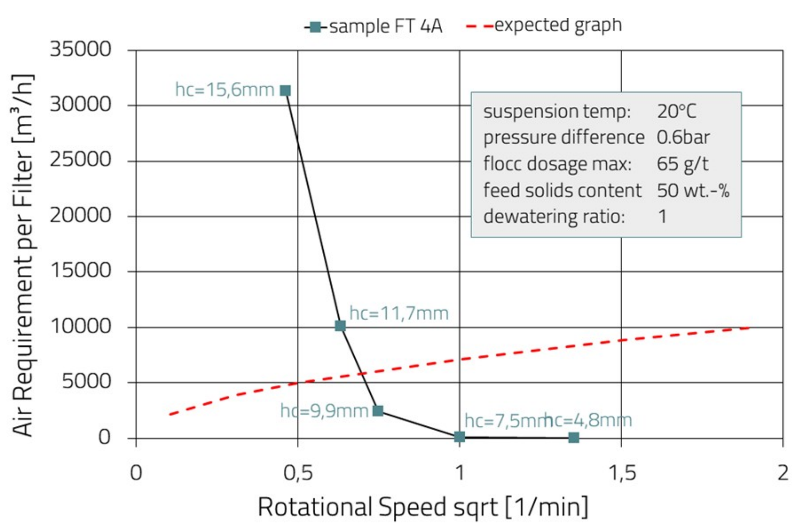

Figure 9. Air requirement per filter vs square root of rotational speed

Figure 9 shows the air requirement of each filter at vacuum pump suction conditions plotted versus the square root of the filter speed. The operation window of the filter is 0.4 … 2.0 rpm (sqrt = 0.63 … 1.41). The red dotted line is showing the expected trend of the air requirement. With increasing rotational speed the cake thickness decreases and the total solids throughout of the filter increases which both results in an increase of the air flow through the cake. But the air requirement measured during lab testing shows exactly the opposite. A detailed investigation revealed that crack formation was observed during the dry time. This resulted in an air bypass which increased with increasing cake thickness. In order to safely maintain a vacuum of -60 kPa (-0.6 bar) within the operation window of 0.4–2.0 rpm rotational speed, a vacuum pump with 13,000 m³/h capacity was chosen for each filter to ensure that there was enough pump capacity available even at the low speed end. Furthermore, the control head design with two ports in the drying zone of the filter was selected as shown in Figure 10. This design enables the operators and/or the filter control to minimize the air bypass in case of crack formation and maintain a high vacuum to ensure target solids throughput and moisture.

Figure 10. Installed filters

Commissioning Phase

Now, the filters were manufactured, the auxiliaries ordered and sent to the mine site for installation. Some months later the plant was ready for commissioning (Figure 9). The filters were equipped with monofilament bags which were used during lab testing. During the first days of commissioning, the amount of filtrate solids was far higher than what was expected from the lab test. Apart from that, the filters were producing 170 t/h solids at a speed of less than 1 rpm at a moisture in the range of 21–22 %w/w. It was decided to change the filter bags to needle felt. It took about two weeks to get a full set of needle felt bags for one filter to site. Immediately after the installation of these bags, the filtrate became clear with < 1 g/l solids and the issue was solved.

Segment Corrosion

After two years of operation the segments showed severe corrosion. During the project design phase, it was decided that with a pH > 10 the use of mild steel for segments and filtrate pipes should be possible to stay within the project budget. This differs from standard MoC (Material of Construction) of stainless steel grade 304 for these parts. As a consequence, regular repair of the segments was required in the third year. In the following years the repair cost rose higher and higher and put an increasing load on the maintenance budget. Therefore, a decision was made in the sixth year to change all segments to stainless steel grade 304.

Change in Particle Size Distribution
In the period of 5–7 yrs after commissioning the filter was building thicker and thicker cakes and the automatic filter control was reducing the speed to almost minimum speed. As a consequence, the operators were reducing the flocculant dosage to the filter step by step and finally did not add any flocculant at all. A filter feed sample was taken and the particle size distribution was measured. This revealed that the median particle size had increased from 25 µm to 40 µm. The nice advantage of this change was the reduction in operation cost by more than Euro 200,000 with the stoppage of flocculant dosage. In addition, the moisture improved by more than 1 %w/w. However, this was not helpful for the process, because the cement mixer requires a minimum moisture and 20–21 %w/w is too low for proper mixing. To accommodate the increased solids concentration, makeup water addition was increased.

Filtrate Pipes
After identifying the segment corrosion, it was expected the mild steel filtrate pipes would eventually experience corrosion as well. Planning could be completed at an early stage for a change to a centre barrel with stainless steel filtrate pipes. One barrel was replaced with a new barrel and the two original barrels were repaired and equipped with stainless steel filtrate pipes (Figure 10). Now the plant maintains a rotating spare barrel which is a cost effective way to minimize the risk of lost production.

Figure 10. Centre barrel with trapezoidal filtrate pipes

Conclusion
Mining operations are designed to run for many years or decades. It is important to do a proper selection and sizing of the equipment during the engineering phase in order to ensure a smooth commissioning and long term operation of the plant. The filter sizing should include a safety margin in order to make sure that the equipment fulfills the process guarantee even if the plant/filter feed experiences variations in feed properties, as mining operations always have.

If CAPEX constraints lead to some compromises in the procurement phase, it is still important to know the possible consequences and to have an alternate plan. This plan should enable the operation to make moderate changes on the equipment/filters selected to rectify the issues. In no way this should require a total change of the type of equipment/filter.

Acknowledgement
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Acronyms

%w/w	percent weight of solids divided by total weight
$d_{20}/d_{50}/d_{80}$	particle diameter
hc	cake thickness
kPa	pressure in kiloPascal
masl	meters above sea level