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Testing, Design, Commissioning and Operation—A Disc Filter Life Experience on a Backfill Plant

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ABSTRACT

The paper reports on both, the design and decision making for the filters in a backfill plant in Europe as well as more then 10 years of operation and maintenance experience of the vacuum disc filters installed. 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.

Based on the physical properties of the sample and the process targets of the client for the backfill plant, the paper shows the logic steps taken in the laboratory to ensure the target moisture, determine the required filtration area and filter size as well as the selection of the ancillary units and the formulation of the performance guarantee.

The paper discusses some issues with filter operation during the commissioning phase and the actions taken. Finally, the paper concludes by highlighting the gradual change over the more than 10 years of operation and how this change affected filter performance and operating costs.

INTRODUCTION

The treatment of tailings has become an increasing attention in the discussion of proper mining operation as well as the decision-making for new operations. Safety hassards, environmental risks and a significant consumption of fresh water are only the main topics to be considered. However, most, if not all, of these issues are solved, if mine backfill is used as the solution for tailing treatment and deposit. Although 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. In any way it 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 is showing the general design of a backfill plant.

At the ground level of the building is the positive displacement pump which is feeding the pipeline that goes to the underground. Above this pump is 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. And 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.

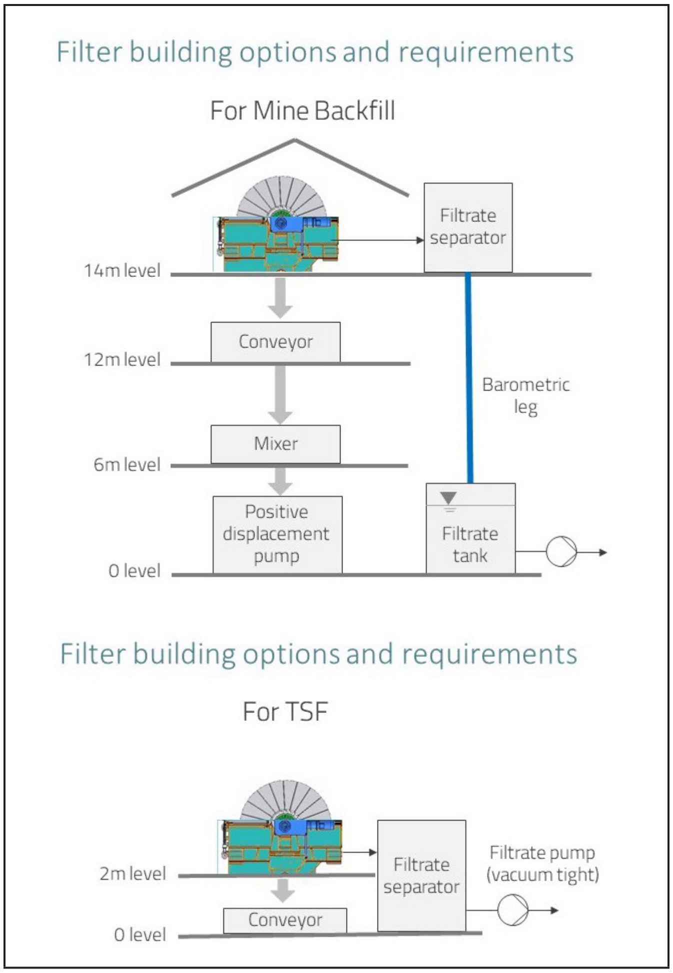

Figure 1. Filter building options for mine backfill and for TSF

TESTING AND FILTER SIZING

The plant operator typically sets a maximum permitted moisture. Accordingly, the first step is the selection and sizing of the filter which has to consider the major project parameters. In the project described here these are as follows:

- Plant location: Eastern Europe
- Kind 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-%

Test Sample

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:

a. a sample representing the best case for filtration,
b. a sample representing the nominal case for filtration.
c. a sample representing the 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 get prepared for the conditions of tailing filtration in the next few years.

The gold and copper plant provided two samples, the nominal case and the worst case. But the worst case was expected during about 25 % of the time. Therefore, the decision was made to do the filter sizing on the worst case scenario. If the time for worst case filter feed would be 5 % or less, it would be valuable to discuss the opportunity of accepting 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 made 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_{20} = 92,4 µm
- solids density: 3,1 t/m^3
- pH = 9 …10
- solids content: 50 w/w-%
- Temperature: ambient

Now all data was available for lab testing.

Moisture content

The first step in the lab is to check whether the target moisture, which was 23 wt% in this case, can be reached with vacuum or does it require pressure filtration.

Figure 2 shows the moisture of the filter cake plotted versus the filtration pressure difference. Already, 40 kPa are enough to get a moisture better than the maximum permitted moisture of 23 w/w%. Therefore, vacuum filtration is a suitable method to filter the tailings prior to mixing with cement as the following calculation shows:

- The ambient pressure at the plant site is: 95 kPa
- The suction pressure of a standard vacuum pump is: 20 kPa
- This results in a maximum pressure difference of: 75 kPa
- The pressure loss of a modern vacuum disc filter is: 10–20 kPa
- This results in an available pressure difference of: 55–65 kPa

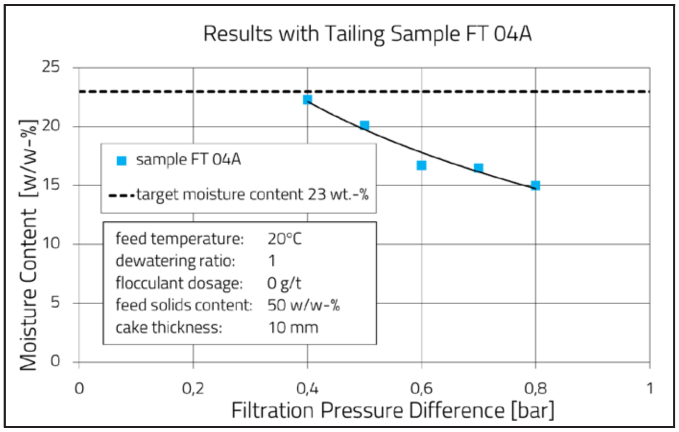

Figure 2. Moisture of filter cake plotted versus filtration pressure difference

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 3 shows the cake moisture plotted versus the dewatering ratio which is defined as the quotient of the cake drying time divided by the cake formation time.

Modern vacuum disc filters are designed for maximum solids throughput and run with slurry levels of up to 50 %. 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 up to 35 %. This means that 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 3 shows that any dewatering ratio <0.5 will be suitable to achieve the <23 %w/w moisture.

Solids Throughput

The final step to filter sizing is the specific solids throughput which is plotted in a Figure 4.

Figure 4 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/m^2/h while the modern design is getting up to 110 kg/m^2/h. However, for a total of 170 t/h this would result in a requirement of filtration area of 1545 m^2. This would be 9 modern vacuum disc filters with 176 m^2 each. 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 is fix) or addition of flocculant which normally has a negative impact on moisture.

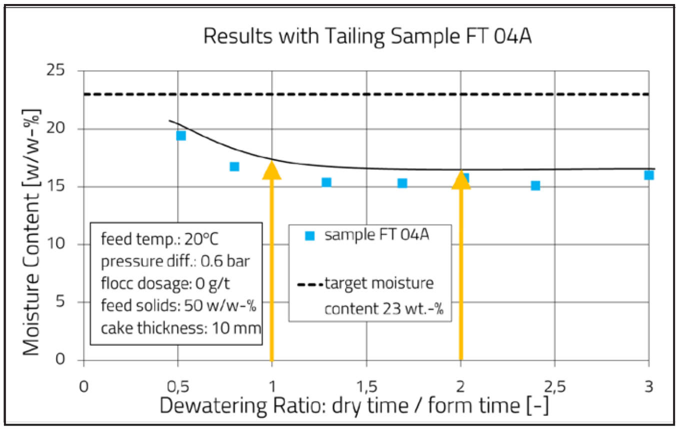

Figure 3. Moisture content vs dewatering ratio (cake drying time / cake formation time)

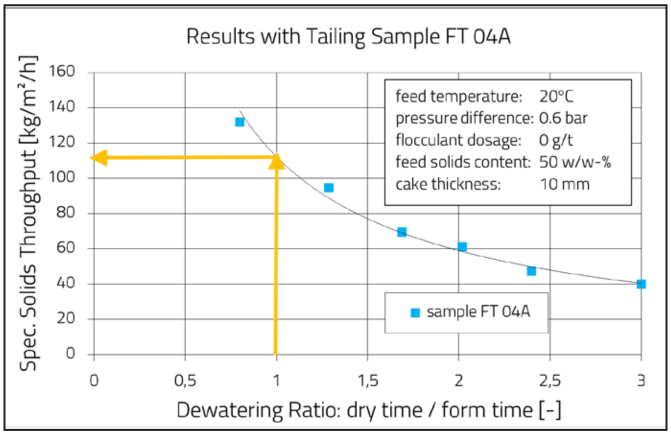

Figure 4. Specific solids throughput versus dewatering ratio

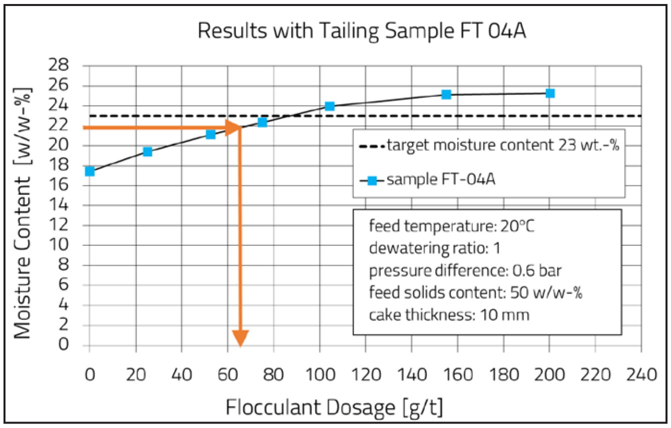

Figure 5. Moisture content of filter cake vs flocculant dosage

Figure 5 shows the cake moisture with increasing amount of flocculant added. And 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

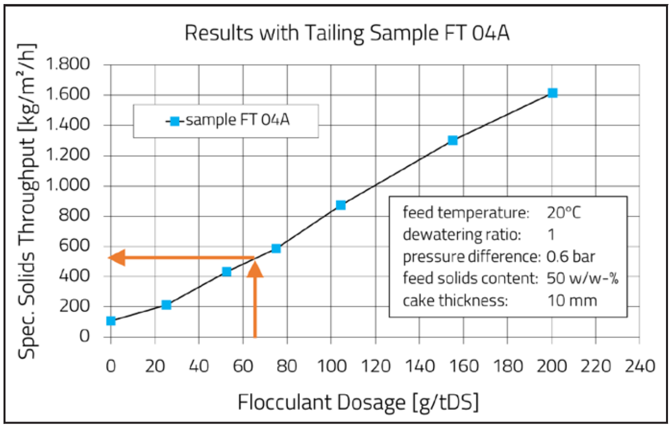

Figure 6. Specific solids throughput vs flocculant dosage

on dry solids). However, later on we need a safety margin when it comes to the process guarantee. This is why a moisture of 22 %w/w is chosen as the design line and only a maximum of 65 g/t flocculant dosage is used.

Nevertheless, this pushed the specific solids throughput already from 110 kg/m^2/h with 0 g/t flocculant dosage to 520 kg/m^2/h with 65 g/t flocculant dosage as shown in figure 6. For a total solids throughput of 170 t/h this resulted in a required filtration area of 327 m^2 what requires only 2 modern vacuum disc filters with 176 m^2 each. This is a very significant reduction in number of filters.

Now the question was what could be be guaranteed? For the moisture, the design flocculant dosage was already limited to 65 g/t in order to reach a moistzure of 22 %w/w and keep the 1 %w/w safety margin. The modern vacuum disc filters are safely discharging cake thicknesses down to 7 mm. Figure 7 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 will be speeded up to reach the 7 mm cake thickness at a speed of about 1.3 rpm (sqrt = 1.14), the specific solids throughput increases to 680 kg/m^2/h. This is 30 % more than required for the 170 t/h total solids throughput.

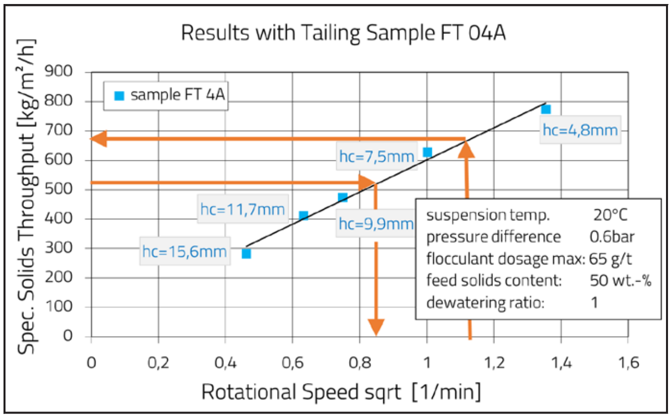

Figure 7. Specific solids throughput versus square root of the rotation speed

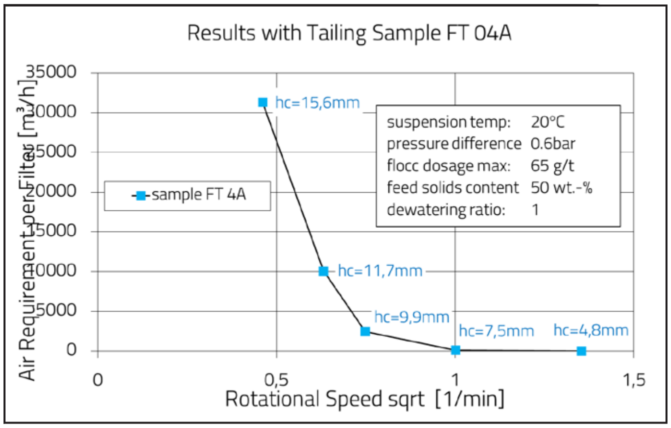

Figure 8. Air requirement of each filter versus square root of the filter speed at vacuum pump suction conditions

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
- at a solids throughput of 170 t/h (on dry basis)

However, this guarantee applied to a tailings sample characterized by specific values of particle size distribution, mineral composition, clay content, feed solids and feed temperature.

Finally, it was important to size the auxiliary units vacuum pump and blower. The blow air requirement is dependant 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 8 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). Therefore, a vacuum pump with 13,000 m^3/h was chosen for each filter to ensure that there is enough pump capacity available over the full speed range.

COMMISSIONING PHASE AND 10 YEARS OF OPERATION

After the filters had been manufactured, the auxiliaries were ordered and were sent to the mine site for installation. Some months later the plant was ready for commissioning as the following photo shows.

Figure 9. View of installed Bovac Disc Filter with 176 m^2 filtration area

Filtrate Solids Higher Than Expected

The filters were equipped with monofilamt 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 reaching 170 t/h 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. This 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.

After Two Years Operation

Segment Corrosion

After two years of operation the segments showed severe corrosion. During decision making it was decided that with a pH > 10 the use of mild steel for segments and filtrate pipes should be possible although the standard MoC is ss304 for these parts. But this was decided to stay within the project budget. In the third year of operation the repair of the segments started as a first step to deal with this issue because of maintenance budget restraints. This repair strategy was continued for almost three years. Then the decision was made to change to ss304 segments.

Filtrate Pipes Corrosion

After the issue with segment corrosion had become aware, it was only a question of time, when this issue will reach the filtrate pipes which were made of mild steel as well. But as this issue was expected to come, the planning could be made at an early stage for a change to a centre barrel with stainless steel filtrate pipes. One barrel was changed to a new barrel and the two original barrels were repaired and equipped with stainless steel filtrate pipes. Now the plant has a rotating spare barrel which is a smart way of minimizing the risk of loosing production.

Figure 10. View of new filter barrel with stainless steel filtrate pipes

After Five Years Operation

Change in Particle Size Distribution

In the period of 5 … 7 years 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 reduced the flocculant dosage to the filter step by step and finally did not add any flocculant. A filter feed sample was taken and the particle size distribution was measured. This revealed that the medium particle size had increased from 25 μm to 40 μm what explained the situation very well. The nice side effect was the reduction in operation cost by more than Euro 200,000 per year with the total stop of flocculant dosage. And, in addition, the moisture improved i.e., reduced 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 propper mixing. Therefore, makeup water addition was increased.

CONCLUSION

Mining operations are designed to run for many years or decades. Therefore, it is important to do a proper selection and sizing of the equipment during the engineering phase in order to ensure a smooth commissioning of the plant. It is important that the filter sizing has some safety margin incorporated in order to ensure that the equipment fullfill the process guarantee even if the plant/filter feed is having some variations as mining operation 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 a plan B. This plan B should enable the operation to do moderate changes on the selected equipment/filters to deal with the issue. In no way this should require a total change of the type of equipment/filter.

Finally, the selected filter should be able to deal with process changes that have to do either with the ore that is processed or the OPEX optimization phase which is an ongoing process over the life time of of the operation.

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The Bond Legacy

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ABSTRACT

Fred C. Bond is recognized throughout the mineral processing world as the father of comminution equipment applied science and engineering. The Bond Work Index became a universal standard, and is the most widely used measurement tool for comminution energy consumption. This biography is the story of his lifetime of study, work experiences, experimentation, analyses and findings. His numerous published writings are reviewed. His legacy is one of comminution process engineering that will be used in perpetuity.

INTRODUCTION

Fred Bond was a strong student; an analyst; an engineer; and a writer. He was also a spiritual thinker, which the writers have concluded contributed importantly to his technical achievements because of the honesty and humility so instilled in him. Bond never allowed his preconceptions to cast doubt on measured data. If there is a primary lesson to be learned from the study of his professional life it is that creating a valuable legacy requires unbiased acceptance of the all the facts.

Bond long struggled with how to measure "size reduction" from one complete size distribution to another, a requirement of relating size reduction to energy input. Rittinger's premise based on new surface area appeared logical, but could not be proven (or dis-proven) with any certainty because of the difficulty of measuring surface area, as well as the undoubtably different efficiencies of different breakage machinery. Taggart's eighty percent passing size was therefore essential to Bond's discovery of his Work Index relationship. However, much of his working life from the time of this major discovery he spent dealing with its limitations and inadequacies, applying "correction factors" and the like. His final publication on the topic of his "Third Theory" literally stunned these writers.

Nevertheless, nothing can diminish the absolute brilliance of a simple equation that empowers process metallurgists to compare any size reduction (machine or circuit) energy usage to any other one on the planet. The Bond standard of the equivalent energy to reduce rock from infinite size to one hundred microns remains the most powerful and wisely used measurement tool in comminution process engineering.

This is a biography of Bond's professional life. He was also a detailed journal keeper and photographer, historian, and theologian. He wrote prolifically on these as well as technical topics, and completed a personal autobiography. The reader is referred to the chronology in the Appendix for a summary of his education and working life