BOKELA

TAILINGS

Capex and opex depending on tailing properties - two case studies

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WHITEPAPER

ABSTRACT

The treatment of tailings is increasingly becoming the focus of discussion and decision-making in mining operations. Safety hazards, environmental risks and huge fresh water consumption are just the main topics that are discussed. And most if not all of the problems could be solved, if the tailings were dry stacked and most of the water was recycled back into the process. However, this is not for free and results in significant CAPEX and OPEX.

Many experts consider filtration with filter presses to be the solution when it comes to enabling dry stacking. From a process perspective, there is nothing wrong with this answer. However, the CAPEX and OPEX of filter presses are the highest compared to most other options. For the South American mega tailings projects with capacities of 100 000 t/d to 200 000 t/d and above, the capital expenditure for filter presses exceeds the margin of 1 000 000 000 US$. It is therefore important to take a closer look at the filtration equipment required for safe dry stacking.

The paper presents two case studies with different outcome and discusses the reasons for the different results. Case Study 1 is for a „fine" tailing with 35 % w/w (weight/weight) < 10 micron and requires pressure filtration to achieve the moisture required for dry stacking. Case Study 2 is for a „coarse" tailing with 15 % w/w < 10 microns. High-performance vacuum disc filters achieve the moisture required for dry stacking. Switching from filter presses to high-performance vacuum disc filters reduces capital costs from over 1 000 000 000 US$ to less than 300 000 000 US$ as shown in Case Study 2.

INTRODUCTION

The treatment of tailings has become more and more the focus of decision-making for new mining projects as well as for existing operations. Safety hazards, 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 tailings are filtered and dry stacked in a TSF (tailings storage facility) (Inci et al. 2023). This requires a certain moisture of the filtered tailings. On the one hand to ensure, that liquefaction does not occur on the conveyor belt on the way to the TSF. And on the other hand, to meet all geotechnical requirements for stable and safe dry stacking (McKenna 2023). The moisture required depends on the properties of the tailings, mainly particle size, but also on the chemical and mineralogical composition like clay content. When a project starts with the conceptual study most of this data is not known and there are many assumptions at this stage. One of these assumptions is that the moisture should be no more than 15 % w/w. This goes hand in hand with the opinion, that filter presses will get this 15 % w/w moisture. And subsequently filter presses as shown in Figure 1 are used as the filtration solution in the conceptual studies and in the pre-feasibility studies.

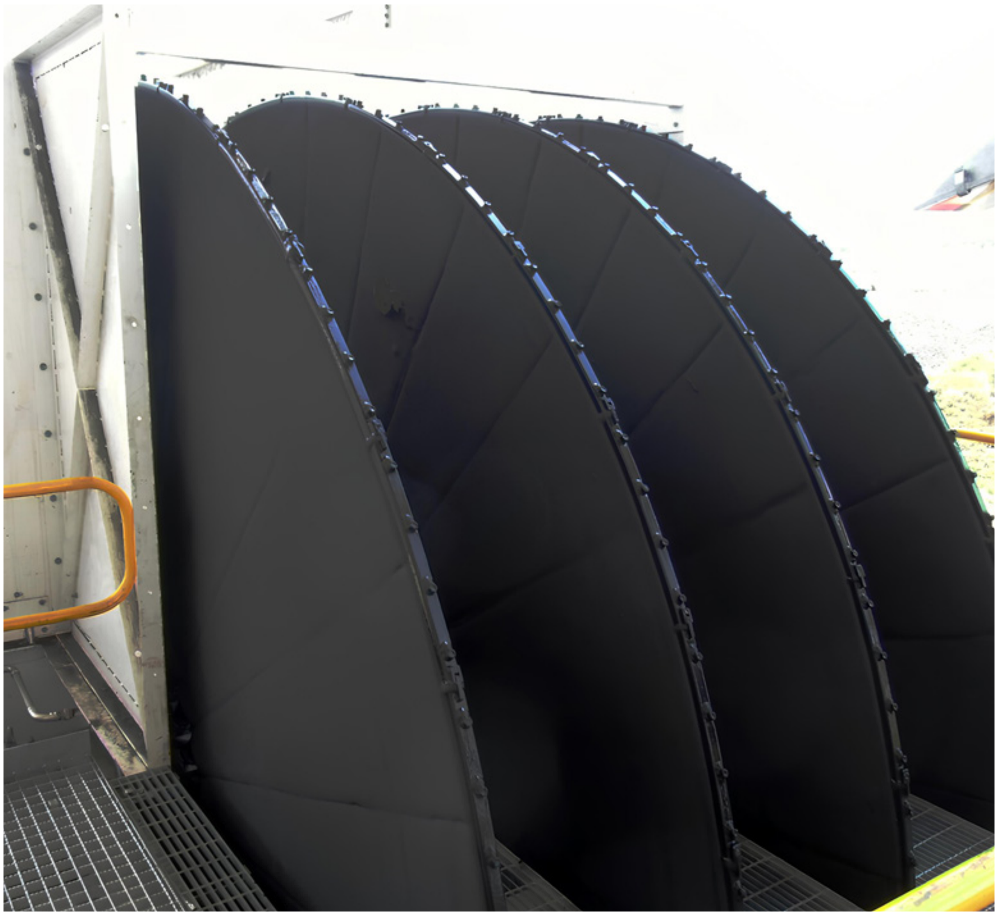
During the conceptual study phase of the project, this is certainly the right way to proceed. First, there is very little risk, that a filter press will not get to the 15 % w/w moisture. Second, this minimizes the time required to get to a study result. However, at the feasibility study stage it is of high importance to take a wider look on dewatering equipment that might be suitable for tailings filtration.

Figure 3

View on a filter press

Figure 2

High-performance vacuum disc filter



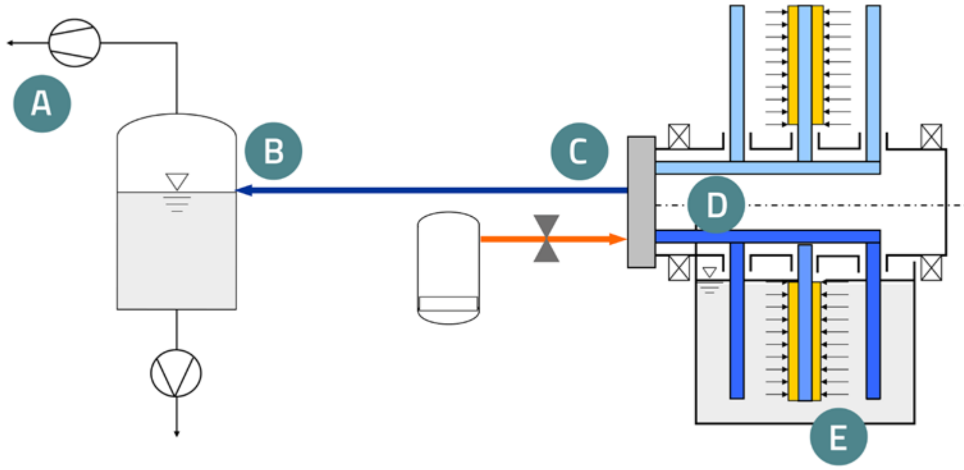
HIGH-PERFORMANCE VACUUM DISC FILTERS

For tailing filtration in mine backfill applications the use of vacuum disc filters, both standard design and high-performance design, is common practice. It can be argued that the moisture requirement for mine backfill is in the low 20s as the tailings are typically mixed with cement and for this step the proper moisture is in the range of 20 % w/w to 25 % w/w.

But modern vacuum disc filters, so called „high-performance vacuum disc filters" as shown in Figure 2, are designed for maximum solids throughput and run with much higher slurry levels (up to 50 %) compared to standard vacuum disc filters. This means that half of the filtration area is used for cake formation and the other half for cake drying while standard vacuum disc filters use only 25 % of the area for cake formation. Furthermore, high-performance vacuum disc filters (Hahn 2023) are designed to minimize pressure losses by using trapezoidal filtrate pipes, pre-separation control heads, high perforated filter segments and online cloth wash. While standard vacuum disc filters get about half of the vacuum (-30 kPa to -45 kPa) at the filter cake compared with the -80 kPa provided by the vacuum pump as Column E in Figure 3 in line „Standard disc" shows, high-performance vacuum disc filters still get about 90 % of the vacuum (-65 kPa to -75 kPa) at the filter cake compared with the -80 kPa provided by the vacuum pump (see line „HPDF Tec").

Figure 3

Pressure drop on standard disc filters and on high-performance vacuum disc filters (HDPF)



Vaccum at	Standard Disc	HPDF Tec
A - Vacuum Pump	-80 kPA	-80 kPa
B - Receiver Inlet	-70 ... -75 kPA	-78 ... -79 kPa
C - Control Head	-55 ... -65 kPA	-74 ... -78 kPa
D - Segment Outlet	-45 ... -55 kPA	-70 ... -76 kPa
E - Filter Cloth	-30 ... -45 kPA	-65 ... -75 kPa

And this has a major impact on solids throughput as well as on cake moisture. The diagram in Figure 4 shows the moisture of a tailing sample filtered at different vacuum levels.

The standard vacuum disc filter provides a vacuum of about -40 kPa (-0.4 bar) at the filter cake and thus the moisture will be 22 % w/w. Due to the reduced pressure losses of the high-performance vacuum disc filters, it provides a vacuum of about -70 kPa (-0.7 bar) and thus a moisture of 16.5 % w/w. This is more than 5 % w/w points less moisture than the standard design disc filters. Therefore, it is recommended to consider high-performance vacuum disc filters as an option for tailings filtration in the case of dry stacking.

Figure 4

Moisture vs active pressure difference at the filter cake

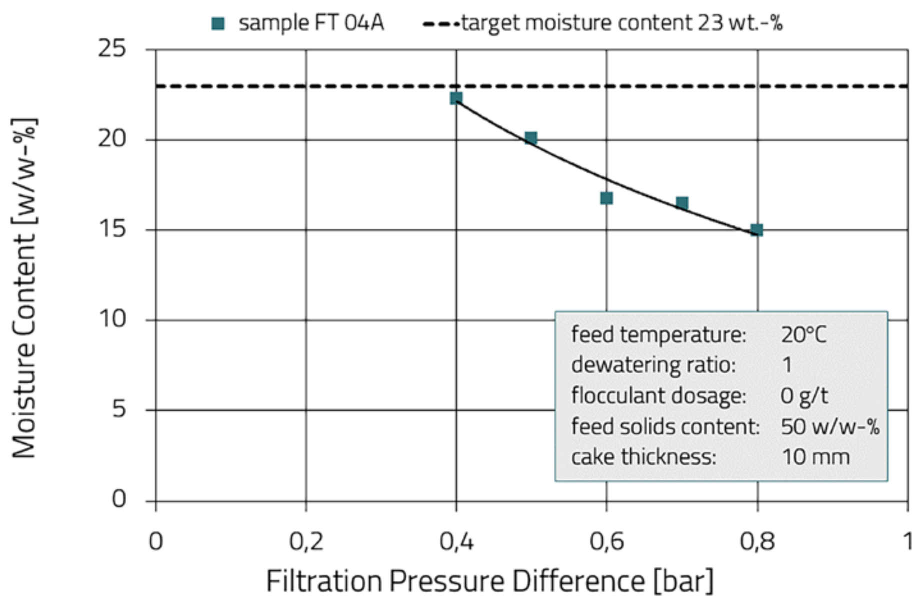
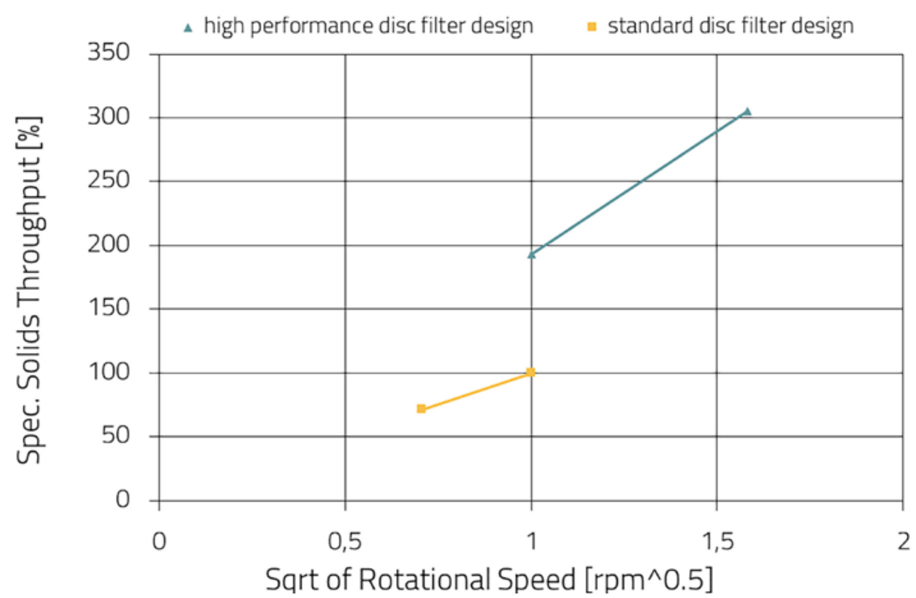


Figure 5

Specific solids throughput vs rotational speed



But not only the moisture is significantly improved on high-performance vacuum disc filters, also the solids throughput will more than double per 1 m² filtration area. A brief look into the filtration theory will explain why.

$$M_S = m_S \cdot A_f = \rho_S(1-\varepsilon) \cdot \sqrt{\frac{2}{\eta_L r_C}} \cdot \sqrt{\kappa} \cdot \sqrt{\Delta p} \cdot \sqrt{\frac{n}{60}} \cdot \sqrt{\frac{\alpha_1}{360°}} \cdot A_f \cdot 3\,600 \qquad (1)$$

The above formula calculates the solids throughput of a rotational filter. The main differences bet-ween a standard vacuum disc filter and a high-performance vacuum disc filter are shown in Table 1.

Table 1

Differences between a standard vacuum disc filter and a high-performance disc filter

	Unit	Standard Disc Filter	High Performance Disc Filter
Maximum cake formation angle	[°]	90	180
Pressure difference at the cake	[kPa]	37.5	70
Rotational speed	[rpm]	0.5 – 1.0	1.0 – 2.5

The standard disc filter at its maximum rotational speed is used as the base line for the specific solid throughput in Figure 5. According to filtration theory, the pressure difference at the filter cake, the rotational speed of the filter and the cake formation angle all increase the solids throughput in relation to their square root. If the figures of Table 1 for the high-performance vacuum disc filter design are used, then the maximum solids throughput of the high-performance vacuum disc filter design will be 305 % compared to the 100 % of the standard vacuum disc filter design. In other words, a project needs only a third of the filtration area if high-performance vacuum disc filters are used instead of standard vacuum disc filters.

These high-performance vacuum disc filters are available with sizes up to 352 m^2 filtration area. And with the moisture improvements and solids throughput increase shown above, they are challenging filter presses for the filtration of tailings to be deposited in TSFs.

CASE STUDY FOR PROJECT 1

The treatment of tailings gets an increasing importance, if the metal content in the ore is low and if the production of concentrate is high. Both conditions fit very well to copper mining and processing in South America. Two projects were chosen for case studies. In both cases, 150 000 t/d of tailings need to be filtered. However, the characteristics of the tailings are different as shown in Table 2. While the tailings of Project 1 were quite fine with 35 % w/w < 10 micron plus a high clay content, the tailings of Project 2 were coarser with 15 % w/w < 10 micron and a low clay content. Furthermore, the 94 kPa ambient pressure of Project 2 at an elevation of 600 masl was also preferable for vacuum filtration.

Table 2

Data of tailings of two mega tailings projects in South America

	Unit	Project 1	Project 2
Particles < 10 micron	[% w/w]	35	15
Clay content	-	high	low
Target moisture	[% w/w]	12	15
Plant elevation	[masl]	1 000	600
Ambient pressure	[kPa]	89	94

The filtration data of Project 1 for both high-performance vacuum disc filters and filter presses are known and plotted in Table 3. Now, the biggest units available on the market are used for the comparison. While the filter presses benefit from the high pressure and the huge filtration area, the high-performance vacuum disc filters benefit from the short cycle time, the much thinner cake that can be discharged and the continuous operation (Kern & Stahl 1986). Taking all these aspects into account, the following performance data results for 150 000 t/d tailing filtration as shown in Table 3.

Table 3

Performance data of HPDF and filter press for 150 000 t/d tailing filtration

	Unit	High Performance Disc Filter	Filter Press
Total solids throughput	[t/d]	150 000	150 000
Moisture target / moisture reached	[% w/w]	12.0 / 19.5	12.0 / 14.5
Total filtration area of filter	[m²]	352	2 800
Solids throughput per filter	[t/d]	3 275	8 050
Filters operating / installed	-	46 / 50	19 / 22
Energy requirement per filter	[kW]	310	750
Total energy requirement per year	[MW/y]	124 900	124 800
Flocculant dosage	[g/t]	0	0

The moisture target for dry stacking on TSF is 12 % w/w. Both filter types are not able to reach this target. Therefore, it is required to spread the tailings on the TSF and let it air/sun dry till the final moisture for safe dry stacking is reach. The moisture difference in case of press filters is 2.5 % w/w and 7.5 % w/w for the vacuum disc filters. Therefore, the area for spreading and drying is three times larger for the vacuum disc filters compared to the press filters. If the TSF has enough surface area, then both filtration technologies can be used and the OPEX and CAPEX calculation can be done on the basis of the filtration equipment.

CASE STUDY FOR PROJECT 2

The moisture target for dry stacking on TSF is 12 % w/w. Both filter types are not able to reach this target. Therefore, it is required to spread the tailings on the TSF and let it air/ sun dry till the final moisture for safe dry stacking is reach. The moisture difference in case of press filters is 2.5 % w/w and 7.5 % w/w for the vacuum disc filters. Therefore, the area for spreading and drying is three times larger for the vacuum disc filters compared to the press filters. If the TSF has enough surface area, then both filtration technologies can be used and the OPEX and CAPEX calculation can be done on the basis of the filtration equipment.

Table 4

Performance data of HPDF and filter press for 150 000 t/d tailing filtration

	Unit	High Performance Disc Filter	Filter Press
Total solids throughput	[t/d]	150 000	150 000
Moisture target / moisture reached	[% w/w]	15.0 / 14.5	15.0 / 12.0
Total filtration area of filter	[m²]	352	2 800
Solids throughput per filter	[t/d]	6 140	12 230
Filters operating / installed	-	25 / 28	13 / 15
Energy requirement per filter	[kW]	572	900
Total energy requirement per year	[MW/y]	125 160	102 500
Flocculant dosage	[g/t]	0	0

OPEX FOR PROJECT 2

The operational expenditures (OPEX) of a filtration project are the sum of the main factors:

- energy consumption
- filter aid consumption
- fresh water consumption
- consumables (mainly filter cloths)
- operational and maintenance staff
- spare parts

Table 5 lists the technical data required to calculate the operational expenditures for both filter types. The total energy consumption for the filtration of 150 000 t/d tailings was already listed in Table 4 and is now repeated in Table 5. The energy cost used for the calculation is 0.08 €/kWh. The total energy consumption of the high-performance vacuum disc filters is higher with 125 200 MW/y than the requirement of 102 500 MW/y for the filter presses. This is in line with the results known from other commodities like coal (Hahn & Elsmore 2023) where the energy consumption of vacuum filtration is higher compared to pressure filters, when the target moisture is close to the minimum moisture achievable with vacuum.

Table 5

OPEX calculation of Project 2

No filter aids were used.

		Unit	High Performance Disc Filter	Filter Press
	Total solids throughput	[t/d]	150 000	150 000
	Moisture target / moisture reached	%-w/w	15.0 / 14.5	15.0 / 12.0
	Total filtration area per filter	m²	352	2 800
	Solids throughput per filter	t/d	6 140	12 230
	Filters operating / installed	-	25 / 28	13 / 15
Energy	Energy requirement per filter	[kW]	572	900
	Total energy requirement per year	[MW/y]	125 160	102 500
	Total energy cost per year	[€/y]	10 012 700	8 199 360
Filter aid	Flocculant dosage	[g/t]	0	0
	Total filter aid cost per year	[€/t]	0	0
Consumables	Number of cloth changes per year	-	6	8
	Quantity of cloths per filter	-	180	560
	Cost per filter cloth	[€]	50	300
	Cost per filter per year	[€]	54 000	1 344 000
	Total cost of cloths per year	[€/t]	1 350 000	17 472 000
Spare parts	Cost per filter with auxiliaries	[€]	40 000	260 000
	Total cost of spares per year	[€/y]	1 000 000	3 380 000
	Total OPEX	**[€/y]**	**12 362 700**	**29 051 360**

The water consumption differs for the two filter types. Each high-performance vacuum disc filter consumes about 1 m³/h water for cloth wash plus an additional volume of the same range for make up water for the vacuum pump seal water circuit. But the exact volume depends on the circuit design and whether heat exchange or a cooling tower is used to reduce water temperature. Typically, each filter press requires 145 m³/h of process water. For the purposes of this case study the OPEX calculation and comparison is based on the use of recycled water so the water cost is taken as zero.

The required man hours of operational and maintenance staff could not be determined in such details as to use it in this comparison. Also, the cost of spare parts is calculated on the basis of 2 % of the investment cost for both filters and auxiliary units.

In summary, it can be stated that the operational expenditures for Project 2 will be 29 051 360 € for the filter presses compared to 12 362 700 € for the high-performance vacuum disc filters. This means that the filter presses require almost 2.5 times the OPEX compared to high-performance vacuum disc filters. This is mainly based on the high cost for consumables and spare parts. Considering the experience from running plants, it is expected, that the water consumption and the personnel requirement of the filter presses will be higher, which will consolidate the above difference in OPEX.

CAPEX FOR PROJECT 2

Again, the biggest available filters on the market were used for the case studies of both projects. As both are relatively new on the market the price basis is not as firm as it is for smaller units. Furthermore, the political turbulence in the last two years following the corona period have led to significant increases of energy and metal cost, the increase of inflation rates, difficulties in supply chains, etc. Therefore, the CAPEX figures for Project 2 will have an accuracy of no better than ± 25 %. Nevertheless, this does not have a big influence on the final outcome as Table 6 shows.

The cost for the fifteen filter presses required for the 150 000 t/d tailing filtration is 195 000 000 € compared to the 56 000 000 € for the 28 high-performance vacuum disc filters. This is the filtration equipment with auxiliaries only. If the filter building, the piping, cabling, electric and electronic equipment, the engineering, construction and commissioning is included, these figures have to be multiplied with a factor in the range of 2.5 to 3.5. This means the turn-key cost will be in the range of 140 000 000 € to 196 000 000 € for the high-performance vacuum disc filters option and 487 500 000 € to 682 500 000 € for the filter press option. And because both filter types provide a cake with a moisture of < 15 % w/w, both filter types are suitable and acceptable for the project. But the project can save 347 500 000 € to 486 500 000 € with the vacuum filter option.

Table 6

Performance data of Project 2

	Unit	High Performance Disc Filter	Filter Press
Total solids throughput	[t/d]	150 000	150 000
Total filtration area of filter	[m²]	352	2 800
Number of filters in operation	-	25	13
Number of filters installed	-	28	15
Cost per filter including auxiliaries	[€/unit]	2 000 000	13 000 000
Total equipment cost	[€]	56 000 000	195 000 000

CONCLUSION

The importance of tailings filtration as the right tool to reduce safety hazards, environmental risks and fresh water consumption will become an increasing factor for the prolongation of mining operations and the permission for new processing plants. But the investment cost as well as the operational expenditures for tailing filtration are huge and make the owner think twice about deciding to take this step. However, a closer look onto the characteristics of the tailings and their filtration properties may offer alternative filtration technologies such as high-performance vacuum disc filters that will reduce both CAPEX ad OPEX. Certainly, the door opener is the condition that the tailings characteristics are as such as to get the target moisture with the vacuum filters. This can be checked with lab testing at an early stage with very little cost impact. And, if this confirms the use of high-performance vacuum disc filters for the project, then the project can profit from the far lower CAPEX and OPEX if going ahead with high-performance vacuum disc filters. And this can make the difference of a project to be feasible and going ahead or not.

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