

**PILOTING OF THE ISHIGAKI FIBRE-WAKISHIMIZU (Fibre
Media Rapid Filtration Equipment) AT SKORPION ZINC**

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Summary

The quality of Pregnant Leach Solution (PLS) at Skorpion Zinc is of utmost importance for efficient operation of the Solvent Extraction (SX) Plant. Suspended solids in the PLS forms CRUD in the settlers, resulting in reduced zinc transfer capacity and increased impurity carry over to Electrowinning.

The Ishigaki Fibre-Wakishimizu filter (fibre media rapid filtration equipment) has been identified as polishing filter that potentially could remove solids from the PLS of Skorpion Zinc. A pilot unit with 20m³/h capacity was tested on site over a period of 9 months under plant operating conditions in the refinery.

The FW filter produces a clear filtrate, acceptable for the Solvent Extraction. Turbidity is improved by 72%. Gravimetric analysis indicates a 47% removal of solids. However, the gravimetric method is biased by a co-precipitation of saturated salts during the analysis.

Filter media is blinded by the Skorpion Zinc PLS solution, as result of suspended solids and process chemistry. The media could not be regenerated to acceptable conditions. Further testwork to investigate the impact of process solution chemistry modification on blinding is undertaken. Based on the outcome of this investigation a final decision on the FW filter can be taken.

1 Introduction

The quality of Pregnant Leach Solution (PLS) at Skorpion Zinc is of utmost importance for efficient operation of the Solvent Extraction (SX) Plant. Suspended solids in the PLS forms CRUD in the settlers, resulting in reduced zinc transfer capacity and increased impurity carry over to Electrowinning. Due to this, Technicas Reunidas (TR) had the harsh specification of an average of 10 mg/l and a maximum of 25 mg/l suspended solids in the PLS reporting to SX.

Sand filters, installed as part of the design, proved to be unsuitable to polish the Skorpion Zinc PLS. Gypsum formation on the sand media resulted in blocking of the media. A Larox polishing belt filter has also been piloted at Skorpion Zinc without success. The cloth blinded over a short period and could not be restored to original condition to maintain throughput rates. A pilot GL&V reactor clarifier proved inefficient due to extremely low rise rates (<1m/h) required to efficiently remove suspended solids. Focus has returned to thickener operations to improve clarity to remain consistently below 100 mg/l with an average between 60 and 80 mg/l.

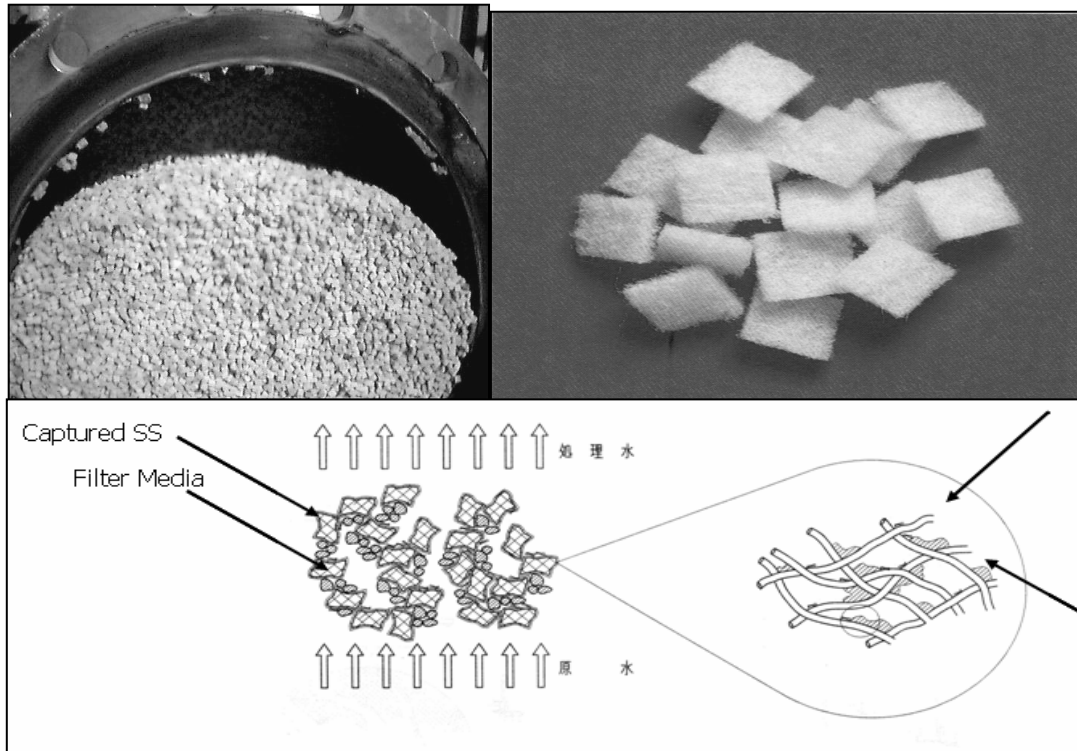
The Ishigaki Fibre-Wakishimizu filter (fiber media rapid filtration equipment) has been identified as polishing filter that potentially could remove solids from the PLS of Skorpion Zinc. A pilot unit with 20m³/h capacity was tested on site over a period of 9 months under plant operating conditions in the refinery. This report will summarise the most important findings of the testwork.

2 The Fibre-Wakishimizu Filter – principles of operation

The Fibre Wakishimizu (FW) filter is distinctly different from typical filters. Firstly the media used for filtration and secondly the agitation introduced during the backwash / cleaning cycle are unique features of the filter that enhances performance. The media is a fine woven polyethylene that is produced in 5 X 5 mm blocks. Figure 2.1 illustrates the media used in the filter. The filter media has a 94% open area and is heat treated for prolonged use.

The filter media fills 50% of the filter volume. During normal operation, flow through the unit is upward. The bed is compressed on the upper half of the filter during this filtration cycle. Differential pressures over the unit vary from 40 to 80 kPa. Flow rate to the pilot unit is manually controlled by adjusting the feed valves. Flow control on industrial units will be done automatically by control valves and online flow meters. When the maximum differential pressure is reached, the unit is put into backwash mode. The first step is to close all flow through the unit as illustrated in Figure 2.2. An agitator installed at the bottom of the unit will start and agitate to loosen the bed. After one minute, backwash solution will be feed in from the top and exit the filter at the bottom while the agitator is still turning to rinse out solids from the filter media. This ensures that solids that have caked around the media is efficiently removed.

Figure 2.1: Fibre Media



Feed solution or clean filtrate can be used as backwash solution. Backwash is continued till the outlet solution reached the same clarity as the inlet solution, indicating that all solids have been removed. The unit is then put on filtration mode again. Figure 2.3 illustrates the construction and layout of the FW filter.

Figure 2.2: Operating sequence

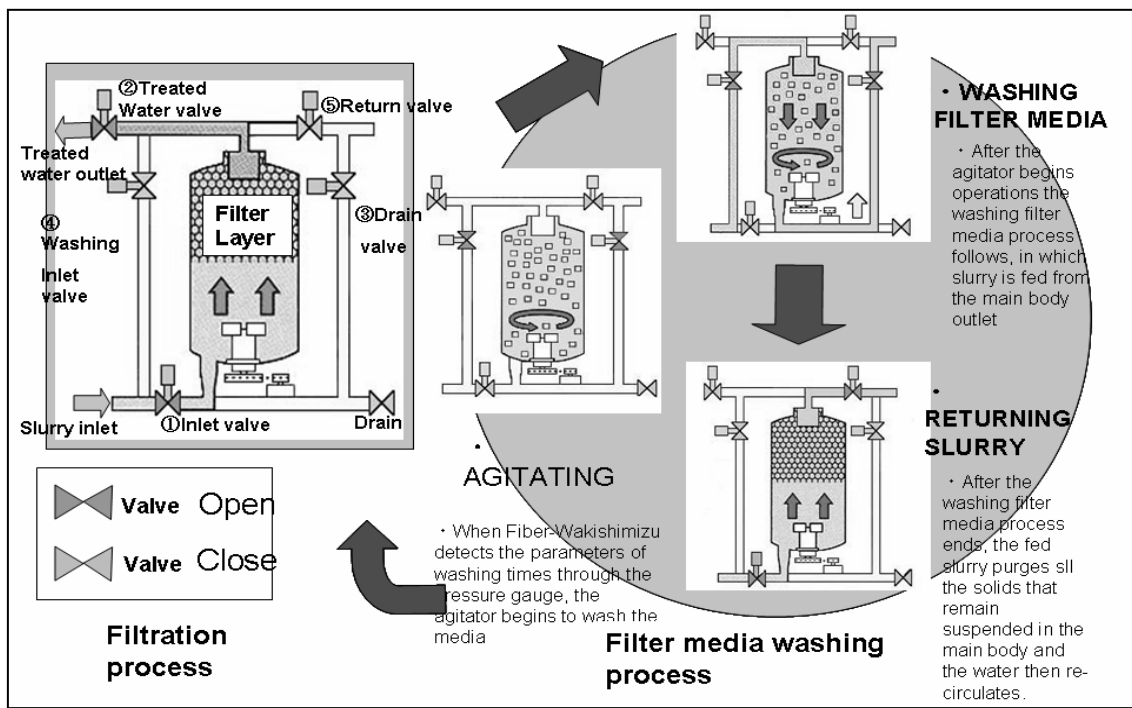
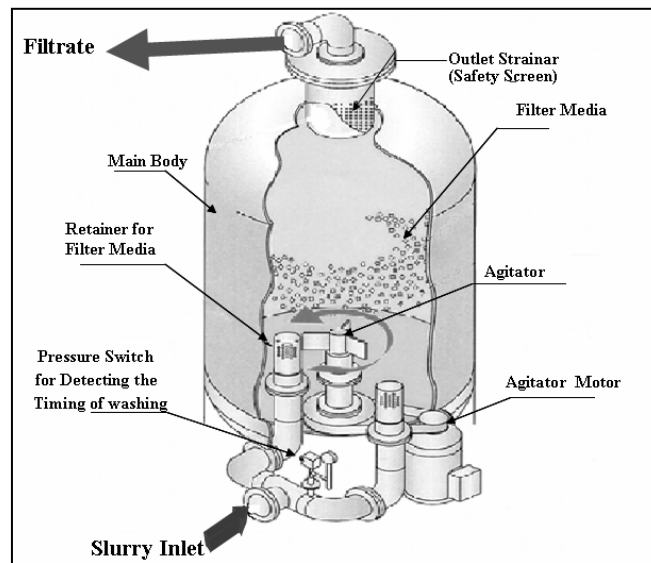


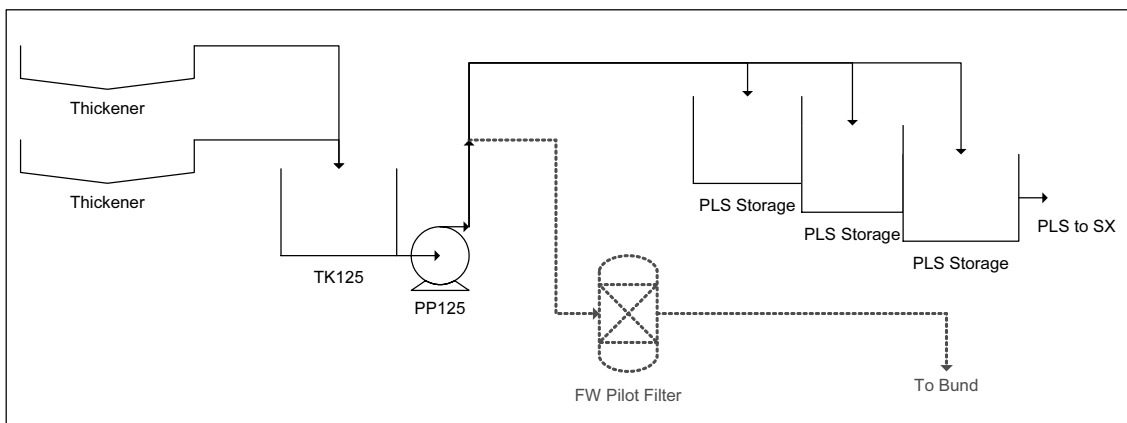
Figure 2.3: FW construction



3 Experimental set-up

Neutralisation thickener overflow (PLS) was used as feed to the FW filter. The connection was made on the thickener overflow (D03PG125) pump discharge. PLS solution was also used to backwash the filter. Filtrate was routed to the sump pumps and recycled back into the process. Figure 3.1 illustrates the process flow and location of the FW filter.

Figure 3.1: Process flow and setup of FW filter



The filter was operated on a continuous base, Monday to Friday and seven days per week from Jan 2007. Flow rate to the unit was manually controlled by adjusting the feed valve to the filter. Initially, flow rate was determined hourly by manual measurements of time it takes to fill a 200 liter tank. Later in the campaign, feed rate was controlled by a flow meter and automated control valve to make operations easier. Feed pressure and a turbidity measurement of the feed solution and filtrate solution were

taken and logged hourly over the entire campaign. A portable Hach 2100 (Catalogue Number 46500) meter was used for the turbidity measurements.

Exploratory testwork was conducted in April 2006 (Run 1 – 30) to prove viability. The pilot plant was brought back to Skorpion for an extended campaign, from September 2006 till June 2007 (Run 31 to 391) to evaluate performance of the media for an extended period.

Exploratory testwork was conducted to determine the cycle and backwash times of the filter. During this period, hourly samples of the feed and discharge solution was taken and submitted to the Skorpion Zinc laboratory for determination of suspended solids (measured in mg/l) by a gravimetric method [4]. After a cycle time of seven hours was established, the unit was run for an extended period with 7 hour cycle times and 20 minute backwash times (Run 31 – 104) to observe performance under plant conditions. During this extended period and onwards, a composite sample of the feed and discharge was taken for suspended solids analysis.

Short cycles and high feed pressures were experienced in run 86 to 104. The operating philosophy was changed (from run 105) to backwash the filter when inlet pressures reaches 120 kPa. This will prevent the unit to be operated at elevated feed pressures for long periods.

Figure 3.2: Pilot FW filter used for testwork



Testwork was also conducted to investigate performance at varying flow rates in the range from 10m³/h to the design rate of 20m³/h. At lower flow rates, the bed will be less compact and performance under this condition needs to be evaluated. Flow through industrial filters will vary due to flow requirements from the plant.

Industrial units will be installed after the newly commissioned buffer ponds. The ponds will add additional retention time that could possibly cause the PLS solution to age. After run 283 the feed was taken from solution after the ponds to determine the performance of the filter under this condition.

4 Results and Discussion

4.1 Solids removal

Two methods used for analysis of performance were turbidity and gravimetric analysis. Turbidity is a measure of how much of the light traveling through solution is scattered by suspended particles. The scattering of light increases with increasing suspended solids content. A turbidimeter measures this scattering of light, and provides a relative measure of turbidity expressed in Nephelometric Turbidity Units (NTU). Because turbidity is primarily influenced by total suspended solids, the factors affecting TSS will also affect turbidity.

Turbidity measurement was added as technique to evaluate performance of the filter as TSS results have been observed to be variable in previous test campaigns. Results are influenced by a co-precipitation of solids during the filtration step [1]. Solution chemistry and ageing of solution also affects results significantly. Ageing of solution over a period of 12 hours could increase the measured suspended solids by 15% to 100%. The extent to which solution chemistry impacts on measured suspended solids has not been quantified.

Figure 4.1: Performance of the FW filter based on turbidity measurements

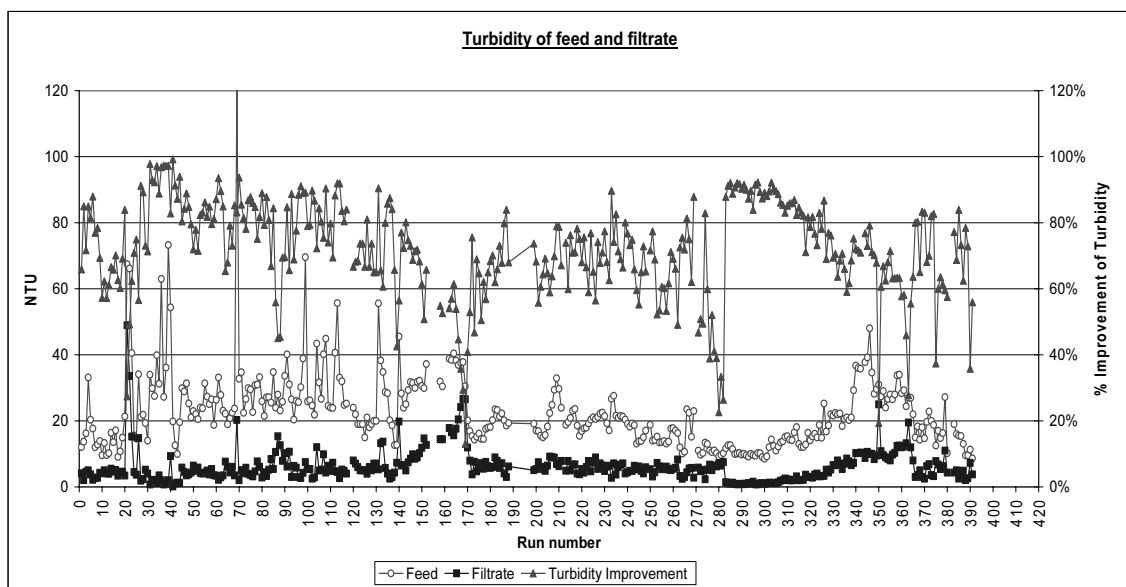


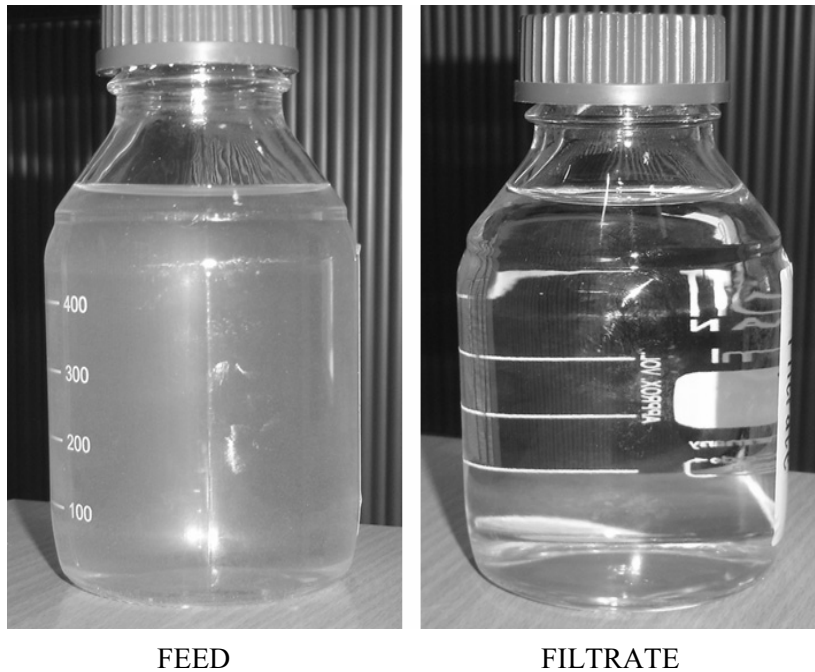
Figure 4.1 presents the performance of the FW filter based on turbidity measurements. It is evident that turbidity improves by 60% - 90% with an average improvement of 72% under plant operating conditions. Efficiency is lower at lower feed turbidity and

increase with a more dirty solution. Even at real upset conditions in the plant (dirty thickener overflow) the filtrate clarity could be maintained below 15 NTU. The reason for poor performance during run 21 to 23, 86 to 88, and 160 to 170 was due to a build up of a cake on top of the filter media and poor backwashes during these runs.

The filter is also sensitive to media depth in the filter. At run 46 some media was removed and a step change from ~95% to 80% solids removal was observed. Similarly, after run 282, media was topped up and a step increase in performance was observed.

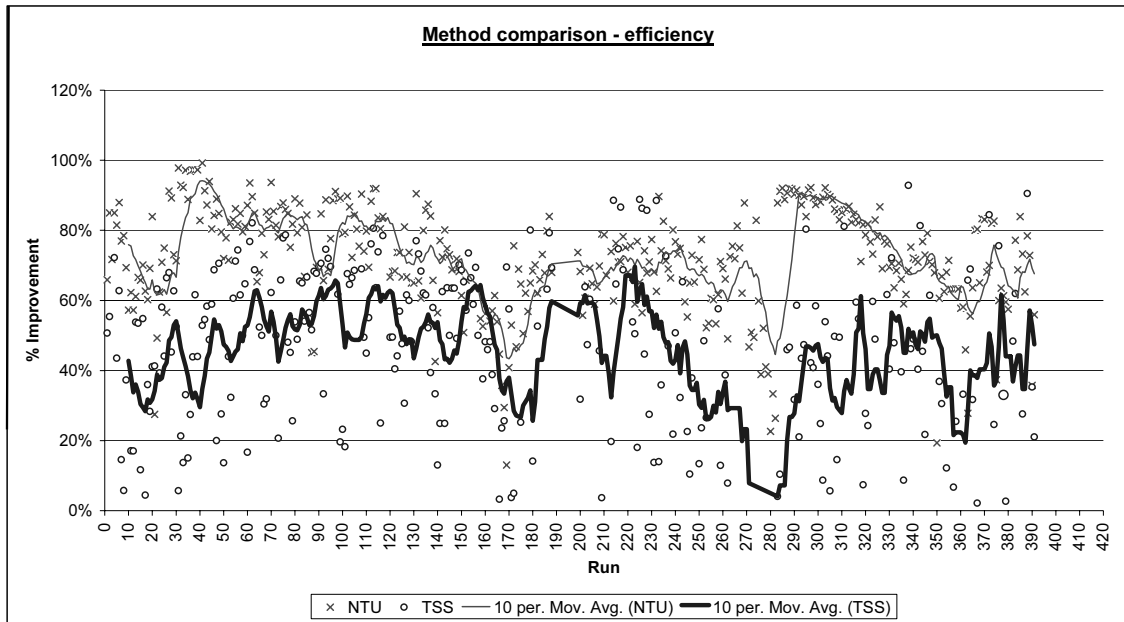
Visual observations of the filtrate from the unit were consistently good as illustrated in Figure 4.2. It was also observed that over a period of days to two weeks, further precipitates form in the feed sample that on some occasions flocculates and settles and in other instances remains in solution. Filtrate samples remained crystal clear over time.

Figure 4.2: Typical feed and filtrate sample



The gravimetric method does in comparison have a wider spread of results and percentage solids removal as illustrated in Figure 4.3. During testwork it was observed that laboratory analysis indicate high suspended solids in the filtrate, whilst turbidity measurements and visual observations proves that the filtrate is clear. Detailed investigation into the laboratory methods concluded that the method used is comparable with international standard and methods. Quality control samples confirm that there is no bias and no variance on the method and execution thereof. Variance is due to process variances, co-precipitation of salts during filtration, ageing of solution and solution chemistry [1].

Figure 4.3: Comparison of the gravimetric method to turbidity measurements

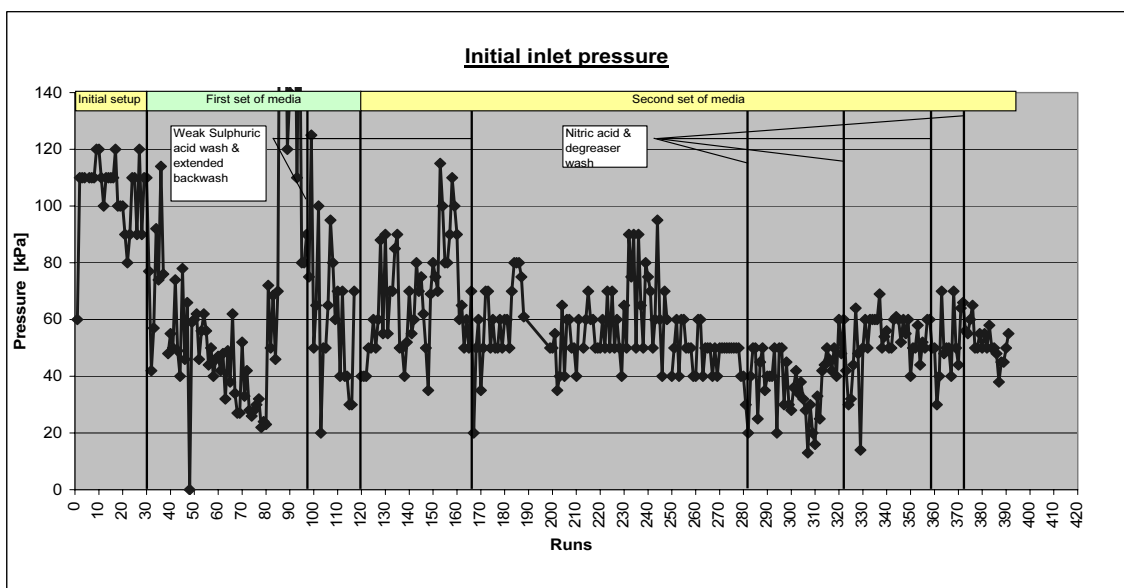


The gravimetric method indicates that on average, 47% of the solids is removed by the FW filter.

Based on turbidity measurements and visual observations of the filtrate it is concluded that the filter will effectively remove suspended solids under a wide range of operating conditions.

4.2 Cycle time

Figure 4.5: Initial filter inlet pressure



The FW filter is designed to operate at a feed pressure of 40 kPa and to start the backwash cycle when the inlet pressure reaches 80 kPa. During initial runs it was found that inlet pressures are higher than the designed 40 kPa and dependent on the media condition and head losses over the filtrate piping. To determine the cycle times, an increase of inlet pressure to 120 kPa was used as cut off point for the cycle, where after a backwash is initiated. This relates to a differential pressure increase between 40 and 60 kPa over the cycle. At this cut-off point, flow rates through the filter are not negatively impacted upon. Pressure increase above 120 kPa was avoided to curb Gypsum precipitation from high pressure differentials. Figure 4.5 illustrates the initial feed pressures to the filter over time.

Inlet pressures for the first 30 runs were 110 kPa. Consistent long cycle times were achieved during this period. This high inlet pressure was due to the filtrate line set-up causing high back-pressure. This set-up was corrected in the subsequent test work. High inlet pressures of run 91 to 100 were due to cake formation and blinding of the media.

Figure 4.6: Cycle time

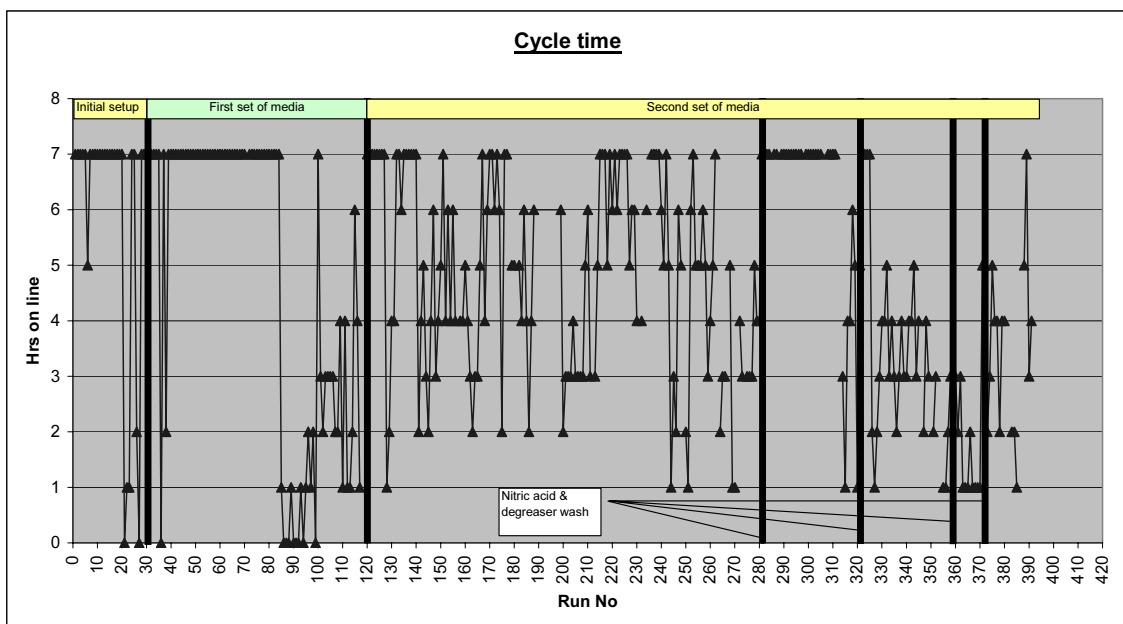
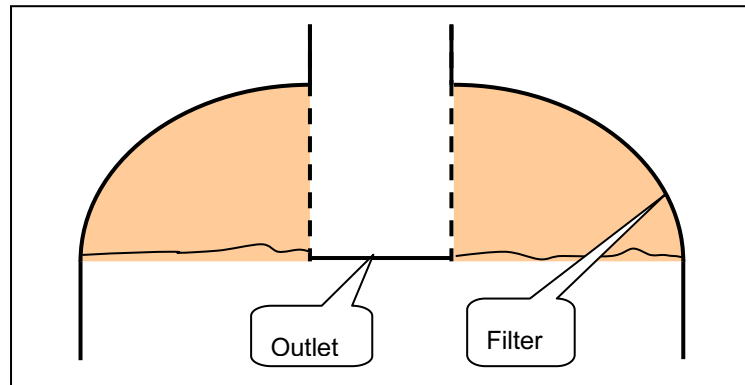


Figure 4.6 illustrates the cycle times over the full period of testing. Run 21 to 27 were conducted on a dirty feed solution, containing suspended solids up to 250 mg/l. As expected, very short cycle times were achieved with this high solids loading. However, the media was restored by long backwash times (60 min) and long cycle times (7hrs) was achieved up to run 84 when a cake built up around the outlet strainer restricted flow.

This 'cake' is formed when all the solids are not washed out of the media during backwash and the filter is then put on line and over pressured. The media and solids bridges between the outlet strainer and the filter body (Figure 4.7). The 'bridged media' is not released during the following backwash cycle and then not backwashed

efficiently. Solids accumulation here eventually restricts the flow. This built up then has to be manually removed by opening the filter and breaking the 'cake'.

Figure 4.7: Schematic diagram of 'cake' around the outlet strainer



On the industrial unit, the distance between the filter shell and the outlet strainer will be significantly higher than on the pilot unit, preventing 'bridging' to occur. It happened on isolated cases and is not a concern for the industrial units.

Short cycle times from run 90 to 99 occurred due to an unknown event, causing blinding of the media. This change could have occurred as soon as run 84. Low concentration (35 g/l) sulphuric acid wash and long backwash times (60 min) after run 99 improved the cycle times from a low ~1 hr to around 3 hrs, but the long 7 hr cycle times could not be reached. Media was replaced after run 120 and good cycle times were achieved. During run 127 to 129, old media was put back in the filter. Short cycle times then achieved proved that the major cause to the short filtration time is the blinded media and not the feed solution. New media was again inserted after run 129 and long runtimes could be achieved for another week. After run 140, cycle time reduced, indicating that the media was blinded again.

Longer cycle time is preferred with a minimum cycle time of 4 hours. A cycle time of 2 hrs or less is un-economical (due to the high percentage recycle load) with 3 hrs on the economical border line. The target cycle time of a minimum of 4 hrs has been set for the pilot campaign to prove viability of the unit.

As with other filtration units, it is expected that the cycle time is strongly dictated by the amount of solids in the feed. It was found that no correlation exists for this application at Skorpion Zinc as illustrated in Figure 4.8 and 4.9. The primary reason for not observing the correlation could be related to the blinding of the media.

Figure 4.8: Feed Turbidity and Cycle time

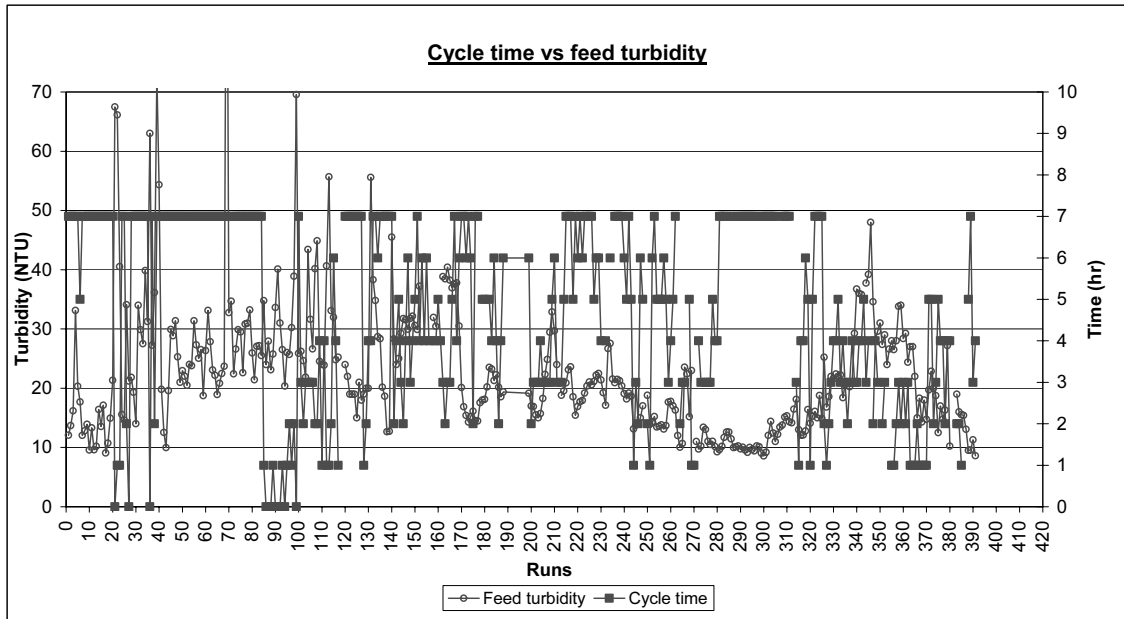
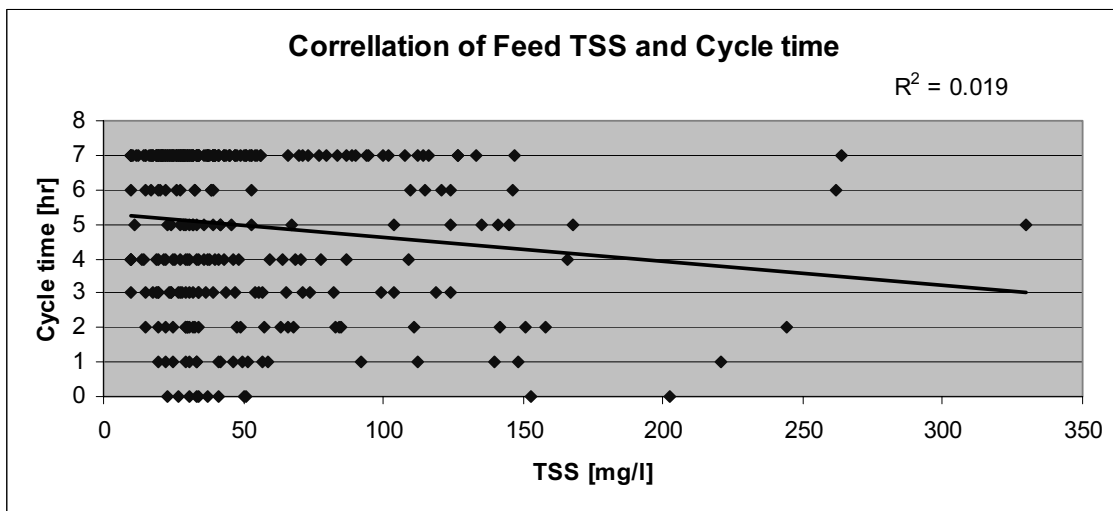


Figure 4.7: Correlation between feed suspended solids and cycle time



4.3 Backwash

Backwash profiles were conducted on selected runs as illustrated in Figure 4.10 below. The profiles were determined by measuring the turbidity of the backwash solution as it exits the filter. The testwork indicates that the clarity improves by 80% over the first 20 minutes and 90% over the first 45 minutes. Included in the testwork was run 99 which had a very short cycle. The backwash of this run followed a similar trend as the previous runs. The profiles indicates that most of the solids removal takes place in over the first 20 minutes and volumes required to remove the last solids increases exponentially.

Figure 4.10: Backwash profiles of the FW filter

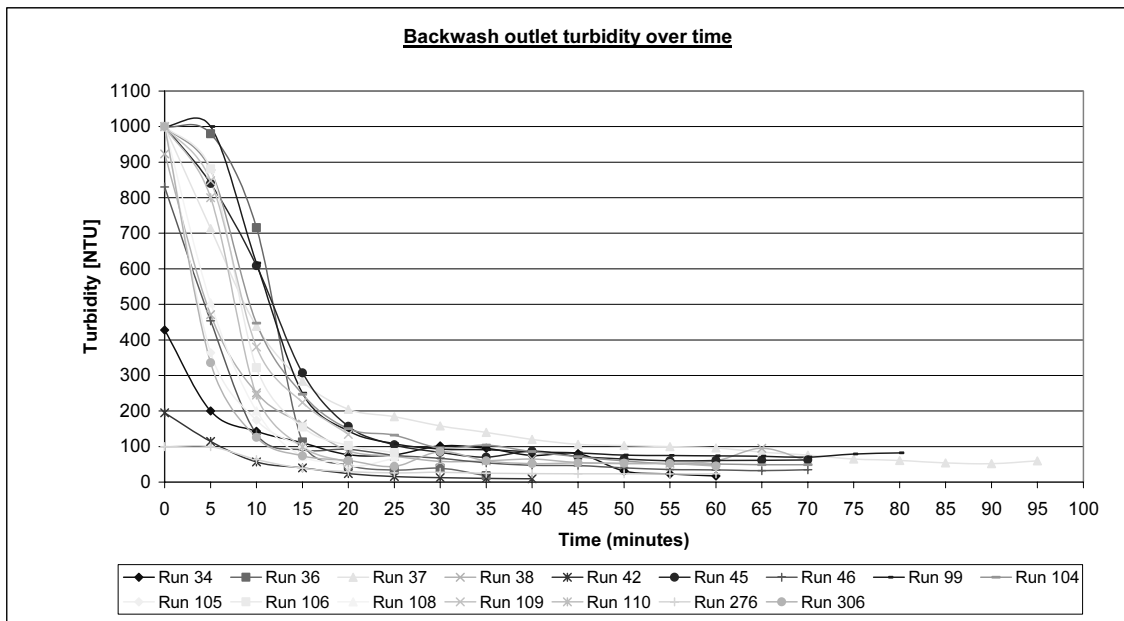
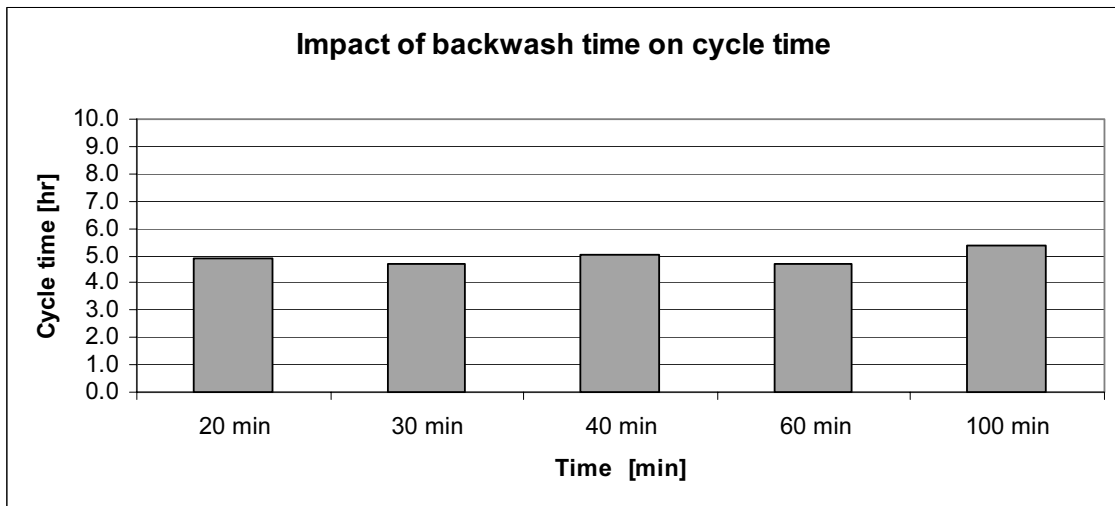


Figure 4.11 illustrates that an extended backwash does not improve cycle times. The optimum backwash time is therefore around 20 minutes where the bulk of the solids are removed.

Figure 4.11: Impact of backwash time on cycle time



4.4 Regeneration of the filter media

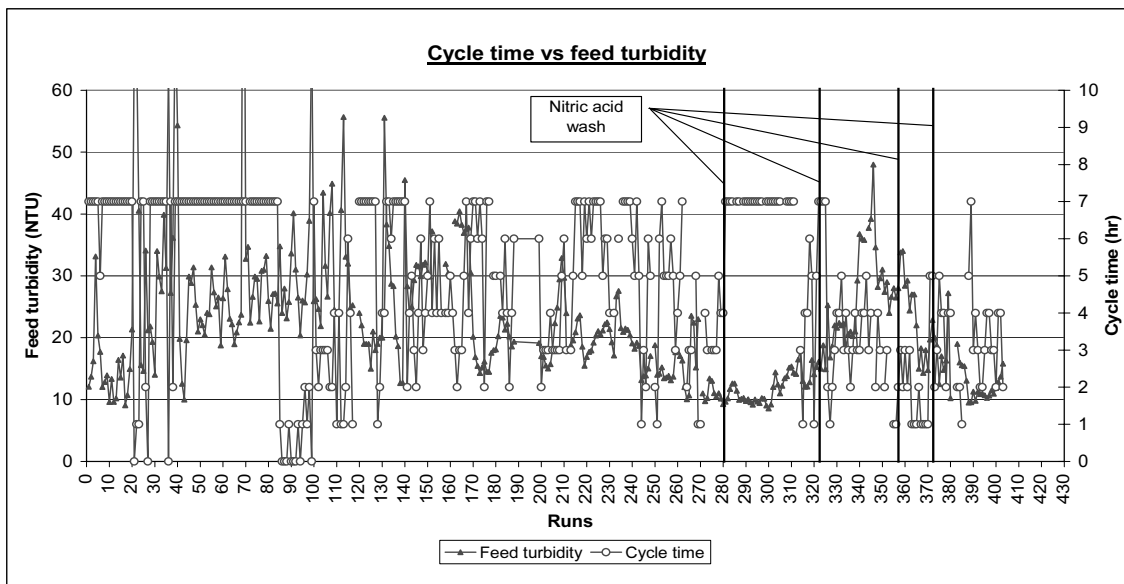
Blinding of the media is the primary factor impairing performance of the FW filter. Although the media lasts considerably longer than sand filters and the Larox polishing

filter (months compared to days), the replacement of the media is costly and associated operating costs due to media blinding (~ NAD16 million per annum for media replacement) makes the FW filter an unattractive option.

Investigations indicate that the fine solids in the feed to the filter consists of zinc hydroxides, amorphous Al-Si precipitate, gypsum and minor quantities of Sericite, K-Feldspar and Montmorillonite2 clay minerals. [2]

A range of laboratory tests were conducted [3] to determine a method to regenerate the media. Testwork indicated that on laboratory scale, media could be regenerated with a 10% hot nitric acid wash followed by a wash with a degreaser. This recommendation was tested on the pilot plant media (Figure 4.12).

Figure 4.12: Media regeneration

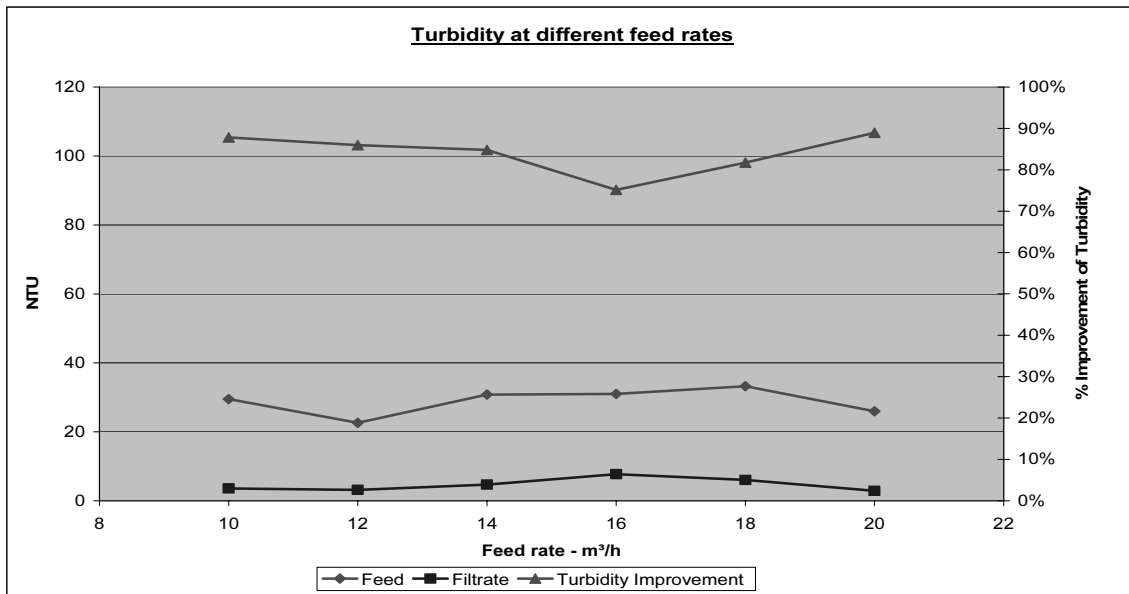


The first nitric acid wash (before run 283) was very successful, though the feed contained a low amount of suspended solids. When feed turbidity picked up to normal levels, short cycle times were again experienced. Subsequent acid washes proved to be unsuccessful.

4.5 Varying feed rates to the FW filter

At lower flow rates, bed compaction will decrease and a higher amount of solids could pass through the media bed. Test runs 75 to 80 were used to test the performance of the unit at lower flow rates. Feed were varied from 10m³/h to 18m³/h to observe quality of the filtrate at different compaction ratios of the filter bed. Testwork proved that filtrate quality and efficiencies remained good (Figure 4.13).

Figure 4.13: Efficiency of the FW filter at lower feed rates



This indicates that the FW unit is not overly sensitive to the feed rates and it will be able to efficiently remove solids during times when lower throughput is required.

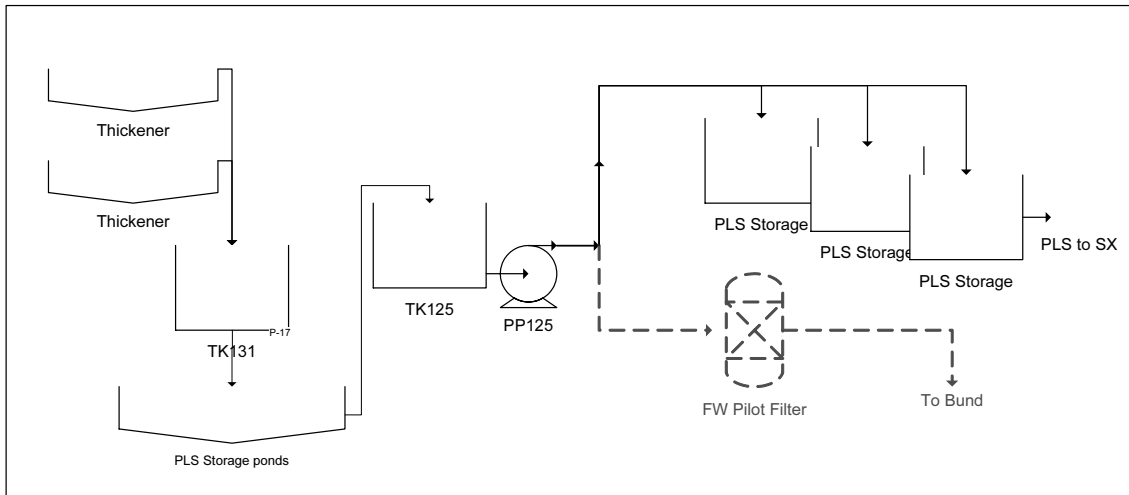
4.6 Ageing of PLS prior to filtration

The industrial installation of the FW filter will be after newly commissioned PLS storage ponds. The filter is highly sensitive to an overload of solids in the feed (>200 mg/l). The ponds will buffer the FW filter from operational upsets in the thickeners.

Solution will age in the PLS ponds (9 to 29 hrs) and the effect thereof on filtration and cycle times of the FW filter was evaluated. The PLS solution is at a pH of ~ 4.2 allowing polymerisation of soluble silicic acid in PLS to continue after the solid-liquid separation stage. At a pH above 3.2 and at low over-saturation levels of soluble silicon in solution, aggregation will form such that filterable precipitates will form in solution. The impact of this precipitates on the filterability of the solution and the FW filter performance needs to be investigated.

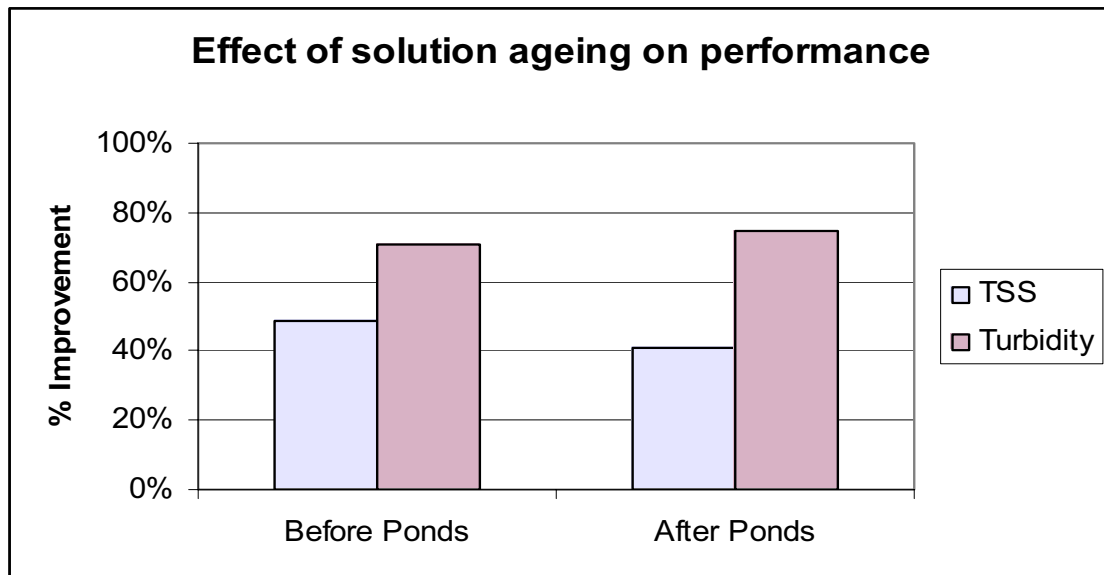
The ponds were put on line 14 March 2007 and the FW filter received feed from solution after storage in the ponds as illustrated in Figure 4.14, from this date (run 283)

Figure 4.14: Experimental layout including new PLS storage ponds



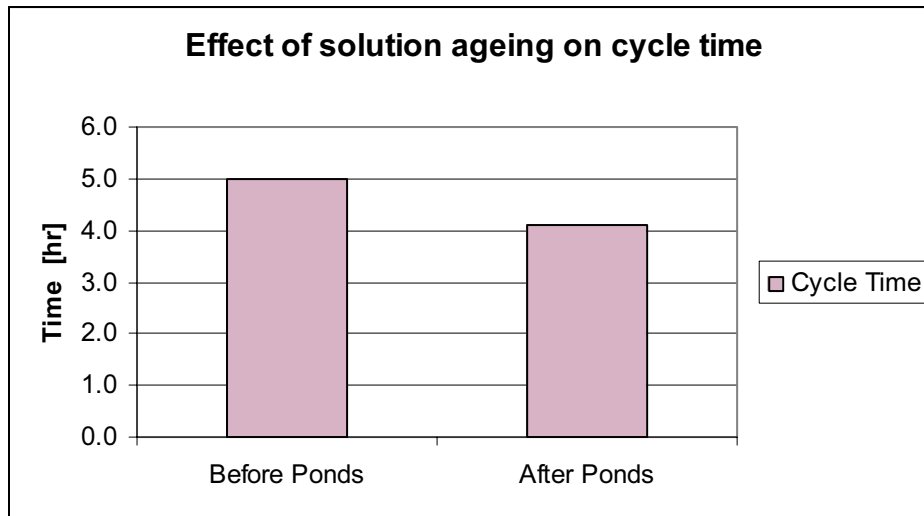
It was found that there was no significant difference in the solids removal efficiency and turbidity improvement with extended ageing time of the PLS as illustrated in Figure 4.15.

Figure 4.15: Impact of aged solution on filtration efficiency



Test work (Figure 4.16) indicates that there was on average a slight reduction in cycle time with an increased ageing of PLS solution. The results could however be biased by blinding of media over time and hence no definite conclusion can be made. The decrease is however low enough to rather install units after the ponds.

Figure 4.16: Impact of aged solution on cycle time.



4.7 Filter media consumption

The media used is slowly destroyed during the backwash cycle due to attrition by the agitator. Fine strains from the media could be observed during backwash of the unit. During the feed forward cycle, none of the fibre strains was observed in the filtrate. The supplier recommends one bed volume top up, per FW filter over one year.

On the pilot plant, over a 3.5 month continuously operating period, approximately 20% - 30% of the media was lost (equivalent to approximately one bed volume per year). In addition, media loss was measured over a 72 hrs continuous backwash period. Media loss over this period equates to a 65% loss of one bed volume of media over one year. Though scale-up of media losses from the pilot plant to industrial units is not one hundred percent accurate, data confirms the suppliers projected media loss.

4.8 Maintenance

No corrective maintenance was required on the pilot unit apart from a pressure gauge that had to be replaced. Material of construction of the filter is 304 SS. Over the operating period, no visual corrosion was evident and inlet and outlet strainers did not fail and was containing media effectively.

The only moving part on the filter is a mechanical seal at the bottom, where the shaft for the agitator enters the vessel. No problems were experienced with the mechanical seal.

Minimal maintenance is required on the FW filter when the correct material of construction is selected.

5 Conclusion

- It is concluded that the FW filter produces a clear filtrate, acceptable for the Solvent Extraction. Turbidity is improved by 72%. Gravimetric analysis indicates a 47% removal of solids. However, the gravimetric method is biased by a co-precipitation of saturated salts during the analysis.
- The filter is very sensitive to high solids in the feed as expected of polishing filters and feed needs to be maintained below 200 mg/l.
- A backwash time of ~ 20 minutes is optimum for the filter.
- Filter media is blinded by the Skorpion Zinc PLS solution, as result of suspended solids and process chemistry. This is very much site specific and dependent on solution chemistry and type of solids present in the PLS. The media could not be regenerated to acceptable conditions.
- Acid treatment of the filter media improves condition of the media on the short term.
- The pilot plant test campaign confirms the suppliers recommended media consumption.
- The equipment is robust with easy operation and low maintenance costs.

6 Recommendation

Further investigation is currently conducted in the laboratory to understand the impact of process solution chemistry on the filterability of the solution. Indications are that the suspended solids content in the solution could be reduced by reducing the PLS solution pH from ~4.2 to ~3.0. It is recommended that the adjustment of PLS pH is tested on the pilot plant to conclude testing the application of the Fibre Wakishimizu Filter at Skorpion Zinc.

7 References

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