

The Challenge to Scavenge IRON from Tailings Produced By FLOTATION A New Approach: The Super-WHIMS & the BigFLUX Magnetic Matrix

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1. Introduction

The scavenging of Iron from tailings produced by flotation, typically grinded to -75 microns, as well as the slimes that are not fed to the flotation plant, cannot be efficiently achieved with the standard equipment available in the worldwide market. The first demand to run such a process is the necessity of magnetic field inductions higher than 18,000 Gauss using Grooved Plate Matrixes set at a 1.5 mm gap, or even smaller, to scavenge ultrafine particles. Meshed type matrixes, although attractive, cannot be used since the blocking of these matrixes will be unavoidable. In fact, standard flotation plants display no up-stream WHIMS steps, so a very small amount of high susceptibility particles will statistically report to the tailings.

Abstract

Tailings recovery has been a constant challenge for most engineers. Along more than five years, GAUSTEC joined major players in the mining Industry to scavenge Iron from tailings produced by flotation making use of WHIMS (Wet High Intensity Magnetic Separation). In the early 1980s, in USA, the US 4,192,738 patent was granted with promising results. Despite this, thirty years have passed with no significant application worldwide. One main reason is reported: the market missed a really high feed capacity WHIMS in order to avoid the huge number of the WHIMS that were available at that time (such projects would typically require more than 20 WHIMS to scavenge iron from tailings produced by flotation plants). Such a huge asset to scavenge low grade iron tailings would not payback. The Mega sized WHIMS launched by GAUSTEC in 2014, the GHX-1400, improved by the Super-WHIMS Technology (18.000 Gauss) and BigFlow Magnetic Matrixes (Gaps smaller than 1.5 mm), faced this challenge. Specially designed ancillary equipment described here also played a decisive role in the scene.

Keywords: whims, tailings, matrix, concentration, separation, iron, vale, gaustec, noblock, flotation, slimes.

Although small in quantity, it is a matter of time for the clogging to take place. The clogging in meshed type matrixes is impossible to overcome.

Reportedly, the use of Grooved Plate Matrix is the most suitable way to address the clogging issue caused by magnetic particles contained in the tailings. In fact, the chance to wash out the magnetic particles imprisoned inside the channels between the grooves is normally promptly achieved thanks to the unhindered water flow. Of course, proper positioning of the sprays nozzles on the top and/or at the bottom of the magnetic matrix, at a convenient chosen pressure and water flow, is a must to keep the operation perfect. To allow the utilization of the Super-WHIMS technology

described here to deliver the high intensity magnetic field required by the process, a new type of High Flux Grooved Plate Matrix (BigFLUX) has been developed. This BigFLUX Matrix displays a free flow area between the stainless steel plates 22 % bigger in comparison with the Standard Grooved Plate Matrix (8 ridges per inch) at the same 1.1 mm gap. Completing the solutions, to avoid the clogging of the matrixes (which without a safe solution makes any high intensity magnetic separation impossible), a Motorized NoBLOCK® Filter is installed in the Super-WHIMS® plant flow sheet. In this project, the NoBLOCK has been applied to remove oversized particles above 0.6 mm. These technological achievements were tested on industrial

scale with the total support of the VALE Engineering Team, recovering Iron from the tailings produced by the Vargem Grande Flotation Plant. Preliminary tests run on laboratory scale used the Minimag® with promising results. Based on these results and within an agreement with VALE, a Super-

WHIMS® Mobile Concentration Plant has been built to confirm the results in industrial scale process. This plant has been designed and constructed by GAUSTEC making use of the WHIMS GX-300 @ feed rate of 80 m³/h of slurry containing 40 tph of solids @ 40 % solids in average, run from Feb-

ruary to April 2017 eight hours per day. Twenty two tests were sampled on a daily basis by VALE VGR Engineering Team, achieving results that confirmed the lab scale tests. Reportedly, 1350 MTPY of Pellet Feed Concentrate @ 60 % Fe can be scavenged from the tailings discharge.

2. The Mobile Super-WHIMS® Concentration Plant

The industrial scale plant built by GAUSTEC to fulfill the VALE Agreement, had to be designed as a Mobile Unit to be

easily displaced in several plant operations inside VALE facilities. Picture 1 discloses the Mobile Plant driven by a Scania Trac-

tor Truck 400 HP and a Low Bed Semi Trailer 22 meters long. The total payload summed up 45 tons.



Figure 1
From the left side:
Electrical Cabinet, NoBLOCK®
Filter and GX-300 Super- WHIMS®.

This innovative Mobile Plant, designed and built by GAUSTEC, probably the first of its

kind ever constructed, proved its performance according the severe safety rules of

VALE and along all tests in a time frame without any reported non-conformity.

3. The Super-WHIMS® Technology

3.1 Magnetic Field Intensity above 18,000 Gauss and General Considerations

The feed size distribution of the analyzed flotation tailings reported 98 % -150 microns; 82% -75 microns and 54% - 37 microns. The chemical analysis (head) reported 24.3% Fe and

62% SiO₂. These data, for very finely ground and low grade tailings, clearly shows the necessity of a huge magnetic field and a very small gap opening in the magnetic matrix to scavenge the

Iron. For this task GAUSTEC devised the Super-WHIMS®. Figure 2 shows the basic structure of a typical WHIMS magnetic separator with its coils, rotors, and shaft.

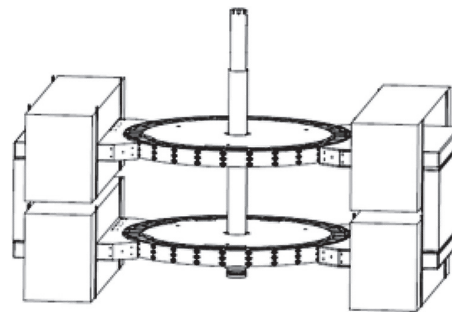


Figure 2
A typical WHIMS structure displaying
Coils, Rotors and Magnetic Circuit.

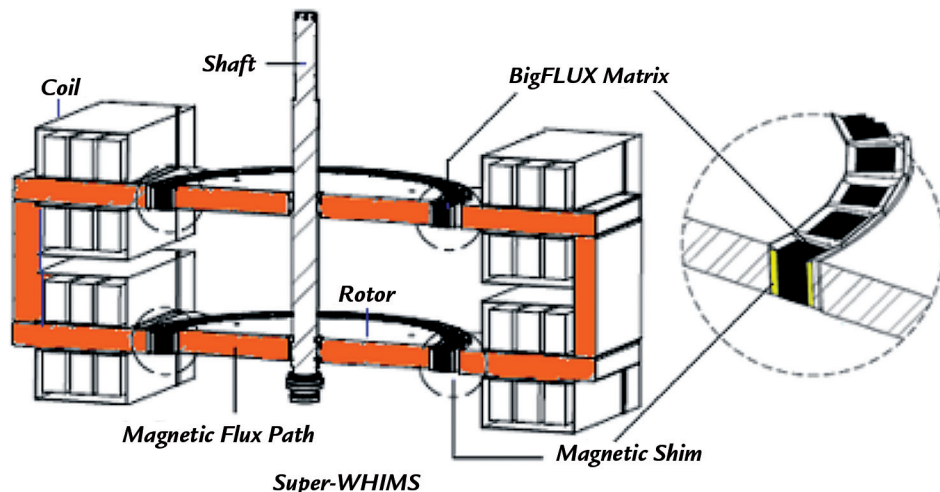


Figure 3
The view cut showing the
Magnetic Shim and BigFLUX Matrix.

The means to increase the Magnetic Induction is disclosed in Figure 3 where a Magnetic Steel Shim, of magnetic permeability equal or higher than 500, is mounted

surrounding the rotor surface and at the side of the BigFLUX matrixes. This Magnetic Shim decreases overall reluctance of the magnetic circuit, consequently increasing, as

a direct effect, the magnetic induction inside the BigFLUX Matrix. Figure 4 displays the Standard Magnetic Matrix (pitch 3.175 mm between grooves) without shims.

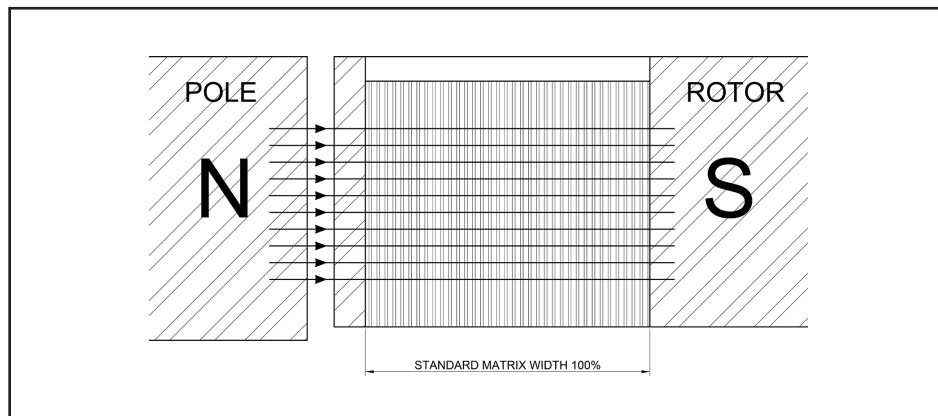


Figure 4
Standard Magnetic Matrix with no Magnetic Shims.

Figure 5 shows the Magnetic Shims mounted at both sides of the BigFLUX Ma-

trix and Figure 6 shows the Shims at the side of the BigFLUX Matrix closer to the rotor.

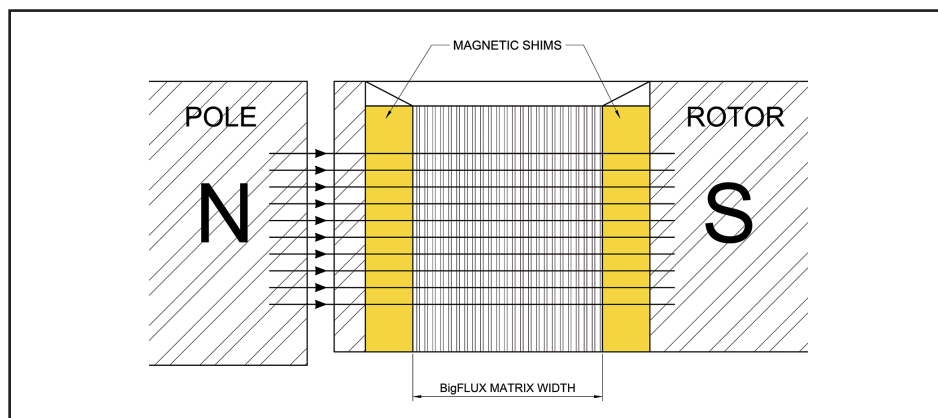


Figure 5
BigFLUX Matrix with Shims on both sides.

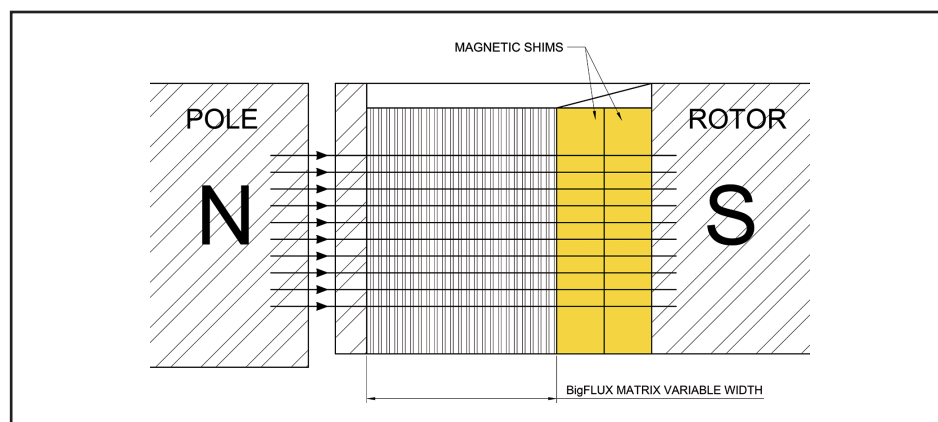


Figure 6
The BigFLUX Matrix with Magnetic Shims mounted on the side closer to the rotor.

A third possible position not shown in these figures is the installation of the shims at the side of the matrix

closer to the pole. Although possible, this position of the shims is not recommended due to the increase of the

fringe flux coming from the pole, which reduces the magnetic induction inside the matrix.

3.2 The Behavior of the Magnetic Field in the Super-WHIMS

The magnetic field induction inside the matrix has been measured with several magnetic shims gradually changing its thickness. The tests were run using a standard matrix with a gap of 1.5 mm between the

grooved plates. The starting width of the matrix was 255 mm corresponding to 100 % and at the rated power coils induced in the matrix 14.000 Gauss. Decreasing the matrix width gradually down to 67 % and

adjusting the magnetic shims, keeping the rated power in the coils, the magnetic induction stepped up to 18,100 Gauss.

The results were plotted and summarized in the graph in Figure 7.

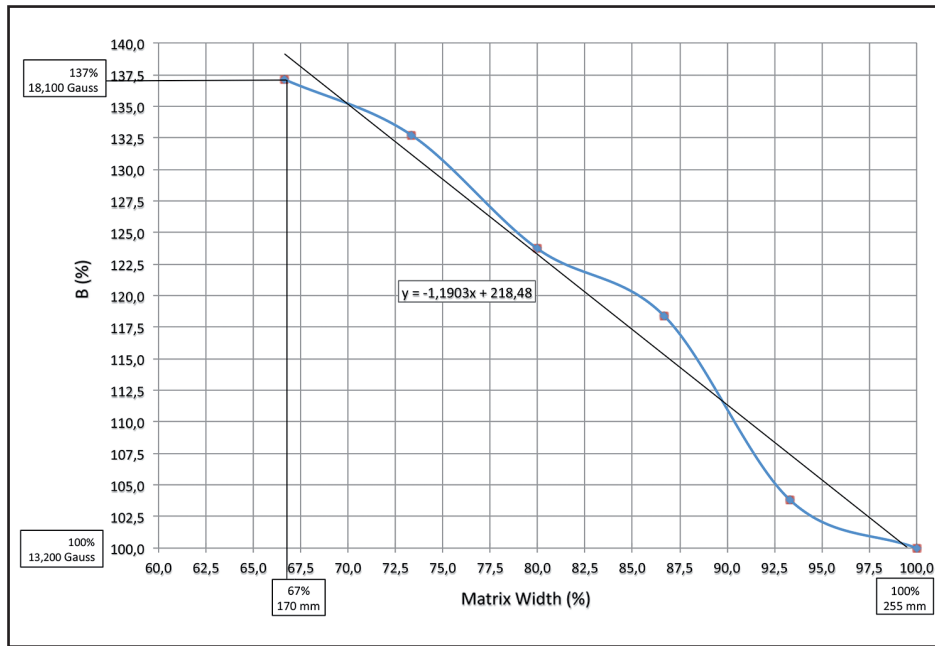


Figure 7
Magnetic Induction increase in function of the Matrix Variable Width Decrease.

Although any magnetic matrix can have the benefits regarding higher magnetic fields if demanded by the concentration process, there is a feed capacity reduction that is a trade off with the mass recovery and tailings reduction. This way, a key factor for the proper performance of the Super-WHIMS is the use of a GAUSTEC

special designed matrix to avoid reducing the slurry flux capacity due to the reduction of the matrix area as a consequence of the introduction of the magnetic shims. The BigFLUX is designed with a pitch of 4.5 mm between grooves increasing the open area of the matrix compensating the magnetic shim reduction. This larger

area, in relation to the open area of the standard matrix with its 3.175 mm pitch between grooves, improves the operational and process performance of the magnetic separation. Furthermore, the BigFLUX Matrix in operation at the Super-WHIMS Mobile Plant achieved a peak of magnetic induction at 18.520 Gauss.

4. The BigFLUX Matrix Technology

4.1 The Purpose and the Design of the New Matrix

All the benefits which the Super-WHIMS concept can offer to the High Intensity Magnetic Separation Process would be only partial if its use resulted in the reduction of the rated capacity of the Magnetic Separator. The rated capacity of the WHIMS, calculated worldwide based on the long matured standard matrix, eight grooves per inch, which leads

to the 3.175 mm pitch between grooves. The New BigFLUX Matrix was designed keeping all features of the matured standard matrix but with a clear target in mind: the new matrix should offer at least double of the open area offered by the standard matrix. This should more than compensate the reduction of the matrix open area caused by

the introduction of the magnetic shims required by the Super-WHIMS Technique. To establish a clear reference of the open area provided by the standard matrix, Figure 8 shows a partial cut this matrix with the tips touching each other, creating this way squares which can be compared with the squares of the newly created matrix at its side.

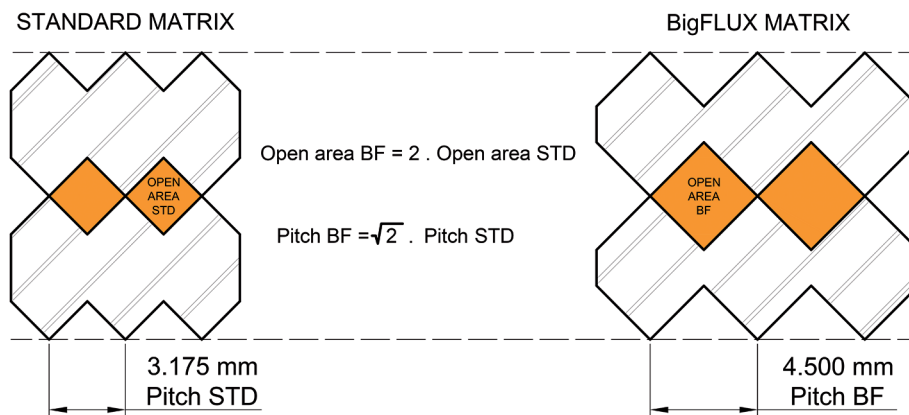


Figure 8
Open Area comparison between the BigFLUX Matrix and the Standard Matrix @ “Gap Zero”.

To double the area of the square, its diagonal, or the pitch between

grooves, must be multiplied by $\sqrt{2}$ defining this way the pitch of the Big-

FLUX Matrix equal to 4.490 rounded to 4.500mm. This way,

$$\text{Area STD} = 3.175^2/2 = 5.040 \text{ mm}^2 \text{ and } \text{Area BF} = 4.5^2/2 = 10.125 \text{ mm}^2.$$

The Total Open Area of the Big-FLUX Matrix, with the square geometry above, is effectively increased by approxi-

mately 43 %, since the number of grooves per length of each standard steel plate is close to 93 grooves @ 3.175 mm pitch and

66 grooves @ 4.500 mm pitch.

In fact, the Total Open Area between plates is:

$$\text{Total STD area} = 93 \times 5.040 = 468.720 \text{ mm}^2 \text{ and Total BiF Area} = 66 \times 10.125 = 668.250 \text{ mm}^2$$

Of course the effective relationship between open areas will change as the gaps

between tips change. Figure 9 shows the open area for both matrixes at the same

gap opening @ 1.5 mm, and in this case the open area increase is approximately 22 %.

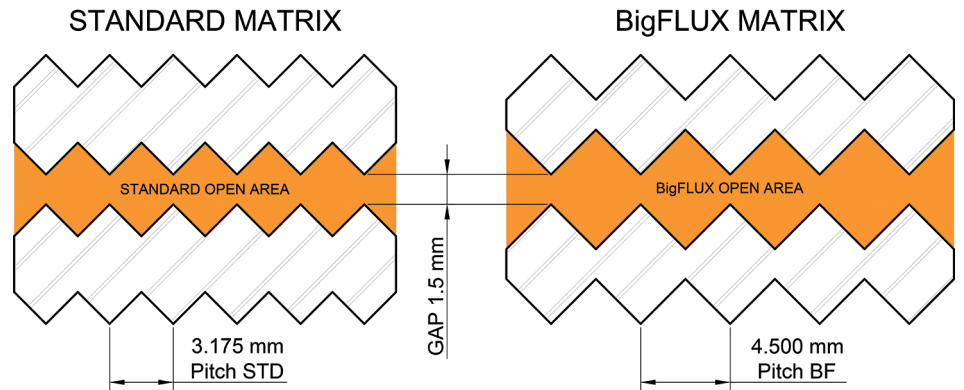


Figure 9
Open Area Comparison of Standard and BigFLUX Matrix @ Gap 1.5 mm.

The same calculations comparing the same gaps on both matrix, indicate an increase of 26 % @ gap 1.0 mm

and 32 % @ gap 0.5 mm. Of course, as already mentioned, the use of gaps smaller than 1.5 mm within the standard

matrixes, on industrial scale, has never been reported since in the long run it resulted in extensive clogging.

4.2 Further Features of the BigFLUX Matrix

Although the BigFLUX Matrix has been designed primarily to increase the slurry flux throughput in the Super-WHIMS technology, it has additionally greatly improved the process and the operation of the magnetic separation in two very important issues. The first improvement is that the wider

dimensions of the open area turned the BigFLUX Matrix totally clogging free even at the 1.1 mm tested in the Mobile Super-WHIMS Plant. The second improvement is that the washing of this matrix became more efficient and effective to upgrade the quality thanks to the easier water flow through the

groove space. These characteristics may open a new field of applications in the gap below 1.5 mm which up to now could not be well explored due to the clogging problems. The success in using this matrix will depend, as always, on the behavior of each type of ore to be processed.

5. The Super-WHIMS Mobile Plant Performance

5.1 The Process Flow Sheet

The process to scavenge iron from the tailings has been designed

to recover the slurry feed through three stages Rougher, Cleaner and

Re-Cleaner according to the flow sheet of Figure 10.

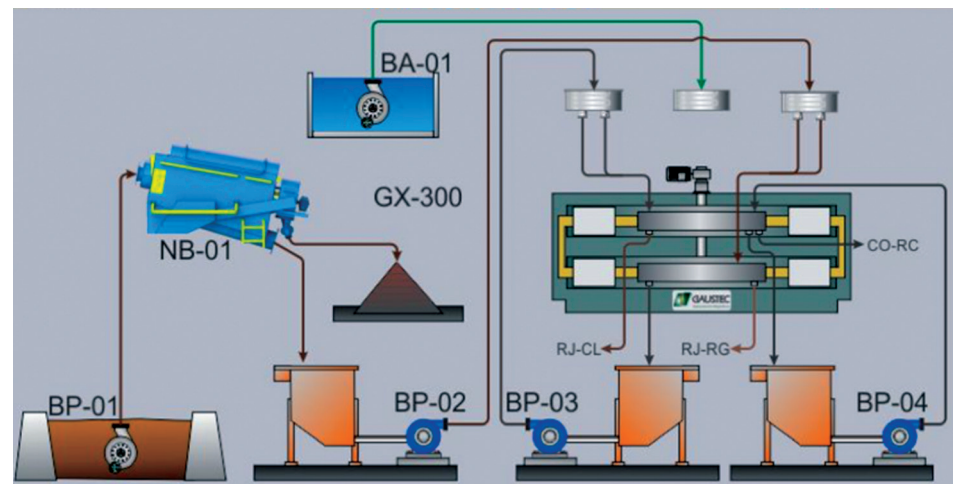


Figure 10
The Mobile Plant Flow Sheet.

The slurry coming from the flotation plant is collected in a sump and then Pump BP-01 transports a controlled volume to the

motorized Filter NoBLOCK NB-01. The filter removes oversized particles above 0.6 mm and the underflow - 0.6 mm is trans-

ferred to a tank and from there the slurry pump BP-02 feeds the bottom rotor of the magnetic separator GX-300 through four

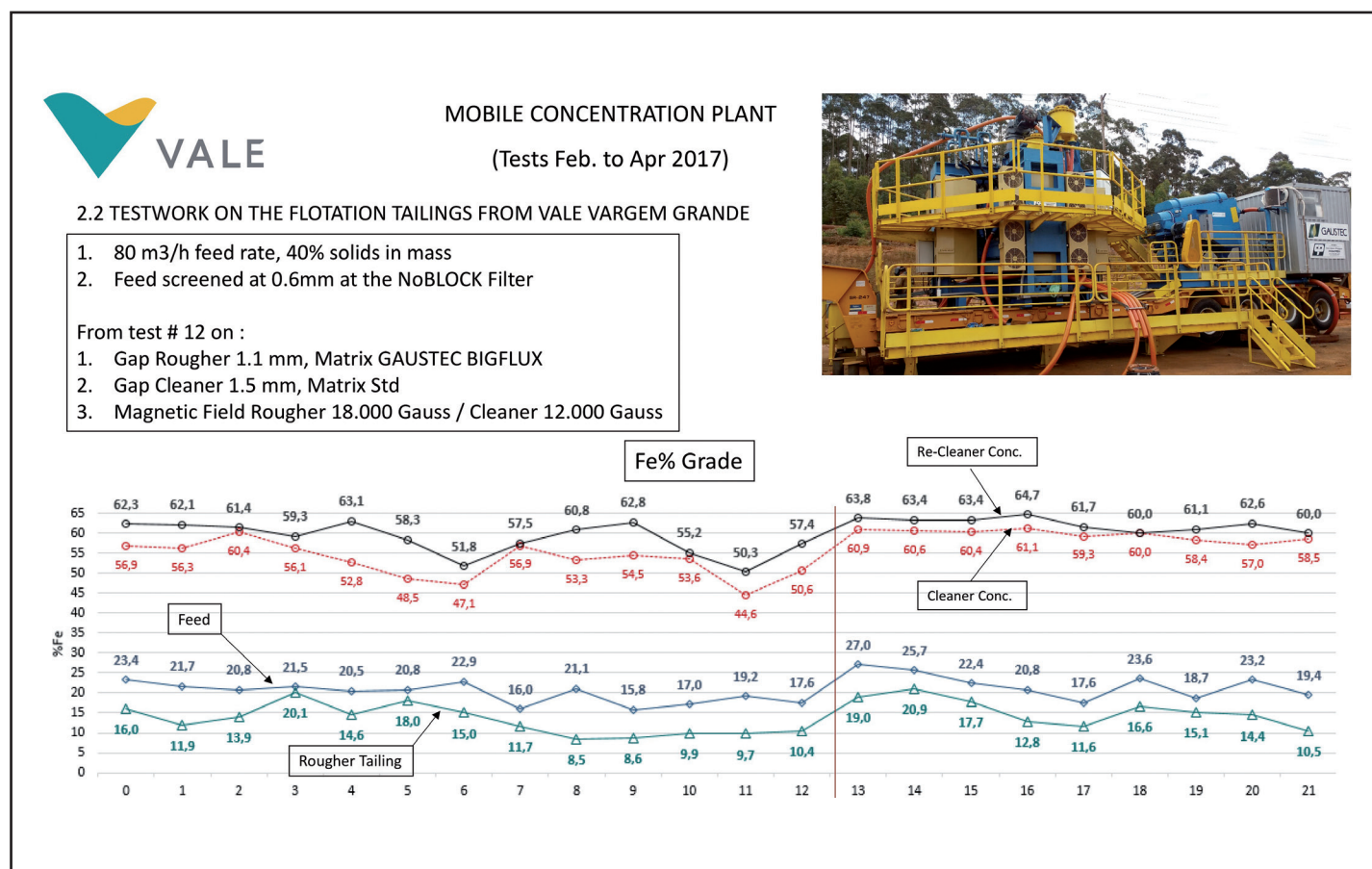
feed boxes. The bottom rotor performs the Rougher stage with adjustable DC current from an AC/DC Converter independent from the top rotor. These coils induce in the matrixes a magnetic field of 18,000 Gauss.

After passing in the Rougher stage, the Rougher Tailings RJ-RG are discharged by gravity to the tailings pond. The Rougher Concentrate CO-RG flows to a tank from where the pump BP-03 feeds two of the four feed boxes of the top rotor, and half of this rotor performs the cleaner stage. From the Cleaner stage the tailings flow to the tailing pond and the

Cleaner Concentrate CO-CL is pumped by BP-04 to the two remaining feed boxes of the top rotor, and in this way the second half of the top rotor performs the Re-Cleaner stage producing the final concentrate CO-RC which is collected on a metal box for sampling purposes. The top rotor is equipped with standard matrixes set at a gap of 1.5 mm and the magnetic field is adjusted at 12,000 Gauss. All the coils of the top rotor are supplied with DC Current from a separate AC/DC converter. Since there is an AC/DC converter for each rotor, the magnetic field can be adjusted independently at each rotor. This

is a must for the process control, since the magnetic susceptibility of the Cleaner and Re-cleaner concentrates are much higher than that of the tailings. This possibility here described has been introduced after test number 12 to overcome the lack of independent field control for each rotor. The introduction of the BigFLUX Matrix was made at the same time of the installation of the second AC/DC converter, so after test 12, the process became fairly stable and provided confidence for an industrial scale operation. The results of these tests prepared by Vale Engineering Team are plotted in Figure 11.

Figure 11
Overall Test Results Prepared by VALE Engineering Team.



6. Conclusions

The various technologies here reported have been applied to scavenge iron from the tailings produced by flotation plants and have proved to be a viable solution. Tested at an industrial feed rate of 40 tph, these results can be scaled up to larger scale production with no further concerns. Starting at an average of 20 % Fe in the tailings, a marketable product of above 60 % Fe can be produced with a mass recovery of up to 14 %. According to VALE

figures, a yearly production of more than one million tons per year can be achieved. Important to mention that the feed rate and the results give support to state that the total volume of tailings from flotation in the order of 1800 m³/h can be processed by making use of 03 WHIMS GHX-1400 for the Rougher stage equipped with the BigFLUX Matrix with the 1.1 mm gap. The Cleaner and Re-Cleaner stages can be processed by three GX-500, each one

coupled with one GHX-1400 forming three independent production lines. Each line will be able to produce 50 tph, which when running 7000 hours per Year, will result in a total production of 350,000 tpy per line.

The practical aspects of this project feasibility is that in 1980, as mentioned, with the standard WHIMS of that time, 18 machines would be necessary to realize this project. It would be rendered impossible to be turned into reality.

Acknowledgments

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