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AN EVALUATION OF THE MOZLEY MGS FOR FINE PARTICLE GRAVITY SEPARATION

A. TRAORE[§†], P. CONIL[§], R. HOUOT[†] and M. SAVE[†]

§ Département minéralurgie, BRGM, Orléans, France
† Laboratoire environnement et minéralurgie, ENSG, Nancy, France
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ABSTRACT

The Multi-Gravity Separator (MGS), a new fine-particle gravity equipment that has recently appeared on the market, was tested in order to evaluate its potential. In the first instance, the influence of its different operating parameters on the quality of gravity separation were studied using a synthetic ore. This revealed the dominating role of three parameters: speed of rotation, shake frequency and shake amplitude. The MGS was then tested with a natural tungsten ore, which corroborated the results obtained with the synthetic ore. Finally, in order to assess the contribution that this new equipment represents in relation to other types of gravity separator, a comparative performance study was made between the MGS and a Fines table.

Keywords
Gravity separation; Mozley Multi-Gravity Separator (MGS)

INTRODUCTION

Recovery of the valuable minerals contained in fine particles is a difficult problem in mineral processing and particularly in gravity separation. With decreasing particle size (<100 µm), the force associated with the water flow becomes dominant over that associated with gravity. Because of this, a large part of the valuable minerals contained in the fine particles prove to be irrecoverable with traditional methods of gravity separation. To remedy this problem, various gravity-separation methods and machines have been developed over the last few decades, notably Fines tables. Recently, a new gravity-based processor, the Multi-Gravity Separator (MGS), has appeared on the market with an operating principle that seems to be very promising for processing fine particles. It is based on increasing the properties related to particle density under the effect of a centrifugal force, and should contribute to limiting the above-mentioned problem.

The potential and limitations of this equipment, however, are still poorly known. The present study was made in order to determine the relative influence of the equipment's operating parameters on the quality of the concentrate, the final objective being to optimize, depending on the characteristics of the ore to be processed, the performance of the MGS. So as to be able to carry out a precise quantitative study, notably by avoiding composite/liberation problems, the study was carried out using a synthetic ore made up of quartz and ferrosilicon. The experimentation, aimed at determining the most influential operating parameters and optimal operating conditions, was carried out according to a factorial design. Tests were also carried out using natural ores, notably a tungsten ore with a very low WO_3 content.

So as to quantify the contribution that this equipment represents with respect to traditional methods, a comparative performance study was carried out between the MGS and a GEC Fines table.

FEATURES AND OPERATING PRINCIPLE OF THE MGS — EXPERIMENTAL PROCEDURE

Description of the equipment

With the pilot MGS (Figure 1) separation is obtained through the combined action of centrifugal force provided by the rotation of a drum and the force provided by shakes of variable amplitude and frequency. One of the original features of the MGS is the presence, inside the drum, of scrapers to drag the heavy minerals to the concentrate outlet. The ore processing capacity of the pilot unit, according to the manufacturer, is as much as 200 kg/h; an industrial unit also exists, with two drums mounted back to back, that has an ore-processing capacity of 2 t/h.

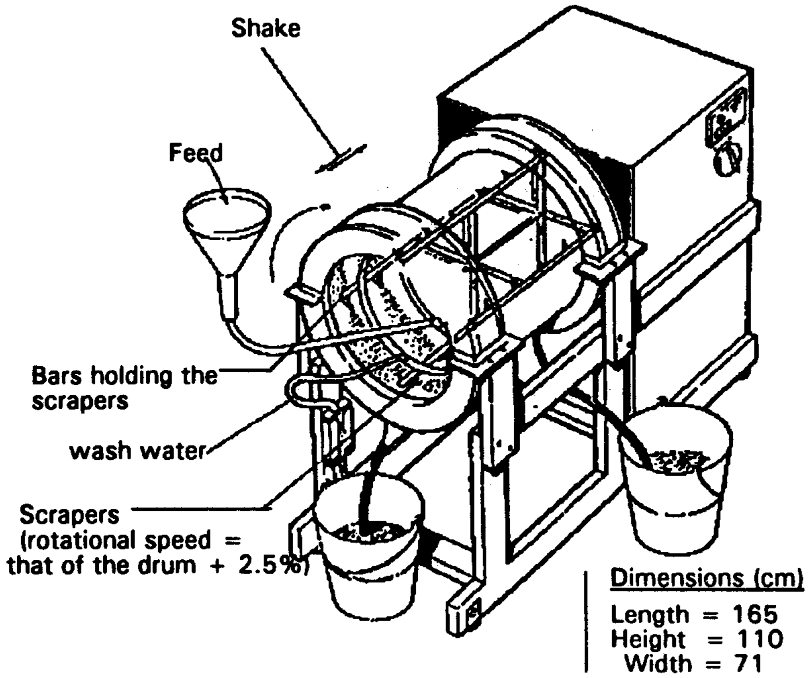

Fig.1 General features of the pilot MGS

The pulp is fed continuously inside the drum via a meshed ring so as to reduce the turbulence caused by introducing the pulp. The wash water is added via a similar mesh placed near the open end of the drum.

Observation shows that the pulp describes a spiral movement within the drum. Under the effect of the centrifugal force, the heaviest particles penetrate the film formed by the pulp and plaster themselves against the inner surface of the drum. They are then dragged to the concentrate outlet by the movement of the scrapers. An intermediate layer of finer and less-dense particles forms over the first. The lightest particles (the gangue) are carried by the wash water to the rear of the drum and the tailings outlet. The shakes, by temporarily disrupting these layers, help limit the mechanical trapping of light particles by the heavy particles and thus minimize the amount of gangue caught up with the concentrate.

Because the centrifugal force applied to the particles is far greater than the force of gravity exercised on a conventional shaking table, the separation between heavy and light minerals is in principle easier with the MGS than with conventional equipment.

DESCRIPTION OF THE ORES USED FOR THE STUDY

a) Synthetic ore

The use of a synthetic ore based on quartz and ferrosilicon (densities of 2.65 and 6.25 respectively) made it possible to smooth over the problems found with natural ores (composites) and thus obtain much more interpretable data; such an ore is obviously easier to process, but it provides more precise data concerning the equipment's behaviour. The feed particle size was fixed at <80 µm. In view of the magnetic properties of the ferrosilicon (99% magnetic products), which was here considered as the valuable mineral, the measurements were made through magnetic separation in a Davis tube. The composition of the synthetic ore is summarized in Table 1.

TABLE 1 Composition of the synthetic ore

Mesh (µm)	Weight per fraction (%)	Ferrosilicon grade per fraction (%)
+63	13.73	17.52
+40	19.95	13.63
+20	26.26	10.41
+10	15.88	13.72
−10	24.18	14.89
Feed	100.00	13.64

b) Tungsten ore

The natural ore that was used is a tungsten ore grading 0.3% WO_3 with scheelite as the main tungsten carrier; wolframite represents less than 1% of the total tungsten. The gangue minerals are mainly quartz, feldspar, mica and garnet. Sulphide minerals are also present. The feed particle size was fixed at <100 µm, one mesh below that at which it is necessary to work with this ore in order to obtain an acceptable liberation of the tungsten carriers.

Experimental procedure

The tests were carried out using a continuous feed from a semi-industrial type unit (Figure 2). The pulp feed rate was generally around 100 l/h (45 kg/h of ore).

So as to assure the reliability and reproducibility of the tests, sample collection when the MGS was running could only be carried out once equilibrium of the equipment had been attained. Preliminary tests showed that the stabilization time varied according to the type of ore and the operating conditions, and that balanced running of the equipment was attained after about 45 minutes. For the experimental procedure, it was determined that sampling would be carried out only one hour after start up of the equipment.

Processing and sample analysis

So as to avoid problems of behaviour equivalence between the small heavy particles and the large light particles, particle size analysis cannot be done by settling or cyclosizer. The wet samples from the MGS (feed, concentrate and tailings) were therefore sieved to 20 µm through cloth screens to obtain four size fractions.

The content of each particle size fraction was then analysed using magnetic separation (Davis tube) for the synthetic ore and chemical analysis (WO_3 content) for the tungsten ore.

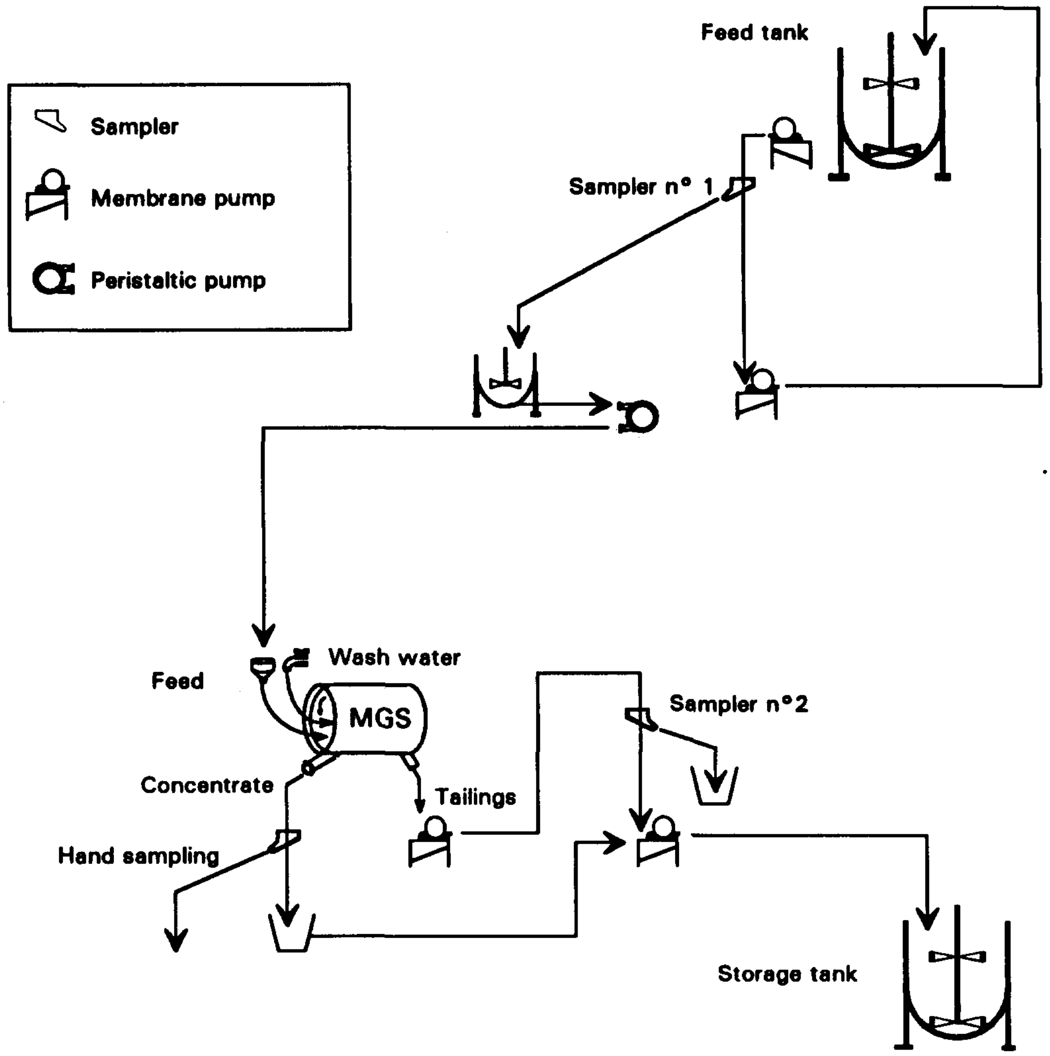

Fig.2 Processing flowsheet

INFLUENCE OF THE EQUIPMENT OPERATING PARAMETERS

Use of the factorial design to quantify the operating parameters

In numerous experiments it is necessary to examine the effects produced by the variation of two (or more) factors. For a complete investigation in such cases, it is not enough to vary just one factor at a time; one has to examine all the combinations of the different levels of the factors to elucidate the qualitative influence of each factor. The factorial design not only enables such an approach to be followed, but also makes it possible to detect interactions between the various factors.

a) Choice of variables

The study was carried out for the five operating parameters of the equipment (speed of drum rotation, wash water flow rate, angle of tilt of the drum, amplitude and frequency of the shakes), using two levels for each variable. The number of tests required for a complete design is given by the formula $N = 2^k$, where N = number of tests and k = number of variables; thus 32 tests in the present case. Preliminary tests enabled the values of the different variables to be determined through taking into account first of all the extreme points and then a few intermediate points. These values are given in Table 2.

TABLE 2 Levels of the variables

Variable	Symbol	Levels	
		1 (−)	2 (+)
Wash water (l/min)	W	3	5
Rotation speed (rpm)	S	150	170
Amplitude (mm)	A	12.5	25.4
Frequency (cps)	F	4	5.7
Tilt (degrees)	T	5	7

b) Experimental procedure

The experimental procedure was the same as that described in the previous paragraphs. The tests were carried out independently of each other, the equipment being stopped and emptied following each test.

c) Performance of the MGS

The influence of each of the five parameters and their interactions was quantified by comparison with the experimental error (i.e. the measure of the degree of test reproducibility). This comparison was done using the Student–Fischer significance test.

The set of tests carried out enabled a first study of the results and an assessment of the experimental performance of the MGS. The analysis was made not only of the bulk balance (concentrate and tailings, all size fractions together) but also of the balance of each particle size fraction. The grade-recovery curve of the bulk concentrate is given in Figure 3; it shows that the MGS gives an excellent separation, with the five operating conditions at the break in the curve apparently being best for a good grade and recovery optimization. The results for the different particle size fractions are given in Figure 4; this shows that separation by the MGS is almost perfect for the coarser fractions (>40 μm), deteriorates very slightly for the −40+20 μm fraction and much more so for the <20 μm particles. These very good results are obviously partly explained by the favourable conditions under which the equipment was being operated (total liberation, large density difference between the heavy and light elements). Nevertheless they give hope that the equipment will perform well with natural ores.

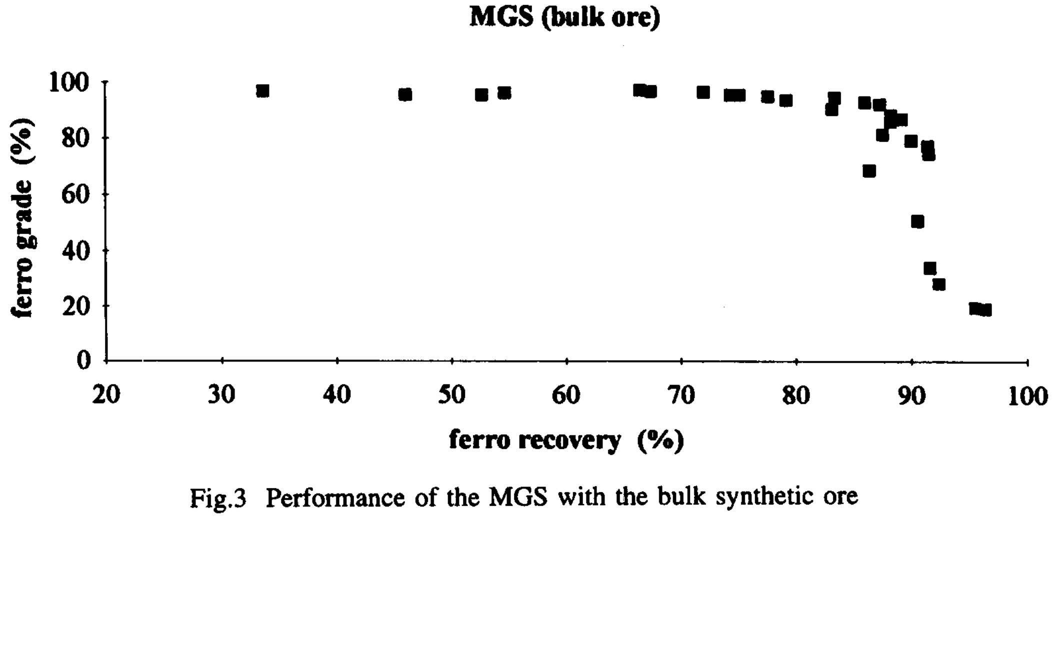

Fig.3 Performance of the MGS with the bulk synthetic ore

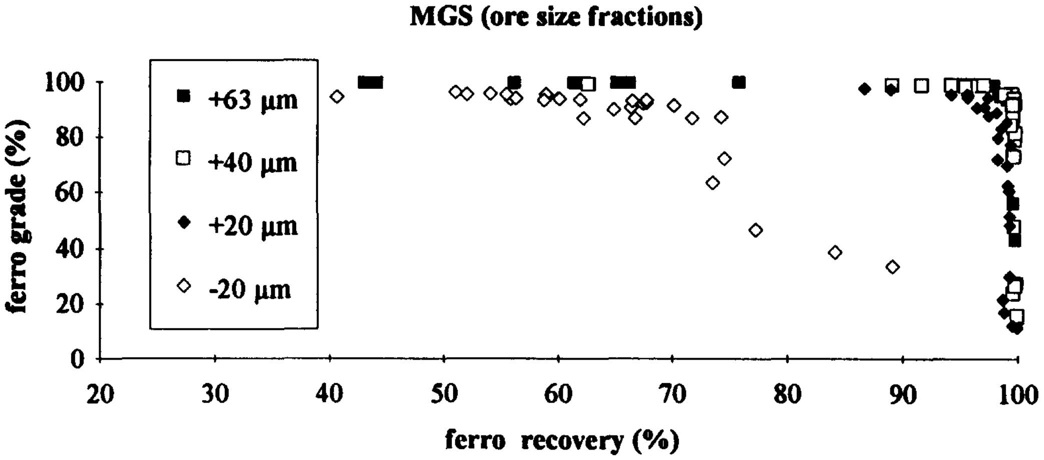

Fig.4 Performance of the MGS with different particle size fractions of the synthetic ore

d) Statistical processing of the data: analysis of the recovery (0–20 µm fraction)

The statistical processing of the results can be illustrated using the 0–20 µm fraction. Statistical methods can provide an important contribution to industrial research because they enable clear and unambiguous conclusions to be drawn from a minimum number of tests, thus minimizing costs.

The data from the variance analysis is summarized in Table 3. The variance of the experimental error was estimated from four tests repeated under identical conditions. The last column gives the significance of the variables at:

*** 99.9% ** 99% * 95%.

The table also shows that the operating parameters influencing the recovery in the 0–20 µm fraction are:

Drum rotation speed which is significant at 99%; this is easily understood because an increase in drum rotation speed causes an increase in the centrifugal force which helps plaster more heavy minerals onto the inner surface of the drum.

Amplitude and frequency of the shakes: these two parameters are each equally significant at 99%. A strong shake disrupts the concentrate plastered against the inside of the drum and allows the wash water to carry the heavy minerals along with the tailings.

The importance of these three parameters is confirmed by their interactions by pairs (SA, SF and AF) each of which are also significant at 99%. These associations show that the parameters do not act independently and that the variation of the one must equally take account the variation of the others. The link between these three parameters is again clearly demonstrated by the effect of rotation speed + amplitude + frequency (SAF) (second order interaction), which has a significance of 99 %.

Application to a tungsten ore

The study with a synthetic ore having shown the importance of the drum rotation speed and of the amplitude and frequency of the shake, these observations were verified with a natural tungsten ore.

TABLE 3 Variance analysis data

	Coefficient	Variance	Significance
Constant function	55.6	102370	***
Principal effects			
W (water)	-2.87	263.41	*
S (rotation speed)	11.99	4595.27	**
A (amplitude)	-10.00	3200.20	**
F (frequency)	-11.91	4539.38	**
T (tilt)	-2.19	153.78	*
1st order interactions			
SA	4.84	750.68	**
SF	4.26	582.00	**
AF	-6.94	1542.76	**
2nd order interactions			
WSA	-1.85	109.33	*
SAF	6.61	1399.87	**
3rd order interactions			
SAFR	-1.83	107.86	*
Tailings		10.12	

a) Drum rotation speed

The rotation speed is a very important parameter that determines the purity of the concentrate. Figure 5 shows the grade, recovery and weight yield of the concentrate versus rotation speed for tests carried out under the following operating conditions:

Tilt: 5° Wash water: 3.5 l/min
Amplitude: 19 mm Rotation speed: variable from 165 to 180 rpm
Frequency: 5.8 cps
Feed rate: 34 kg/h Solids concentration: 32%

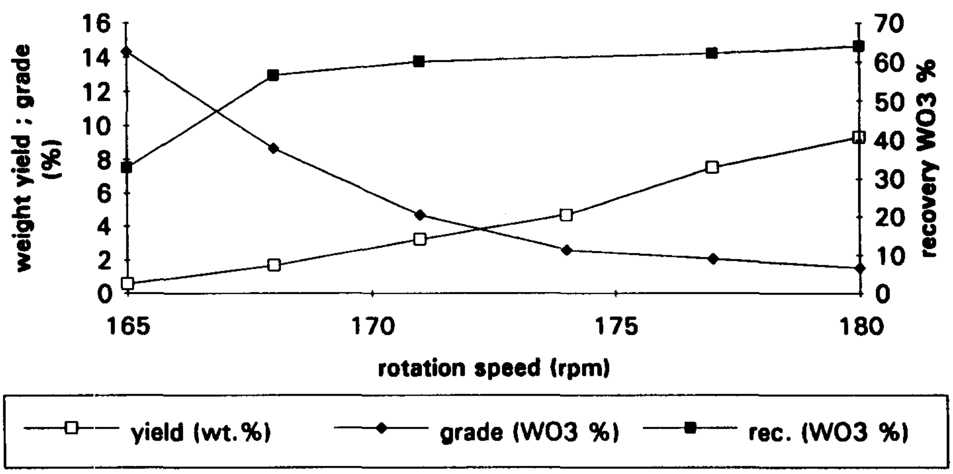

Fig.5 Variation in drum rotation speed

The curves of Figure 5 show a significant increase in the weight yield and a lowering of the grade of the concentrate with increasing rotation speed, even by a small amount (increments of 3 revolutions per minute between the different operating conditions). This confirms the high separation sensitivity of this parameter and thus the importance of it being carefully controlled.

b) Shake amplitude

The equipment is limited to three levels of adjustment for shake amplitude. The tests were thus carried out under the following operating conditions:

Tilt: 6° Wash water: 3.5 l/min
Frequency: 5.8 cps Rotation speed: 192 rpm
Amplitude: variable at 12.5, 19 and 24.5 mm
Feed rate: 34 kg/h Solids concentration: 32%

Increasing the amplitude of the shakes causes a reduction in weight yield (Figure 6). This is explained by the fact that a strong shake disrupts the layer of concentrate plastered onto the inside of the drum and allows the wash water to carry the minerals into the tailings. The heaviest minerals rapidly become replastered and are dragged by the scrapers, hence the observed increase in grade.

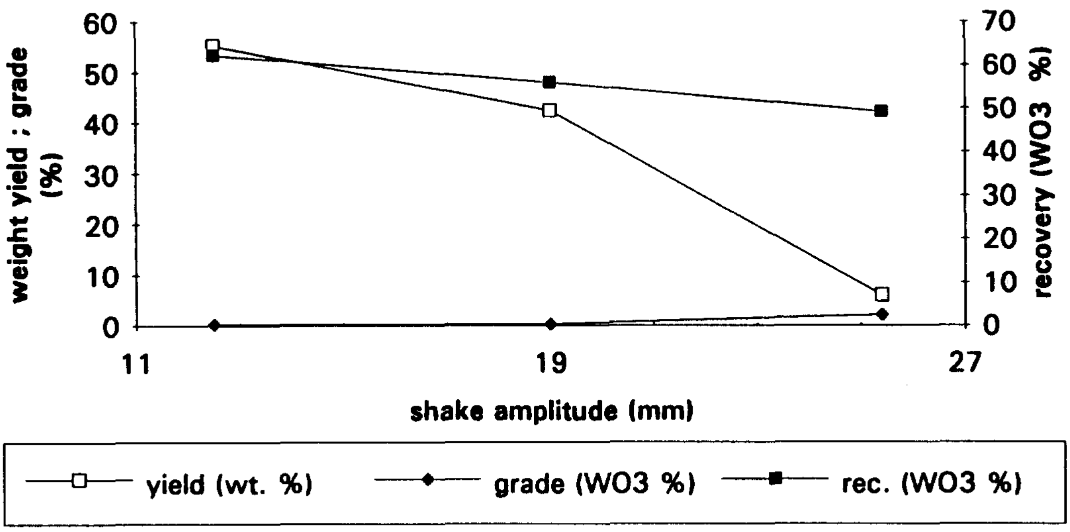

Fig.6 Variation in shake amplitude

c) Shake frequency

As with the amplitude, the frequency of the shakes is a parameter for which the adjustment is limited to three levels. The tests were therefore carried out under the following operating conditions:

Tilt: 5° Wash water: 3.5 l/min
Amplitude: 19 mm Rotation speed: 171 rpm
Frequency: variable at 4, 4.7 and 5.8 cps
Feed rate: 34 kg/h Solids concentration: 32%

Increasing the shake frequency causes a remobilization of the concentrate layer (Figure 7), thus facilitating its being carried along by the water flowing towards the tailings outlet. Hence a reduction in the weight yield of the concentrate and an increase in its grade.

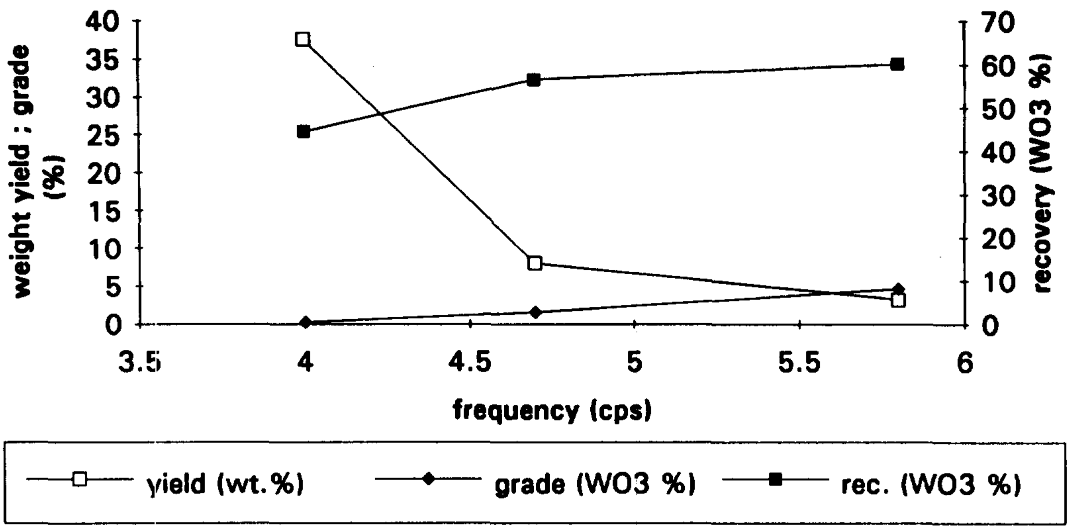

Fig.7 Variation in shake frequency

d) Wash water and tilt

These two parameters mainly affect the grade of the concentrate.

Increasing the wash water flow rate, when this is moderate, gives a "cleaner" concentrate, cleared of the non-tungsten minerals; hence a reduction in the weight yield and an increase in WO_3 grade. An exaggerated increase in the water flow rate, however, results in heavy particles being carried along in the tailings; hence a drop in the WO_3 recovery above a certain threshold (here 5 l/min).

Increasing the angle of tilt causes a reduction in the weight yield and a better WO_3 grade. Too steep a tilt, however, would tend to reduce recovery of the heavy minerals in the concentrate. Selection of the tilt angle should be made in relation to the particle size of the material to be processed; the tilt of the equipment being greater with larger size particles.

COMPARATIVE PERFORMANCE STUDY BETWEEN THE MGS AND A FINES TABLE

This study was done using the synthetic ore. The Fines table that was used is a pilot model of the Duplex concentrator type (GEC). For the tests outlined below it was fed at an average rate of 15 kg/h of ore, the pulp having a solids concentration of 35%. Following orientation and equipment adjustment trials, the tests were carried out according to the five operating conditions given in Table 4. The results of the tests are summarized in Table 5.

The data obtained for the MGS with the factorial design were used as the basis for the comparative study.

Figure 8, which compares the results in terms of grade-recovery for the bulk concentrate (all particle size fractions together), shows that the MGS presents a certain advantage over the Fines table. Where performance according size fraction is concerned, it is seen that the efficiency of the MGS is better than that of the GEC table (Figures 9, 10, 11); the difference in performance is particularly well marked with the 0–20 μm fraction (Figure 12).

TABLE 4 Test conditions with the GEC table

	Wash water (l/h)	Running time (min)	Feed time (sec)
condition 1	700	5	15
condition 2	1400	5	15
condition 3	700	10	15
condition 4	1400	10	15
condition 5	1050	7.5	15

TABLE 5 Separation results with the Fines table

Overall concentrate		Results by particle size fraction							
		+63-80 µm		+40-63µm		+20-40 µm		0-20 µm	
recov.	grade	recov.	grade	recov.	grade	recov	grade	recov.	grade
75.19	32.41	97.12	37.32	97.95	29.89	82.62	27.65	34.35	37.37
64.37	47.18	85.38	55.15	92.44	44.69	74.48	40.09	23.69	50.52
73.70	50.08	92.87	60.42	93.71	46.68	77.58	43.02	31.14	48.94
61.39	83.89	80.27	95.02	83.66	86.17	67.75	73.29	21.81	74.89
73.23	51.74	95.59	62.72	96.44	49.88	75.67	41.98	27.64	50.32
89.24	17.18	99.55	18.34	99.87	14.16	96.25	13.37	67.75	29.79
82.67	18.38	98.54	15.54	99.56	15.31	91.59	18.22	53.76	37.38
88.44	21.44	98.80	22.34	99.79	18.99	94.57	17.72	61.91	34.18
81.03	27.26	96.49	26.46	97.93	24.82	88.38	24.29	48.33	44.25
86.55	22.45	98.87	30.91	99.69	18.22	96.42	16.47	55.03	34.83

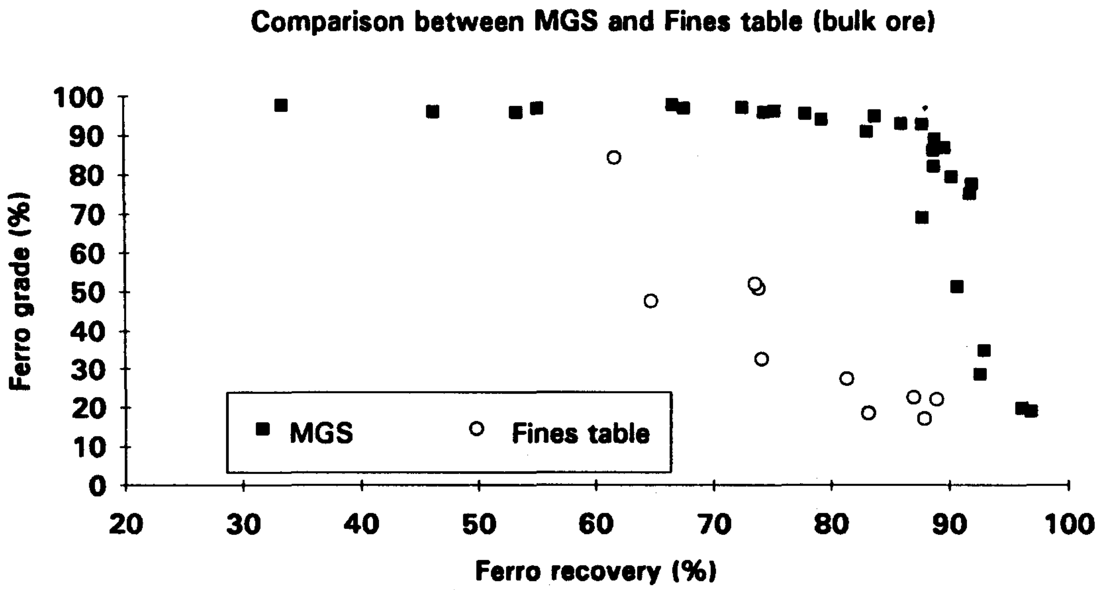

Fig.8 Compared efficiencies of the MGS and a Fines table — bulk ore

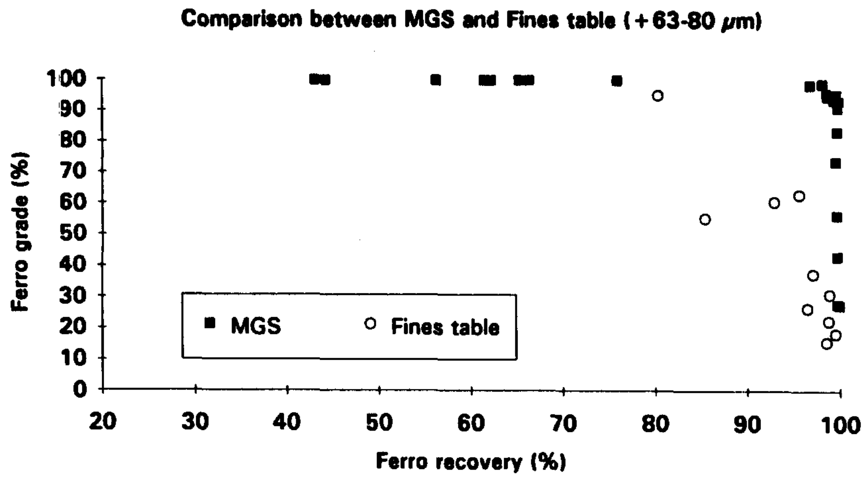

Fig.9 Compared efficiencies of the MGS and a Fines table — +63–80 μm fraction

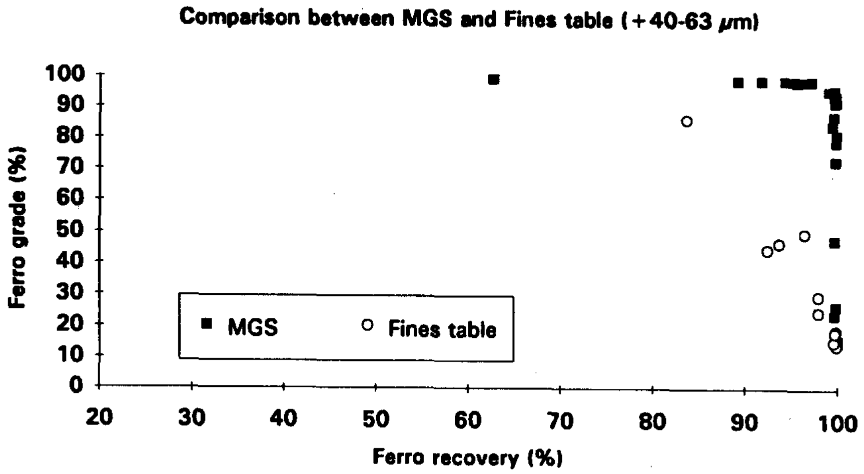

Fig.10 Compared efficiencies of the MGS and a Fines table — +40–63 μm fraction

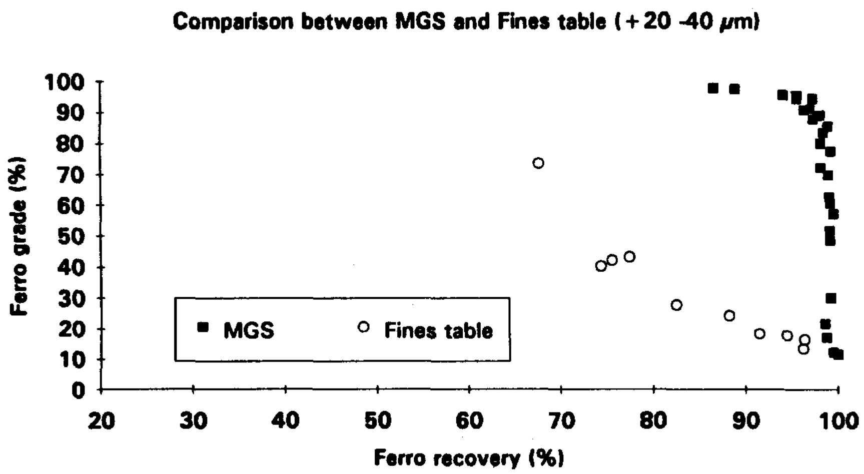

Fig.11 Compared efficiencies of the MGS and a Fines table — +20–40 μm fraction

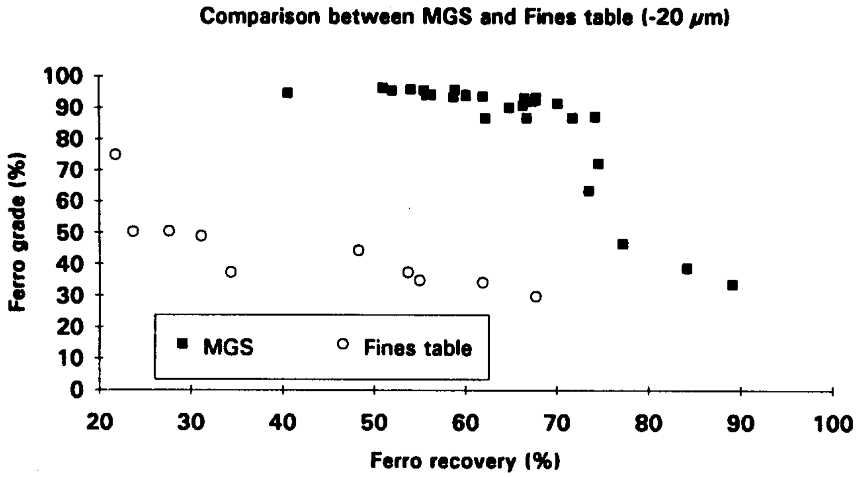

Fig.12 Compared efficiencies of the MGS and a Fines table — 0–20 µm fraction

CONCLUSION

This study has provided a qualitative and quantitative knowledge of the MGS operating parameters, and the first results show that this equipment can provide a notable saving in the recovery of fine particles by gravity. The MGS appears to obtain better results than a Fines table, especially for particles of less than 20 µm. Studies are still in progress, mainly to obtain a better understanding of the behaviour of ultrafine particles (particle size of less than 10 µm).

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