Gravity Concentration — A Better Way (or How to Produce Heavy Mineral Concentrate and Not Recirculating Loads)

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ABSTRACT

Over the past few years developments in heavy minerals processing have concentrated on the mineral separation portion of the business. The best example of this would include new developments in rare-earth magnetic separators and associated flowsheet modifications. Except for some minor modifications in spirals, the 'wet' side of the separation business has lagged behind the 'dry' side. Basic concentrator design has not changed in 20 years.

Recent pilot trials by Outokumpu Technology have shown the benefits of a new gravity flowsheet that combines density separation and spiral concentration on a variety of heavy mineral deposits. This concept is already well utilised within the iron ore industry.

The synergistic combination of these two technologies allows smaller, simpler, and controllable gravity concentrators to be built while providing equivalent or better grade and recoveries of valuable heavy mineral. This is contrasted to the all spiral flowsheet characterised by the diminishing returns of multiple stages of spirals and associated recirculating loads.

Examples of the flowsheets and associated benefits will be presented from a variety of cases.

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INTRODUCTION

Over the last 50+ years, the Physical Separation Division of Outokumpu Technology has conducted numerous studies designed to improve the efficiency of processing circuits for mineral sand and other industrial mineral producers, worldwide. These studies have involved both wet and dry processes, and have resulted in improved operations as well as the development or modification of new physical separation process equipment.

Recent studies by Outokumpu Technology have focused on the wet-gravity process circuit. Specifically Outokumpu has investigated the effects of integrating a Floatex density separator with spiral concentrators. These studies show that a Spiral-Floatex wet-gravity circuit results in a higher recovery of heavy minerals at the same or higher concentrate grade. In addition, the integrated circuit can better accommodate changes in feed material, is easier to maintain and operate, and has lower capital costs.

Presented are data generated from mineral sand laboratory and pilot-scale testwork which integrated a Floatex density separator with spiral concentrators. The Floatex separator was positioned differently in each application to maximise its separation efficiency and to accommodate plant and client requirements.

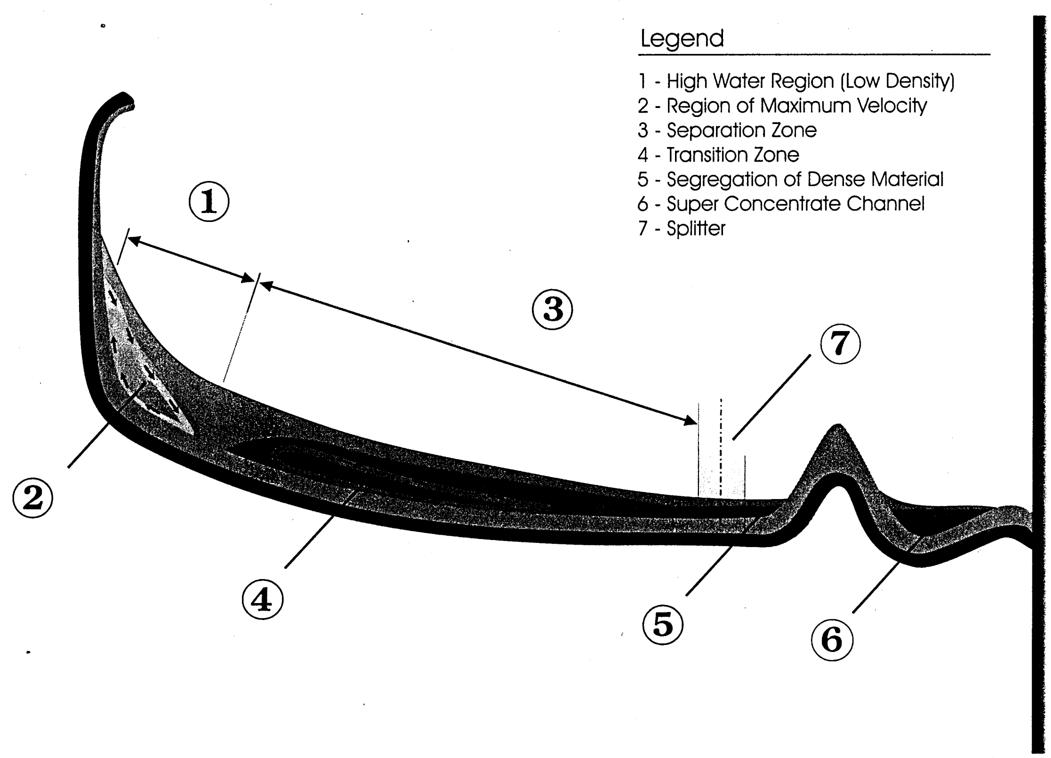

FIG 1 - Cross-section/profile regions of a Spiral concentrator.

BACKGROUND

Spirals and Floatex separators are common to mineral sand wet-gravity operations. Spirals are commonly used to beneficiate the ore material and for the production of a heavy mineral concentrate. A Floatex unit is used for the removal of fine particles attritioned from the surface of the concentrate minerals and any fine quartz remaining in the heavy mineral concentrate after spiral concentration. This use of a Floatex unit in wet-gravity circuits is relatively new and is rapidly growing in popularity.

A spiral is a flowing-film concentrator in which the slurried feed material is subject to centrifugal and gravitational forces (Figure 1). The centrifugal force causes the upper layers of water to flow outward and carry with it particles of lower density and larger size. The centrifugal force on the bottom layer of water is retarded by friction with the spiral; consequently the lower layers of water flow sideways toward the spiral's inner edge carrying with it particles of higher density and of smaller relative size. Equilibrium between the centrifugal force outward and the gravitational force downward allows for the separation of particles based on their density and size.

Spirals, because of their versatility and relatively low installation and operational costs, are used in quantity in mineral sand operations. Typically the sand material, after the removal of oversize boulders and undersize clay, is slurried to approximately 30 per cent solids and presented as feed to a four-stage spiral circuit (Figure 2).

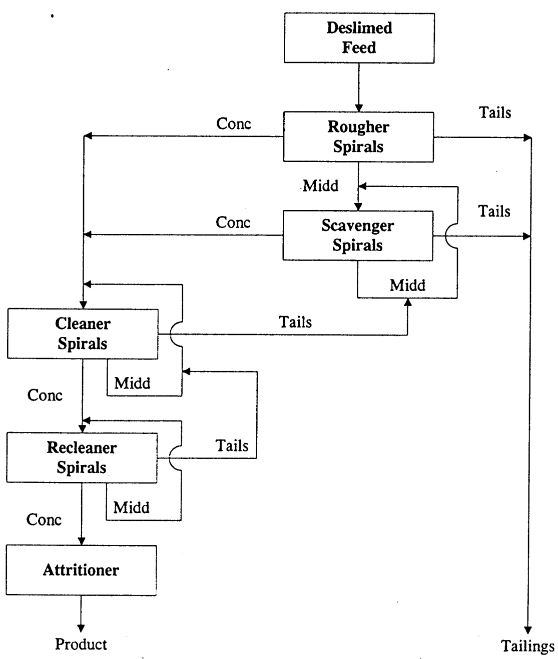

FIG 2 - Typical four-stage all-spiral wet gravity circuit.

A Floatex density separator is a hindered-bed classifier. Feed slurry is introduced tangentially through a centralised feedwell that extends to approximately one third of the length of the tank section. Fluidising (teeter water) is introduced over the entire cross-sectional area at the base of the teeter chamber through evenly spaced water distribution pipes. The rising current of water causes the feed entering the separation zone to expand into a teetered or fluidised bed (Figure 3).

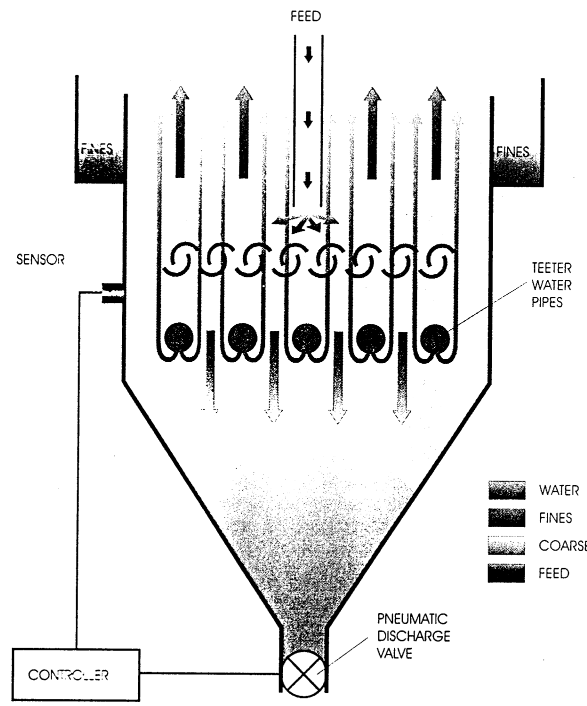

FIG 3 - Cross-section/profile regions of a Floatex density separator.

The separation takes place in the tank's intermediate zone with the lighter and finer sized particles lifted upwards and exiting the separator from the upper zone while the heavier and coarser particles migrate downward, exiting the separator through the lower conical section. The pressure, sensed by a DP cell mounted in the tank's wall, is transmitted to the underflow control valve thereby maintaining a constant height of the teeter bed and a steady discharge of the underflow.

DISCUSSION

Case Study 1: Removal of fine particles from the spiral heavy mineral concentrate using a Floatex density separator

A common problem in many wet-gravity circuits is the presence of fine silica in the final heavy mineral concentrate. This material adversely impacts the performance of the subsequent dry electrostatic and magnetic separation processes, as its removal is both difficult and expensive. As wet-mill spiral operators strive to improve the concentrate grade by removing the fine silica they trade-off the recovery of coarser ilmenite and other heavy minerals which are pushed to the spirals outer rim.

A Floatex density separator positioned at the end of the wet-gravity circuit is ideally suited for the removal of the fine particles attritioned from the surface of the heavy minerals and any residual fine silica remaining in the concentrate (Figure 4).

This placement allows for a three per cent increase in the grade of the heavy mineral concentrate with no practical loss of the economic heavy minerals (Table 1). Even greater increases in concentrate grade can be achieved with higher volumes of teeter water.

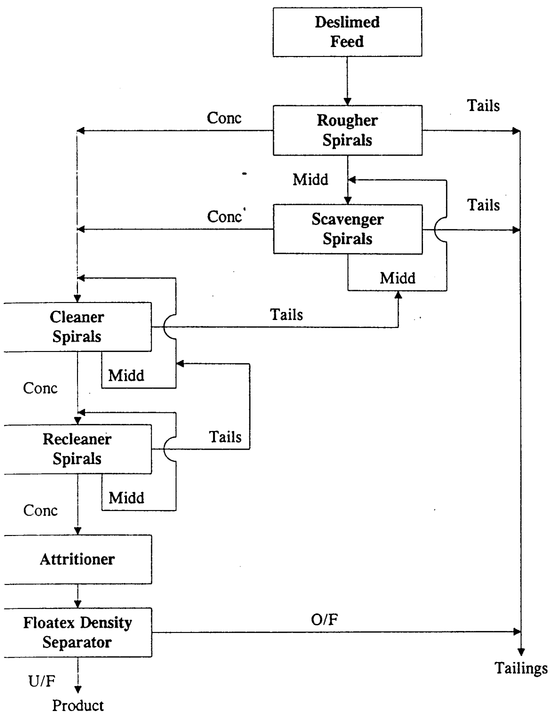

FIG 4 - Floatex-Spiral wet gravity circuit for removal of fine particles.

TABLE 1

Influence of teeter water on heavy mineral grade and recovery.

	Teeter water 85 gpm		Teeter water 100 gpm	
	Grade % HM	Recovery % HM	Grade % HM	Recovery % HM
Floatex feed	93.5		93.5	
Floatex underflow (Product)	96.2	99.3	98.7	96.6
Floatex overflow	19.4	0.7	37.2	3.4

Case Study 2: Recovery of heavy minerals from mineral sand ore materials

One of the many factors determining the separation efficiency of the wet-gravity circuit is the heavy mineral content of the ore material. The heavy mineral content of mineral sand ores generally ranges between three and 20 per cent. The corresponding heavy mineral recovery is generally between 85 and 95 per cent at a concentrate grade of 90 per cent. In an all-spiral circuit, wet-mill operators maximise recovery by reducing the amount of material reporting to the rougher and scavenger spiral tailings. Doing so results in an increase in the re-circulating middling material and thus requires a corresponding increase in the number of spirals, and to some degree, an increase in the overall complexity of the spiral circuit.

Pilot-plant studies by Outokumpu Technology of a higher-grade and a lower-grade mineral sand ores show that the placement of a Floatex density separator 'into' rather than 'at the end of' the spiral circuit results in a higher heavy mineral recovery and/or grade of product.

For ores with a high heavy mineral content the Floatex unit is positioned to treat the concentrate material generated from the rougher and scavenger spirals (Figure 5). This placement allows the coarser and denser minerals to immediately report to the underflow and final concentrate product. The medium and smaller-sized low-density minerals, as well as the smallest high-density minerals report to the Floatex overflow. The overflow is subjected to further concentration using spirals where the well-classified material is efficiently separated and the finer-sized high-density minerals are recovered.

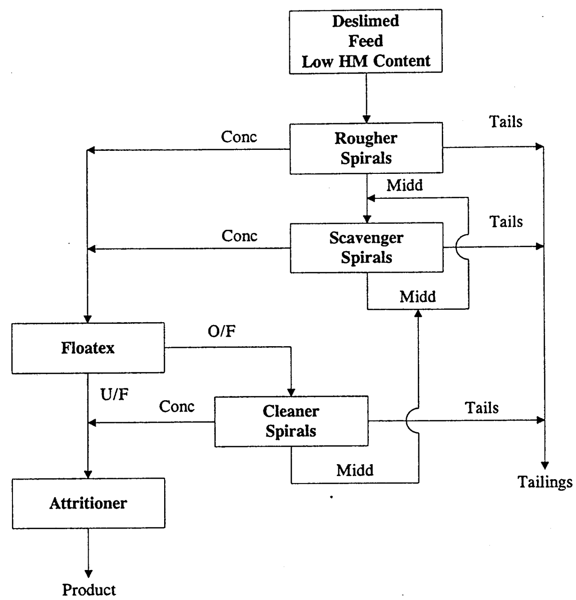

FIG 5 - Spiral-Floatex circuit for higher grade mineral sand ore material.

A comparative study of a Spiral-Floatex circuit versus an all-spiral circuit using a high-grade mineral sand feed material shows that the Spiral-Floatex circuit improves the recovery of heavy minerals by more than two per cent with no reduction in concentrate grade (Table 2).

TABLE 2

Comparison of heavy mineral grade and recovery from Spiral-Floatex and all-spiral wet-gravity separation circuit for high-grade mineral sand ore material.

	Spirals - Floatex	All - Spirals
Head feed grade (% HM)	18	18
Concentrate grade (% HM)	92.5	92.5
HM recovery (%)	95.7	93.3

It must be noted that the distribution of minerals by particle size must be considered when integrating a Floatex unit into the spiral circuit. By design, the Floatex unit captures coarse heavy minerals, (ie ilmenite), and the coarser light minerals, (ie quartz). In order to maintain concentrate grade the coarser lighter minerals must be removed from the Floatex underflow product. In these studies, the coarser quartz and other lower density minerals (eg staurolite) were easily removed by coarse screening as these lower density minerals were substantially coarser than their higher density counterparts.

Using a low-grade mineral sand ore as feed, the Floatex unit is placed nearer the end of circuit to treat the concentrates from the cleaner spirals. The Floatex underflow is a finished concentrate product. The overflow is again subjected to spirals for the recovery of the finer-sized heavy minerals and added to the coarser concentrate (Figure 6).

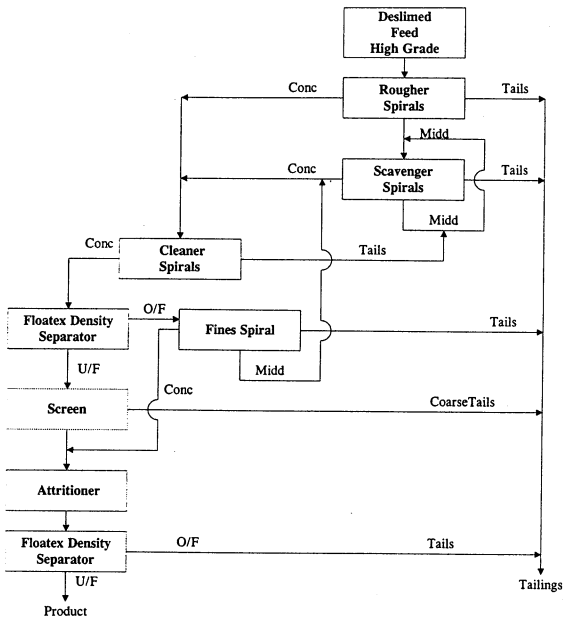

FIG 6 - Floatex-spiral circuit of lower grade mineral sand ore material.

For the low-grade material the Floatex-Spiral circuit achieved an improvement in both heavy mineral recovery and concentrate grade (Table 3).

TABLE 3

Comparison of heavy-mineral grade and recovery from a Spiral-Floatex and all-spiral wet-gravity circuit for a low-grade mineral sand ore material.

	Spiral - Floatex	Spirals - Only
Head feed grade (%HM)	3.0	3.0
Concentrate grade (%HM)	94.6	92.0
HM recovery (%)	75.4	69.5
TiO_2 recovery	88.0	N/A

In addition to increased recovery of heavy minerals, the Spiral-Floatex circuit requires substantially fewer spirals as the recirculating material is reduced due to the more immediate recovery of coarse heavy minerals by the Floatex unit, and the more efficiently recovery of the finer-sized heavies in the well-classified feed. In a typical four-stage all-spiral circuit the number of spirals used as scavengers and cleaners is equal to the number of rougher spirals. The number of the final stage re-cleaner spirals is one-half the number of the rougher spirals (Table 4).

TABLE 5

Comparison of costs of wet-gravity process equipment required to process 500 tph high-grade mineral sand.

Circuit	No of Spirals	No of Floatex Units	No of Attritioner	No of Screening Unit	Est Total Capital Cost
Spiral/Floatex	840	2	1	1	\$3.2 M
All-Spirals	1176	1	1	0	\$3.6 M

The reduction in spirals in the Spiral-Floatex circuit allows for a reduction in the capital equipment costs. However this reduction is slightly offset by the need for an additional Floatex unit and screening equipment (Table 5).

TABLE 4

Comparison of number of spirals required to process 500 tph high-grade mineral sand.

Circuit	Rougher	Scavenger	Cleaner	Re-Cleaner	Total
Spiral/Floatex	336	252	168	84	840
All-Spiral	336	336	336	168	1176

CONCLUSION

Outokumpu's investigations show that improvements in the performance of a wet-gravity circuit can be realised by integrating a hindered bed classifier with spiral concentrators. Specifically:

- The recovery of heavy minerals from a high-grade and low-grade mineral sand ore increased by 2.4 per cent and 6.9 per cent respectively using the integrated circuit.
- The increase in heavy mineral recovery was achieved without a reduction in concentrate grade for the high-grade ore, and with a 2.6 per cent increase in the grade of the concentrate from the low-grade ore material.
- The Spiral-Floatex integrated circuit requires approximately 25 per cent fewer spirals than an all-spiral circuit, and thus lower associated capital and operating costs.
- The Spiral-Floatex circuit provides operators a mechanism that can be automatically or manually adjusted to accommodate variations in plant feed and product quality.

These increases in heavy mineral recovery and grade add directly to the operation's revenue over the life of the project, and illustrate Outokumpu's commitment to client support and to advancing process technology in the mineral industry.

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