

# A Review of Spiral Technology for Fine Gravity Beneficiation

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## INTRODUCTION

The metallurgical, operational and economic advantages of using gravity beneficiation in appropriate duties are well recognised and documented (Burt 1999). The selection of the most appropriate gravity separation device and resultant plant flow sheet is dependant on a range of criteria including particle size distribution of both "heavy" and "light" constituents and the required throughput rate. This paper will concentrate on recent work to expand the applicable size ranges that can be successfully treated by spiral separators and on increasing the unit capacity of these devices.

Specific areas of investigation are:

- The recovery of fine (<100 $\mu$ m) heavy mineral (>2.85 S.G.)
- Increased spiral unit capacities to 7.0 t/h per start.

## FINE MINERAL RECOVERY

Traditionally, operators of spiral separators treating material finer than 100 $\mu$ m have had to contend with relatively poor separation efficiencies, grades and recoveries compared to operations treating coarser materials. The recently reported development of the FM1 spiral (Richards et al 2000) has effectively reduced this lower limit on the particle size range that can now be effectively treated using modern spiral technology.

The wide range of spiral models currently available is based on several classes of trough profile including constant pitch and variable pitch trough designs. Each of the resultant spiral troughs developed for specific and often diverse processing requirements demonstrate a balance between the metallurgical separation and materials handling aspects of the trough. These considerations have been carefully addressed in the development of the FM1 spiral.

The flow regime necessary to maintain both the materials handling and metallurgical performance characteristics of a spiral trough when treating material coarser than 100 $\mu$ m will generally be inefficient in the treatment of finer material. For the recovery of heavy minerals finer than 100 $\mu$ m to the spiral concentrate product the flow on the spiral trough must be controlled to minimise turbulence that will entrain fine particles in the outer section of the trough. The FM1 trough profile has been specifically designed to ensure a more laminar flow regime to allow the finer mineral particles to settle to the trough surface and migrate to the concentrate collection area. This laminar flow requirement has lead to a reduction in the unit capacity of this profile.

The need to recover fine heavy particles from process streams is becoming increasingly necessary in the mineral sands industry as a number of the potential reserves available for future mining contain finer heavy minerals than those being treated currently. Many of these fine grained deposits have been found in the Murray Basin mineral sands province in Australia. As the development of the deposits within this region is currently being pursued by large, small and potential producers alike, considerable testing of a fine-grained Australian mineral sand was carried out as part of the FM1 spiral development programme. The size distribution and assay of this material is given in Figure 1.

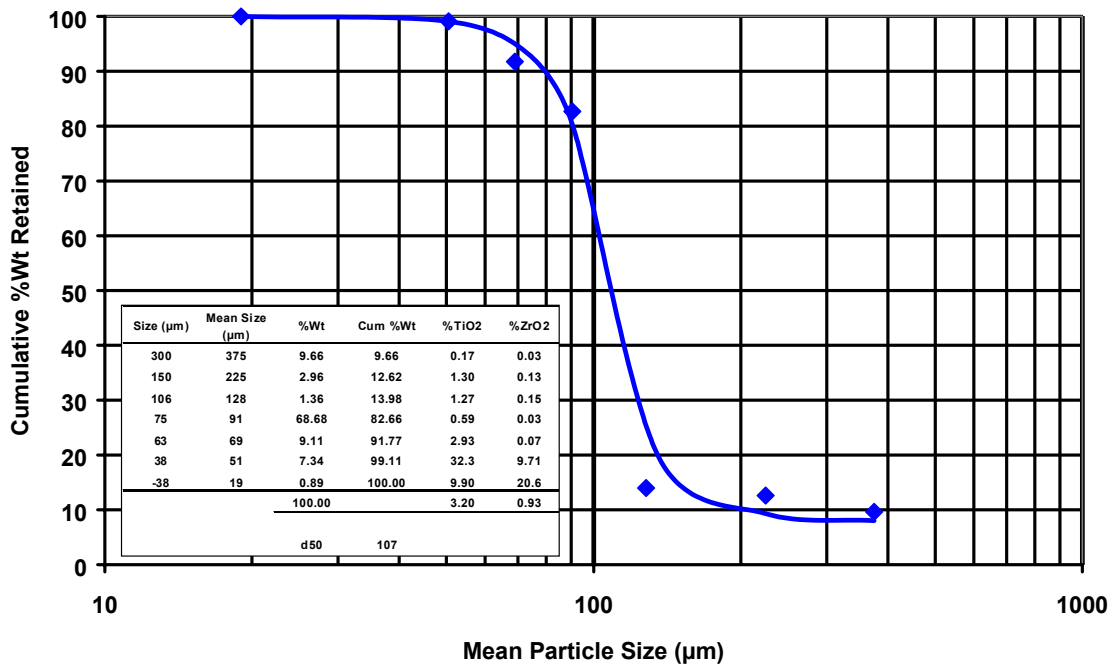


Fig.1 – Fine grained Australian mineral sand size analysis

The size analysis of this fine grained material indicates a  $d_{50}$  of 107  $\mu\text{m}$ . This material also demonstrates a relatively narrow size range which is conducive to good gravity separation performance.

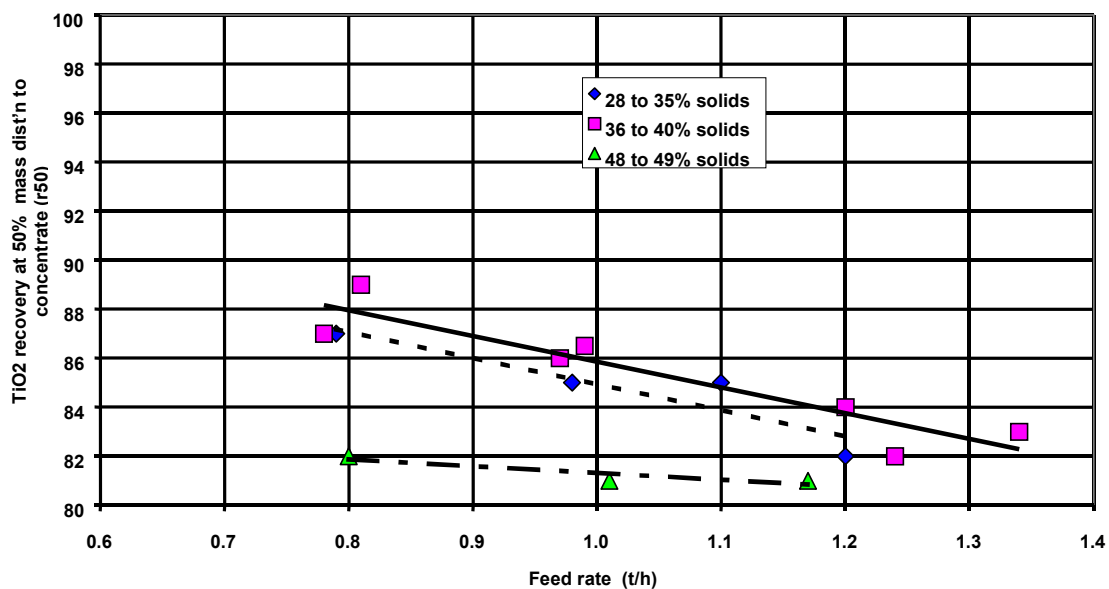


Fig.2 – FM1 spiral performance on fine-grained Australian mineral sand – Effect of feed rate on  $\text{TiO}_2$  recovery

Fig. 2 indicates the performance of the spiral separator under the effect of both feed pulp density and feed rate. It is evident that a pulp density in the range of 36 to 40% solids is near the optimum, in fact these data suggest that feed pulp densities  $>48\%$  are detrimental to the performance. This is due to the higher apparent viscosity effect of the high density pulp which thereby hinders the transport of the pulp components through the fluid media.

The increase in performance with reduced feed rate at around 36% solids feed density is due to minimizing the volume flow of the spiral separator and hence reducing the turbulence. The reduction in turbulence reduces the probability of particles being re-mixed after they are separated.

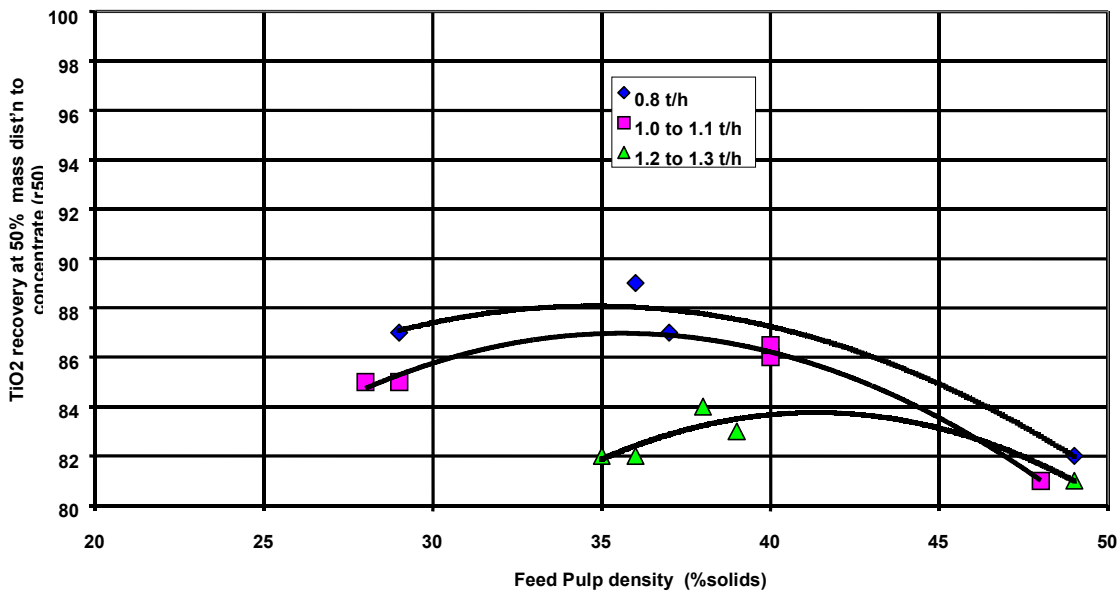


Fig.3 – FM1 spiral performance on fine-grained Australian mineral sand – Effect of feed density on TiO<sub>2</sub> recovery.

Fig. 3 illustrates the optimum feed conditions for the FM1 fine mineral spiral at a values recovery of 50% viz. low feed rate 0.8 t/h and feed pulp density of 35-36 %solids.

The benefits of using the FM1 spiral for the treatment of fine grained silica sand, tin tailings, iron ore and copper were also investigated (Richards et al 2000).

Other potential applications for the use of fine spiral technology include operations that currently grind their feed material to 80% passing 75µm to achieve satisfactory liberation. While the use of spiral separation technology to treat this material has historically been ineffective at this size range, the use of FM1 type spirals may enable a reduction in the amount of material treated through subsequent processing stages by the rejection of fine liberated gangue material after grinding. For example in the preparation of material for flotation, significant gangue material may be rejected in a gravity stage prior to the flotation stage, hence reducing the size of the flotation circuit and therefore reducing capital and operating expenses.

### INCREASED UNIT CAPACITY

The use of spiral separators in high tonnage industries such as Iron Ore, Mineral Sands and Coal is well known. In some of these operations it is not uncommon to find primary spiral circuits treating more than 3000 tonnes per hour with similar capacities in the combined cleaning and scavenging stages. Spiral separators remain the most economic option for these operations due to their relatively low operating and capital cost.

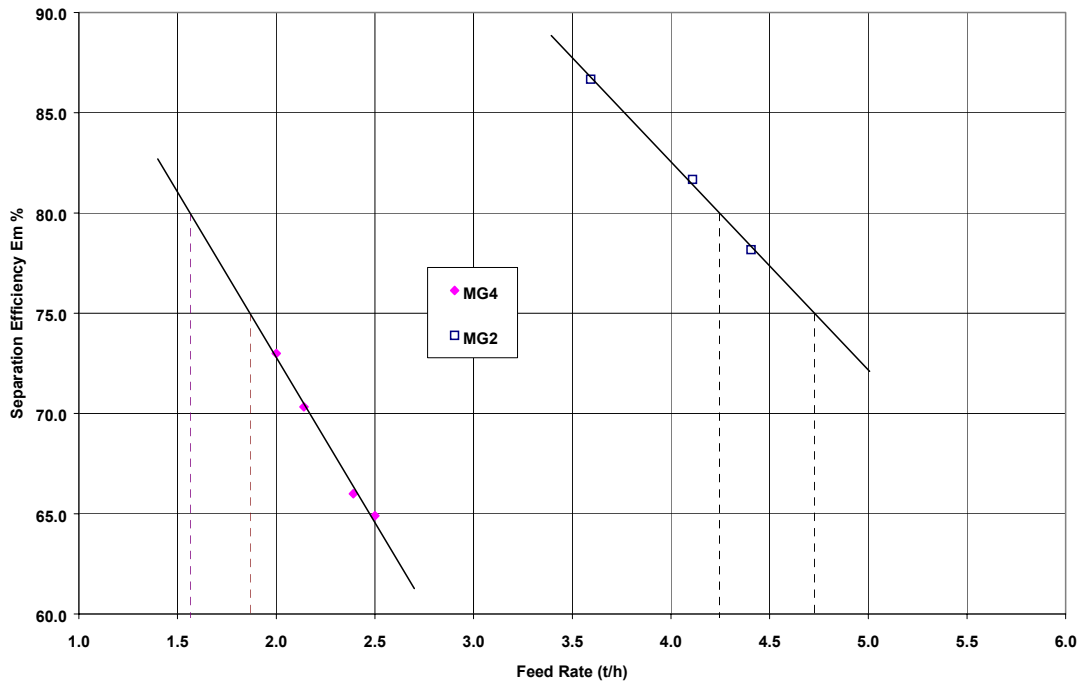
With typical spiral unit capacities in the order of 2.5 t/h many of these larger gravity plants could have well over 2000 installed spiral starts. The use of twin, triple and sometimes quad start spirals reduces the overall number of spiral assemblies required.

The recent development of the MG2 high capacity spiral (Richards and Palmer, 1997) capable of treatment rates 2-2.5 times higher than conventional spirals (at equivalent separation efficiency) has enabled plant designers to reduce the size, cost and complexity of large gravity plants. The benefits of high capacity spirals include:

- Reduced plant foot-print for a given throughput resulting in a reduced capital cost,
- Reduced plant height as a result of shorter feed distribution and product laundering pipe work (at the nominated pipe slopes),

- Fewer installed units requiring operational attention and metallurgical adjustment/control.

The performance of this spiral has been compared to that of the MG4 (figure 4). The MG4 spiral has been used extensively around the world in applications such as the treatment of mineral sands and silica sand.



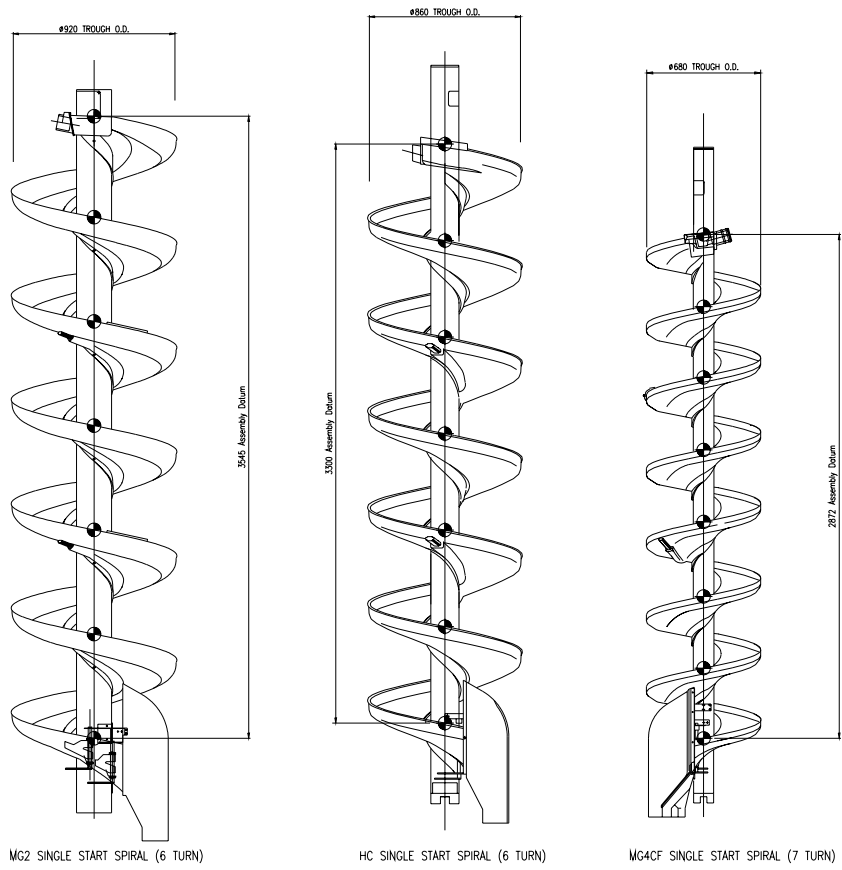
**Figure 4 - Comparative performance of High/Standard Capacity Mineral Spirals.**  
(after Holland-Batt[xx])

Continued testing of the MG2 spiral, using differing feed types, has shown that the separating performance of the unit is generally excellent. However on some feed types the performance of the MG2 is similar to that of the MG4, which tends to negate the increased capacity benefits of the larger spiral.

Continuing work into the development of high capacity spirals has now resulted in the design and preliminary testing of a new high capacity prototype spiral (HCP). The performance of this new trough design has been compared to the previously developed and reported high capacity spiral, model MG2, as well as the commonly used alternative for similar applications, the model MG4 spiral.

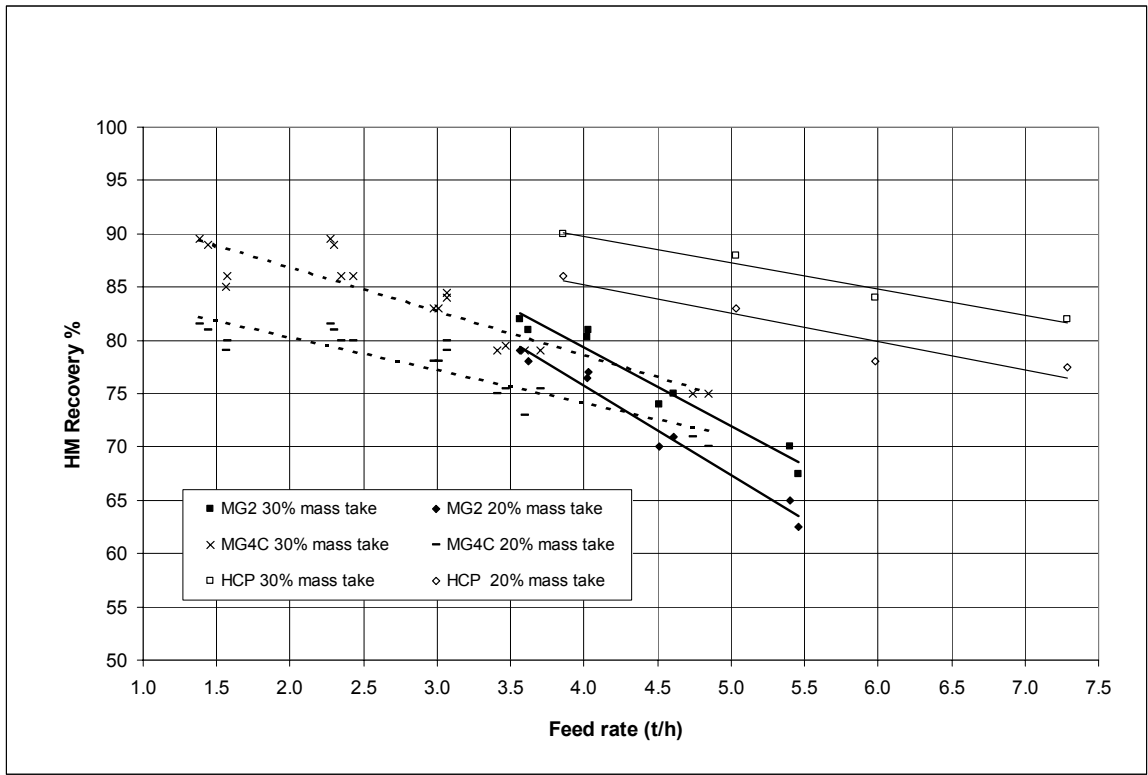
The dimensional differences between the MG2, HCP and MG4 spiral separators are shown in fig 5. In summary, the diameters are 920mm, 850mm and 680mm respectively while the overall spiral heights are 3545mm, 3300mm and 2872mm respectively. Both the HCP and MG2 spirals are 6 turn spirals whilst the MG4 spiral is a 7 turn unit. The success of the design of the HCP spiral is due to the careful adaptation of the profile and the design of the repulper system.

The removal of concentrate at several points down the trough has generally shown benefit in increasing separator performance. This feature has been incorporated in the development of the high capacity spiral separator with auxiliary splitters at turns 2 and 4.



**Figure 5 - General Arrangement drawing comparing the MG2, HCP and MG4 spiral separators**

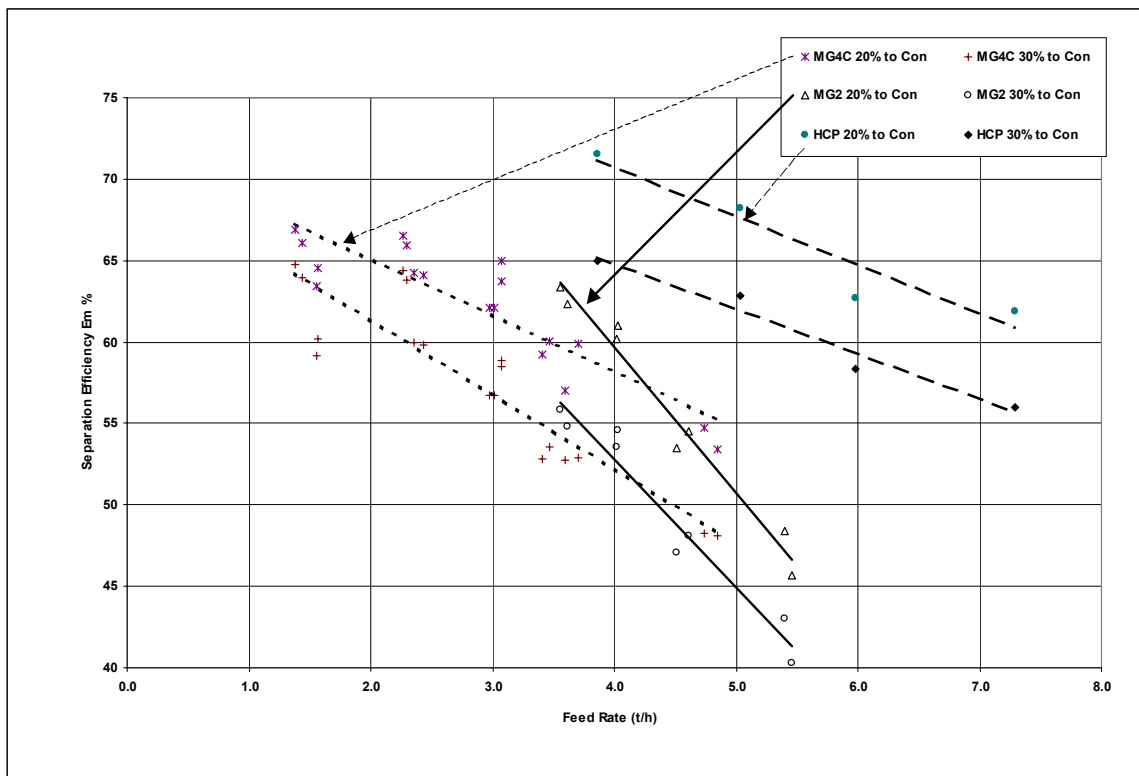
Considerable development testwork has been undertaken on a typical Western Australian mineral sand feed material containing 7% Heavy Mineral (Yaxley, 1999). The results of this work have been encouraging and indicate that the HCP spiral will effectively treat suitable feed material at rates up to 7.5 t/h per start (figure 6).



**Figure 6 - MG4C compared to MG2 and HCP**

The above comparison shows the effect of feed rate of heavy mineral recovery with the spiral concentrate splitters set to yield either 20% and 30% of the feed mass to the concentrate fraction.

For this particular feed material the performance of the model MG2 and MG4 spirals at elevated feed rates is similar. In contrast, the performance of the HCP spiral indicates a step increase in performance at elevated feed rates (up to 7.5 t/h).



**Figure 7 - Separation Efficiency for 3 spiral models**

Figure 7 shows the performance comparison of the three spiral separators in terms of separation efficiency. Again the performance of the HCP spiral is comparable with that of the MG4 spiral albeit at a significant increase in capacity viz. at 60% efficiency and 30% mass to concentrate the MG4 indicates a capacity of 3.5 t/h compared to 7.5 t/h for the HCP spiral.

Additional feed types are currently being sourced to quantify the performance of this new spiral type for use in other fine gravity separation duties.

## REFERENCES

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