APPLICATIONS OF KELSEY CENTRIFUGAL JIG IN THE RECOVERY OF TAILINGS STREAMS:

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Enhanced gravity separation provides a process to recover mineral values lost to tailings. For processing duties where the valuable constituent particulates are very fine or there are small density or hydraulic differences between liberated mineral species, centrifugal gravity concentrators have found application. The Kelsey Centrifugal Jig is widely applicable to fine mineral recovery duties, with key application areas including mineral sands, tin, gold and nickel. Other areas of application include: iron ore, chromite, base metals, PGMs, soil remediation and scheelite.The operation of the Kelsey Centrifugal Jig is discussed and the performance for a number of scavenging applications is reviewed with data from several applications, including:

- Scavenging of cassiterite from tin tailings
- Fine gold / sulphide recovery from leach tailings
- Recovery of hematite from iron ore tailings.

Keywords: Gravity separation, Kelsey jig, tailings

Theme: Concentration by gravimetric methods

INTRODUCTION

Traditional gravity separation equipment is only generally effective in the recovery of relatively coarse minerals. Past operations using these 1-g devices have produced many tailings dumps around the world that contain significant valuable minerals, predominantly in the finer size fractions. Similarly, many current plants also produce tailings steams that contain sufficient valuable mineral to justify stockpiling and/or retreatment rather than final rejection.

The use of centrifugal force to enhance the effectiveness of gravity separation has been utilized in a number of mineral separation devices (Silva et al (1999)). The Kelsey Jig is one such device which, with the ability to vary the apparent gravitational field by up to 100 times the normal gravitational force, can facilitate major improvements to separation efficiencies, particularly for very fine mineral feeds and / or for the separation of mineral particulates with small density differences. The Kelsey Jig utilizes the same parameters as a conventional jig but superimposes the additional feature of being able to vary the apparent gravitational field acting on fine particles across a ragging bed by spinning the jigging mechanism. (Laplante (2003)).

The high efficiency of separation, as well as the introduction of the high-capacity J1800 model, makes the Kelsey Centrifugal Jig an excellent option for processing existing tailings deposits and scavenging current plant tailings streams to recover fine valuable minerals, as well as for removing environmentally unacceptable minerals from plant waste materials

KELSEY JIG OPERATION

The Kelsey Jig is fed down a fixed central pipe and distributed over a ragging bed supported by a cylindrical shaped screen, which is spun coaxially with the rotor. The bed is pulsed and pressurized hutch water is introduced to fluidize the ragging bed and facilitate stratification / sorting. This results in particles of density greater or equal to that of the ragging passing through the ragging bed via the mechanisms of hindered settling and interstitial trickling, which are enhanced by the apparent higher gravitational forces. The denser particles pass through the internal screen to concentrate hutches and then through spigots to a concentrate launder, while the lighter mineral particles are discharged over a ragging retention ring into a tailings launder.

OPERATING PARAMETERS

The key operating variables on a Kelsey Jig include:

- Spin speed;
- Pulse rate;
- Stroke length;
- Ragging s.g.;
- Ragging size;

- Hutch water addition.

For a specific duty in a particular application, there will be an optimum set of operating conditions. Although a number of the variables can be determined from the characteristics of the feed materials (feed rate, density, sizing), others require testwork to establish the most effective combination/s. It follows that the evaluation of potential jig performance is not a trivial testwork exercise. However, recent improvements to Kelsey Jig control systems have facilitated faster rationalization of appropriate operational parameters.

IMPROVEMENTS

In response to previously established limitations to throughput capacity on the earlier model J650 and J1300 Kelsey Jig machines, the J1800 development culminated in the first commercial installation in a Bolivian tin operation in 2001. Subsequent J1800 machines have been successfully installed and are now operational for the recovery of gold-containing sulphides from CIP tailings and for the upgrading of nickel ore flotation concentrate. Further J1800 units are due to be installed early in 2004 for the recovery of zircon from old and new mineral sands plant tailings.

Specific machine improvements, some of which have resulted from experience gained in these first J1800 Kelsey Jig installations include:

- Automatic screen cleaning system;
- Improved diaphragms;
- Upgraded lubrication systems;
- Improved internal screen design;
- Improved control systems.

Some of these improvements have been necessitated from a need to accommodate the requirements for higher throughput capacity (up to 80 t/h), whilst other features have evolved from a desire to introduce more user-friendly operational aspects to the machines. The effectiveness of the improvements have been demonstrated in higher availabilities associated with longer maintenance intervals and the attendant reductions in operating costs.

PERFORMANCE OF KELSEY CENTRIFUGAL JIG IN TREATMENT OF TAILINGS STREAMS

Scavenging of cassiterite from tin tailings

The processing of tin-bearing ores typically involves a large number of physical and chemical unit operations. These ores generally contain sulphide mineral impurities that are removed via flotation, either at the front of the circuit (after grinding to at least 300 μm) or after preconcentration in a gravity circuit. Traditional gravity circuits incorporate hydroclassifiers, spirals and shaking tables and produce concentrate grades in the order of 45-50% Sn (after sulphide flotation). A cassiterite flotation circuit is typically used to recover fine tin minerals not recovered in the gravity and sulphide flotation circuits. Typically, cassiterite flotation concentrates contain 25-40% Sn and are further upgraded before being combined with gravity concentrates.

The Kelsey Centrifugal Jig is ideally suited to the recovery of fine cassiterite and can be applied to a number of different duties within a tin plant, including:

- Preconcentrating tin-bearing minerals prior to sulphide flotation
- Reducing recirculting loads and overgrinding of tin-bearing minerals in the grinding circuit
- Increasing concentrate grades to 60-65+ % Sn
- Processing gravity tailings, reducing or eliminating the need for high cost cassiterite flotation
- Recovery of fine cassiterite from final plant tailings

The results from on-site testing of the Kelsey Centrifugal Jig, treating a final plant tailings material (d_{50} ~40 μm) containing ~1.2% Sn are presented in Figure 1. The data illustrate the range of results (summarised in Table 1) achievable by a Kelsey Centrifugal Jig in a single stage of processing, from:

- Production of a high grade concentrate at relatively high tin recovery and low concentrate mass yield, to
- High tin recovery and relatively high mass recovery into a lower grade concentrate

Table 1: Range of Kelsey Centrifugal Jig performance in recovery of tin from final plant tailings

	Concentrate Grade (% Sn)	Concentrate Upgrade Ratio	Recovery to Concentrate % Sn	Recovery to Concentrate % Mass
High concentrate grade	15	12.5:1	60	5
High recovery	5	4:1	80-90	20

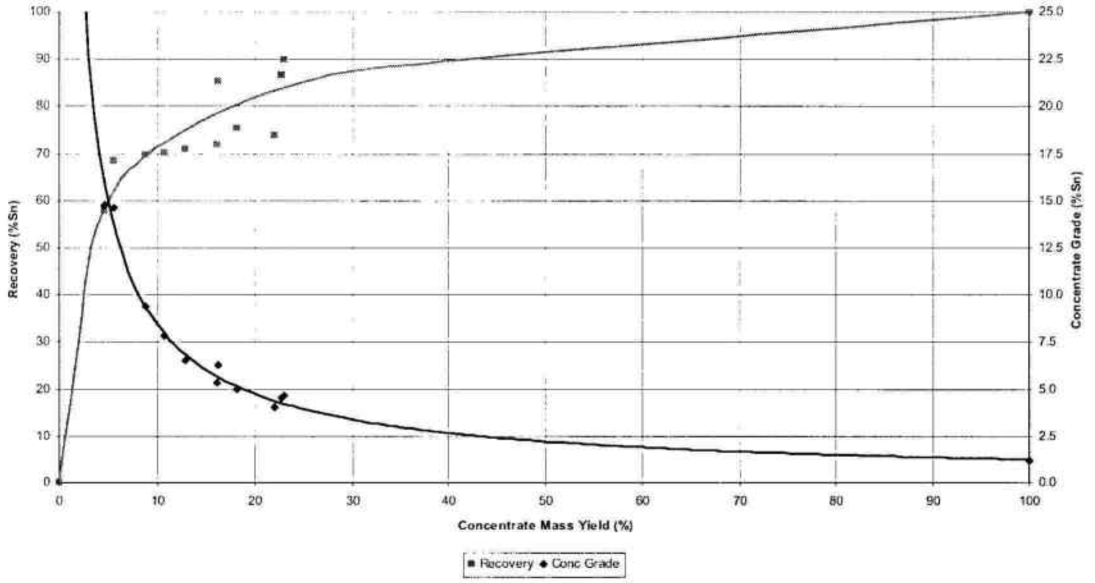

Figure 1: Recovery of tin from final plant tailings with the Kelsey Centrifugal Jig

Separate Kelsey Centrifugal Jig testing of final tailings material containing ~1.4% Sn, from another operation, resulted in an upgrade of ~18:1 to produce a relatively high grade (~25% Sn) concentrate at a tin recovery of ~45% and a corresponding mass recovery of ~2.5%.

Fine gold / sulphide recovery from leach tailings

Gravity equipment has long been used to pre-concentrate free (or gravity recoverable) gold in the primary milling stage of gold circuits (Broman et al., 1986). However, quantifying the increase in gold recovery and real economic benefit associated with such circuit changes can be difficult. On the other hand, the economics of treating a final tailings steam to recover additional gold are more straightforward.

Methods such as froth flotation can be applied to the retreatment of gold / sulphide plant tailings, but such methods have inherent complexities and environmental concerns. Consequently, gravity separation techniques have often been employed with cone and spiral concentrators (Butcher and Laplante, 2003), but generally these circuits have exhibited poor metallurgical performance, due to the very fine particle size of contained valuable minerals. The ability of the Kelsey Centrifugal Jig to recover very fine minerals with small density differences offers a potential solution to the recovery of gold-containing sulphide minerals from leach tailings streams. The economic benefits of this application are supplemented by the environmental benefits of reducing the effect of acid mine drainage from tailings dams through the removal of sulphide minerals from waste dumps.

The performance of the Kelsey Centrifugal Jig in the recovery of gold-containing sulphides from CIP tailings is illustrated in Figure 2. By varying appropriate operating parameters, it is possible to achieve a wide range of performance (further illustrated in Table 2), from:

- Relatively low concentrate upgrade ratios at high recoveries, to
- Higher concentrate upgrade ratios at lower, but still quite significant, recoveries

Table 2: Range of Kelsey Centrifugal Jig performance in recovery of gold-containing sulphides from CIP tailings

Performance Focus	Concentrate Upgrade Ratio		Recovery to Concentrate (%)		
	Au	S	Au	S	Mass
High recovery	3:1	4:1	70	80	20
High concentrate grade	10:1	15:1	57	70	5

The ability of the Kelsey Centrifugal Jig to recover fine gold values is shown in Figure 2. These data indicate recoveries of >90% in the 20-53 μm size range. Recovery of Au in the -20 μm size range exceeded 50%, whilst low recoveries from the coarser (+75 μm) fraction are attributed to poor liberation of the Au/S particles with gangue at this particle size.

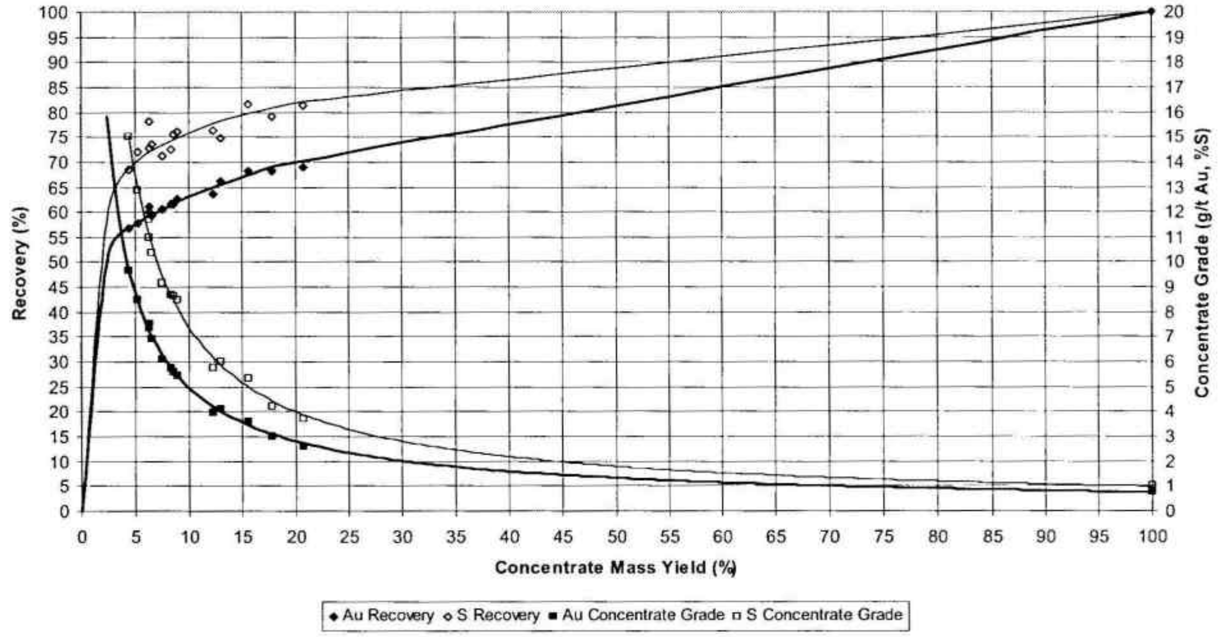

Figure 2: Recovery of gold-containing sulphides from CIP tailings with the Kelsey Centrifugal Jig

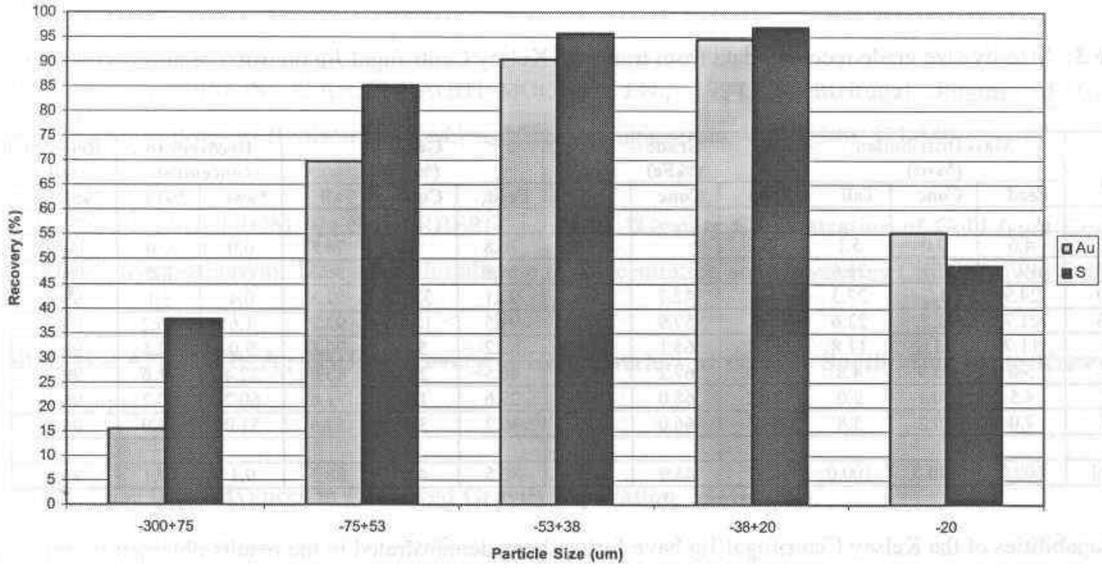

Figure 3: Recovery of gold-containing sulphides from fine size fractions of CIP tailings

The increase in overall plant recovery will depend on how conducive the Kelsey Centrifugal Jig concentrate is to recovery of Au by cyanidation (typically following ultra fine grinding).

Recovery of hematite from iron ore tailings

The recovery of hematite from iron ore deposits has conventionally been conducted using gravity and magnetic separation. In these operations, separation efficiencies generally begin to fall when the particle size is lower than approximately 100-150 µm. This is particularly true when there is a requirement to meet high concentrate grade targets. This requirement has become more prevalent with the advent of new refining routes, such as direct reduced iron (DRI). These factors have resulted in the production of large tailings deposits that contain significant fine iron values. The Kelsey Centrifugal Jig has been demonstrated to effectively treat the material contained in these tailings dumps/streams.

The first example of this application involved the installation of a Model J1800 Kelsey Centrifugal Jig to treat a stream that was reporting to final tailings after being subjected to two stages of gravity separation and one stage of magnetic separation. The stream still contained liberated hematite but with a significant proportion of unliberated iron minerals and silica particles which were predominantly coarser than the liberated valuable minerals.
A feed rate of ~55 tph solids was maintained for the trial period which involved several hundred hours operation. Trials resulted in final concentrate grades consistently in excess of 65% Fe and frequently in excess of 67% Fe. Size-by-size grade/recovery data from a set of trial samples (see Table 3) demonstrates the ability of the Kelsey Centrifugal Jig to produce final grade concentrate from a low grade, partially liberated stream in a single stage of processing.

Table 3: Size-by-size grade/recovery data from trial with Kelsey Centrifugal Jig on iron ore tailings material

Size (μm)	Mass Distribution (%wt)			Grade (%Fe)			Grade (%Si)			Recovery to concentrate		Rejec. to tail
	Feed	Conc	Tail	Feed	Conc	Tail	Feed	Conc	Tail	%wt	%Fe	%Si
300	4.6	0.0	5.1	13.2		13.2	76.8		76.8	0.0	0.0	100.0
212	19.7	0.3	21.6	8.4		8.4	86.8		86.9	0.1	0.0	100.0
150	24.9	1.2	27.3	6.1	42.7	5.9	92.1	32.9	92.3	0.4	3.1	99.8
106	21.7	3.7	23.6	5.9	57.9	5.1	91.5	15.1	92.7	1.6	15.2	99.7
75	11.7	11.6	11.8	11.1	65.1	5.8	83.2	5.8	90.8	9.0	52.5	99.4
53	5.6	13.9	4.8	21.0	67.2	7.7	66.5	2.5	85.0	22.4	71.6	99.2
45	4.5	30.1	2.0	45.2	68.0	10.6	29.6	1.8	71.6	60.2	90.7	96.4
-45	7.0	39.2	3.8	44.3	66.0	21.8	30.2	3.8	57.6	51.0	75.9	93.6
Total	100.0	100.0	100.0	12.7	65.9	7.4	80.5	4.0	88.2	9.1	47.1	99.5

The capabilities of the Kelsey Centrifugal Jig have further been demonstrated in the results obtained from testing of a very fine (d_{50} ~20 μm) iron ore tailings material containing ~49% Fe. In this a high-grade (>67% Fe) concentrate which met all required targets for elemental composition (Table 4) was produced at a mass yield of 31% and a recovery of 42.5% Fe.

Table 4: Elemental composition of a gravity concentrate produced from a fine iron ore tailings material using a Kelsey Centrifugal Jig

Element		%Fe	%SiO_2	%P	%S	%K_2O	%Zn
Concentrate Grade	Actual	67.2	2.4	0.14	0.07	0.10	0.01
	Target	>63	<4.5	<0.2	<0.2	<0.14	<0.03

CONCLUSIONS

The introduction and further evolutionary development of the Kelsey Jig has facilitated the reintroduction of gravity separation to ultra-fine or otherwise difficult separations. Furthermore, the relatively high capacity of the J1800 model Kelsey Jig has favoured the cost benefits for this sophisticated device in several now proven application areas. No other commercial-scale gravity separation equipment is able to achieve the separation efficiencies routinely demonstrated by the Kelsey Jig.

Future developments are expected to include:

- Modularization of Kelsey Jig separating plants, for ease of retrofitting into existing operations, installation in green fields projects, and for tailings scavenging duties.
- New applications, including soil remediation, and differential separation of fine close-density minerals.
- Complementary applications with other mineral processing technologies, for example flotation and other gravity separation systems.

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