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CURRENT TRENDS IN GRAVITY SEPARATION TECHNOLOGY

FOR FINE GOLD RECOVERY

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ABSTRACT

Recent advances in gravity separation technology applicable to the recovery of fine gold from alluvial ores has lead to the development of hardware including spiral separators, the Knudsen Bowl, and the Gemeni Gold Table.

The attributes of these unit processes are discussed and illustrated by way of metallurgical performance data.

The fine gold recovery characteristics of this recently developed hardware are complementary to traditional gravity separation processing systems used in the treatment of alluvial gold ore. This synergism is illustrated by flowsheets and operating data for alluvial gold operations.

INTRODUCTION

The use of gravity separation techniques for the recovery of gold, has been commonplace since ancient times. The dramatic difference in specific gravity between gold and gangue minerals allowed the simple techniques of early operations to recover coarse gold with relative ease.

Gravity separation has always maintained a predominant position in the treatment of alluvial deposits. In the treatment of hardrock gold deposits, however, the development of froth flotation and leaching techniques broadened the scope of available technology, and interest digressed from gravity separation for gold recovery.

A revival of interest in gravity concentration has taken place in recent years. This resurgence can be attributed to two important factors:

1) Rapid increases in gold prices; and
2) Significant advances in technology for the recovery of fine gold.

Gravity systems are now commonly incorporated as a necessary component in the treatment of hard-rock deposits especially within grinding circuits preceding CIL or CIP systems.

The advantages of gravity separation can readily be appreciated. The method is non-polluting; an aspect of increasing importance to the mining industry. Low operating costs and high energy efficiency makes gravity separation attractive for gold recovery.

Operators today face a more difficult task than their predecessors. Coarse gold recovery was the primary objective in early operations while recovery of fine gold was largely overlooked. Modern operations cannot tolerate such losses of fine gold. Deposits that are rich by today's standards, would scarcely have been considered viable not so many years ago.

The increasing demand of better recovery of gold at finer particle sizes, has been met with newer and more efficient technology.

TRADITIONAL GRAVITY TECHNOLOGY

The first type of gravity concentrator with any considerable capacity was the sluice. Material spread over a wide size range, was commonly fed to sluices in a fast-flowing slurry. Attention focused on coarse gold while recovery of fine gold was, for the main part, neglected.

Later, the adoption of screening to remove gross oversize, and the transition to the more effective strakes, improved fine gold recovery. However, losses of gold below 0.25mm were still significant. These losses were usually not fully recognised since poor sampling and analytical methods often resulted in dramatically underestimated levels of gold at finer sizes. (Fricker, 1984)

Jigs

Jigs have the advantage of continuous operation. They are able to tolerate a wide feed size range and fluctuations in tonnage. Their introduction resulted in increased metallurgical efficiencies and the ability to recover gold down to particle sizes of between 0.1mm and 0.2mm.

Jigs still enjoy a firm position and are considered the appropriate device for the recovery of alluvial gold down to 0.2mm.

Shaking Tables

Wet shaking tables also maintain an important role in the gravity concentration of gold and are popularly selected for cleaning concentrates derived from up-stream devices. The flattened particle shape provides greater contact area, enhancing drag forces and results in improved metallurgical performance. Whereas, the operation of jigs tends to cause these flat particles to remain suspended in the bed where they are eventually lost to tailings. Like jigs, shaking tables allow continuous processing.

Disadvantages associated with shaking tables include:

i) the hydrophobicity of gold whereby the fine particles tend to float across the bed (Feather & Koen, 1973), and

ii) the necessity of a large plant area and a stable platform.

As outlined above, the high specific gravity of gold compared with gangue minerals makes gravity separation an appealing technique for gold recovery. There are other properties of gold, however, that may have a retarding effect on gravity separation. The two most important of these are:

i) shape factor, (Lashley, 1983) and

ii) surface characteristics, such as hydrophobicity, porosity and surface coatings.

These retarding properties are generally accentuated take on a more pronounced effect as the particle size decreases.

Shape Factor

The malleability of gold results in the mechanical flattening of particles, particularly in alluvial deposits, thereby off-setting the advantage of the high relative density. Generally, alluvial gold particles become more "flakey" as the particle size decreases.

Surface Characteristics

Metallic gold often displays a natural hydrophobicity (which may be enhanced by surface coatings) resulting in flotation of gold particles and thereby nullifying gravity separation mechanisms.

As well as contributing to hydrophobicity, surface coatings can reduce the effective specific gravity of gold particles, and significantly effect the amalgamability of the gold.

Smaller particles, having a larger surface area to weight ratio, are affected to a greater degree than larger particles.

CURRENT TECHNOLOGY

It is not the intention here to cover the entire scope of new technology in the gravity concentration of gold. Rather, attention will focus on three types of devices considered by the authors to be currently of considerable importance with extensive potential to contribute to the industry.

Spiral Separators

The spiral, originally developed by Humphreys, was designed for the treatment of chromite sands. The inherent virtues of the spiral concept were quickly recognised and spirals were adapted to the treatment of many other minerals.

Many developments and refinements have taken place since the original unit, leading to a wide variety of models now available. One of the most significant developments, with regard to gold recovery, is the washwaterless spiral. Early wash water models were reasonably successful down to 75um, however, wash water additions tended to wash fine gold to tailings.

Profile designs have become more complex with some models incorporating a continuously changing profile throughout the length of the spiral to compensate for changes in the behaviour of the slurry as it descends, thereby improving separation efficiency.

Several types of spiral separators are now available that are considered appropriate for the recovery of gold in the size range -1.0 +0.04mm. (Balderson, 1982).

Selection of the appropriate spiral separator depends chiefly on:

i) the mineral assemblage of the material to be treated, i.e. overall heavy mineral content, mineral composition, and size distribution, and

ii) the relative position of the spirals in the circuit, i.e. whether they perform a roughing or a cleaning duty.

The above factors will determine the nature of action of the solids in the pulp bed.

Spiral separators are available in single, double or triple starts (referring to the number of troughs per column). Clearly, the advantage of multi-start columns is the increased tonnage handling rate for the same floor space.

Typical operating conditions for those spirals suited to gold recovery would be as follows, depending on the model:

Feed (per start)

Capacity	:	1-3 tph solids
Pulp Density	:	35-45% solids W/W
Particle Size Range	:	-2 +0.03mm

For simplicity of piping and laundering, spirals are usually installed in banks of between 2 and 8 columns, (with each column having up to 3 troughs). A single set of ganged splitters at the end of each set of troughs makes for minimum operator attention and reduces likely gold traps.

Spiral separators incorporate no mechanically moving parts so maintenance and operating costs are kept to a minimum.

Test results showing spiral performance for the recovery of placer gold is given in Table 1. (Robinson & Ferree, 1983.)

TABLE 1
Spiral Performance on Alluvial Gold

A. Snake River Gold, Idaho - LG7 spiral @ 2 tph (all gold -150μm)

	Wt. Distn (%)	mg of Au	Gold Distn (%)
Concentrate	2.2	17.58	92.1
Tailings	97.8	1.51	7.9
Feed	100.0	19.09	100.0

B. Greenhorn Gold, California
Gold recovery to spiral concentrate by size

Size (μm)	Size Distn of Gold in Feed (%)	Rec'y to Spiral Con (%) (by size)
+850	-	-
-850 +250	33.3	100.0
-250 +104	51.8	95.6
-104 +75	11.2	81.0
-75	3.7	96.7
	100.0	95.1

Knudsen Bowl

The Knudsen Bowl is a recently developed device designed on the concept of enhancing the density difference between gold and gangue. The spinning bowl induces centrifugal forces which compound with gravitational forces on the particles within the bed.

These machines have gained acceptance within the industry and although generally considered most suited to performing a cleaning duty, e.g. for treatment of spiral or jig concentrates, they are sometimes employed as a roughing device. Knudsen Bowls can also be used in series.

Although Knudsen Bowls suffer the disadvantage of being discontinuous in operation, they are capable of high recoveries of fine gold. In some cases the Knudsen Bowl is claimed to recover gold effectively at finer sizes than that recoverable with jigs and/or spirals.

Important operating parameters for the Knudsen Bowl include feed-rate, rotational velocity of the bowl and water flowrate. The Knudsen Bowl also features the option of including baffle blades which attach to three positions on the frame, allowing them to be evenly spaced around the inside of the bowl. They can be adjusted to move towards the centre or towards the perimeter of the bowl. It is sometimes the practice of operators to remove these blades.

Operating conditions for a Knudsen Bowl are typically as follows:

Capacity	: 1.5-3.0 (dependent on heavy mineral content)
Pulp density	: 20-25% solids
Feed Size	: Nominally -4mm (Up to 6-8mm depending on particle shape)

To remove the concentrate, the machine must be stopped. A bucket is placed under the bottom outlet, the plug is removed, and the the bowl is hosed out by spraying between the riffles.

Very little performance data has been published for the Knudsen Bowl. However, tests in which the Knudsen Bowl was fed with an alluvial gold jig concentrate, indicate that gold recoveries of approximately 80% are readily achievable in one pass with indicated additional stage gold recoveries of approximately 75% achieved in retreating the primary tailings, the overall gold recovery is increased to approximately 95%.

Of the gold particles contained in the feed for the above test, approximately 97% was within the size range -2.0 +0.25mm.

Gemeni Table

Small-scale tables are among the most effective concentrating devices for fine gold. (W. Wenquian & G.W. Poling, 1983). The recently developed Gemeni Table is a prime example of improved technology applied to a conventional concept.

The Gemeni Table features a twin deck with each half producing four fractions: supercon, concentrate and middlings and tailings.

The deck has grooves to replace riffles in which gold particles become trapped and make their way to the concentrate groove that runs longitudinally along the top of each semi-deck to ports where they are collected in screw-on bottles. Close control of water addition at many regular points along the table can be maintained by adjusting individual valves.

The primary concentrate is very high grade and can normally be directly smelted.

The Gemeni Table is used as a cleaning device for concentrates produced from jigs, spirals, shaking tables, Knudsen bowls or other equipment.

Models are currently available in two sizes with the following base operating conditions:

	Gemeni 250	Gemeni 60
Feed Rate	120 kg/hr	30 kg/hr
Feed Size	-850 μm	-850 μm
Water Usage	Max 1.5 m^3/hr	Max 0.75 m^3/hr
Power	0.5 HP	0.5 HP
Dimensions (mm)	1320 W x 2000 L x 1050 H	850 W x 1290 L x 820 H

The Gemeni Table is capable of very high gold recoveries, even at surprisingly small size fractions.

The following table contains size-by-size test data derived from work carried out on a sample of jig concentrate from an alluvial gold ore.

Table 2
Gemeni Table Test Data

Jig Concentrate

	Wt. Distn (%)	Au (ppm)	% Gold Distn
Supercon	0.20	35 990	85.8
Con	2.18	523	13.3
Mid	7.40	3.45	0.3
Tail	90.22	0.58	0.5
	100.00	85.84	100.0

Au Rec'y to Supercon & Con by size (mm)		Rec'y (%)
	+1	98.2
-1	+0.5	99.5
-0.5	+0.25	99.4
-0.25	+0.125	94.1
-0.125	+0.075	94.1
-0.075		21.3

Table 2 (cont'd)

Knudsen Bowl Concentrate

	Wt. Distn (%)	Au (ppm)	% Gold Distn
Supercon	0.63	53 390	93.7
Con	3.46	629	6.1
Mid	10.26	0.23	0.01
Tail	85.65	0.75	0.18
	100.00	358	100.0

Au Rec'y to Supercon & Con by size (mm)		Rec'y (%)
	+1	99.8
-1	+0.5	99.9
-0.5	+0.25	99.5
-0.25	+0.125	99.1
-0.125	+0.075	99.0
-0.075		96.4

FLOWSHEET APPLICATIONS

The application of spiral separators and Knudsen Bowls in an alluvial gold concentrator plant is illustrated in the generalised flowsheet (Figure 1).

Typically, the jig tailings are screened at 2-3mm and scavenged for fine gold using spiral separators in several stages of concentration. The spiral separator concentrate reports to Knudsen Bowls for final gold recovery. If significant levels of magnetic minerals are present, pre-treatment of the spiral concentrate using magnetic separation may be considered prior to the Knudsen Bowls.

The use of the Gemeni Gold Table together with a Knudsen Bowl in gold room practice is illustrated in two alternative flowsheet options (Figure 2). The use of the Gemeni Table to further upgrade primary wet shaking table concentrates is most appropriate, as is the scavenging of table tailings using a Knudsen Bowl.

CONCLUSION

Attention to the efficient recovery of fine gold from alluvial deposits is now significant to the economics of many alluvial gold operations. The introduction of new technology including spiral separators, Knudsen Bowls and Gemeni Gold Tables to alluvial gold concentrator plants and/or in gold room wet concentrating circuits has enhanced the viability of alluvial gold operations in which the gold is relatively fine, and grades as low as 0.2 g/t are being mined.

REFERENCES

Balderson, G. F., 1982. Recent developments and applications of spiral concentrators, South African Mining World, Nov.

Feather, C. E. and Koen, G. M., 1973. The significance of the mineralogical and surface characteristics of gold grains in the recovery process, J. Sth. Afr. Inst. Min. Metall. vol.73, no.7, pp.223-431.

Fricker, A. G., 1984. Metallurgical efficiency in the recovery of alluvial gold, Proc. Australas. Inst. Min. Metall. No.289, pp.59-67.

Lashley, W. C., 1983. The flatness factor, Am. Soc. Appl. Tech., Sept. 1983.

Robinson, C. N. and Ferree, T. J., 1983. Fine gold recovery using Reichert technology, 5th Annual Conf. of Alaskan Placer Mining, Fairbanks, Alaska.

Wenquian, W. and Poling, G. W., 1983. Methods for recovering fine placer gold, CIM Bulletin 76, pp.47-56.

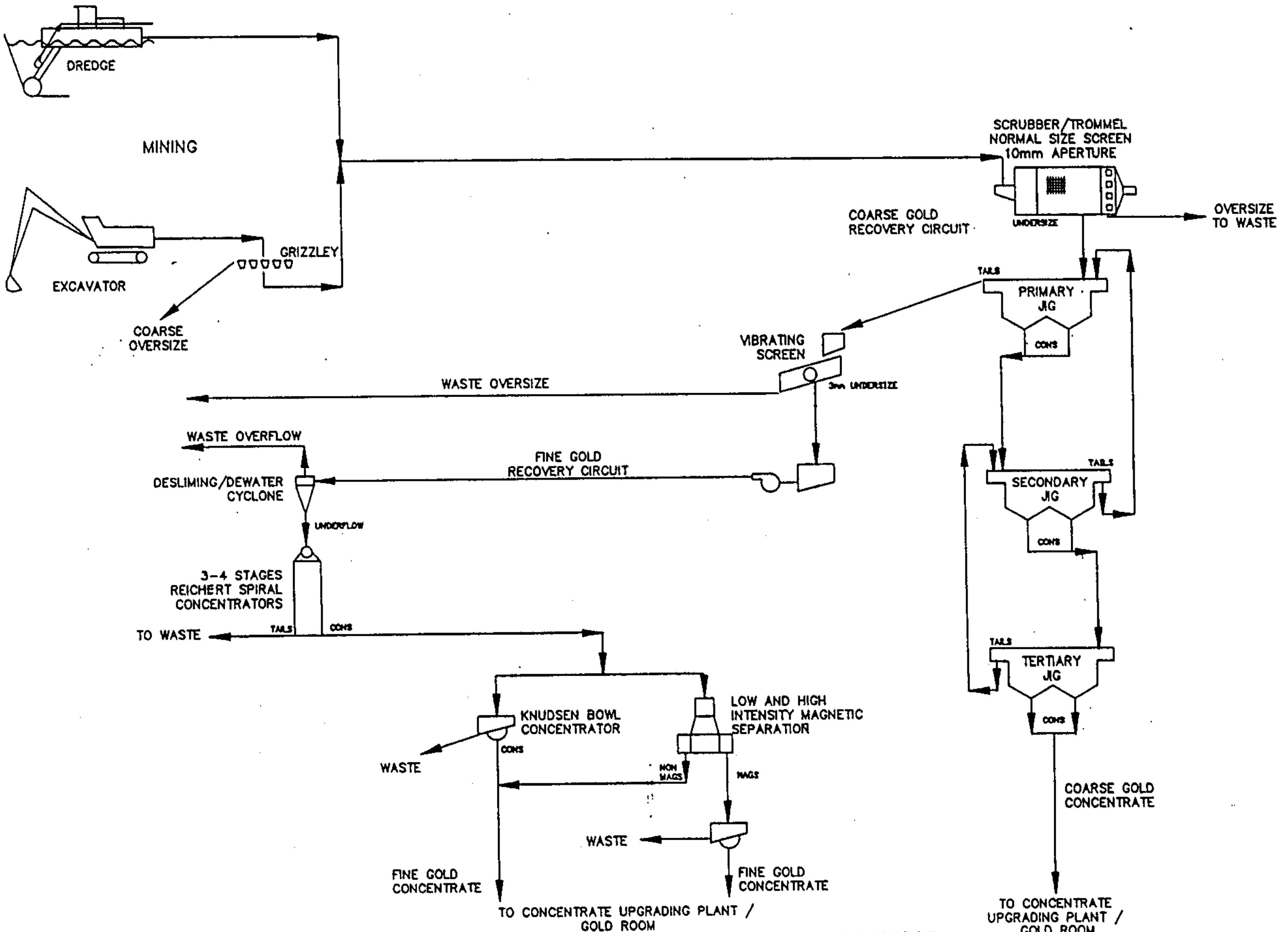

FIGURE 1. GENERALISED FLOWSHEET FOR ALLUVIAL GOLD PROCESSING

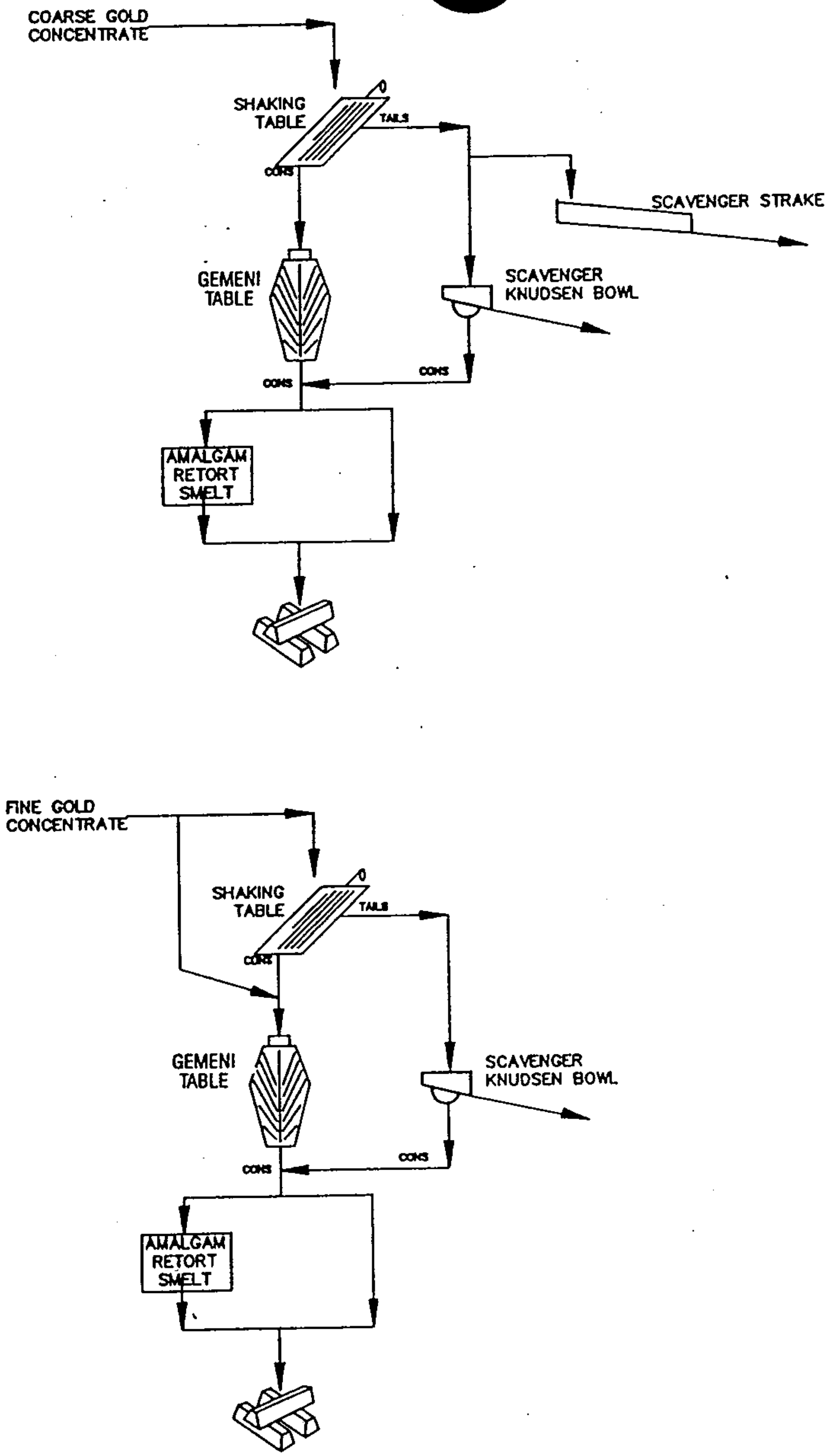

FIGURE 2. GOLD ROOM FLOWSHEET OPTIONS