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GENCAPD REPORT

Diamond Recovery Technology in Guyana

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Contents

1.0 Terms of Reference

Diamond Recovery Technology in Guyana

1.1 Nature of the work

- That a Canadian placer diamond expert with environmental recovery expertise provide Guyana Geology and Mines Commission (GGMC) and Guyana Gold and Diamond Miners Association (GGDMA) with an estimate of the effectiveness of present diamond recovery method using the *lavador*. The diamond expert will also provide a demonstration on the use of flocculants to reduce turbidity plumes and on the use of recycled water for diamond extraction.

1.2 Scope of work

- **Comprehensive study** – A Canadian diamond expert will be in Guyana between February 22nd to March 15th 2001 to provide scientific knowledge to the placer diamond industry of Guyana and also on appropriate environmental methods of recovery. During the stay in Guyana, he will travel to a mining site selected by the Guyana Geology and Mines Commission.
- In the field, the expert:
  - Will make use of diamond density equivalent tracers to evaluate the recovery of a *lavador.* The operation will run for a period of time and then shut down to recover the tracers. The percentage recovery of the tracers will provide an estimate of the efficiency of the *lavador* and the expert will provide council to increase diamond recovery, if feasible.
  - Will demonstrate to the mining industry and the geological commission representatives that recycled water can be use without reducing the diamond recovery efficiency by using an operation with clean and recycled water in parallel. The system will have to run for one week before shutdown for evaluation of the test work using tracers.
  - Will use flocculants (cationic + anionic) to demonstrate a method of reducing the extent of the turbidity plume in the aquatic environment. This is pertinent to the health of local Amerindians communities that rely on the river water for basic use.
- In the office, the expert:
  - Will mobilize all the necessary equipment needed for his test work.
  - Will write a mission report at the end of the study.

- **Deliverables –** An evaluation report at the end of the contract.

- **Schedule –** From February 22nd to March 15th 2002

2.0 Schedule

February 28
- Discussion of fieldwork to be undertaken with the GGDMA.

March 1
- Presentation of the work to be undertaken in the field and general diamond recovery aspects to the GGMC, GGDMA and other parties in the Tower Hotel, Georgetown.
- The text of the presentation is given in Appendix 7.4.

March 5
- Discussions with GGDMA diamond mine operators.

March 6 to 9
- Field tracer and flocculant tests in the Kurupung Mining District and visit to the Mazaruni river dredges.
- The demonstration or test work schedule is given in Appendix 7.5.

March 12
- Discussion of the results of the field-tests with the GGMC.

March 13
- Visit to the Vannessa Ventures Diamond project.

March 14
- Discussion of the results of the field-tests with the GGDMA.

3.0 Field Test Work

3.1 Jig tracer tests

- **Location**

The mine site for the test work (tests #1 and #2) was on Mr. Ades lease in Region VII-2 Mazaruni. The diamond mining area is on the lower Takuba River, which feeds into the Kurupung and Mazaruni Rivers. The mine site is approx 245km WSW of Georgetown at 6°10’ N, 60°16’ W.

- **Small-scale diamond mining**

The mine operations on the lower Takuba River are shown in the photographs in Appendix 7.6. The operation is typical of the small-scale diamond mining operations in Guyana, which use hydraulic mining methods (locally known as “land dredges”) to recover diamond bearing alluvial sands and gravels for processing.

Mining equipment consists of;

- a gas engine driven high pressure water pump (using either river or ‘recycle’ water)
- a gas engine driven gravel pump to deliver the slurried gravel to the *lavador*
- Note: the term *lavador* (Spanish/Portuguese for “washer”) is used to describe a simple jig.

Processing equipment consists of;

- a two compartment *lavador* or jig, sizes vary and depend upon accessibility to the site, small units are 2ft x 4ft and larger units 4ft x 6ft. The jig compartment water pulse is created by either a water driven (by water from the river pump) motor or a small gas engine.

- **Jig description**

The ‘Brazilian’ jig as it is locally known, is a fabricated steel box consisting of two open top compartments and a vertically mounted tyre (mechanical piston) between the two compartments. The tyre, connected by a rod to the drive motor, moves horizontally to create a pulsating water action in the two compartments.

In the upper portion of each compartment a 20-25mm wire mesh on an angle iron frame supports a 1mm square aperture wire mesh. A 25mm wire mesh and frame supported by 50mm diameter lengths of rope provide security for the jig concentrate. The top mesh can be locked through the side of the jig with a padlock.

- **Jig operation**

The jig is termed a 4” or 6” unit based on the size of the feed inlet pipe i.e. 4” or 6” diameter. The diameter of the feed pipe is driven by the size of the material to be pumped from the mining area to the jig. A large rock size requires a large pipe diameter to reduce the frequency of pipeline blockages. A large pipe diameter also requires a high water flow rate to maintain the particle velocity above the critical settling velocity to prevent pipeline blockages. Hence for a large diameter pipeline, a large pump is necessary to produce the high flow rate required to maintain the solids in suspension and reduce line blockages. The pump and delivery line to the jig must be sized to suit the solids and water (volume) handling capacity for a specific jig size.

The stroke or pulse rate is usually set at 100 to 120 strokes per minute. The stroke length is varied by an adjustable rod and, this is usually set at ½” to ¾” depending upon the type and size of the feed material. The stroke rate and stroke length are two of the operating variables which allow the heavier minerals to ‘sink’ through the jig bed as it ‘opens’ on the upward water pulse, and concentrate on the lower screen mesh on the downward suction pulse. The heavy mineral concentrate collects on top of the 1mm screen mesh.

Hydraulically mined material enters the jig at one end of the unit via a distributor and chute into a feed box. The material is subjected to the upward and downward pulses created by the water in the compartments; this (and the volume of water from the pump) transfers the material across the jig to a discharge chute. During the pulsations, the opening bed allows heavier minerals to concentrate onto the screen mesh.

Reject material and water discharge from the jig and flow by gravity to a lower area of the mine site. Depending upon the mine area (i.e. the presence of clay), high levels of suspended solids in the water can enter the local rivers and watercourses.

Small-scale mining operations rely on gravity flow to remove rejects and process water from the immediate site. Attempts have been made to impound mine water and construct settling areas but these are usually only temporary in nature as the majority of the settling areas or ponds are in flood prone valley floors.

Fine material that passes through the 1mm screen mesh is drained from the lower part of the jig compartment by a 25mm pipe and rejected. The flow is controlled by placing the end of the hose in a bucket or drum.

- **Mine operations**

The mining operation is shown in Appendix 7.6;

1. the high pressure water pump supplies water to the mine area where one or two water hoses (photo 1a) are used to slurry the gravel,
2. to a sump from where the gravel pump (photo 1b),
3. transfers the material by pipeline (photo 1c),
4. to the *lavador* (photo 2a).

The jigging recovery process can be termed as a 'batch process', i.e. it is not a continuous process, the feed to the jig must be stopped periodically (after 3 to 5 days) to recover the diamond concentrate.

- **Diamond recovery operations**

The concentrate recovery sequence is shown in Appendix 7.6;

1. after the feed has been stopped, the jig bed (photo 2b)
2. is manually removed and the coarse (barren) material sieved out (photo 2c) and rejected,
3. the concentrate is collected (photo 2d) from the top of the 1mm wire mesh screen,
4. the top security mesh is replaced for the next (photo 2e) operational cycle,
5. the concentrate is then sized into different fractions and hand jigged in water (photo 2f) on a circular sieve to re-concentrate the heavy mineral fraction into the center of the sieve,
6. for the recovery of diamonds (photo 2g) and, sometimes, nugget gold.

3.1.1 Field test tracer tests

At the mine site, it was realized that time and operational constraints would limit the scope of the test work as envisaged in the original proposed schedule (Appendix 7.5).

The results of the tracer tests and the jig operating conditions are given below;

- **Test #1**

Test date: March 6, 2002
Mine site: Dredge # 3333, Michael Corriea Mining Company
Tracers used: 30 x 8mm 3.53sg, 20 x 4mm 3.53sg, 20 x 2mm 3.53sg

Test conditions:

- Jig stroke – 120 per minute
- Run time – 2 hours
- Material treated – approx 48m^3 or 24m^3/hr (35tph)
- Tracer addition: added as a batch, during 2 to 3 minutes, to the jig feed box between feed surges i.e. at a low jig feed rate.

Results:

Tracers in		Tracers recovered			
Size	Number	1st box	2nd box	Total	% Recovery
8mm	30	23	4	27	90%
4mm	20	10	3	13	65%
2mm	20	6	3	9	45%

Diamonds recovered:
13 stones in total, the largest approx 0.25ct, 8 stones approx 2mm in size, total weight approx 1.50ct.

- **Test # 2**

Test date: March 7, 2002
Mine site: Dredge # 3333, Michael Corriea Mining Company
Tracers used: 30 x 8mm 3.53sg, 20 x 4mm 3.53sg, 20 x 2mm 3.53sg

Test conditions:

- Jig stroke – 120 per minute
- Run time – 3½ hours
- Material treated – not estimated
- Tracer addition: added as a batch, during 2 to 3 minutes, to the jig feed box at full feed i.e. at a high jig feed rate.

Results:

Tracers in		Tracers recovered			
Size	Number	1st box	2nd box	Total	% Recovery
8mm	30	3	18	21	70%
4mm	20	2	0	2	10%
2mm	20	0	2	2	10%

Diamonds recovered:
16 stones in total, 3 stones in the 1^{st} box, 13 stones in the 2^{nd} box, the largest approx 0.50ct, total weight approx 1.75ct. The diamonds and density tracers are shown in Appendix 6.6 (photo 2h).

Unfortunately, on the third day, the gravel feed pump broke down and mining operations were suspended. During the time available flocculant tests were undertaken in the area, see section 3.2.

The remaining diamond equivalent density tracers were left with the mine operators to carry out another test once operations resumed; the results obtained are shown below.

- **Test #3**

Test date: March 11, 2002
Mine site: Dredge # 3055, Guyana Diamond Trading Company
Tracers used: 30 x 8mm 3.53sg, 20 x 4mm 3.53sg, 20 x 2mm 3.53sg

Test conditions:

- Jig stroke – not reported
- Run time – not reported, 5 or 6 days?
- Material treated – not reported
- Tracer addition: not reported but assumed to be added at the gravel pump suction.

Results:

Tracers in		Tracers recovered			
Size	Number	1st box	2nd box	Total	% Recovery
8mm	30	not recorded		10	33%
4mm	20	not recorded		3	15%
2mm	20	not recorded		0	0%

Diamonds recovered:
Not reported.

3.2 Water treatment test results

A series of water treatment tests were undertaken at the mine site on the Lower Takuba River with solids contaminated jig water and with mine discharge effluent on the Upper Takuba River.

- **Lower Takuba River**

The jig tailings water (though not high in clay) was found to flocculate and settle easily with a cationic flocculant followed by the addition of an anionic flocculant, a clear supernatant was produced with the addition of approximately;

1ml 0.5% solution Percol 368
1ml 0.5% solution Percol 156

- **Upper Takuba River**

Mine discharge water entering the river was tested as shown in Appendix 7.6. The river water prior to flocculant addition is shown in photo 3a, a cloudy and very slow (if at all) settling suspension of clay-sized solids.

1ml 0.5% solution Percol 368 was added to 500ml river water, the cylinder was inverted five times at which time small 'pin' flocs could be seen to be forming. 1ml 0.5% solution Percol 156 was then added and the cylinder inverted again five times.
Immediately large flocs formed (photo 3b) and the solids settled to the bottom of the cylinder (photo 3c) after a few seconds.

The same tests were performed with 0.5% solutions of Percol 7117 and Percol 10, this combination of cationic and anionic flocculants produced similar results to the 368/156 combination. The resulting flocs were 'stringy' and the supernatant slightly cloudy.

Another test was performed with the solid polymers Percol CA1 and Percol AN1, solid forms of 368 and 156. Good flocs, a high settling rate and good supernatant clarity were achieved.

No problems were encountered in settling any of the mine effluent suspended solids with the synthetic polymers. Rapid settling rates and high clarity supernatant water is easily achieved with suitable polymers, a low solids percent and adequate reagent dosage rates.

4.0 Discussion

4.1 Tracer test interpretation

Only a very limited number of tests could be untaken in the field due to;

1. duration of the test, minimum of 1 day, ideally a full production or batch run of 2 to 5 days under monitored conditions is preferred.
2. limitations imposed by the test on the mining operation, each test required the dismantling of the feed pipe, distributor, feed chute, removal of the screen meshes, collection of the jig concentrate, concentrate sizing and hand jigging, this could take 3 to 4 hours in total.
3. operational issues such as blocked feed lines and pump breakdowns.

The site for the tracer tests, even though 'recycle' (and not river) water was used in the mining operation, was not in a particularly 'high clay' area. Thus it was not possible to tracer test the jig with river water only and then recycle water only, as originally hoped. Based on the above it can be seen that even if possible, the 'rearrangement' of the pumps for different water sources would have put an undue additional strain on the limited manpower available.

The tests with diamond density equivalent tracers indicated that recovery efficiencies are acceptable in the 8mm size range at low jig feed rates. The tracer recovery efficiencies reduce at the smaller sizes i.e. larger diamonds are easier to recover and the losses of larger stones will be lower when compared to the smaller diamond sizes.

The tracer tests also indicated that the apparent diamond recovery efficiency is significantly reduced at higher jig feed rates.

4.1.1 Factors affecting efficient jig operation

The overall diamond recovery efficiency of a jig compared to other recovery technologies (i.e. HMS) can only be considered as 'moderately efficient'.

For efficient jig operation, the following factors need to be considered;

- If the specific gravity difference between the particles is small, the feed should be close sized, i.e. the difference between the largest and smallest particles should be small, and the suction stroke gentle. The feed to the jig should preferably be screened to remove oversize particles.
- The capacity of a jig is proportional to;
  1. the screen area
  2. the efficient delivery of the feed over the full width of the jig
  3. the transporting effect of the horizontal current from the feed to discharge end. The horizontal speed is determined by;
     I. The volume of feed, ore + water.

II. The cross section normal to the flow.
III. The net volume of jig water, excess of pulsion over suction.

- To aid the transporting rate, a slight drop from one compartment to the next, to create a slope on the bed, is better than the use of streaming water. Though the bed depth should not be sacrificed, as the separation efficiency will be affected. Operators of the Brazilian jigs have already determined this and routinely ‘cut down’ the dividing plates between the compartments on a new jig, thereby increasing the capacity of the jig.
- Two factors determine the maximum efficient rate of feed to the jig;
  1. The time required for the smallest diamond (or tracer) to settle to the screen mesh.
  2. The smoothness of the working conditions in the jig box. If the feed rate is so high that the bed churns it will take longer for stratification of the minerals to occur and the separation and diamond recovery will suffer. A violent stroke and too much hydraulic water can also cause a local breakthrough in the bed destroying stratification. Partially blocked screen meshes can also create a similar effect.
- In addition to variation of the length and rate of the strokes, and the addition of hydraulic water another important variable is the bedding or ‘ragging’ layer which rests immediately on the jig screen. The bed should be thick and heavy enough to hold the concentrate particles whilst rejecting gangue minerals. Generally, the Brazilian jigs appeared not to be operated with a ragging layer, maybe this is due to the lack of availability of suitable material.

4.1.2 Density tracers

- **Tracer description**

The density tracer is commonly cube shaped (though it can be manufactured in a variety of shapes) and is made from plastic (epoxy resin) with a high-density filler (usually wolframite, sg = 7.3). By varying the amount of filler in the resin mix, the final density of the tracer can be varied. A colour is also added to the resin to denote a particular density. The various colours can then be separated after a tracer test to produce a graph known as a partition or Tromp curve. The curve is used to determine the separating parameters for the process or equipment.

Plastic density tracers have been in use for over two decades in the mineral processing industry; they are used to determine the ‘cut point’ and ‘separation efficiency’ of the process or the equipment. Tracers are commonly used in large diamond operations where heavy medium separation (HMS) is used. The tracers provide a quick and visual efficiency determination.

The tracers are used in any mineral processing industry where separation and recovery are based on a mineral density difference, particularly in heavy medium separation processes for +1mm material e.g.;

coal	- coal sg = 1.2, shale sg = 2.6,
tin	- cassiterite sg = 7.0, quartz sg = 2.7,
fluorspar	- fluorspar sg = 3.2, limestone sg = 2.6,
diamond	- diamond sg = 3.5, quartz/kimberlite sg = 2.7
iron ore	- hematite sg = 5.2, quartz sg = 2.7

The density tracer has gained a wide industry acceptance.

- **Density tracer costs**

The costs of the 0.03 tolerance 3.53sg orange tracers used for the tests are;

8mm	US$0.95 each
4mm	US$0.50 each
2mm	US$0.35 each

These are available through Bateman Minerals in South Africa, the detailed density tracer list and contact details are shown in Appendix 7.7.

- **Density tracer tests**

The coloured density tracer is basically a 'tool' that can be used to determine the efficiency of a process or piece of equipment. The density and sizes of the tracer are selected (or manufactured) to imitate a component of the ore feed in the process. In the case of the jig diamond recovery efficiency determination, diamond density equivalent tracers of 3.53sg in three sizes were chosen, 8mm, 4mm and 2mm to represent a range of potential diamond sizes. When a known number of tracers are added to the feed of the jig or process it is relatively easy to recover the tracers at the end of the process and calculate the indicated recovery efficiency.
A tracer test procedure for jig operations is given in Appendix 7.8.

- **Partition curves**

Partition curves can be created when a range of density tracers of different sizes are used in a test. The partition curve is used to determine the density range of minerals reporting to a concentrate or reject product. The curve indicates the probability a particular density of particle will have in either reporting to the concentrate or reject fraction.

  - **Cut point**

    From the curves in Figure 1, the separation or cut-point specific gravity, i.e. when a particle has an equal, 50:50, probability of reporting to either product, is the specific gravity at the 50% value.
    For a typical HMS cyclone used in diamond separation, the cut point or d50 values are;

8mm	3.10
4mm	3.15
2mm	3.20

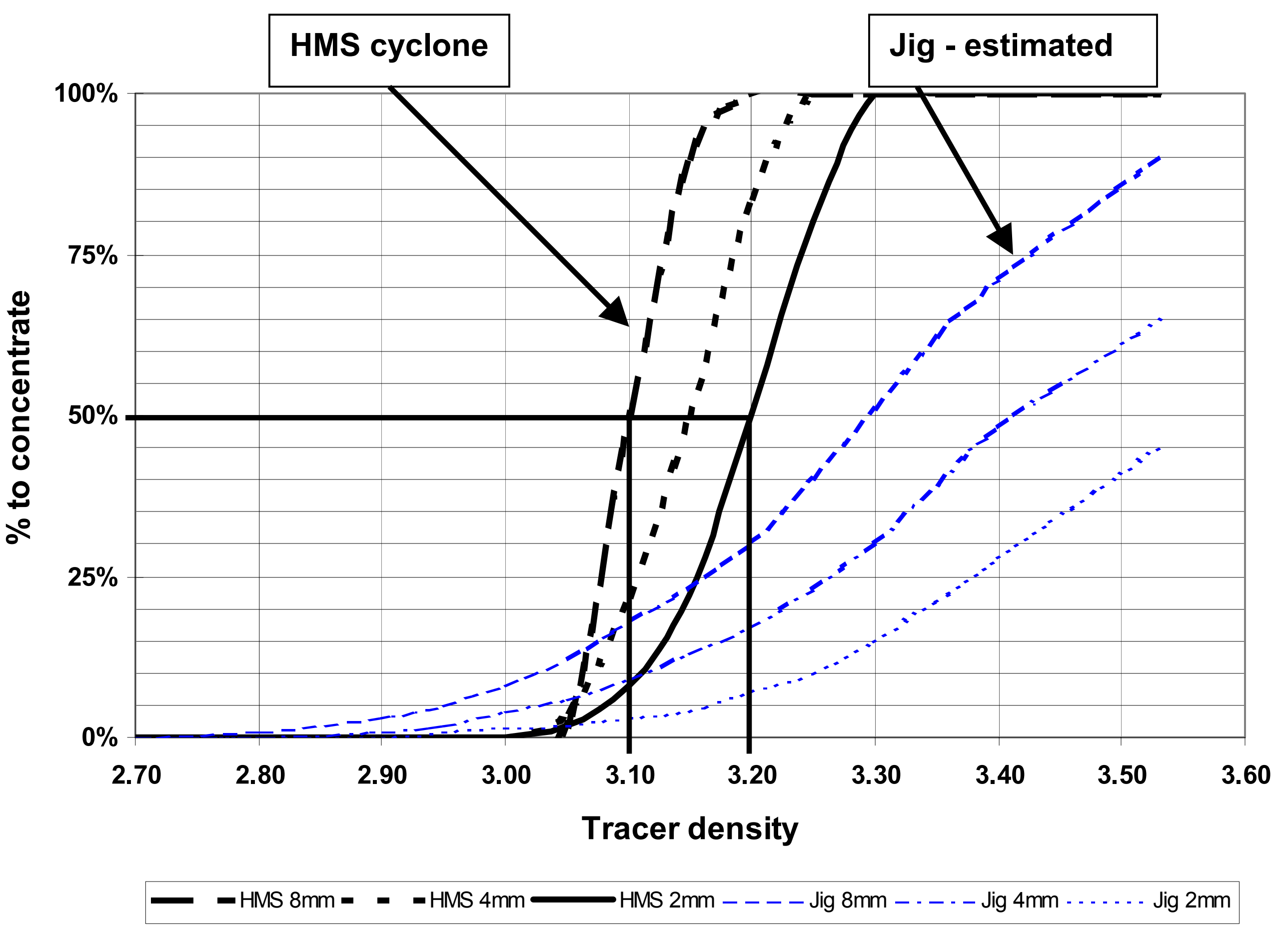
These values are the theoretical density for each size above which a particle of higher density will report to the concentrate and for which a particle of lower density will report to the reject.

- **Separation efficiency**
  This is determined from the curve and is half the specific gravity difference between the 25% and 75% values. This is termed the epm, 'ecart probable moyen'. The lower the epm, the more perfect the separation.
  The value is typical for a size of material and the type of separator.
  For a typical HMS cyclone used in diamond separation, the epm values are;

8mm	(3.12-3.08)/2 = 0.020
4mm	(3.18-3.11)/2 = 0.035
2mm	(3.24-3.16)/2 = 0.040

FIGURE 1

HMS & JIG PARTITION CURVES



As the typical HMS cyclone results show, the apparent separation cut point increases as the particle size reduces and also the separation efficiency reduces (the epm value increases) with reducing particle size. If density tracers less than 1mm were used, the partition curve would be further to the right hand side of the graph with the top part of the curve very close to the diamond density value of 3.53, i.e. showing that diamond recovery in a HMS cyclone at sizes less than 1mm could result in losses to the reject. The normally accepted lower treatment size in production sized HMS cyclones is 1mm.

The jig recovered percentage values for the 3.53sg tracer are also shown in Figure 1, and estimated for the remainder of the partition curve. The recovery efficiency and separation efficiency are less than ideal when compared to the HMS cyclone. For this reason, the jig is not used as a primary separation device in the large-scale diamond industry.

4.2 Flocculants and their potential use

Flocculation and thickening technical information is appended in Appendix 7.3.

The synthetic flocculants tested fall into two main types;

Cationic	- the polymer has a positive charge
Anionic	- the polymer has a negative charge

The flocculants are manufactured in a range of molecular weights and charges to suit the various processing requirements.

The Ciba Percol flocculants taken to Guyana were;

Cationic	368, CN2, 402, 7117
Anionic	156, AN1, 10, 333, 336, 342, 356, 919
Non-ionic	351
Copolymer	455, 5350L

These were left with the GGMC so that further testing can be undertaken as required.

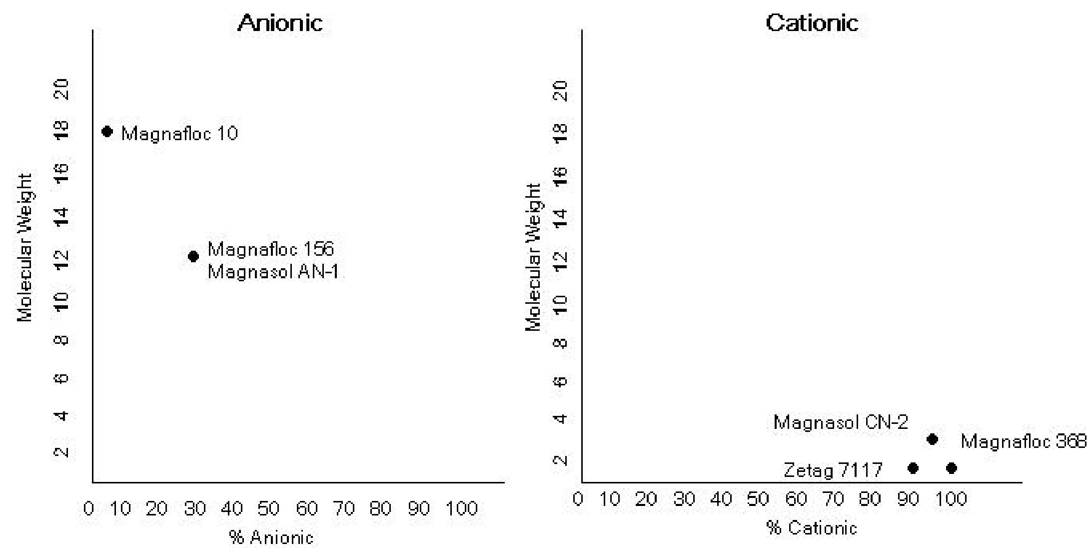
It is recommended that the Ciba representative to Guyana be contacted to discuss potential uses for this type of product, the contact details are;
Serge Baril
142 Brassard
St-Joseph du Lac, Quebec, J0N 1M0
Canada
Tel 450 472 3484
Fax 450 472 4779
Email serge.baril@cibasc.com

Synthetic flocculants are used extensively for water treatment in the mining, chemical, steel, pulp and paper industries where the settlement of solids and water clarification is required. They are also used in municipal water treatment plants.

Figure 2 shows the molecular weight and charge of the flocculants used for the tests.

FIGURE 2

Molecular Weight vs Charge
Guyana – March 2002



Powdered flocculants are relatively high cost and require specialized mixing, storage and dosing equipment if they are to be used effectively and efficiently. Cationic flocculants dissolve in water readily whilst anionic flocculants can be difficult to dissolve.

In order to overcome some of these issues a range of flocculants are available in solid block form, see the polymer block product information in section 6.3. The solid form allows the user to place a polymer block at the outfall of a discharge line containing fine suspended solids. Note, the polymer blocks are not intended for use in flows containing coarse particles, as these will quickly erode the block. The flow of water across the block dissolves sufficient polymer to flocculate and settle the solids in a settling pond (or series of ponds) before the water discharges into the receiving environment, i.e. a river or stream. The manufacturers recommendations should be followed when the blocks are used.

5.0 Recommendations

5.1 Small scale diamond mining operations

The Brazilian jig, by its nature, i.e. it is small, relatively low cost and easy to relocate to different mining areas, will continue to be used in Guyana in diamond recovery operations. It has had a positive impact on the diamond mining industry in Guyana and has allowed increased diamond production, it is an effective recovery device when compared to the older sluice technology. However, as the limited tracer testing has shown, it is relatively inefficient.

To aid the small-scale miner using this type of equipment, the introduction of diamond equivalent tracers will assist the operator to ‘see’ how the jig is performing. The use of tracers will allow a competent operator to ‘fine tune’ and maximize the jig recovery efficiency. Jigs are not easy to operate due to the complexity of the factors affecting their performance.

Knowledge of the best operating practices and ideal jig operating parameters will also assist the small-scale miner to improve the jig recovery efficiencies.

To do this it is recommended that a controlled test program be undertaken to determine the following jig operating parameters;

- Feed size distribution
- Gravel feed rate
- Water flow rate
- Bed depth and ragging (is it required?)
- Stroke rate and length for a particular type/size of gravel

The field tracer tests have shown that it would be difficult to determine these parameters at a mine site. Ideally, the test program would be a good project for students to undertake in the Mining Department at the University of Guyana if sufficient resources and funding can be found.

At the same time it could be feasible to look at closed circuit water treatment methods using the polymer blocks.

5.2 Large scale diamond mining operations

Technology and equipment exist to improve diamond recovery efficiencies beyond those capable of the jig. HMS technology has been used for over 40 years and there are now several manufacturers (two are given in Appendices 6.1 & 7.1 – hardcopy and electronic versions) that have perfected the modular plant concept.

Vannessa Ventures at Maple Creek will be using a small 20tph HMS plant with feed preparation facilities consisting of a scrubber and jigs to prepare feed for the HMS module.

A variety of sizes of plant are now available to suit the larger scale diamond mining operations in Guyana.

The advantages of this size of plant from an environmental and socio-economic aspect are;

- it will be a dry mining operation, the elimination of hydraulic mining in river flood plains will reduce the sediment load discharging into the rivers
- it is a larger semi-permanent facility
- it will allow a greater degree of control at the planning stage for the implementation of a closed water circuit operation including water treatment and controlled discharge into the receiving environment
- reclamation and reforestation can be controlled
- a higher level of worker safety
- a higher skill level required to support the operation, more higher paid jobs
- the basis for a permanent, high efficiency, alluvial diamond and gold mining industry

The plant required for this type of operation is given below, this is an example only. A full feasibility study should be implemented for each site to determine the project viability in terms of the capital cost, operating costs and return on the investment.

Details of the equipment are shown in the attached appendices 6.1 & 7.1, a conceptual general arrangement drawing for a 100tph (front end) alluvial diamond and gold plant is shown in section 6.1.

Large scale diamond and gold mining operations in Guyana - equipment requirements

Processing Plant

Feed Preparation section
Purpose – Prepare a sized gravel feed for Heavy Medium Separation (HMS), removes clay, fine sand (-1mm), breaks down loose and friable material, removes large barren rock (+25mm).
Equipment – feed hopper, vibrating grizzly feeder, rotating drum scrubber, vibrating horizontal double deck sizing screen, conveyors.

Heavy Medium Separation (HMS) section
Purpose – Separates sized gravel feed (–25+1mm) into high and low density mineral fractions, alluvial diamond operations typically generate a heavy mineral concentrate of 0.5 to 2% of the original plant feed.
Equipment – feed preparation screen, ferrosilicon mixing box, cyclone feed pump, HM cyclone, float and sink drain/rinse vibrating screens, ferrosilicon recovery circuit comprising pumps, magnetic separator, densifying cyclone, density controller.

Diamond Recovery section
Purpose – to recover diamonds from the HMS concentrate for final sorting.
Equipment – sizing screen, x-ray sorter, grease table (not all alluvial diamonds are amenable to grease recovery).

Gold Recovery section
Purpose – to recover gold less than 1mm in size from the screen underflow in the Feed Preparation section.
Equipment – centrifugal gravity concentrator (see details in section 6.2), pumps.

Water Treatment section
Purpose – to minimize new water requirements, settle fine solids and recirculate water for processing operations.
Equipment – according to site, from settling ponds using polymer blocks for the flocculation of fine solids to high rate thickeners and polymer dosing equipment, pumps.

Power Generation section
Purpose – to generate power for the processing sections.
Equipment – modular diesel generator set, fuel storage tanks, pumps.

Mining Equipment

Earthmoving equipment
Purpose – to remove ground cover, overburden and recover ore for the process plant.
Equipment – various, site dependant, typically – grader, dozer, excavator, dump tucks, front-end loaders.

Support Services and Equipment
Camp and services - accommodation, water supply, sewage disposal
Maintenance workshop, warehouse
Support vehicles

Budget costs
The costs indicated below are **budget only** and given to present an 'order of magnitude' cost estimate only. Costs will vary depending upon the site location. Road and river infrastructure costs, site accommodation and contingency have been omitted. The final cost will depend upon the equipment chosen and the age/condition of the mining fleet purchased.

To consider such a capital investment a full feasibility study of the mining operation must be undertaken to determine the ore value and the capital and operating costs that can be supported by the project.

The engineering companies (and several others with alluvial diamond mining experience) shown in appendices 6.1 & 7.1 are capable of assisting mine owners and operators with this type of development and design support.

Plant	Directs	
	60-120tph Feed Preparation section	US$400-650,000
	20-50tph HMS section	US$150-300,000
	2-4tph Diamond Recovery section	US$250-300,000
	30-60tph Gold Recovery section	US$300-600,000
	Water Treatment section	US$200-350,000
	Power Generation (used)	US$100-200,000
	Spares (1 year)	US$100-200,000
	Indirects (location dependant)	
	Engineering, design	US$150-250,000
	Transport	US$200-350,000
	Installation, labour, civils	US$200-400,000
	Plant, 60-120tph, total (budget)	**US$2.6-3.6M**
Mining	Directs	
	Grader, 14G, 1994-1996	US$100-140,000
	Dozer, D6, 1995-1996	US$150-190,000
	Excavator, 345, 1996-1997	US$170-200,000
	FEL, 966, 1996-1999	US$130-200,000
	FEL, 988, 1999-2000	US$400-460,000
	Truck, D300, 1996-1998	US$120-180,000
	Spares (1 year)	US$100-200,000
	Indirects	
	Workshop	US$100-200,000
	Transport	US$100-200,000
	Mining, total (budget)	**US$2-3M**

6.0 Supplier and product information list (hardcopy)

6.1 Modular diamond plant suppliers and equipment details

6.1.1 Bateman
6.1.2 Fluor Daniel/Metco Global/ADP Projects

6.2 Centrifugal gravity concentrators

6.2.1 Knelson concentrators
6.2.2 Falcon concentrators

6.3 Flocculant polymer block details

6.1 Modular diamond plant suppliers and equipment details

6.1.1 Bateman

- Modular process plants that work
- Diamond services, projects, products and services for diamond producers
- Diamond process plants that work
- Bateman modular plant capability statement (also in electronic format)
- Engineers & project managers, building process plants that work
- The design and development of modular process plants for small scale diamond mining operations

6.1.2 Fluor Daniel/Metco Global/ADP Projects

- Company profile
- ADP, the company
- Selected projects
- Marine mining services/selected marine projects
- Dry mining services
- Cutter suction dredge
- 10/55tph DMS plants
- 300tph stockpiling conveyor
- 70/100/300tph in field screening plants
- Alluvial diamond & gold plant general arrangement drawing

6.2 Centrifugal gravity concentrators

6.2.1 Knelson concentrators

- Model KC-XD30 specification sheet, 45tph
- Model KC-CD30 specification sheet, 36tph
- Equipment type versus gold particle size recovery chart

6.2.2 Falcon concentrators

- Nominal specifications for models C10 to C40, 5 to 200tph, B12 to B20, 0.5 to 25tph, SB4 to SB38, 0.3 to 60tph

6.3 Flocculant polymer block details

- Magnasol AN1 floc-bloc
- Percol AN1 and Percol CN1, anionic and cationic power blocks
- Easy dissolving polymer blocks for remote applications

Appendices

APPENDIX 7.1

Modular Diamond Plant Supplier and Equipment Brochures:

7.1.1 Fluor Daniel/Metco/ADP Projects

Company Profile

Dry Mining Services

Cutter Suction Dredger

In-Field Screening Plant MB100

In-Field Screening Plant MB200

Mobile DMS Plant 10tph

Mobile DMS Plant 55tph

7.1.2 Bateman

Modular Plants – Capability Statement

Company Profile

ADP Projects a Metco Global Company

The Company.

ADP Projects (Pty) Ltd, is a multi-disciplined Project and Process engineering company specializing in the design, development and manufacture of a range of products and services for the land and marine diamond industries as well as for other heavy minerals industries.
From main offices and manufacturing works in Parow Industria, Cape Town, products are designed and manufactured by a team of engineers and support staff for both the marine and land based industries. ADP also has representative offices in Richards Bay, and Luanda, with the marine industry being serviced by a dedicated office at the harbour, Foreshore, Cape Town.
The company is a wholly owned subsidiary of Metco Global Limited, an offshore company with directors based in the USA, Portugal, RSA and the UK.

Associations.

ADP Projects, the exclusively appointed manufacturing agent for Metco Global Ltd has entered into an association with a major project management company, **Fluor Daniel SA** and a specialist structural engineering and draughting company, **Euro-Technology.**
Further, ADP has formed an agreement with **Weir Envirotech** whereby jet pumping technology is developed and **TORE** technology for the marine industry is marketed.

Range of Services and Products.

Registered in 1997, ADP has undertaken a range of projects in Africa, supplying DMS plants, in-field screening plants, mobile prospecting plants, jigging plants, cutter suction dredgers with on-board screening plants and final recovery modules.
In addition to the marine and land based equipment range, the company has established services that include **project management, product development and feasibility studies, procurement technical services** and **Operations management services.**

Marine Projects.

ADP marine engineering services have completed several projects, namely ship plant upgrades, turnkey process plant installations, feasibility studies and technology development projects.

Contract Mining.

ADP is currently undertaking a "own and operate" mining contract with a major heavy minerals producer, pumping sand at design capacities in excess of 1000 TPH directly into a floating treatment plant.

Company Strategy.

ADP Projects believes it adds value to its clients by focusing on niche market sectors. Our engineers are highly skilled at understanding client requirements and interpreting these to produce simple, practical and cost effective solutions.
The use of alliances and networking with key consultants, specialists, suppliers and clients as a basis for developing and marketing new products, forms an integral part of the business strategy.

Products and Services.

- Modular and Mobile Plant.
- Process Engineering.
- Project Management.
- Product Development.
- Feasibility Studies.
- Operations Management.
- Procurement Technical Services.
- Jet pump design and supply for Marine Projects.

For further information, please contact

SHT A001/1

A METCO GLOBAL Company

ADP PROJECTS (PTY) LIMITED
36 Assegaai Road
Parow Industria 7490
PO Box 1272
Parow 7499
Cape Town
South Africa

Tel: (27) 21 933 1203
Fax: (27) 21 931 8415
e-mail: adp@adpmetco.co.za

Dry Mining Services

Dry Mining Services.

ADP has developed a unique, efficient dry mining capability focused on mining mineral rich dune sands which are inaccessible or un-economic to recover using pond-type dredging systems.

Production rates.

Through-puts up to 1500tph of dry mined in-situe material are regularly achieved using a simple stream plant. Larger capacity plants can be designed as required.

Mining Methodology.

Front end mining methodology is custom designed to site specific requirements thus ensuring optimum efficiency in all phases of the operation.

Safety and Occupational Health.

ADP pursues the highest safety and occupational health standards and its operators and strives to ensure that a minimum standard equivalent to the NOSA 3 star rating is maintained at all times.

Employment Equity.

ADP promotes the principles of fair employment practices and will tailor its employment policies to parallel those of its clients when undertaking long term operation type contracts at clients' mines.

Contract Format.

A range of contractual options is available. These are typically tailored to match site specific conditions.

For further information, please contact:

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ADP PROJECTS (PTY) LIMITED
36 Assegaai Road
Parow Industria 7490
PO Box 1272
Parow 7499
Cape Town
South Africa

Tel: (27) 21 933 1203
Fax: (27) 21 931 8415
e-mail: adp@adpmetco.co.za

METCO Global

Cutter Suction Dredger D250

Manufactured by ADP Projects a Metco Global Company

Cutter suction dredger in operation in Angola.

ADP designed 5 blade cutter, 1100 mm diameter with replaceable pick teeth

Multi-articulated ladder head and operating cylinder during construction

General Description

The D250 dredger is custom designed for the recovery of diamonds from the bed of fast flowing rivers. The dredger is equipped with a heavy duty cutter fitted with replaceable pick teeth for penetrating boulder beds and soft bed rock and is capable of dredging 250TPH of solids.

The hull consists of five pontoons, with dimensions that allow individual transport by road or sea. These pontoons can be connected and disconnected by means of bolts at deck level and hook-in coupling blocks at the bottom.

The ladder trunnion assemblies are mounted on the two main side pontoons and are fitted with custom designed anti-vibration pads to reduce shock loading forces from the cutter being transmitted to the dredger hull. Both the ladder lifting and slewing winches are mounted on the ladder. The dredge is secured upstream by a bow winch. Two slewing winches drag the cutter through the sediment from starboard to port across the river. Mining control is maintained by a winch rendering system and constant bow tension.

Dredge product is de-watered and screened on board. Diamond bearing gravel is pumped to shore via a floating pipeline for storage and further processing. Power supply to the standard dredge is from a shore based generator and step-up transformer, with a 6,3kV trailing cable feeding an on-board step-down transformer and motor control centre. An on-board 380V generator feeding the motor control centre is offered as an option. To date ADP Projects has supplied four of these standard cutter suction dredges.

METCO MB100 In-Field Screening Plant

Manufactured by ADP Projects a Metco Global Company

General Description

The METCO 100 TPH In-Field screening plant is designed to provide high capacity feed preparation, utilizing the benefits of vibro-grizzly scalping, combined with conventional scrubbing and screening, to deliver sized gravel product from run-of-mine material. The following features and benefits are offered.

- Four module containerized design
- Double deck heavy duty vibro-grizzly and feeders suitable for CAT 966 Front End Loader or equivalent.
- 1.8dia x 4m scrubber with inner and outer trommel.
- Water booster pump for high pressure water spray bars.
- Skid mounted 1.2 x 3.6m double deck vibrating screen module with oversize transfer conveyor.
- Standard supply mobile stockpiling conveyors with tow hitch and stub axle wheels.
- MCC mounted in container room.

Plants can be supplied skid mounted or trailer mounted, with generator and water supply and effluent pumps offered as options.

METCO MB200 In-Field Screening Plant

Manufactured by ADP Projects a Metco Global Company

MB 200 In-Field screening plant under construction in ADP Projects Cape Town factory.

General Description

The 200 TPH in-field screening plants were designed to provide high capacity feed preparation, utilizing the benefits of vibro-grizzly scalping, jet pumping and screening to deliver sized gravel product from run-of-mine material. The following features and benefits are offered.

- Two module containerized design
- Double deck heavy duty vibro-grizzly suitable for CAT 966 Front End Loader or equivalent.
- Custom design hydraulic tilt static grizzly for boulder scalping.
- $8m^3$ surge hopper with controlled jet pump feed to sizing screen.
- Integrated water re-cycle facility complete with fresh water tank, recycle water tank and transfer pump.
- Static drain panel feed chute and single deck screen for maximum fines removal capacity.
- Skid mounted fines effluent pump.
- Standard supply mobile stockpiling conveyor with tow hitch and stub axle wheels..
- Separate 3 meter container MCC enclosure.
- Container skids suitable for pulling with CAT D8 Dozer or equivalent.

Plants can be supplied skid mounted or trailer mounted, with generator and water supply, single or double deck screening and water supply/effluent pumps offered as options.

10 TPH Containerized DMS Plant

Manufactured by ADP Projects a Metco Global Company

General Description

The standard 10 TPH MS plant was developed specifically for operations that are remote and where site-works are problematic and mobility is important. The unit can be offered for land or marine duty applications. 5 to 25 TPH feed rates are offered.

Features:

The features of the plant include:-

- Complete package fully containerized.
- Integrated catch sump for spillage.
- Single deck screen for feed preparation, floats and sinks.
- Auto-density control system as standard.
- Full automation optional.
- Separation cyclone. Hi-chrome or PU.
- Minimal site-works and no civils works required.
- Optional diesel generator supply.
- Feed rates up to 25 TPH can be supplied in this model.

Full plant specification overleaf.

55 TPH Mobile DMS Plant

Manufactured by ADP Projects a Metco Global Company

General Description

The standard mobile 55 TPH DMS plant was developed specifically for operations that are remote and where site-works are problematic and mobility is important.

Features:

The features of the plant include:-

- Complete package fully containerized with air conditioned control room.
- Integrated catch sump for spillage.
- Secure concentrates storage facility.
- Correct medium densification.
- Full automation optional.
- Separation cyclone with barrel extension for maximum separation efficiency.
- Minimal site-works and no civils works required.
- Fully mobile feed preparation trailer, complete with surge bin, jet pumps, water supply, effluent pump and feed preparation screen offered as optional extra.

Full plant specification overleaf.

BATEMAN

Bateman Modular Plants

Capability Statement

INDEX

A 50 t/h DMS module in the fabricator's yard, ready for delivery.

Commitment

We, in BATEMAN's Modular Plants business line, are totally committed to:

- Providing our clients with value for money plants, products and services.
- Building plants which meet environmental requirements.
- Providing our clients with service excellence in all their dealings with BATEMAN.
- Supporting our products with spares and technical advice.
- Meeting or exceeding safety standards set by our clients and the authorities in the countries where our plants operate.
- Providing our shareholders with a fair return on their investment.

A typical BATEMAN 1 t/h transportable DMS module, ready for delivery.

A typical BATEMAN 50 t/h modular DMS plant for processing kimberlite, fully erected at the factory.

The 150 t/h BATEMAN DMS plant featuring two cyclones fully erected at the fabricator's site before transport to MIBA, Mbujimayi, DRC.

The Modular Concept

A containerised x-ray recovery unit. Easy access for maintenance of equipment is provided through the double doors at the ends of the containers.

A pre-erected 50 t/h modular DMS plant before dispatch to ALROSA at Mirny, Siberia.

BATEMAN has recognised the need to provide clients with mineral-extraction solutions which are unconventional and which depart from the traditional way of building plants. The concept of modularisation is a philosophy, which goes beyond putting plant into boxes. We provide customers with:

- Standardised, but flexible, design options
- Standardised, but flexible, plant options
- Significantly reduced engineering and construction times
- Significantly reduced capital cost
- A total service, comprising:
  - technical support
  - fast spares delivery service
  - 24-hour attention.

The basic concept of a modular design is to build a plant in sections, which do not necessarily need concrete foundations. Most modules are skid mounted and in some cases only require a level, compacted, ground base. These modules are interconnected by piping, conveyors and electrical / instrumentation cabling. The most significant feature of a modular plant that distinguishes it from all other plants is that the structures, equipment, piping and electrics are factory assembled and tested prior to shipment to site. Shipment may be in containers or in the assembled condition, depending on destination and transport limitations. In this fashion, site assembly and erection may be achieved in a matter of weeks rather than the months required for a conventional plant. BATEMAN has supplied modular plants which can be integrated into conventional plants in numerous different applications.

The on-site activities for BATEMAN are usually limited to site supervision, commissioning and training, which requires virtually no site establishment since the client can invariably supply accommodation, feeding and transport for a site supervisor or commissioning engineers. This is of particular importance for the supply of plants into places not supported by existing infrastructure.

BATEMAN makes extensive use of nominated sub-contractors for the supply of equipment and for fabrication. This philosophy achieves a vast reduction in commercial staff and paperwork and achieves a commensurate reduction in lead times. Projects are typically run by one engineer and the required draughtsmen. Other staff are brought in on an ad-hoc basis, as required. Most of the staff have been with the organisation for many years and can be entrusted with all facets of project management and require minimal systems support.

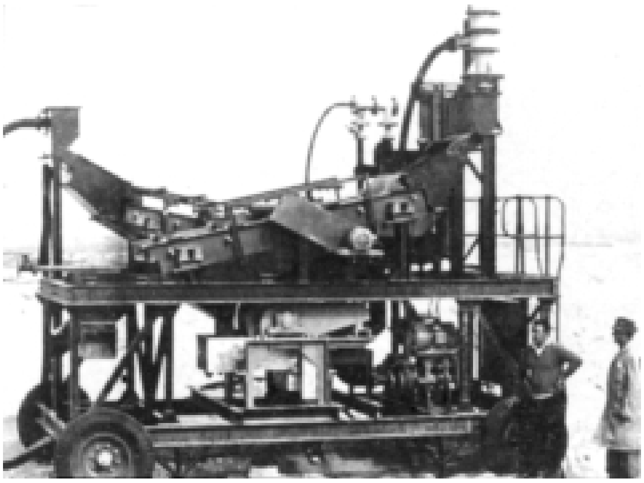
Factory testing the trailer-mounted modular diamond sampling plant. This plant was supplied to Alexkor, Alexander Bay.

Background and History

In the 1960s, Van Eck and Lurie (VEL), a private company which served the mining industry in South Africa and abroad for many years, pioneered a way of building and pre-commissioning plants prior to shipping them to site. This philosophy enabled VEL to build plants for installation on ships, barges and in the most remote locations where conventional plants would not have been considered.

In 1992 BATEMAN purchased VEL to complement its minerals business. For the next eight years VEL operated under its own name, but under the umbrella of the BATEMAN Group of companies.

In 2000 BATEMAN decided to abolish the name of VEL, mainly due to client confusion, and created a new in-house business line, Bateman Modular Plants. The new company maintained the basic business principles and philosophies which for many years had made VEL a successful company. The stability of the workforce has been paramount in the continuous success of Bateman Modular Plants.



The first modular plant, a 10 t/h DMS module for diamonds, was delivered to Brazil Diamante (Trans Hex) on the South West African coast in 1967.

A ship-mounted 10 t/h diamond-processing module operating off the west coast of South Africa.

DiamondWorks' containerised X-ray diamond-recovery plant in Angola, in the left foreground of the picture.

Capabilities and Achievements

Namco's MV Kovambo at sea off the Luderitz coast with its diamond recovery plant.

Ship- and Barge-Mounted Plants

- Gal Marine

Supplied all shipmounted diamond-processing plants since 1998 – eight in total.

- BHP/Benco

Bulk diamond-sampling plant on board the prospecting vessel '*Geomaster*'.

- Benco

Complete equipping of the diamond-mining vessel, the '*Moonstar*'.

- Namco

Bulk diamond-sampling plant on board the prospecting vessel '*Namco 1*'.

Complete diamond-process plant on board the mining vessel '*Kovambo*'.

- ODM

Complete diamond-process plant on board the sampling vessel '*Oceandia*'.

Complete diamond-process plant on board the mining vessel '*Namibian Gem*'.

Dense-media-separation (DMS) plant on board the diamond-mining vessel '*Ivan Prinsep*'.

- Le-Ro Marine Mining (Pty) Ltd

Test work and study.

- Miba

Converted jig-plant dredge to a DMS operation.

- ITM Mining

Supplied two dredge-mounted plants.

- Ashton Mining, Indonesia

Supplied a complete 120 t/h DMS plant and diamond-recovery plant.

The BATEMAN modular diamond recovery plant aboard the Moonstar.

The 140 t/h DMS module with X-ray recovery module supplied to a dredge mounted diamond recovery plant in Indonesia.

Capabilities and Achievements – *continued*

Minerals

Modular plants have been engineered and supplied to process the following minerals and metals:

- Diamonds – about 300 complete plants or sections of plants (e.g. X-ray separation plants), with DMS units varying from 1 t/h to 150 t/h. These plants were designed to process kimberlite and alluvial- and marine-diamond deposits, as well as for research institutions (e.g. Lakefield Research, Canada). The list would be significantly longer if subsequent modifications and additions to the plants were included.
- Coal – four modular coal-washing and beneficiation plants. The largest of these incorporated a 180 t/h DMS unit. BATEMAN/VEL was awarded a systems and design award by the South African Institution of Mechanical Engineering for this particular plant.
- Gold – three modular sections of gold-processing plants. These consisted of a 1,5 t/h continuous elution module, a 5 t/h pilot flotation plant and a 100 t/h gravity gold concentrator. At present, BATEMAN is involved with a study to design a complete, modular gold plant for a Canadian mine.
- Andalusite – three modular DMS plants.
- Platinum – one modular DMS plant and one purpose designed plant.
- Chromite – one 30 t/h DMS module for recovery of chromite ore in the United Arab Emirates.
- Graphite – two graphite-handling and beneficiation modules.
- Magnesite – one DMS module for magnesite beneficiation.
- Other – a 'HICOM' modular milling test plant for Warman Australia.

The 180 t/h modular coal-processing plant installed at New Clydesdale Colliery, RSA.

The Havercroft Andalusite Mine process plant, RSA.

A 30 t/h DMS chromite-processing plant in the United Arab Emirates.

A modular platinum-processing plant.

The graphite plant at Ancuabe, Mozambique. This view shows the front-end scrubbing plant in the foreground with the flotation and packaging plants at the back.

Capabilities and Achievements – *continued*

A typical BATEMAN 1 t/h DMS module, as supplied to an emerald mine in Zimbabwe.

Geographical

Modular plants have been supplied to all continents (excluding Antarctica) and in the following countries:

South Africa
Namibia
Botswana
Zimbabwe
Democratic Republic of Congo
Angola
Sierra Leone
Swaziland
Lesotho
Tanzania
Mozambique
United Arab Emirates
Greece
USA
Australia
Brazil
Burma
Syria
China
India
Canada
Indonesia
Russia.

Below: A movable diamond-sampling plant at Jagersfontein, in the Free State, RSA.

A complete diamond recovery plant in Angola incorporating a 50 t/h DMS module.

A 1 t/h 'Prospector' DMS module purchased by a client from India for diamond prospecting.

A pre-erected 50 t/h modular DMS plant before dispatch to Mirny, Siberia.

The frozen location of the Koala 30 t/h diamond sampling plant in the Canadian North West Territories.

Capabilities and Achievements – *continued*

Other Projects

Occasionally plants are required which fall outside the conventional modular-plant envelope. BATEMAN has engineered and constructed several such plants, the most significant of which are the following:

- Baken Project, RSA
  This was for the design, construction, project management and commissioning of an alluvial diamond plant of 1 300 t/h of headfeed and two 150 t/h DMS modules.
- MIBA – NLK1 Project, DRC
  This project was for the design, fabrication, project management and commissioning of an kimberlite-diamond plant of 400 t/h headfeed, complete with 150 t/h modular DMS. This client has subsequently ordered a second plant (a mirror image of NLK1) to be erected on the same property.

Trans Hex Mining's twin 150 t/h DMS modules, trial erected at the factory.

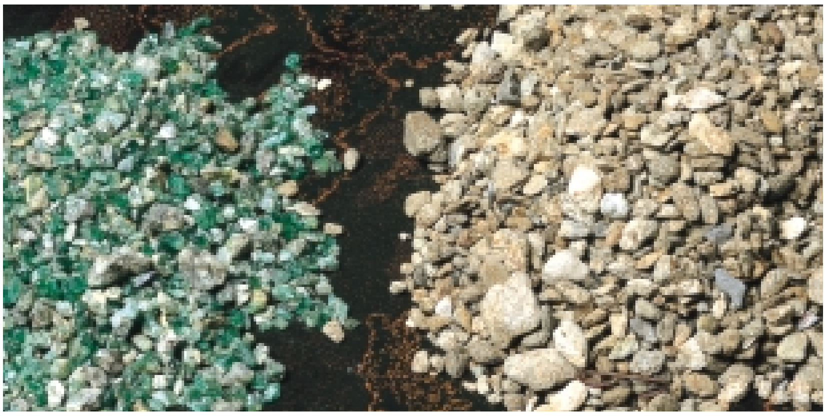
Services

To provide clients with a complete service, BATEMAN also provides the following:

- Feasibility Studies.
  A total of 15 studies of this nature have been completed for clients in diamonds, tantalite and zinc. Many of these studies led to eventual projects.
- Spares.
  BATEMAN offers a full spares, consumables and commodities, supply service for its own supplied plant and also for plant supplied by others. The range of supply may include actual equipment spares, tracers for setting up and tuning of plant, ferrosilicon (FeSi), and a whole range of diamond-plant requisites. Some clients prefer to use BATEMAN as a trading house, especially where the client does not have an infrastructure to do its own sourcing and buying. By virtue of its experience, BATEMAN efficiently handles all facets of over-border supply into Africa and elsewhere to optimise tax implications, transport, customs documentation, etc.

MIBA's 400 t/h kimberlite process plant at Mbujimayi, DRC.

BATEMAN density tracers, sized from 0,8 mm to 30 mm, are offered in a wide range of densities, depending on client requirements.



Emeralds separated from run-of-mine ore during testwork at BATEMAN.

Personnel

At the core of the success of Bateman Modular Plants is the quality and experience of its personnel. Most have a long history with BATEMAN and, previously, VEL. Their experience consists of a good blend of hands-on operating experience and sound engineering and design practices, supplemented by a dedication to a common philosophy and loyalty.

The staff comprises:

- Management
- Process Engineering
- Engineering / Project Management
- Drawing Office
- Administrative

Most of the staff are multi-disciplined and routinely handle estimating, procurement, inspection and expediting in addition to their functional responsibilities. The team in the Bateman Modular Plants business line is as follows:

MANAGEMENT

Robert Abate
General Manager, Modular Plants
44 years in the minerals-extraction industry. Involved in all of the modular plants ever supplied by BATEMAN and VEL. Experience includes employment with Anglo American / De Beers on many of their mines and projects.

Ellen Coetzee
Secretary and Personal Assistant to the General Manager.
22 years secretarial work, which include six years with the Modular Plants business line, eight years with a BATEMAN marketing department and eight years as secretary to the MD of IPC, a BATEMAN subsidiary.

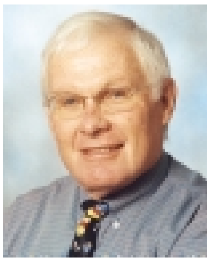
PROCESS ENGINEERS

Derek Lahee
Senior Process Engineer
13 years in design, operating, commissioning and auditing of metallurgical ship-mounted plants in Angola and Zaire.
Higher National Diploma in metallurgy from the Witwatersrand Technikon's School of Mines.

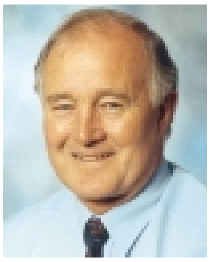
John Wightman
Senior Process Engineer
15 years in design, operating and commissioning of diamond- and gold-treatment plants, with De Beers Research Laboratories and BATEMAN in Angola, China, Canada, India and on ship-mounted plants. HND in extraction metallurgy from the Witwatersrand Technikon.

Gavin Boyle
Process Engineer
10 years in the design, commissioning and operating of diamond-, gold- and platinum-processing plants, with Goldfields of SA, Nordberg, Ergo and recently with BATEMAN. HND in extractive metallurgy from the Witwatersrand Technikon.

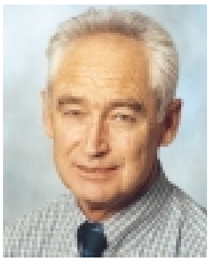
PROJECT MANAGERS / ENGINEERS



Mike Landey
Project Manager / Engineer
40 years in project management, design, estimating, procurement, expediting, QA, supervision and commissioning of mining and metallurgical plant. The past 12 years were spent in the Modular Plants business line.



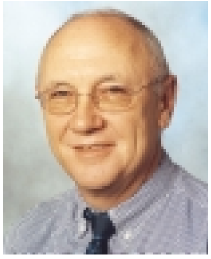
Cliff Shorter
Project Manager / Engineer
42 years in project management, design, estimating, procurement, expediting, QA, supervision and commissioning of mining and metallurgical plant.
The past five years were spent in the Modular Plants business line.



Scott Brebnor
Project Manager / Engineer
34 years in mining and construction, 30 years of which were in the execution of projects. The past five years were with the Bateman Modular Plants business line on studies and executing diamond-plant projects.

Louis Nell
Principal Engineer
34 years in the aircraft, mining, engineering and power-generation industries. Four years with BATEMAN on proposals and estimating. Ten years with De Beers / Anglo American.
B.Sc., B.Eng. and registered Professional Engineer.

Personnel – *continued*



Mike van Rensburg
Project Manager/ Engineer
28 years in design and construction of diamond plants in Tanzania, Lesotho and Botswana. 26 years with Anglo American / De Beers. Two years with BATEMAN on design, construction and commissioning of modular diamond plants.

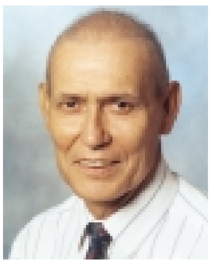
Wally Wilson
Project Manager / Engineer
40 years in drawing office, fabrication, site erection, project management including expediting and QA.
Past 12 years with BATEMAN.
Advanced Technical Diploma (II) from the Germiston Technical College.

Reinhardt Cemernjak
Electrical Engineer
35 years on electrical / instrumentation design and engineering projects, of which 28 with BATEMAN. Has worked in the chemical and power-generation industries in RSA and Austria. Electrical Engineering Certificate (Austria) and registered Professional Technologist.

Mike Mitchell
Mechanical Engineer / Estimator
29 years in proposals, mechanical engineering, construction and plant commissioning, including 12 years as structural and materials-handling draughtsman. 11 years with BATEMAN. NTC 5 from the Witwatersrand Technical College.

Wally Pienaar
Project Manager / Engineer
31 years in mining and construction, including costing, manufacture of new mining equipment, plant erection and commissioning, of which the past 5 years in central and west Africa, last 2 years with BATEMAN. Welding Eng. Tech. Diploma from Wits Technicon.

DRAUGHTSMEN



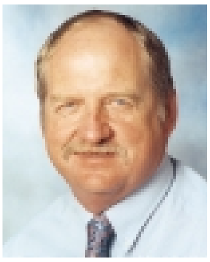
Derrick du Croq
Senior Section Leader
37 years as engineering draughtsman in metallurgy / mining. With BATEMAN for 25 years, on treatment plants, including diamonds, coal, gold, iron ore, platinum, chrome, vanadium, andalusite and magnesite. NTC 4 from the Witwatersrand Technical College.

Allan Emmett
Senior Design Draughtsman
42 years experience, of which the past nine years with BATEMAN on diamond, coal, gold and materials-handling projects. Obtained GCE and served a mechanical engineering apprenticeship in the UK.

Maurice Hammond
Draughtsman / Section Leader
20 years in design, detailing and checking of plants for the diamond, gold, coal and platinum industries. Also involved in drawing smelters and furnaces and for the automotive and sugar industries. 17 years with BATEMAN. Engineering Technicians Diploma (T6) from the UK.

Matthew Dennison
Layout/Design Draughtsman
Five years experience in design, detailing and checking of plants for processing diamonds and magnesite. Served a draughting apprenticeship with BATEMAN and has spent five years in total with the group. N6 in mechanical design and an S2 in Civil Engineering (current).

Morgan Motshabi
Trainee/Junior Draughtsman
One year post-qualifying experience.
Involved in detailing of modular diamond plants at BATEMAN.
Engineering Technical Certificate (N4) and Detail CADD Draughtsman, African Academy for CADD Training.



Arnold Sturitis
Manager, Layout engineering
32 years in mechanical handling and mining. Last 7 years with BATEMAN on diamond, coal, coking, iron ore, platinum, rhodium, andalusite, copper, cobalt, nickel, chrome and uranium plants. Apprenticed draughtsman and Certificate of Additional Studies for Technician Engineers (British).

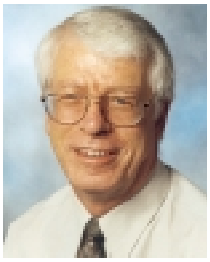
George Cooke
Draughtsman
40 years in project drawing office on chemical, gold, platinum, coal, uranium, cement, copper, diamonds, paper and pulp, sugar, sands and potash projects.
Advanced Technical Certificate (ATC1) from the Johannesburg Technical College.

Continued overleaf

Personnel – continued

Naomi Myburgh
CAD operator / Secretary
26 years in a drawing office environment. 16 years with BATEMAN. Experience with Autocad 2000 on detail, process and electrical drawings. Secretarial experience includes Excel, PowerPoint and Microsoft Word.

ADMINISTRATION



Arjan Leemans
Procurement Manager
20 years in procurement in cement, chemicals and mining, five years as draughtsman and with BATEMAN as buyer, sub-contract administrator and procurement manager. Diploma in Management of Procurement and member of the Purchasing Institute of SA.

Enzo Pultrone
Buyer
Experience in procurement of mining spares, sales of spares, import, export, shipping and transport. Six years experience of sourcing and procurement for projects mounted by Bateman Modular Plants.

Lea Seaga
Typist
17 years with BATEMAN of which the last five years as a procurement typist for the Modular Plants business line. Experience includes receptionist, clerk and typist.
Matriculation Certificate and many on-the-job training courses.

Cas Scheepers
Senior Cost Engineer
19 years as site administrator and cost engineer on a variety of projects in the mining and metallurgy industry. The last 17 years have been with BATEMAN. Member of the Cost Engineering Association of SA.

VISION – BATEMAN Modular Plants

- To continue to provide existing and new clients with plants of proven design and quality.
- To be the supplier of choice due to service excellence and best-value-for-money plants.
- To develop a new generation of modular plants suitable for the processing of other mineral and metal processes.
- To develop 3D modelling for both marketing and engineering purposes.
- To continue to make a significant contribution to the profitability of BATEMAN.
- To promote the BATEMAN vision – which is to be an innovative solutions provider to the natural-resources industry internationally, providing a comprehensive blend of skills comprising process-orientated engineering, specialist niche technologies, financial and commercial facilitation and contracting and project management.

Reference List

BATEMAN diamond reference list (International)

Client	Location	Project Description	Year	Scope of Supply	Gravel Type
Escom	Angola	125 t/h diamond-treatment plant	2002	DPC	A
Robow Investments	Namibia	50 t/h DMS	2001	DPC	M
Oryx Resources	DRC	250 t/h diamond-treatment plant	2001	DC	K
Oryx Resources	DRC	125 t/h diamond-treatment plant	2001	DC	A
Debswana	Botswana	150 t/h modular DMS plants and 50 reconcentration circuits	2001	DC	K
Oryx Resources	DRC	2 x 5 t/h DMS plants with containerised-recovery plants	2001	DC	A & K
De Beers	Jagersfontein	Dump sampling plant	2000	DPC	K
Alrosa	Russia	5 and 50 t/h DMS plants, Mirny, Aykhal	Oct – 2000	DPC	K
Lakefield Research	Canada	1 t/h DMS plant, Peterborough	Sep – 2000	DC	Var
Liqhobong	Lesotho	60 t/h DMS	Aug – 2000	FS	K
MIBA	Congo	400 t/h treatment plant NLK2		D	
Nat. Mineral Dev Corp	India	50 t/h DMS, Panna, Hyderabad	Jul – 99	DPC	K
Nat. Mineral Dev Corp	India	1 t/h DMS plant, Panna, Hyderabad	Jun – 99	DPC	K
Confidential	Russia	200 t/h kimberlite-processing plant	May – 99	Study	K
Rio Tinto	Zimbabwe	25 t/h bulk-sampling plant	Feb – 99	DPC	K
MIBA	Congo	Existing Centrale De Triage (Recovery upgrade) NCTB	Jan – 99	DPC	K
MIBA	Congo	400 t/h complete diamond-recovery plant, including feed preparation, 150 t/h DMS plant for NLK1	Jan – 99	DPC	K
Debswana	Botswana	400 t/h kimberlite-process plant at BK9, Orapa	Nov – 98	20% + 10% Total Study	K
Salene Diamonds	Congo	20 t/h DMS plant and ancillary equipment	Oct – 98	P	A
SDM	Angola	50 t/h DMS plant and ancilliaries	Jul – 98	DPC	A
Diamond Works	Angola	50 t/h DMS and feed-preparation plant, Yetwene	Jun – 98	DPC	A
ITM	Angola	50 t/h DMS	May – 98	DP	A
ITM	Angola	20 t/h DMS	Mar – 98	DP	A
Diamond Works	Angola	Containerised X- ray sorting plant, Yetwene	Feb – 98	DPC	A
Ashton Mining	Angola	Complete kimberlite-process plant project, Camutue	Jul – 97	Study	K
Ashton Mining	Indonesia	150 t/h dredge plant	Feb – 97	DPC	A
Confidential	Russia	400 t/h kimberlite-process plant	Dec – 96	Study	K
SDM	Angola	Due diligence study for complete plant, Catoca	Sep – 96	Study	K
Miba	Congo	200 t/h feed-preparation and DMS plant, Disele	Jun – 96	DPC	K
ITM	Angola	Two dredge-mounted plants, Chicapa	May – 96	DP	A
AAA Diamonds	Congo	50 t/h DMS plant	Mar – 96	DPC	A
Gal Marine	Namibia	50 t/h DMS plant	Feb – 96	DPC	M
MIBA	Congo	Dump conveyors, Usine Centrale	Aug – 95	DPC	A
Branch Energy	Sierra Leone	Total diamond-treatment plant incl. DMS and recovery plant	Jul – 95	DPC	K
Sominor	Angola	30 t/h DMS and recovery plant	Apr – 95	DPC	A
BHP	Canada	Total prospecting plant incl. DMS, Koala	Dec – 94	DPC	K
Gal Marine	Namibia	50 t/h DMS plant for MV *Shelf Explorer*	Nov – 94	DPC	M
BHP	USA	X-ray recovery module, Nevada	Oct – 94	DPC	K
MIBA	Congo	Peripheral DMS plant, Disele	Sep – 94	DPC	A
MIBA	Congo	50 t/h DMS plant, Disele	Aug – 94	DPC	A
MIBA	Congo	Emergency gravel-feed system	Jul – 94	DPC	A
Gal Marine	Namibia	X-ray plant	Jun – 94	DPC	M
Gal Marine	Namibia	30 t/h DMS plant for MV *Anja*	Jun – 94	DPC	M
MIBA	Congo	Total pretreatment plant	May – 94	DPC	A
ITM	Angola	2 x 50 t/h DMS plants	Apr – 94	DP	A
ODM	Namibia	Total process design incl. a 50 t/h DMS plant for MV *Namibian Gem*	Apr – 94	DPC	M
ITM	Angola	Dump retreatment plant	Mar – 94	DP	A
ITM	Angola	50 t/h DMS plant	Mar – 94	DP	A
Canemera	Canada	1 t/h DMS plant, Vancouver	Feb – 94	DP	K
Alluvial Diamonds	Congo	Converted dredge-mounted jig plant to DMS	Jan – 94	DP	A
MIBA	Congo	Dibindi recovery-plant upgrade	Dec – 93	DPC	A
Namco	Namibia	10 t/h DMS plant	Nov – 93	DPC	M
Diamond Exploration Inc	USA	Total 10 t/h bulk sampling plant incl. DMS and recovery plant, Arkansas	Oct – 93	DPC	K
MIBA	Congo	Kanshi III pretreatment plant	Aug – 93	DPC	A
MIBA	Congo	New scrubbing and screening modules, Usine Centrale	Jul – 93	DPC	A
Ashton	Canada	1 t/h DMS plant	Jun – 93	DPC	K

Abbreviations K = Kimberlite D = Design A = Alluvial P = Erection & Supervision M = Marine C = Commission FS = Feasibility Study

BATEMAN diamond reference list (International – continued)

Client	Location	Project Description	Year	Scope of Supply	Gravel Type
Oderbrecht Mining Services Inc	Angola	15 t/h DMS plant	Nov – 92	DPC	A
Oderbrecht Mining Services Inc	Angola	Scrubbing and screening plant	Oct – 92	DPC	A
Oderbrecht Mining Services Inc	Angola	Janenge 15 t/h DMS plant	Sep – 92	DPC	A
Oderbrecht Mining Services Inc	Angola	Scrubbing and screening plant	Aug – 92	DPC	A
De Beers Namdeb	Namibia	50 t/h DMS and recovery plant, Elizabeth Bay	Jun – 92	Study	M
YAM Diamonds	Namibia	50 t/h DMS plant for MV *Lady Sarah*	May – 92	Study	M
National Mineral Dev. Corp	India	50 t/h DMS plant, Panna, Hyderabad	Jan – 92	DPC	K
AAC De Beers	Botswana	5 t/h DMS plant, Jwaneng	Aug – 91	DPC	K
OMSI	Angola	X-ray sorting recovery module	May – 91	DPC	A
Mercantex	Angola	15 t/h DMS module	May – 91	DPC	A
MIBA	Congo	Modification to existing Usine Centrale plant, incl. 2 x 40 t/h gravity DMS plants	Apr – 91	DPC	A
Star Diamonds	Guinea	50 t/h plant, conceptual layout	Aug – 90	Study	A
SPE	Angola	DMS and jig plant and x-ray equipment	Jun – 90	DPC	A
Farground(Elbuk)	Ghana	Ghana cons diamonds	May – 90	Study	A
De Beers Namdeb	Namibia	40 t/h DMS plant, Oranjemund	Oct – 89	DPC	K
De Beers Namdeb	Namibia	50 t/h DMS plant, Oranjemund	Sep – 89	DPC	A & M
Mercantex	Angola	20 t/h DMS plant	Aug – 89	Study	M
MIBA	Congo	Feed-preparation plant incl. 2 x 40 t/h DMS plants, Dibindi	Jul – 89	DPC	A
Mercantex RST	Angola	15 t/h DMS plant, Field 1	Jun – 89	DPC	A
Confidential	China	2 x 40 t/h DMS plants and a 10 t/h DMS plant	May – 89	DPC	K
MIBA	Congo	5 t/h DMS plant, Geology Dept	Apr – 89	DPC	A
Debswana	Botswana	160 t/h DMS plant, Jwaneng	Mar – 89	DPC	K
RST	Angola	120 t/h diamond-treatment plant, including a 50 t/h DMS and recovery plant, Cangau	Jan – 89	DPC	A
Intraco	Angola	50 t/h DMS plant	Aug – 88	DP	A
Confidential	Syria	Kimberlite-sampling plant	Jul – 88	D	K
Miba	Congo	30 t/h dredge-mounted DMS plant and a 10 t/h DMS audit plant	Jun – 88	DC	A
Miba	Congo	160 t/h DMS plant	May – 88	Study	A
De Beers	Botswana	50 t/h DMS plant, Orapa,	Apr – 88	DPC	K
De Beers	Botswana	420 t/h recrush DMS plant, Jwaneng	Feb – 88	DPC	K
Mining corporation	Burma	DMS and x-ray recovery modules	Dec – 87	DC	A
Intraco	Angola	DMS and x-ray recovery modules	Dec – 86	DP	A
De Beers	Namibia	2 x 40 t/h DMS modules, CDM	Nov – 86	DPC	A

BATEMAN diamond reference list (South Africa – incl. non-modular)

Vaalbosch	RSA	1 x 50 t/h DMS Plant	2001	DPC	A
Sonop Delwerye	RSA	1 x 12 t/h modularised recovery plant	2001	DPC	A
Sonop Delwerye	RSA	2 x 100 t/h feed preparation plants	2001	DPC	A
Sonop Delwerye	RSA	4 x 50 t/h DMS	Sep – 2000	DPC	A
CMDSF	Kimberley	Sampling plant	Mar – 2000	DSDEC	D
Transhex	Northern Cape	1 000 t/h diamond treatment plant	Feb – 2000	DSDEC	D
Southern Era Resources	RSA	10 t/h DMS core sample plant, Potgietersrus	Mar – 99	DPC	K
ODM	RSA	40 t/h DMS plant, marine application	Aug – 98	DPC	M
Alexkor	RSA	Modifications to existing recovery plant	Jul – 98	DPC	A & M
NAMCO	RSA	Complete ship mounted diamond recovery plant	Jun – 98	DPC	M
BHP	RSA	Complete ship-mounted plant including DMS and recovery, *Benco*	Apr – 96	DPC	M
Alexkor	RSA	Mobile sampling plant incl. DMS, Alexander Bay	Apr – 95	DPC	A
BHP	RSA	Total marine sampling plant incl. DMS and recovery plant, *Geomaster*	Dec – 94	DPC	M

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BATEMAN diamond reference list (South Africa – incl. non-modular – cont.)

Client	Location	Project Description	Year	Scope of Supply	Gravel Type
Nautical Diamonds	RSA	Complete bulk sample plant incl. feed prep, DMS and recovery	Jun – 94	DPC	M
Rio Tinto	RSA	Mafikeng tails re-treatment plant	Dec – 91	FS	K
AAC De Beers	RSA	Extension to existing recovery plant, Venetia	May – 91	D	K
Alexkor	RSA	400 t/h feed prep plant, Rietfontein	Oct – 90	DPC	M
Alexkor	RSA	SAT 1 scrubber installation, Alexander Bay	Jun – 90	DPC	A
AAC De Beers	RSA	Main treatment plant, Venetia	Nov – 89	DPC	K
De Beers	RSA	20 t/h DMS sampling plant, Premier Mine	Sep – 89	DPC	K
Alexkor	RSA	50 t/h DMS, Klipfontein	Mar – 89	DPC	A
AAC De Beers	RSA	Bulk sampling 50 t/h DMS, Venetia	Feb – 89	DPC	K
AAC De Beers	RSA	Total 140 t/h treatment plant incl. 50 t/h DMS plant and recovery	Feb – 89	DPC	K
Shenandoah Mining	RSA	65 - 100 t/h treatment plant including x-ray plant	Dec – 88	DPC	A
Jhb Mining	RSA	8 - 10 t/h jig plant	Nov – 88	D	K
Gal Marine	RSA	10 t/h on board DMS plant, West Coast	Sep – 88	DPC	M
De Beers	RSA	Sampling plant, Kleinzee	Oct – 87	DPC	A
Dawn Diamonds	RSA	X-ray plant	Aug – 87	D	M
Dawn Diamonds	RSA	On board DMS plant and ancillaries	Oct – 86	D	M
Star Diamonds	RSA	80 - 90 t/h treatment plant	Dec – 85	DPC	K
Rio Tinto	RSA	100 t/h treatment plant and recovery plant	Dec – 83	DPC	A
Buffelsbank Diamante	RSA	50-60 t/h diamond treatment plant	Jun – 81	DC	A
De Beers	RSA	5 million t/yr diamond treatment plant, Finsch	Dec – 80	DPC	K
State Alluvial Diggings	RSA	80 t/h DMS cyclone plant	Jun – 78	DC	A
State Alluvial Diggings	RSA	25 t/h DMS plant	Dec – 75	C	A
De Beers	RSA	90 t/h bulk sample plant, Kimberley	Feb – 75	DC	K
De Beers	RSA	15 t/h DMS plant, Koffiefontein Mine	Jan – 74	D	K
De Beers	RSA	20 t/h underground sample plant, Finsch Mine	Mar – 73	D	K
De Beers	RSA	300 t/h DMS cyclone plant, Kleinzee	May – 71	DC	A
State Alluvial Diggings	RSA	2 diamond prospecting plants	Mar – 69	DC	A
De Beers	RSA	Test pan plant	Feb – 68	DC	Various
Buffelsbank Diamante	RSA	60 t/h diamond treatment plant	Nov – 67	DPC	A

Other minerals (incl. non-modular)

Client	Project	Year	Location
Norilsk	Nickel pilot plant feasibility study	2001	Russia
Sub Saharan	Tantalite feasibility study	2000	Mozambique
Amplats	Waterfall platinum feasibility study	2000	RSA
Grecian Magnesite	30 t/h DMS plant	Nov – 2000	Greece
Rosh Pinah	100 t/h plant (study)	Oct – 2000	Namibia
Sandawana Emeralds	2 x 1 t/h DMS plants	Mar – 2000	Zimbabwe
Goldfields	180 t/h DMS module for coal benefication	Feb – 97	Witbank
Amplats	140 t/h DMS module for platinum upgrading	Oct – 96	Rustenburg
Havercroft	1 x 50 t/h DMS module and 1 x 30 t/h DMS module for andalusite	Sept – 96	North Eastern Transvaal
Derwent Mining	30 t/h DMS module for recovery of chromite ore	May – 95	United Arab Emirates
Warman Research	'Hicom' modular milling plant for gold and diamond recovery	Sept – 93	Transvaal
Kenmare	Process plant for handling 750 t/h dried flake graphite, Ancuabe	Aug – 93	Mozambique
General Mining	1,5 t/h continuous elution module	June – 91	Weltevreden GM, Orange Free State
Rossing Uranium	20 t/h graphite crushing and screening plant with 2 t/h flotation plant with 2 stage regrind, filtration, drying screening and bagging	Feb – 91	Otjiwarongo, Namibia
Zimco Industries	15 t/h HMS cyclone plant for Annesley Andalusite	June – 88	North East Transvaal
Zimco industries	40 t/h HMS cyclone plant for Annesley Andalusite	June – 88	North East Transvaal
Anglo American Corporation Limited	5 t/h pilot flotation plant for gold ore	Jan – 85	Orange Free State, RSA
Cofiki	100 t/h alluvial gold plant with scrubber, screens jig and Knelson concentrators	Jan – 85	Zaire (DRC)

Abbreviations K = Kimberlite D = Design A = Alluvial P = Erection & Supervision M = Marine C = Commission FS = Feasibility Study

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Website: www.bateman.co.za

BATEMAN

– process plants that work

APPENDIX 7.2

Ciba® Synthetic Flocculants – Product List

Ciba® SYNTHETIC FLOCCULANTS FOR INDUSTRIAL AND MINERAL PROCESSING APPLICACATIONS

Ciba® MAGNAFLOC®	High Molecular weight synthetic flocculants designed for a wide variety of industrial and mineral processing applications.
Ciba® ZETAG®	High molecular weight synthetic flocculants designed for a wide variety of industrial and mineral processing applications.
Ciba® MAGNAFLOC® 351/333	Nonionic polyarcrylamide. Particularly suitable for hydrometallurgical processes in the middle and low pH range.
Ciba® MAGNAFLOC® 455	Cationic polyacrylamide. Effective at low pH and on organic solids.
Ciba® MAGNAFLOC® 7692/7503	Cationic polyacrylamides. Effective at low pH and on organic solids.
Ciba® MAGNAFLOC® 155/156/336/338/342/ 10/1011/919/611	Anionic polyacrylamides finding many applications in the mining and mineral processing industry and in the treatment of industrial effluents. Active throughout the pH range.
Ciba® MAGNAFLOC® 1597/1697/368	Organic coagulants. For flocculation of organic and microbiological suspensions and slimy or colloidal clays.
Ciba® MAGNAFLOC® 90L/110L/120L	Anionic polyacrylamides in micro dispersion form.
Ciba® MAGNAFLOC® LT Series	High molecular weight synthetic flocculants of high purity produced to health standards required by water, food and drug authorities.
Ciba® MAGNAFLOC® LT20	Nonionic polyacrylamide for potable water clarification.
Ciba® MAGNAFLOC® LT25/LT26/LT27/ LT30/LT27AG	Anionic polyacrylamides for potable water and sugar juice clarification.
Ciba® MAGNAFLOC® LT22/LT22S/LT24	Cationic polyacrylamides for potable water clarification.
Ciba® MAGNASOL® BLOCKS	Flocculant in the form of a solid block which has been specially designed to slowly dissolve in the effluent flow and flocculate the suspended solids. Ideally suited for remote locations where electricity is not available.
Ciba® ALCLAR®	A range of synthetic flocculants developed specifically for the flocculation of red mud in the manufacture of alumina by the alkaline digestion of bauxite and laterites. Flocculants for use in decanters, washers and hydrate thickening are available.
Ciba® TIOFLOC®	A range of speciality flocculants for the titanium dioxide industry. For use in both the pre- and post-hydrolysis stages of the sulphate process.

APPENDIX 7.3

Technical Information

1. Flocculation
2. Thickening and Clarification
3. Glossary

TECHNICAL INFORMATION

FLOCCULATION
INTRODUCTION

Flocculation is the aggregation of single particles, or small groups of particles, into multi-particle aggregates or 'flocs'. The technique is used in many industrial processes to enhance solid-liquid separation.

In terms of definition it is necessary to make a distinction between coagulation and flocculation, as both involve particle aggregation but by different mechanisms. The process of coagulation involves particle aggregation by surface charge neutralisation, thus overcoming the repulsive potential barrier between particles. Particle surface charge is invariably negative and multivalent inorganic coagulants like lime, ferrous sulphate, ferric sulphate and alum are used to effect aggregation and form 'coagula'. Flocculation *stricto sensu* is the aggregation of particles by long-chain polymers, where particle surface charge may or may not be changed.

The term flocculation is derived from the Latin *flocculus*, which describes a tuft of wool, as this was likened to the "fluffy" aggregates that resulted from particle flocculation. The term flocculant is sometimes used as an adjective to describe the appearance of flocculated substances.

HISTORY
The action of inorganic coagulants has been known for a long time; silt-laden river waters entering saline oceans and subsequently dumping their aggregated particulates to form deltas, being an example. Lime has been used as a coagulant in the mining industry since the turn of the 20th Century and alum is a well-established treatment chemical for water clarification.

Flocculants first evolved from natural sources. Crushed nuts from the Nirmali tree (*Strychnos potatum*) were used in India for centuries to clarify water. Acid treatment of isinglass (crushed swim bladders of Sturgeon fish) produces 'finings' which is used to clarify beer. Both these examples owe their effectiveness to water-soluble polymers.

As technology progressed, naturally derived flocculants included the polysaccharides starch, dextrin and guar gum and the proteinaceous hydrophilic colloids animal glue, casein, gelatin and alginates. All these products found application in mineral processing solid-liquid separation.

Although some of these naturally derived products have found niche markets, they have been markedly superseded in the minerals industry by synthetic flocculants. Synthetic flocculants are based mostly on acrylic raw materials derived from petrochemicals. These synthetic products were first introduced into the minerals industry in the 1960s.

The advantages of synthetic flocculants are that their molecules or macro-ions can be tailored in terms of chemical content and molecular weight (chain length) to suit virtually any conditions encountered in mineral processing and hydrometallurgy. As they are manufactured from synthetic feedstocks their consistent quality and supply are advantages over naturally derived products. The ability to manufacture much higher molecular weight polymers than found in the naturally derived counterparts ensures that synthetic products are ultimately more cost-effective in solid-liquid separation processes.

Because of the eminence of synthetic flocculants, the remainder of discussions will be solely on these types of product.

FLOCCULANTS
From a chemical and application standpoint, flocculants can be divided into two categories:

- High molecular weight polyacrylamide-based flocculants
- Primary coagulants

High Molecular Weight Polyacrylamide-based Flocculants
These products are manufactured in anionic, nonionic and cationic forms by polymerisation and copolymerisation of sodium acrylate, acrylamide and cationic monomers like DMAEA (dimethylamino ethyl acrylate). Composition can be varied from completely anionic through nonionic to totally cationic with all compositions in between, thus producing a spectrum of products. Molecular weights, which govern chain length, of such products can exceed 20 million. Thus a whole matrix of products can be tailored based on compositional variation and molecular weight, with each product having a different performance efficiency under various conditions of solid-liquid separation.

The term 'polyelectrolyte' was originally coined for the anionic and cationic types of this category of flocculant but is now used indiscriminately to include nonionic types as well.
These products are manufactured in powder, micro-bead, dispersion and emulsion forms.

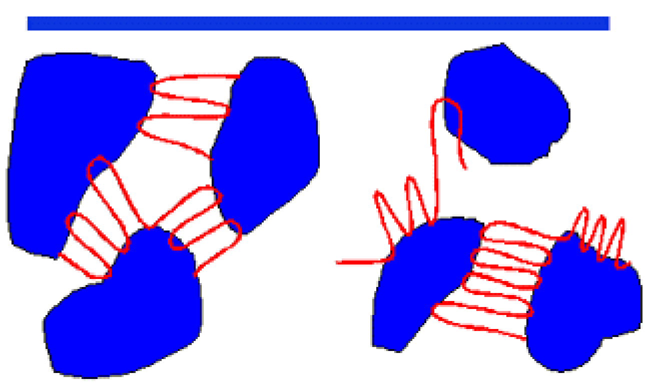
Primary Coagulants
In contrast to the category above, primary coagulants are highly cationic, low molecular weight polymers (2 million). Most are supplied as concentrated solutions, though some can be in solid form.

The two common types of primary coagulant are based on polyDADMAC (diallyl dimethyl ammonium chloride and polyamine.

Primary coagulants can be used alone or in conjunction with high molecular weight products.

THE PROCESS OF FLOCCULATION
High molecular weight flocculants exist in solution as coiled, hydrated long chains. The anionic and cationic types, which carry electrical charges along the "backbone" of the macro-ion, are more extended in solution due to neighbouring group charge repulsion than in the uncharged nonionic types.

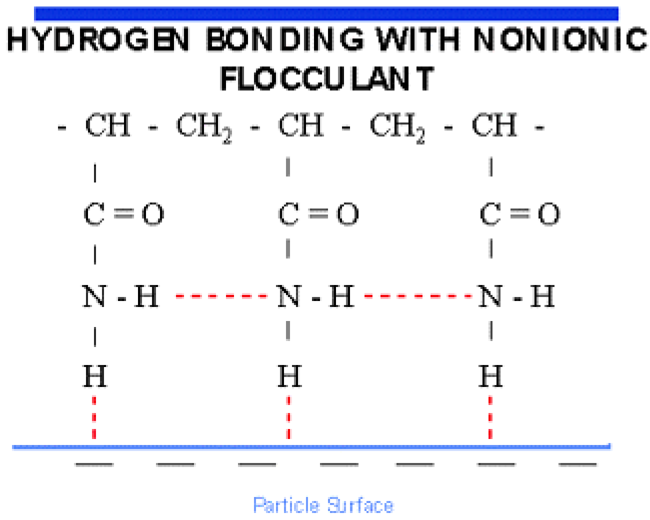
In order to flocculate a particulate suspension, the polymer chains have to adsorb on several particle surfaces simultaneously and "tie" the particles together, thus forming flocs. This process is known as bridging flocculation and applies to anionic, cationic and nonionic types of polymer. The following diagram illustrates bridging flocculation.



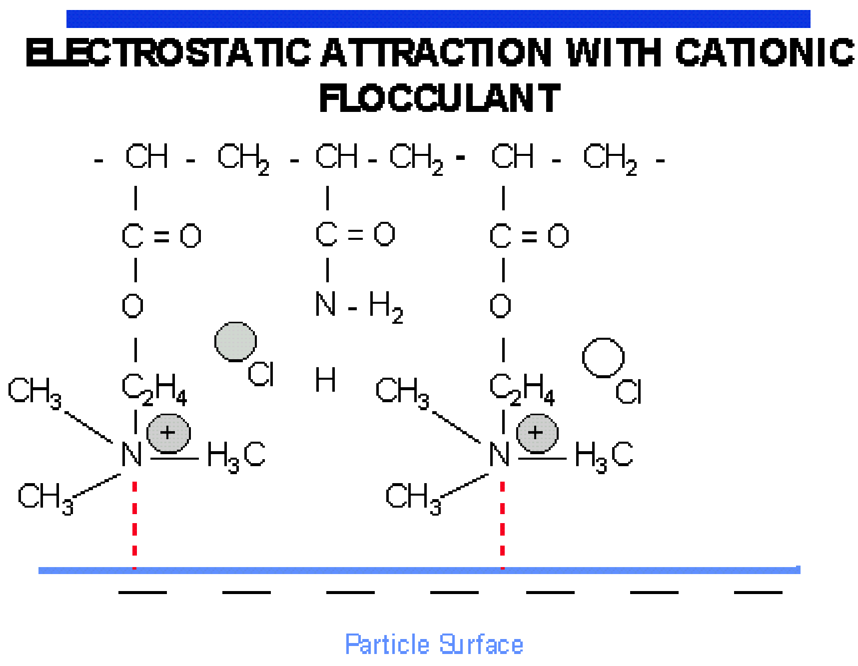
BRIDGING FLOCCULATION
WITH HIGH MOLECULAR
WEIGHT POLYMERS

The mechanism of adsorption depends on the type of flocculant used and the groups present on the surface of the mineral particles. The following series of diagrams illustrate the mechanisms of polymer adsorption which lead to flocculation.

Nonionic polyacrylamide flocculants adsorb by hydrogen bonding to oxygen atoms present on the mineral surface.

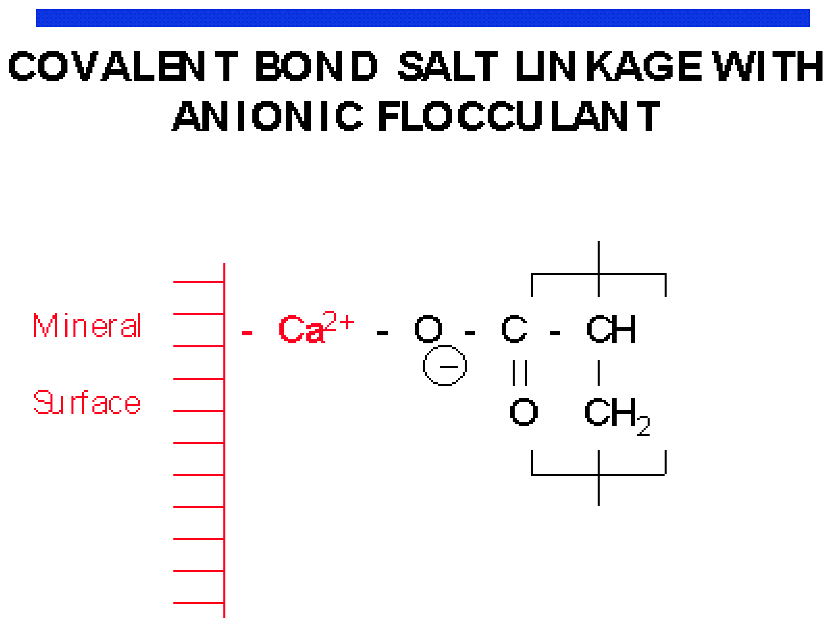


Cationic polymers adsorb by electrostatic attraction between the positively charged quaternary nitrogen and negatively charged groups on the surface of the mineral. Most minerals are negatively charged at normal pH values.



Primary coagulants adsorb by this mechanism and are suited to treating highly negatively charged particles, where an emphasis is on charge neutralisation as well as bridging.

The minerals industry tends to use more anionic flocculants than the other two types. Adsorption, leading to flocculation, is by covalent bonding or "salt linkage" where electrons are transferred from the acrylate group of the polymer to multivalent cations like calcium and iron present in or on the mineral surface. This type of bonding produces a strong floc.



CHOICE OF FLOCCULANT

Many factors are involved in what determines the "optimum" flocculant for a particular application. The following list shows some of the contributory factors but is not exhaustive by any means:

- Design of the actual dewatering equipment to be used
- Minerals present in the slurry - their surface chemistry, concentration and particle size
- Chemical make up of the slurry liquid - ionic strength and pH
- Type of floc structure required - weak, strong, large or small

The multiplicity of factors that determine the suitability of a flocculant for an application emphasises the need for thorough test work to be carried out.

Ciba Speciality Chemicals PLC

TECHNICAL INFORMATION

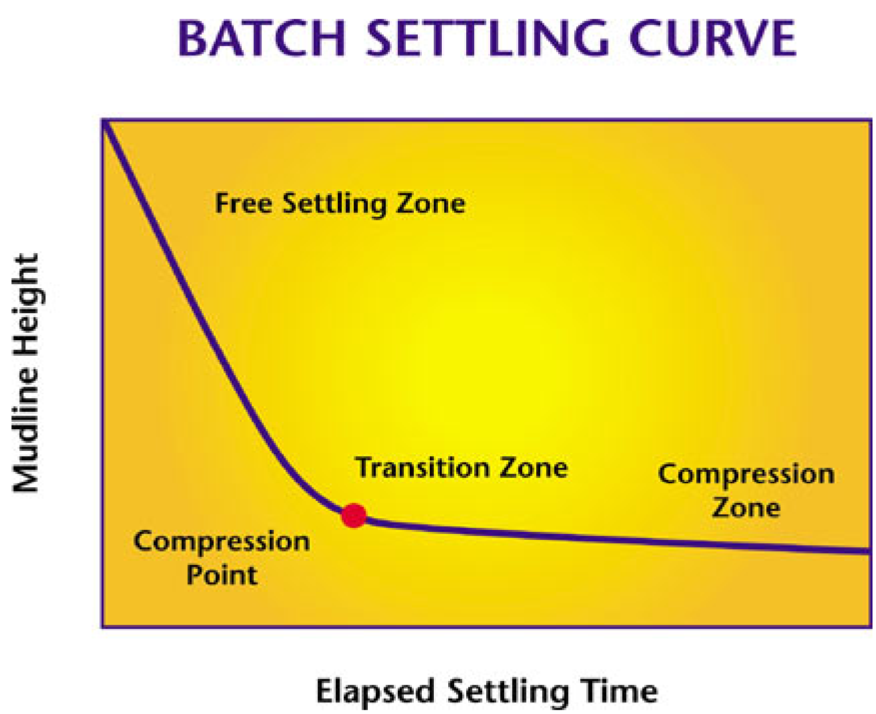
THICKENING AND CLARIFICATION
INTRODUCTION

The most basic solid-liquid separation process is the sedimentation of solids through liquid, under the influence of gravity. This process has been employed in mineral processing operations for centuries and in its original form would have involved a pit in the ground into which slurry was directed and the top water later decanted. Today, sedimentation is still the most prevalent form of solid-liquid separation in the minerals industry and sophisticated equipment has evolved along with high-performance flocculants to make the process fit in a high-technology flowsheet. The sedimentation process can be described in terms of thickening and clarification.

TYPES OF SEDIMENTATION.
Generally, two types of settling behaviour are seen in mineral processing pulps and slurries. The difference is due to solids content. This is readily demonstrated in the laboratory using a measuring cylinder or a beaker. At very low solids, a true interface between solids and liquid, or mudline, is not formed, even when flocculants are used. Flocs fall loosely through the water and a bottom sediment builds up, giving a rising interface as solids accumulate on the bottom of the cylinder or beaker. A 'bulk-settling rate' can sometimes be measured which is the time for the majority of solids to settle through a given distance. Generally, turbidity measurement is the best way of measuring flocculant or coagulant performance. The behaviour described is typical of low solids slurries and is called clarification; on a plant scale a clarifier is used to perform this separation. In clarification, the emphasis is usually to produce solids-free liquid as opposed to highly dewatered solids.

For slurries with solids contents greater than about 3% by weight, settling occurs with a mudline separating liquid and solids. This type of settling behaviour is known as zone settling, or more commonly, thickening. The emphasis here is on producing highly dewatered solids by allowing time for the settled flocs to consolidate and express water from their structure. The process is carried out on an industrial scale in a thickener.

The progress of the fall of the mudline can be measured against time and plotted to give a batch settling curve. Such curves can be used to assess the suitability of flocculants and to size industrial thickeners. A typical curve is shown below.

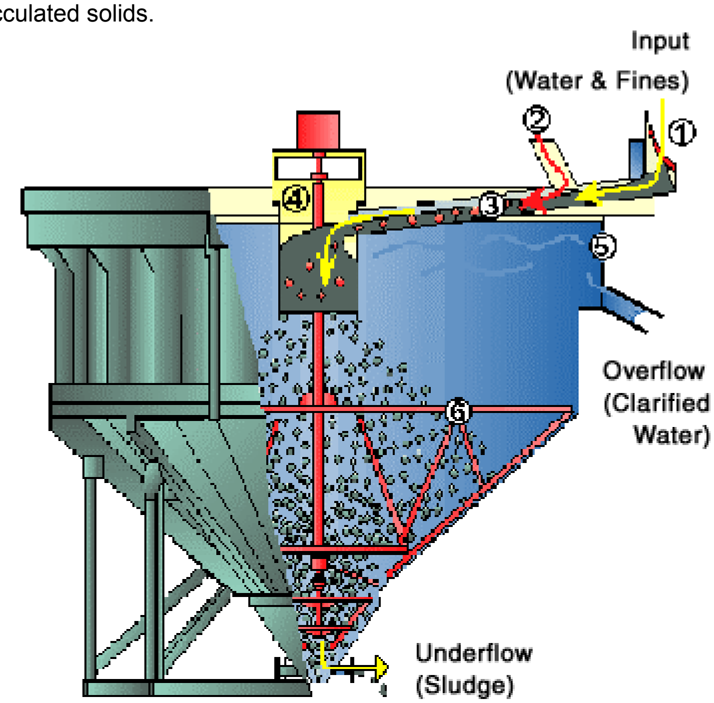


The curve typically consists of three zones; a simple interpretation is as follows:

- Free Settling Zone. Settling rate is constant over this linear part of the curve and the whole settling mass has the concentration of the initial "feed" in the cylinder or beaker. Flocs at the bottom of this column are passing down into the transition zone. Flocs are not in contact and therefore do not interfere with each other allowing liquid to escape upwards freely between the structures
- Transition Zone. The free settling zone disappears after a short time. In the transition zone flocs come much closer together and begin to interfere with each other. Settling rate slows down as the channels between the flocs are more restricted and liquid escapes upwards more slowly. Flocs in the transition zone pass into the compression zone
- Compression Zone. After the compression point is reached, flocs are in contact with each other and squeezing takes place depending on the weight of overlying solids. Here increase in solids concentration is slow and is due to liquid being exuded from the interior of the flocs.

A laboratory settling test, as just described, is a batch process whereas a continuous process takes place in a thickener.

THICKENERS AND CLARIFIERS
The basic designs of conventional clarifiers and thickeners are similar. Thickeners tend to be more heavy duty in construction to cope with the extra solids load. A diagram below illustrates typical features of a clarifier or thickener. Both types of unit consist of a settling tank with an overflow weir and launder around the top annulus to convey clarified water away (5). A raking mechanism (6) conveys settled solids to the underflow outlet at the bottom of the tank. Flocculant solution (2) is added to the feed (1). A central feedwell (4) receives the flocculated solids.



Many different designs of clarifiers and thickeners are available but the above description is adequate to explain the basic principles involved.

CONTROLLING FACTORS FOR THICKENING AND CLARIFICATION
For the efficient operation of clarifiers and thickeners several factors influence the accepted design. Because the emphasis of duty is different for the two types of equipment, so are the design factors.

The primary function of a thickener is to dewater solids. All the traditional methods of sizing the equipment (Coe and Clevenger, Talmage and Fitch and the Oltmann techniques) are based on the premise that settling in the free settling zone controls the diameter of the thickener. The sizing concept is based on unit area, that is the area required to settle unit weight of solids in the feed to the required underflow concentration in unit time. Provided the conical part of the tank accommodating the compression zone is adequately deep to provide the necessary retention time, the sizing of the tank relies solely on unit area and thus diameter derived from the free settling zone.

Unit areas are derived from batch settling curves using one of the above mentioned methods. One of the problems involved in the calculations is the precise position of the compression point.
In contrast, the factors taken into account for the sizing of clarifiers are rise rate and liquid retention time.

Rise rate, sometimes called upflow or overflow rate, has to be within limits to prevent hydraulic overload of the equipment and solids carry over. Rise rates are determined from bulk settling test times. If the slurry is instantly and completely flocculated such that required turbidity values are reached very quickly, a clarification rate test is used to confirm rise rate which determines clarifier diameter.

If the slurry is slowly flocculating, a second order kinetic test is used to determine the required retention time. Clarifier diameter and height are finally decided from the larger values stemming from either rise rate or retention time measurements.

Some slurries show intermediate behaviour to thickening and clarification. In these cases, the attribute which requires the larger equipment dimensions is used as design choice.

Adequate safety factors are applied to clarifier and thickener sizing calculations to allow for 'short circuiting' away from idealised flow and feed slurry variations.

Ciba Speciality Chemicals PLC

TECHNICAL INFORMATION

GLOSSARY

1. *Adsorbed.* To be attached to a solid surface.

2. *Adsorption.* The process whereby a chemical species becomes attached to a solid surface. The attachment or bonding can be either chemical or physical in nature.

3. *Agglomeration.* The combining of single particles to produce a multi-particle structure.

4. *Antiscalants.* Chemical additives that prevent deposition from solution and build-up of deposits (scale) in industrial equipment.

5. *Barren Solution.* A process solution from a hydrometallurgical circuit that has been stripped of its valuable component (raffinate).

6. *Beneficiation.* The process of upgrading or concentrating a valuable component in a mixture by removing the unwanted components.

7. *Calcination.* The heating of solid materials, usually to cause a physical change or chemical reaction.

8. *Concentrate.* The stream from a separating process that contains the valuable component.

9. *Centrifuge.* A spinning device for separating solids from liquids by the action of centrifugal force.

10. *Centrifugation.* The application of centrifugal force to enhance solids settling and solid-liquid separation.

11. *Clarification.* The process whereby fine suspended solids are removed from a liquid by sedimentation.

12. *Crystal Modifiers.* Chemical additives that adsorb onto the surfaces of growing nuclei or crystals and change their rate of growth, size or shape.

13. *Dewatering.* The process whereby water is removed from a solid-liquid slurry.

14. *Digestion.* The dissolving of minerals by the application of a chemical solution, often accompanied by heating.

15. *Electrolysis.* The separation of the components of a solution by the application of an electric current. This electrolytic process can be used to recover valuable metals from solution by cathode deposition, a technique known as electrowinning.

16. *Eluted.* The removal of a chemical species adsorbed on a solid by application of a wash solution.

17. *Filtercake.* Partially dewatered, moist solids deposited on a filter medium.

18. *Filtration.* The process by which solids are separated from water by deposition onto a water-permeable filter medium.

19. *Fines.* The small fraction in a particle size distribution, often taken as below 50μm diameter.

20. *Flocculants.* Long-chain polymer molecules or macro-ions used to cause particle aggregation in suspensions.

21. *Flocculate.* To cause aggregation of single particles into multi-particle flocs.

22. *Flocculation*. Particle aggregation by long-chain polymers.

23. *Flotation*. The separation of components of a mineral mixture by aeration of the chemically conditioned pulp. Particles rendered hydrophobic attached to air bubbles and are levitated to the surface while hydrophilic particles remain suspended in the pulp.

24. *Flotation Reagent*. Chemical additives used to modify the surface chemistry of mineral particles, such that the particles respond to the process of froth flotation.

25. *Gangue*. The unwanted or waste fraction of a mineral mixture (cf. tailings).

26. *Gassing off*. The effervescence of air bubbles from a solution or suspension.

27. *Goethite Process*. A unit operation within the Electrolytic Zinc Process whereby excess iron is precipitated from solution as goethite, FeO.OH.

28. *Heap Leaching*. Removal of valuable metal in solution by percolation of a solvent through a constructed heap of crushed ore.

29. *Hydrate*. Aluminium trihydrate or more correctly, aluminium hydroxide, $Al(OH)_3$.

30. *Hydrometallurgical*. A type of process whereby metals are separated and recovered by leaching or dissolving ore in an aqueous medium.

31. *Hydrophilic*. Water-attracting, as applied to a surface of a solid.

32. *Hydrophobic*. Water-repelling, as applied to a surface of a solid.

33. *Immiscible*. Will not mix to give a homogeneous solution.

34. *Indurated*. Hardened.

35. *Jarosite Process*. A unit process within the Electrolytic Zinc Process whereby excess iron is precipitated from solution as jarosite, $2NH_4Fe_3(SO4)_2(OH)_6$.

36. *Leachant*. Liquid used to dissolve minerals or metals; solvent or lixiviant.

37. *Leaching*. The process by which metals or minerals are dissolved by a solvent.

38. *Nucleation*. The coalescence of ions in the initial stages of crystal growth to produce crystal embryos.

39. *Overflow*. Clarified water or liquor, which emerges from the launder of a thickener.

40. *Ponding*. To retain liquid or slurry in a lagoon or pond.

41. *Precipitated*. The separation of solid material by crystallisation from a solution.

42. *Precipitation*. The process by which solids crystallise from a solution.

43. *Pregnant Liquor*. A process liquid containing high concentrations of dissolved metal or mineral.

44. *Purification*. Generally, to remove impurities from a substance.

45. *Pyrometallurgical*. A process by which metals or minerals are recovered by the application of heat eg. smelting.

46. *Reducibility*. The ease with which oxygen is removed from a substance, generally during smelting to produce metal from oxide mineral.

47. *Sedimentation*. Settling of particulate matter through a liquid under the influence of gravity.

48. *Stripped*. The removal of valuable metal from an absorbent solid or solvent by application of a chemical solution.

49. *Synthetic Flocculant*. A long-chain polymer produced from synthetic raw materials as opposed to chemicals derived from natural sources.

50. *Tailings*. The unwanted portion of a mineral mixture, after a separation process has taken place (cf. gangue).

51. *Thickener*. A device for separating solids from liquid by sedimentation. The usual construction is a raked tank with a feedwell, an annular overflow launder and a bottom underflow outlet.

52. *Thickening*. The concentration of solids from a solid-liquid suspension by the action of gravity sedimentation.

53. *Underflow*. Thickened pulp that is pumped from the bottom outlet of a thickener or clarifier.

54. *Underflow Rheology*. The flow characteristics of an underflow slurry; viscosity is a major factor.

55. *Value/Values*. The valuable component of a mineral mixture, as opposed *to the* gangue material.

APPENDIX 7.4

GENCAPD presentation Tower Hotel, March 1, 2002

Introduction

- Michael Rylatt employed by BHP Billiton Diamonds Inc. at the Ekati mine in Canada.
- 23 years experience in mineral processing with nearly 18 years in the diamond industry.
- Operation and design of alluvial, marine and kimberlite diamond mines in southern Africa and Canada.
- The Ekati mine currently treats 3.6 million tonnes producing approx 4 million carats per year.

Purpose

- To review current diamond recovery operations in Guyana and make recommendations to increase recovery efficiencies if possible and reduce the environmental impact of the mining methods.
  - Field testwork will be undertaken to evaluate the performance of a jig (lavador) with diamond density equivalent tracers (3.53SG) using river and recycle water.
  - Flocculants will be tested to determine suitable reagents which could be used to reduce the amount of suspended solids in water discharged from a diamond mining operation.

Diamond Recovery

- The primary method used for diamond recovery is gravity concentration.
  - The applicability of a gravity concentration process to the separation of two minerals of different specific gravity and the size range that can be treated is obtained using the Concentration Criterion (Taggart).
  - The criterion is determined by the following formula where

  ρ_H = specific gravity of heavy mineral

  ρ_L = specific gravity of light mineral

  ρ_M = specific gravity of the fluid
  - Concentration Criterion = $\rho_H - \rho_M / \rho_L - \rho_M$

Diamond Recovery

- Gold and diamond concentration criterion;
- For gold with a specific gravity of 17 to 19, water with a specific gravity of 1 and quartz rock with a specific gravity of 2.6, the concentration criterion is 10.
  - Therefore gold recovery is relatively easy down to 74 microns.
- For diamond with a specific gravity of 3.53 and quartz rock, the concentration criterion is 1.6.
  - Diamond recovery is possible down to 2mm but is difficult.
  - The sluice box is efficient for separations when the concentration criteria is greater than 3.5 (Taggart). For diamond recovery, the use of a sluice box is not recommended.

Diamond Recovery

- The size range of the applicability of gravity concentration is shown below;

Criterion	Size range of applicability
>2.5	Separation easy down to 74 micron
2.50-1.75	Separation effective down to 149 micron
1.75-1.50	Separation possible down to 1.68mm but difficult
1.50-1.25	Separation possible down 6.35mm but difficult
<1.25	Relative processes impossible but absolute processes possible eg heavy medium separation

  - Relative process (eg sluice box, jig) uses differences in settling velocities of particles in a fluid (eg water).
  - Absolute process uses a fluid with a specific gravity between that of the ore particles to be separated using a true liquid or fine suspension eg magnetite or ferrosilicon.

Diamond jig operation

- Jigs (lavadors) are not used in large (Australian, South African, Canadian) diamond operations due to lower recovery efficiencies.
- For efficient operation, a jig requires;
  - Sized feed, the average feed top size is usually 12mm or less
  - Size ratio of the largest lighter mineral to the smallest heavier mineral, maximum of 3:1
  - Steady non fluctuating feed
  - Higher level of operator attention

Diamond recovery processes

- The most common concentration process used for diamond recovery is Heavy Medium Separation (HMS).
- The advantages of HMS are;
  - Treats a broad size range, 1 to 25mm
  - Removes products continuously
  - Sharp separation, high concentration ratio, and high recovery efficiency (99+%)
  - High capacity, relatively low operating costs and capital investment per tonne of capacity
  - Higher level of security for the concentrate diamond due to enclosed pipes and storage bins

Jig field tests

- A jig efficiency will be checked in the Kurupung area using 3.53SG density tracers when operating on river and recycle water.
- Tracer sizes of 8, 4 and 2mm will be used for the tests to determine efficiencies at different sizes.
- Jig feed water samples will be taken to determine the suspended solids for each test.
- Tracer tests will take from 1 to 2 days depending upon the jig operation using 10 to 20 tracers of each size.
- River water can contain a high percent of suspended solids from mine operations up river, testing will be verified by GGMC personnel.

Flocculant field tests

- A range of different types of flocculants will be tested to evaluate settling characteristics and ability to produce low suspended solids in mine water.
- Flocculants are inert synthetic long chain polymers which are used extensively in municipal water treatment facilities.
- 1/2 litre samples of jig effluent water will be taken and the different flocculants added to determine the settling rates and dosage requirements. This is usually termed ‘jar testing’.

APPENDIX 7.5

Demonstration schedule, Kurupung, March 6-9, 2002

DIAMOND RECOVERY TEST SCHEDULE

March 6 to 9, 2002
Kurupung Mining District

The test program will involve;
A) Jig diamond recovery efficiency tests using;
1) river, and
2) recycle water, 2 tests each.

B) Flocculant tests to determine suitable reagents which could be used to reduce the suspended solids in mine effluent water.

Wednesday March 6
Depart Georgetown, arrive Kurupung

Test 1 Jig/lavador test using 20 each of 8, 4 & 2mm 3.53SG density tracers.

Jig operation
- treating gravel using river water
- tracers added to the jig feed in the morning
- tracers removed and counted in the afternoon, 6 hours required between addition and removal

River and jig water samples to be taken during the test for % solids determination.

Flocculant testing will take place during the tracer tests to determine suitable reagents for water clarification.

Thursday March 7
Test 2 Repeat of Test 1 to confirm jig efficiency using river water.

Friday March 8
Test 3 Jig efficiency test using recycle/dirty water to determine the recovery efficiency with diamond density equivalent tracers.

Recycle/dirty and jig water samples to be taken during the test for % solids determination.

Saturday March 9
Test 4 Repeat of Test 3 to confirm jig recovery efficiency using recycle/dirty water.

Depart Kurupung, arrive Georgetown.

APPENDIX 7.6

Small scale diamond mining operations – photos

1. Mining – Lower Takuba River
2. Processing and diamond recovery
3. Flocculant tests – Upper Takuba River

SMALL SCALE DIAMOND MINING OPERATIONS

1) Mining - Lower Takuba River

a) Hydraulic mining alluvial gravel

b) Mine gravel pump

c) Mined area and gravel feed pipe to the Lavador

2) <u>Processing and diamond recovery</u>

a) The *lavador* or jig

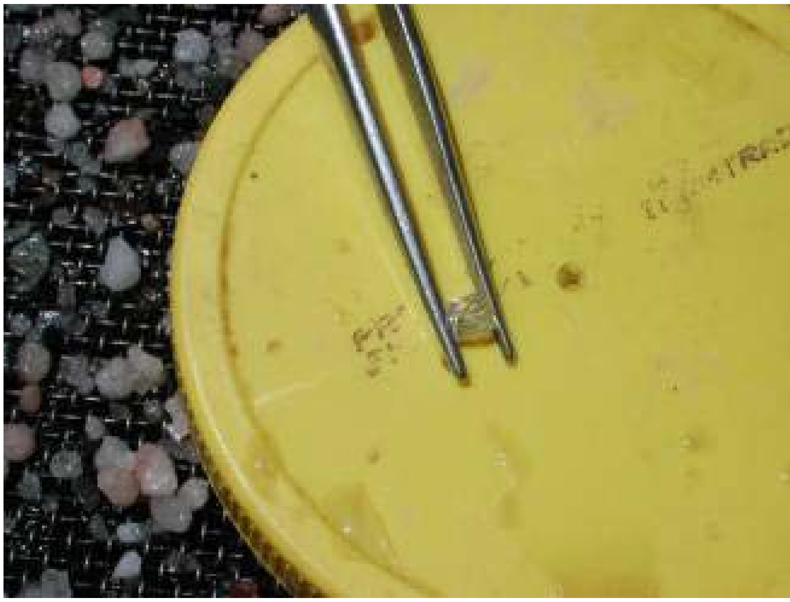
b) Top of the jig bed

c) Removing the jig bed

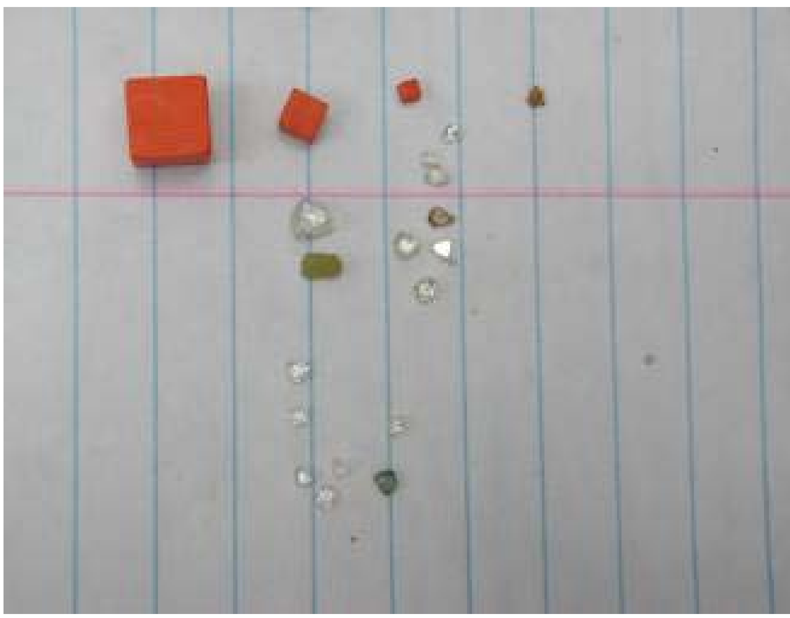
d) Jig concentrate removal

e) Jig top mesh replaced and ready for operation

f) Hand jigging the lavador concentrate



g) Recovered diamond



h) Diamonds and orange 8, 4 & 2mm tracers

3) Flocculant tests - Upper Takuba River

a) River water before flocculant addition

b) Solids flocculating

c) Settled solids

APPENDIX 7.7

Density tracer test price list and supplier information

BATEMAN MINERALS (PTY) LIMITED

REG. NO. 1967/001810/07
P O BOX 25937 EAST RAND 1462 REPUBLIC OF SOUTH AFRICA
FOUNDERS 4 BUILDING BATEMAN OFFICE COMPLEX BARTLETT ROAD
BEYERS PARK BOKSBURG
TEL. : +27 11 899 3265 FAX : +27 11 894 4701

THESE EPOXY RESIN TRACERS, MADE TO CLOSE TOLERANCE DENSITIES HAVE PROVED INVALUABLE IN THE FOLLOWING APPLICATIONS :-
DENSITY COLUMNS : MINERAL SEPARATION : BENEFICATION PROCESSES, AND ANY PROCESS RELYING ON DENSITY VARIATION

COLOURS DENOTE DENSITY (gm/cc)				CUBES	
HIGH DENSITY RANGE		LOW DENSITY RANGE		SIDES OF CUBES	PRICE EACH – US$
MUSTARD	4.20	LIGHT GREY	2.40	0,8mm	0.35
PEACH	4.10	GRASS GREEN	2.30	1,0mm	0.35
AVOCADO GRN	4.00	MAUVE	2.20	2,0mm	0.35
ORANGE	3.53	PINK	2.10	3,0mm	0.50
LIGHT PINK	3.40	TURQUOISE	2.00	4,0mm	0.50
BROWN	3.30	LIGHT BRN	1.90	5,0mm	0.50
CREAM	3.25	WHITE	1.80	6,0mm	0.95
CINNAMON	3.20	ORANGE	1.70	8,0mm	0.95
OLIVE GREEN	3.15	GREY	1.60	10,0mm	1.40
GREEN	3.10	YELLOW	1.50	12,0mm	3.30
BUFF	3.05	RED	1.40	16,0mm	9.10
BLUE	3.00	GREEN	1.30	18,0mm	13.50
LILAC	2.95	BLUE	1.20	20,0mm	15.50
YELLOW	2.90				
NAVY BLUE	2.85				
LIME GREEN	2.80				
SKY BLUE	2.75				
BLACK	2.70				
PURPLE	2.65				
CREAM	2.60				
APRICOT	2.55				
DARK PINK	2.50				

TOLERANCES : DENSITY ±0.03 (APPROX. 1%) DIMENSIONS ±0.1mm
TRACERS WITH DENSITY TOLERANCES OF ±0.01 CAN BE MADE TO ORDER AT A PREMIUM OF 50%

SPECIAL REQUIREMENTS : PRISMS. RHOMBOIDS. OTHER SIZES AND DENSITIES UP TO S.G. 4.00 CAN BE MADE ON REQUEST.
DETAILS ON APPLICATION.

ALL CUBES MADE TO ORDER. DELIVERY DEPENDENT OF QUANTITY. POST AND PACKING EXTRA.
PAYMENT 100% WITH ORDER.

PLEASE ADVISE METHOD OF TRANSPORT REQUIRED. AIR OR SURFACE MAIL

APPENDIX 7.8

Tracer test procedure

TRACER TEST PROCEDURE

Diamond density tracer tests for jig (lavador) operations.

The following steps can be followed to determine the possible recovery efficiency of a diamond jig or lavador. The diamond density tracer cubes will give an INDICATION only of the diamond recovery efficiency. The same density tracers can be used for jigs or HMS heavy medium cyclone operations.

1) Count out 20 ORANGE colour 3.53sg tracer cubes for each size range to be used.

    - A tracer test could comprise of 8mm, 4mm and 2mm cubes in one test or a combination of these, say 20 x 8mm and 20 x 2mm cubes or just 20 x 8mm cubes. The key is to know how many were introduced to the lavador or separating device under test.

2) Add the tracers a few at a time, say during 2 to 3 hours or over a full day of operation, to the suction of the pump feeding the lavador.

    - The tracers will be pumped to the lavador and as they are the same density as diamond, the tracer can be used to determine the indicated recovery efficiency and fine-tune the lavador operation.

3) Operate the lavador as normal.

    - Take note of the lavador operating conditions, if possible determine the following;

        i. gravel feedrate
        ii. water flowrate (pump speed, though this will be dictated by the line size to the lavador to prevent gravel settling in the line)
        iii. gravel type and size (amount of sand and large gravel)
        iv. pulse rate and stroke length

4) Recover the lavador concentrate as normal.

    - Recover the tracers in the same way as the diamonds. Separate and count the tracers in each size fraction. The number of orange 3.53sg tracers recovered is an INDICATION **only** of the possible diamond recovery efficiency.

5) Calculate the tracer recovery efficiencies.

- If 20 x 8mm tracers were added to the lavador feed and 20 were recovered, the recovery efficiency is 100%, i.e. there is a very low probability of a 8mm diamond being lost.
- If 20 x 4mm tracers were added to the lavador feed and 16 were recovered, the recovery efficiency is 80%, i.e. 20% of the 4mm sized diamonds might not be recovered.
- It is normal for a separating vessel to concentrate according to size, so the probability of diamond recovery is lower for small stones, just as for gold, the finer the gold the more difficult it is to recover.

6) Re-test and collect more tracer recovery efficiency data.

7) Modify the lavador (jig) operation.

- When several sets of data have been collected, try and vary the lavador feed conditions (one at a time) to see if the tracer recovery efficiency can be improved.

- Factors to vary could include;

  i. Reduce the solids feedrate i.e. the amount of gravel pumped to the lavador.
  ii. Maintain a steady feedrate, try and reduce the amount of surging from the pump to the lavador. Steady state operating conditions are crucial for good recoveries.
  iii. Reduce the flowrate, is the water flowrate too high for the lavador? This could mean a smaller pipe size to the lavador otherwise more line blockages will occur.
  iv. Vary the pulse rate and stroke.
  v. Reduce the feed top size, could the larger material be screened out of the feed? This would reduce the need for a high line velocity (to keep the line from blocking) and would also reduce the water flowrate to the lavador.

8) Repeat the tracer testing but make only one operating change at a time otherwise it will be difficult to determine which change had an effect.