APPENDIX II

STILFONTEIN GOLD MINING COMPANY LIMITED MINE OVERSEER'S DISCUSSION PERIODS

PROGRAMME

Early morning—Office
Afternoon —Normal routine
Subjects for discussion from 9 a.m. to 11 a.m. Weekly alternate, Wednesdays and Saturdays

Sequence	Subjects (1 hour each)	Discussion Group Leader
1.	(*a*) Introduction and the art of listening	Assistant Manager. Production
	(*b*) How you can assist the sec. department	Mine secretary
2.	(*c*) Leadership	Gen. manager
	(*d*) How you can assist the compound	Compound manager
3.	(*e*) Supervision	Assistant manager. Planning
	(*f*) How you can assist the eng. dept.	Res. engineer
4.	(*g*) Inducting a new employee	Personnel officer
	(*h*) Geology of Stilfontein with emphasis on faults	Geologist
5.	(*i*) Reprimands and planning a job	Assistant manager. production
	(*j*) How you can assist the survey dept.	Chief surveyor
6.	(*k*) Responsibility costing	Assistant manager, ~~planning~~
	(*l*) Waste to the mill	Assistant manager. planning
7.	(*m*) Settling grievances and personnel problems (Europeans)	Personnel officer
	(*n*) Accumulations and sampling dept. problems	Chief sampler
8.	(*o*) Safety in relation to production	Gen. manager
	(*p*) Mine ventilation problems	Vent. officer
9.	(*q*) Productivity	Assistant manager, planning
	(*r*) Alterations to mining regulations	Mine overseer, training
10.	(*s*) Labour control	Assistant manager, production
	(*t*) Crush and lamp houses	Native time office and group study dept.
11.	(*u*) The hospital and the mine	S.M. officer
	(*v*) How to popularize the mine amongst the Natives	Asst. P/O (African)
12.	(*w*) Settling grievances and problems—non-Europeans	Compound manager

MODIFICATION OF A DIAPHRAGM JIG TO TREAT LARGE TONNAGES OF DIAMOND BEARING KIMBERLITE

By **R. G. WEAVIND** (Member) and **D. F. C. McLACHLAN** (Visitor)

SYNOPSIS

Because the jigs at Premier treat —2mm. kimberlite at a very high feed rate it was found necessary to modify them to maintain an efficient minerals separation. The accuracy of the separation was deduced from the behaviour of radio-active diamond tracers in the jig.

INTRODUCTION

The Premier Mine jig plant treats some 160 t.p.h. of classified —2mm. feed. The plant comprises eight primary and two secondary diaphragm type jigs.

This high feed rate of 20 t.p.h. to each primary jig is considerably more than the jig was originally designed to handle and accordingly, the jig characteristics were studied in order to modify the operating variables to treat the large tonnage most effectively.

This was done by studying the primary jigs treating the normal production feed. A feature of the method of study was the use of radio-active diamond tracers to determine the behaviour of diamonds in the jigging process.

ESTIMATION OF JIG PERFORMANCE

Two methods were used to assess the efficiency of minerals separation in the jig viz. radio-active diamond tracers and the Tromp curve.

(i) *Radio-active diamond tracers*

Use of the radio-active tracer to test the efficiency of diamond concentrators was first reported by Adamson*. The behaviour of diamonds in the jig was studied by introducing a tracer diamond into the feed and following its path through the jig. The time of residence was also noted.

Each tracer was prepared by cementing a short length of radio-active cobalt wire into a 0.5 mm. hole drilled into a diamond of selected size. The specific gravity of the tracer stone was kept at 3.5 by counterbalancing the effects of the cobalt and the cement. The sizes of the two diamonds used in the tests were —9+10 and —10+14 mesh Tyler. The shape of the larger stone was octahedral but the smaller stone was relatively flat.

(ii) *Tromp curve*

The tromp curve needs no introduction to the coal dresser but its use in mineral dressing has been somewhat limited up to now. It is simply a graph of the percentage recovery of particles of one product e.g. the hutch product of the jig, plotted against

*Adamson, R. J. "Some Account of Diamond Winning Practices in Southern Africa", presidential address to the *S.A. Inst. of Min. & Met.*, August 1959.

the particle specific gravity; a specimen Tromp curve is given later in the paper. The curve therefore shows how efficiently the lighter mineral fractions were rejected from the jig and how efficiently the heavier minerals including the diamond were recovered in the hutch product.

The shape of the Tromp curve provides an estimate of the efficiency of mineral-separation and is defined by a single parameter, the Belugou imperfection coefficient B.

$$\text{where } B = \frac{\rho_{75}-\rho_{25}}{2\,(\rho_{50}-1)}$$

and where ρ_x is the s.g. of a particle of which the recovery to the hutch product was x per cent.

It will therefore be deduced from the above that $(\rho_{75}-\rho_{25})$ is the statisticians' interquartile range and that ρ_{50} is the effective density of separation in the jigging process. Tromp curve results for the beneficiation of coal and iron in the size range $-9+10$ mesh Tyler i.e. $-2+1$ mm. show how the imperfection coefficient reflects the accuracy of separation:

0.20 poor; 0.10 fair; 0.06 good; 0.02 excellent.

The advantages of the Tromp curve lie in the fact that a single parameter is sufficient to define the accuracy of separation, and that its value is broadly independent of the density composition of the feed and the concentration ratio in the jigging process. Perhaps the main objection to the Tromp curve is that it is influenced by the shape of the particles i.e. a flat particle may behave like a particle of lower s.g. This point has not been thoroughly investigated but it may be noted that the results showed that when the Tromp curve indicated a recovery of 87 per cent for $-10+14$ mesh kimberlite of density 3.5, the recovery of the flattish tracer diamond was 89 per cent.

Assessment of jig performance was, therefore, made by both the Tromp curve ~~and the radio-active tracers.~~ However, the tracers were used for most of the testing because they provided a more rapid estimate of the jig efficiency.

THE JIG CIRCUIT

Feed to the jig circuit at Premier comprises about 160 t.p.h. (dry weight) of a -9 mesh Tyler product from rake classifiers that nominally reject all -28 mesh material.

All jigs at Premier are the 24 by 36 in. "Denver duplex" mineral jigs. Eight primary jigs each receive about 20 t.p.h. new feed and the combined hutch products are distributed to two secondary jigs. Tailings from the primary jigs are rejected but all the secondary jig tailings are recycled to the feed of four of the primary jigs.

Concentrates from the secondary jigs are further concentrated over vibrating grease tables on which the diamonds are recovered.

DESCRIPTION OF THE STANDARD JIG

During the course of the investigation it was found necessary to modify the jig but the following is a description of the standard "Denver duplex" before being modified.

The duplex jig comprises two compartments, in series. The screen over each compartment is 24in. wide and 36in. long and is made of 3 mm. aperture wedge wire. Water is pulsed through the screens by two top driven diaphragms connected to a pivoted walking beam that is in turn driven by an eccentric. Adjustment of the eccentric allows stroke variation of 0 to $\frac{3}{4}$ in., and the speed is 290—300 strokes per minute. The eccentric shaft also drives a rotating water valve that limits water addition so as to reduce the intensity of the suction stroke. The bedding material is steel shot.

TEST PROCEDURE

The test procedure was generally to change each of the variables, one at a time, and to note the effect on the diamond recovery as determined by the radio-active tracer method. Of course, the diamond recovery was very dependent on the concentration ratio and whenever this ratio did show much change as a result of altering a variable, this was taken into account—if only empirically. Wider use of the Tromp curve would therefore have allowed a more elegant assessment of the results and a more rapid method of Tromp curve analysis is now being devised for use in any future test work.

Each of the jig variables was controlled as follows:

(i) The feed rate was normally held at about 20 t.p.h. through the *r.o.m.* control and most testing was carried out under these conditions.

(ii) No water was added to the feed—the moisture content of the feed was 25 per cent. Water addition to each hutch was controlled by valves and the combined water consumption to the two hutches was measured.

(iii) The bedding originally comprised steel shot but this was later replaced by alluvial gravels.

(iv) Stroke frequency was controlled by a variable speed drive.

(v) Stroke amplitude was varied up to a maximum of $\frac{3}{4}$ in.

The effects of the variables were mainly determined by using the smallest radio-active tracer viz. the $-10+14$ mesh flat shaped diamond. The period of residence of this diamond in the jig bed and its recovery from either the first or the second compartment were noted.

EFFECT OF THE VARIABLES ON THE JIG PERFORMANCE

Detailed experimental test results of the effect of the variables are not given but Table I does illustrate how the radio-active tracer diamond was used to assess the effect of some of the variables. It may be noted that the accuracy of the percentages given in the table is limited because only about thirty tracer additions were used in each test e.g. the table shows that under one particular set of conditions, the apparent recovery of the $-10+14$ mesh tracer was 100 per cent, yet it was later shown that under the same conditions, the tracer was recovered only 89 times after 100 additions. This therefore showed that although thirty tracer additions did give an indication of the recovery efficiency, a larger number were needed to give an accurate estimate. The question is clearly one of statistical probability.

Examination of the effect of the variables was further complicated by the fact that it was not always valid to assume the condition *ceteris paribus*. For instance, jig operators will readily appreciate that although a particular stroke frequency may give optimum results at one stroke length, a different stroke length may be required at some other frequency.

(i) *The feed*

An irregular feed to the jig was caused by the necessarily irregular discharge from the rake classifier and in fact, these surges tended to scour the jig bed away

TABLE I
SOME TEST RESULTS WITH THE RADIO-ACTIVE TRACER DIAMONDS

Feed rate (t.p.h.)	Rotary valve	Water flow (g.p.h.)	Bedding: Type	Bedding: Weight per jig (lb)	Stroke: Amplitude (in.)	Stroke: Frequency (c.p.m.)	Concentrate (per cent)	Diamonds reported in first hutch (per cent)	Per cent diamond recovery from both hutches: −9+10 mesh Tyler	Per cent diamond recovery from both hutches: 10–14 mesh Tyler
19·9	Yes	7,600	Steel shot	620	$\frac{5}{16}$	290—300	12·8	32	78	72
								30	—	
20·0	Yes	7,600	Alluvial gravels	300	$\frac{5}{16}$	290—300	10·5	50	100	92
								45	—	
20·0	No	11,500	Steel shot	460	$\frac{3}{8}$	290—300	12·9	72	92	84
								38	—	
20·1	No	9,500	Alluvial gravels	260	$\frac{1}{2}$	270	10·3	85	100	100
								80	—	

from the feed end. The difficulty was overcome simply by mounting a plate about 3 in. above the feed weir so that the feed piled up slightly behind this barrier and flowed smoothly through the gap. Fig. 1 shows how the barrier plate was located.

It was assumed that the optimum feed rate was 20 tons per hour and the jig variables were adjusted to handle this tonnage.

(ii) *Water flow*

The high feed rate necessitated a comparatively large amount of water in order to produce compaction and dilation of material in the jig bed. However, too much water caused turbulence and tended to sweep away the heavy minerals indiscriminately with the light. Valves were fitted to regulate the water to each hutch.

The optimum flow of water to the two hutches was determined to be 11,500 g.p.h. when a bed of steel shot was used and 9,500 g.p.h. with the bed of alluvial gravel.

The rotating water valve restricted the water flow to 7,600 g.p.h. and it was therefore found that the accuracy of separation in the jig was much better without the rotating water valve than with it. The fact that the rotating water valve reduced the intensity of the suction stroke was perhaps a disadvantage in itself. Williams* reports that the Denver jig operated better without the rotating water valve and Charbonnier†, in a theoretical analysis of jig action, draws the conclusion that it is mainly during the suction cycle that true gravity concentration takes place.

(iii) *Bedding*

Because the specific gravity of the diamond (3.5) and that of most of the associated kimberlite minerals (2.7) are much less than steel (7.2), the bed of steel shot was replaced with a bed of heavy alluvial gravels (3.2) from the Consolidated Diamond Mines of S.W.A. Limited. The gravel was sized in the range —10+6 mm. and 130 lb was used in each compartment to produce a depth of 2 to 3 in. Fig. 2 shows both the steel shot and the gravel bedding.

*Williams F. A., Author's reply to discussion of "Recovery of semi-heavy minerals in jigs". *Inst. of Min. and Met.*, Vol. 68, part 9, pp. 423-456.
†Charbonnier R. P., "A study of a simplified theory of gravity concentration in coal jigs". *Canadian Min. and Met. Bull.*, June 1959, pp. 385-388.

Fig. 1 Photograph showing divisions in jig screen compartments and feed distribution plate, as viewed from the tailings end

However, owing to the low s.g. of this bed, it tended to displace to the discharge end of the jig screen and to the side of the screen furthest from the diaphragm. This bed movement was successfully countered by dividing the screen compartment into 12 sections of 9 by 8 in., each section 4 to 5 in. deep. Fig. 1 shows these divisions, which were effected with strips of screen cloth having apertures $\frac{3}{4}$ in. by $\frac{3}{16}$ in.

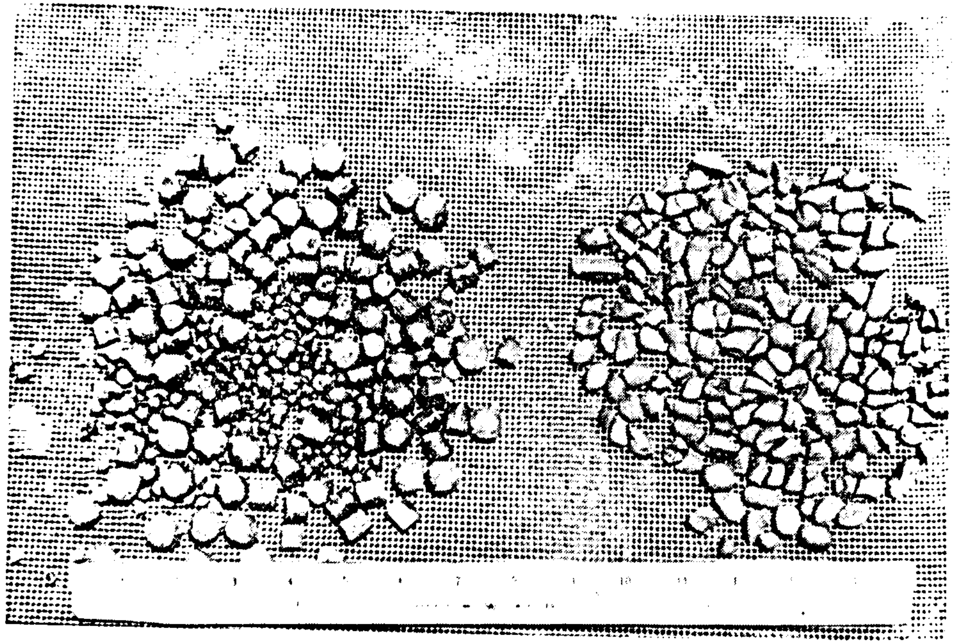

Fig.2 Steel shot (left), and gravel bedding

This bed of alluvial gravels resulted in a marked improvement in the accuracy of separation.

(iv) *Stroke frequency*

With the bed of alluvial gravels, a stroke frequency greater than 300 cycles per minute produced a permanent state of dilation of the bed, whilst a frequency less than 250 cycles per minute was not sufficient to dilate the bed evenly. The speed finally selected was 270 cycles per minute.

(v) *Stroke amplitude*

At 270 cycles per minute the optimum amplitude was found to be ½ in. When much less than this e.g. ¼ in., the bed tended to compact permanently whilst an amplitude up to ¾ in. caused excessive turbulence in the bed.

RESULT OF JIGGING AT 20 T.P.H.

The efficiency of the jig was determined under the following conditions:

(i) Feed rate, 20 t.p.h.
(ii) Water flow, 9,500 g.p.h. per compartment.
(iii) Bedding, 130 lb of —10 + 6 mm. alluvial gravels per compartment.
(iv) Stroke frequency, 270 cycles per minute.
(v) Stroke length, ½ in.

Before these modifications were made, the Tromp curve imperfection value for the concentration was 0.11 for —10 + 14 mesh particles but after the above conditions had been established, the imperfection value in the same size range was improved to 0.07.

The Tromp curve given in Fig. 3 for the separation under these modified operating conditions also showed that the recovery of —10 + 14 mesh particles of s.g. 3.5 was 87 per cent. This value was confirmed by adding the —10 + 14 mesh radio-active tracer diamond to the feed 100 times, when on 89 occasions it reported to the concentrates. It may be added that the octahedral shaped —9 + 10 mesh tracer reported to the concentrates 90 times out of 90.

CONCLUSIONS

Estimation of the result of a diamond concentration process is seldom conclusive simply because the diamond is very rare and because it is not amenable to chemical assay. Nevertheless, estimation of diamond recovery by the radio-active tracer method appears to be reliable. The Tromp curve procedure provides a complete picture of the behaviour of all the minerals present but it sufferes the disadvantages of being laborious to produce and of assuming that the diamond porosity and shape are the same as those of the average kimberlite mineral of density 3.5. Just how

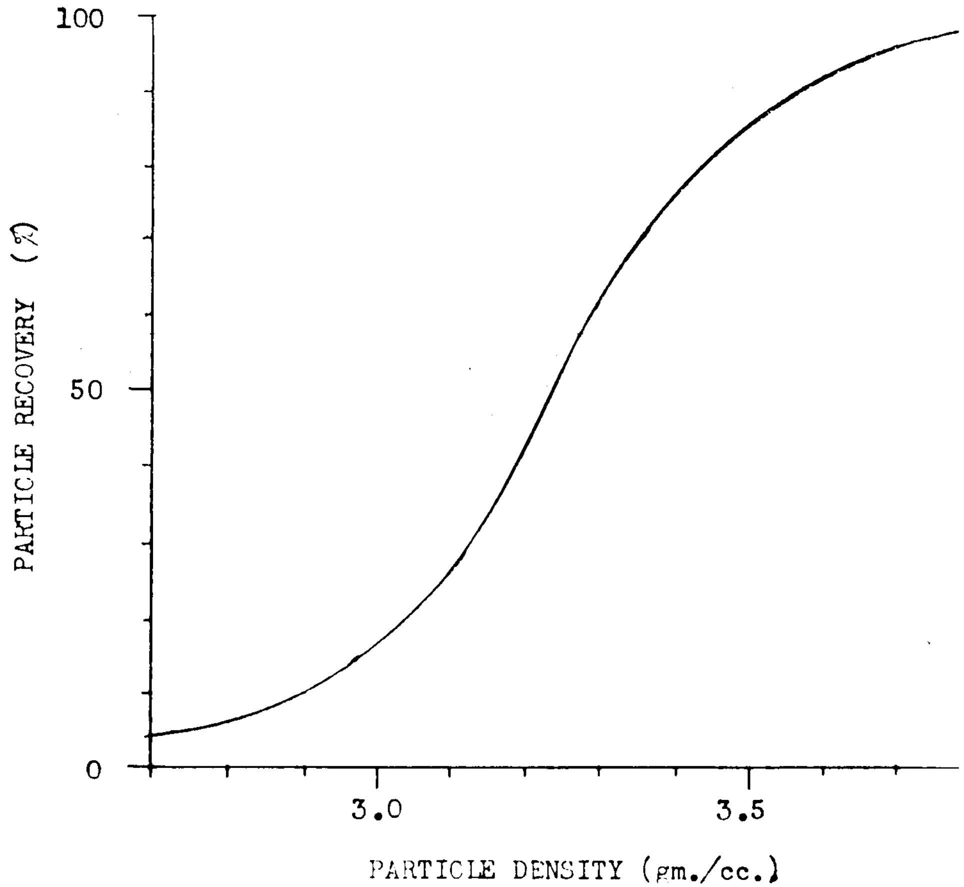

Fig. 3 – Tromp curve showing the accuracy of separation in the modified jig

valid these assumptions are, is a question that has not yet been studied in full, but the available results definitely indicate that the average kimberlite mineral of density 3.5 behaves similarly to a flattish diamond having the same mesh size.

The feed rate was a variable that could not be changed much without changing the number of operating jigs, and in modifying the jig to handle the large tonnage, the two most important alterations were to the jig bed and to the water flow. The quantity of water flow to each compartment was found to be critical and the test results pointed to the value of maintaining a strong suction stroke; it was for these reasons that the rotating water valve was discarded. The substitution of an alluvial gravel bed for the steel shot resulted perhaps, in the most pronounced improvement of the jig efficiency.

At 20 t.p.h. the improved jig efficiency resulted in a marked increase of diamond recovery with a diminution of the quantity of final concentrates, but it may be added that even under the improved operating conditions, this efficiency showed a pronounced decline at a feed rate much in excess of 20 t.p.h.

ON THE DEPARTURE OF ORE VALUE DISTRIBUTIONS FROM THE LOGNORMAL MODEL IN SOUTH AFRICAN GOLD MINES

By **D. G. Krige** (Member)

Published in the *Journal*, November, 1960

Contributions to Discussion

H. S. Sichel (Member): The lognormal law was introduced by the writer to ore valuation in 1947 because the logarithms of inch-dwt values appeared to be well represented by the normal frequency distribution. Subsequently Messrs Krige and Ross independently verified my findings. Later, overseas investigators also reported considerable success with this model. Once interest was aroused in statistical valuation methods, more and more data came to hand and deviations from the original model made their appearances on several occasions. In the absence of any other method we carried on with lognormal theory as the best possible approximation needed in the solution of practical problems.

Mr Krige, in his present paper, has made a valuable contribution to the subject by suggesting the addition of a constant a to observed inch-dwt values before switching into logarithms. By so doing the moderate negative skewness arising from the conventional log-transformation is largely eliminated and the existing knowledge of lognormal theory may still be used, as in the past, because the logarithms of inch-dwt plus a are normally distributed for most of the observations examined to-date.

Lest I be misunderstood in what I shall have to say later on, when reviewing critically Mr Krige's new proposal, I should like to state that I am wholeheartedly in favour of this method of transformation.

I have tried it out in several practical problems with which I was recently confronted and I am satisfied that the addition of constant a leads to better grade estimates and associated confidence limits than hitherto obtained with the conventional method.

Professor Kerrich has on many occasions stressed that the statistician is the conscience of the research worker. In carrying out this professional function of a conscience I may perhaps be forgiven if I offer a few searching remarks.

Inch-dwt values may run from zero to very large positive values but they obviously cannot be negative. If use is made of Mr Krige's transformation $y=log_e(z+a)$, where z denotes inch-dwt, the y variable terminates at $log_e a$ if the observed value is zero.

The normal distribution fitted to the y's, however, will extend to negative logarithms and when these are transformed back to the original scale the mathematical model will produce negative inch-dwt values which do not exist. Seen from this angle, the suggested new model is definitely incorrect whereas the old model did not suffer from this inconsistency. Mr Krige's histograms of the Merriespruit values are redrawn in Fig. 1 and 2 *without* breaking the abscissa scale as he has done.