In his paper the author makes a very important point when he advocates the use of two-cell jigs with a long stroke. The only circumstances where the use of four-cell or more jigs can be justified is in the treatment of ground which only contains very fine particles of heavy mineral. In this one case there is no middle size range of heavy mineral to lose despite continued jigging. The fine heavy mineral will continue to be recovered in successive cells of the jig in the form of a low-grade concentrate in which the finer size fractions are considerably enriched. The coarse barren material can then be screened from the concentrate and rejected while the enriched finer fraction can be tabled economically.

Recovery of Semi-Heavy Minerals in Jigs

F. A. WILLIAMS, B.Sc., MEMBER

Further contributed remarks on paper published in February, 1959, pp. 161–75* (Transactions, *vol. 68, 1958–59*)

Mr. J. C. Allan: Describing the remarkable efficiency of jigs to recover semi-heavy minerals, the author was, however, referring to clean minerals and the lightest mineral was topaz with a specific gravity of 3·5. With quartz at 2·7 and wolfram at 7·0 sp. gr., an average of 3·5 would be the equivalent of mixed particles carrying 28·4 per cent WO_3.

In practice, of course, comminution is carried out to the extent that will produce an effective liberation of the valuable mineral from the gangue. On the other hand, when treating friable minerals, such as wolframite and cassiterite it must not be carried too far, to avoid sliming. While a considerable proportion of the valuable mineral may be free, therefore, in order to obtain a high extraction of the 'chats', or mixed particles, the specific gravity differential splitting concentrates and tailings must be brought down to very low figures.

In order to study the incidence of values in the tailings at Panasqueira a 1-ton sample was collected over several days and then carefully hand-picked into the following categories (for this purpose sulphides, where present, were considered as mineral): (i) quartz apparently free from mineral; (ii) schist apparently free from mineral; (iii) mixed mineral quartz grains; (iv) schist particles showing mineral, and (v) undifferentiated fines. These five fractions were sampled and assayed with the results given in Table A. From this it will be seen that 83·03 per cent of the values in the tailings were contained in 10·00 per cent of the total weight. Unfortunately a sizing distribution of the mineralized fragments was not made, but, in view of the lower extractions shown in the coarser sizes in Table D and the limitations of hand-picking, it is probable that the bulk of this 10 per cent was in the coarser range.

TABLE A

Product	Wt. distribution %	Assay % WO_3	Assay % Sn	Assay % Units WO_3	% total WO_3 values
i	30	0·004	0·002	0·0012	83·3
ii	57·7	0·004	0·010	0·002308	
iii	10·00	0·324	0·040	0·032400	
iv	1·00	0·074	0·010	0·00074	
v	1·3	0·174		0·00226	
	100·00			0·0389	

With quartz at a sp. gr. of 2·7 and wolfram and cassiterite at 7, a mixed mineral with an assay of 0·324 per cent WO_3 and 0·040 per cent Sn will have a sp. gr. of 2·7081, a differential over quartz insufficient to allow the particles to sink in the bed.

Clearly this is the average differential of all the particles picked out, but it is reasonable to suppose that the jig under these conditions was operating with a specific gravity differential between concentrates and tailings of not over 0·02. A mixed particle of quartz and wolfram with this specific gravity differential over clean quartz would contain 0·886 per cent WO_3 by weight and 0·451 per cent by volume. This situation is completely different from that reported by Mr. Williams, where the lightest clean mineral he studied was topaz with sp. gr. 3·5.

The circular jig admittedly avoids the inherent defects of the conventional rectangular machine, but it is suggested that the results reported by the author, working, it must again be emphasized, on clean mineral, only go to show how easy it is to obtain some sort of concentration by jigging. High extraction on a comminuted ore requires a much narrower gravity differential between concentrate and tailings and it is very probable that a circular jig with its manifest advantages would give a much higher recuperation of semi-heavy minerals over the whole size range of a deslimed feed than anything possible with a conventional rectangular jig. An 8-ft circular jig has seven times the length of tailings weir of a 42-in four-compartment rectangular jig and, while the feed to the latter has about twice the travel in the jig, when treating clean mineral the extra length only serves as a 'policeman' to endeavour to catch material that should have been caught in the first two cells. Clean heavy mineral of the larger fraction can certainly be caught, even when the jig is heavily overloaded, but without reasonably accurate tailing samples no real metallurgical control is possible.

---

*The author has already replied to discussion on his paper (*Trans.* vol. 68, pp. 448–56).

TABLE B.—*Buddle Jig Tests*

(Feed direct from bin, i.e. all − 6 × 9 mm product)

Feed to Buddle Jig 41 tons /h − 6 × 9 mm	Screen Analysis, %	Weight tons /h	Assay			Units per Hour		
			% WO_3	% Sn	Total % Metal	WO_3	Sn	Total Metal
+ 5 × 7 mm	13·4	5·49	0·06	0·10	0·16	0·33	0·55	0·88
− 5 × 7 + 3 × 5 mm	23·1	9·47	0·27	0·14	0·41	2·56	1·32	3·88
− 3 × 5 + 1½ mm	28·6	11·73	0·37	0·17	0·54	4·34	1·99	6·33
− 1½ mm + 60 mesh	23·4	9·50	1·03	0·34	1·37	9·88	3·26	13·14
− 60 + 100 mesh	2·9	1·19	1·14	0·44	1·58	1·36	0·52	1·88
− 100 + 200 mesh	2·9	1·19	1·16	0·48	1·64	1·38	0·57	1·95
− 200 + 300 mesh	1·0	0·41	0·91	0·35	1·26	0·37	0·14	0·51
− 300 mesh	4·7	1·93	0·26	0·09	0·35	0·50	0·17	0·67
	100·0	41·00	0·50	0·21	0·71	20·72	8·52	29·24
Check sample of above	100·0		0·46	0·20	0·66	18·86	8·20	27·06
Buddle Jig Concentrate 11 tons /h								
+ 5 × 7 mm	2·3	0·25	1·12	1·46	2·58	0·28	0·37	0·65
− 5 × 7 + 3 × 5 mm	13·3	1·46	1·60	0·71	2·31	2·34	1·03	3·37
− 3 × 5 + 1½ mm	28·8	3·17	1·30	0·59	1·89	4·12	1·87	5·99
− 1½ mm + 60 mesh	40·2	4·42	2·08	0·73	2·81	9·19	3·23	12·42
− 60 + 100 mesh	7·1	0·78	1·60	0·64	2·24	1·25	0·50	1·75
− 100 + 200 mesh	5·4	0·60	2·15	0·94	3·09	1·29	0·56	1·85
− 200 + 300 mesh	1·1	0·12	3·06	1·06	4·12	0·37	0·13	0·50
− 300 mesh	1·8	0·20	0·77	0·23	1·00	0·15	0·05	0·20
	100·0	11·00	1·73	0·70	2·43	18·99	7·74	26·73
Check sample of above	100·0		1·70	0·68	2·38	18·70	7·48	26·18
Buddle Jig Tailings 30 tons /h								
+ 5 × 7 mm	12·8	3·84	0·008	0·025	0·033	0·03	0·10	0·13
− 5 × 7 + 3 × 5 mm	34·6	10·38	0·014	0·020	0·034	0·14	0·21	0·35
− 3 × 5 + 1½ mm	28·6	8·58	0·014	0·015	0·029	0·12	0·13	0·25
− 1½ mm + 60 mesh	14·4	4·32	0·010	0·010	0·020	0·04	0·04	0·08
− 60 + 100 mesh	1·3	0·39	0·012	0·020	0·032	—	0·01	0·01
+ 100 + 200 mesh	1·7	0·51	0·030	0·025	0·055	0·02	0·01	0·03
− 200 + 300 mesh	1·0	0·30	0·094	0·065	0·159	0·03	0·02	0·05
− 300 mesh	5·6	1·68	0·290	0·075	0·365	0·49	0·12	0·61
	100·0	30·00	0·029	0·021	0·050	0·87	0·64	1·51
Check sample of above	100·0		0·028	0·025	0·053	0·84	0·75	1·59

TABLE C.—*Buddle Jig Test (First Run)*

Duplex Classifier Sand Product, 36 tons /h set for 60 mesh Classification	Screen Analysis, %	Weight tons /h	Assay			Units per Hour		
			% WO_3	% Sn	Total, % Metal	WO_3	Sn	Total Metal
+ 5 × 7 mm	5·1	1·84	0·10	0·05	0·15	0·18	0·09	0·27
+ 3 × 5 − 5 × 7 mm	31·2	11·23	0·11	0·07	0·18	1·23	0·79	2·02
+ 14 mesh − 3 × 5 mm	34·7	12·49	0·33	0·16	0·49	4·12	2·00	6·12
+ 60 − 14 mesh	19·8	7·13	0·84	0·35	1·19	5·99	2·50	8·49
+ 100 − 60 mesh	2·6	0·94	1·23	0·53	1·76	1·16	0·50	1·66
+ 200 − 100 mesh	1·6	0·57	1·22	0·49	1·71	0·71	0·28	0·99
+ 300 − 200 mesh	0·9	0·32	0·83	0·30	1·13	0·27	0·10	0·37
− 300 mesh	4·1	1·48	0·28	0·07	0·35	0·41	0·10	0·51
	100·0	36·00	0·39	0·18	0·57	14·07	6·36	20·43
Buddle Jig Concentrate 9·4 tons /h								
+ 5 × 7 mm	0·7	0·07	0·75	1·20	1·95	0·05	0·08	0·14
+ 3 × 5 − 5 × 7 mm	17·3	1·63	2·16	0·65	2·81	3·52	1·06	4·58
+ 14 mesh − 3 × 5 mm	42·5	4·00	1·62	0·40	2·02	6·48	1·60	8·08
+ 60 − 14 mesh	31·7	2·98	1·41	0·60	2·01	4·20	1·79	5·99
+ 100 − 60 mesh	3·1	0·29	1·30	0·80	2·10	0·38	0·23	0·61
+ 200 − 100 mesh	3·2	0·30	1·84	0·85	2·69	0·55	0·26	0·81
+ 300 − 200 mesh	0·6	0·06	2·06	0·80	2·86	0·12	0·05	0·17
− 300 mesh	0·9	0·08	1·22	0·35	1·57	0·10	0·03	0·13
	100·0	9·40	1·64	0·54	2·18	15·40	5·10	20·51
Buddle Jig Tailings 26·6 tons /h								
+ 5 × 7 mm	12·1	3·22	0·014	0·030	0·044	0·045	0·097	0·142
+ 3 × 5 − 5 × 7 mm	39·0	10·37	0·014	0·015	0·029	0·145	0·156	0·301
+ 14 mesh − 3 × 5 mm	37·4	9·95	0·008	0·010	0·018	0·080	0·100	0·180
+ 60 − 14 mesh	8·6	2·29	0·010	0·015	0·025	0·023	0·034	0·057
+ 100 − 60 mesh	0·5	0·13	0·046	0·020	0·066	0·006	0·003	0·009
+ 200 − 100 mesh	0·5	0·13	0·028	0·025	0·053	0·004	0·003	0·007
+ 300 − 200 mesh	0·3	0·08	0·046	0·035	0·081	0·004	0·003	0·007
− 300 mesh	1·6	0·43	0·200	0·080	0·280	0·086	0·034	0·120
	100·0	26·60	0·015	0·016	0·031	0·393	0·430	0·823

TABLE D

Size of fraction	Units per hour						Extraction, %			
	Heads		Concentrates		Concentrates + Tailings		Concentrates / Heads		Concentrates + Tailings	
	WO_3	Sn	WO_3	Sn	WO_3	Sn	WO_3	Sn	WO_3	Sn
+ 5 × 7 mm	0·33	0·55	0·28	0·37	0·31	0·47	84·85	67·27	90·32	78·72
- 5 × 7 + 3 × 5 mm	2·56	1·32	2·34	1·03	2·48	1·24	91·40	78·03	94·35	83·06
- 3 × 5 + 1·5 mm	4·34	1·99	4·12	1·87	4·24	2·00	94·93	93·97	97·17	93·50
- 1·5 mm + 60 mesh	9·88	3·26	9·19	3·23	9·23	3·27	93·02	99·08	99·57	98·78
- 60 + 100 mesh	1·36	0·52	1·25	0·50	1·25	0·51	91·91	96·15	100·00	98·04
- 100 + 200 mesh	1·38	0·57	1·29	0·56	1·31	0·57	93·48	98·25	98·47	98·25
- 200 + 300 mesh	0·37	0·14	0·37	0·13	0·40	0·15	100·00	92·86	92·50	86·67
- 300 mesh	0·50	0·17	0·15	0·05	0·64	0·17	30·00	29·41	23·44	29·41
Totals	20·72	8·52	18·99	7·74	19·86	8·38	91·65	90·85	95·62	92·36
Check samples	18·86	8·20	18·70	7·48	19·54	8·23	99·15	91·22	95·70	90·89

TABLE E

Size of fraction	Units per hour						Extraction, %			
	Heads		Concentrates + Tailings		Concentrates		Concentrates / Heads		Concentrates Heads + Tailings	
	WO_3	Sn	WO_3	Sn	WO_3	Sn	WO_3	Sn	WO_3	Sn
+ 5 × 7 mm	0·18	0·09	0·095	0·105	0·05	0·08	27·78	88·89	52·63	76·19
+ 3 × 5 − 5 × 7 mm	1·23	0·79	3·665	1·216	3·52	1·06	286·18	134·18	96·04	87·17
+ 14 mesh − 3 × 5 mm	4·12	2·00	6·560	1·700	6·48	1·60	157·28	80·00	99·45	94·12
+ 60 − 14 mesh	5·99	2·50	4·223	1·824	4·20	1·79	70·12	71·60	99·45	98·13
+ 100 − 60 mesh	1·16	0·50	0·386	0·233	0·38	0·23	32·76	46·00	98·44	98·71
+ 200 − 100 mesh	0·71	0·28	0·554	0·263	0·55	0·26	77·46	92·86	99·28	98·86
+ 300 − 200 mesh	0·27	0·10	0·124	0·053	0·12	0·05	44·44	50·00	96·77	78·12
− 300 mesh	0·41	0·10	0·186	0·064	0·10	0·03	24·39	30·00	80·64	46·82
Totals	14·07	6·36	15·793	5·458	15·40	5·10	105·45	80·19	97·51	93·44

In mines treating ore that requires comminution to liberate the mineral, the normal practice is for lower feed rates than any of those indicated as being common practice when treating alluvials. In conventional rectangular jigs it is only when the feed rate is reduced and careful jigging is done in an effort to reduce the disturbance in the cells to a minimum that it is possible to catch the chats with small specific gravity differential. Feed to such jigs tends to be closely classified and the stroke length graded to the particle size. In opening the discussion (p. 423) Mr. Ackroyd confirmed this by pointing out that when the feed rate was cut down the recovery of columbite increased and there was a much better recovery of fine mineral.

With the circular jig large quantities of water are not required and the dilation of the bed is effected by the much sounder mechanical principle of lifting the material with the moving tray and dilating it by the rapid withdrawal of support. This, together with the short stroke, makes for a minimum of harmful disturbance. Under these conditions the mechanical effects reported by Kirchberg and Hentschel will have less importance and settlement will take place according to specific gravity, regardless of grain size.

The details of test work carried out on the performance of the jig are shown in Tables B and C. In practice it has been found to be extremely difficult to get coherent results from head sampling. With the extremes of high-grade mineral and barren gangue in a long-range product it is necessary to take such a large proportion of the material to be sampled, and reduce it to a more homogeneous size in an attempt to get consistent results, that it is not a practicable proposition. However, in Tables D and E the extractions are shown calculated both against the head sample and against the sum of the concentrates and tailings. The assays of the concentrates can, of course, be correlated with production and the low values in the tailings, probably all as mixed particles, make the reliable sampling of this product a more feasible proposition.

To illustrate the point Tables D and E show extraction calculated on both bases. Table B shows the results of a test carried out on mill feed direct from the bin, whereas Table C refers to a test on classifier rake product. The −60 mesh in Table C is, of course, due to the difficulty of getting complete elimination of fine material in a rake classifier. It is suggested that these tables demonstrate the efficiency of the jig in obtaining a high extraction and low-grade tailings over a wide range of sizes. It is just possible that the values shown in Table D for the recovery on the −60 +100-mesh fraction on the concentrates/heads calculation may to some extent be due to the interesting theory put forward by Harris* but it would require much more detailed work before the complicated flowsheet he suggests would appear to be justified.

All the rectangular jigs are but mechanical improvements of a design of great antiquity and all strive in differing ways to improve the efficiency of converting piston movement into rising current. None, however, attempt to solve the problem of the adjustment of the treatment of the material in the jig to suit particles of diminishing gravity differential. On the contrary, in the conventional rectangular jigs the concentrating conditions become progressively less favourable. It is suggested, therefore, that instead of a more complicated flowsheet there is an urgent need for a high-capacity gravity concentrating unit that breaks away from tradition and provides adequate treatment as the material being jigged is progressively impoverished.

---

*Harris, J. H. Serial gravity concentration: a new tool in mineral processing. *Trans. Instn Min. Metall., Lond.*, **69**, 1959–60 (*Bull. Instn Min. Metall., Lond.*, 637, Dec. 1959), 85–94.

Removal of the Coarser Solids from Underground Water at the Bancroft Mine, Northern Rhodesia, by Hydraulic Cyclones

D. F. KELSALL, M.A., MEMBER, and
J. A. HOLMES, B.Sc., A.M.I.Chem.E., ASSOCIATE MEMBER

Authors' reply to discussion on paper published in September, 1959* (Transactions, *vol. 68, 1958–59*), *pp. 549–553*

Mr. J. A. Holmes: Both Mr. Kelsall and I express our appreciation to the contributors to the discussion. Our special thanks are due to Mr. Noakes for kindly undertaking the presentation on our behalf.

Before replying specifically to the various points raised, I feel it is necessary to make one or two general observations on the scope and objects of the work which formed the basis of the paper.

At the time the project was initiated, the Bancroft management was involved in heavy expenditure for pump maintenance. They had already taken the decision to suspend installation of extra settlers which had been planned in order that test work to prove or disprove the applicability of cyclones could be conducted. Time was therefore of great importance. In consultation with Bancroft engineers when the quoted results were obtained, it was agreed that further work would not be justifiable, having regard to the minor improvements which could be expected, and that design and installation should proceed as quickly as possible. The whole period of test work from the first tests with the conventional 24-in cyclone to the final recommendation was four weeks, which included periods spent in fabrication and erection of the 3-stage unit.

It should be remembered that the paper referred to the test work which led to the installation. As noted, the tests were conducted on the surface on water which had already passed through the underground pumps.

---

*pp. 122-34.