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McGraw Hill encyclopedia of science and technology: an international reference work in 15 volumes including an index. (1960.) R Q Ref. 503.

Aston, John Geldart *and* James John Fritz. Thermodynamics and statistical thermodynamics. (1959.) R 536.7.

Kaye, Joseph *and* John A. Welsh, *eds*. Direct conversion of heat to electricity, *etc*. (1960.) R 537.65.

Smit, Jan *and* Henricus Petrus Johannes Wijn. Ferrites: physical properties of ferrimagnetic oxides in relation to their technical applications . . . (tr. by G. E. Luton). (Philips' technical library.) (1959.) R 538.22.

Wilson, Allen C. Industrial thermal insulation: materials, application methods, specifications. (1959.) R 536.2.

Fuchs, Nikolai Albertovich. Evaporation and droplet growth in gaseous media; tr. . . . by J. M. Pratt; ed. by R. S. Bradley. (1959.) R 541.3452.

Badgley, Peter C. . . . Structural methods for the exploration geologist and a series of problems for structural geology students. (Harper's geoscience series.) (1959.) R Q 551.8.

Bishop, Margaret S. Subsurface mapping. (1960.) R 551.7.

Chapman, Sydney. IGY: year of discovery: the story of the International geophysical year. (1959.) R Q 551.

Garrels, Robert Minard. Mineral equilibria at low temperature and pressure. (Harper's geoscience series.) (1960.) R 551.94.

Institution of mining and metallurgy *and* United Kingdom metal mining association. The future of non-ferrous mining in Great Britain and Ireland: a symposium . . . held on 23rd and 24th September, 1958, *etc*. (1959.) R553.0942 (Store).

Nalivkin, D. Y. The geology of the U.S.S.R. . . . including a 1:7,500,000 scale geological map of the U.S.S.R. in full colour . . . tr. from the Russian by S. I. Tomkeieff; tr. ed. (by) J. E. Richy. (International series of monographs on earth sciences, v. 8). (1960.) R 554.7.

Runcorn, Stanley Keith, *ed*. Methods and techniques in geophysics. (1960.) R 551.

Scaioni, E. . . . Minerals and rocks; (text) by H. W. Ball; photographs by Scaiono. (Splendour in nature.) (1959.) R Q 549.

American society of mechanical engineers. A re . of available information on corrosion and der coal- and oil-fired boilers and gas turbin . (1959.) R Q 621.56.

Andersen, Svend Aage. Automatic refrige . (1959.) R 621.56.

Cement and concrete association. Proceedin . symposium on the strength of concrete stru . London, May 1956 . . . editor Ralph P. Ar . (1958.) R 620.137.

Marter, Donald H. Thermodynamics and the . engine, *etc*. (1960.) R 621.101.

Spruth, Fritz. Steel roadway supports: a pra . handbook . . . English translation by the Na . coal board translation section. (Glückauf r . handbooks, v. 2). (1960.) R 622.28.

Stoeker, Wilbert Frederick. Refrigeration and . conditioning. (McGraw-Hill series in mecha . engineering). (1958.) R 621.56.

American institute of mining and metallurg . engineers. Metallurgical society. Conferences, . Reactive metals: proceedings of the third an . conference . . . Buffalo, New York, 27-29 May, 1 . ed. by W. R. Clough. (1959.) R 669 (Store).

American institute of mining and metallurg . engineers. Metallurgical society. Conferences, . Quality requirements of super-duty steels: proce . ings of a technical conference . . . Pittsburgh 5-6 May, 1958; ed. by R. W. Lindsay. (19 . R 669.1 (Store).

American institute of mining and metallurg . engineers. Metallurgical society. Conferences, . Physical metallurgy of stress corrosion fracture. by Thor N. Rhodin: a symposium . . .Pittsburgh 2-3 April, 1959. (1959.) R 620.1122 (Store.)

Angus, Harold T. Physical and engineering p . perties of cast iron: a data book for engineers . designers. (1960.) R669.11.

Dożinel, Charles M. . . .Modern methods of an . of copper and its alloys; English tr. by George . Andraso. (1960.) R 546.56.

Schwarzkopf, Paul *and* Richard Kieffer. Ceme . carbides, *etc*. (1960.) R 669.73.

Scott, F. H. The physical metallurgy of rol . (1959.) R 671.

Dimock, Marshall Edward. Administrative v . ity: the conflict with bureaucracy. (1960.) R 658.

McFarland, Dalton Edward. Management p . ciples and practices. (1958.) R 658.

Burton, Alfred Joseph *and* Ronald Gerald M . Electronic computers and their business applicati . etc. (1960.) R 651.264.

Hersee, Edward Henry William. A simple appr . to electronic computers. (1960.) R 510.8.

Ivall, Thomas Edward, *ed*. Electronic comp . principles and applications (2nd ed.) 1960.) R671 .

THE ROLE OF JIGS IN MODERN ORE DRESSING

By **F. A. Williams, B.Sc., M.I.M.M.** (Visitor)

SYNOPSIS

The paper reviews progress in the design, performance and applications of jigs and emphasizes the value of the exchange of information between mining industries processing different types of incoherent and comminuted ores.

The evolution of the design of modern jigs in the alluvial tin and gold mining industries is outlined and attention is drawn to their suitability for use in mills processing comminuted ores.

Detailed figures are given for mineral recovery through the screen in jigs in the specific gravity range 7·0 to 3·5 and mesh range 16 to 300. The influence of the specific gravity of the ragging on the recovery of coarse sizes is illustrated. The physical methods of sample analysis used to obtain these figures are described and discussed.

Examples are given of the increasing use of modern jigs in the processing of both incoherent and comminuted ores either as the sole means of mineral recovery or in conjunction with cyanidation, flotation, sink-float and tabling.

The paper concludes with a review of recent developments in the dressing of jig concentrates utilizing screen sizing on nylon mesh, electrostatic, high tension and magnetic separation and dry gravity concentration.

INTRODUCTION

The jig is the oldest mechanical device for recovering heavy minerals from a lighter gangue. In the hard ore mining industry the invention of the Wilfley table in 1893 diverted attention from developing the full potentialities of jigging through the screen for the recovery of finer particles of heavy and semi-heavy minerals and intergrown grains. After World War I the spectacular success of flotation for recovering minerals of fine size tended to perpetuate this neglect of the jig by the hard ore mining industry. Flotation was successfully applied to an ever-increasing number of minerals with the notable exception of cassiterite. Flotation became the popular mineral processing study at technical universities, schools of mines and ore testing research laboratories. A whole generation of mineral processing engineers grew up with their attention centred on flotation or cyanidation. Only a few gave much thought to the scope for improving and applying gravity concentration until the successful development of the sink and float process with heavy media in suspension.

The story of how the development of a new era in mineral recovery through the screen in jigs was initiated in Malaya shortly after World War I by J. F. Newson, one time Head of the Mining School of Stanford University California, U.S.A., has been related by Cleaveland and by Hughes in the discussion of a paper by the author on the recovery of fine cassiterite[1]. With the assistance of two experts from the hard ore mining field at Joplin, Missouri, Newson installed Harz type jigs on all the alluvial tin bucket dredges of Yukon Gold Co., Ltd., Malaya. Within a few years most of the bucket dredges in Malaya were equipped with jigs. The alluvial gold mining industry throughout the world similarly replaced sluice boxes by jigs on their bucket dredges. In this new and stimulating environment the design of jigs was progressively improved.

In recent years the use of hydrocyclones for removing primary slime from jig feeds has extended mineral recovery in jigs to much finer particle sizes. The use of the hydrocyclone and jig combination in Nigeria, first for concentrating intensely decomposed columbite-bearing granite and later to replace sluice-boxes in alluvial mining, stimulated the development of physical methods of sample analysis. These analyses yielded jig performance data in terms of the recovery of heavy and semi-heavy minerals over a wide range of particle sizes. These performance data can be used to estimate recoveries to be expected from other types of ore.

Concurrently machines of improved design for dry screening, electrostatic, high tension and magnetic separation and dry gravity concentration became available in the market. The difficulties encountered in dressing jig concentrates in Nigeria and the value of by-product minerals led to the installation of such equipment and stimulated research on how to use it to get good results.

Now, nearly 30 years after jigs were first introduced in Malaya, the alluvial mining industry can repay its debt to the hard-ore mining industry by handing back a jig of much better design, with a wealth of technical data on how to use it to better advantage and how to separate economic minerals from the resultant concentrates.

PART I

DESIGN

Prior to World War I jigs were of rather crude design. The introduction of jigs to replace sluice boxes on bucket dredges in Malaya in the early 1920's placed a high premium on producing new designs to occupy less space and to give better running time at less cost. The first jigs to be installed in bucket dredges were of the Harz type, then still in use in hard ore mills for sulphide ores, and shown diagrammatically in Fig. 1. The first major improvement effected was the elimination of the hydraulic compartment by the introduction of vertical diaphragm jigs as shown by Fig. 2. This

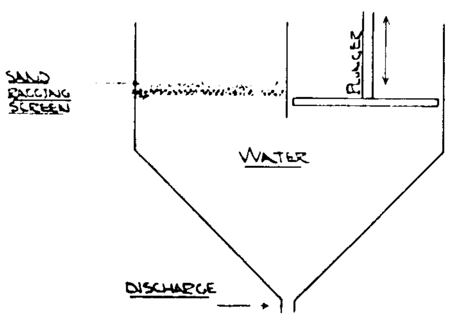

Fig. 1—Harz-type jig

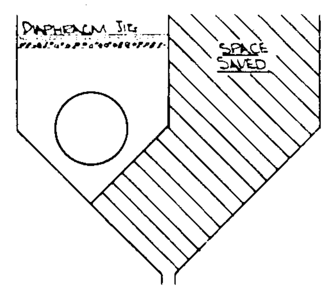

Fig. 2—Comparison of Harz and diaphragm type jigs

saving in lateral space made possible the provision of about twice the effective jigging area on the same hull. Two early types of diaphragm jig were the Ruoss and the

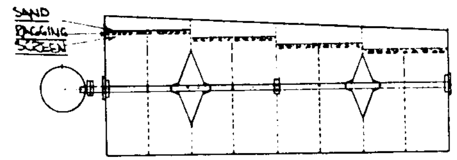

Fig. 3—Ruoss jig

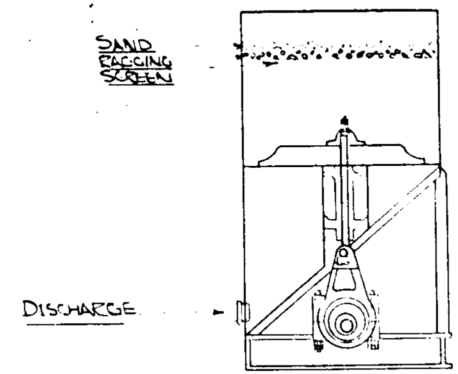

Fig. 4—Bendelari jig

Bendelari shown diagrammatically in Figs. 3 and 4. A major disadvantage of both these types of jig was the difficulty of access to the diaphragms and shaft fittings for maintenance and repair. The next improvement in design was the Pan-American jig shown diagrammatically in Fig. 5. In this jig all the moving parts were external and readily accessible. But it still had two major disadvantages. The drive and the moving lower parts of the hutches took up extra headroom and grit could gain access to the bearings which in consequence wore out rather rapidly. A further improvement in design was the Yuba jig shown diagrammatically in Fig. 6. It has all the advantages

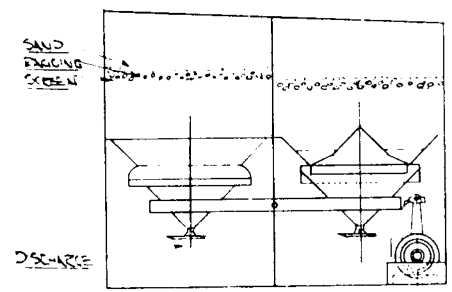

Fig. 5—Pan American jigs

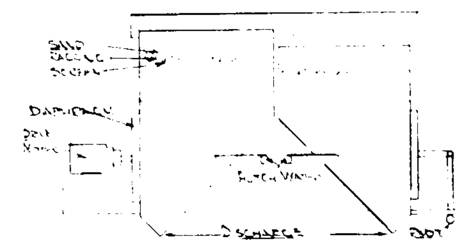

Fig. 6—Yuba jigs

and none of the disadvantages of the Pan-American type. In the Yuba jig the diaphragms are also external and furthermore they can be fitted to either the side or the end of the hutch. They are pulsated by a totally enclosed lubricated mechanism. The cells can be assembled in a variety of arrangements, as shown in Fig. 7 to make maximum use of available space and to give the length of flowline required.

The largest size of Yuba jig has cells 42 in. by 42 in. This is the size most commonly used but two smaller sizes 33in. by 33 in. and 24 in. by 24 in. are also on the market and can be assembled in any of the arrangements shown in Fig. 7. These smaller jigs require

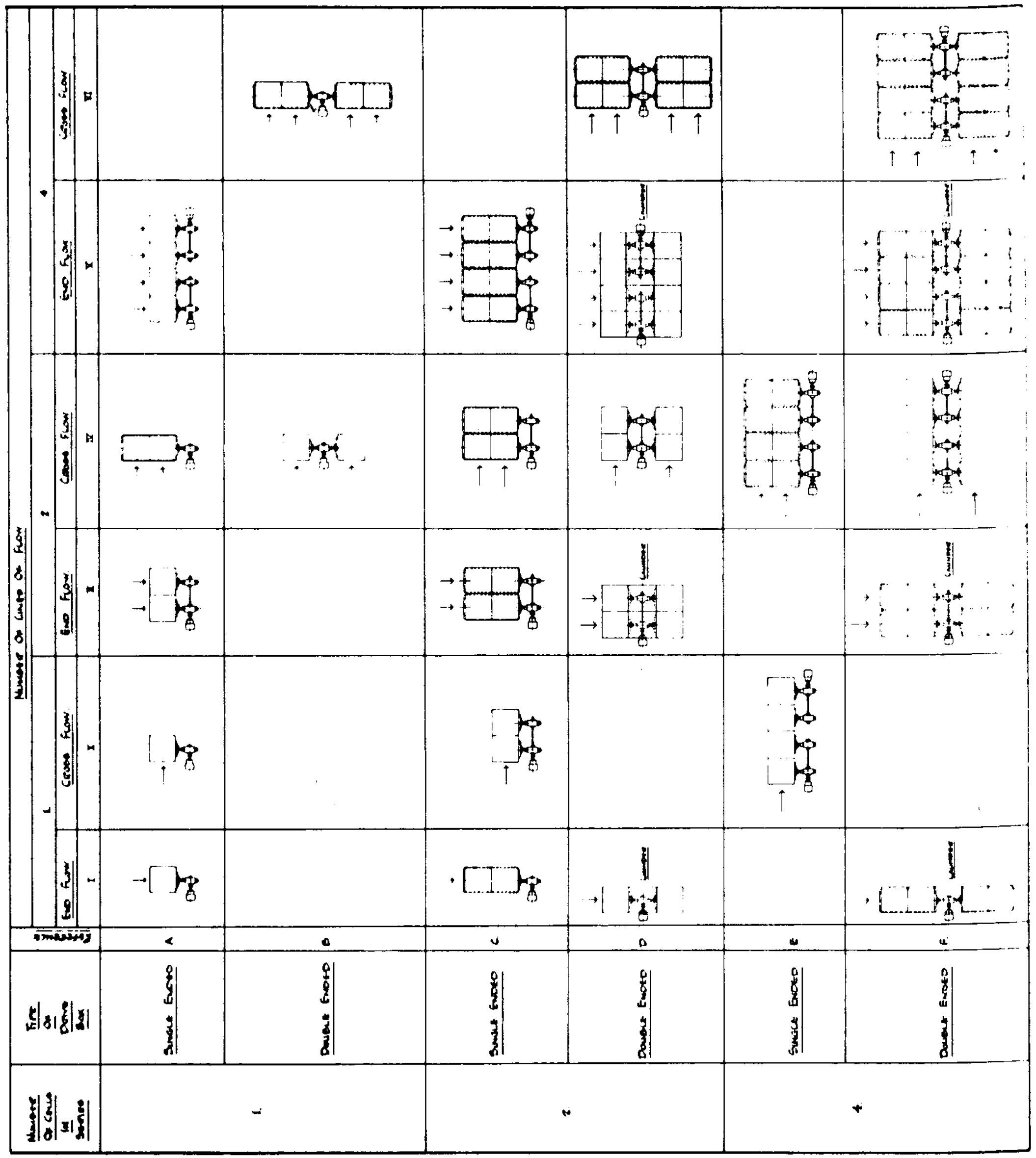

Fig. 7—Arrangements of cells

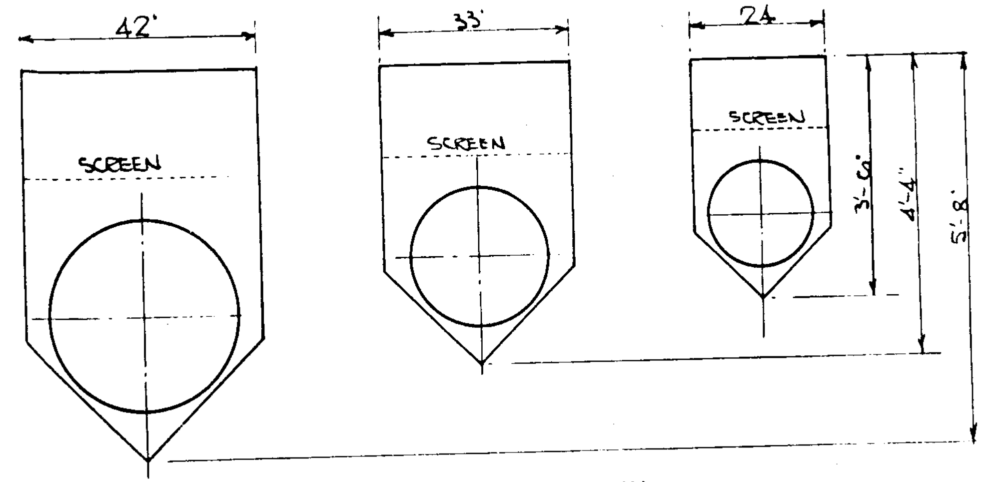

Fig. 8—Headroom in relation to width

correspondingly less headroom as shown in Fig. 8 and this can sometimes be an advantage. They are also useful in small plants to function either as the primary or a clean-up jig. The drive mechanism can be quickly adjusted to give strokes ranging from $\frac{1}{8}$ in. to 3 in. by increments of $\frac{1}{8}$ in. The operating speeds most commonly used are between 100 and 200 r.p.m. but the drive mechanism has been tested up to 600 r.p.m. which presents interesting possibilities for processing feeds of finer particle size than normally fed to jigs.

It is thus apparent that the alluvial mining industry has greatly improved the design of jigs since the old Harz type with its space-wasting hydraulic compartment was originally borrowed from the hard-ore mining industry.

PART II

PERFORMANCE

General remarks

While the use of jigs continued to be confined to mills processing comminuted ores, an adequate appreciation of what jigging through the screen could achieve was inhibited by the difficulty of making physical analyses of the samples in terms of the specific gravities of the particles. The particles in the samples would usually show a continuous range of composition from 100 per cent gangue to 100 per cent free mineral frequently complicated by the presence of other heavy and semi-heavy minerals.

However, as soon as jigs were used on alluvial tin dredges, it became practicable to analyze their efficiency for mineral recovery through the screen over a wide range of both particle sizes and specific gravities by making physical analyses of samples in terms of such free alluvial minerals as topaz sp. gr. 3·5, anatase sp. gr. 3·9, zircon sp. gr. 4·7, monazite sp. gr. 5·1 and cassiterite sp. gr. 7·0. All these minerals were commonly present and can easily be recognized in concentrates and counted under the microscope. Unfortunately there was insufficient economic incentive for anyone in the alluvial tin mining industry to analyze jig performance other than for cassiterite and even these results were not published. Likewise the alluvial gold mining industry was not particularly interested in the identity and recovery of the heavy and semi-heavy minerals reporting in the jig concentrates.

But in 1953, when jigs were first used to concentrate intensely decomposed columbite-bearing granites in Nigeria and later to replace sluice-boxes in the alluvial tin/columbite industry there, the economic incentive arose to investigate in some detail recovery through the screen in relation to particle size and specific gravity. These investigations have been described by the author elsewhere[2, 3, 4]. The decomposed columbite-bearing granites contained the immediately saleable free minerals cassiterite sp. gr. 7·0 columbite sp. gr. 5·5, thorite sp. gr. 5·3 and xenotime sp. gr. 4·5 and later a market was found for the hafnium-rich zircon also sp. gr. 4·5. The problems which arose in dressing both these primary concentrates and subsequently the alluvial concentrates made it economically worthwhile to investigate the recovery of other minerals present including anatase sp. gr. 3·9 and topaz sp. gr. 3·5. The fact that the use of hydrocyclones to remove primary slime from the jig feed had extended mineral recovery in jigs to much finer particle sizes dictated that these investigations should, in most cases, be carried down to 300 mesh. The author's results recorded in this paper were all obtained by sampling commercial plants in normal operation.

The plant scale performance data published by the author relating to incoherent ores can now, of course, be used to estimate the recovery of both free minerals and intergrown grains in the specific gravity range 7·0 to 3·5 from various comminuted ores. If the gangue is heavier than quartz then Taggart's concentration criterion[5] can be used as the standard of reference. This can be defined as the specific gravity of the heavy mineral divided by the specific gravity of the light mineral, each diminished by one.

Against this background of available information on the performance of jigs with incoherent ores the hard rock mining industries could now more easily plan their own programmes of direct research with comminuted ores. This would entail a special study of the practical aspects of laboratory techniques for the gravity fractionation of samples with heavy liquids, molten salts, fine heavy particles in suspension and possibly even gallium-aluminium alloys.

There is need for more experimental work on either a commercial or a pilot plant scale, with both incoherent and comminuted ores, to determine recoveries in relation to the major controllable and uncontrollable variables such as grade of feed, rate of feed, dilution of feed, amount of slime suspended in the water, length of stroke, speed of stroke, depth and nature of ragging and hutch water supply.

A selection of jig assemblies suitable for such tests, which could be installed in existing plants to take determined rates of feed by-passed from the flow of sand or comminuted ore, is shown in Fig. 9. The launder in the middle is removable so that either two or four cells can be used in series. Furthermore the tailing from the second cell can be by-passed and screened to remove large particles and/or cycloned to remove primary slime and water before feeding to the third cell. In type (A) which is necessarily the most expensive, both the length of stroke and the speed of all four cells can be independently varied. Only for advanced experimental work would such a high degree of flexibility normally be required. In type (B) the length of stroke of each of the four cells can still be independently varied and the first and last pair can operate at different speeds. In type (C) both the length of stroke and the speed of the two pairs of jigs can be independently varied. Finally in type (D) which is of course the cheapest, either the length of stroke or the speed or both can be varied for all four cells together.

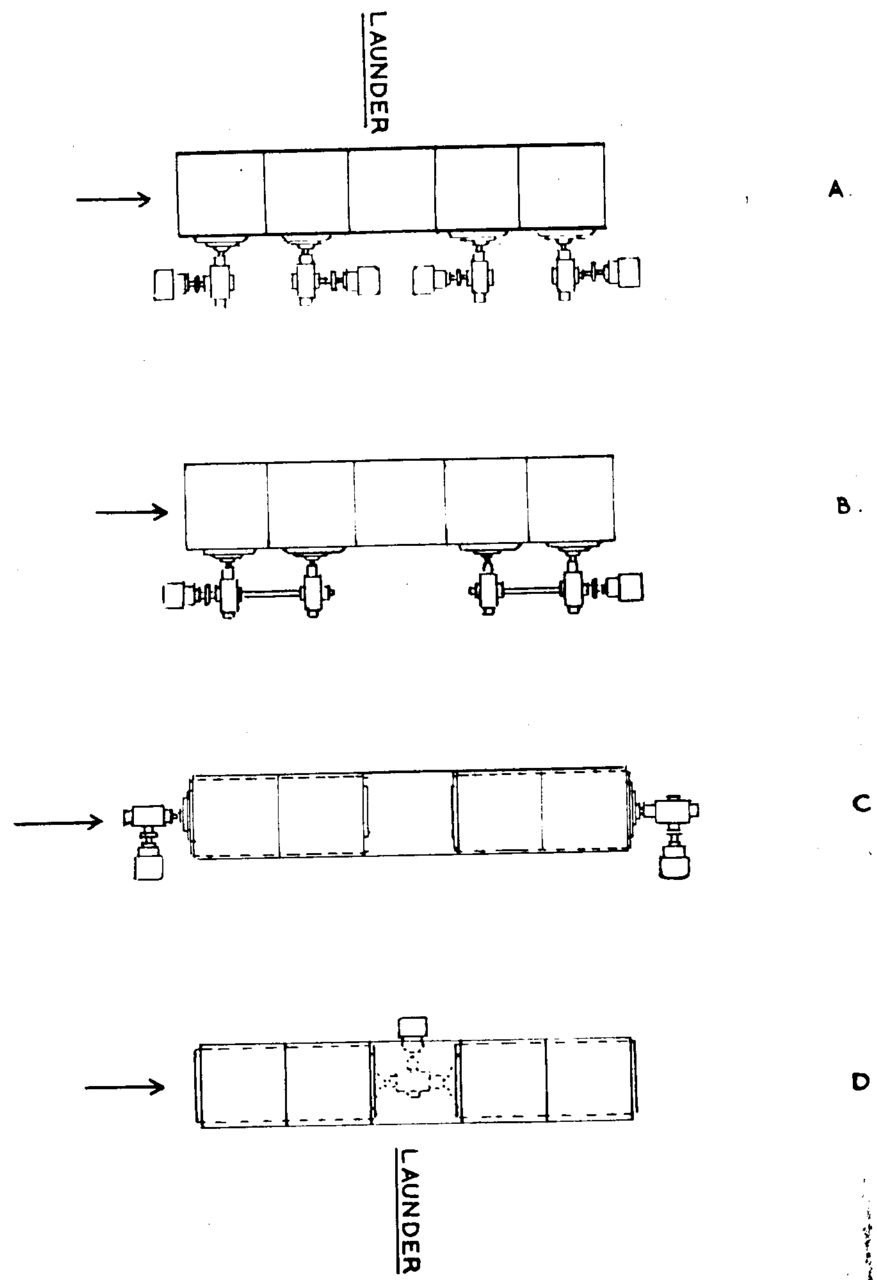

Fig. 9—Four-cell jigs for test work: variable speed motors

RECOVERY IN RELATION TO PARTICLE SIZE AND SPECIFIC GRAVITY

Incoherent ores

By the term incoherent ores is meant those which can be adequately disintegrated without crushing or grinding. It includes intensely decomposed rocks, residual deposits, alluvial deposits and beach sands.

A selection of recovery data from the author's published papers on incoherent ores is reproduced in Table I. It will be noted that for cassiterite effective desliming of the feed results in a recovery of over 99 per cent at 170/240 mesh and still over 94 per cent at 240/300 mesh. For lighter minerals recovery in the finest sizes falls off, but down to 25/52 mesh the recovery of topaz, sp. gr. 3·5 (the same as diamond), is still over 90 per cent. These figures indicate that, in the coarser size range, particles appreciably lighter than topaz could be recovered in jigs. It was in fact observed that a considerable recovery of lateritic nodules, specific gravity probably about 3·0, also took place and jigs are in successful use in Spain for the beneficiation of limonitic iron ore.

An important consideration is the type of ragging used and more particularly its specific gravity and particle size. If it is too heavy then the *coarse* mineral tends to be lost into the tailing. This shows up clearly in Table II. On the Jos Plateau, Nigeria, where this plant was situated, topaz had only a nuisance value and the intention was to reject as much of it as possible. Obviously if it is the intention to recover topaz (or diamond which has the same specific gravity as topaz) a lighter ragging would have to be used.

TABLE II

MINERAL RECOVERY IN RELATION TO SPECIFIC GRAVITY OF RAGGING HEMATITE SP. GR. 4·4

B.S. Sieves		Zircon sp. gr. 4·5					Topaz sp. gr. 3·5				
		Hutch No.				Total	Hutch No.				Total
No.	M.M.	1	2	3	4		1	2	3	4	
		%	%	%	%	%	%	%	%	%	%
5	3·35						1·6	1·6	0·9	0·8	4·9
5/6	3·35/2·81						14·0	13·6	3·5	6·9	38·0
6/8	2·81/2·06						33·9	31·8	14·6	6·3	86·6
8/10	2·06/1·68	84·6	3·7	11·7	—	100·0	41·4	36·8	10·8	5·2	94·2
10/12	1·68/1·40	83·8	7·1	2·4	6·7	100·0	36·4	41·7	12·1	4·8	95·0
12/16	1·40/1·00	69·0	27·7	2·0	1·3	100·0	32·5	41·8	12·2	10·3	96·8

Note: Conditions of operation same as Table IA

Dimensions of screen above each hutch 40 in. by 40 in.

ROCYCLONES

Condition of Operations	Total	Topaz sp. gr. 3·5				
		Hutch No.				Total
		1	2	3	4	
	%	%	%	%	%	%
A { Screened through ¼ in. Cycloned once. Speed 129 r.p.m. Stroke—1½ in. Ragging Hematite —¾ in. + ½ in. sp. gr. 4·4.	1 100·0	32·5	41·8	12·2	10·3	96·8
	16 100·0	45·4	32·2	9·0	9·7	96·3
	25 97·3	55·7	23·9	6·1	7·4	93·1
	52 95·9	48·8	18·3	8·2	8·8	84·1
	72/ 90·3	24·1	21·8	9·5	16·8	72·2
	100 88·3	18·3	15·5	9·3	16·4	59·5
	120 76·9	11·1	13·6	7·5	12·4	44·6
	150 73·7	6·0	9·3	6·2	13·2	34·7
	170 34·9	3·1	4·6	4·0	6·0	17·7
	240					
B { Screened through ¼ in. Cycloned twice. Speed 155 r.p.m. Stroke ½ in. Ragging Hematite—¾ in. + ½ in. sp. gr. 4·4.	1 100·0					
	16, 100·0					
	25, 99·6					
	52, 99·7					
	72/ 99·2					
	100, 97·4					
	120, 95·9					
	150, 91·2					
	170, 76·1					
	240, 43·8					

Microns 1 millimetre. Din

TABLE I

MINERAL RECOVERY FROM QUARTZ IN JIGS IN RELATION TO SPECIFIC GRAVITY AND PARTICLE SIZE AND THE REMOVAL OF PRIMARY SLIME WITH HYDROCYCLONES

Condition of operations	B.S. Sieves		Cassiterite sp. gr. 7·0					Columbite sp. gr. 5·5					Zircon sp. gr. 4·5					Topaz sp. gr. 3·5				
	No.	Aperture	Hutch No. 1	2	3	4	Total	Hutch No. 1	2	3	4	Total	Hutch No. 1	2	3	4	Total	Hutch No. 1	2	3	4	Total
		Microns*	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
A Cycloned once; Speed 129 r.p.m.; Stroke—1½ in.; Ragging Hematite —¾ in. + ½ in. sp. gr. 4·4.	16	1,000	98·0	1·8	0·1	—	99·9	92·1	7·9	—	—	100·0	69·0	27·7	2·0	1·3	100·0	32·5	41·8	12·2	10·3	96·8
	16/25	1,000/599	95·6	3·3	0·1	0·1	99·1	88·8	9·3	0·6	0·4	99·1	62·8	30·2	5·6	1·4	100·0	45·4	32·2	9·0	9·7	96·3
	25/52	599/295	92·3	6·5	0·4	0·1	99·3	85·8	11·1	1·6	0·4	98·9	65·4	16·3	14·3	1·3	97·3	55·7	23·9	6·1	7·4	93·1
	52/72	295/211	87·3	8·9	1·8	0·4	98·4	80·8	12·9	3·3	0·8	97·8	65·9	21·0	6·6	2·3	95·9	48·8	18·3	8·2	8·8	84·1
	72/100	211/152	70·4	18·7	4·3	3·4	96·8	64·8	18·2	8·1	5·1	96·2	39·7	28·5	10·1	12·0	90·3	24·1	21·8	9·5	16·8	72·2
	100/120	152/124	55·6	18·4	11·8	10·7	96·5	50·4	20·9	14·1	11·8	98·2	30·1	22·1	15·1	21·0	88·3	18·3	15·5	9·3	16·4	59·5
	120/150	124/104	46·1	25·0	9·3	14·7	95·1	36·7	29·4	12·3	17·8	96·2	22·8	20·0	12·5	21·6	76·9	11·1	13·6	7·5	12·4	44·6
	150/170	104/89	35·0	33·5	10·5	18·0	97·0	29·9	29·7	13·6	21·9	95·1	16·7	17·2	12·5	27·3	73·7	6·0	9·3	6·2	13·2	34·7
	170/240	89/66	24·6	21·8	9·1	22·3	77·8	22·6	24·7	13·2	27·3	87·8	4·4	8·1	7·2	15·2	34·9	3·1	4·6	4·0	6·0	17·7
	240/300	66/53	9·6	8·6	5·3	12·6	36·1	9·2	9·8	5·4	10·8	35·2										

Condition of operations	No.	Aperture	Cassiterite sp. gr. 7·0					Columbite sp. gr. 5·5					Xenotime sp. gr. 4·5				
B Cycloned twice; Speed 155 r.p.m.; Stroke ¼ in.; Ragging Hematite—¾ in. + ½ in. sp. gr. 4·4.	16	1,000	100·0	—	—	—	100·0	78·7	14·7	6·6	—	100·0	93·8	6·2	—	—	100·0
	16/25	1,000/599	93·6	6·4	—	—	100·0	84·1	13·2	1·7	1·0	100·0	81·3	18·7	—	—	100·0
	25/52	599/295	72·8	24·8	2·4	—	100·0	71·2	16·7	3·4	1·8	99·1	78·1	18·4	1·9	1·2	99·6
	52/72	295/211	68·5	28·2	1·2	2·1	100·0	72·2	20·3	3·1	3·0	98·6	67·9	21·2	5·5	5·1	99·7
	72/100	211/152	67·3	25·7	3·1	3·8	99·9	63·6	26·0	4·2	4·6	98·4	60·5	28·8	4·6	5·3	99·2
	100/120	152/124	62·3	28·1	4·7	4·5	99·6	58·5	26·8	5·4	5·8	96·5	57·1	29·3	5·5	5·5	97·4
	120/150	124/104	56·9	29·3	8·3	5·1	99·6	50·0	32·1	5·9	6·9	94·9	51·1	27·4	8·0	9·4	95·9
	150/170	104/89	48·2	34·7	10·0	6·7	99·6	41·8	31·2	8·7	9·3	91·0	47·7	21·1	10·9	11·5	91·2
	170/240	89/66	46·3	27·6	14·4	10·9	99·2	33·3	26·4	12·2	11·9	83·8	29·1	20·7	13·9	12·4	76·1
	240/300	66/53	26·3	25·5	27·1	15·4	94·3	15·4	12·4	9·8	9·4	47·0	15·5	5·6	15·5	7·2	43·8

*Microns 1 millimetre. Dimensions of Screen above each Hutch 40 in. by 40 in.

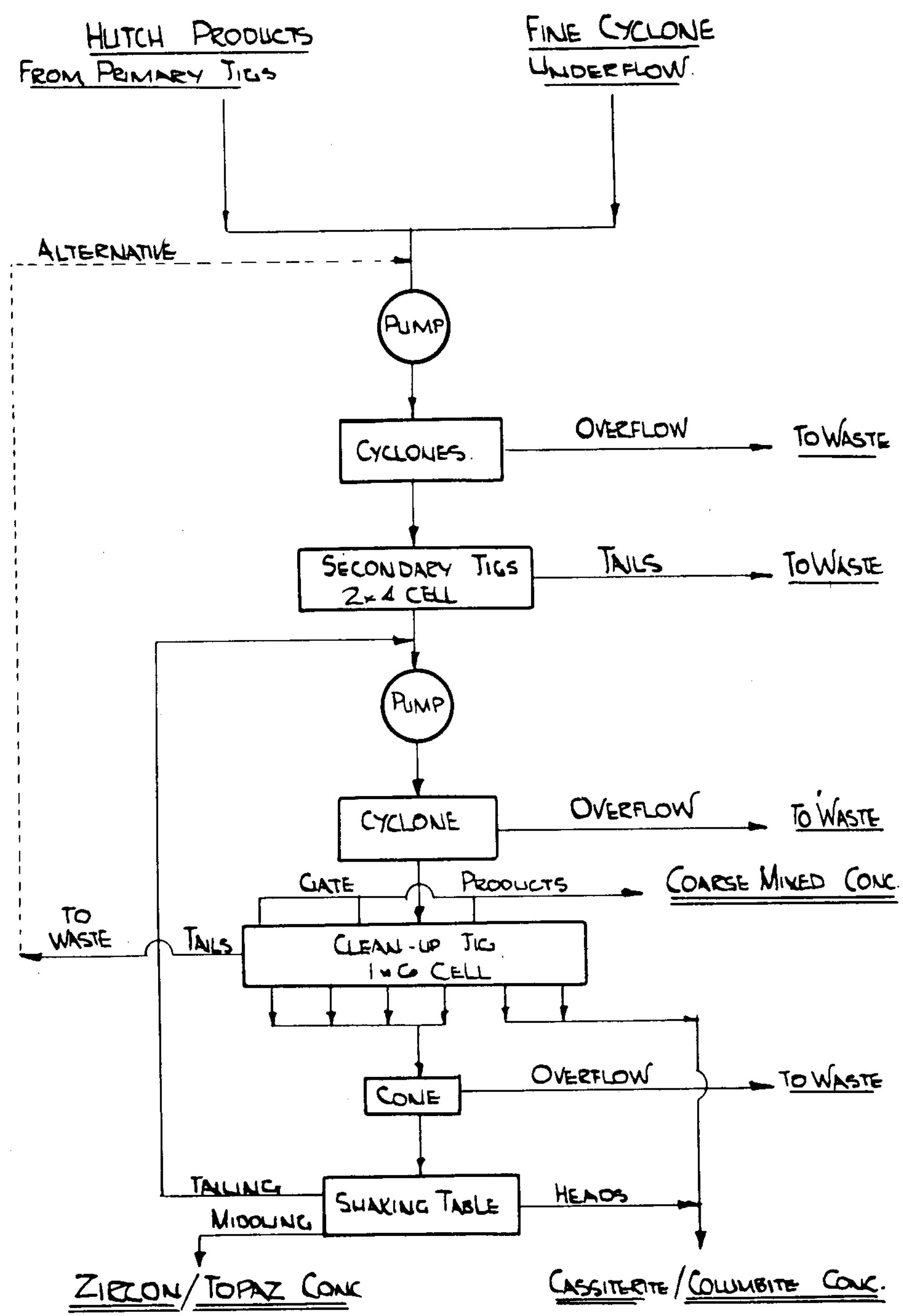

Fig. 10 · Flowsheet showing jigs sampled

A more complex example is presented by the figures for a 6-cell clean-up jig given in Table III. The purpose of the first two cells was to exclude the zircon and topaz as much as possible so as to produce a high grade cassiterite/columbite concentrate. This was achieved by using a heavy ragging of fairly fine size. The objective in the case of the succeeding cells was two-fold, to recover the remaining mostly fine cassiterite and columbite and also to recover zircon and topaz to prevent too much of it accumulating in the closed circuit in which this jig operated. In these cells this two-fold objective was achieved by using a lighter coarser ragging. This product went to a shaking table which separated most of the fine heavy cassiterite and columbite from the coarser and lighter zircon and topaz. This closed circuit is shown in Fig. 10.

The figures in Table Ia and II were obtained by sampling the primary jigs in a plant treating alluvial wash containing an unusually high concentration of topaz. Those in Table Ib were obtained by sampling the secondary jigs shown in Fig. 10 when treating decomposed columbite-bearing granite, hence the performance analysis in terms of xenotime which was a valuable by-product mineral. The figures in Table III represent the performance of the clean-up jig in Fig. 10 when this plant was treating alluvial wash.

Whenever the plant was shut down and the bed in the clean-up jig was examined, it was found to be well stratified. The gate products were mixed as shown in the flowsheet because it was more convenient to separate the constituent minerals in a separate mill handling all the concentrates. But interest attaches to the degree of stratification. This is shown by the mineral analyses in Table III. With the exception of some of the laterite all this mineral was finer than the screen but was held up by the nature of the ragging and the conditions of operation of the jig. At that time the plant was concentrating alluvial wash.

Comminuted ores

In the processing of comminuted ores the commonest use of jigs today is in closed circuit with a ball mill and classifier to minimize overgrinding. Formerly when only mechanical types of classifiers were available both the lateral space and headroom available for jigs was severely limited. But the advent of cyclone classifiers has removed that restriction. In addition modern jigs, as evolved in the alluvial mining industry and which are also suitable for comminuted ores, occupy less space. In such closed circuits, as well as in open circuits, it is now practicable to extend the use of the cheap process of concentration in jigs to the recovery of particles which are much lighter and finer. The tables of results achieved with incoherent ores reproduced in this paper can be used as a preliminary guide to the results likely to be achieved with other types of ore. The old and the new types of closed circuit ballmill flowsheets are compared in Figs. 11 A, B and C. The use of a sufficient number of cells both in parallel and in series and two stages of concentration ensures a high percentage recovery extending to fine sizes and intergrown particles of fairly low specific gravity, coupled with the production of a high grade concentrate. The provision of an adequate number of cells in the clean-up jig permits the simultaneous production of a high grade concentrate and a middling for finer grinding. Finally the use of a shaking table in the closed circuit to handle a relatively small tonnage serves the very useful purpose of extracting the fine free heavy minerals from the middling thus making a further contribution to the objective of minimizing overgrinding. It will be noted that this ballmill closed circuit is based on the well tested flowsheet for incoherent ores recorded in Fig. 10 to which the performance data recorded on Table III relates.

B.S. Si		Topaz sp. gr. 3·5						
C Comı	Total	Hutch No.						Total
No.		1	2	3	4	5	6	
	%	%	%	%	%	%	%	%
·16	72·3	—	—	0·1	0·1	0·7	—	0·9
16/25	93·8	—	—	1·5	2·1	7·4	0·3	11·3
25/52	93·0	—	0·1	10·8	0·6	14·1	2·0	27·6
52/72	94·1	—	0·1	13·4	1·3	19·6	7·3	41·7
72/100	94·8	0·1	0·1	14·8	2·4	22·7	10·4	50·5
100/120	89·3	0·2	0·1	10·2	2·2	17·3	6·5	36·5
120/150	79·3	0·2	0·1	8·8	1·9	11·9	4·5	27·4
150/170	75·1	0·8	0·1	12·6	2·9	16·1	4·8	37·3
170/240	70·4	1·3	0·1	5·4	2·4	9·6	3·7	22·5
240/300	50·0	1·5	—	5·4	0·8	2·7	1·5	11·9
300/325c	30·2	4·2	—	5·4	1·2	—	3·8	14·6
325c	41·8							
		Mineral Analyses of Hutch Products						
…igging		89·6	53·1	3·7	1·0	Tr	0·3	
		4·1	39·0	10·1	5·1	0·6	1·6	
		ND	ND	ND	ND	ND	ND	
		2·8	4·3	40·2	84·3	19·2	42·4	
…eed ..		—	—	—	—	—	—	
…oke ..		0·2	0·1	5·4	2·4	7·4	16·4	
		—	—	—	—	—	—	
		3·3	3·5	40·6	7·2	72·8	39·3	
		100·0	100·0	100·0	100·0	100·0	100·0	
	lbs/hr.	3·6	11·3	2·42	11·0	31·1	3·2	

…10 Microns

TABLE III

MINERAL RECOVERY IN A CLEAN-UP JIG IN RELATION TO THE SIZE AND SPECIFIC GRAVITY OF THE RAGGING

... Sieves	Cassiterite sp. gr. 7·0							Columbite sp. gr. 5·5						
...mercial	Hutch No.						Total	Hutch No.						Total
Aperture Microns	1	2	3	4	5	6		1	2	3	4	5	6	
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
+ 1,000	60·2	21·7	17·6	0·5	—	—	100·0	10·7	7·7	57·6	24·0	—	—	100·0
1,000/599	60·5	29·3	9·8	0·4	—	—	100·0	4·2	53·9	35·1	5·4	1·3	—	99·9
599/295	33·1	61·7	4·8	0·4	—	—	100·0	0·7	66·3	27·8	3·6	1·3	0·2	99·9
295/211	6·3	86·1	6·2	1·2	0·1	0·1	100·0	0·3	50·7	36·3	9·9	2·2	0·5	99·9
211/152	10·8	71·9	15·2	1·9	0·1	0·1	100·0	2·9	43·1	36·0	13·4	3·3	1·2	99·9
152/124	13·6	69·0	13·5	3·5	0·2	0·2	100·0	6·3	44·9	26·7	15·7	4·2	2·0	99·8
124/104	19·4	66·5	8·7	4·0	0·7	0·7	100·0	10·1	41·3	22·6	16·5	6·0	2·8	99·3
104/89	22·8	54·8	13·8	5·1	2·4	1·1	100·0	15·6	26·1	23·8	18·8	9·2	5·6	99·1
89/66	25·5	25·6	24·5	15·6	5·4	3·4	100·0	21·1	13·8	21·7	16·6	17·1	8·1	98·4
66/53	27·6	11·4	23·2	13·8	12·6	4·8	93·4	16·7	6·8	26·4	12·2	22·8	7·5	92·4
53/45	18·8	Tr	15·6	6·2	7·0	8·9	56·5	24·6	—	24·6	8·4	20·7	6·2	93·3
− 45	6·7	Tr	13·0	4·8	14·3	2·5	41·3	13·2	—	21·9	5·4	43·9	3·3	87·7

... Sieves	Zircon sp. gr. 4·5							Topaz sp. gr. 3·5						
...mercial	Hutch No.						Total	Hutch No.						Total
Aperture Microns	1	2	3	4	5	6		1	2	3	4	5	6	
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
+ 1,000	—	0·1	6·1	51·1	13·5	1·5	72·3	—	—	0·1	0·1	0·7	—	0·9
1,000/599	—	0·2	30·1	47·5	14·4	1·6	93·8	—	—	1·5	2·1	7·4	0·3	11·3
599/295	—	2·0	40·6	19·4	25·8	5·2	93·0	—	0·1	10·8	0·6	14·1	2·0	27·6
295/211	0·1	4·0	37·1	12·6	27·9	12·4	94·1	—	0·1	13·4	1·3	19·6	7·3	41·7
211/152	0·5	4·5	35·8	13·9	26·7	13·4	94·8	0·1	0·1	14·8	2·4	22·7	10·4	50·5
152/124	1·2	6·0	32·2	16·6	20·7	12·6	89·3	0·2	0·1	10·2	2·2	17·3	6·5	36·5
124/104	1·8	6·4	23·4	14·6	20·6	13·0	79·3	0·2	0·1	8·8	1·9	11·9	4·5	27·4
104/89	4·5	5·5	24·8	12·8	16·4	11·1	75·1	0·8	0·1	12·6	2·9	16·1	4·8	37·3
89/66	7·1	4·3	20·0	9·1	26·1	8·8	70·4	1·3	0·1	5·4	2·4	9·6	3·7	22·5
66/53	8·3	1·7	14·3	5·0	16·0	4·7	50·0	1·5	—	5·4	0·8	2·7	1·5	11·9
53/45	5·8	0·8	7·0	2·7	8·7	5·2	30·2	4·2	—	5·4	1·2	—	3·8	14·6
− 45	3·8	2·3	7·4	2·4	24·2	1·7	41·8							

Conditions of Operation

.. .. ..	Cassiterite sp. gr. 7·0		Hematite sp. gr. 4·4
	−¼ in.	−½ in.	−½ in.
	+⅛ in.	+½ in.	+⅜ in.
.. .. ..	180 strokes/min.		
.. .. ..	⅛ in.		

	Mineral Analyses of Strata above Ragging				Mineral Analyses of Hutch Products					
Cassiterite	10·3	Tr	—		89·6	53·1	3·7	1·0	Tr	0·3
Columbite	32·4	0·2	Tr		4·1	39·0	10·1	5·1	0·6	1·6
Ilmenite	4·5	Tr	Tr		ND	ND	ND	ND	ND	ND
Zircon	47·7	57·9	16·5		2·8	4·3	40·2	84·3	19·2	42·4
Laterite	0·8	5·2	12·6		—	—	—	—	—	—
Topaz	3·9	36·4	68·4		0·2	0·1	5·4	2·4	7·4	16·4
Limonite	—	—	0·2		—	—	—	—	—	—
Quartz and Others ..	0·4	0·3	2·3		3·3	3·5	40·6	7·2	72·8	39·3
Total	100·0	100·0	100·0		100·0	100·0	100·0	100·0	100·0	100·0
Thickness of Sand ..	½ in.	2 in.	½ in.	lbs/hr.	3·6	11·3	2·42	11·0	31·1	3·2
Thickness of Conc.	2½ in.	2 in.	2 in.							

...ns 1 Millimetre. Dimensions of Screen above each Hutch, 40 in. by 40 in.

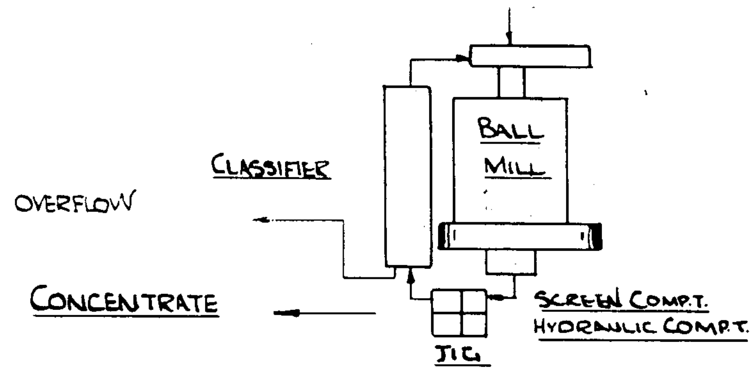

Fig. 11a—Ballmill closed circuits: with hydraulic compartment jig and mechanical classifier

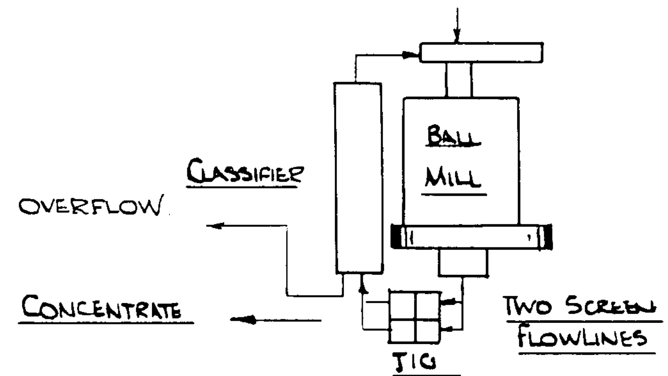

Fig. 11b—Ballmill closed circuits: with jig and mechanical classifier

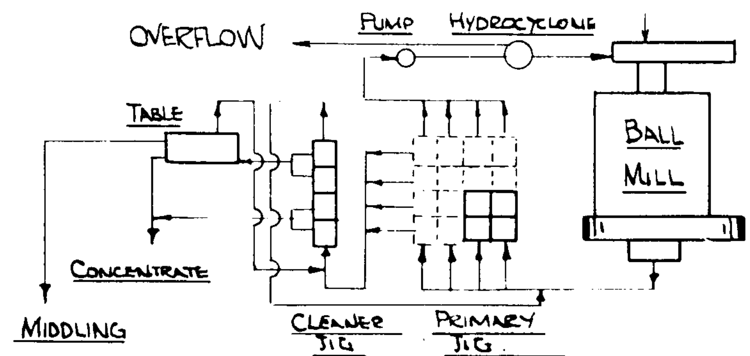

Fig. 11c—Ballmill closed circuits: with jigs and hydrocyclone

The same jig flowsheet can be used to similar advantage in open circuits particularly with rod mills. If the ore is low grade to start with and the valuable mineral content is not too fine the jig tailing may sometimes be discharged to waste without further grinding. But if fine grinding and subsequent treatment is necessary it is usually advantageous to recover as much free mineral and middling as possible cheaply in jigs at an earlier stage.

METHODS OF SAMPLE ANALYSIS

Incoherent ores

The two main considerations are first the size of the final sample to be analyzed and second the choice between mechanical concentration (shaking table and superpanner) and heavy liquids. Hand panning can be used for making a preliminary recovery of heavy minerals but it is commonly advisable to check the pan tailing by mechanical concentration.

The size of the final sample taken for analysis is also determined by two considerations, the maximum particle size of the heavy mineral to be recovered and the grade. When results are required in terms of more than one mineral the sample should be large enough for accurate valuation in terms of the coarser or the rarer constituent. Examples are coarse cassiterite and fine columbite in alluvial deposits or abundant columbite and rarer xenotime both fine in decomposed granite.

The choice between using a superpanner or heavy liquids is sometimes difficult to make but is also mainly determined by two considerations, one regional and the other mineralogical. In hot climates heavy liquids are objectionable to use. At the same time there may be available cheap labour for operating a large number of superpanners. On the other hand cold climates lend themselves to the use of the several heavy liquids and the various light liquids commonly employed for dilution and washing. On a superpanner heavy dark coloured minerals, e.g. cassiterite and ilmenite are relatively easy to recover quantitatively as high grade concentrates. But it is difficult to make a quantitative recovery of light coloured zircon from quartz except as a low grade concentrate for final cleaning in bromoform. For minerals of still lower specific gravity the use of a heavy liquid is essential if quantitative recovery is to be achieved.

The author has described in detail elsewhere[4], [1] the methods developed in Nigeria for analyzing small samples of intensely decomposed granite and large samples of alluvium respectively. As the grade of the decomposed granite was very even and it contained very little heavy mineral coarser than 25 mesh, a ½ lb sample sufficed. But for tin-bearing alluvium the standard method of boring yielded sectional samples of about 50 lb the size of which was justified by the more uneven distribution of values and the coarser particle size of the cassiterite. Both methods have been used for analyzing head and tail samples from concentrating plants. They could be adopted for use with other types of incoherent ore.

Both methods commence with the removal of the primary slime. With the small samples of decomposed granite this was achieved by careful elutriation so as not to lose any fine heavy mineral. With the large samples it is carried out rapidly but thoroughly with a large excess of water and any fine heavy mineral lost is retrieved by pumping the dilute slime through a hydrocyclone. The deslimed sands from the small samples are dried, screen sized and each screen sized fraction is then concentrated in a superpanner, or the heavy mineral content is separated with bromoform. With the large samples the sizing and then concentrating sequence is reversed. The unsized deslimed sands are first hand panned to recover most of the heavy mineral and any losses are retrieved by concentration on a half-size Holman table to yield a final head which is cleaned up on a Haultain superpanner. The concentrate is then dried and all or portion of it is screen sized.

Both procedures thus yield the same end products, screen sized heavy mineral concentrates quantitatively recovered. Before the sized fractions are physically assayed by grain counting each is usually divided into two portions by magnetic separation and some minerals may be demagnetized or decomposed by leaching with hydrochloric acid followed by further magnetic separation.

Special interest attaches to the possibility of adapting the procedure used in Nigeria for large samples to the valuation of samples of diamond-bearing wash and decomposed kimberlite. Where the percentage of industrial diamonds is high, and particularly in the Bakwanga area of the Congo where the product is mostly crushing boart, the price does not diminish nearly so much with dcreasing size as it does with stones of gem quality. Prospecting designed to include fine diamonds and test work on their cheap recovery in jigs at plant scale, may thus be economically attractive in some regions.

In Nigeria it was found that in desliming bore and pit samples the loss of heavy mineral increased very considerably from cassiterite sp. gr. 7·0 to columbite sp. gr. 5·5. Presumably the loss would increase progressively down to the lightest mineral recovered from the samples which is topaz sp. gr. 3·5. There is thus a distinct possibility that some fine diamonds, if present, are lost in desliming samples during the prospecting and valuation of diamond-bearing ground particularly clayey ground such as decomposed kimberlite.

Any such losses could be retrieved by cycloning the slimes in the field as with samples in Nigeria. Owing to the tendency of diamonds to float on water it may not be practicable to check the tails from hand jigging by tabling. However, Baniel and Mitzmager[6] have described the use and recovery of tetrabromoethane (TBE) in mineral dressing and this relatively cheap heavy liquid might prove suitable for recovering any heavy and semi-heavy mineral lost in the tailing. This concentrate could then be treated and examined for the possible presence of fine diamonds.

Comminuted ores

It is fortunate that the knowledge of mineral recovery in jigs in relation to specific gravity and particle size gained from work on incoherent ores containing substantially only free minerals is of wider application because it is much more difficult to analyze samples of comminuted ore. The operations of desliming and screen sizing the samples present no difficulty. But thereafter, in order to produce results comparable in terms of specific gravity as well, each screen sized fraction would have to be separated into specific gravity fractions. A first separation could be made with bromoform sp. gr. 2·8 which is reasonably cheap or with tetrabromoethane which has a slightly higher specific gravity and is cheaper. The sink product could then be further separated in methylene iodide sp. gr. 3·3 which is more expensive. The next step could be to make a separation of the methylene iodide sink product in clerici solution which at room temperature has a specific gravity of about 4·0 but this heavy liquid is even more expensive and also dangerously toxic. Hot clerici solution can be brought to a specific gravity approaching 4·7 but then the manipulation presents difficulties. Fused salts, particularly thallium formate or lead chloride, can be used for separations at a specific gravity of about 5·0. Finally gallium and gallium-aluminium alloys present the possibility of extending the fractionation to a specific gravity of 6·0. Another approach is the use of ferrosilicon and perhaps other heavy fine substances, in suspension in water or in heavy liquids.

The practical problems involved in the specific gravity fractionation of samples are overdue for more adequate attention by ore dressing laboratories.

In a few specific instances, e.g. ores of magnetite or wolfram it may sometimes prove practicable to find a way round direct gravity fractionation by substituting magnetic fractionation. With sized samples this can be carried out with a high degree of precision on a Franz isodynamic magnetic separator.

PART III

APPLICATIONS

General remarks

When jigs are used in the processing of incoherent ores (e.g. alluvial deposits and decomposed rocks) they are usually the main means and often the sole means of mineral recovery. But in the processing of comminuted ores jigs are usually employed in conjunction with other processes such as cyanidation, flotation and sink-float. In both of these spheres of application the use of jigs is expanding. The better understanding of mineral dressing processes which must follow from the more frequent use of combined screen and mineral analyses or screen and specific gravity analyses of samples is likely to lead to a greater use of jigs.

Incoherent ores

Alluvial tin mining

(*a*) Bucket dredging

The greatest user of jigs today is undoubtedly the tin dredging industry of Siam, Malaya and Indonesia. The evolution of improved designs in this environment has been described in Part I. Usually the jigs are arranged in two lines one either side of the trommel and four cells in series are employed to extend the recovery of cassiterite to very fine grain sizes. The need to correlate the valuation of reserves with recovery on these dredges has been described by the author[1] elsewhere. Experiments currently in progress in Malaya designed to increase the recovery of very fine cassiterite include the use of hydrocyclones ahead of the jigs and the use of fine sieve bends for screening the jig tailing to retrieve an undersize which may be worth cycloning for further treatment of the underflow.

Gravel pumping

There are over 500 Chinese owned gravel pumping mines in Malaya. Until quite recently the recovery of cassiterite was always by sluice box. Losses were sufficiently high for tributers to be able to make a living reworking the tails by hand. As the result of plant scale research work carried out by the Mines Department and described by Harris[7] sluice boxes are now rapidly being replaced by plants incorporating cyclones, jigs and sieve bends. The disappearance of the erstwhile tributers once these modern plants are installed is a striking manifestation of their efficiency.

Alluvial gold mining

Modern jigs are standard equipment on gold dredges. As the accompanying alluvial minerals are rarely of economic interest it is customary to use a ragging of steel shot to minimize their recovery and thus produce less weight of concentrate for amalgamation. But in one district in Malaya the recovery of gold along with the cassiterite is considerable and there of course hematite is used for ragging as elsewhere in Malaya.

Alluvial gold and diamonds

In the Congo and in Ghana alluvial deposits are known containing both gold and diamonds. In the Congo a very high percentage recovery of both from a long range unsized feed was achieved in jigs by the simple expedient of using laterite of specific gravity about 3·0 as the ragging. This raises the interesting question of whether it would be possible to use large scale low cost dredging and gravel pumping combined with jigging without sizing for the exploitation of some alluvial diamond deposits, which might be too low grade for the more elaborate sizing and concentrating procedure usually employed. The data on the recovery of topaz sp. gr. 3·5 reproduced in this paper should be of particular interest in this connection.

Alluvial diamond mining

In Sierra Leone and Ghana jigs are extensively used for diamond recovery. Usually the feed is screen sized before jigging and the fraction finer than one or two millimeters is rejected. Such screening must tend to increase costs and restrict the rate of through-put. It would be interesting to make a check on the possible presence of more fine diamonds than have reported by the established methods of sample valuation. Although diamond itself is very valuable, the value of the gravity concentrates is only of about the same order as those recovered in the large scale low cost dredging and gravel pumping of alluvial tin and gold deposits and the author's work with topaz rather suggests that diamonds could be similarly recovered. From this point of view prospecting for suitable deposits for such low cost exploitation might be worth considering.

In Angola, the Congo and South West Africa the sink-float process with ferrosilicon medium is very popular. There would appear to be scope for the greater use of jigs to concentrate sands finer than about 2 or 2½ mm. without sizing. The sink-float process could then treat a larger tonnage of coarser material.

Intensely decomposed rocks

The valuation of the intensely decomposed columbite-bearing granites of Nigeria and the recovery of their contents of primary accessory minerals in a plant incorporating hydrocyclones, jigs, screens and tables has been described by the author in two papers[4] and [2]. In addition to the columbite, other minerals were separated from the jig concentrates and marketed. They were cassiterite, xenotime, a hafnium-rich zircon and a mixture of thorite and zircon saleable for its thoria content. These decomposed granites are of course exceptional but geologists might well bear in mind the possibility of discovering other intensely decomposed rocks and orebodies which could be cheaply excavated and the mineral cheaply recovered in a jig plant.

Enough has been written about application to incoherent ores to indicate that there is attractive scope for the interchange of technical information and ideas between the several mining industries engaged in the valuation and processing of different kinds of incoherent ores.

COMMINUTED ORES

Tin ores

The readiness with which cassiterite breaks up into a fine powder during the crushing and grinding of its ores was responsible for the invention of the shaking table and mechanical vanner. Although these machines are very effective for recovering fine cassiterite their low rate of throughput makes this an expensive method of mineral recovery. However their availability has tended to divert attention from an adequate study of the full potentialities of the recovery of fine cassiterite and middlings more cheaply in jigs in order to reduce overgrinding. The advent of hydrocyclones which make possible the use of more jig cells in ballmill closed circuits has revived interest in jigs for this purpose. Although the figures for cassiterite in Table I were obtained with incoherent ores, i.e. intensely decomposed granite and alluvial wash, they give a good indication of what might be achieved with comminuted tin ores.

Wolfram ores

This is another mineral which is very prone to overgrinding and subsequent loss, in this case due to its good cleavage. Therefore during crushing and grinding preconcentration in jigs to recover as much of the mineral as possible in the form of intergrown grains before the mineral has a chance to cleave is particularly attractive. This middling, being more valuable than the original ore, can be reground and concentrated with greater care or by more expensive processes. However, fine flaked wolframite does not concentrate well on tables. Jones and Stone[8] have described a new type of wet magnetic separator for feebly magnetic minerals. Its operating cost per ton of throughput is considerably higher than that of jigs but it would appear to be suitable for use in closed circuit with a ballmill regrinding rich jig middlings.

TABLE IV

CELL FLOTATION OF LEAD/ZINC ORES

Ore Minerals			Cell Flotation Performance	
Name	Composition	Sp. Gr.	Relative Cost	Relative Recovery
Sulphide Minerals ..				
Galena	PbS	7·5	Moderate	Good
Sphalerite	ZnS	4·1	Moderate	Good
Oxidized Minerals ..				
Cerussite	$PbCO_3$	6·55	Higher	Fair
Calamine	$ZnCO_3$	4·35	Very High	Poor
Anglesite	$PbSO_4$	6·3	Not Usually Floated	Nil
Pyromorphite	$PbCl(PO_4)_3$	7·0		
Willemite	Zn_2SiO_4	4·0		

The combination of modern jigs and the Jones wet magnetic separator appears to offer attractive possibilities for improving the recovery of wolframite from comminuted ores at moderate cost, the low cost of jigging offsetting the higher cost of magnetic separation.

TABLE V

MINERAL RECOVERY IN JIGS FROM LEAD/ZINC ORES IN RELATION TO THE CONCENTRATION CRITERION

Recovery determined		Scale	Recovery deduced	
Cassiterite from quartz	3·64	3·60		
		3·50		
		3·40	3·42	Galena from dolomite
		3·30		
		3·20		
		3·10	3·16	Pyromorphite from dolomite
		3·00		
		2·90	2·89	Cerussite from dolomite
		2·80		
Columbite from quartz	2·73	2·70	2·74	Anglesite from dolomite
		2·60		
		2·50		
		2·40		
		2·30		
		2·20	2·24	Galena from siderite
Zircon from quartz	2·12	2·10		
		2·00	2·07	Pyromorphite from siderite
		1·90	1·90	Cerussite from siderite
		1·80	1·87	Anglesite from siderite
		1·70	1·76	Calamine from dolomite
		1·60	1·63	Sphalerite from dolomite
Topaz from quartz	1·52	1·50	1·58	Willemite from dolomite

Lead/zinc ores

The success of differential flotation in producing adequately clean separate concentrates of galena and sphalerite for separate smelting drove jigs out of mills treating lead/zinc ores. However flotation was only partly successful with oxidized lead/zinc ores and then only at a high cost of reagents as indicated in Table IV. But the advent of the new process for the smelting of mixed lead/zinc concentrates for the separate recovery of lead and zinc described by Morgan[9] appears to call for some new thinking about the role of jigs in mills treating mixed oxidized lead/zinc ores. With jigs a considerable proportion of the total valuable content could often be recovered as a mixed concentrate at an early stage of comminution of the ore to minimize overgrinding. Provisional estimates of recoveries which might be expected in relation to specific gravity and particle size can be made on the basis of the figures recorded in Tables I and V. Some prospects and parts of some developed ore-bodies containing oxidized lead and zinc minerals, but previously considered to be unpayable because of the high cost of flotation and the poor recovery, might now be re-assessed for the production of mixed concentrates cheaply by gravity concentration in jigs.

Gold ores

In the Kalgoorlie goldfield of Western Australia, where most of the gold is contained in the sulphides, jigs were used in some of the grinding circuits in the early 1920's, but they were later discarded in favour of flotation. With the South African banket gold ores the position is quite different. Very little of the gold is contained in the sulphides. It is thus only necessary to use sufficient jigs to make an adequately high recovery of the heavy metallic gold and accept the lighter sulphide recovered as a worthwhile byproduct. The balance of the recoverable gold would be extracted by cyanidation. It is not necessary to use sufficient jig cells either in parallel or in series to achieve a high percentage recovery of sulphide. Had jigs been in general use before the demand for uranium arose it would not have been necessary to install flotation plants. Sufficient sulphide would probably have been available from the jigs and if necessary recovery could have been increased merely by adding more cells in series or in parallel. If jigs now come into more general use for the banket ores, which seems very likely to happen, then the flotation plants for sulphides may no longer be needed. The pending installation of modern jigs in the mill at the Durban Deep mine is most probably a pointer to the future.

Other advantages of jigs for these ores are (1) greater security, (2) less overgrinding, (3) lower 'wet loss' in cyanide pulp tailing, (4) quicker and higher realization and (5) better recovery of osmiridium than on strakes.

Diamond-bearing kimberlite

Adamson[10] has published a flowsheet of the Premier Diamond Mine showing the oversize from 8 mesh screening concentrated by the 'sink and float' process and the screen undersize going to jigs. The author's work on the recovery of topaz in jigs suggests that both the tonnage throughput and overall recovery in this type of plant could probably be improved by screening at a slightly coarser mesh and providing more jigging capacity.

The use of modern alluvial type jigs in conjunction with the 'sink and float' process appears to have a promising future in the diamond mining industry.

PART IV

PROCESSING JIG CONCENTRATES

General remarks

Here again there is attractive scope for an exchange of information and ideas between mining industries treating quite different types of ore if these industries use or could use jigs.

The three outstanding post-war developments have been (1) a better understanding of the processes of mineral separation resulting from the making of combined size and mineral analyses of samples; (2) the introduction of fine dry screening in cascade screens fitted with nylon cloth with apertures down to as fine as 230 mesh, and (3) the availability of better designs of electrostatic, high tension and magnetic separators and pneumatic concentrating tables.

In the sphere of the wet processing of jig concentrates the potentialities of differential table flotation deserve more detailed study. In connection with gravity concentration on tables there is need for modification of the control mechanism of existing hydraulic classifiers to make them more suitable for dealing with a feed of heavy mineral concentrates.

The fusion of concentrates with relatively cheap fluxes which dissolve unwanted minerals, as is sometimes employed in the recovery of fine diamonds from jig concentrates, may find other applications.

On account of the relatively high value of many jig concentrates chemical processing in autoclaves is another attractive line of research which would appear to warrant more attention. Autoclaves are sometimes used in the processing of concentrates from wolfram ores.

CONCENTRATES FROM INCOHERENT ORES

Shaking tables are not very effective for the separation of minerals from each other in specific gravity range 3·5 to 7·0 common in jig concentrates from incoherent ores. The tendency for diamonds to float precludes their use in the processing of diamond-bearing concentrates. The Jones wet magnetic separator[8] appears to be worth investigation for the wet beneficiation of jig concentrates containing magnetic minerals.

For a number of reasons the alternative complete dry processing of jig concentrates is widely used in Nigeria. Some of the practices now well established there might find application elsewhere. In Nigeria the co-existence of normally magnetic columbite and abnormally magnetic cassiterite in the alluvial deposits early led to the use of air-float tables to avoid repeated wetting and drying of partly dressed products between gravity and magnetic fractionation. The use of these dry tables created a need for dry screening to fine mesh sizes. This need became more acute for dressing the very complex jig concentrate obtained from decomposed granite as described by the author[11]. Figures published in that paper showing the sizing achieved with a battery of cascade screens fitted with nylon cloth are of general interest and are reproduced here as Table VI. It was found that such sizing greatly improved both high tension separation and the subsequent magnetic separation carried out in the mill by high tension separators and induced roll magnetic separators respectively.

If the use of jigs to recover alluvial diamonds of finer size becomes more general in Africa some of the Nigerian practices may be found useful for the processing of the fine diamond-bearing concentrates.

TABLE VI

SCREEN ANALYSES OF THE OVERSIZE DISCHARGES OF A BATTERY OF CASCADE SCREENS

B.S. Sieves		Nylon Mesh Number and Aperture (mm.)											
No.	mm.	+16 1·352	+22 0·939	+30 0·660	+40 0·466	+50 0·350	+60 0·282	+70 0·239	+80 0·196	+96 0·159	+108 0·142	+133 0·099	−133
	%	%	%	%	%	%	%	%	%	%	%	%	%
+ 10	1·676	1·33	—	—	—	—	—	—	—	—	—	—	—
+ 12	1·405	19·17	0·08	—	—	—	—	—	—	—	—	—	—
+ 14	1·204	21·02	0·19	—	—	—	—	—	—	—	—	—	—
+ 16	1·003	46·71	5·88	—	—	—	—	—	—	—	—	—	—
+ 18	0·853	10·27	23·05	0·12	0·06	0·01	—	—	—	—	—	—	—
+ 22	0·699	1·02	49·32	5·18	0·06	0·02	—	—	—	—	—	—	—
+ 25	0·599	0·48	15·37	14·60	0·19	0·04	—	—	—	—	—	—	—
+ 30	0·500	—	4·78	44·17	5·31	0·14	0·02	—	—	—	—	—	—
+ 36	0·422	—	0·48	28·86	34·02	1·10	0·06	—	—	—	—	—	—
+ 44	0·353	—	0·10	4·39	36·83	12·41	0·31	0·02	—	—	—	—	—
+ 52	0·295	—	0·06	0·99	18·86	40·02	5·02	0·10	0·05	0·01	0·01	—	—
+ 60	0·251	—	0·09	0·43	3·29	33·31	26·80	0·98	0·16	Tr	Tr	Tr	0·02
+ 72	0·211	—	0·04	0·24	0·57	10·89	42·36	17·49	0·49	Tr	0·02	Tr	Tr
+ 85	0·178	—	0·07	0·26	0·19	1·68	19·75	47·61	9·32	0·39	0·16	0·01	Tr
+100	0·152	—	0·07	0·18	0·16	0·18	4·56	22·41	37·30	4·49	0·02	0·02	Tr
+120	0·124	—	0·06	0·12	0·10	0·08	0·90	9·76	34·42	39·39	3·51	0·08	0·01
+150	0·104	—	0·04	0·10	0·09	0·06	0·12	1·44	12·40	32·88	47·83	10·65	1·33
+170	0·089	—	0·32	0·36	0·27	0·06	0·04	0·13	3·74	11·50	25·16	34·59	11·54
+200	0·076	—	—	—	—	—	0·02	0·04	1·23	4·39	13·71	22·03	17·29
+240	0·066	—	—	—	—	—	0·04	0·02	0·81	1·46	7·06	20·08	32·10
+300	0·053	—	—	—	—	—	—	—	0·08	4·71	2·00	6·80	6·23
+325		—	—	—	—	—	—	—	—	0·64	0·25	3·52	20·80
+400		—	—	—	—	—	—	—	—	0·14	0·16	0·99	4·29
−400		—	—	—	—	—	—	—	—	—	0·11	1·23	6·39
Total		100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Distribution		0·30	0·90	2·93	9·18	11·12	13·23	13·32	17·35	20·64	4·08	4·92	2·03

CONCENTRATES FROM COMMINUTED ORES

The procedures for recovering gold by amalgamation from heavy mineral concentrates, such as those obtained from jigs, are too well known to call for comment here.

The use of a modern alluvial type jig (with its larger jigging area) on the Premier Mine may be the means of increasing the recovery of fine diamonds from a comminuted ore. The test work presents attractive scope for studying practical aspects of dealing with this type of concentrate.

In the case of jig concentrates from lead/zinc ores it is no longer essential to consider the separation of lead minerals from zinc minerals because the new smelting process described by Morgan[9] can effectively extract the lead and zinc separately from such mixed concentrates even when they contain appreciable quantities of copper minerals. The prospects of smelting some more or less self-fluxing middlings are also attractive. However, in some cases, as when germanium-rich magnetic bornite is present, some minerals separation processes with lead/zinc jig concentrates may still be attractive.

The possible extension of the use of jigs to the recovery of the sillimanite group of semi-heavy minerals from metamorphic rocks may present beneficiation problems which could be solved by processes now well established for dealing with heavier concentrates from alluvial deposits and decomposed granites.

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LIST OF REFERENCES

1. WILLIAMS, F. A. Recovery of fine alluvial cassiterite: Correlation of bore valuations with plant scale recovery. (*Trans. Instn. Min. Metall., Lond.*, 70, 1960-61. Paper Nov. 1960, Discussion Feb., 1961.)
2. WILLIAMS, F. A. Performance analyses of screens, hydrocyclones, jigs and tables used in recovering heavy accessory minerals from an intensely decomposed granite on the Jos. Plateau, Nigeria. (*Trans. Instn. Min. Metall., Lond.*, 67, 1957-58.)
3. WILLIAMS, F. A. Recovery of semi-heavy minerals in jigs (*Trans. Instn. Min. Metall., Lond.*, 68, 1958-59).
4. WILLIAMS, F. A. The identification and valuation of decomposed columbite-bearing granites. (*Trans. Instn. Min. Metall.*, 68, 1958-59.)
5. TAGGART, A. F. Elements of ore dressing (N.Y.: John Wiley and Sons; London: Chapman and Hall, 1951).
6. BANIEL, A. and MITZMAGER, A. Use and recovery of tetrabromoethane (TB[illegible]) in mineral dressing. (*Int. Min. Proc. Congr., Lond.*, April, 1960.)
7. HARRIS, J. H. Innovations in gravel pump treatment plant. (*Min. J.*, 252, 1959, Jan. 23, 93-5; Jan. 30, 116-8; Feb. 6, 146-7.)
8. JONES, G. H. and STONE, W. J. D. Wet Magnetic separator for feebly magnetic minerals. (*Int. Min. Proc. Congr., Lond.*, April, 1960.)
9. MORGAN, S. W. K. The production of zinc in a blast furnace. (*Trans. Inst. Min. Metall., Lond.*, 67, 1957-58.)
10. ADAMSON, R. J. Presidential Address. Some account of diamond winning practices in South Africa. (*Journ. S.Afr. Inst. Min. Metall.*, Vol. 60, No. 1, Aug., 1959.)
11. WILLIAMS, F. A. Use of high tension separation in dressing jig concentrate from decomposed columbite-bearing granite, Nigeria. (*Trans. Instn. Min. Metall., Lond.*, 69, 1959-60.)