Heavy-medium and gravity separation at Iscor's tin-ore and iron-ore mines*

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SYNOPSIS

The concentration of cassiterite at Iscor's Uis Mine is described, and information is given on aspects of the concentration of iron ore at Thabazimbi and Sishen Mines.

At Uis, a very low-grade tin ore is concentrated by three-stage jigging, spiral concentration, and tabling to give a high-grade concentrate with a recovery of 80 per cent of the tin. A low-grade tantalite-columbite concentrate is also produced. The possibility of recovering mica, the use of sluice boxes instead of spirals, and the recovery of cassiterite from minus 45 μm material are being investigated.

At the two iron-ore mines, heavy-medium separation is applied to size fractions larger than 0,5 mm. The types of ferrosilicon and the circuits used for the recovery of ferrosilicon from the various dilute-medium circuits are described.

The spiral-concentration plant being installed at Thabazimbi for the treatment of the minus 0,5 mm portion of the ore is described.

SAMEVATTING

Die konsentrasie van kassiteriet by Yskor se Uis-myn word beskryf en inligting word verstrek oor aspekte van die konsentrasie van ystererts by die Thabazimbi- en Sishen-myn.

By Uis word tinerts met 'n baie lae graad deur drietrapwipsifting, spiraalkonsentrasie en vlaktafelkonsentrasie gekonsentreer om 'n hoëgraadse konsentraat met 'n herwinning van 80 persent van die tin te gee. Daar word ook 'n laegraadse tantaliet-columbiet-konsentraat gelewer. Die moontlikheid om mika te herwin, die gebruik van sluiskaste in plaas van spirale, en die herwinning van kassiteriet uit materiaal kleiner as 45 μm word ondersoek.

Swaarmediumskeiding word by die twee ysterertsmyne op groottefraksies groter as 0,5 mm toegepas. Die soorte ferrosilikon en die kringe wat vir die herwinning van ferrosilikon uit die verskillende verdundemediumkringe gebruik word, word beskryf.

Die spiraalkonsentreeraanleg wat by Thabazimbi vir die behandeling van die gedeelte van die erts kleiner as 0,5 mm geïnstalleer word, word beskryf.

INTRODUCTION

Gravity separation is applied at Iscor's tin mine at Uis in South West Africa and at its iron-ore mine at Thabazimbi. Heavy-medium separation is used at Thabazimbi and at Iscor's other iron-ore mine, at Sishen.

This paper discusses the plant at Uis and provides information on some aspects of the processes applied at the two iron-ore mines.

UIS TIN MINE

The Orebody

The mine is located at the north-eastern extremity of a pegmatite-schist belt, about 30 km wide, stretching from Uis to the Atlantic coast near Cape Cross. Drilling has indicated deposits exceeding 30 m in thickness. At the current ratio of tin price to production cost, Uis has sufficient proven reserves to warrant exploitation well into the next century at the present production rate of about 100 t of concentrate per month. There are more than 100 individual pegmatite bodies at the mine. The black cassiterite, characterized by a reddish-brown to purple streak, occurs rarely in the form of recognizable crystals, and can range in size from very coarse grains of up to 25 mm down to tiny specks, with 60 per cent in the range 1 to 5 mm. Veins of iron and manganese oxides are often found, and in such areas increases of the Ta_2O_5 and Nb_2O_5 values occur.

The ore assays an average of 0,12 per cent tin. At the plant, a concentrate of 65 per cent tin is produced at a metal recovery of 80 per cent.

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Design Parameters

The plant design was based on the results of a six-month test operation with ore from various quarries in turn. The testwork was done at the jig plant that was already in operation when Iscor took over the mine. The information showed that

(1) the cassiterite was about 60 per cent liberated at a minus 5 mm crush;

(2) a further 20 to 30 per cent of the cassiterite was liberated by grinding to minus 1,5 mm;

(3) the cassiterite was extremely brittle, and excessive slimed cassiterite occurred in direct milling to minus 1,5 mm; initial extraction had therefore to be done after a 5 mm crush;

(4) the valuable minerals (cassiterite at a relative density of 7,2 and tantalite at 6,5) in a gangue of about 2,7 relative density indicated jigging of the plus 0,5 mm products and spiral treatment of the minus 0,5 mm products;

(5) the milling of the plus 0,5 mm tailings of the first concentration stage had to be done by a means that would give a minimum of fines, which indicated the use of a rod mill;

(6) jigs gave good extraction down to about 0,25 mm, but below this size the recovery decreased rapidly; it was therefore decided to screen at 0,5 mm before jigging and to treat the undersize by means of spirals;

(7) when the plant capacity was increased (in 1964), it was found feasible to double the capacity of the crushing section by increasing the product of the final crushers from 5 mm to about 10 mm, which reduced the 60 per cent of the concentrate extracted in the primary section to 40 per cent; when the existing crushers must be replaced in

future, or when plant extensions are carried out, the aim will again be to crush to 5 mm topsize, using cone crushers, before treatment in the primary section.

Description of the Plant

Crushing Section

The ore is crushed in three stages to minus 10 mm, the second and third crushing stages being in closed circuit. To increase flexibility, the product from each crushing stage is fed onto a surge stockpile.

Primary Jig Section (*Fig.* 1)

Crushed ore is fed onto a sloping screen ahead of the primary Yuba M8-8 jig at 110 t/h. The Yabu jig produces a product assaying about 1,5 per cent tin from the feed of 0,12 per cent tin. It is an eight-compartment jig with minus 12 mm plus 6 mm ferrosilicon ragging. Pieces of cassiterite too large to pass through the 4,5 by 4,5 mm opening screen are occasionally recovered manually from the ragging.

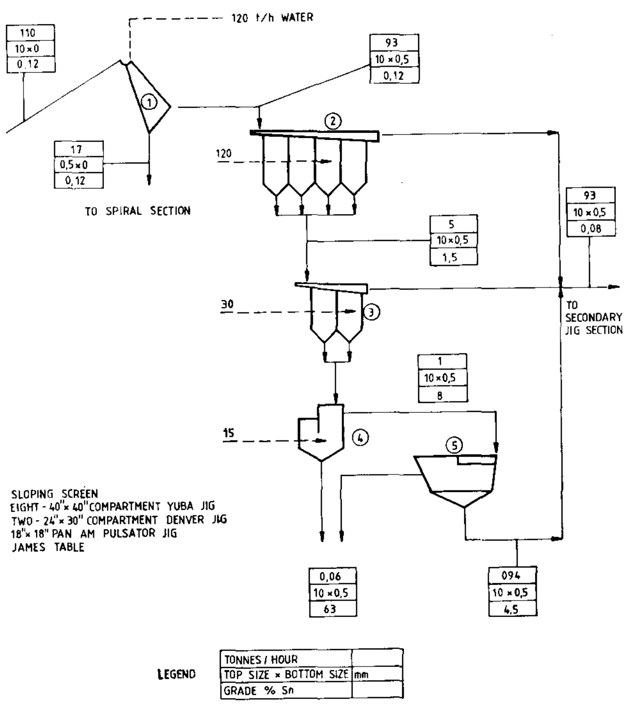

Fig. 1.—The primary jigging section at the Uis Mine

The Yuba product is upgraded to about 8 per cent tin in a 600 by 900 mm Denver Duplex jig fitted with a 4,5 by 4,5 mm screen and using minus 12 mm plus 6 mm ferrosilicon ragging.

The products of this jig are upgraded to 63 per cent tin by means of a Pan Am jig and a James table. The Pan Am is a 450 by 450 mm model, and the screen size and ragging are the same as for the preceding jigs. In practice it is found that the jig overflow, which goes to the James table, has a top size of about 2,5 mm. These concentrates constitute about 40 per cent of the total plant concentrate, 30 per cent being produced by the Pan Am and 10 per cent by the table.

The tailing of the primary jig section, now assaying 0,08 per cent tin, is passed on to the secondary jig section.

As mentioned above, the recovery in this section can be improved by reducing the topsize from the present 10 mm to 5 mm. The screening efficiency can be improved by replacing the sloping screens with vibrating screens, relieving the jigs from the burden of minus 0,5 mm material that cannot be recovered here in any case.

Secondary Jig Section (*Fig.* 2)

The feed is passed over a screen, where minus 1,5 mm material is removed and the oversize fed into a rod mill that is in closed circuit with the screen. The minus 1,5 mm underflow is passed onto a screen where minus 0,5 mm material is removed. The plus 0,5 mm material is fed to the secondary Yuba jig, where the grade is increased from 0,8 per cent to 2 per cent tin.

As before, this product is upgraded further in a Denver jig (to 5 per cent tin) and then in a combination of Pan Am jig and James table to 63 per cent tin. The tailings from the Denver jig and Pan Am jig are returned to the rod mill, while the tailing of the Yuba jig is discarded as waste at 0,03 per cent tin. About 15 per cent of the total concentrate is recovered in this section.

The jigs used in the secondary circuit are the same as those in the primary circuit, but the screen sizes are 2,5 by 2,5 mm throughout and the ragging employed is minus 15 mm plus 6 mm hamatite.

Again, screening of the feed to this section can be improved since some minus 0,5 mm tin, which could have been recovered in the spiral section, is lost in this tailing.

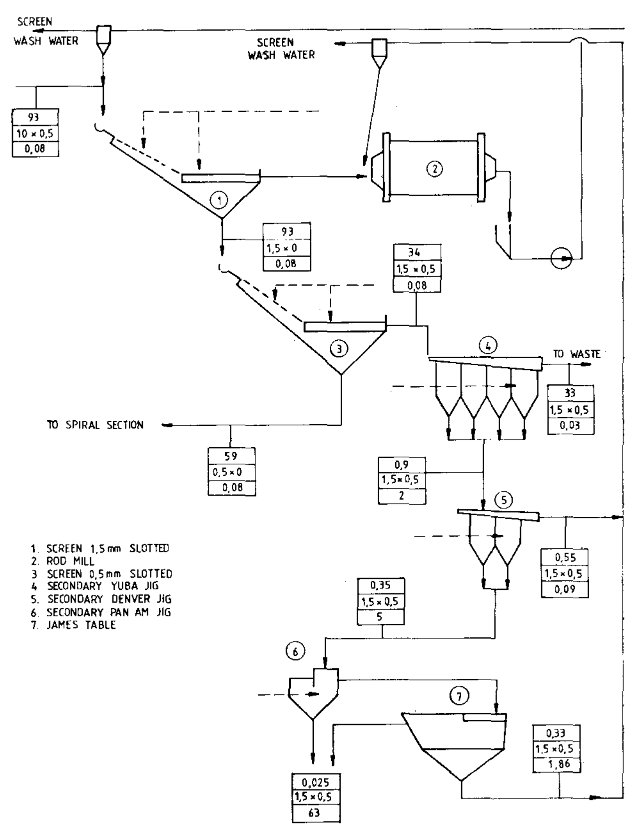

Fig. 2—The rod-milling and secondary jigging section at the Uis Mine

Spiral Section (*Fig.* 3)

The minus 0,5 mm material from the primary and secondary jig sections is deslimed at about 0,05 mm. The slimes, at 0,05 per cent tin, are thickened and pumped to the slimes dam.

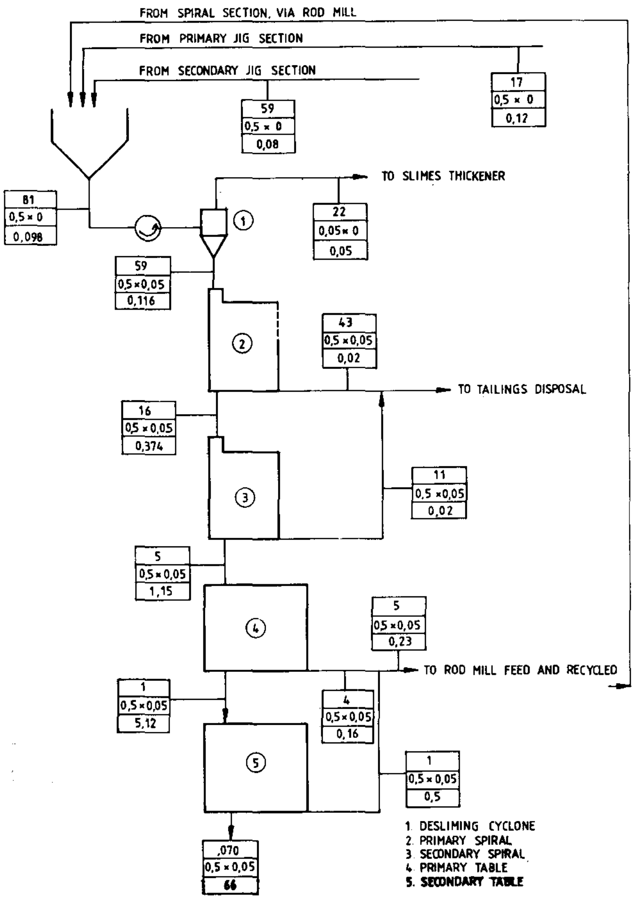

Fig. 3—The spiral section at the Uis Mine

The product of the 96 primary spirals assays about 0,4 per cent tin, and is further upgraded in the 48 secondary spirals to about 1,2 per cent tin. This product is cleaned by means of two tabling stages to 66 per cent tin.

At present, four types of spirals are used, but at least two of these are not suitable for the particular application at Uis and will be replaced.

Final Upgrading

All the minus 1,5 mm concentrates are passed through wet-drum magnetic separators to remove ferromagnetic material, which is discarded. The concentrate is dried and screened into four size fractions: the three minus 1 mm fractions are passed separately through a Rapid high-intensity magnetic-belt separator, and the non-magnetics, together with the plus 1 mm portion of the concentrates, are bagged as final concentrate.

The performance of the dry magnetic separator is not very satisfactory because the screening of the total feed into narrow size fractions ahead of the separator is cumbersome. Testwork with a wet high-intensity magnetic separator is under consideration to produce a crude magnetic concentrate of reduced bulk, which will then be fed to the Rapid.

The Rapid magnetics are treated with 30 per cent sulphuric acid, washed, re-tabled, and again passed through the Rapid. The non-magnetics are added to the tin concentrate, while the magnetics are marketed as a tantalite product (more than 16 per cent tantalite).

Distribution of Feed to the Spirals

When a fire destroyed the total spiral section last year, four types of spirals had to be bought without delay to get the plant back into operation. Since the plant may be extended in the future, it was decided to compare the performances of different spirals so that the best can be selected in future. These tests soon showed up the poor distribution of feed to the spiral banks and to individual spirals. Several improvements were made to the distributors. The effect of one such improvement shown in Fig. 4 is presented graphically in Fig. 5. The effectiveness of the improvement can be seen from Fig. 5, which shows the agreement of the particle-size analysis of the products from the modified distributor. A device that contributed a great deal to better distribution was the so-called 'scroll' feeder developed by Van der Spuy for use with Reichert cones at Palabora Mining Company. Placed at the end of a supply line to a distributor it induces a swirling, mixing action in the slurry.

Comparison of Spirals

When satisfactory distribution had been achieved, tests showed that two types of spirals should be removed as they were not suitable for that particular application while, of the remaining two, only one would be selected for future installation.

Of the four types of spirals tested, two were slightly different models from the same manufacturer, the difference lying in the radial distance of the product-extraction ports from the central column. Both models employed wash water. The model with ports closer to the column was rejected.

Of the other two types, from different manufacturers, one was conventional with extraction ports in each turn and employing wash water, whereas the other was a spiral sluice having product cutters fitted only at the

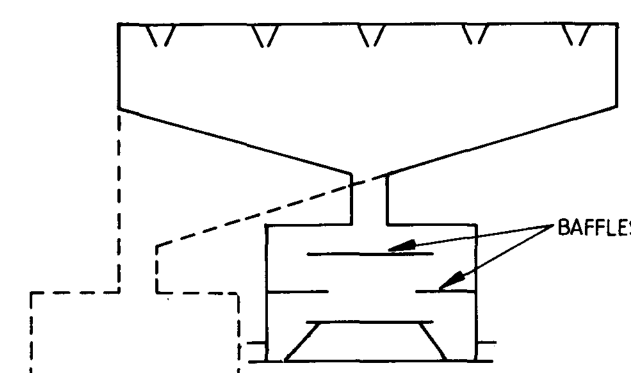

Fig. 4—The modified primary collector box and distributor (the broken line shows the original design)

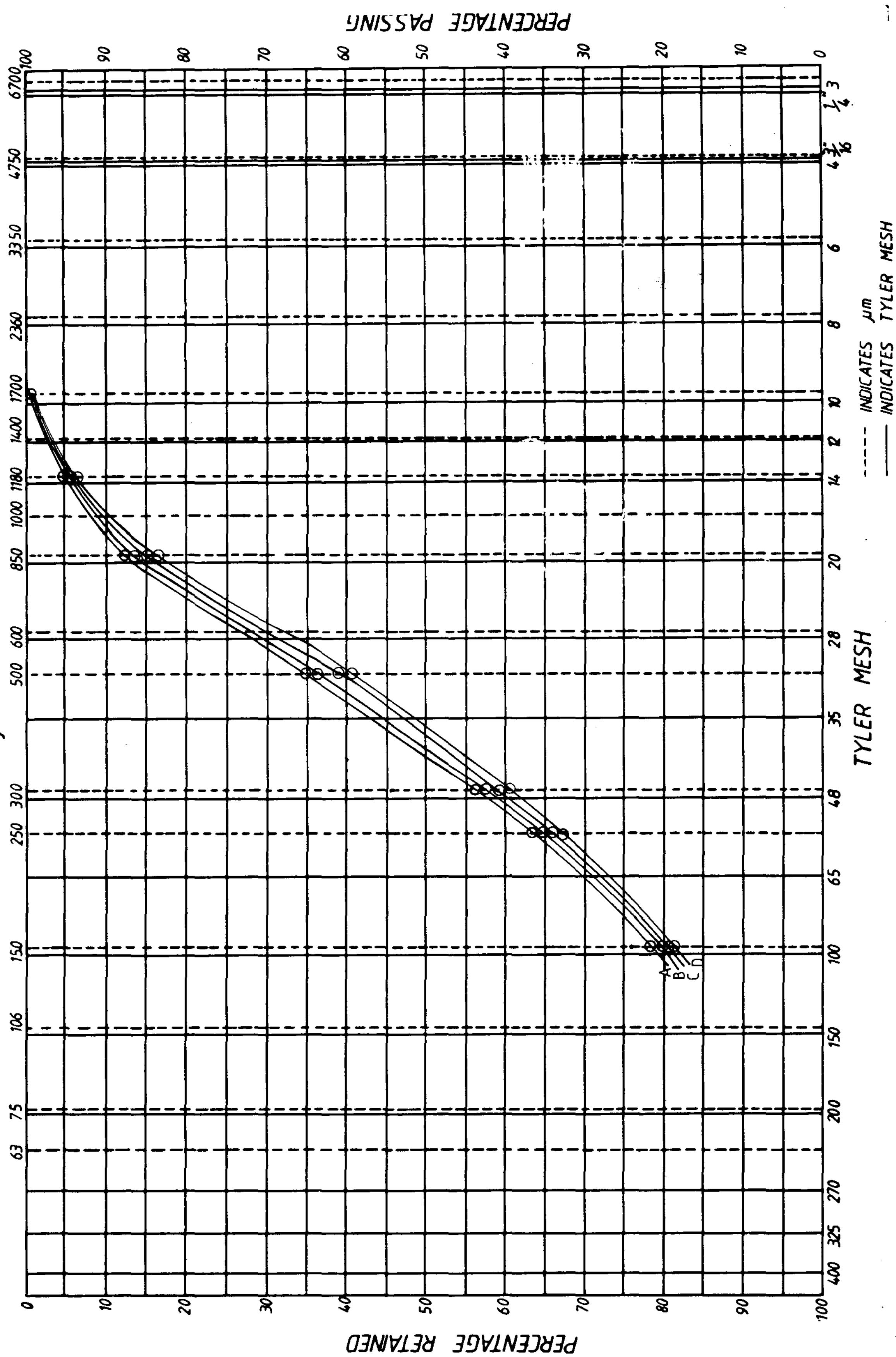

Fig. 5—The size grading of the feed to the secondary distributors after modification of the primary collector box and distributor

bottom of the spiral and not employing wash water. The conventional spiral was rejected since, although very high mineral recoveries were achieved, the upgrading ratios (concentrate assay: feed assay) were poor, ranging from 1,1 to 2,4, the higher value being possible only at excessively high additions of wash water. Clearly, the conventional spiral is more suitable for high-grade feed.

With the feed solids varying between 22 and 40 per cent and the tin in the feed varying between 0,09 and 0,17 per cent, the spiral sluice and the other conventional spiral yielded very similar metallurgical results, with upgrading ratios between 3 and 5,6 and mineral recoveries in the range 80 to 90 per cent.

Since the spiral sluice has certain operational advantages, this type of concentrator will be installed in future.

Possible Future Developments

The pegmatite contains about 10 per cent mica, which is liberated only after rod milling. It has been proved that the mica can be recovered by means of froth flotation, but the cost is prohibitive. However, it has been noticed that most of the mica is carried with the excess water at the outside edge of the spiral, and tests are being conducted on the recovery of this mica by use of an extra cutter in this position.

After the fire last year, a number of sluice boxes were obtained, and these will be tested alongside the primary spirals.

Tests were done with a Bartles–Mozely table to recover a concentrate from the minus 0,05 mm slimes, but the results were very poor. Further tests are being done with the coarser fraction of the slimes on a smooth-deck table.

Discussion

Considering the very low grade of the feed ore at Uis, the 80 per cent recovery achieved is good. A small improvement can be made in the recovery by crushing ahead of the plant to 5 mm instead of 10 mm, improving the screening efficiency, and replacing the spirals not suitable for the application.

An important lesson that has been learnt is that a particular application can demand a particular spiral, and it is encouraging to note that several manufacturers are now offering ranges of spirals with different profiles, pitches, and means of collecting products, as well as with and without the addition of wash water.

THABAZIMBI AND SISHEN IRON-ORE MINES

At both Thabazimbi and Sishen, heavy-medium separation is done only on the plus 0,5 mm size fractions. Up to the present, the minus 0,5 mm material at Thabazimbi has been added to the final ore product untreated, while at Sishen some of this material is discarded as waste. However, these practices lead to considerable fluctuations in the quality of sinter ore produced at Thabazimbi and to the loss of fairly high-grade fine ore at Sishen.

Gravity Separation

Tests with spirals on the minus 0,5 mm material showed acceptable results, while high-intensity wet-magnetic separation gave even better results. In the

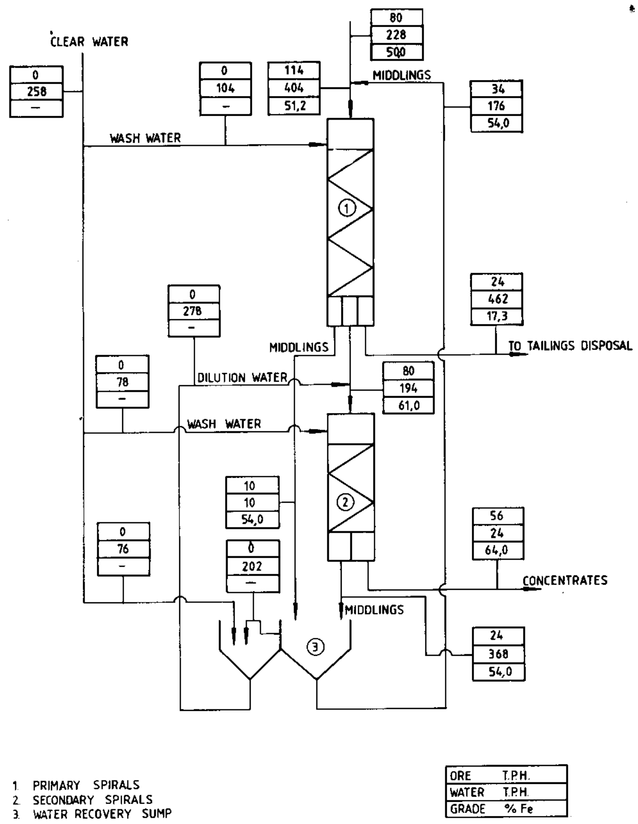

Fig. 6—The fine-ore beneficiation plant at Thabazimbi Mine—the spiral section from the feed-preparation screens

feasibility study done for the Thabazimbi material, spiral treatment was indicated, mainly because of the lower installation cost.

Vickers spirals were installed and the plant is now being commissioned (Fig. 6). A big problem was again posed by uneven distribution, even though this was given special attention during the design stage.

Heavy-medium Separation

The use of heavy-medium separation in the processing of iron ore at Iscor has been described elsewhere[1]. In that paper, the loss of medium due to the blinding of screen cloth was mentioned as a major problem, and it was mentioned that a polyurethane screen cloth under test at that time appeared to be promising. This material has, indeed, turned out to be of immense value and is now used extensively at both Iscor mines. The consumption of ferrosilicon at Sishen is now as low as 0,08 kg per ton of feed ore in the drum plants, and 0,20 kg/t in the cyclone plants. However, there are problems with bacterial attack on this material at Sishen, and this problem is now being investigated.

Dilute-medium Circuits

Thabazimbi Drum Plant

Fig. 7 illustrates the dilute-medium circuit at Thabazimbi drum plant. Dilute medium is flocculated magnetically and settled in a hydroseparator, and the thickened product is pumped to two-stage magnetic recovery, with densification in a spiral densifier. The medium is

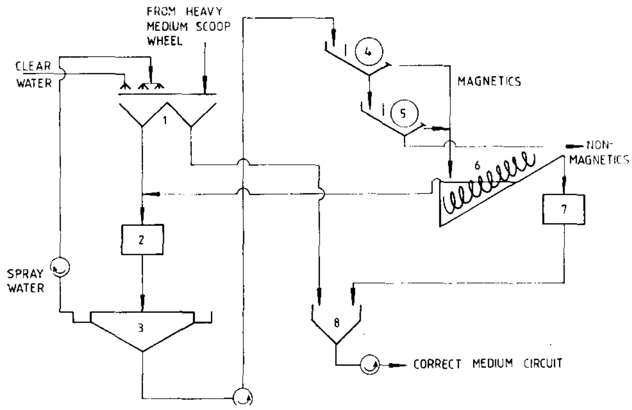

Fig. 7—The dilute-medium circuit of the heavy-medium separation plant (coarse ore) at Thabazimbi Mine

1. **Drain and rinse screens**
2. **Magnetizer**
3. **Hydroseparator**
4. **Primary drum magnetic separator**
5. **Secondary drum magnetic separator**
6. **Spiral densifier**
7. **Demagnetizer**
8. **Correct-medium sump**

demagnetized before being returned to the correct medium circuit.

Cyclone Plants, and the Drum Plant at Sishen North

Fig. 8 illustrates the dilute-medium circuit in the fine-ore beneficiation plant at Thabazimbi. This basic design was also used for the drum plant at Sishen North. Dilute medium is pumped to several primary magnetic separators; the underflow is thickened by means of cyclones, and this underflow is fed to a single secondary magnetic separator. Densification is done by means of centrifugal densifiers. The medium is demagnetized before being returned to the correct medium circuit.

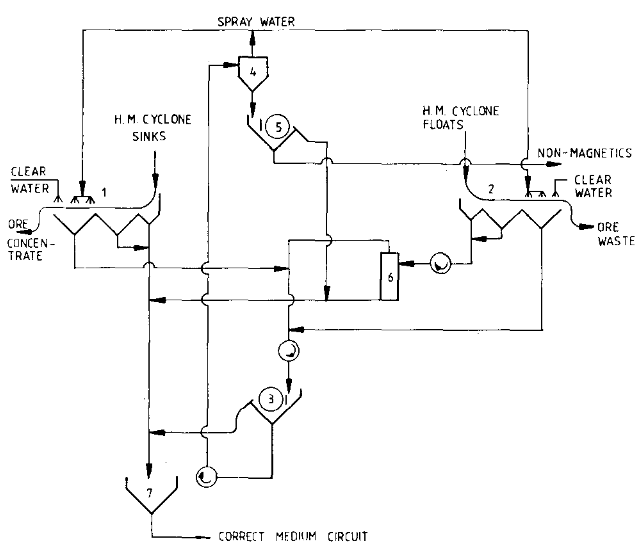

Fig. 8—The dilute-medium section of the fine-ore beneficiation plant at Thabazimbi Mine

1. **Concentrate drain and rinse screen**
2. **Waste drain and rinse screen**
3. **Primary drum magnetic separators**
4. **Spray-water recovery cyclones**
5. **Secondary drum magnetic separators**
6. **Centrifugal densifiers**
7. **Correct-medium sump**

Drum Plant at Sishen South

The Sishen South drum plant (Fig. 9) has a combination of the above two systems. Dilute medium is fed to several primary magnetic separators, and the tailing is thickened in cyclones, of which the underflow is passed through a single secondary magnetic separator. The densification is done by means of a spiral densifier.

A centrifugal densifier is fed from the correct medium tank. Originally the idea was to use this densifier as a classifier to bleed off superfine ferrosilicon, which would then be pumped to the cyclone-plant circuits. This

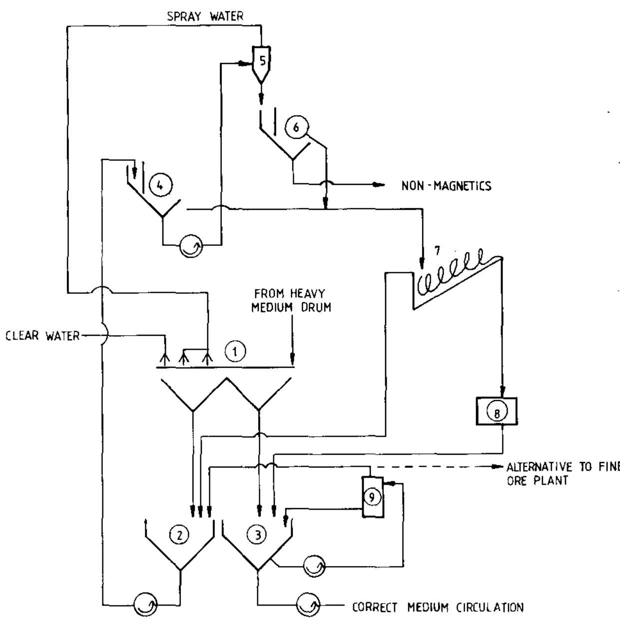

Fig. 9—The dilute-medium circuit of the heavy-medium separation plant (coarse-ore) at Sishen Mine, South Plant

1. **Drain and rinse screens**
2. **Dilute-medium sump**
3. **Correct-medium sump**
4. **Primary drum magnetic cyclone**
5. **Spray-water recovery cyclone**
6. **Secondary drum magnetic separators**
7. **Spiral densifier**
8. **Demagnetizer**
9. **Centrifugal densifier**

densifier is also now used for the removal of iron-ore slimes from the circulating medium. In this case, the overflow of the centrifugal densifier is fed to the dilute-medium circuit.

Types of Ferrosilicon

Coarse Atomized Ferrosilicon

Thabazimbi drum plant has to separate at relative densities of up to 3,8, and the best quality of ferrosilicon available has to be used so that viscosity problems are avoided.

At Sishen, the same material is used in the drum-plant sections, but in this case the minus 45 μm content of the medium is reduced from the normal 40 per cent to about 30 per cent. Because of the very low ferrosilicon losses at Sishen, the medium stays in the circuits for a long time, and the ferrosilicon is worn down until the average particle size becomes so small that viscosity problems are experienced. The reduced amount of minus 45 μm particles in the makeup medium counteracts this, and provision is also made to bleed off superfine medium from the circuits.

Cyclone 60 Ferrosilicon

This ferrosilicon is used in the cyclone-plant circuits of both mines, although it may appear to be too coarse for the circuit at Thabazimbi. With a circulating-medium density of 3,1 g/cm^3, the cutpoint is about 4,0 g/cm^3. In spite of this large differential, a very efficient separation is achieved.

Efficiency of Separation

With iron ore it is not possible to do a sink–float analysis of the plant products because of the non-existence of suitable heavy liquids. An excellent solution to this problem is the classification of a number of ore pieces into different relative density intervals and the painting of the particles in different colours according to their classification. Whenever the performance of a heavy-medium drum separator is suspect, the feed is stopped, and the coloured ore particles are fed into the separator and recovered at the product screens. Iscor is now looking into the possiblility of manufacturing such coloured particles with different relative densities from polyurethane loaded with ferrosilicon.

CONCLUSION

Metallurgists working at these plants face a constant challenge to carry out Iscor's policy of continuous improvement of the beneficiation processes. At the older plants, new developments have to be considered, while the new plants often require adjustment before the most-efficient operation is achieved.

ACKNOWLEDGEMENTS

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REFERENCE

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Wind-energy systems

The Fourth International Symposium on Wind Energy Systems, organized by BHRA Fluid Engineering, in conjunction with the National Swedish Board for Energy Source Development, will be held in Stockholm, Sweden, from 21st to 24th September, 1982.

Among the renewable sources of energy currently receiving attention, wind-energy systems are the first to approach commercial viability. The rapid increase in the price of fossil fuels, which seems certain to be maintained as resources are depleted, and rapid technological advances have encouraged the United States Government to launch an eight-year development programme, which is already bringing costs down sharply. By 1983, wind power is likely to be cost effective in the windier regions of the United States. In a number of other countries that include Great Britain, Japan, Denmark, and Sweden, commercial arguments for wind power exist, and much research effort is being directed towards the development of large aerogenerators capable of generating electricity at a constant voltage and frequency. The latest in a successful series, the Symposium will provide a unique opportunity for delegates to discuss new ideas and developments in wind energy systems.

The official language of the Symposium will be English, and all the papers will be printed in English.

All enquiries should be addressed to Symposium Organizer, 4th Wind Energy, BHRA Fluid Engineering, Cranfield, Bedford MK43 OAJ, England. Tel: (0234) 750422. Telex: 825059 BHRA G.

Metal forming and machinery

A seminar on efficient metal forming and machining will be held in Pretoria on 16th November, 1982. The seminar is being organized by the South African Institute for Production Engineering and the Council for Scientific and Industrial Research.

Papers will be presented by speakers from America, England, Germany, Israel, and South Africa on the following topics:

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