Note: An electric tin smelter for the processing of low-grade tin concentrates in South Africa

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Gold Fields of South Africa Limited is the largest producer of tin in the form of concentrates in South Africa, more than 55 per cent of the South African tin production being produced by the tin mines of the Group. Most of these concentrates are exported to be custom-smelted in overseas smelters, but the modern tendency is for tin-mining countries to establish their own smelters. Smelting charges, shipping costs, and other expenses have soared and are still increasing at alarming rates.

The establishment of a smelter capable of treating all grades of concentrates in South Africa as part of the operations at the Rooiberg Minerals Development Company, the largest tin mine of the Group, therefore appeared to be the obvious route to follow. A preliminary feasibility study showed that such a project could be economically viable. A programme was consequently launched to investigate all the aspects associated with the erection of a smelter with a capacity sufficient to process not only the concentrates produced by the Gold Fields mines but, should it become necessary, the entire South African production (Table I).

TABLE I

PRODUCTION OF TIN IN CONCENTRATES IN SOUTH AFRICA

Producer		Tin metal, t
Gold Fields Mines	Rooiberg Minerals	2000
	Union tin mines	300
	Brandberg West	120
		2420
Other producers	Kamativi	
	Uis	
	Zaaiplaats	
		1970
	TOTAL	4390

The existence of bronze can be traced back to 3500 B.C. The ancient workings in the vicinity of the Rooiberg Mine yielded more than 2000 tons of tin metal and it has been estimated that the workings could date back from 500 to 1000 years. The start of the traditional two-stage reductive smelting process of today dates back as early as the 16th century. Yet, in spite of the long history of tin smelting, the production of tin metal from medium- and low-grade concentrates remains a metallurgical problem. Large quantities of iron are usually present, and its separation from the tin is the most difficult problem in the smelting of tin concentrates.

Tin mineralization in the areas of the Gold Fields mines occurs in quartzites, the predominating minerals being cassiterite, magnetite, hematite, pyrite, and chalcopyrite. Arsenic, antimony, bismuth, lead, cobalt, and nickel minerals also occur, and the presence of any of these impurities in the concentrate affects the process design. The gangue consists of ankerite, quartz and orthoclase.

The ores are upgraded into concentrates, classified as low grade (20 to 45 per cent Sn), medium grade (50 to 60 per cent Sn), and high grade (60 to 66 per cent Sn), in the various tin-dressing plants operated by the Group. Typical analyses of five of these products are given in Table II, from which the high iron content is immediately obvious.

TABLE II

ANALYSES OF FIVE GOLD FIELDS TIN CONCENTRATES

Constituent	High grade %	Medium grade %	Low grade %	Medium grade %	Low grade %
Sn	64,71	57,30	32,20	50,04	30,39
Fe_2O_3	3,82	13,56	22,73	13,64	24,46
FeO	4,09	2,89	2,68	4,26	0,26
SiO_2	3,25	4,32	6,39	9,92	18,23
S	2,79	0,81	5,68	1,58	2,39
Al_2O_3	1,53	1,53	3,59	4,97	9,56
TiO_2	1,45	2,85	8,81	0,43	2,85
MgO	0,57	0,48	2,55	0,57	1,15
CaO	0,56	0,70	0,53	0,38	0,34
Pb	0,05	0,01	0,03	0,23	0,27
Zn	0,01	0,01	0,01	0,03	0,08
Cd	0,01	0,01	0,01	0,01	0,01
Ni	0,01	0,01	0,03	0,01	0,01
Cu	0,07	0,06	0,35	0,18	1,50
Mn	0,08	0,08	0,21	0,08	0,16
As	0,02	0,01	0,08	0,11	0,36
Sb	0,01	0,01	0,01	0,01	0,01
Bi	0,01	0,01	0,01	0,01	0,01

The tin-smelting industry makes widespread use of blast and reverberatory furnaces. Very few electric furnaces are in operation, and all of these treat high-grade concentrates, very little being known about the application of this type of furnace to the smelting of low-grade tin concentrates.

A comparative study of the three types of furnace highlighted the following as possible advantages of the electric furnace in tin smelting:

- the availability of relatively cheap energy,
- smaller space occupied,
- flexibility
- higher temperatures available,
- favourable metallurgical conditions, and
- lower operating cost.

It was therefore decided to use a submerged-arc furnace in laboratory-scale tests, with the aim of ultimately using electric furnaces in a full-scale plant.

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Roasting and smelting tests are being conducted to determine the technical feasibility of a tin smelter treating mixtures of low-medium-grade and high-grade concentrates, a 65 kVA submerged-arc furnace being used for the smelting tests. Theoretical metal and mass balances for the smelting circuit were calculated by computer on a programme that was prepared by use of the Wright[1] mathematical model for the tin circuit. The results of the tests so far have been promising.

The presence of significant quantities of impurities in the concentrates makes it necessary to roast the material before smelting and to refine the crude metal after smelting. Impurities such as sulphides, arsenic, and small amounts of lead and bismuth are removed during the preliminary roasting stage, which is carried out in three steps: under reducing, oxidizing, and chloridizing conditions.

Smelting of the roasted concentrate is difficult because of the high iron content. The stannic and ferric oxides formed during roasting are readily reduced during smelting, but the reactions must be carefully controlled so that crude metal with a low iron content is formed during the first-stage smelt. A low tin content in the slag from the second-stage smelt is aimed for, thus producing final slag and hardhead.

The latter is circulated back to the first-stage smelt, there being a practical limit to the load of hardhead that can be circulated. As the tin content of the concentrate decreases, the amount of iron to be circulated and the volume of final slag increase. Iron going into the circuit must equal the iron leaving the circuit, and, to maintain this balance, the mass of final slag could become unpractical.

The procedure for the refining of the crude tin depends on the purity required. To obtain an end product with a tin content of not less than 99,85 per cent, dry refining would normally suffice. An electrolysis step may have to be included if higher purities are demanded. A reduction of the iron content to less than 0,01 per cent is achieved by liquidation and centrifuging of the crude metal directly after tapping, the dross thus formed being recirculated.

The copper, arsenic, antimony, and lead are removed by thermal refining in externally heated, mechanically stirred kettles. The step addition of sulphur, zinc, and chlorine gas is necessary.

In conclusion, it is worth mentioning that it is our duty to exploit our mineral and metal wealth to the maximum advantage of the country. One step in this direction is to treat our ores, concentrates, and minerals locally. A tin smelter capable of treating all the tin concentrates produced in South Africa would be justified, not only because of the financial benefit to the Gold Fields Group, but also because of the benefits to the country as a whole. Apart from the fact that the Republic would become independent by producing its own requirements of tin metal, it could become an exporter of tin, making considerable savings in foreign exchange and providing new labour opportunities.

It is hoped that the Rooiberg tin smelter will achieve this goal in the near future by producing pure tin metal for both the local and the export market.

Reference

1. Wright, P. A. Optimization of the standard tin smelting circuit. I.M.M. Symposium, 1971.