SEPARATION OF WARINGIN HEAVY MINERAL SANDS FROM CENTRAL KALIMANTAN

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ABSTRACT

Central Kalimantan has grown rapidly as a heavy mineral producer. Zircon is the main mineral concentrate, but other valuable heavy minerals are present. With particular interest in the upgrading of zircon and its recovery, tekMIRA's laboratory has developed beneficiation steps of heavy minerals to produce marketable zircon concentrate. Using a series of concentration equipments that includes spiral concentrator, shaking table, magnetic separator and electrostatic separator; the content of zircon in the end concentrate reaches up to 65% ZrO_2.

Keywords: heavy minerals, zircon sand, beneficiation, zircon concentrate

INTRODUCTION

During the past 10 years, Central Kalimantan has emerged as the major producer of heavy mineral sands. However, there is no official record of the quantity as well as the quality of zircon products, rutile and ilmenite, which were mainly collected as by product of abandon alluvial gold mines or panning product of artisanal gold mines.

Heavy minerals are also commonly produce by tin mines in Bangka Island, typical minerals includes zircon can be found in tailings (Soepriyanto et al., 2005) as shown in Figure 1. The flowsheet of tinshed of PT Koba Tin (Figure 2) shows that tin concentrate as main product, while ilmenite and monazite as the by products. Few more minerals can also be successfully separated from tin ore (Pramusanto and Fadli, 2006). Instead of tin, the heavy minerals from various sites in Kalimantan also contains gold.

More recently (Pramusanto et al., 2009), a series of tests using Shaking Table, Magnetic Separator and High Tension Separator on the treatment of zircon sand samples of Katingan, Central Kalimantan, has been succesfully concentrated to produce premium grade concentrate that is suitable for feed in the zirconia smelting. Raw zircon sand contains 35.38% ZrO_2, 0.85% HfO_2, 44.76% SiO_2 and 13.99% TiO_2 can be upgraded to yield a concentrate of 68.75% (ZrO_2 + HfO_2), 0.62% Fe_2O_3, 22.93% SiO_2 and 0.15% TiO_2. The concentrate obtained has been fully fulfiled as feed materials in the zirconia preparation with minimum specification 65% (ZrO_2 + HfO_2), and total impurities (TiO_2 + Fe_2O_3) are less than 1% (Consolidated Rutile Limited, 2005; Porter, 2009). Furthermore, the consumption of zircon sand in the zirconium industry in China will reach 630,000 tonnes by 2015 (current estimated at 400,000 tonnes from global consumption of 1.2 million tonnes) (Porter, 2009). On the other hand, Indonesian zircon as

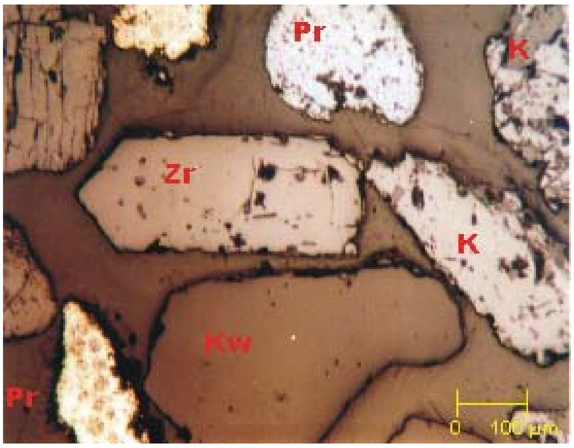

Figure 1. Minerals of zircon (Zr), quartz (Kw), pyrite (Pr), cassiterite (K) in tailings of tin mines in Bangka

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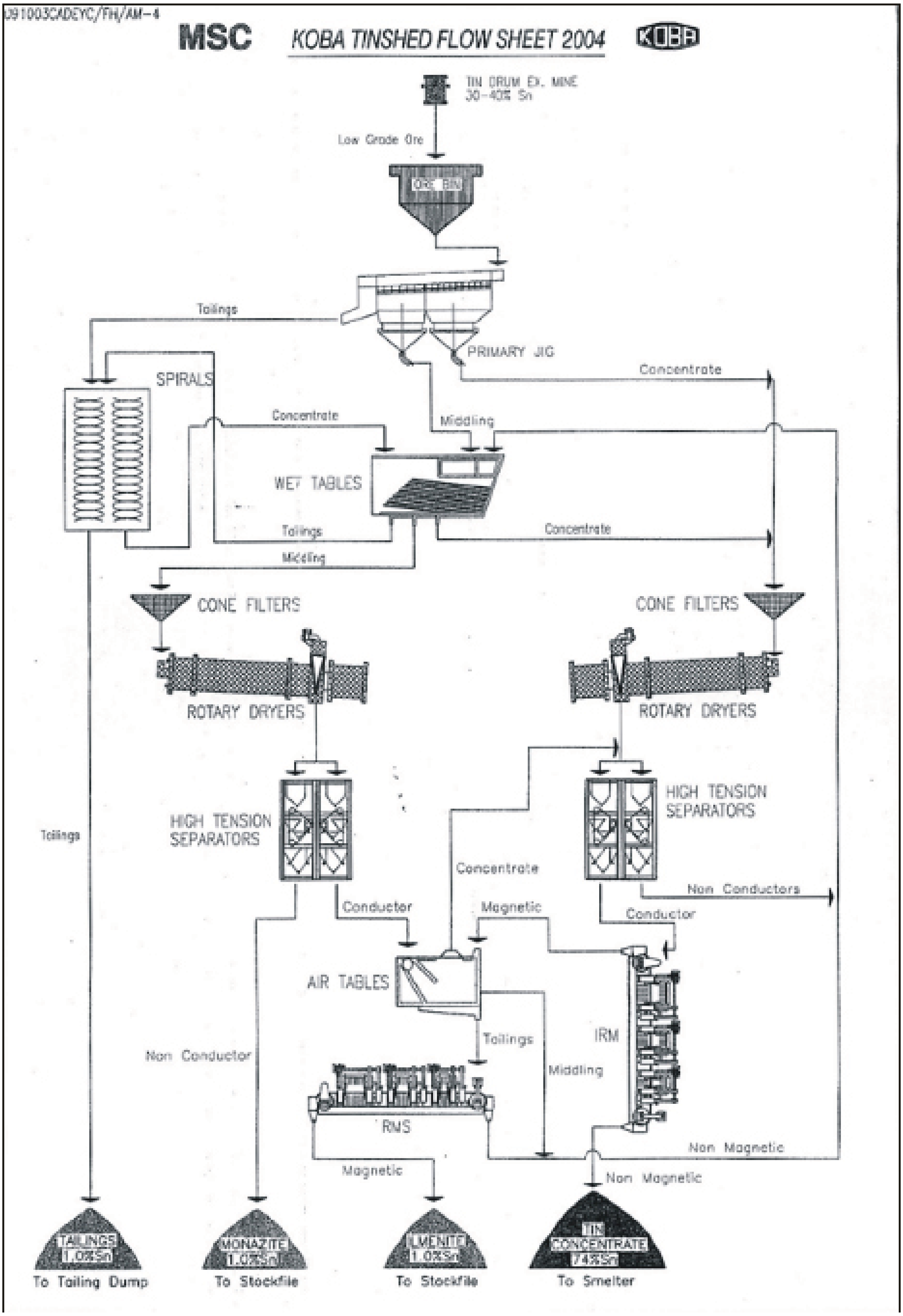


Figure 2. A flowsheet of Koba tinshed, Bangka (Pramusanto and Fadli, 2006)

exported commodity was rapidly decreasing due to lack of development of advanced recovery technology to produce minerals to be used in a modern society.

The implemention of Mining Law No.4 / 2009 with the obligation to upgrade the mining product prior to be exported, would become a good opportunity for the local producer to get added values of their mining products (Parson, 2009). Due to the local producer is lacks experience in treating various heavy mineral sands, more information is required by the local government regarding processing development of their resources in terms of gaining more valuable commodities. Therefore, it is essential for a research institution to conduct a programs related to the added value of the resources. In this case, it belongs to the recovery of zircon mineral.

EXPERIMENTAL

Raw Material

The samples of raw zircon were originally obtained from West Waringin, Central Kalimantan, which contains 39.91% ZrO_2, 0.948% HfO_2, 43.33% SiO_2 and 9.51% TiO_2. A high content of zircon indicates that the samples have been pre-concentrated by either panning or as tailing product of alluvial gold mining.

Procedure

The samples were upgraded by a series of laboratory tests by combining gravity concentration, high gradient magnetic separator and electrostatic separator. Two different routes of concentration methods were conducted as shown in Figure 3. The first route was a combination of shaking table with high gradient magnetic separator (HGMS) and electrostatic separator. In the second route, the HGMS was omitted in the process, where dried final concentrate of shaking table was directly fed into electrostatic separation. Chemical analyses of raw zircon and the zircon concentrate were conducted by XRF method.

Existing Plant Grades and Recoveries

There are wide variations in the composition of the heavy mineral fractions of the material being mined from different orebodies and mining grades, that expressed as percentages of total heavy mineral, without further qualification have no valuable meaning. Rutile and zircon for examples, are essential economic component of the heavy mineral mined and the average feed grade of all operating plant between 0.3 and 0.4 percent of each of the minerals (Canning, 1980; www.wipo.int/pctdb/en/wo).

Metallurgical recoveries from the concentrating plants can be expressed in term of total heavy minerals, but due to wide variation in specific gravity of various mineral components, these figures are only useful as a comparative guide for the operators on the particular plant. Zircon recovery is usually 2 to 3 percent higher than rutile recovery. The average rutile-zircon metallurgical grade from this type of concentrating plant is normally in excess of 85 percent [Canning, 1980]. In these laboratory tests, the particular interest is in the zircon upgrading and its recovery. The available data will be used as basic information in the future plant design.

Sequences of experiment conducted includes: (a) chemical analysis of raw zircon and beneficiation products, (b) rougher concentration by shaking table, (c) cleaner concentration of cleaner concentrate using high gradient magnetic separator and electrostatic separator, (d) removing of TiO_2 in cleaner concentrate by passing of dried feed to electrostatic separator and (e) scavenging concentration by combining shaking table and high gradient magnetic separator processes.

RESULTS AND DISCUSSION

Sample Characterization

Result of XRF analysis on raw zircon is shown in Table 1.

Table 1. Chemical compositions of raw zircon

No.	Compositions	%
1.	ZrO_2	39.91
2.	HfO_2	0.948
3.	SiO_2	43.33
4.	TiO_2	9.51

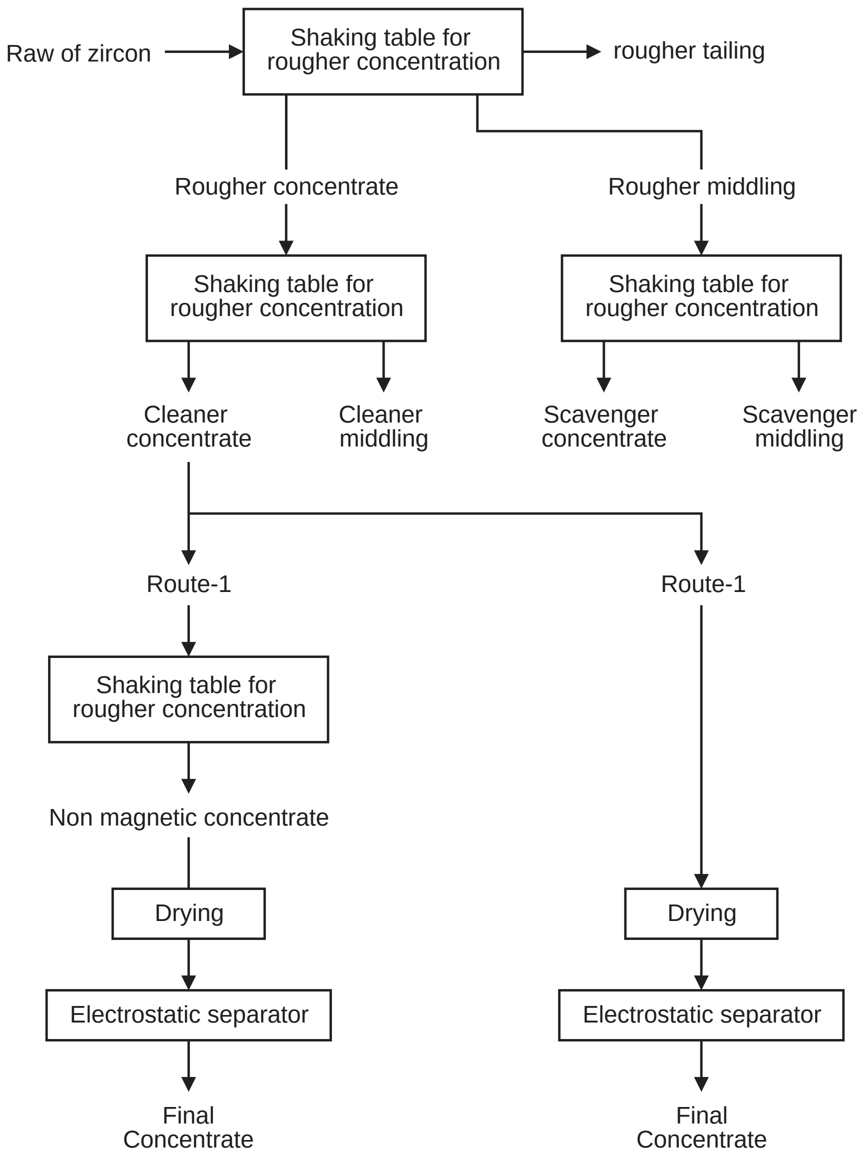


Figure 3. A Flowsheet of concentrations routes on Waringin's zircon

As the source of zirconium, hafnium and thorium (Macdonald Encyclopedia, 1991), the zircon structure can be destroyed by radioactive elements both thorium and uranium, that substitute for up to 4% of the zirconium. Furthermore, it might also contains up to 20% hafnium, then named as hafnon. However, in this case, no attempt had been made to observe the structure as well as the morphology of the ore more deeply using such as Scanning Electron Microscope equipped with an Energy Dispersive X-ray Spectroscope (SEM-EDS), which is beyond the scope of this work. The following important data of zircon obtained from mineral references being used in the grade and recovery calculation.

Chemical Formula	:	$ZrSiO_4$ (zirconium silicate)		
Composition	:	Molecular weight = 183.31		
		Zirconium	49.77 % Zr	67.22% ZrO_2
		Silicon	15.32 % Si	32.78% SiO_2
		Oxygen	34.91 % O	+
			100.00 %,	100.00 %
			= TOTAL OXIDE	

By calculation, pure zircon silicate contains ZrO_2 as much as 67.22% and SiO_2 as much as 32.78% . Then, in the raw zircon contains (43.33%-32.78%) = 10.55% of SiO_2 that would be removed through such Gravity, Magnetic and Electrostatic separation.

Up Grading Results

Rougher concentration by Shaking Table

Concentration using a shaking table shows that the zircon content raises from 39.91% ZrO_2 up to 60.24% ZrO_2, and SiO_2 can be removed from 43.33% down to 27.26%. This indicates that the free silica content in the concentrate has completely removed. Since TiO_2 decreases from 9.51% down to 6.69%, the HfO_2 content increases from 0.95% up to 1.25%. The content of ZrO_2 is always accompanied by HfO_2 within concentrate, as a substitution of hafnium in the zircon structure. Recovery of ZrO_2 in rougher step is 44.22% and the mass of concentrate is 29.29%.

Middling from the rougher step contains 17.54% of mass weight performing grade of 54.73% ZrO_2, 1.3% HfO_2, 30.2% SiO_2 and 9.24% TiO_2. However, the tailing contains 53.17% of mass weight, with grade 23.80% ZrO_2, 0.73% HfO_2, 56.52% SiO_2 and 11.34% TiO_2. Material balances of rougher step can be shown in Figure 4.

Cleaner concentration by Shaking Table

Using a Shaking Table for cleaning over rougher concentrate, the zircon content raises from 60.24% ZrO_2 up to 62.12% ZrO_2, SiO_2 removes from 27.26% to 26.27%. TiO_2 decrease from 6.69% down to 4.45%. Since HfO_2 as a substitution in the ZrO_2 structure, the content of HfO_2 rises up from 1.25% to 1.27%. Recovery of ZrO_2 in cleaner step is 50.94%. Mass of concentrate is 14.46%.

Middling of cleaner step contains 14.83% of weight, 58.37% ZrO_2, 1.23% HfO_2, 28.23% SiO_2 and 8.87% TiO_2. Material balances of cleaner step can be shown in Figure 5.

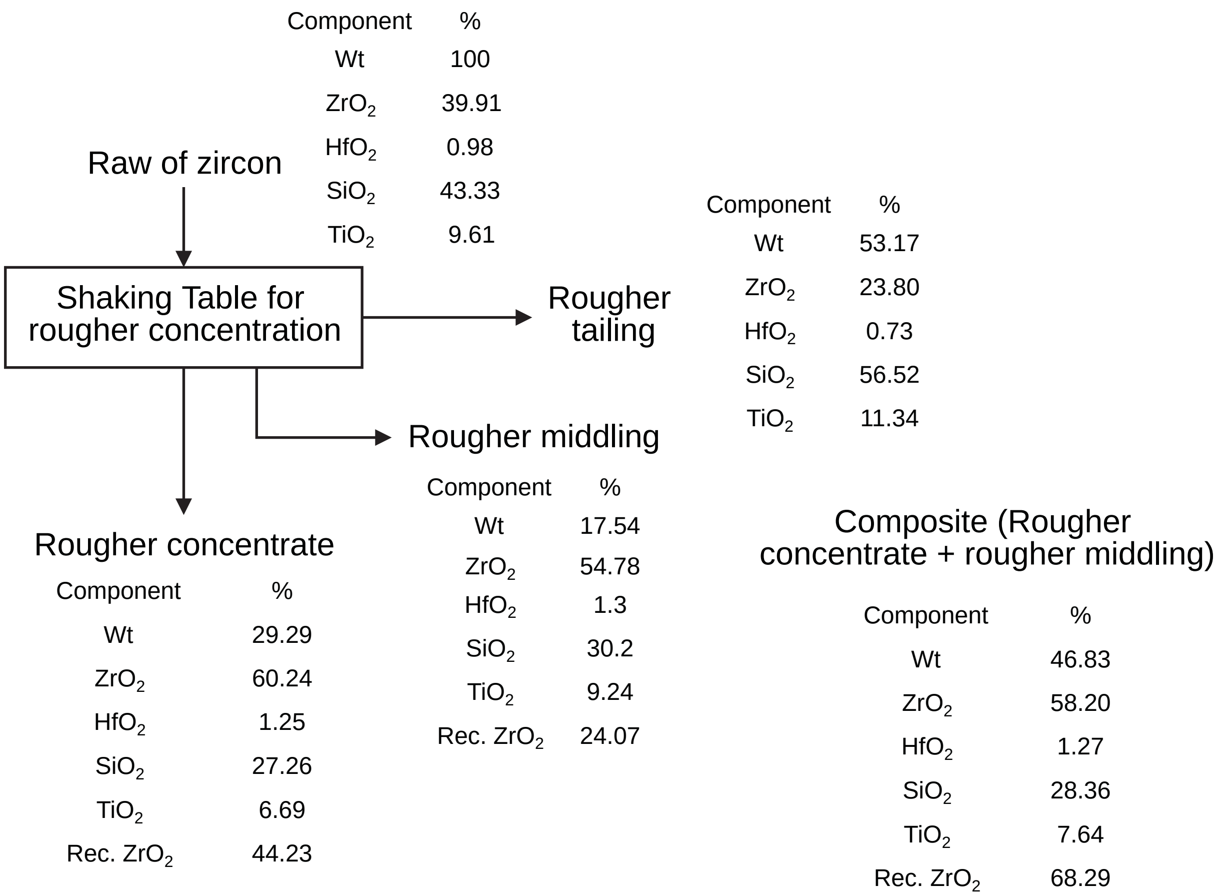


Figure 4. Material balances of rougher step

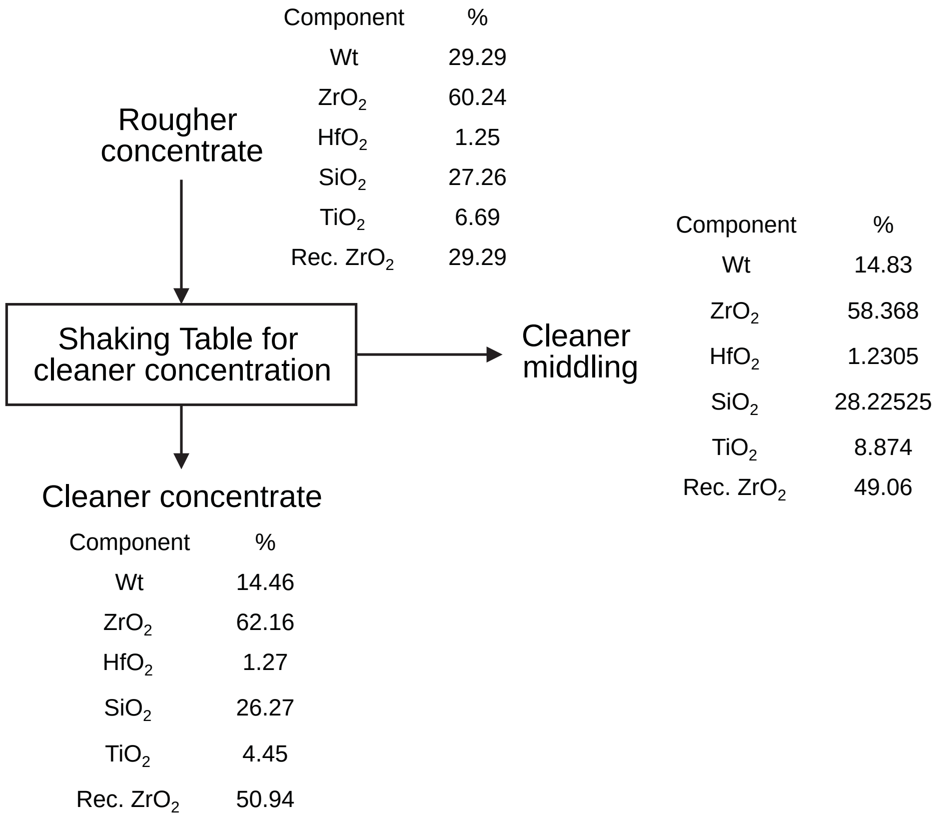


Figure 5. Material balances of cleaner step

Removing of TiO_2 by HGMS and ES

TiO_2 of cleaner concentrate can be eliminated using HGMS and ES. The content decreases from 4.45% to 3.42%. However, the TiO_2 content is still high and it does not yet meet the standard product of zircon concentrate, which total content of SiO_2 and Fe_2O_3 should be less then 1%. ZrO_2+HfO_2 reaches to 65.09%. The HGMS could not significantly eliminate the TiO_2 due to applied magnetic intensity was low. Compare to HGMS performance to process middling rougher, the TiO_2 content drops from 7.62% to 1.3%. The material balance of HGMS – ES processes shown in Figure 6.

Direct Removal TiO_2 by ES

TiO_2 within cleaner concentrate can be eliminated from 4.45% to 4.14%. Total ZrO_2+HfO_2 in concentrate is below 65.0%. It is below the market requirement (Porter, 2009). The material balance of direct ES process can be shown in Figure 7.

Scavenging concentration by ST - HGMS

The fact tha the content of ZrO_2 in middling product of rougher shaking table (ST) is still high, result in the cleaning by ST and HGMS is required. The ST product from middling-cleaner contains 7.62% TiO_2 and 59.91% ZrO_2+HfO_2. Eliminating the TiO_2 content by HGMS result in the decrease of TiO_2 content to 1.3% and ZrO_2+HfO_2 up to 64.01% as shown in Figure 8.

To improve the HGSM performance to remove ilmenite from ST concentrate, magnetic intensity was increased from 12.000 to 20.000 Gauss. The result of such as improvement is shown in Figure 9.

Some recommendations in the development of beneficiation circuit of zircon based on laboratory tests can be proposed such as the use of Reichert Cone Concentrator and Kelsey jigs (Jones et al.,2007). Their high capacity as multi-stage static gravity separators have a relatively occupy-

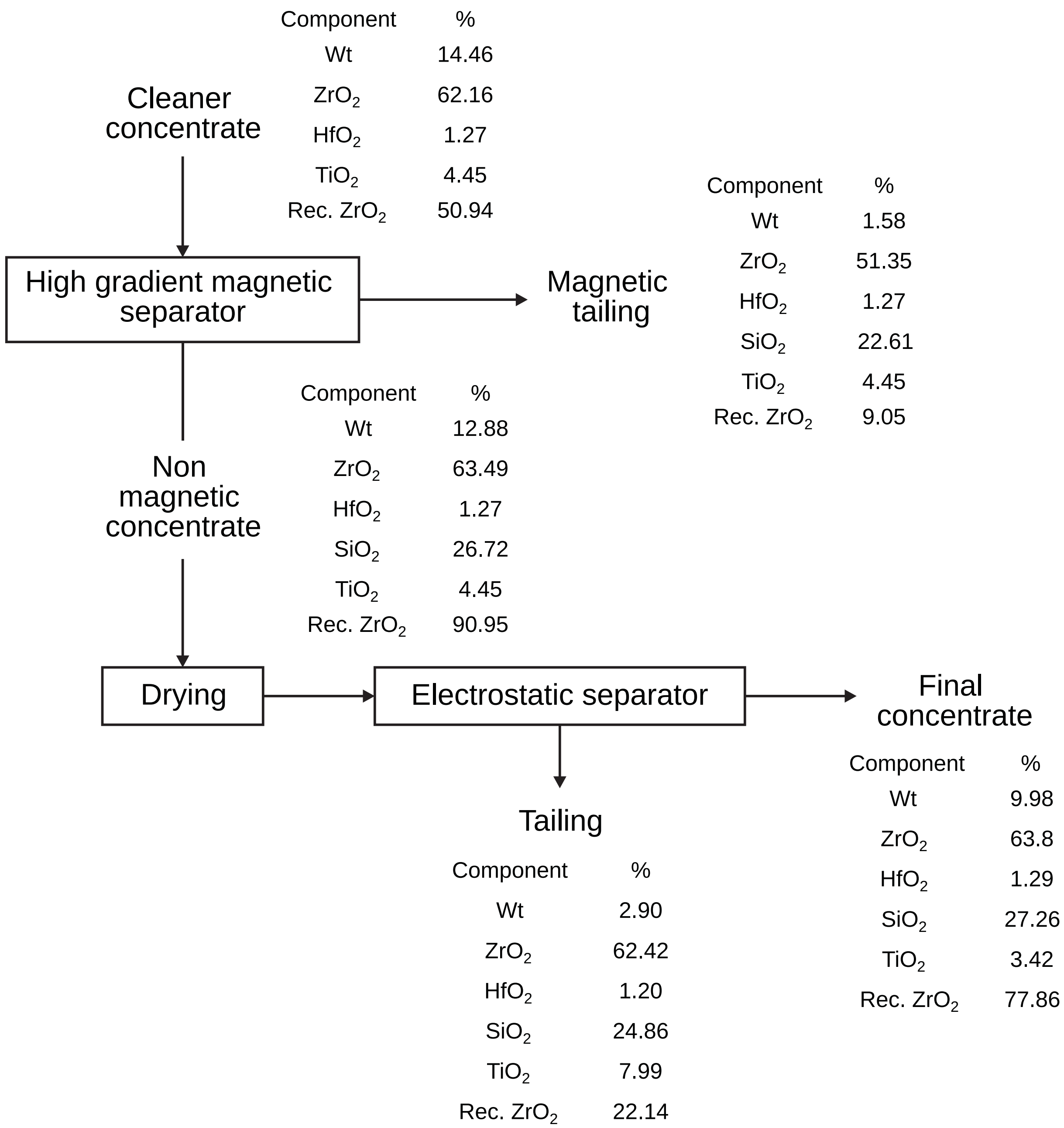
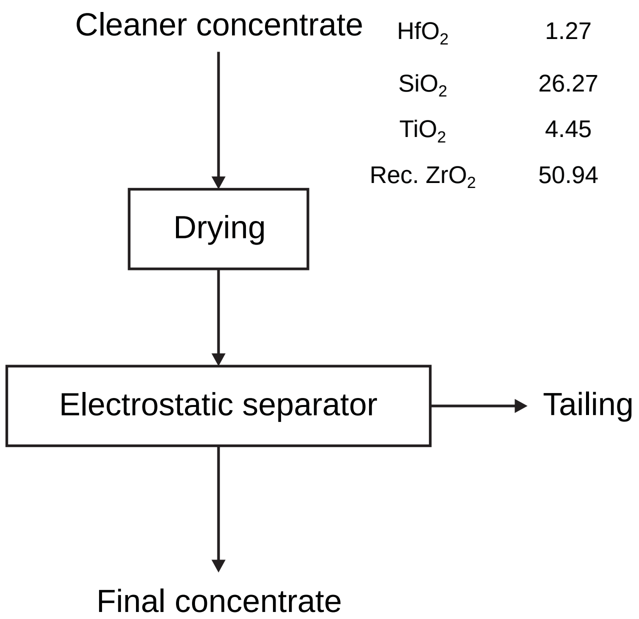


Figure 6. Material balances of HGMS - ES



Cleaner concentrate

Component	%
Wt	14.46
ZrO_2	62.16
HfO_2	1.27
SiO_2	26.27
TiO_2	4.45
Rec. ZrO_2	50.94

Tailing

Component	%
Wt	3.37
ZrO_2	62.32
HfO_2	1.34
SiO_2	24.49
TiO_2	5.47
Rec. ZrO_2	23.34

Final concentrate

Component	%
Wt	11.10
ZrO_2	62.11
HfO_2	1.25
SiO_2	26.81
TiO_2	4.14
Rec. ZrO_2	76.66

Figure 7. Material balances of direct ES

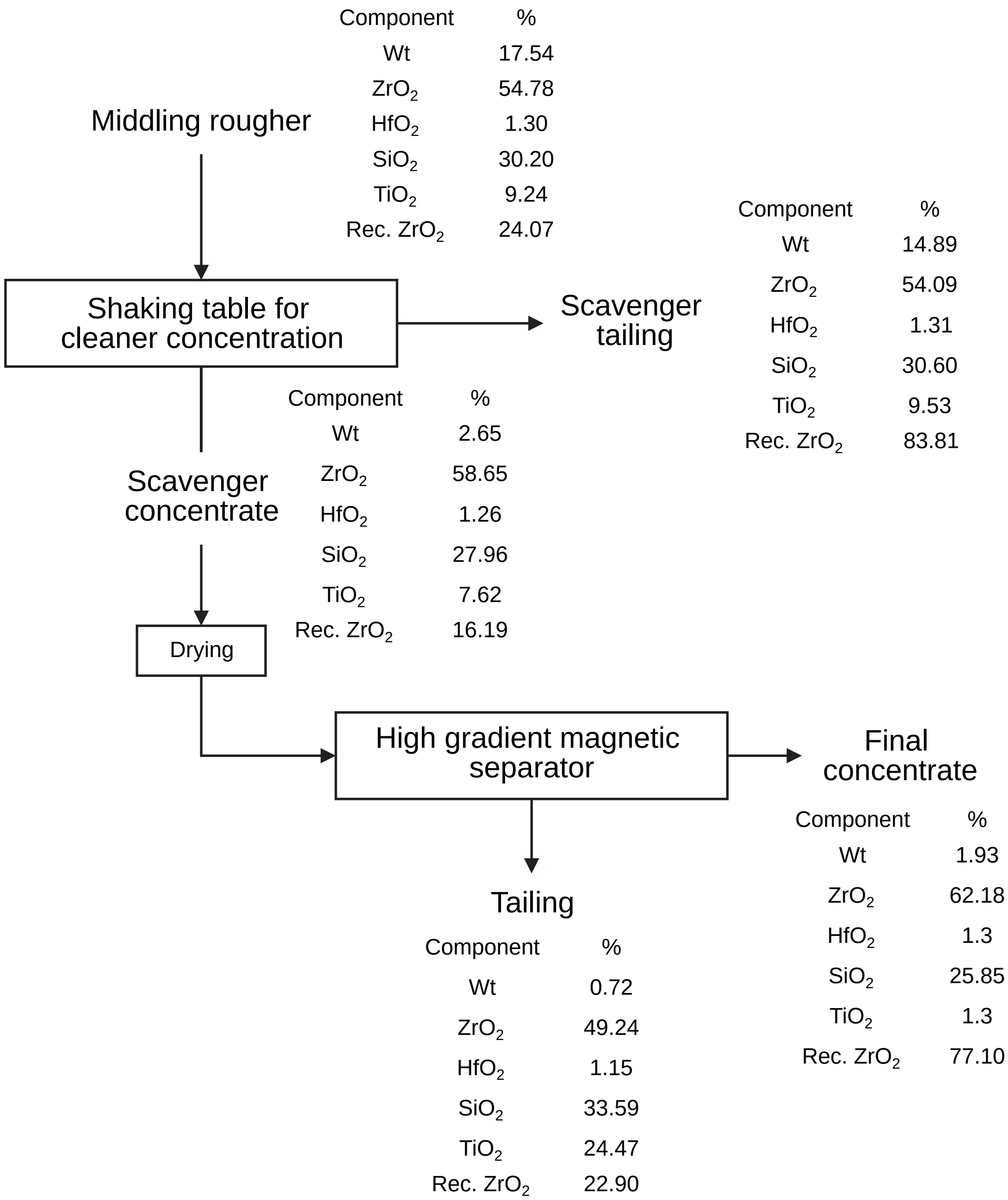


Figure 8. Material balances of ST-HGMS

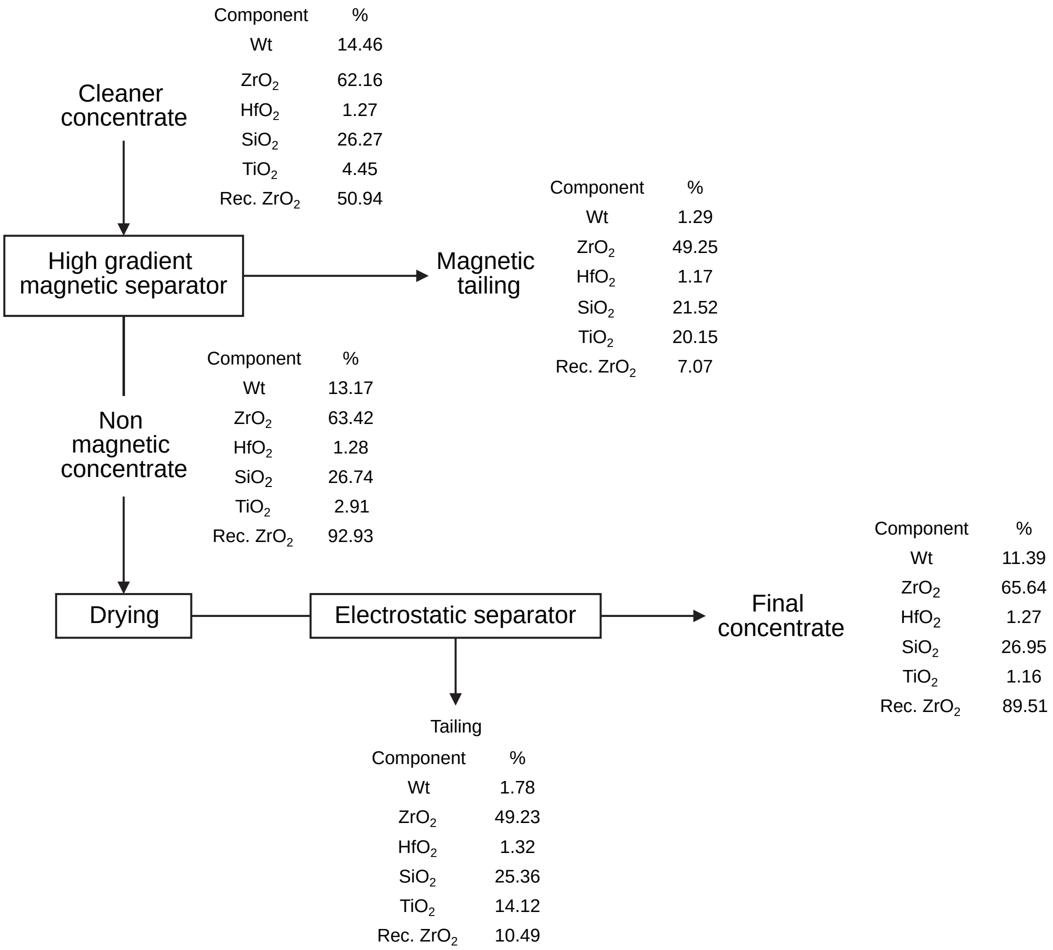
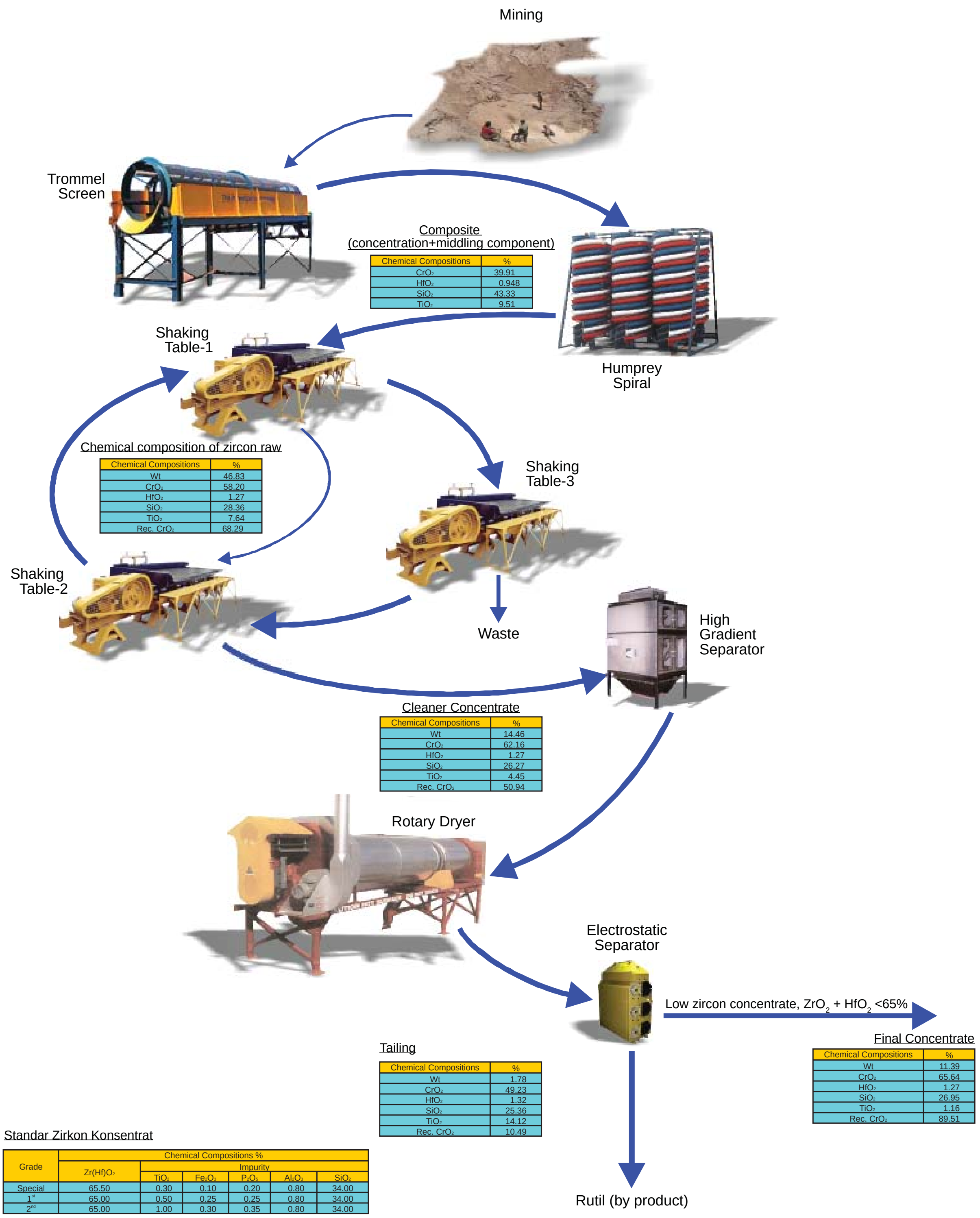


Figure 9. Improvement process for material balances of ST - HGMS

ing small floor space and offering operating cost economies and water circuit efficiencies as shown in Figure 10 (Canning, 1980; www.rochemt.com.au). Since no laboratory size available, a suggested flowsheet is shown in Figure 11. The process consisted of following sections.

- the sand slurry from the mining is screened in a large Trommol to remove roots and trash,
- the screened slurry is pumped through stages of Gravity Separators, Spirals to remove the silica, Shaking Tables to remove the remaining silica,
- the concentrate from the last stage of gravity separator is further treated in wet HGMS to remove major portion of the magnetic ilmenite from the rutile and zircon concentrate,
- the wet concentrate is dried in a rotary dryer before further treated in electrostatic separator to separate the rutile and the final zircon concentrate.

Figure 10. Reichert Cone Concentration (Canning, 1980)



Composite (concentration+middling component)

Chemical Compositions	%
CrO_2	39.91
HfO_2	0.948
SiO_2	43.33
TiO_2	9.51

Chemical composition of zircon raw

Chemical Compositions	%
Wt	46.83
CrO_2	58.20
HfO_2	1.27
SiO_2	28.36
TiO_2	7.64
Rec. CrO_2	68.29

Cleaner Concentrate

Chemical Compositions	%
Wt	14.46
CrO_2	62.16
HfO_2	1.27
SiO_2	26.27
TiO_2	4.45
Rec. CrO_2	50.94

Final Concentrate

Chemical Compositions	%
Wt	11.39
CrO_2	65.64
HfO_2	1.27
SiO_2	26.95
TiO_2	1.16
Rec. CrO_2	89.51

Tailing

Chemical Compositions	%
Wt	1.78
CrO_2	49.23
HfO_2	1.32
SiO_2	25.36
TiO_2	14.12
Rec. CrO_2	10.49

Standar Zirkon Konsentrat

Grade	Chemical Compositions %					
	Zr(Hf)O_2	Impurity				
		TiO_2	Fe_2O_3	P_2O_5	Al_2O_3	SiO_2
Special	65.50	0.30	0.10	0.20	0.80	34.00
1st	65.00	0.50	0.25	0.25	0.80	34.00
2nd	65.00	1.00	0.30	0.35	0.80	34.00

Figure 11. Recommended flowsheet of zircon processing

CONCLUSIONS

1. Zircon sand contains a lot of gangue minerals such as free silica, ilmenite, and rutile that must be eliminated by combining gravity, HGMS, ES separation method to produces marketable zircon concentrate.

2. Gravity separation by humphrey spiral and shaking table can significantly increase zircon grade from 39.31% ZrO_2 to 62.12% ZrO_2.

3. The remaining content of 4.45% TiO_2 in shaking table concentrate needs to be decreased using combination of magnetic separation and electrostatic separation in terms of increasing the zircon content in final concentrate. A high intensity induced roll Magnetic Separator is commonly used to refine the final product from the magnetic ilmenite.

4. The final concentrate of combining gravity, HGMS, ES separation method contains 65.65% ZrO_2, 1.27% HfO_2, 26.95% SiO_2 and 1.16% TiO2 that would fulfill marketable zircon.

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