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ABSTRACT

Extensive exploration is being undertaken throughout the world in search for heavy minerals, particularly rutile and other titanium minerals. The federal government is sponsoring research involving rutile ores and recovery of stockpile-grade concentrates from domestic sources. Producers are being forced to turn to deposits with a heavy mineral content as low as 0.50% (essentially rutile and zircon).

The North Carolina State University Minerals Research Laboratory investigated the possibilities of recovering heavy minerals from the amine tailings of the Texasgulf Inc.'s phosphate plant at Aurora, North Carolina. One laboratory beneficiation procedure resulted in the recovery of 78.7% of the heavy minerals in the amine tailings. Based on this percentage recovery and the present rate of phosphate mining, approximately 15,000 tons per year of heavy minerals (principally ilmenite and zircon) with a potential value of $384,000 could be recovered. The economic potential for recovery of these heavy minerals appears to be favorable.

INTRODUCTION

As a part of the program to explore the potential of Texasgulf Inc.'s phosphate holdings at Aurora, North Carolina, the North Carolina State University Minerals Research Laboratory investigated the possibilities of recovering heavy minerals from the ore.(1) During FMC Corporation's phosphate pilot plant project at the Laboratory, heavy minerals reported with the phosphate concentrate in the rougher circuit and with the tailings in the cleaner circuit.(2)

The objective of this investigation was to determine the feasibility of recovering the heavy minerals from the amine tailings of the Texasgulf Inc. On March 5, 1968 after the Texasgulf Inc. phosphate plant had been in production for several years, approximately eight hundred pounds of amine tailings were obtained and sent to the Laboratory for beneficiation tests. A heavy mineral concentrate was obtained with a Humphrey spiral and/or Wilfley table, and mineral products were produced by electrostatic and magnetic processes.

SAMPLE

A representative sample of the amine tailings was obtained by riffling. Part of this sample was sent by the North Carolina State University Minerals Research Laboratory to Southern Testing and Research Laboratories for P_2O_5 analysis, and part was separated into floats and sinks by heavy liquid (sp. gr. 2.95). The amine tailings were found to contain 6.25% P_2O_5 and 4.0% heavy minerals.

HUMPHREY SPIRAL TEST

One half of the sample was fed through a Humphreys spiral to upgrade the heavy minerals from 4.0% in the feed to 34.0% in the concentrate, for a concentration ratio of 9 to 1. Forty-two percent of the heavy minerals were recovered in the spiral concentrate with 34.0% reporting as middlings.

Additional upgrading with the spiral was not attempted because of the small quantity of material involved.

The concentrate from the Humphreys spiral was dried in a gas-fired oven and then processed as shown in the flowsheet, Figure 1. The bulk of the material fed to the electrostatic separator reported to the thrown (conductor) products, with the phosphate reporting to the middlings and a small amount of material reporting to the pinned (non-conductor) product. The middlings and pinned material were considered as waste. The thrown (conductor) fraction was fed to a Stearns induced-roll magnet where two magnetic fractions and one nonmagnetic fraction were obtained. The magnetic fractions were upgraded by rerunning over the Stearns magnet to produce an ilmenite product, an associated titanium product, and a nonmagnetic product composed mostly of garnet.

The nonmagnetics from the first pass over the magnet were repulped and fed to a Wilfley shaking table for the removal of quartz and concentration of zircon. The quartz was discarded as waste, and the zircon concentrate was fed to a Stearns magnet for the removal of remaining magnetic minerals. A final electrostatic beneficiation of the zircon concentrate removed some remaining gangue minerals and produced a finished zircon product.

By this additional beneficiation with electrostatic and magnetic separators, 84.6% of the minerals in the concentrate were recovered. The total potential products recovered from the Humphrey spiral and subsequent processing was 35.5% of the heavy minerals in the amine tailings.

Grain counts were obtained for each of the flowsheet products. These data were consolidated to show a mineral distribution in the Humphrey spiral concentrate of 56.2% ilmenite, 12.5% zircon, 3.3% rutile, 13.9% garnet, and 14.1% brown miscellaneous minerals, as shown in Table I.

WILFLEY TABLE TEST

In this test, a Wilfley shaking table was used to upgrade the heavy minerals from 4.0% in the feed to 97.0% in the concentrate by processing through several stages. The Wilfley table was of such size that the small amount of feed material could be processed without any difficulty. Ninety-four percent of the heavy minerals was recovered in the table concentrate.

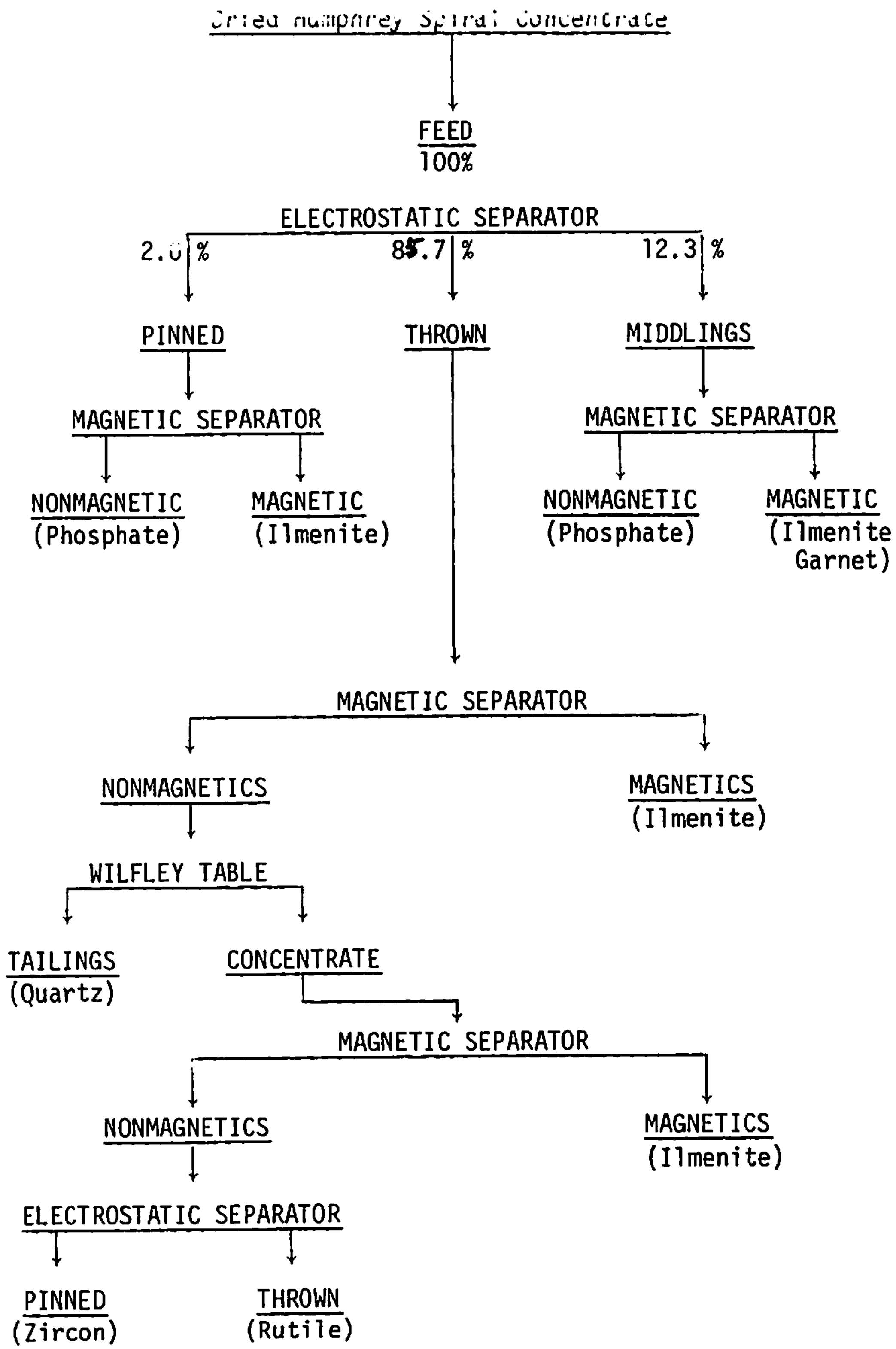

Figure 1. General flowsheet for processing Humphreys spiral concentrate.

TABLE I

DISTRIBUTION OF PRODUCTS FROM SPIRAL CONCENTRATE

Product	Wt. %
Ilmenite	56.2
Black Opaques	-
Zircon	12.5
Rutile	3.3
Garnet	13.9
Brown misc. minerals	14.1
Total	100.0

A simplified flowsheet for additional processing was introduced as a result of the high grade (97.0%) heavy mineral concentrate obtained with the shaking table. A zircon concentrate was produced by electrostatics and cleaned by magnetic separation. The remaining material was fed to a Stearns magnetic separator, and various machine settings were used in an effort to effect the desired separation. Observations of the products revealed the lack of a sharp separation which apparently was caused by the high operating ampere range (1.5-3.0) of the magnet. It was felt that the minimum (1.5 amps.) was still sufficient to cause the slightly magnetic minerals to report with the magnetics. In order to widen the operating range of the magnet to 0.0-3.0 amperes, a powerstat was installed to be used in conjunction with the existing rheostat. This increased the sharpness of the separation by permitting operation in the lower ampere range and resulted in the products designated as ilmenite and black opaques.

The additional beneficiation recovered 83.7% of the heavy minerals from the Wilfley table concentrates. The total products recovered was 78.7% of the heavy minerals in the amine tailings.

Data derived from grain counts were used to determine the distribution of products as shown in Table II. The dollar value of these products, based on assumed tonnages and operating time, is shown in Table III. A material balance and chemical analyses of the products are shown in Table IV. The theoretical chemical compositions of ilmenite, zircon, garnet, and rutile are shown in Table V, and chemical analyses of marketed products are shown in Table VI.

TABLE II

DISTRIBUTION OF PRODUCTS FROM WILFLEY TABLE CONCENTRATE

Product	Wt. %
Ilmenite	64.4
Black Opaques	8.3
Zircon	11.0
Rutile	-
Garnet	8.4
Brown misc. minerals	7.9
Total	100.0

DISCUSSION AND CONCLUSIONS

There are several features which would classify the recovery of heavy minerals from phosphate tailings as a good potential by-product venture. The heavy mineral content of the feed (4.0%) is as high as that of the feed of operating companies which are presently producing heavy minerals successfully. The land preparation, mining, pumping, and desliming costs will have been adsorbed by the phosphate operation, and this would result in a less costly operation than that of present heavy mineral producers. However, the above costs could be proportioned between the phosphate and heavy minerals plants.

TABLE III

PRODUCT TONNAGES AND DOLLAR VALUE

Product	Wt. %	Tons/Year	$/Ton	$/Year
Ilmenite	64.4	9,974	25	$249,350
Zircon	11.0	1,703	60	102,180
Black Opaques	8.3	1,285	25	32,125
Miscellaneous	16.3	2,524	-	-
Total	100.0	15,486		$383,655

The approximate values of the products before deductions are based on assumed tonnages and operating time as follows:

Ore tons per hour	1,200
Hours per year	6,864
Percent of ore reporting to amine tailings	5.0%
Percent heavy mineral in amine tailings	4.0%
Tons heavy mineral per year	16,474
Tons heavy mineral recovered @ 94%	15,486
Tons economic mineral products recovered @ 78.7% (83.7% x 94%)	12,962

TABLE IV

MATERIAL BALANCE AND CHEMICAL ANALYSES OF HEAVY MINERAL PRODUCTS FROM TABLE CONCENTRATE

Product	Wt. %	TiO_2	ZrO_2	Fe_2O_3	Al_2O_3	SiO_2
Ilmenite	64.4	51.73	0.58	37.75	-	-
Zircon	11.0	6.85	52.28	0.33	-	-
Garnet	8.4	11.14	-	17.45	-	16.50
Black Opaques	8.3	57.08	-	10.87	3.76	3.10
Brown Misc.	7.9	15.74	-	13.73	20.89	17.80
Total	100.0	38.98	6.12	27.80	1.96	3.06
Head Feed		35.02	7.43	26.17	2.59	3.30

TABLE V

THEORETICAL CHEMICAL ANALYSES

Product	TiO_2	ZrO_2	Fe_2O_3	FeO	Al_2O_3	SiO_2
Ilmenite ($FeO \cdot TiO_2$)	52.7			47.3		
Zircon ($Zr \cdot SiO_4$)		67.2				32.8
Garnet ($3FeO \cdot Al_2O_3 \cdot 3SiO_2$)			43.3		20.5	36.2
Rutile ($Fe \cdot TiO_3$)	90.0		0.0-10.0			

TABLE VI

CHEMICAL ANALYSES OF MARKETED PRODUCTS

	TiO_2	ZrO_2	Fe_2O_3	FeO	Fe
Ilmenite (Jax., Fla.)	60.3		26.3	5.6	22.7
Leucoxene (Trail Ridge, Fla.)	82.1		9.0	1.6	7.5
Rutile (Jax., Fla.)	94.2		1.71		1.2
Zircon (Jax., Fla.)		60.0			

The following statements were abstracted from the April and May, 1971 issues of Industrial Minerals.

> The titanium market has doubled in the past ten years and additional expansion is anticipated.
>
> Producers are being forced to turn to deposits with a heavy mineral content as low as 0.50% (essentially rutile and zircon). Another prospecting company has proved reserves based on a heavy mineral content of 0.20% to 0.22% rutile and zircon. Products with a TiO_2 content of 52.0% minimum are apparently used by the Japanese in steel mills to supplement iron sand. Deposits are worked in Norway which produce a 44.0% TiO_2 concentrate.

The heavy minerals recovered from the amine tailings contain economic minerals such as ilmenite, rutile, and zircon, and 78.7% of these heavy minerals were recovered from the amine tailing in the Laboratory. Based on this percentage recovery and the present rate of phosphate mining, approximately 15,000 tons per year of heavy minerals (principally ilmenite and zircon) with a potential value of $384,000 could be recovered, Table III. Furthermore, these minerals are becoming more valuable as lower-grade ore deposits are being mined. Among the alternatives which should be considered at this time are:

1) Construction of a plant for the recovery and production of heavy mineral products.
2) Construction of a wet concentration plant for recovery and storage of heavy minerals for future processing into products.
3) Pumping amine tailings, which contain heavy minerals, to separate storage area for future mining as a heavy mineral deposit. This would allow for a higher production rate than could be obtained by processing the tailings as a by-product of a phosphate plant.

REFERENCES

(1) Redeker, I. H., North Carolina Phosphate Concentration Texasgulf Inc. Project, AIME Transactions, Vol. 250, p. 71, March 1971.

(2) Lewis, R. M., FMC Phosphate Project Report No. 7, North Carolina State University Minerals Research Laboratory, Asheville, North Carolina, April 1967.