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RECOVERY OF HEAVY MINERALS FROM NORTH CAROLINA PHOSPHATE MATRIX

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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 has given approval to research programs 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 Texas Gulf Sulphur Company's phosphate plant at Aurora, North Carolina. This investigation showed the tailings contained a sufficient quantity of ilmenite, zircon, and rutile to be worth considering recovering.

GENERAL INTRODUCTION

As a part of the program aimed at exploring the potential of Texas Gulf Sulphur Company'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) On March 5, 1968 after the TGS Company 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. The percent heavy minerals in the tailings was determined by heavy liquid procedure. A heavy mineral concentrate was obtained with a Humphrey spiral and/or Wilfley table, and mineral products were produced by electrostatic and magnetic processes. It was concluded, based on present rate of phosphate mining, that approximately 15,000 tons of heavy minerals (principally ilmenite and zircon) per year with a potential value of $384,000 were being sent to waste.

GENERAL PROCEDURE

A representative sample of the amine tailings was obtained by riffling. Part of this sample was sent 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. The bulk sample was equally divided and fed to a Humphreys spiral in one test and a Wilfley table in another test for heavy mineral concentration. The concentrates from both of these gravity separations were processed with electrostatic separators and magnetic separators to produce final products.

HUMPHREY SPIRAL TEST

Introduction

In this test, a Humphreys spiral was used 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. Eighty-four and six-tenths percent of the minerals in the concentrate were recovered as potential products by additional beneficiation with electrostatic and magnetic separators.

Procedure

The concentrate from the Humphreys spiral was dried in a gas-fired oven and then fed to an electrostatic separator. The bulk of the material 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.

Results

The flowsheet used for processing spiral concentrate is shown in Figure 1. Grain counts were obtained for each of the flowsheet products. This data was consolidated to show a mineral distribution consisting of 56.2% ilmenite, 12.5% zircon, 3.3% rutile, 13.9% garnet, and 14.1% brown miscellaneous.

Discussion

The Humphreys spiral was effective in upgrading the heavy minerals from 4.0% in the feed to 34.0% in the concentrate with one pass. Additional upgrading with the spiral was abandoned because of the small quantity of material involved. The material responded satisfactorily when subjected to electrostatic and magnetic processes.

WILFLEY TABLE TEST

Introduction

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. Ninety-four percent of the heavy minerals were recovered in the table concentrate. Eighty-three and seven-tenths percent of these minerals were recovered as products by additional beneficiation.

The total economic mineral products recovered as a percent of heavy minerals in the amine tailings amounted to 78.7%.

Procedure

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.

Various machine settings were used in an effort to effect the desired separation. Observations of the products revealed the lack of a sharp separation. It became apparent that a possible reason for the lack of a sharp separation was 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, the writer installed a powerstat to be used in conjunction with the existing rheostat. This increased the sharpness of the separation by allowing for operating in the lower ampere range and resulted in the products designated as ilmenite and black opaques.

Results

Data derived from grain counts were used to determine the distribution of products as shown in Table 2. The dollar value of these products, based on assumed tonnages and operating time, is shown in Table 3. A material balance and chemical analyses of the products are shown in Table 4. The theoretical chemical compositions of ilmenite, zircon, garnet, and rutile are shown in Table 5. Chemical analyses of marketed products are shown in Table 6.

Discussion

The Wilfley table was of such size that the small amount of feed material could be processed without any difficulty. The heavy minerals were upgraded from 4.0% in the feed to 97.0% in the concentrate by rerunning the concentrate several times across the table. The material responded satisfactorily when subjected to electrostatic and magnetic processes.

GENERAL DISCUSSION AND CONCLUSIONS

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

The following statements were interpreted 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. These minerals are becoming more valuable as lower-grade ore deposits are being considered. There are several alternatives which can be considered when arriving at what to do with this project or one of similar nature:

1) Construct a plant for the recovery and production of heavy mineral products.
2) Construct a wet concentration plant for recovery and storage of heavy minerals for future processing into products.
3) Pump 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 when processing as a by-product of a phosphate plant.

REFERENCES

(1) Redeker, I. H., North Carolina Phosphate Concentration, Texas Gulf Sulphur Company Project. AIME Annual Meeting, New York, February 1971, Transactions - Vol. 250, page 71, March 1971.

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

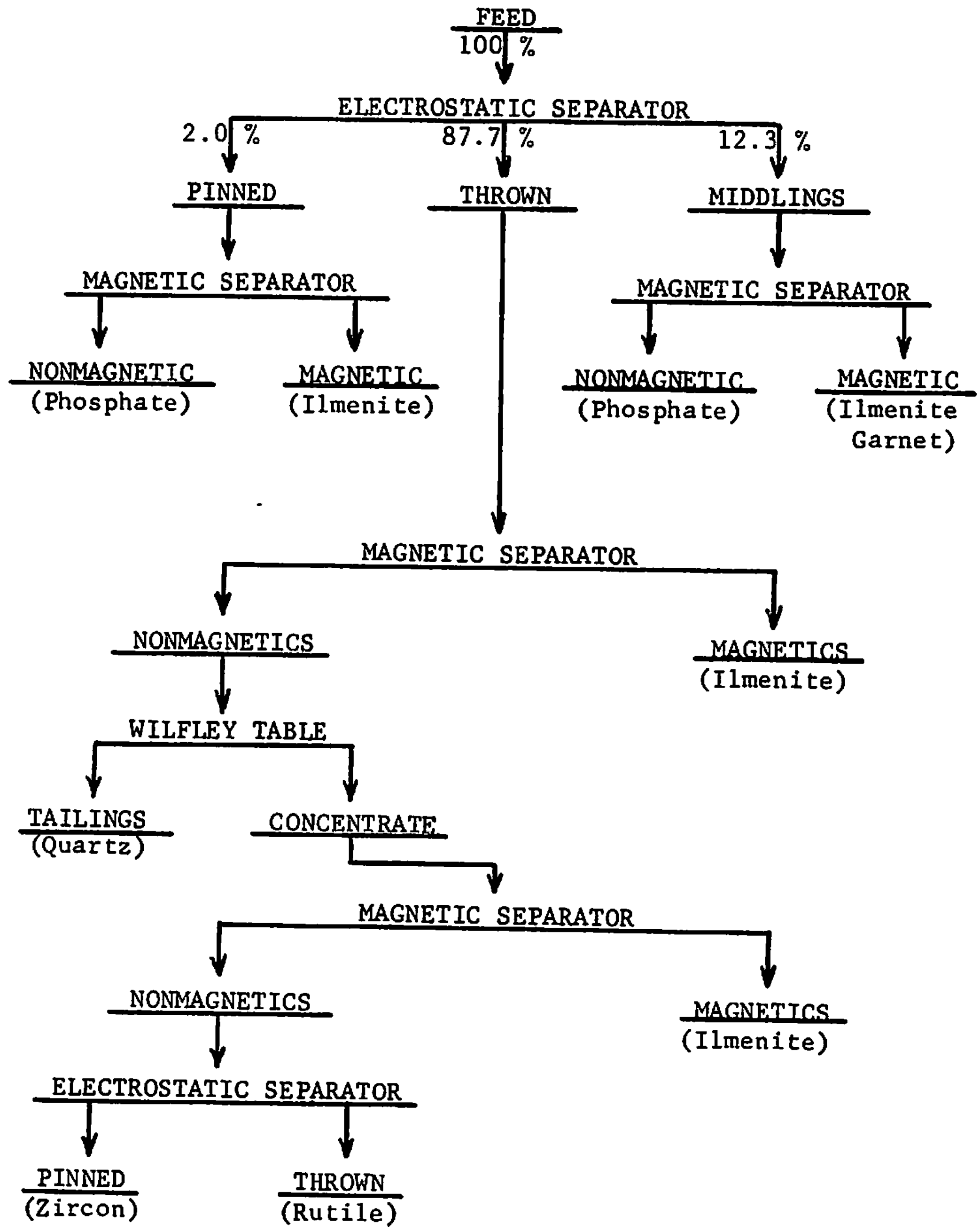

FIGURE 1. GENERAL FLOWSHEET FOR PROCESSING HUMPHREYS SPIRAL CONCENTRATE

TABLE 1

Distribution of Products from Spiral Concentrate

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

TABLE 2

Distribution of Products from Table Concentrate

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

TABLE 3

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 4

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 5

Theoretical Chemical Analyses

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

TABLE 6

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			