TESTS ON A HIGH INTENSITY WET MAGNETIC SEPARATOR
April 1969 Progress Report

Lab. Nos. 3396, 3397, 3398, 3406,
3407, 3408, - Book 227

by
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Background of Tests

During the summer of 1968, Mr. Dean Thomas of Eriez Magnetics visited the Minerals Research Laboratory and discussed with the engineering staff the possibility of loaning an Eriez laboratory-size HIW (High Intensity Wet) magnetic separator for various minerals separation tests of interest to the MRL. Also, an opportunity would then be present for various mineral producers in North Carolina to visit the MRL and run samples of their own through the machine. It was finally agreed that Eriez would loan a Series L Model 4 HIW separator to the MRL for a period of about 3 weeks.

Description of HIW Separator

A basic description of this machine, published by Eriez Magnetics, is attached (Form B-75: Figs. 2a & b). The machine loaned to MRL, however, had the following improvements:

1) Voltage to magnetic coils was 200 VDC maximum permitting higher flux.
2) Several additional types of magnetic elements were furnished:
   a) One set of 1 inch mesh heavy gauge expanded steel sheets.
   b) One set of grooved steel plates, 1/4 inch ridges.

c) One set of grooved steel plates, 1/2 inch ridges (these were not used).

Other literature on this machine stated that its throughput in any given test could be multiplied by a factor of 10 to obtain an equivalent throughput figure for the pilot-plant size HIW machine (Model 10CC) nominally rated at 1.0 TPH capacity. Since the two larger Eriez HIW machines - Models 100CF and 200CF - have rated capacities of 10 TPH and 20 TPH, respectively, it is also possible to calculate from throughput rate on the laboratory-size model to theoretical rates for those two plant-size machines, using factors of 100 and 200. Unlike the Model 4, the larger machines are constructed with revolving chambers, making possible a flux-purge cycle in each chamber, so that continuous flow of feed is possible. The accuracy of equivalent rate calculations is based on the fact that the depth of the flux chamber of the laboratory machine is equal to that of the larger models; the horizontal cross-section being the only variation.

Testing Technique

Since the machine was on loan for only a short period, no standard agitating mechanism or procedure was developed. The most satisfactory pulp agitating and feeding procedure developed was as follows: The mineral sample, diluted to between 10 percent and 20 percent solids, was placed in a cylinder and agitated end for end until all solids were dispersed through the pulp. The cylinder was then dumped into a funnel fastened to the magnetic chamber of the machine. Rate of flow through the magnetic chamber was controlled by using funnels with stems of varying diameter. Figure 1 illustrates the apparatus involved.

Samples Tested

During its term of loan to the MRL, plant products of six mineral-producing companies were put through the separator. Two companies ran their own tests and results on these are not known. The plant samples processed by the MRL were as follows:

Lab. Sample No. 3396 - Spiral mica concentrate from a weathered pegmatite near Kings Mountain, North Carolina.

Lab. Sample No. 3397 - Flotation mica concentrate, same source as No. 3396.

Lab. Sample No. 3398 - A flotation machine discharge from the same weathered pegmatite as No. 3396 and 3397; containing feldspar, quartz, and unremoved mica and iron minerals.

Composite Filter Cake - A filter cake fine tailings product from a Spruce Pine feldspar flotation plant, containing muscovite, biotite, clay, iron minerals, and quartz; produced from a relatively unweathered alaskite orebody.

Lab. Sample No. 3407 - A flotation machine discharge from the same source and origin as the preceding composite: minus 20 mesh, and containing feldspar and quartz; with principal impurities muscovite, biotite, garnet, and free iron. Similar to No. 3398, but with more impurities.

Lab. Sample No. 3408 - A flotation mica concentrate from a highly-decomposed deposit near Spruce Pine, North Carolina.

Lab. Sample No. 3406 - A silica sand product from a sand and gravel operation, partially washed, essentially minus 20 mesh; attrition scrubbed and deslimed in the Laboratory: containing the impurities ilmenite, monazite, tourmaline, kyanite with iron-mineral inclusions, and some quartz with like inclusions.

The HIW magnetic tests on these samples are described in the sections following.

Lab. Sample No. 3396 - Spiral Mica Concentrate. The sample was mainly a white mica of fairly low bulk density, but containing a certain amount of biotite or iron-stained mica. Since this mica is sold for a use where lightness or high reflectance is important, it was hoped to improve the quality in this respect by use of the HIW separator.

The sample contained 16.5 percent mica above 20-mesh size. Since this could not easily be processed through the machine, and since it contained little or no darker mineral, it was screened out.

For this test (No. 3396-2N), conditions were as follows: A sample of the minus-20 mesh fraction weighing 160 grams was diluted to 15 percent solids and poured at a rate of 4 liters per minute through the machine. The one-inch grids of expanded metal were used, and current was set at 80 VDC, 12 amps. Throughput rate equivalent to the No. 100CF HIW machine (rated at 10 TPH) is calculated at about 4.4 TPH. The first nonmagnetic product was passed through a second time under the same conditions - after demagnetizing, removing, and washing the chamber. Thus, two magnetic products were derived. Optimum pulp density for throughput of this mineral needs to be determined, as well as maximum tonnage per hour.

The final nonmagnetic mica product was compared in quality to the original sample by means of a Photovolt Reflectance Meter equipped with "Tristimulus" filters. Quantitative results of Test No. 3396-2N are shown in Table 1.

Table 1

HIW Magnetic Separation on a -20 Mesh Spiral Mica Concentrate: Test No. 3396-2N

Product	Percent Weight	Color Reflectance Green	Amber	Blue
Total minus 20	83.5	60.3	61.1	52.0
Total plus 20	16.5	--	--	--
Total	100.0%			
Minus 20:				
Magn. Prod. No. 1	3.7			
Magn. Prod. No. 2	0.6			
Nonmagn.	79.2	62.4	63.7	54.4
Total	83.5%			

Lab. Sample No. 3397 - Flotation Mica Concentrate. This sample was similar to Sample No. 3396, preceding, coming from the same producer and the same general orebody, although the method of concentration differed. The entire sample was essentially minus 28 mesh, and was therefore processed without prior screening. Two tests on this mica were run on the HIW machine. Conditions of the first were identical to Test No. 3396-2N, first cited, and the second was changed only as to rate of throughput. Table 2 gives data on the two tests.

Table 2

HIW Magnetic Separation on a Mica Flotation Concentrate

Test No.	% Weights Mag. No.1	Mag. No.2	Non-Mag.	Non-Mag. Color Green	Amber	Blue	Machine # 100CF: Feed Rate,TPH
3397-1N	3.9	1.7	94.4	59.7	61.2	51	4.4
3397-2N	2.1	0.7	97.2	58.2	60.0	49.8	16.5
Orig. Sample				56	57	46.3	

Lab Sample No. 3398 - Feldspar Plus Quartz. This sample, which was minus 28 mesh, contained small remnants of mica, biotite, garnet, and other iron-bearing minerals, but Fe_2O_3 content was only 0.049 percent. In the two tests cited in Table 3, a pulp of 20 percent solids was put through the machine. In the first test, solids throughput was equivalent to 4 to 4.5 TPH, based on the Eriez Separator No. 100CF, and in the second test the rate was about 15 TPH, on the same basis. As with previous samples, the material was fed through the separator twice.

Table 3

HIW Magnetic Separation on Spar-Quartz Machine Discharge

Test	Feed Rate (TPH)	Product	% Wt.	% Fe_2O_3
3398-1N	4.5	Magn. No. 1 & No. 2	2.0 plus 0.5	-
		Non-magnetics	97.5	0.021
3398-2N	15	Magn. No. 1 & No. 2	0.35 plus 0.05	-
		Non-magnetics	99.6	0.024
Head Sample			100.0	0.049

It appears that the high-iron minerals are quite easily removed in this case, with only small additional benefit from slower throughput.

Composite Filter Cake Tailings. This sample was typical of the fines discarded in the tailings of the feldspar-producing plants in the Spruce Pine area. Since flotation tests had established that it contained a large amount of useable feldspar and quartz, an effort was made to create a saleable product from it by lowering Fe_2O_3 analysis by use of the HIW separator. Proximate chemical analysis of this material was as follows:

K_2O -	4.1%
Na_2O -	43%
Fe_2O_3 -	1.0%
Al_2O_3 -	17.6%
SiO_2 -	69.8%
CaO -	1.4%
Ign. Loss -	1.1%
	99.3%

Estimated mineral percentages were: feldspar, 50; quartz, 30; mica, 5; iron minerals 2; clay minerals, 13.

Screen analysis of this composite was as follows:

Plus 20 mesh -	0.0%
20 to 150 mesh -	5.1%
150 to 200 mesh -	4.0%
200 to 325 mesh -	18.2%
Minus 325 mesh -	72.7%
	100.0%

For this material, the 1/4 inch mesh expanded steel grids were placed in the element box. A 200-gram sample, diluted to 10 percent solids, was fed at a rate of 4 liters per minute. Power input was 115 VDC, 18 amps. A double throughput was performed.

Ninety-nine percent of the sample reported as nonmagnetics and one percent as magnetics. Fe_2O_3 on the nonmagnetics was 0.70 percent, indicating a decided beneficiation from 1.01 percent. A test on the same sample, dried, was run on a small cross-belt magnetic separator by a feldspar producer. Approximately the same percentage of magnetics was drawn off, but the Fe_2O_3 assay was 0.83 percent, indicating the possible superiority of wet magnetic separation for this type feed. It appears, however, that beneficiation of this material solely by any sort of magnetic separator would not yield a high-grade product: other treatment seems needed as well.

It should be noted here that a beneficiated product from this type sample was run through the machine under the same conditions, and good results secured. A feldspar-quartz flotation concentrate, essentially minus 400 mesh, having an average particle size of 15 microns, and with most mica and iron minerals removed by flotation, was changed in assay from 0.10 percent to 0.07 percent Fe_2O_3. This material was then very close to being within required specifications for ceramic or filler grade feldspar, without the cost of fine-grinding.

Lab Sample No. 3407 - Feldspar Plus Quartz. This material contained quartz, feldspar, and substantial remnants of muscovite, biotite, and garnet. The ore from which it came was relatively unweathered, unlike the ore which yielded sample No. 3398. It was, in addition, essentially minus 20 mesh, while No. 3398 was essentially minus 28 mesh.

In Test No. 3407-1N a 500-gram portion of No. 3407 was diluted to

20 percent solids, agitated, and put through at a rate of 53 TPH, based on a No. 200 HIW machine. This fast rate was due to an error in calculation. However, the sample was put through a second time.

A comparison between this performance and that of a Stearns laboratory-size rolls-type high-intensity dry magnetic separator was attempted. Conditions of this test (No. 3407-2N) were as follows:

Gaps (between mag. pole and roll) - 1/4 inch.

RPM of rolls (4 inch diam.) - 93.

Ampere turns - 5700 turns x 4 amps.

Rate of feed - 500 g. in 20 secs.

Divider settings, upper and lower - 2 1/2

It was considered that these conditions approximated industrial production on a full size machine of the same type.

To help evaluate both of these tests, a Frantz Isodynamic Magnetic Separator was used to determine quantities of muscovite, biotite, and garnet in the head sample and in the beneficiated products from both the wet and the dry tests. In addition, an analysis was run for percent Fe_2O_3 of the two products. Table 5 gives data relating to these tests.

Table 5

Wet and Dry Magnetic Separation Tests on Sample No. 3407

Test No.	Product	% Wt. of Orig. Sample	Composition % Spar-Qtz.	% Musc.	% Biot.	% Garnet	% Fe_2O_3
-	Feed	100	97.3	0.8	1.5	0.4	-
3407-1N (HIW wet)	Non-magn.	95.5	99.4	0.5	0.1	0.1	0.08
	Magn. prod #1	1.7					
	Magn. prod #2	0.4					
	Losses	2.4					
3407-2N (Stearns dry)	Non-magn.	95.4	99.5	0.5	Tr.	Tr.	0.07
	Upper magn.	2.7					
	Lower magn.	0.4					
	Losses	0.8					

Lab Sample No. 3408 - Second Flotation Mica Concentrate. This sample came from a producer in a different location in North Carolina than the one who furnished Sample No. 3397. It was desired in this case to improve color by removing a fraction having a yellowish cast. Conditions of the single test run approximated those of Test No. 2N on sample No. 3397. Since the application of magnetic flux failed to cause a more yellowish fraction to report with either magnetics or nonmagnetics, no further work was done on this sample.

Lab. Sample No. 3406 - Silica Sand with Impurities. This sample, as received, contained a small quantity of slimes and minus 100 mesh material. Before testing on the HIW separator, it was screened through 20 mesh and across 100 mesh, attrition-scrubbed, and heavily deslimed, leaving very little material below 100 mesh. Other information on this sample is in Lab Notebook No. 227.

Reference is made here, also, to a later Sample: No. 3411 - the two samples being nearly identical.

Conditions of the three tests were as follows: in the first, feed rate was equivalent to 15 TPH for the No. 100 machine. Pulp was 20 percent solids. The subsequent tests varied only as to current input. A double throughput was run on each test, each at the rate cited in Table 4.

Table 4

HIW Magnetic Separation on a Glass Sand Ore

Test No.	Variable	Prod.	% Wgt.	% Fe_2O_3
3406-18N	85 VDC, 12 amps	Magn. total	0.6	-
		Nonmagn., +100m	98.8	0.036
		Nonmagn., -100m	0.6	-
3406-19N	115 VDC, 18 amps	Magn., total	0.6	
		Nonmagn., +100m	98.9	0.032
		Nonmagn., -100m	0.5	
3406-20N	190 VDC, 30 amps	Magn., total	0.6	
		Nonmagn., +100	98.9	0.032
		Nonmagn., -100	0.5	
		Initial feed	100.0	0.08

It appears that the particles in this ore which will respond magnetically, all do so in a relatively low flux with no additional benefit derived from a stronger field.

Another magnetic separation test run on a portion of this sample which had been screened and deslimed, but not scrubbed, yielded a product analyzing 0.06 percent Fe_2O_3, indicating that scrubbing and additional desliming play a significant part in enabling good removal of these magnetics.

Conclusions

1) The HIW Separator as received is relatively easy to operate and clean and is a desirable laboratory tool. Additional advantages of the HIW Separator are: lack of dust; low losses in magnetic products; and lack of accumulation of fines and magnetics in the field area.

2) Some micas can be beneficiated with regard to color grade, especially where biotite or iron-stained mica are involved.

3) The HIW Separator is effective in removing garnet, biotite, and other minerals of like magnetic susceptibility, as well as free iron.

4) On the basis of tests performed so far, it appears the machine is not a dependable means of concentrating all muscovite as a magnetic product.

5) For further beneficiation of a minus 20 mesh feldspar or feldspar-quartz concentrate, the machine compares very favorably with a dry rolls-type separator.

6) Use of the HIW Separator as a single means of removing iron minerals appears practical on quartz sands containing heavy oxide or silicate-type iron-bearing minerals, although it is assumed that minerals having substantially no magnetic response (pyrites, etc.) would not be removed.

7) Beneficiation of extremely fine material (minus 200 mesh or finer) is most effective with fine grids and slow throughput. The machine may have its greatest usefulness in this application as a supplementary device following flotation, where low iron assay is required.

8) Pulp density of feed is a variable needing study: there appears to be an optimum dilution for a given rate of solids throughput.

9) With power at 18 amps. (115 VDC) the machine appears to be close to maximum operating effectiveness for weakly magnetic minerals.

10) In most cases, given proper feed conditions and grid selection, a second throughput of a sample does not yield high additional beneficiation.

Since it appears that the HIW-type magnetic separator has definite applications in the minerals beneficiation industry, ownership of a laboratory-size unit seems a wise and practical goal for any agency performing ore-dressing research.

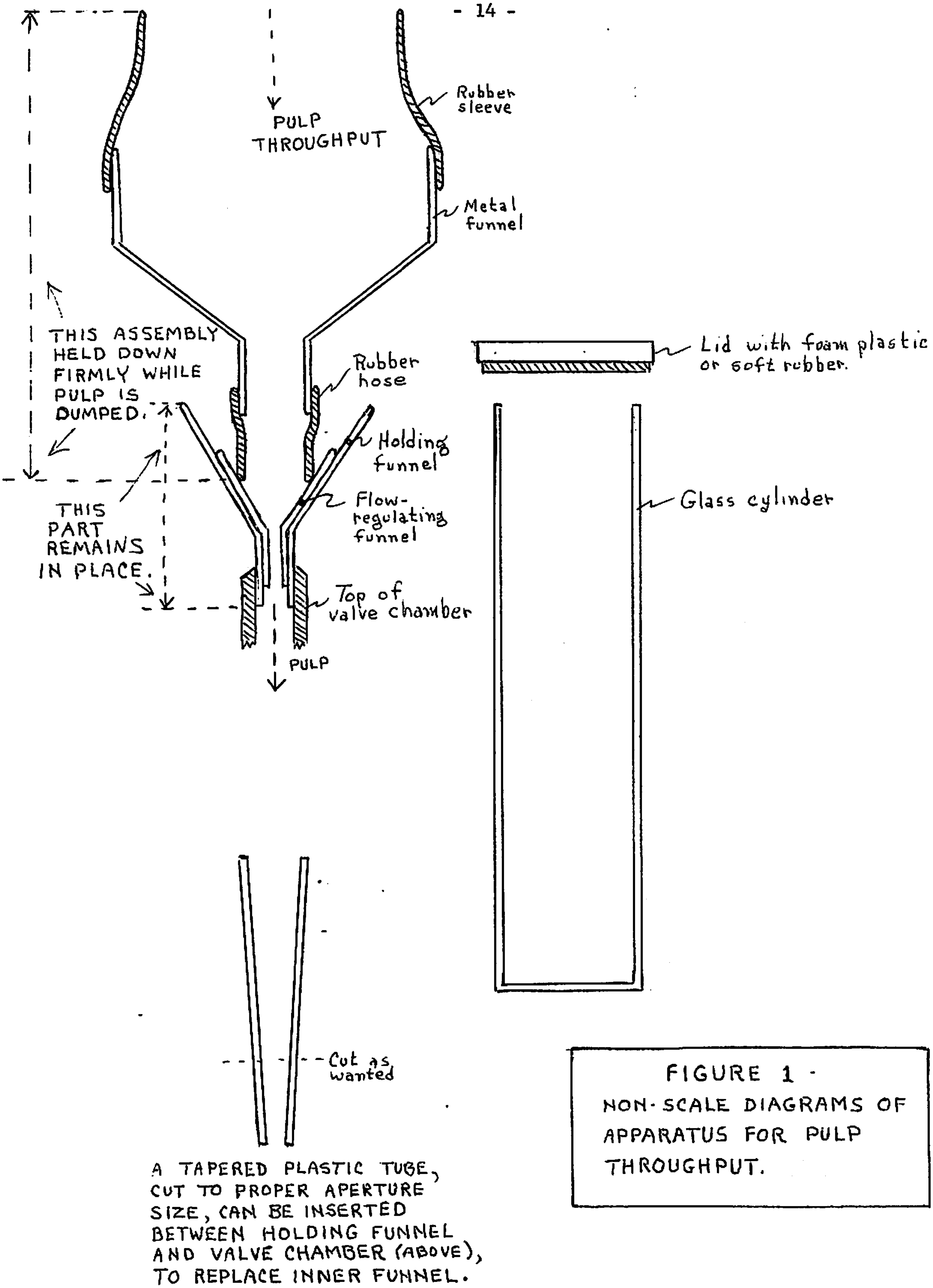
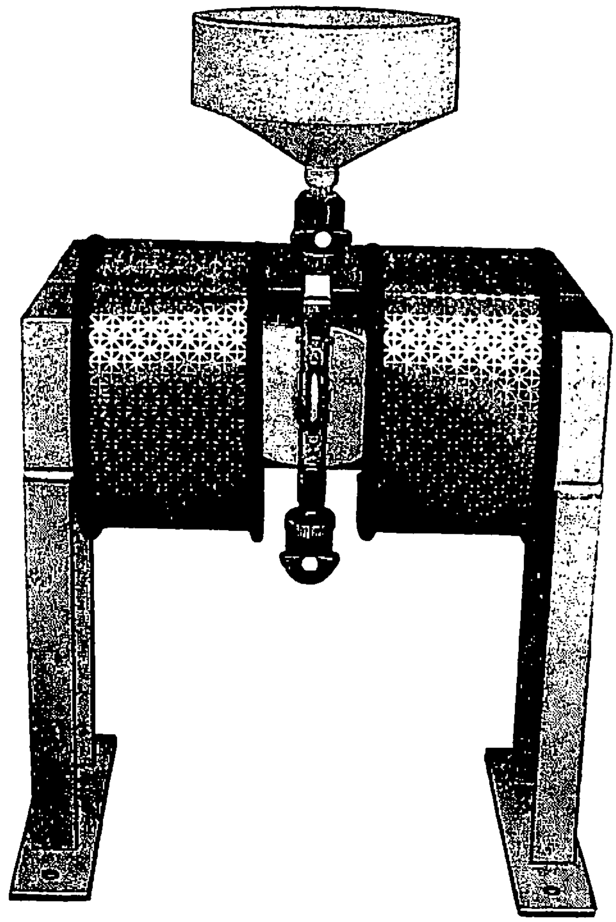


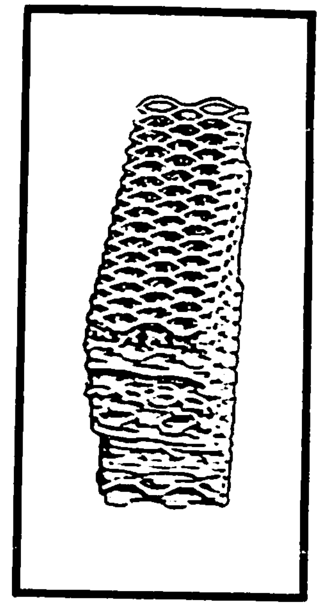
FIGURE 1 - NON-SCALE DIAGRAMS OF APPARATUS FOR PULP THROUGHPUT.

ERIEZ MAGNETICS

High Intensity Wet Magnetic Series L Model 4 Laboratory Separator

FIGURE 2-A





Here is the most advanced, highly selective, magnetic separator available for the concentration and separation of feebly magnetic materials.

For separation of paramagnetic materials such as:

(1). Hematite and goethite in the beneficiation of iron ores.

(2). Iron oxides and ferrosilicates from quartz and clays used for manufacturing glass, ceramics and glazes.

(3). Ilmenite, wolframite, columbite and xenotime from gangue during concentration.

(4). Ferro-oxides and ferrotitanium oxides from cassiterite, zircon and rutile concentrate.

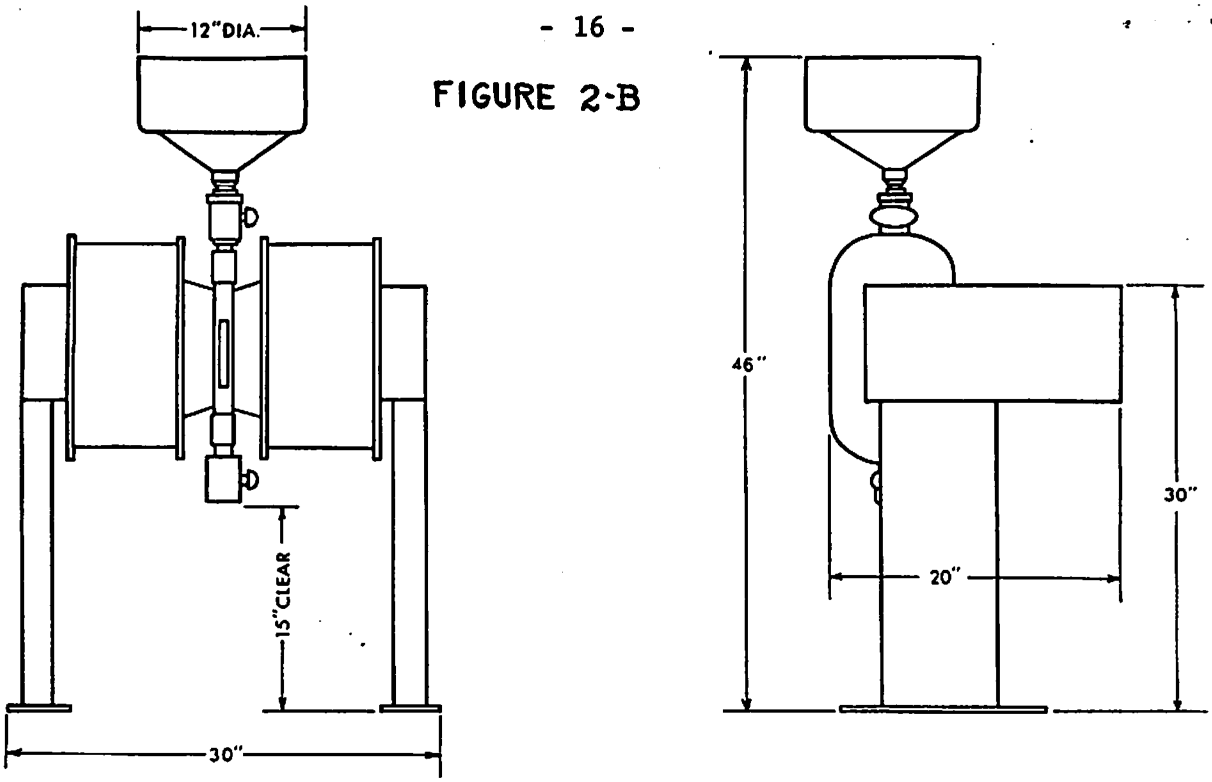
Eriez Series L Model 4 Laboratory Separator consists of two electromagnetic coils with a stainless steel box containing a flux converging element located between the magnetic poles. This pole box is 8" high x 2" wide x 1" deep with inlet and outlet valves. A funnel is supplied for hand-feed operation.

Illustration shows the L-4 separator with the elements shown in inset. Note the many sharp edges to which the feed material is exposed. Each edge becomes highly induced during operation and provides the necessary high intensity, high gradient field to remove the weakly magnetic particles. When stacked, the element plates form vertically running grooves which assures clean discharge of nonmagnetics.

This laboratory separator has a capacity of 4 GPM of feed pulp at approximately 20% solids with particles in the -30 mesh size range. It is completely controllable by hand so that all factors are independently variable for maximum flexibility of operation. Compact size provides utmost in convenience for handling small batch samples.

(OVER)

FIGURE 2-B



SPECIFICATIONS

Unit is shipped complete with detachable feed funnel, hand operated feed inlet and outlet valves, removable magnetic element box and three sets of interchangeable magnetic elements consisting of the following:

1 set - ½" mesh heavy gauge expanded steel sheets
1 set - ¼" mesh heavy gauge expanded steel sheets
1 set - ½" diameter round steel balls

Separator control is a separate cabinet incorporating silicon diode rectifier, AC switch, voltmeter and variable autotransformer to reduce current to zero.

UNIT SPECIFICATIONS

Voltage	- 115 DC
Cold amperage	- 26.3 amps
Cold wattage	- 3000
Net weight	- 1200#
Shipping weight	- 1350#
O. A. Dimensions	- 30" wide x 46" high x 20" deep
Boxed Dimensions	- 36" wide x 52" high x 26" deep

CONTROL SPECIFICATIONS

Voltage	- 115 or 230 AC
O. A. Dimensions	- 18" wide x 12" high x 26" long
Boxed Dimensions	- 24" wide x 18" high x 32" long
Net weight	- 150#
Shipping weight	- 180#

OPERATIONS

Series L4 is designed to test materials and predict operation and performance data for full sized models. With this unit an investigator can analyze on a small sample the results, advantages and disadvantages of varying factors such as magnetic intensity, flux converging elements, feed rate, percentage of solids, timing, etc.

The same field pattern generated in larger operational models is duplicated in this unit: 10,000 gauss is developed in the centerline of the empty gap with a maximum of 23,000 gauss on the element edges.

Tests are run by pouring or pumping a pulped sample into the separator with magnet energized. Magnetic particles collect in the magnetic element during operation and nonmagnetic particles are carried through this magnetic zone by drag forces. Magnetics are flushed out by feeding water through the pole box with magnet turned off. Feeding and wash cycles can easily be timed and products weighed and assayed for separation efficiency calculations.

By operating at reduced voltage the laboratory unit can also be used as a scalper for removal of more highly magnetic particles.

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