OTTAWA April 1, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2020.

Part 1.

Pilot Plant Investigation on a Nepheline Syenite Rock Deposit of the American Nepheline Ltd., Lakefield, Ontario.

(Copy No. 13.)

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Bureau of Mines
Division of Metallic
Minerals.
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A April 1, 1946.

R E P O R T

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SECTION A. - GENERAL

Introduction:

Mr. E. Craig, of the American Nepheline Limited, Lakefield, Ontario, requested the Bureau of Mines, Ore Dressing Laboratories, Ottawa, to conduct an investigation to determine the most suitable flowsheet to produce a marketable Nepheline Syenite product for use in the glass and ceramic industries.

This flowsheet was to include, depending upon the facilities of the Laboratories, a comprehensive study of crushing grinding and concentration methods for the removal of iron minerals, namely magnetite, hematite, pyrite, pyrrhotite, biotite mica, and also corundum and muscovite mica.

Specifications regarding the finished product and recommended by Company officials were:

1. A relatively coarse grind, minus 28 mesh with a minimum of minus 200 mesh product.
2. Chemical analysis to show a finished product containing less than 0.05% Fe_2O_3 .
3. Chemical analysis to show a finished product containing less than 0.05% Corundum and especially the necessity for the complete elimination of all coarse particles of this mineral.

To assist in this investigation Mr. Wm. D. Hubler, Metallurgical Engineer, and Mr. L. K. Lichty, representing the American Nepheline Ltd., were present during the research project and collaborated with the Bureau of Mines' Engineers.

The majority of routine chemical analyses were done at Lakefield, Ontario by Nepheline Products Ltd. under the direction of Mr. B. D. Weaver.

<u>Shipments:</u>

The first shipment of 9 tons from the Lakefield Quarry was received at the Ore Dressing Laboratories, November 22nd, 1945. Since this date there have been received 22 additional shipments or a total of 170 tons of Nepheline Syenite for test purposes.

The shipments were submitted by Mr. E. Craig of the American Nepheline Ltd., Lakefield, Ontario.

<u>Location of Property:</u>

The property of the American Nepheline Ltd. from which the above shipments were received is located at Blue Mountain, Methuen Township, Peterborough County, 26 miles by road from Lakefield, Ontario. The rock from the quarry is transported by truck or barge to Lakefield which is on a branch line of the Canadian National Railway from Peterborough, Ontario.

The Company have at present two plants in operation, The American Nepheline Corporation, Rochester, N. Y. and the American Nepheline Ltd., Lakefield, Ontario.

Both of these plants use a dry process for the separation of the impurities. The Rochester plant has tried a wet process involving flotation several times unsuccessfully due to mechanical and flowsheet difficulties.

Purpose of the Investigation:

The purpose of the investigation was primarily to develop a flowsheet which would be applicable to the treatment of the Nepheline Syenite Rock, so that specifications of the finished product, previously outlined, would be acceptable to the Glass and Ceramic Industry.

In the development of the flowsheet, crushing, assuming that preliminary breaking had been done using a Jaw Crusher, was to include a comparison of a Jaw Crusher and Gyratory Crusher for secondary stage crushing, followed by a comparison of Symons Cone Crusher, Rolls Crusher, and Hammer Mills for tertiary stage crushing.

Combinations of the above mentioned equipment were also to be investigated in order to obtain a product with a minimum of fines produced.

Having established a satisfactory method of crushing, grinding using a screen in closed circuit was to be studied.

Grinding was to include a comparison of both dry and wet methods, using in both cases a low discharge Rod Mill. This type of mill was thought to be the most suitable for the reduction of the Nepheline Syenite to keep "sliming" to a minimum.

Flotation of the impurities from the Nepheline Syenite was considered to be the major part of the investigation. This research would involve a study of flotation reagents to determine a suitable combination, and a study of general flotation conditions as would be required for the elimination of operating difficulties.

In the event that flotation methods did not remove the coarse size impurities, a gravity method, such as tabling, was presumed to be a probable approach for their removal.

High intensity magnetic separation was to be tried as the final method of concentration of the remaining impurities in the Nepheline Syenite after flotation and tabling. This would determine what grade of finished product could be expected in plant operation.

CONCLUSIONS AND RECOMMENDATIONS

CRUSHING

Primary Crushing may be accomplished by the use of a Jaw Crusher.

Secondary Crushing should employ either a Jaw Crusher or a Gyratory Crusher.

Tertiary Crushing can be performed by the use of a Symons Cone Crusher.

GRINDING

The grinding unit used in mill tests was a low discharge 3' x 6' Marcy Rod mill. Such a type mill, if the dimensions are kept as small as possible, should result in a grind producing a minimum of minus 200 mesh product.

No grinding results have been obtained using a pebble mill.

Comparative tests employing dry grinding showed that a similar product could be made as when a wet circuit was used. Capacity in dry grinding was approximately 60% of the wet grinding tonnage.

The use of Ty-Rod screens showed an increased grinding capacity over the use of standard square mesh screen cloth.

Grinding to minus 28 mesh will not give complete liberation of the iron and corundum minerals in the Nepheline Syenite.

CONCENTRATION - FLOTATION AND TABLING

By the combination of flotation and tabling methods it has been shown possible to produce a Nepheline Syenite product having a chemical analysis of Fe_2O_3 0.31%, Corundum 0.06% with a recovery of 89% by weight of the mill feed.

The recovery of Fe_2O_3 and Corundum are 75%, and 84% respectively, of the Fe_2O_3 and Corundum in the mill feed.

FLOWSHEET

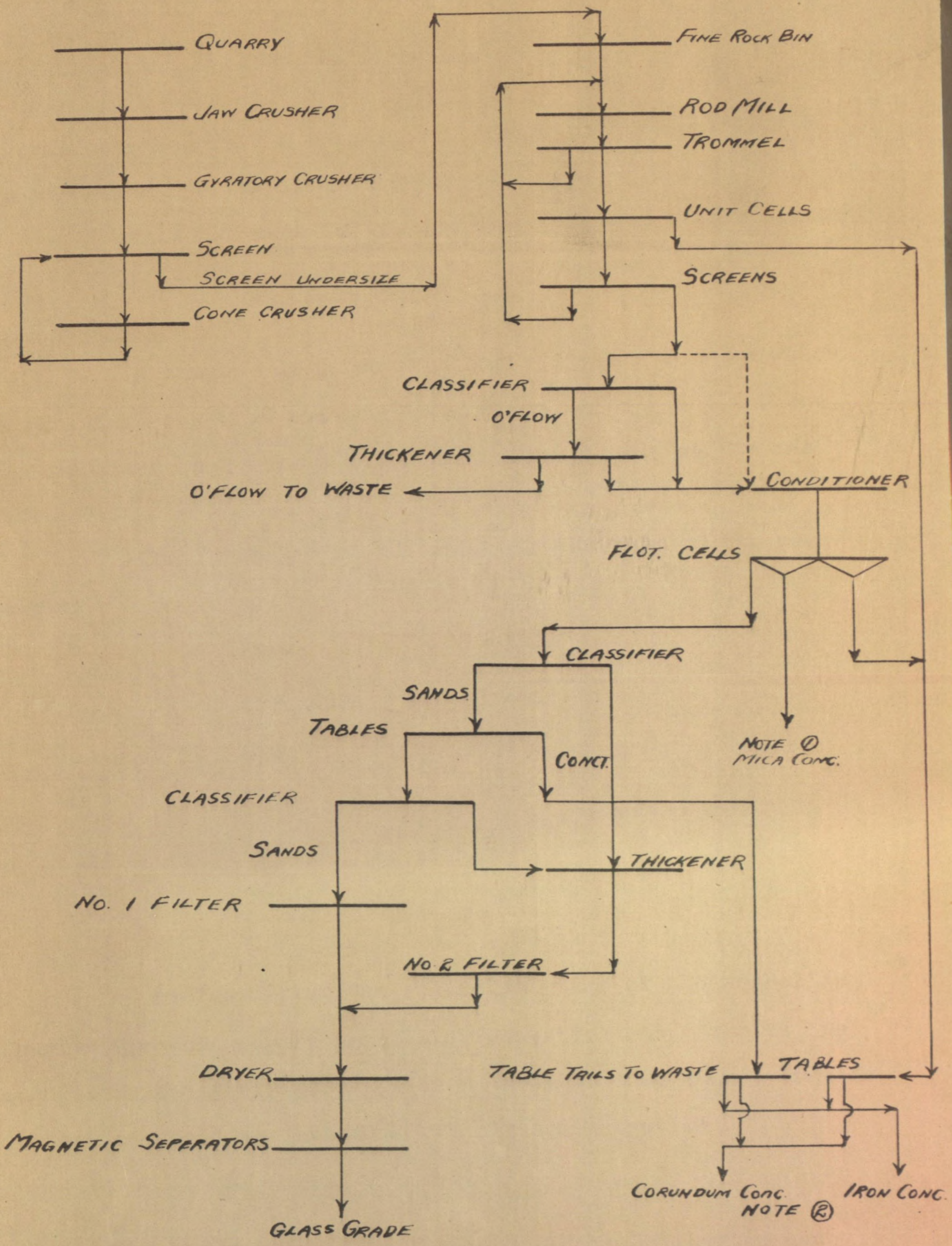
In any discussion of the flowsheet which may be reported it should be acknowledged that through the collaboration of Company Engineers assigned to this project much information was obtained which will prove invaluable.

It would be an impossibility to report in detail the experience gained in the treatment of this Nepheline Syenite.

In the design of any flowsheet processing Nepheline Syenite the fact that this material is very abrasive should be considered in selecting equipment.

A flowsheet developed from this investigation is shown in Drawing No. 1.

DRAWING NO 1



NOTE ① - MICA CONC. TO FURTHER CONCENTRATION IF PRACTICAL
NOTE ② - IRON & CORUNDUM CONCT. TO STOCK PILES

FLOWSHEET INDICATED FOR TREATMENT OF NEPHELINE SYENITE BASED UPON THE BUREAU OF MINES ORE TESTING LABORATORIES INVESTIGATION FOR AMERICAN NEPHELINE LTD.

APRIL 1, 1946

Characteristics of the Nepheline Syenite

In this report there will be no attempt made to describe the complete chemical or mineralogical composition of the Nepheline Syenite from this deposit.

This has been fully described in several other reports two of which are mentioned.[1]

Head Analysis

A sample was taken from each of the shipments which represented rock from the new development underground. These were combined on a weight basis from which a head sample was obtained.

The following is the chemical analysis of the head sample:

Fe_2O_3	1.30%
Corundum	.46%
SiO_2	59.12%
Al_2O_3	24.81%
CaO	0.55%
Total S	.0044%
S in SO_4	.0023%

In describing the characteristics of the Nepheline Syenite for this report particular attention was given to the impurities and their association with syenite so that a successful method could be devised for their concentration.

1 Adam, F.D. and Barlow, A.E. "Geology of the Haliburton and Bancroft Areas, Province of Ontario, Geological Survey, Dept. of Mines, Ottawa Memoir No. 6 (1910)

Keith, MacL. "Petrology of the Akaline Intrusive at Blue Mountain Ontario," Bulletin, Geological Society of America, Vol. 50 (10) October 1939.

Three separate investigations were made to provide this information including microscopic examination of polished sections, a petrographic examination - thin sections, and a detailed study of specific products from concentration operations.

The above mentioned investigations should not be considered a complete description relating to the characteristics of the Nepheline Syenite. The samples which were chosen represented a picture of what mill feed should be expected for concentration.

The Nepheline Syenite as received was predominately white, but there was a small proportion of pink or iron stained Syenite present. This apparently occurs in bands in the Blue Mountain deposit and small quantities would be expected to be present in mill feed, regardless of what mining method was employed. Until a more complete study has been made on the pink Syenite it is recommended that the quantity of this iron bearing formation be kept to a minimum in the mill feed as it responds to treatment similar to the white Syenite. Its presence would possibly influence the Fe_2O_3 analysis in the final product.

There was also present some green stained syenite which formed the contact zone between the magnetite bands and the white Syenite. This was not apparent where the Magnetite was disseminated. There is a possibility that carbonates are present in this green material.

The Nepheline Syenite was a medium to fine grained rock with no definite cleavage planes. This would have a definite effect in crushing operations.

The samples submitted for microscopic examination did not include specimens showing the extreme coarseness of the magnetite, corundum, and mica impurities.

Since some specimens showed these inclusions as large as one inch it was assumed without further study there would be little difficulty in obtaining their liberation at the specified grind.

Microscopic Examination - Polished Sections

The following is a report of the microscopic examination of the opaque minerals and their association with corundum made from six polished sections of Nepheline Syenite prepared and examined under a reflecting microscope:

Metallic Minerals:

In only one of the sections are metallic minerals relatively abundant; in the other five polished surfaces metallic mineralization is very sparse.

Magnetite predominates as irregular disseminated grains and small masses up to three or four millimetres in size, with the average being probably about one-half millimetre (-28+35 Tyler mesh). It contains occasional small inclusions of gangue and rather numerous, narrow, ragged veinlets of hematite. Fig. 1.

Besides the narrow veinlets in magnetite noted above, hematite is visible as occasional to rare scattered grains, whose average size is much smaller than that of the magnetic iron oxide. Only one large grain of hematite occurs in the six polished sections. It presents a cross-section which is roughly rectangular in shape, about 2 x 1¼ millimetres in size, and contains one tiny inclusion of gangue and three or four small remnants of magnetite. Figure 2. These apparently residual inclusions, together with the ragged outlines of the hematite veinlets in magnetite, suggest that the former mineral has replaced the latter mineral.

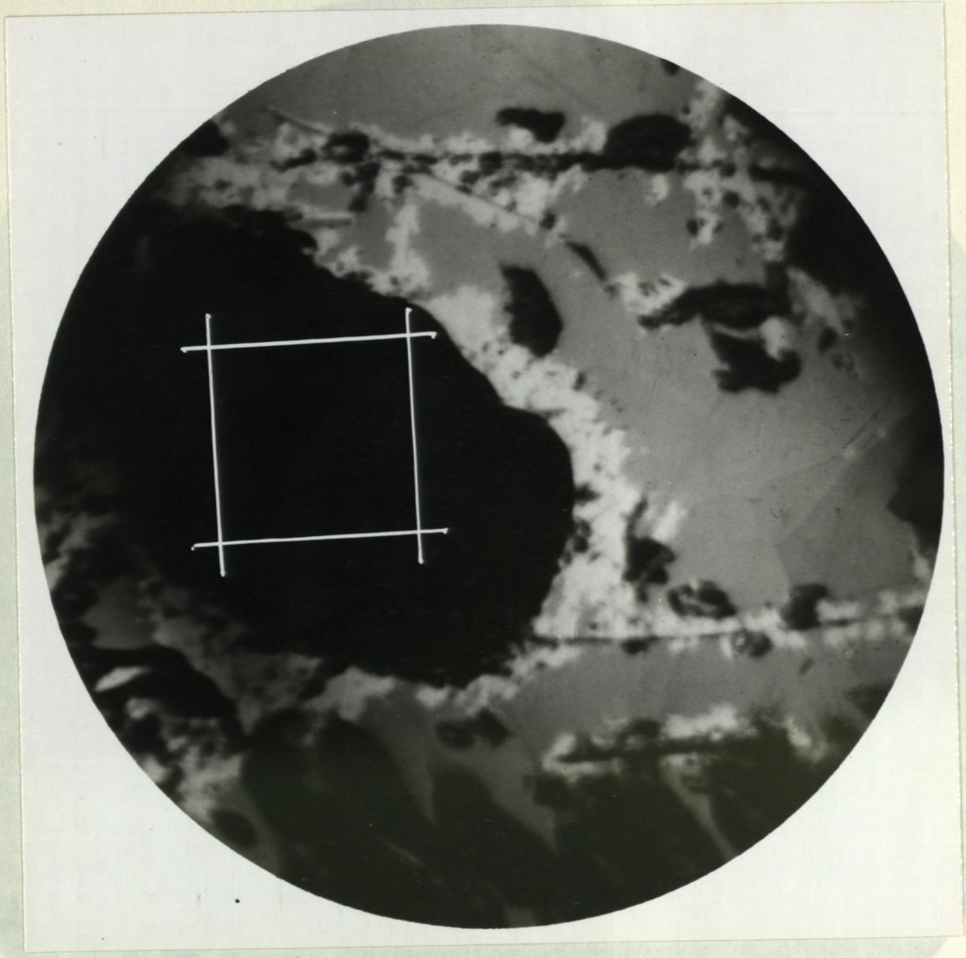
In one of the polished sections pyrite is present as occasional small scattered grains, which range from about one-half millimetre down to only a few microns in size.

Corundum:

In two or three of the polished surfaces, grains of corundum can be recognized by their hardness and colour (brown). They are very irregular in shape but are usually more or less elongated and occur in grains up to almost two millimetres in their longest direction. Careful inspection of these corundum crystals under a high power objective reveals that most, if not all, of them enclose numerous tiny needles and laths of hematite with a parallel orientation. Figure 3. This association may assist in the separation of the corundum by high intensity magnetic separation.

Under crossed nicols and by means of a binocular microscope it was seen that the brown colour is not uniform throughout all the crystals. One was observed which is entirely colourless except for a comparatively small portion at one end. Close examination showed this grain to contain tiny spikes of hematite also, a good indication that such inclusions are not confined to the coloured corundum only.

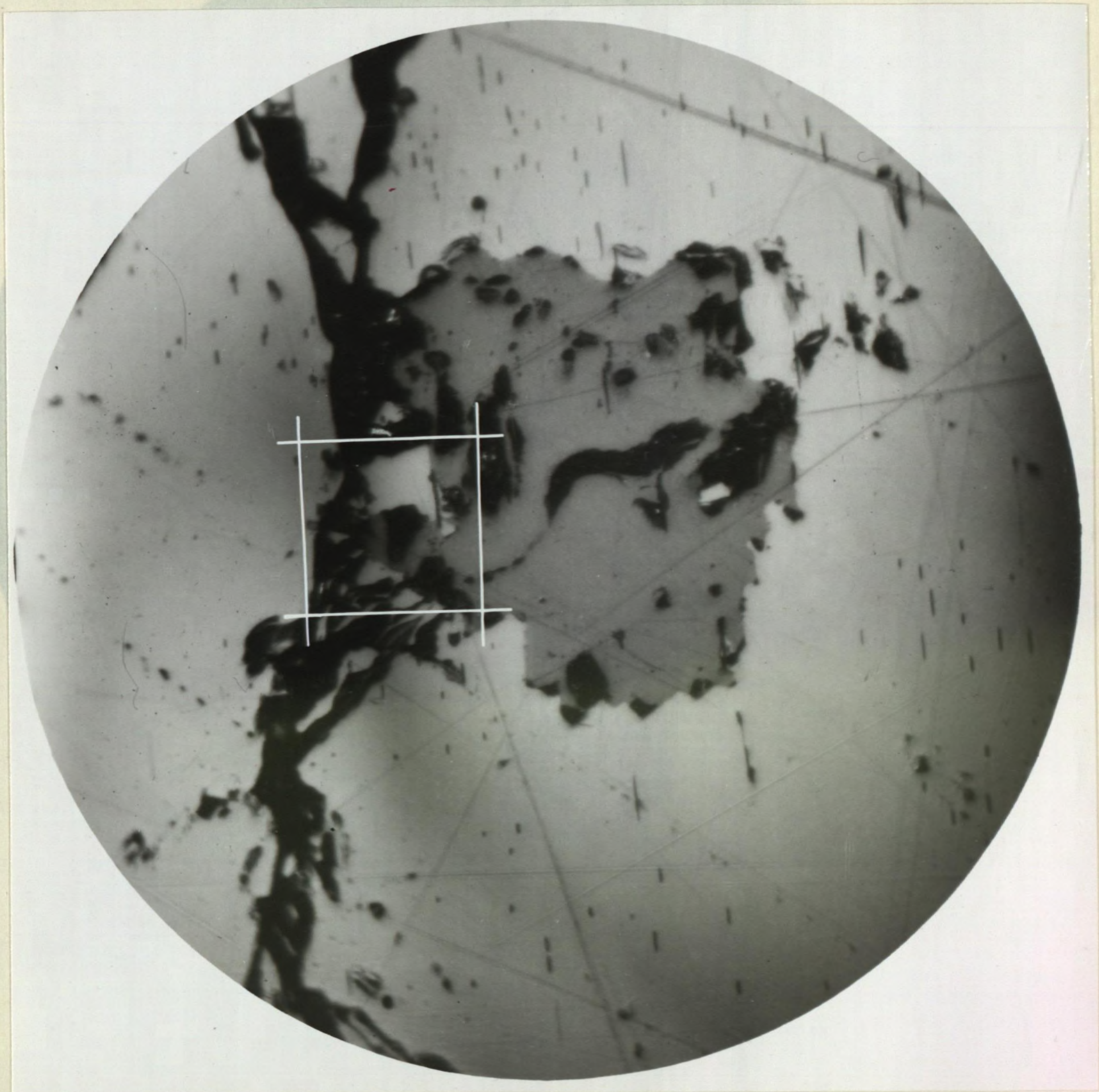
Figure 1.



350 X Oil Immersion

Polished section showing narrow veinlets of hematite (white) around an inclusion of gangue (black, rounded body under grid) in magnetite and transgressing apparently dense magnetic iron oxide. Note ragged outlines where the two iron oxides meet and medial lines along hematite veinlets. The other black areas are pits. The white grid represents a 200 - mesh Tyler screen opening.

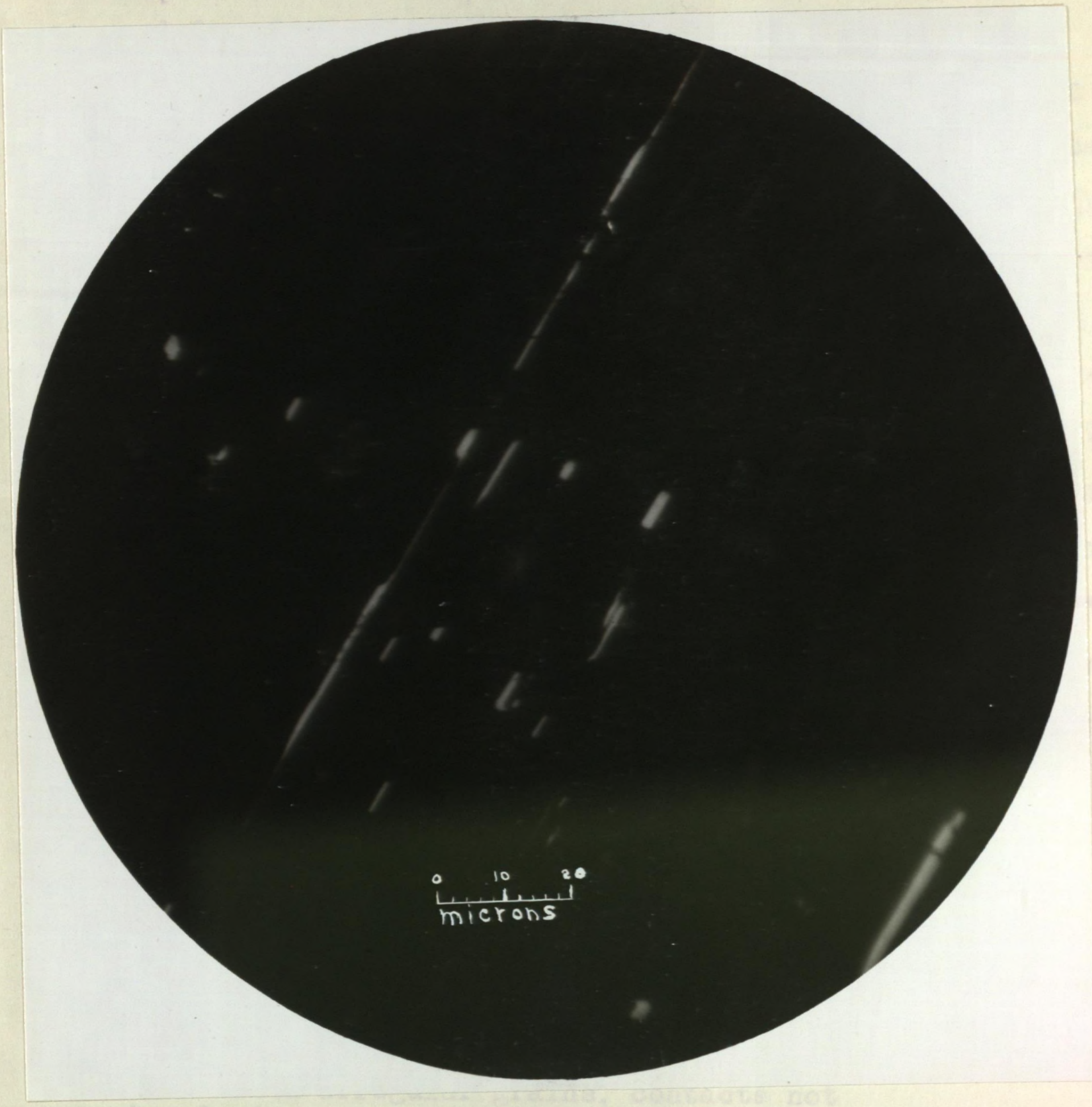
Figure 2.



350X Oil Immersion

Polished section showing what is thought to be a residual inclusion of magnetite (dark gray) in hematite (light gray). Note corroded outline of host-guest contact. Straight lines are scratches and pits are black. A 200-mesh Tyler screen opening is superimposed.

Figure 3.



1000 X Oil Immersion

Photomicrograph of polished section showing parallel needles and laths of hematite (white) in corundum (black).

Microscopic Examination - Thin Sections

The following is a microscopic report by Dr. M.E. Wilson of the Geological Survey, made on thin sections of the same samples as used for obtaining the polished sections:

These rocks are all nepheline pegmatite consisting mainly of nepheline, albite, microcline with microperthite in some samples. The nepheline occurs for the most part in coarse grains having smoothly irregular margins. There are a few grains that are .1 mm. in diameter, but probably over 95% are over .5 mm. in diameter. Other minerals present in all the samples are muscovite and magnetite. The magnetite grains are round to irregular in form--minimum size .1 mm. Hematite occurs in a few minute angular grains in Samples B and C. It is fairly abundant in coarser grains in F. Corundum is present in a single grain in sample B. It is common in very irregular grains or areas associated with magnetite and hematite in sample F. The minimum size of the corundum grains is .05 mm., but these are not abundant. At least 95% of the grains are over .5 mm. in diameter. More detailed descriptions of the thin sections of the different samples are as follows:

SECTION "A"

Mineral Descriptions	Minimum diameter of grains
Albite in fresh irregular grains, contacts not sharply irregular or sutured, abundant.	
Microcline in moderately coarse grains, contacts smooth, moderately abundant.	
Microperthite--only a few grains; boundaries irregular, but not sutured.	
Nepheline--mostly in coarse grains; contact smoothly irregular, mostly fresh . Some grains cut by irregular minute fractures filled with muscovite.	.1 mm
Muscovite in well defined straight edged crystals, the smallest .3 mm. long x .1 mm. wide; not abundant.	.1 mm
Magnetite in aggregates; round to irregularly shaped grains.	.1 mm
No corundum.	
No hematite	

The rock is nepheline pegmatite.

SECTION "B"

Albite -- for the most part coarse-grained, fresh, contacts in part smooth, in part sutured on a minute scale; projections corresponding to the ends of the twinning laminae, abundant.

Microcline--medium-grained, contact smooth, fairly abundant.

Nepheline--for the most part in coarse fresh grains; a few grains traversed by fractures containing muscovite, contact smoothly irregular. .15 mm.

Muscovite in crystals having the usual tabular form; the smallest .2 mm. x .1 mm. .1 mm.

Hematite-- a few scattered angular veins; one aggregate of grains. .05 mm.

The rock is nepheline pegmatite.

SECTION "C"

Albite--for the most part in coarse grains, fresh; contacts smoothly irregular but tooth-like projections occur in places at the end of the twinning laminae, abundant.

Microcline in grains of medium size here and there, margins of grains smooth, fresh.

Nepheline in medium to large crystals, irregular grains mostly fresh, but a few grains are fractures and contain minute aggregates of muscovite. .1 mm.

Muscovite in well defined scattered tabular crystals; minimum size .2 mm. x .04 mm. .04 mm.

Magnetite in a few scattered grains, rectangular, round, or irregular in form. .1 mm.

Hematite--a single angular grain noted. .1 mm.

Zircon--a single crystal .25 mm. x .1 mm.

No corundum.

The rock is nepheline pegmatite.

SECTION "D"

Albite--abundant, for the most part in coarse grains; smoothly irregular in form except at the ends of twinning laminae where tooth-like projections occur in places.

Microcline in some medium to large size grains, smoothly irregular in form.

Microperthite--a few grains of microcline,intergrown with albite.

Nepheline--mostly in medium to large smoothly irregular grains; altered to a radially lamellar mineral, probably giesechite; colour, light brown.

(Section "D", contin'd)

Muscovite--a few scattered tabular crystals, the smallest .4 mm x .25 mm.

Scapolite--only two grains noted

Magnetite--a few small scattered grains .1 mm

The rock is nepheline pegmatite

SECTION "E"

Albite, microcline and microperthite as in previous section

Nepheline in medium to large smoothly irregular grains brown in colour from alteration to gieseckite .1 mm

Muscovite in several very large crystals and in two large areas, one of which surrounds magnetite .05 mm

Magnetite--partly in a few scattered grains, but mainly in elongated areas surrounding a hole in the section which may have been wholly magnetite originally; the outer contact of magnetite has a dodecahedral form. .1 mm

The section is crossed by a vein consisting of chlorite and a very little carbonate --width 1mm.

No corundum

The rock is nepheline pegmatite

SECTION "F"

Albite--occurs for the most part in smoothly irregular grains, but in some cases projecting at the ends of twinning laminae; abundant.

Microcline--mostly irregular grains, not very abundant.

Nepheline --not abundant; it occurs in zones around corundum or in one case around muscovite. Minimum width of zone about .05 mm. .05 mm

Muscovite--mostly in areas of considerable size associated with corundum, magnetite and hematite

Magnetite--in medium sized irregular to angular grains .35 mm

Hematite--in areas adjoining or surrounding magnetite; also associated with corundum in places .05 mm

Corundum--partly in areas adjoining magnetite and hematite; partly in groups of scattered, very irregular grains, most intricate in form; see photomicrographs to follow.

The rock is nepheline-corundum-bearing pegmatite.

Figure 4

65X Transmitted light

Thin section F showing a differentially coloured crystal of corundum (c) penetrating a grain of metallics (M). The portion in the metallics is outlined in white due to dense brown colour which made it opaque to light on the photographic plate.

Figure 5

200 X Transmitted light

Thin section F showing group of small irregular grains of corundum (high relief) in Nepheline syenite.

Heavy Mineral Identification

The following is a report by V.L. Eardley-Wilmot on the identification of some of the heavy minerals contained in the Nepheline Syenite and obtained during preliminary tabling tests.

Samples of approximately 30 grams each were taken from two bags of "Non-Magnetic" concentrate that were collected from tabling and low intensity magnetic separation. These samples were treated with a strong hand magnet with the following separations and observations being made.

No. 1 - Highly magnetic material.

No. 2 - Weakly magnetic material.

No. 3 - Non magnetic material.

No. 1 Highly magnetic - This is Magnetite and chemical analysis of the cleanest portion (very little attached particles) was Fe 70.34% or 97.1% Fe_3O_4

Insolubile, mainly silica 0.14%

Titanium Ti and Vanadium V - Nil.

No. 2 Weakly magnetic - This was at first thought to be Ilmenite, but spectrographic analysis showed only a trace of Ti. Chemical analysis of the cleanest portion gave

Fe 63.06%

Insolubiles (SiO_2 etc) 4.1%

Ti & V both nil.

It looked like specular iron but under the microscope there was only an occasional grain, which on fine pulverizing showed a transparent blood-red, typical of specular hematite. Dr. E. Poitevin of the Geological Survey stated it is a transition stage between Magnetite and Hematite and might be Martite.

Small cuts made at the 1st, 2nd and 3rd half inch of the concentrate band on the table showed that slightly more of this mineral than the true mineral was in the heaviest section. This would indicate that it is slightly heavier than magnetite but Dana (Textbook of Mineralogy) reports Martite as having a lower specific gravity.

The composition according to the above assay would be about 95% Fe_2O_3 + Fe_3O_4 .

Average samples of the above three products were micro-examined and it was noted that many of the grains of No. 1 and No. 2 had attached particles mainly of transparent white minerals.

No. 3 Non-Magnetic - The non-magnetic portion showed considerable opaque or semi-opaque brown, and to a lesser extent transparent white minerals. Tests indicated they were both Corundum and therefore two types of corundum occur, the white being the purest.

Under the ultra violet light an occasional orange fluorescent grain indicated the presence of Zircon. A few grains of a pale blue fluorescent mineral was sent for spectrographic analysis and showed major W and Ca, proving it to be Scheelite. It is uncertain if this scheelite was in the original rock or if it was picked up in the mill circuit, as scheelite ore was treated about a year ago. However, a cut from the heaviest ½ inch of the table concentrate taken two weeks later showed about 100 scheelite grains in a sample weighing 0.3 grams which was the non-magnetic portion and which represented 0.7% of the sample obtained in the cut; the remaining 99.3% being magnetite - hematite with attached minerals.

About 50 grains of a transparent green heavy non-magnetic mineral was sent for spectrographic analysis and showed major Al and Zn indicating the Spinel mineral Gahnite , a zinc aluminate.

(Note- both Gahnite and Zircon occur associated with the Craigmont Corundum)

Tables A and B show the proportion of the three products reported, that occur in the Non-Magnetic portion of the table concentrate.

Table A

Non-Magnetic Portion of Concentrate from Wilfley Table treating FEED after further Hand Magnet Concentration.

Product	Wt %
No. 1 Magnetite + about 12% transparent white minerals attached	2.94 %
No. 2 Martite? + about 8% transparent white minerals attached	29.81 %
No. 3 Non-Magnetics	67.25 %

Table B

Non-Magnetic Portions of Concentrate from Wilfley Table treating MIDDLINGS from 1st table, after further Hand Magnet Concentration.

Product	Wt %
No. 1 Magnetite + about 5% transparent white minerals attached	2.04 %
No. 2 Martite? + about 5% transparent white minerals attached	34.52 %
No. 3 Non-Magnetics	61.63 %

Calcite - The pile of Nepheline Syenite stacked on the floor of the mill was examined with Ultra Violet light after dark, for the presence of Calcite. Only a few pieces of rock were notedthat contained streaks and "blobs" of calcite. It was estimated that the percentage of calcite in that particular shipment would be very low - probably not more than 0.1%.

Table C is a report of the Qualitative Spectrographic analyses made on the samples as discussed.

Table C

ANALYSES

	ELEMENTS 1	2	3	4	5	ND	REMARKS
1. Outside ½" of table Non-Magnetics	Al	W	Fe Si Cu P Mn As Bi Zn	Pb Mg V	Cr Sn Ti Ca		Mainly corundum with grains of gahnite, Scheelite, etc.
2. Next 1" of table Non-Magnetics	Al	Na Si	Fe Mn V		Mg Sn Ti Cw W		Mainly corundum attached nepheline and traces of above minerals in No.1.
3. Outside ½" of table. Cleaned Feebly magnetic mineral (Blue black)	Fe		Mn Sn Si	Mg Al V Ti	Ni Cu Ca		Martite (between Magnetite and Hematite)
4. Outside ½" of table. Grains of bottle green mineral only	Al	Zn	Si Fe Mn Mg		P Cu Ca		Gahnite (Zinc Aluminate)
5. Outside ½" of table very magnetic, (cleaned) (Dull black)	Fe		Si Mn Sn	Mg Ni Al Cu V	Ti Ca		Magnetite
6. Brown & Bronze semi opaque grains (cleaned) in ASSAY Residue	Al		Ca Fe Si Mg	Mn	Ti V		Corundum

Estimated Importance

1 - Major constituent
2 - Minor constituent
3 - Strong trace
4 - Trace
5 - Faint trace
ND - non-detected

SECTION B - PREPARATION.

Crushing.

To develop this part of the flowsheet it was assumed the rock, as received, had been broken to a size which would be somewhat representative of the preliminary breaking operation as done by a jaw crusher. In this respect it is anticipated that a crusher of this type, breaking run-of-mine, or quarry rock, would discharge approximately 6" to 8" lump.

To reduce this size of lump to minus ¾" for feed to the grinding unit (a size later established as suitable feed to a rod mill) it was considered advisable to employ secondary and tertiary stages of crushing for the minimum production of minus 28 mesh product. Since this was the specified size of ground product, any excessive amount produced in crushing operations would undoubtedly increase the overall grind, especially in the finer sizes, resulting in a higher slime loss.

The equipment used in the investigation is listed as follows:

Jaw Crusher - Hadfield (Blake Type) 8"x12".
Gyratory Crusher - Austin No. 103.
Symons Cone Crusher - 20" Shorthead - Fine Bowl.
Rolls Crusher - Allis Chalmers 24" Diam. 14" Face.
Hammer Mill - Sturtevant No. 00-3400R.P.M.

Secondary Crushing.

Jaw Crusher - Gyratory Crusher.

The use of a jaw crusher and a gyratory crusher each set to discharge at 1½" were employed as a means of obtaining secondary crushing conditions.

Samples of 1000 lbs. were crushed by each of these crushers and the discharge products were screened. Hand screening was used on the coarser sizes followed by mechanical methods on the finer sizes. This change in screening methods resulted in a slight irregularity as will be noticed on the plotted results.

Table 1 gives the comparative screen analyses of the Nepheline Syenite crushed by jaw crusher and gyratory crusher. These results are plotted on the graph as Test 1 and Test 3, respectively.

Table 1.

Screen analyses of Nepheline Syenite crushed by Jaw Crusher Test 1 and Gyratory Crusher Test 3, each crusher set to discharge at $1\frac{1}{2}$".

Product Mesh	Jaw Crusher, Test #1. Wt. %	Cum. Wt. %.	Gyratory Crusher, Test #3. Wt. %.	Cum. Wt. %.
$-1\frac{1}{2}$" + 1"	63.37	63.37	33.65	33.65
-1" + $\frac{1}{2}$"	16.32	79.69	35.14	68.79
$-\frac{1}{2}$" + 3m.	8.26	87.95	14.04	82.83
-3 + 4	2.07	90.03	3.29	86.12
-4 + 6	1.21	91.23	2.69	88.81
-6 + 8	1.41	92.64	1.39	90.20
-8 +10	1.00	93.64	1.64	91.84
-10 +14	.18	93.82	.36	92.20
-14 +20	.77	94.59	1.10	93.30
-20 +28	.76	95.35	.96	94.26
-28 +35	.78	96.13	.98	95.24
-35 +48	.68	96.81	.82	96.06
-48 +65	.41	97.22	.77	96.83
-65 +100	.69	97.91	.67	97.50
-100 +150	.53	98.44	.66	98.16
-150 +200	.41	98.85	.52	98.68
-200	1.15	100.00	1.32	100.00

The results of this test showed that the gyratory produced less of the coarse size $-1\frac{1}{2}$" +1" due possibly to the nature in which the Nepheline Syenite breaks. The gyratory crusher discharge contained much less "slab" product and gave a more uniform breaking effect.

If breaking and screening to minus 1 inch would be satisfactory in plant operation of the grinding unit, screen tests show that using a gyratory crusher only 33.65% of the mill feed would have to be further crushed as compared with 63.37% when using a jaw crusher.

There is very little difference in the amount of minus 28 mesh product when using either crusher, so this condition should not be taken into consideration in selection of a secondary crusher.

Tertiary Crushing.

In this stage of crushing, Symons Crusher, Rolls Crusher, Hammer Mills and combinations of those crushers mentioned were studied.

Symons Cone Crusher.

To show the effect of a third stage of crushing, samples of the same weight were passed through the jaw crusher and gyratory crusher, each set to $1\frac{1}{2}$" and then crushed in a symons crusher set to 5/8" without screening between crushing. In plant operation, screening before further crushing would be expected to be employed but for this comparative test was not considered essential.

Table 2 shows the comparative screen analyses of the Symons Crusher products. These results are plotted on the graph as Test 2 for the Jaw Crusher test and Test 4 for the Gyratory Crusher test.

Table 2.

Screen analyses of Nepheline Syenite crushed by Jaw Crusher set $1\frac{1}{2}$" followed by Symons Crusher set 5/8" Test 2. Similar settings Test 4, Gyratory and Symons.

Product Mesh	Jaw Crusher - Symons Crusher Test #2. Wt. %	Cum. Wt. %.	Gyratory Crusher - Symons Crusher Test #4. Wt. %.	Cum. Wt. %.
+ ½"	50.20	50.20	46.20	46.20
- ½ + 3m	25.96	76.16	27.54	73.74
- 3 + 4	4.56	80.72	5.30	79.04
- 4 + 6	3.14	83.86	3.67	82.71
- 6 + 8	2.64	86.50	2.60	85.31
- 8 + 10	2.33	88.83	2.14	87.45
- 10 + 14	1.12	89.95	2.24	89.69
- 14 + 20	.86	90.81	.30	89.99
- 20 + 28	1.49	92.30	1.30	91.37
- 28 + 35	1.47	93.77	1.60	92.97
- 35 + 48	1.25	95.02	1.39	94.36
- 48 + 65	1.18	96.20	1.30	95.66
- 65 +100	.91	97.11	1.07	96.73
-100 +150	.93	98.04	1.05	97.78
-150 +200	.67	98.71	.78	97.56
-200	1.29	100.00	1.44	100.0

From the results of these tests it is evident that a Symons Cone Crusher can crush a product containing a higher proportion of coarse "slab" Nepheline Syenite resulting from Jaw Crushing to give results comparative to Gyratory Crushing followed by Symons.

The percentage of minus 28 mesh product in each case is practically the same; the amount of minus 200 mesh less than $1\frac{1}{2}$%.

Rochester Crushing Plant.

The screen analysis of the crusher product from the Company's plant at Rochester, N. Y., is included in the report as a matter of interest.

The equipment used in crushing operations consisted of a Jaw Crusher set $1\frac{1}{2}$" and a 2'C" Symons Cone Crusher set at $\frac{3}{4}$".

The sample was screened at Ore Dressing Laboratories, Ottawa. The results are reported in Table 3 and plotted on the graph as Test R.

Table 3.

Screen analysis of product from Rochester Plant of American Nepheline Corporation. Crushers used consisted of Jaw Crusher set 1½ and Symons Cone Crusher set ¾".

Test R.

Product Mesh	A.N.C. Rochester Operations	
	Wt. %	Cum. Wt. %
+ 1"	3.73	3.73
- 1" + ¾"	10.85	14.58
- ¾" + ½"	37.59	52.17
- ½" + 3m.	24.74	76.91
- 3 + 4	5.03	81.94
- 4 + 6	3.30	85.24
- 6 + 8	2.43	87.67
- 8 + 10	1.65	89.32
- 10 + 14	1.22	90.54
- 14 + 20	1.13	91.67
- 20 + 28	.73	92.40
- 28 + 35	1.17	93.57
- 35 + 48	1.03	94.60
- 48 + 65	1.02	95.62
- 65 +100	0.80	96.42
-100 +150	0.91	97.33
-150 +200	0.70	98.03
-200	1.97	100.00

The results of this test are quite conformable with results obtained in the Departments test using similar type of equipment.

Symons Cone Crusher - Fine Crushing.

In the event that a finer product before grinding was desired a test was made to show the effect of a finer set on the Symons Crusher. In this test a 1000-lb. sample was passed through the Jaw Crusher Set 1½" and then crushed in the Symons Crusher set 3/16".

This test is plotted on the graph as Test #9, the results of which are shown in Table 4.

Table 4.

Screen analysis of Nepheline Syenite crushed by Jaw Crusher set 1½" followed by Symons Cone Crusher set 3/16".

Test #9.

Product Mesh	Jaw Crusher - Symons Crusher	
	Wt. %	Cum. Wt.%
+ 3m.	53.64	53.64
- 3 + 4	11.76	65.40
- 4 + 6	8.18	73.58
- 6 + 8	3.69	77.27
- 8 + 10	4.39	81.66
- 10 + 14	2.99	84.65
- 14 + 20	2.19	86.84
- 20 + 28	2.59	89.43
- 28 + 35	.32	89.75
- 35 + 48	1.65	91.40
- 48 + 65	1.99	93.39
- 65 +100	1.56	94.95
-100 +150	1.57	96.52
-150 +200	1.17	97.69
-200	2.31	100.00

The plotted results of this test show an interesting comparison with that of the previous test using a Symons at a coarser setting.

A test of a similar nature was made using a Symons Cone Crusher, only in this case the sample was successively crushed at settings of 5/8", 7/16" and 3/16" with the minus 28 mesh product removed after each crushing by the Symons.

The results of this test are plotted as Test 8 and the screen analysis reported in Table 5.

Table 5.

Screen analysis of Nepheline Syenite crushed by Jaw Crusher set $1\frac{1}{2}$" and Symons Cone Crusher successively at 5/8, 7/16 and 3/16" openings. Minus 28 mesh product removed after each crushing by Symons Cone Crusher.

Test 8.

Product Mesh	Jaw Crusher - Symons Cone Crusher	
	Wt. %.	Cum. Wt. %
+ 3m.	52.01	52.01
- 3 + 4	11.58	63.59
- 4 + 6	7.21	70.80
- 6 + 8	4.06	74.86
- 8 + 10	3.86	78.72
- 10 + 14	3.25	81.97
- 14 + 20	2.84	84.81
- 20 + 28	1.68	86.49
- 28 + 35	1.17	87.66
- 35 + 48	2.52	90.18
- 48 + 65	2.33	92.51
- 65 +100	1.85	94.36
-100 +150	1.82	96.18
-150 +200	1.31	97.49
-200	2.51	100.00

As would be expected from such a test the amount of crushing done is slightly greater than would be accomplished in a single pass through the Symons Cone crusher to the same opening as reported in the previous test. However, the difference does not warrant this method of crushing.

If a proper stage crushing test had been conducted, one in which all the size product of following crusher discharge opening was removed before subsequent crushing, the results of this test would have yielded slightly more information.

Roll Crushing.

Continuing the investigation of studying the necessity of producing a finer crushed product tests were made employing the use of Rolls crushers.

In the first test Rolls set to $\frac{1}{4}$" were used to crush a product which had been previously crushed in a Jaw Crusher set $1\frac{1}{2}$", followed by a Symons Cone Crusher set 5/8" and having the minus 28 mesh screened out after the latter crushing.

The results are plotted as Test 6 and tabulated in Table 6.

Table 6.

Screen Analysis of Nepheline Syenite crushed in Jaw Crusher set 1½", Symons Cone Crusher set 5/8", minus 28 mesh screened out and subsecuently crushed by Rolls set ¼".

Test #6

Product Mesh	Jaw Crusher - Symons Crusher - Rolls Wt. %	Cum. Wt. %
- ¼" + 3m.	48.84	48.84
- 3 + 4	15.18	64.02
- 4 + 6	8.24	72.26
- 6 + 8	4.92	77.18
- 8 + 10	3.82	81.00
- 10 + 14	3.02	84.02
- 14 + 20	2.01	86.03
- 20 + 28	1.61	87.64
- 28 + 35	.95	88.59
- 35 + 48	2.14	90.73
- 48 + 65	2.13	92.86
- 65 +100	1.71	94.57
-100 +150	1.67	96.24
-150 +200	1.26	97.50
-200	2.50	100.00

Comparing the results of this test with that of Test 9 in which only a Symons Crusher set to 3/16" was used it would appear evident that the Symons equipped with a fine bowl would do the same amount of work as a combined set up of Symons to reduce the secondary crusher product followed by Rolls to produce the finer size. The plotted results of Test 5 and Test 9 show this condition.

In the second test using Rolls a further crushing effect was studied. The 1000-lb. sample was crushed in Jaw Crusher set 1½" and Symons Cone Crusher set 3/16". After screening out the minus 28 mesh the oversize was crushed in Rolls at settings of 1/8" and 8-10 mesh with the minus 28 mesh screen out between roll crushings.

The results of this test are reported in Table 7 and plotted as Test 10.

Table 7.

Screen analysis of Nepheline Syenite crushed by Jaw Crusher set 1½", Symons Crusher set 3/16", Rolls Crusher at 1/8" and 8-10 mesh settings with minus 28 mesh product screened out after Symons and Rolls crushings.

Test #10.

Product Mesh	Jaw Crusher, Symons Cone, Rolls Crusher Wt. %	Cum. Wt. %
+ 8m	37.92	37.92
- 8 + 10	16.25	54.17
- 10 + 14	10.31	64.48
- 14 + 20	5.52	70.00
-20 + 28	5.63	75.63
- 28 + 35	1.80	77.43
- 35 + 48	4.77	82.20
- 48 + 65	4.44	86.64
- 65 +100	3.53	90.17
-100 +150	3.32	93.49
-150 +200	2.31	95.80
-200	4.20	100.00

The above results would indicate that if fine crushing was a desired condition, a flowsheet combining the equipment used in this test would have definite application. For the amount of crushing done, as illustrated quite clearly on the graph, this flowsheet did not produce an excessive amount of minus 200 mesh material.

Lakefield Test.

To further investigate the possibility of using Rolls Crushers as a means of producing a minus 28 mesh product a test was conducted at the Lakefield Plant of the American Nepheline Limited.

This was done under operating conditions, taking the Jaw Crusher discharge and stage crushing in two sets of Rolls set at ¼" and 20 mesh respectively, using 28 mesh screens in both cases, with the second screen being in closed circuit with the second set of Rolls.

The results of this test are reported in Table 8 and plotted on the graph as Test L.

Table 8.

Screen analyses of products from continuous test using Stage Rolls Crushing as a means of producing a minus 28 mesh product.

Product Mesh	Jaw Crusher Discharge		#1 Roll Discharge		#1 Screen Oversize		#2 Roll Discharge		#2 Screen Oversize		Feed To Separator	
	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
+ 4	69.32	69.32	58.51	58.51	30.60	30.60	10.75	10.75	8.87	8.87	--	--
- 4 + 8	7.51	76.83	15.71	74.22	20.17	50.77	17.59	28.34	22.83	31.70	--	--
- 8 + 14	--	--	--	--	--	--	--	--	--	--	--	--
- 14 + 20	7.88	84.71	11.36	85.58	29.14	79.91	28.43	56.77	40.77	72.47	--	--
- 20 + 28	1.83	86.54	2.22	87.80	7.36	87.27	7.17	63.94	8.57	81.04	0.64	.64
- 28 + 35	2.46	89.00	2.56	90.36	7.86	95.13	9.77	73.71	9.84	90.88	10.04	10.68
- 35 + 48	2.21	91.21	2.04	92.40	2.39	97.52	5.84	79.55	3.90	94.78	17.76	28.44
- 48 + 65	2.19	93.40	1.97	94.37	1.08	98.60	4.75	84.30	1.94	96.72	17.70	46.14
- 65 +100	2.05	95.45	1.63	96.00	0.61	99.21	3.87	88.17	1.15	97.87	14.36	60.50
-100 +150	1.83	97.28	1.44	97.44	0.40	99.61	3.38	91.55	0.86	98.73	12.84	73.34
-150 +200	1.16	98.44	0.93	98.37	0.12	99.73	2.34	93.89	0.49	99.22	8.32	81.66
-200	1.56	100.00	1.63	100.00	0.27	100.00	6.11	100.00	0.78	100.00	18.34	100.00

Note:

Dust collectors were used in circuit. The dust loss was not measured.

Hammer Mill.

An interesting series of tests were conducted using a Hammer Mill for tertiary stage crushing. Possibly in this particular flowsheet such a crusher would not be applicable due to the abrasive nature of the Nepheline Syenite but the results are reported to show what crushing can be accomplished by Hammer Mills.

In Test 5, 1000 lb. of Nepheline Syenite was crushed in a Gyratory Crusher set 1½" and then crushed in the Hammer Mill equipped with ½" grates.

In Test 11, the above procedure was repeated, and after screening out the minus 28 mesh product, the oversize was re-crushed in the Hammer Mill equipped with 1/8" grates.

The capacity of the Hammer Mill used was established as approximately 3 ton per hour.

The results of this investigation are reported in Table 9 and plotted on the graph as Test 5 and Test 11.

Test 9.

Screen analyses of Nepheline Syenite crushed by Gyratory Crusher set 1½", Hammer Mill ½" grates Test 5; and Test 11 with the above procedure repeated, the minus 28 mesh product screened out and re-crushed in Hammer Mill using 1/8" grates.

Product Mesh	Test #5. Gyratory Crusher Hammer Mill ½" grates		Test #11. Gyratory Crusher Hammer Mill ½" & 1/8" grates	
	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
- ½" + 3m.	18.58	18.58	--	--
- 3 + 4	10.89	29.37	--	--
- 4 + 6	10.50	39.87	--	--
- 6 + 8	7.97	47.84	14.99	14.99
- 8 + 10	7.47	55.31	10.39	25.38
- 10 + 14	7.11	62.42	10.29	35.67
- 14 + 20	1.95	64.37	8.59	44.26
- 20 + 28	5.87	70.24	10.09	54.35
- 28 + 35	5.95	76.19	3.75	58.10
- 35 + 48	5.19	81.38	8.71	66.81
- 48 + 65	4.45	85.83	8.24	75.05
- 65 +100	3.54	89.37	6.02	81.07
-100 +150	3.35	92.72	5.78	86.85
-150 +200	2.28	95.00	4.00	90.85
-200	5.00	100.00	9.15	100.00

Summary - Crushing.

Preliminary breaking would be accomplished successfully by the use of a Jaw Crusher.

Secondary Crushing may employ either a Jaw Crusher or a Gyratory Crusher. It would be advisable to consult manufacturers of Gyratory Crushers for information regarding the reduction of preliminary crusher discharge to mill feed size without the use of tertiary crushing.

Tertiary crushing, if required, would be best accomplished by the use of a Cone Crusher. (Symons type). This type of crusher will allow a reduction resulting in a discharge product ranging from 1½" to 3/16" without an appreciable increase in the percentage of fines produced.

If crushing without grinding was contemplated, a minus 28 mesh product could be produced by stage crushing employing Rolls.

The use of Hammer Mills for crushing Nepheline Syenite would not appear to be applicable due to the abrasive nature of the rock. In all probability there would be high maintenance costs in plant operation.

Grinding.

The characteristics of the required ground Nepheline Syenite product decided to a great extent the type of grinding unit to be used.

To meet trade specifications it was essential that a coarse grind, approximately minus 28 mesh, be established and keeping to a minimum the amount of resulting minus 200 mesh product.

A type of mill having a high center discharge would be detrimental in this latter respect as such a unit would produce a higher percentage of the size which may have to be considered a loss in plant operation.

The alternative was to examine a low discharge type of grinding unit. Two types of standard equipment employing this feature would be applicable -

a grate discharge ball mill.
a low discharge rod mill.

For the purpose of this investigation it was decided to use the latter type.

Test work should also include a comparative study on the use of a pebble mill and a steel mill, namely, a rod mill, for reasons discussed under the heading of concentration by flotation. This test is contemplated but since it did not effect the general flowsheet being developed, other than the proper selection of grinding unit, it was decided to include this in a supplementary report.

In the grinding test the Company requested that consideration be given to the possible use of a dry grinding unit.

The Department did not have an air swept mill available capable of handling a grind of this nature, so any tests undertaken were on a direct comparison of dry and wet conditions in the mill.

For reasons also discussed under flotation it is the Department's opinion that wet grinding will have definite physical and chemical advantages for the flotation of the iron and corundum minerals.

Grinding Conditions - General.

Dry Grinding, Test 14.
Wet Grinding, Test 15.
Wet Grinding, Test 18.
Wet Grinding, Test 21.

The mill used in the above mentioned tests was a low discharge Marcy Rod Mill 3' diameter by 6' long, inside the shell, having a rod load of 2151 lbs. or approximately 25% of the mill volume and a speed of 31 R.P.M. The rods consisted of a mixed charge varying from $2\frac{1}{2}$" to 1" in diameter.

In tests 14 and 15 the mill was operated in closed circuit with a 3' and 5' Hummer Screen using a Tyler standard 26 mesh square opening screen cloth.

In tests 18 and 21 a medium heavy wire Ty-Rod screen No. 9902 with 0.0215" opening (26 mesh) replaced the standard

26 mesh square opening.

The mill feed in all tests reported was a 3/4" Symons Cone crusher discharge.

Dry Grinding - Test #19.

The operating conditions used in the dry grinding test was a feed rate of 1890 lbs. per hour, maintaining a circulating load of 100%.

The results of this test are plotted on the graph as Test #14 and are reported in Table 10.

Table 10.

Screen analyses of products from Dry Grinding Test #14, Rod Mill in closed circuit with Hummer Screen using a Tyler Standard 26 mesh square opening screen cloth.

Product Mesh	Head Feed		Rod Mill Discharge		Screen Oversize		Screen Undersize	
	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
- 1" + 3/4"	5.59	5.59	--	--	--	--	--	--
- 3/4" + 1/2"	15.51	21.10	--	--	--	--	--	--
- 1/2" + 3m.	32.14	53.24	--	--	--	--	--	--
- 3 + 4m.	22.60	75.84	--	--	--	--	--	--
- 4 + 6	5.84	81.68	--	--	--	--	--	--
- 6 + 8	3.58	85.62	--	--	--	--	--	--
- 8 + 10	2.76	88.02	3.05	3.05	3.02	3.02	--	--
- 10 + 14	1.63	89.65	7.80	10.85	10.62	13.64	--	--
- 14 + 20	1.63	91.28	10.04	20.89	14.93	28.57	--	--
- 20 + 28	1.44	92.72	14.01	34.90	28.13	56.70	--	--
- 28	.79	93.51	19.55	54.45	32.58	89.28	--	--
- 28	--		--		10.72	100.00	13.4	13.4
- 28 + 35	1.34	94.85	11.11	65.56	--	--	16.9	30.3
- 35 + 48	1.16	96.01	8.15	73.71	--	--	15.0	45.3
- 48 + 65	1.04	97.05	6.74	80.45	--	--	11.0	56.3
- 65 +100	0.79	97.84	4.51	84.96	--	--	12.2	68.5
-100 +150	0.85	98.69	4.28	89.24	--	--	8.7	77.2
-150 +200	0.56	98.25	2.69	91.93	--	--	22.8	100.0
-200	0.75	100.00	8.07	100.00				

Wet Grinding - Test #15, Tyler Standard 26 Mesh Screen.

Comparative operating conditions used in the wet grinding test was a feed rate of 2970 lbs. per hour maintaining a circulating load of slightly over a 100%. Pulp densities in the circuit were: Rod mill discharge 62% solids; screen oversize 61% solids; and screen undersize 25% solids.

The results of this test are plotted on the graph as Test #15 and reported in Table 11.

Table 11.

Screen analyses of products from wet grinding, Test #15, Rod Mill in closed circuit with Hummer Screen using a Tyler Standard 26 square opening screen cloth.

Product Mesh	Rod Mill Discharge		Screen Oversize		Screen Undersize	
	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
+ 14	1.85	1.85	7.85	7.85	--	--
- 14 + 20	4.75	6.60	12.90	20.75	--	--
- 20 + 28	12.10	18.70	24.50	45.25	0.1	0.1
- 28 + 35	21.75	40.45	30.00	75.25	8.3	8.4
- 35 + 48	16.25	56.70	11.90	87.15	16.9	25.3
- 48 + 65	12.45	69.15	6.30	93.45	17.2	42.5
- 65 +100	8.10	77.25	3.00	96.45	12.6	55.1
-100 +150	7.55	84.80	1.75	98.20	12.5	67.6
-150 +200	4.85	89.65	0.70	98.90	9.0	76.6
-200	10.35	100.00	1.10	100.00	23.4	100.0

Wet Grinding - Test #18, Tyler Ty-Rod #9902 Screen.

In this test the Tyler Standard 26 mesh screen cloth was replaced with a Tyler Ty-Rod Screen No. 9902 - 0.0215" opening. A screen cloth of this type and approximate opening would result in conditions more closely representing plant operation.

A feed rate was maintained at 2880 lb. per hour with a circulating load of 70%. Pulp densities in the circuit were: Rod mill discharge 60% screen oversize 58%, and screen undersize 17% solids.

The results of this test are plotted on the graph as Test #18 and reported in Table 12.

Table 12.

Screen analyses of products from Wet Grinding Test #18, Rod mill in closed circuit with Hummer Screen using a Ty-Rod No. 9902 - 0.0215" opening screen cloth

Product Mesh	Rod Mill Discharge		Screen Oversize		Screen Undersize	
	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
+ 14	10.75	10.75	34.00	34.00	--	--
- 14 + 20	13.40	24.15	36.75	70.75	--	--
- 20 + 28	14.40	38.55	21.00	91.75	12.6	12.6
- 28 + 35	12.40	50.95	5.15	96.90	16.1	28.7
- 35 + 48	9.95	60.95	1.55	98.45	14.3	43.0
- 48 + 65	8.95	69.90	.65	99.10	12.8	55.8
- 65 +100	6.40	76.30	.30	99.40	9.9	65.7
-100 +150	6.95	83.24	.15	99.55	10.0	75.7
-150 +200	4.65	87.90	.15	99.70	6.9	82.6
-200	12.15	100.00	.30	100.00	17.4	100.0

It is important to note that in this test and test 15 the Rod mill discharge was elevated by means of a bucket elevator a distance sufficient to allow a good gravity return of the screen oversize to the Rod mill. A difficulty encountered under such conditions was a packing or segregation of the coarse material in the buckets making discharge difficult.

Wet Grinding - Test #21, Tyler Ty-Rod No. 9902.

Owing to the difficulty of solids packing in the buckets in Test #18, the flowsheet was arranged so that a gravity flow from the Rod mill was used, with the bucket elevator returning only the screen oversize to an elevation sufficient to give a good gravity return of this material.

Under such conditions it was possible to conduct a more efficient test. The feed rate was increased to 3720 lbs. per hour. Pulp densities in the circuit were: Rod mill discharge 65%; screen oversize 52%; and screen undersize 32% solids.

The results of this test are reported in Table 13 and plotted in red on graph as Test #21.

Table 13.

Screen Analyses of Products from Wet Grinding Test #21. Condition similar to Test #18. Rod mill discharge gravity flow to screen.

Product Mesh		Rod Mill Discharge		Screen Oversize		Screen Undersize	
		Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
	+ 14	1.00	1.00	3.55	3.55	--	--
- 14	+ 20	4.55	5.55	13.25	16.80	--	--
- 20	+ 28	13.05	18.60	27.80	44.60	6.5	6.5
- 28	+ 35	18.05	36.65	21.80	66.40	17.1	23.6
- 35	+ 48	13.90	50.55	9.65	76.05	17.5	41.1
- 48	+ 65	11.65	62.20	5.90	81.95	14.5	55.6
- 65	+100	8.90	71.10	4.05	86.00	11.0	66.6
-100	+150	8.00	79.10	3.55	89.55	9.0	75.6
-150	+200	5.95	85.05	2.60	92.15	6.8	82.4
-200		14.95	100.00	7.85	100.00	17.6	100.0

Middlings.

An important feature of a grind of this nature on the Nepheline Syenite is the subject of Middlings.

From microscopic examination made on polished sections and thin sections it is definitely shown that a grind to minus 28 mesh will not give complete liberation, especially of the iron impurities. These impurities are so disseminated that even a grind to minus 200 would not give complete liberation.

Concentration by flotation or gravity methods to eliminate such material and produce a sufficiently low Fe_2O_3 content in the Nepheline Syenite product would be very difficult, if not impossible.

High intensity magnetic separation would no doubt be an effective method to lower the Fe_2O_3 content, but it should be borne in mind that losses of Nepheline Syenite due to middlings occur.

This is more clearly illustrated by the following series of photomicrographs showing the presence of middlings in each of the screen sizes, with the exception of the minus 200 mesh size, as obtained from the grind circuit.

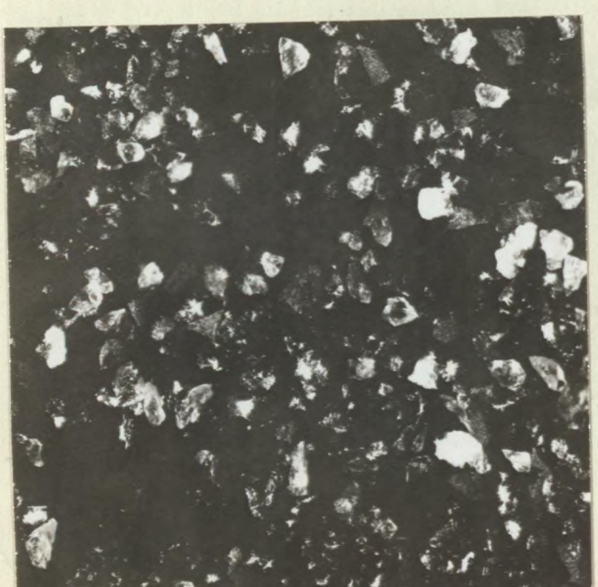
<u>Photomicrographs of Middling Particles in Screen Sizes Shown.</u>

-28 +35.

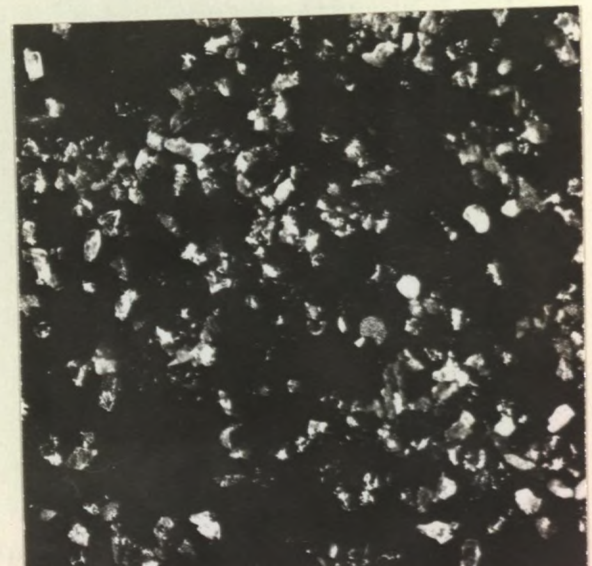
-35 +48.

-48 +65.

-65 +100.



-100 +150.



-150 +200.

Summary - Grinding.

The comparison between the dry grinding and wet grinding tests showed the following results:

Wet and dry grinding give a ground product of approximately the same screen analyses with the percentage of minus 200 mesh slightly lower using a wet circuit. The minus 200 mesh product in screen undersize was less than 20% in both dry and wet grinding using a 3' x 6' low discharge rod mill.

Wet grinding showed a marked increase in the capacity of the unit.

Screen cloth of the Ty-Rod type increased screening efficiency in the grinding circuit. The use of this cloth also materially increased the capacity of the unit.

The use of pumps to deliver rod mill discharge to the screen was tried but proved unsuccessful. Bucket elevators were substituted for the pumps to perform this operation and also were not successful due to material packing in the buckets. Such a condition was overcome by placing the screen so that it received a gravity flow from the rod mill discharge with the bucket elevator only returning screen oversize to the rod mill.

Grinding to minus 28 mesh will not give complete liberation of the iron and corundum minerals in the Nepheline Syenite.

SECTION C.

Concentration.

Concentration tests employing flotation and tabling methods for the elimination of the impurities, namely magnetite, hematite, corundum and mica are reported by the results obtained in laboratory batch tests and continuous mill runs.

Chemical analyses on many of the tests do not include an analysis for corundum. This analysis was omitted, especially in batch tests, in order to make a quick survey of the many possible reagent combinations which could be tried.

It was thought advisable only to further investigate those conditions which indicated good concentration of the Fe_2O_3 impurities.

Corundum analyses were made on mill runs which were considered encouraging.

Laboratory tests were also conducted in conjunction with mill tests and proved the necessity of having small scale equipment available to investigate many of the enigmas which seemingly always take place in a mill circuit.

Laboratory Tests.

Laboratory tests developed included conditions for standard tests which formed the basis for all subsequent work.

The variables considered most important and studied in the flotation treatment of the Nepheline Syenite, other than the use of different flotation reagents, of which there are an unlimited number of unknowns which could be investigated, included

Group A - Effect of grinding in an iron mill as compared to grinding in a pebble mill.

" B - Effect of desliming before flotation.

" C - Effect of pH.

" D - Effect of impeller speed.

" E - Effect of pulp temperature.

" F - Effect of the water supply.

The conditions observed for the above variables only refer to the reagents tested.

Conditions for Standard Tests.

Pebble mill: A sample, 800 gms., ground in pebble mill with 400 mls. distilled water for 20 min. with 3200 gms. of pebbles.

Iron mill: A sample, 800 gms., ground in iron mill with 400 mls. distilled water for 15 min. with 3000 gms. of iron balls.

Table 14 shows the screen analyses of the ground products from the standard tests.

Table 14.

Screen analyses of Nepheline Syenite from Standard Tests using a Pebble mill and an Iron Mill.

Product Mesh		Pebble Mill		Iron Mill	
		Wt.%	Cum.Wt.%	Wt.%	Cum.Wt.%
	+ 28	3.17	3.17	1.10	1.10
- 28	+ 35	2.67	5.84	3.30	4.40
- 35	+ 48	6.41	12.25	16.80	21.20
- 48	+ 65	15.74	27.99	19.30	40.50
- 65	+100	18.85	46.84	18.20	58.70
-100	+150	14.84	61.68	12.20	70.90
-150	+200	8.90	70.58	5.70	76.60
-200		29.42	100.00	23.40	100.00

Group "A" - Standard Tests.
(Tests #43, #58, and #59)

Test #43 - Standard pebble mill test.
Reagents ground in: .75#/T. Oleic acid.
.1#/T. Cresylic acid.
Reagents to mica float: .05#/T. AMAC CoCoB.

Test #58 - Standard iron mill test.
Reagents ground in: same as Test #43.
Reagents to mica float: .10#/T. AMAC CoCoB.

Test #59 - Standard iron mill test.
Reagents ground in: .75#/T. Oleic acid, .1#/T. Cresylic acid
.20#/T. Potassium Ferrocyanide.
Reagents to mica float: .1#/T. AMAC CoCoB.
.3#/T. Neo-Fat D-142.

The results of the standard tests are reported in Table 15.

Table 15.

Results of standard tests using pebble mill and iron mill.

Test No.	Product	% Wt.	% Fe_2O_3	Distribution % Fe_2O_3.
43	Head	100.0	1.38	100.0
	Conc.	7.9	15.19	85.2
	Tail	92.1	0.23	14.8
58	Head	100.0	1.04	100.0
	Conc.	10.9	6.29	68.8
	Tail.	89.1	0.38	31.2
59	Head	100.0	1.08	100.0
	Conc.	10.5	8.72	83.4
	Tail	89.5	0.22	16.6

REMARKS: Grinding in an iron mill produces rusty coloured slimes and a voluminous lightly laden froth appears as in Test #58. An addition of potassium ferrocyanide counteracts this effect as shown in Test #59.

Group "B" - Desliming Test.
(Test 22)

Test #22 - Reagents to grind: 0.75#/T. Neo-Fat D-142.
0.10#/T. Cresylic acid.
Sample deslimed after grind.
Reagents to mica float: 0.35#/T. AMAC-1120.

The results of desliming before flotation are shown in Table 16.

Table 16.

Desliming Before Flotation.

Test No.	Product	% Wt.	% Fe_2O_3	Distribution % Fe_2O_3
22	Heads	100.0	1.61	100.0
	#1 Conc.	2.8	38.25	66.2
	#2 Conc.	3.8	5.88	14.3
	Tail	75.7	.28	13.3
	Slime	17.7	.58	5.2

Group "C" - Effect of pH.
(Tests #42, #44, #43, and #45)

Test #42 - Pebble mill grind pH - 6.6.
Reagents to grind: .75#/T. D-142, .10#/T. Cresylic
.75#/T. H_2SO_4(conc.).
Reagents to mica float: .05#/T. AMAC CoCoB.
Test #44 - Same as #42 except with .4#/T. H_2SO_4(conc.) pH-7.4.
Test #43 - Same as #42 without H_2SO_4. pH - 8.6.
Test #45 - Same as #43 except with .75#/T. Soda Ash. pH - 9.2.

The results of the tests showing the effect of pH in flotation are shown in Table 17.

Table 17.

Effect of pH in Flotation.

Test No.	Product	% Wt.	% Fe_2O_3	Distribution % Fe_2O_3
42 pH-6.6	Head	100.0	1.63	100.0
	Conc.	14.9	2.18	22.1
	Tail.	85.1	1.29	77.9
44 pH-7.4	Head	100.0	1.52	100.0
	Conc.	24.8	4.55	74.5
	Tail.	75.2	.51	25.5
43 pH-8.6	Head	100.0	1.38	100.0
	Conc.	7.9	15.19	85.2
	Tail.	92.1	.23	14.8
45 pH-9.2	Head	100.0	1.46	100.0
	Conc.	2.9	34.97	69.0
	Tail.	97.1	.47	31.0

REMARKS: As shown above, the addition of H_2SO_4 lowers both the recovery and the ratio of concentration. However, the addition of soda ash increases the selectivity.

Group "D" - Effect of Impeller Speed.
(Tests #43, #46 and #47)

Test #43 - Standard pebble test - R.P.M. of impeller = 1250.
Test #46 - " " " " " " = 1730.
Test #47 - " " " " " "" = 2142.

The results of the tests showing the effect of varying the impeller speed are shown in Table 18.

Table 18.

Effect of Impeller Speed.

Test No.	Product	% Wt.	% Fe_2O_3	Distribution % Fe_2O_3
43	Head	100.0	1.38	100.0
	Conc.	7.9	15.19	85.2
	Tail.	92.1	.23	14.8
46	Head	100.0	1.42	100.0
	Conc.	6.2	18.19	79.9
	Tail.	93.8	.29	20.1
47	Head	100.0	1.42	100.0
	Conc.	4.2	26.69	74.9
	Tail.	95.8	.36	25.1

REMARKS: An increase in impeller speed causes the froth to shower its load resulting in a slightly cleaner concentrate but a poorer recovery.

Group "E" - Effect of Temperature.
(Tests #43, #35, #37) (Tests #20, #32, #33) (Tests #31, #36

Test #43 - Standard using .75#/T. Oleic, Temp. 78° F.
Test #35 - Standard " " " " 56° F.
Test #37 - " " " " " 40° F.
Test #20 - " " " Neo-Fat D-142 Temp. 78° F.
Test #32 - " " " " " " 120° F.
Test #33 - " " " " " " 50° F.
Test #31 - " " " Naphthenic Acid "H",
Temp. 78° F.
Test #36 - " " " " " " 53° F.

The results of tests showing the effect of temperature in flotation are shown in Table 19.

See following page for Table 19.

Table 19.

Effect of Temperature.

Test No.	Product	Wt. %	Fe_2O_3 %	Distribution % Fe_2O_3
43	Head	100.0	1.38	100.0
78°F.	Conc.	7.9	15.19	85.2
	Tail.	92.1	.23	14.8
35	Head	100.0	1.14	100.0
56°F.	#1 Conc.	3.7	20.64	66.3
	#2 Conc.	3.3	4.66	13.4
	Tail.	93.0	0.25	20.3
37	Head	100.0	1.04	100.0
40°F.	#1 Conc.	4.2	17.11	70.0
	#2 Conc.	3.9	3.47	13.0
	Tail.	91.9	0.19	17.0
20	Head	100.0	1.64	100.0
78°F.	#1 Conc.	15.6	8.10	76.8
	#2 Conc.	5.1	2.58	15.9
	Tail.	79.3	0.15	7.3
32	Head	100.0	1.16	100.0
	#1 Conc.	8.5	9.16	73.4
120°F.	#2 Conc.	3.3	3.81	10.8
	Tail.	88.2	0.21	15.8
33	Head	100.0	1.04	100.0
	#1 Conc.	4.1	17.66	69.5
50°F.	#2 Conc.	3.8	3.70	13.8
	Tail.	92.1	0.19	16.7
31	Head	100.0	1.14	100.0
	#1 Conc.	6.3	12.69	70.0
78°F.	#2 Conc.	29.4	.48	12.4
	Tail.	64.3	.31	17.6
36	Head	100.0	1.08	100.0
	#1 Conc.	2.1	23.07	44.3
53°F.	#2 Conc.	3.5	3.69	12.0
	Tail.	94.4	.50	43.7

REMARKS: Using either Oleic acid or Neo-Fat D-142, a lower temperature was not harmful to flotation of the iron minerals, under existing conditions, e.g. reagents ground in. However, using Naphthenic acid in a cooler pulp produced a definite browner froth indicating this reagent's preference for corundum over the iron minerals.

Group "F" - Effect of the Water Supply.
(Tests 43, 58, 48, 62, 63, 76 and 77).

This series of tests were conducted to study the effect of the water used in flotation. Three samples of water were tested using an iron mill and a pebble mill, namely - Ottawa City Tap Water,
Distilled Water,
Lakefield Water.

Test 43 - Standard pebble mill test - dist. H_2O.
" 58 - " Iron " " - "
" 48 - " " " - Ottawa tap water.
" 63 - " " " " - dist. H_2O - 1.0# Pot. Ferrocyanide.
" 62 - " " " " - Ottawa tap H_2O - 1.0# Pot. Ferrocyanide.
" 76 - " " " " - Lakefield H_2O
" 77 - " " " " - " " - .2#/T. Pot. Ferrocyanide.

The results of these tests are reported in Table 20.

Table 20.

Effect of the Water Supply.

Test No.	Product	% Wt.	% Fe_2O_3	Distribution % Fe_2O_3
43	Head	100.0	1.38	100.0
	Conc.	7.9	15.19	85.2
	Tail	92.1	0.23	14.8
58	Head	100.0	1.04	100.0
	Conc.	10.9	6.29	68.8
	Tail	89.1	0.38	31.2
48	Head	100.0	1.53	100.0
	Conc.	17.8	8.89	70.0
	Tail	82.2	0.53	30.0
63	Head	100.0	1.18	100.0
	Conc.	9.8	9.16	77.8
	Tail	90.2	0.33	22.2
62	Head	100.0	1.09	100.0
	Conc.	10.3	9.27	83.3
	Tail	89.7	0.22	16.7
76	Head	100.0	1.64	100.0
	Conc.	18.1	6.16	67.1
	Tail	81.9	0.66	32.9
77	Head	100.0	2.14	100.0
	Conc.	8.7	14.26	82.7
	Tail	91.3	0.43	17.3

REMARKS: As shown above, the use of Ottawa water or Lakefield water in place of distilled water, in iron mill tests, was detrimental to results. However, the use of potassium ferrocyanide overcame this effect.

The number of tests conducted on this investigation were not sufficient to prove conclusively the effect of the water supply in flotation.

Soluble Salts.

Flotation often has a direct bearing on the soluble salts transferred to the pulp during grinding operations.

Since the pH of the pulp in this case was in the range of 8.6 two tests were made in which 1000 gram samples of the rock were ground in an iron mill and a pebble mill, using distilled water for a period of 30 minutes.

The filtrate from each test was analysed for soluble salts, the results of which are reported in Table 21.

Table 21.

Report on soluble salts in filtrate after grinding in an iron mill and a pebble mill using distilled water.

Product	Iron Mill p.p.m.	Pebble Mill p.p.m.
Alkalinity($CaCO_3$)	90.0	86.6
SiO_2	23	16
Fe	1020	820
Ca	8	9
SO_4	70	68
Alkalis(Na)	90	90
pH	9.6	9.8

The pH is higher than standard grind due to the longer period of grind.

Mill Tests.

Mill tests were conducted to establish a flowsheet and duplicate, if possible, results obtained by laboratory testing.

In grinding tests previously reported the feed to rod mill, when using a Ty-Rod screen in closed circuit with the mill, was approximately two tons per hour. Such a condition if applied to test runs would have required a great quantity of rock from the mine. To reduce the feed but still use a rod mill in the circuit, the rod load was balanced to grind at a feed rate of approximately 1200 lbs. per hour and maintain as close as possible the same grind as reported in Test 21.(See graph)

The use of a rod mill cannot be definitely recommended as the most suitable type of grinding until until further test work has been completed using a pebble mill. This is mentioned now as the use of an iron mill effected flotation conditions reported in the following tests.

It is presumed that the iron from the mill caused a physical chemical reaction, or possible chemical reaction, which resulted in poor metallurgy.

To correct this iron condition in the circuit it was found necessary to add a quantity of potassium ferrocyanide and soda ash to the grinding unit.

It is very difficult to explain what reaction takes place but one important observation noticed was that the pulp retained its "white" appearance as compared to the "brownish" appearance when the ferrocyanide was not used.

It is further thought that in the use of a pebble mill such a reagent would not be necessary thereby lowering reagent costs 10 to 15 cents per ton of rock milled.

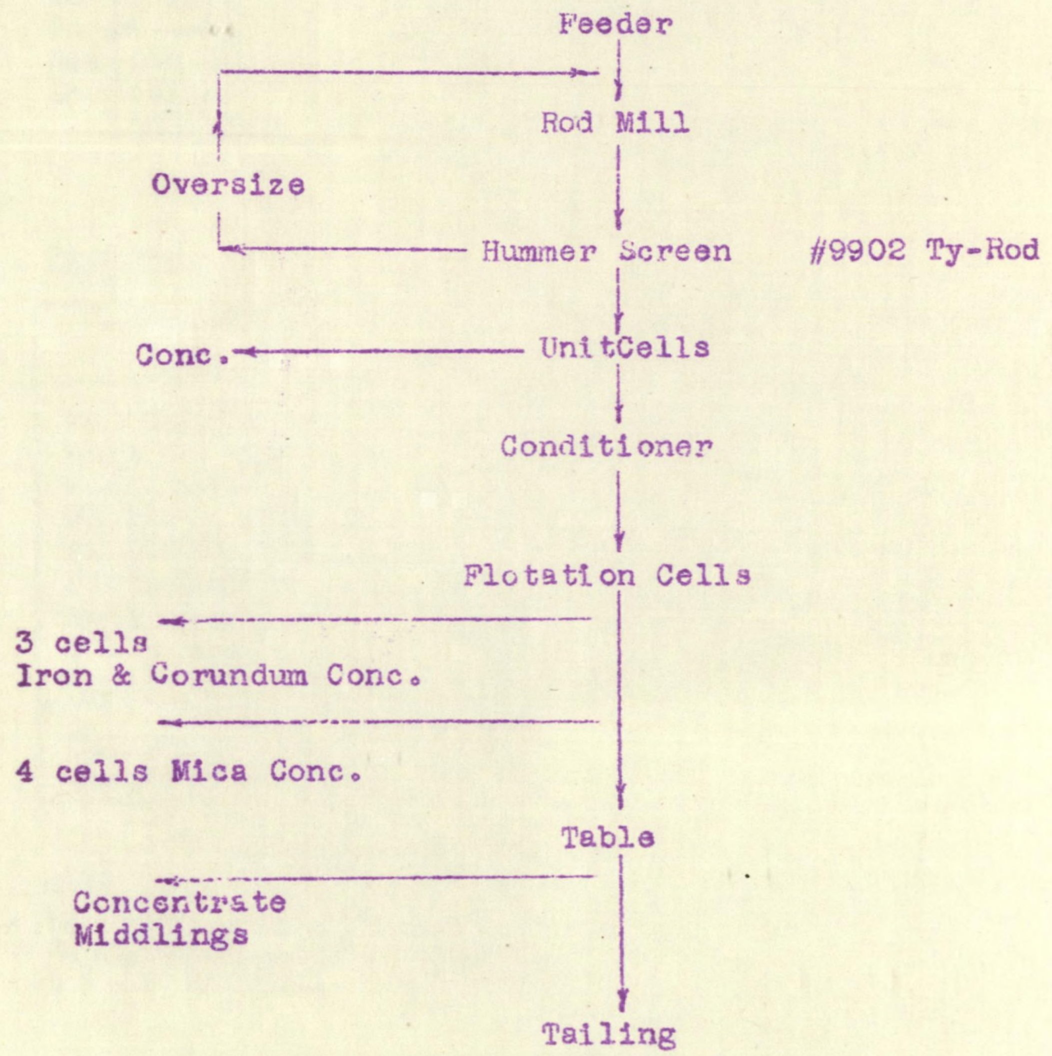
Since the final Nepheline Syenite product has to meet definite iron specifications when used in the glass or ceramic industries the use of a pebble mill would appear to have one definite advantage over a rod mill in not having to later remove by flotation or other methods any iron contamination as caused by liner and rod consumption.

The mill tests reported represent the different flowsheets using a rod mill and the reagent combinations tested.

Note: Recovery of Nepheline as reported is based on the weight percent of total feed.

FLOWSHEET NO. 1.

Flotation - Tabling



Mill run 10 represents the results obtained using flowsheet No. 1 and is reported in Table 22.

Table 22.

Mill Run #10

Reagents:

To Rod Mill	-	0.40 lb./ton Ferro CN, 1.0 lb./ton Oleic acid, 0.6 lb./ton soda ash.
To Conditioner	-	0.10 lb./ton Naphthenic acid H, 0.06 lb./ton Oleic acid.
To #2 Cell	-	0.03 lb./ton Cresylic acid.
To #4 Cell	-	0.025 lb./ton AMAC CoCoB.
To #6 Cell	-	0.015 lb./ton AMAC CoCoB.
Reagent cost	-	40¢/ton.
Operating conditions	-	Densities:- R.M.D.-61%, Flot. Feed 40%, Temperature 71° F., pH - 10.4.

Results:

Product	Wt. %	Assays % Fe_2O_3	Assays % Cor.	Distribution % Fe_2O_3	Distribution % Cor.
Sc. Undersize	100.0	1.36	0.54	100.0	100.0
Unit C. Conc.	2.1	42.62	14.04	51.1	48.0
Flot. Feed	97.9	1.00	0.26	48.9	52.0
#1 Flot. Conc.	0.9	10.73	4.56	5.5	6.7
#2 Flot. Conc.	1.6	3.92	1.00	3.6	2.6
Flot. Tails.	95.4	0.59	0.22	39.8	42.7
Table Conc.	0.6	67.06	11.80	22.9	11.6
Table Midds.	2.1	2.70	2.90	3.2	9.9
Table Tails.	92.7	0.26	0.14	13.7	21.2

Calculated Feed - 1.75% Fe_2O_3 and 0.61% Cor.
Recovery of Nepheline - 92.7%, Fe_2O_3 .26%, Corundum .14%.

A screen analysis on the table tailing product, Mill run #10, showing the percent Fe_2O_3 content in each of the size fractions and the percent distribution of the Fe_2O_3 is reported in Table 23.

Table 23.

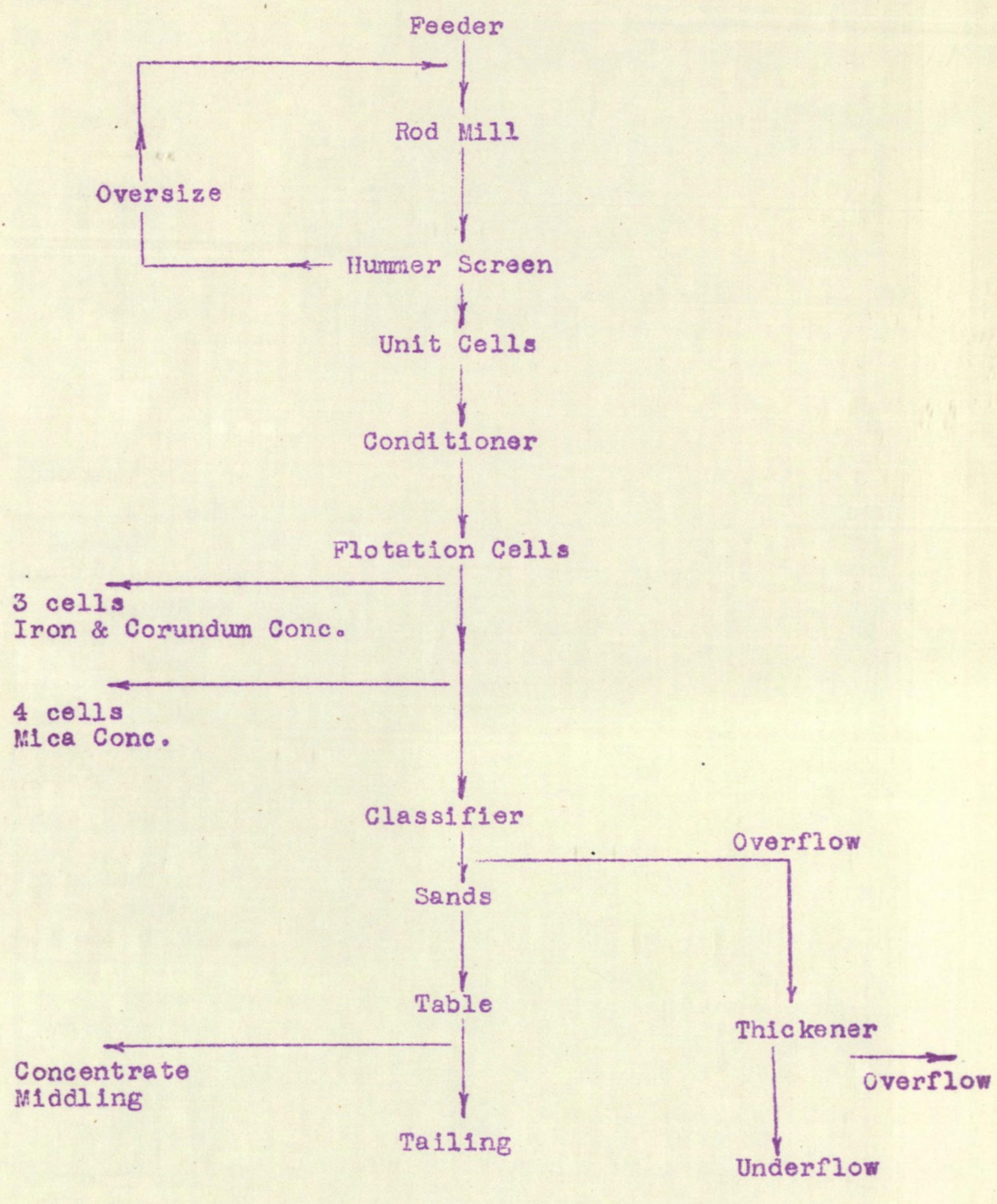
Screen analysis and Fe_2O_3 distribution in table tailing from Mill run #10.

Table Tailing - Mill Run #10.

Product Mesh	Wt. %	Assay Fe_2O_3 %	Distribution Fe_2O_3 %
+ 28	2.7	0.64	6.6
- 28 + 35	7.0	0.48	12.8
- 35 + 48	15.0	0.41	23.4
- 48 + 65	15.4	0.36	21.1
- 65 +100	11.1	0.30	12.7
-100 +150	13.4	0.12	6.3
-150 +200	8.9	0.10	3.2
-200	26.5	0.14	13.9
Totals	100.0	0.17	100.0

FLOWSHEET NO. 2.

Flotation - Classification - Tabling



Mill Runs 12, 13, 14, 15 and 16 represent the results obtained using flowsheet No. 2 and are reported in Tables 24, 25, 26, 27 and 28, respectively.

Table 24.

Mill Run #12

Reagents:

To Rod Mill - 0.5 lb./ton soda ash, 0.4 lb./ton Ferro CN, 1.0 lb./ton Oleic acid, 0.05 lb./ton Cresylic acid.

To Conditioner - 0.7 lb./ton Oleic acid, 0.03 lb/ton Cresylic acid, 0.10 lb./ton Fuel Oil, 0.10 lb./ton Naphthenic acid H.

To #4 Cell - 0.025 lb./ton AMAC CoCoB.

To #6 Cell - 0.015 lb./ton AMAC CoCoB.

Reagent cost - 43¢/ton.

Operating Conditions - Densities:- R.M.D.-65%, Flot. Feed 37%, Temperature 78° F., pH - 10.5

Results:

Product	Wt. %	Assays %		Distribution %	
		Fe_2O_3	Cor.	Fe_2O_3	Cor.
Sc. Undersize	100.0	1.07	0.12	100.0	100.0
Unit C. Conc.	1.7	14.95	1.14	26.1	23.9
Flot. Feed	98.3	0.99	0.06	73.9	76.1
#1 Flot. Conc.	2.0	9.72	0.42	19.9	10.4
#2 Flot. Conc.	2.1	3.23	0.14	7.0	3.6
Flot. Tails	94.3	0.52	0.08	47.0	62.1
Thick. Underflow	16.2	0.25	0.02	4.1	3.9
Thick. Overflow	1.3	0.85	0.06	1.1	1.0
Table Conc.	0.1	83.40	0.84	8.5	1.0
Table Midds.	1.1	10.17	1.40	11.5	19.0
Table Tails	75.5	0.28	0.04	21.8	37.2

Calculated Feed - 0.97% Fe_2O_3 and 0.08% Cor.
Combined Table Tails, and Thick. Underflow (Calculated Results).

Recovery of Nepheline 91.7%
Fe_2O_3 in " 0.28%
Corundum " 0.04%

Table 25.

Mill Run #13

Reagents:

To Rod Mill	- 0.5 lb./ton soda ash, 0.4 lb./ton Ferro CN, 0.40 lb./ton #708, 0.03 lb./ton 712.
To Conditioner	- 0.03 lb./ton 708, 0.03 lb./ton 712.
To #2 Cell	- 0.03 lb./ton 712.
To #4 Cell	- 0.025 lb./ton AMAC CoCoB.
To #6 Cell	- 0.015 lb./ton AMAC CoCoB
Reagent cost	- 22¢/ton.
Operating Conditions	- Densities:- R.M.D. 62%, Flot. Feed 39%, Temperature 73° F., pH - 9.3.

Results:

Product	Wt. %	Assays %		Distribution %	
		Fe_2O_3	Cor.	Fe_2O_3	Cor.
Sc. Undersize	100.0	1.47	0.32	100.0	100.0
Unit C. Conc.	4.8	9.39	--	40.9	--
Flot. Feed	95.2	0.77	--	59.1	--
#1 Flot. Conc.	2.3	7.48	--	5.2	--
#2 Flot. Conc.	1.5	2.84	--	3.9	--
Flot. Tails	91.4	0.69	0.12	50.0	34.4
Thick. Overflow	0.5	1.33	--	0.5	--
Thick.Underflow	14.0	0.45	0.14	5.7	6.2
Table Conc.	0.3	53.59	--	14.6	--
Table Midds.	1.3	8.49	--	10.0	--
Table Tails.	75.3	0.28	0.04	19.2	9.4

Calculated Feed - 1.10% Fe_2O_3.

(Calculated Results) Recovery of Nepheline - 89.3 %
Fe_2O_3 in " - 0.3 %
Corundum in " - 0.06%

Table 26.

Mill Run #14

Reagents:

To Rod Mill - 0.40 lb./ton Ferro CN, 0.6 lb./ton D-142, 0.5 lb./ton soda ash.
To Conditioner - 0.10 lb./ton D142, 0.05 lb./ton Cresylic acid.
To Unit Cell - 0.10 lb./ton Cresylic acid.
To #3 Cell - 0.10 lb./ton D142.
To #4 Cell - 0.10 lb./ton Cresylic acid, 0.03 lb./ton AMAC CoCoB.
To #6 Cell - 0.01 lb./ton AMAC CoCoB.
Reagent cost - 38¢/ton.
Operating Conditions - Densities:- R.M.D. - 57%, Flot. Feed 36%, Temperature 70° F., pH - 9.7.

Results:

Product	Wt. %	Assays %		Distribution %	
		Fe_2O_3	Cor.	Fe_2O_3	Cor.
Sc. Undersize	100.0	1.41	0.46	100.0	100.0
Unit C. Conc.	2.7	15.05	4.41	37.1	35.3
Flot. Feed	97.3	0.81	0.22	62.9	64.7
#1 Flot. Conc.	1.2	6.12	1.54	6.7	5.5
#2 Flot. Conc.	2.1	2.88	0.42	5.5	2.6
Flot. Tails	94.0	0.41	0.15	50.7	56.6
Thick. Overflow	1.7	1.04	0.00	1.6	0.0
Thick. Underflow	13.4	0.32	0.02	3.9	0.8
Table Conc.	0.1	84.62	2.72	7.8	0.8
Table Midds.	1.3	8.75	5.92	10.4	22.8
Table Tails.	77.5	0.38	0.14	27.0	32.2

Calculated Feed - 1.09% Fe_2O_3, 0.34% Cor.

Combined Table Tails. and Thick. Underflow (Calculated Results)

Recovery of Nepheline - 90.9 %
Fe_2O_3 in " - 0.37%
Corundum " - 0.11%

Table 27.

Mill Run #15

Reagents:

To Rod Mill - 0.4 lb./ton Ferro CN, 0.6 lb./ton D142.
To Unit Cell - 0.08 lb./ton Cresylic acid, 0.01 lb./ton AMAC CoCoB.
To Conditioner - 0.10 lb./ton D-142, 0.08 lb./ton Cresylic acid.
To #2 Cell - 0.05 lb./ton Cresylic acid.
To #4 Cell - 0.05 lb./ton D-142, 0.025 lb./ton AMAC CoCoB.
To #6 Cell - 0.01 lb./ton AMAC CoCoB.
Reagent cost - 35¢/ton.
Operating Conditions - Densities:- R.M.D. - 62%, Flot Feed 39%, Temperature 69° F., pH - 9.6.

Results:

Product	Weight %	Assays %		Distribution %	
		Fe_2O_3	Cor.	Fe_2O_3	Cor.
Sc. Undersize	100.0	1.37	0.60	100.0	100.0
Unit C. Conc.	2.0	18.80	5.92	32.1	44.2
Flot. Feed	98.0	1.12	.26	67.9	55.8
#1 Flot. Conc.	2.5	5.06	.84	10.7	7.8
#2 Flot. Conc.	5.9	2.19	.34	11.0	7.5
Flot. Tails.	89.6	0.70	.20	46.2	40.5
Thick. Overflow	2.3	1.19	Nil	1.9	--
Thick. Underflow	13.3	0.47	.04	5.4	1.9
Table Conc.	0.1	79.60	6.12	6.7	2.2
Table Midds.	1.3	8.93	4.08	9.9	19.8
Table Tails.	72.6	0.36	0.06	22.3	16.6

Calculated Feed - 1.17% Fe_2O_3, 0.27% Cor.

Combined Table Tails and Thick. Underflow (Calculated Results)

Recovery of Nepheline - 85.9%
F_2O_3 in " - 0.38%
Corundum " - 0.06%

Table 28.

Mill Run #16

Reagents:

To Rod Mill	- 0.4 lb./ton Ferro CN, 0.6 lb./ton D-142, 0.5 lb./ton soda ash.
To Unit Cell	- 0.12 lb./ton Cresylic acid, 0.01 lb./ton AMAC CoCoB.
To Conditioner	- 0.10 lb./ton D-142, 0.08 lb./ton Cresylic acid.
To #2 Cell	- 0.05 lb./ton Cresylic acid.
To #4 Cell	- 0.05 lb./ton D-142, 0.025 lb./ton AMAC CoCoB.
To #6 Cell	- 0.01 lb./ton AMAC CoCoB.
Reagent cost	- 39¢/ton.
Operating Conditions	- Densities:- R.M.D. - 62%, Flot Feed 38%, Temperature 55° F., pH - 10.2.

Results:

Product	Wt. %	Assays %		Distribution %	
		Fe_2O_3	Cor.	Fe_2O_3	Cor.
Sc. Undersize	100.0	1.44	0.32	100.0	100.0
Unit Cell Conc.	2.0	17.55	5.12	28.0	37.0
Flot. Feed	98.0	1.12	0.20	72.0	63.0
#1 Flot. Conc.	1.2	12.60	3.08	12.1	13.4
#2 Flot. Conc.	1.9	5.87	0.86	8.9	5.9
Flot. Tails.	94.9	0.68	0.14	51.0	43.7
Thick. Overflow	2.9	1.00	nil	2.3	nil
Thick. Underflow	15.3	0.47	0.04	5.7	2.2
Table Conc.	0.1	77.72	4.76	6.2	1.8
Table Midds.	1.1	15.04	4.52	13.2	18.1
Table Tails.	75.5	0.39	0.08	23.6	21.6

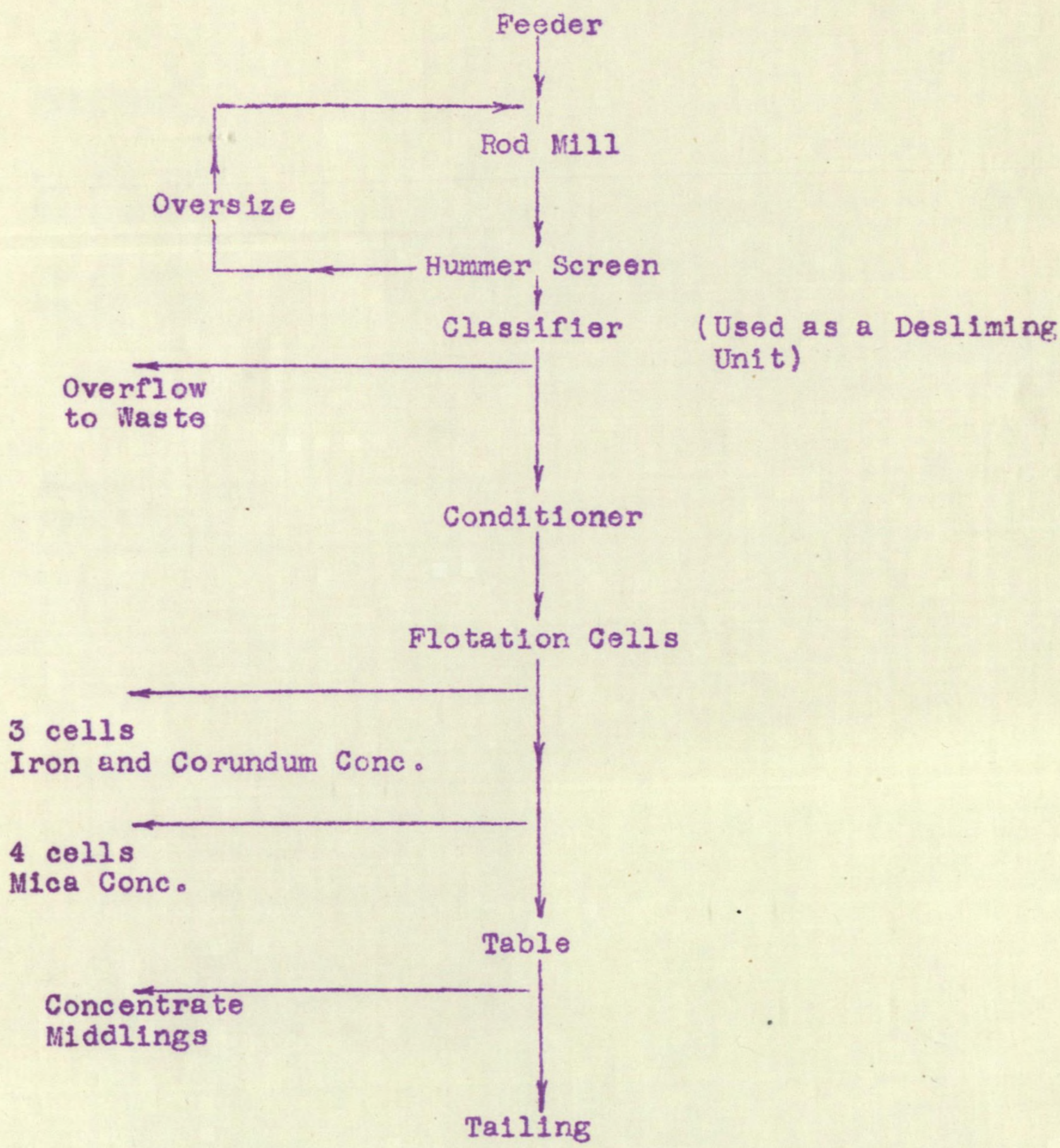
Calculated Feed - 1.25% Fe_2O_3, 0.32% Cor.

Combined Table Tails. and Thick. Underflow (Calculated Results)

Recovery of Nepheline - 90.8 %
Fe_2O_3 in " - 0.40%
Corundum in " - 0.07%

FLOWSHEET NO. 3.

Desliming - Flotation - Tabling



Mill runs 6, 7 and 8 represent the results obtained using flowsheet No. 3 and are reported in Tables 29, 30 and 31, respectively.

Table 29.

Mill Run #6

Reagents:

To Rod Mill - No reagents to rod mill.
To Conditioner - 0.60 lb./ton Naphthenic acid H, 0.05 lb./ton Cresylic acid.
To #4 Cell - 0.025 lb./ton AMAC CoCoB.
To #6 Cell - 0.015 lb./ton AMAC CoCoB.

Oleic acid was added to the conditioner in varying amounts but resulted in a nepheline floc.

Reagent cost - 14¢/ton.
Operating Conditions - Densities:- R.M.D.-63%, Flot. Feed 41%, Temperature 68° F., pH - 9.3.

Results:

Product	Weight %	Assays % Fe_2O_3	Distribution % Fe_2O_3
Sc. Undersize	100.0	1.40	100.0
Class.Overflow	11.8	1.58	13.1
Flot. Feed	88.2	1.15	86.9
#1 Flot. Conc.	7.7	8.09	43.7
#2 Flot. Conc.	2.0	1.40	2.0
Flot. Tails.	78.5	0.67	41.2
Table Conc.	0.2	64.69	9.1
Table Midds.	5.8	3.26	13.3
Table Tails.	72.5	0.37	18.8

Calculated feed - 1.42% Fe_2O_3.
Recovery of Nepheline - 72.5%
Fe_2O_3 in " - 0.37%

Table 30.

Mill Run #7

Reagents:

To Rod Mill - 0.30 lb./ton Ferro CN.
To Conditioner - 0.60 lb./ton Naphthenic acid H, 0.05 lb./ton Cresylic acid.
To #4 Cell - 0.025 lb./ton AMAC CoCoB.
To #6 Cell - 0.015 lb./ton AMAC CoCoB.
Reagent cost - 21¢/ton.
Operating Conditions - Densities:- R.M.D.-64%, Flot. Feed 39%, Temperature 75° F., pH - 9.5.

Results:

Product	Weight %	Assays % Fe_2O_3	Distribution % Fe_2O_3
Sc. Undersize	100.0	1.46	100.0
Class. Overflow	12.0	1.46	15.7
Flot. Feed	88.0	1.18	84.3
#1 Flot. Conc.	4.4	9.52	37.6
#2 Flot. Conc.	1.3	1.52	1.8
Flot. Tails.	82.3	0.70	44.9
Table Conc.	0.4	46.59	16.7
Table Midds.	4.6	1.13	4.7
Table Tails.	77.3	0.34	23.5

Calculated feed - 1.12% Fe_2O_3.
Recovery of Nepheline - 77.3%.
Fe_2O_3 in " - 0.34%.

Table 31.

Mill Run #8

Reagents:

To Rod Mill - 0.30 lb./ton Ferro CN, 0.5 lb./ton soad ash.
To Conditioner - 0.60 lb./ton Naphthenic acid H, 0.05 lb./ton Cresylic acid.
To #3 Cell - 0.03 lb./ton Cresylic acid.
To #4 Cell - 0.025 lb./ton AMAC CoCoB.
To #6 Cell - 0.015 lb./ton AMAC CoCoB.
Reagent cost - 24¢/ton.
Operating Conditions - Densities:- R.M.D.-64%, Flot. Feed 40%, Temperature 75° F., pH - 10.3.

Results:

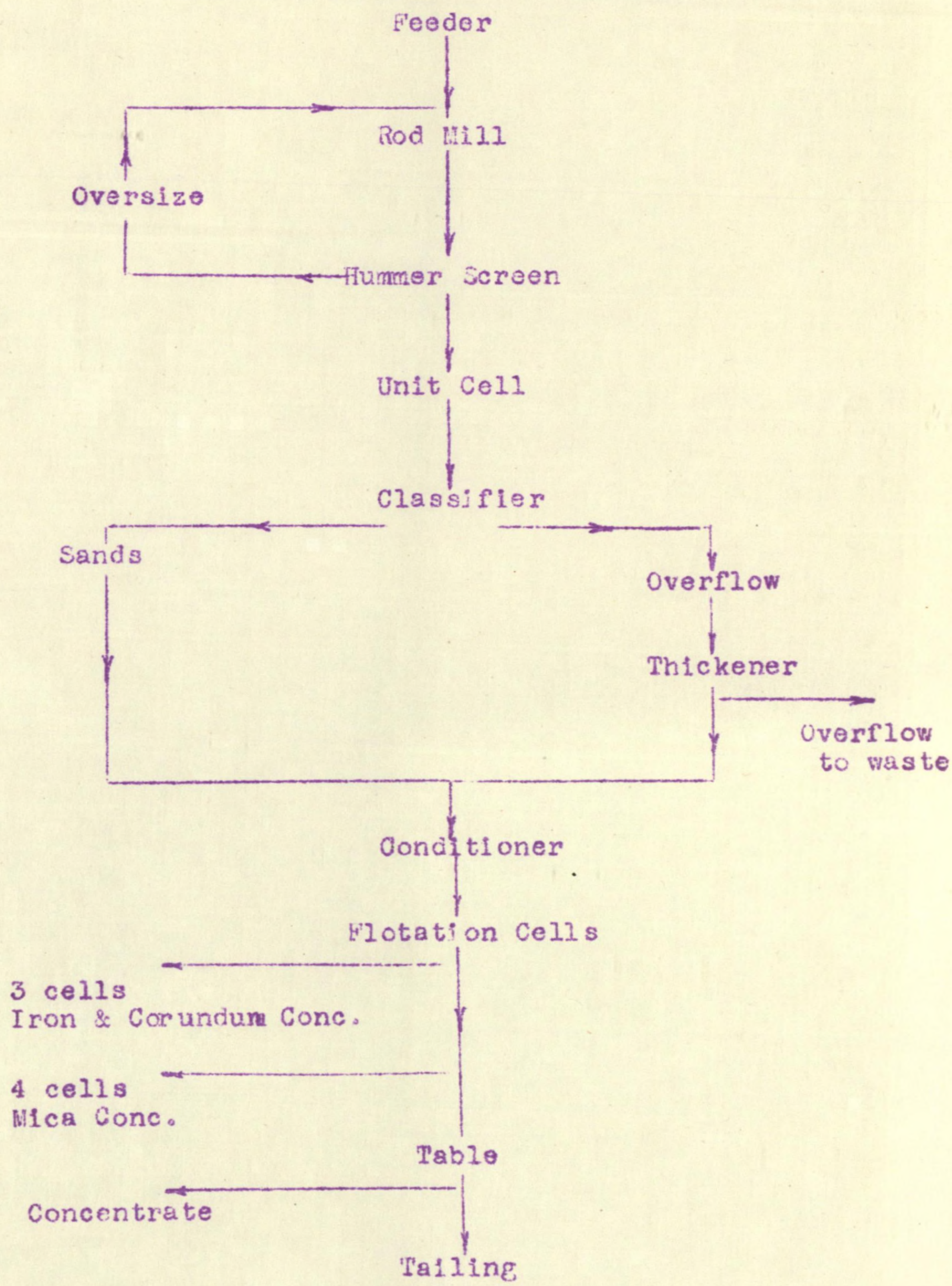
Product	Weight %	Assay % Fe_2O_3	Distribution % Fe_2O_3
Sc. Undersize	100.0	1.29	100.0
Class. Overflow	10.9	1.19	9.9
Flot. Feed	89.1	0.84	90.1
#1 Flot. Conc.	7.0	7.84	41.6
#2 Flot. Conc.	2.4	0.84	1.5
Flot. Tails	79.6	0.50	47.0
Table Conc.	0.6	55.53	25.3
Table Midds.	4.2	1.11	3.6
Table Tails.	74.9	0.32	18.1

Calculated Feed - 1.32% Fe_2O_3.

Recovery of Nepheline - 74.9 %
Fe_2O_3 in " - 0.32%

FLOWSHEET NO. 4.

Dewatering - Flotation - Tabling



Mill run 17 represents conditions used in Flowsheet 4 and is reported in Table 32.

Table 32.

Mill Run #17

Reagents:

To Rod Mill	-	0.4 lb./ton Ferro CN, 0.6 lb./ton D-142, 0.04 lb./ton Z5, 0.5 lb./ton soda ash.
To Unit Cell	-	0.11 lb./ton Cresylic acid.
To Conditioner	-	0.08 lb./ton Cresylic acid, 0.10 lb./ton D-142, 0.01 lb./ton Z5.
To #2 Cell	-	0.05 lb./ton D-142.
To #4 Cell	-	0.03 lb./ton AMAC CoCoB.
To #6 Cell	-	0.01 lb./ton AMAC CoCoB.
Reagent cost	-	40¢/ton.
Operating Conditions	-	Densities:- R.M.D.-60%, Flot. Feed 37%, Temperature 60° F., pH - 10.0.

Results:

Product	Weight %	Assays		Distribution	
		Fe_2O_3	Cor %	Fe_2O_3	Cor %
Sc. Undersize	100.0	1.69	0.52	100.0	100.0
Unit Cell Conc.	3.7	15.67	5.40	45.4	48.6
Cone. Overflow	2.0	1.47	0.02	2.3	0.2
Cone. Underflow	9.7	0.79	0.06	5.0	1.5
Flot. Feed	94.3	--	--	52.3	51.2
#1 Flot. Conc.	1.5	7.20	2.38	8.4	8.8
#2 Flot. Conc.	2.7	2.99	0.20	6.3	1.2
Flot. Tails.	90.1	1.03	0.16	37.6	41.2
Table Conc.	0.2	62.37	7.16	9.8	3.4
Table Midds.	1.3	9.72	5.12	9.8	16.1
Table Tails.	88.6	0.26	0.10	18.0	21.7

Calculated Feed - 1.28% Fe_2O_3, and 0.41% Cor.

Combined Table Tails. and Thick. Underflow (Calculated Results)

Recovery of Nepheline - 88.6 %
Fe_2O_3 in " - 0.26%
Corundum in " - 0.10%

Table 33.

SUMMARY OF METALLURGICAL RESULTS FROM MILL RUNS

Mill Run No.	FEED		PRODUCT		RECOVERIES			Reagent Costs Cts. per ton Milled
	% Fe_2O_3	% Corundum	% Fe_2O_3	% Corundum	% Nepheline	% Fe_2O_3	% Corundum	
10	1.36	0.54	0.26	0.14	92.7	86.3	78.8	0.40
12	1.07	0.12	0.28	0.04	91.7	74.1	58.9	0.43
13	1.47	0.32	0.31	0.06	89.3	75.1	84.4	0.22
14	1.41	0.46	0.37	0.11	90.9	69.1	67.0	0.38
15	1.37	0.60	0.38	0.06	85.9	72.3	81.5	0.35
16	1.44	0.32	0.40	0.07	90.8	70.7	76.2	0.39
6	1.40	--	0.37	--	72.5	81.2	--	0.14
7	1.46	--	0.34	--	77.3	76.5	--	0.21
8	1.29	--	0.32	--	74.9	81.9	--	0.24
17	1.69	0.52	0.26	0.10	88.6	82.0	78.3	0.40

Discussion of Metallurgy

The results of test work both in batch tests and continuous mill runs have shown many interesting facts pertaining to the problem of eliminating the iron and corundum impurities from Nepheline Syenite.

The metallurgical results obtained in mill runs are tabulated in Table 33.

Mill run 13 resulted in the most satisfactory metallurgy. Treating a mill feed containing 1.47% Fe_2O_3 and 0.32% corundum a flotation-tabling product having an analysis of .31% Fe_2O_3 and 0.06% corundum was obtained. The recovery of Fe_2O_3 in the concentrates was 75% and of the corundum 84%.

The recovery of Nepheline Syenite was 89% of the total mill feed.

Reagents costs using an iron mill were 22¢ per ton total mill feed.

Middlings - Magnetic Separation

Middlings as described under Grinding, Section 2, play an important role in this problem. A thorough study of this fact will show why it is impossible to reduce the iron and corundum analyses much below those reported in the preceding tests.

It must therefore be realized that further concentration employing the use of high intensity magnetic separation is a necessity.

Insufficient test work on magnetic separation has been conducted by the Bureau of Mines Laboratories at the time of writing this report. Therefore, no reference will be made to any results obtained.

Since specifications of finished product are of a critical nature it is the Departments recommendation that a sample of Nepheline Syenite produced by flotation and tabling methods be submitted to manufacturers of magnetic separating equipment for a comprehensive report.

Coarse Free Iron and Corundum Particles - Tabling

The grind as necessitated by specifications presented a definite problem other than Middlings in the treatment of this rock. The coarse impurities are difficult to float and it is questionable whether successful flotation conditions will be developed which will ensure the complete removal of such particles.

For this reason it is believed essential to provide a "safeguard", or a method to remove these coarse free particles, especially the corundum and hematite. Tabling of a classified product after flotation proved to be a successful method.

Pebble Mill - Iron Mill

The use of a pebble mill in grinding for flotation must be considered.

Batch tests have shown that grinding in a pebble mill will result in better flotation conditions without the use of additional reagents. To counteract the affect of solubile iron salts when grinding in a rod mill, it was found necessary to use Potassium Ferrocyanide which increases the total cost of reagents 10 to 15 cents per ton of rock milled.

Test work is contemplated to study the difference in flotation conditions when the rock is ground in a pebble mill and will be discussed in Part 2 of this report to be submitted at some future date.

Desliming

Desliming as an aid to flotation was not beneficial. A greater loss of Nepheline Syenite resulted without showing any appreciable change in recovery of impurities.

Reagents used as collectors showed improved metallurgy if ground in with the rock.

If desliming were practiced, under the above condition, flotation costs would increase due to a higher reagent consumption.

Dewatering

Dewatering after the grinding circuit should be considered, especially so if any difficulty is encountered in screening operations making it necessary to add a greater volume of spray water. Such a condition would result in too low a density for flotation.

pH

The Nepheline Syenite on grinding in water gives a natural pulp pH value of approximately 8.6. This pH is very satisfactory for flotation conditions.

Lowering the pH value below 7 with H_2SO_4 indicated a lower recovery of Nepheline Syenite with a greater Fe_2O_3 content.

Increasing the pH value by the use of soda ash showed greater selectivity of the iron minerals but did not give as low an iron analysis in the Nepheline Syenite product as when the natural pH was used.

Impeller Speed

In batch tests on this rock a flotation cell was used having an impeller speed range between 1000 and 2300 R.P.M.

Slow to medium speeds indicated better flotation conditions for the iron and corundum than when higher speeds were employed. It is not certain whether impeller speed had any effect in the mica float.

Either or both of the following conditions may have affected flotation.

(a) The high impeller speed caused a too severe scrubbing action and displaced the collector coating on the iron and corundum minerals.

(b) The increased aeration with high impeller speed resulted in unstable froth characteristics, which caused excessive showering of the iron and corundum minerals.

Temperature of Pulp

Test work has shown that a temperature range between 50 and 60° F was the most satisfactory for flotation. It is generally believed that low temperatures are detrimental when using fatty acids but such was not the experience in this investigation. To substantiate this statement satisfactory results were obtained when ice cubes were used in the grind and flotation cell. A pulp temperature of 41° F was maintained throughout this test.

Water Supply

Standard tests were made using distilled water in order that results may be duplicated in other laboratories.

Tests indicated that the use of Lakefield water (Big Mountain Lake) gave substantially the same results as obtained when using Ottawa City water.

Distilled water however, gave slightly better recovery and grade of Nepheline Syenite product.

Reagents

Many reagents were investigated during this project; the object being to first float the iron and corundum minerals followed by a removal of mica. The tests were conducted with the view of cost of reagents and their properties to give satisfactory metallurgical results.

As tabulated in Table 33, the most satisfactory combination of reagents is shown in Mill Run 13. This combination resulted in the lowest reagent cost reported.

Combinations of reagents as reported in other mill runs have merit, but show an increase in cost.

Although not shown by chemical analysis the combination of cresylic acid and AMAC Coco B floated mica well.

The study of reagents should be continued as it is thought other combinations may be developed which would show improved metallurgy.

Flowsheet - Variation

The flowsheet as established by the test work is shown in Drawing No. 1 .

There is one variation which should be considered, namely, classification before screening. This operation would have the advantage of removing the fine fraction from the mill discharge, thereby reducing the load and resulting in a higher screening efficiency. It would also result in a decreased volume of spray water to the screen thus lessening the washing effect and subsequent removal of collector coating from the iron and corundum particles.

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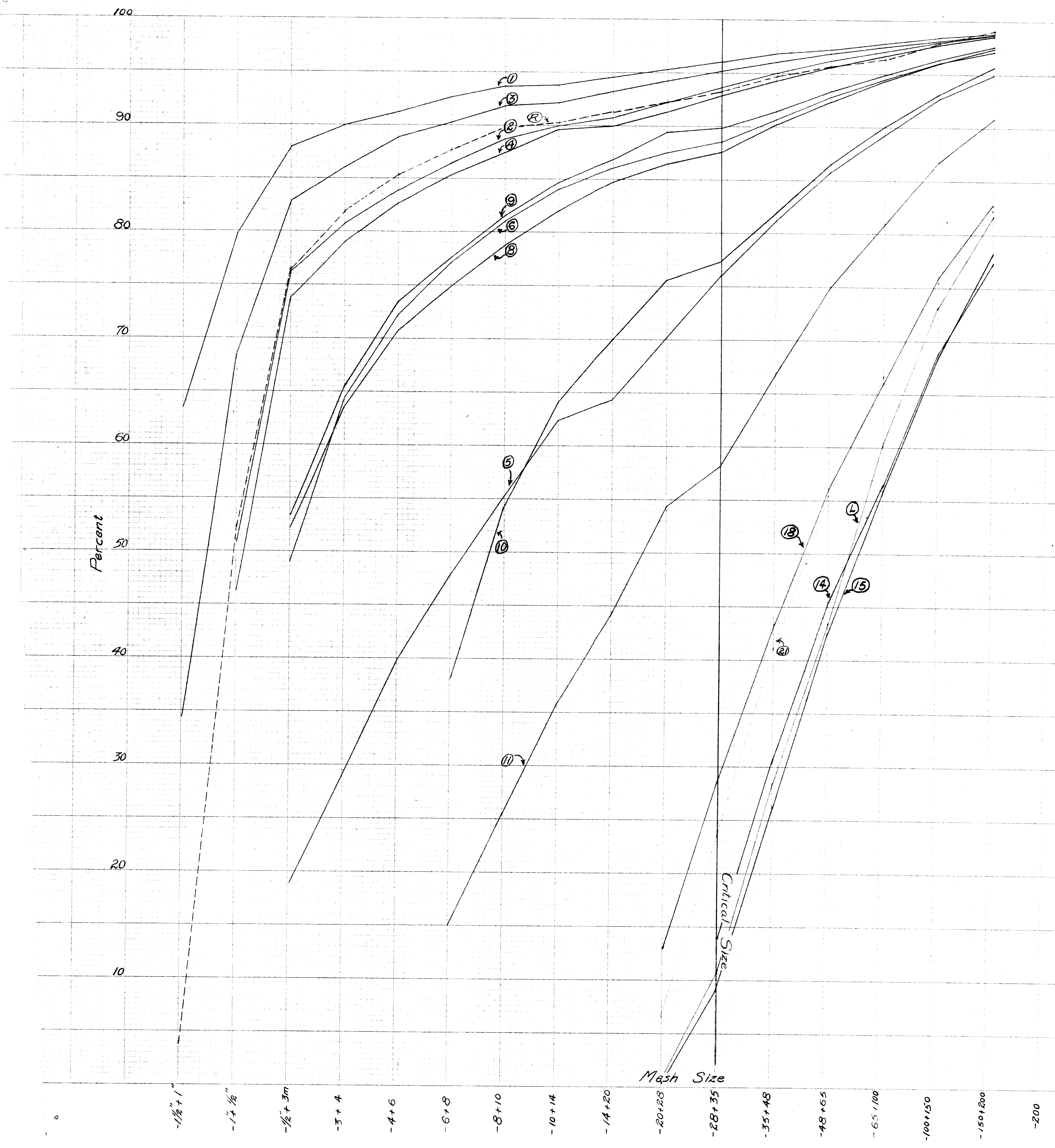

TEST No. — **LEGEND**
CRUSHING

Test No.	
1	Rock crushed through jaw crusher Set 1½"
3	Rock crushed through Gyratory Set 1½"
2	Rock crushed through jaw crusher Set 1½" Symons 3/8 - ½"
4	Rock crushed through Gyratory Set 1½" Symons 3/8 - ½"
6	Rock crushed through jaw Crusher Set 1½" Symons 3/8 - ½" -28 mesh screened out +28 mesh through rolls Set ¼"
5	Rock crushed through Gyratory Set 1½" Hammer Mill - ½" Grates
8	Rock crushed through Jaw Crusher Set 1½" Symons 3/8 - 28 mesh screened out Symons 1/16 - 28 mesh screened out Symons 3/16
9 - 9A	Rock crushed through Jaw Crusher Set 1½" Symons 3/16
10	Rock crushed through Jaw Crusher Set 1½" Symons at 3/16" - 28 mesh screened out Through rolls at 1/8 - 28 mesh screened out Through rolls at 8 mesh
11	Gyratory at 1½" - Hammer Mill at ½" Grates -28 Mesh Screened Out - Hammer Mill at 1/8" Grates
R	Head Feed - Rochester Plant Jaw Crusher set 1½" - 2' Symons at ¾"
L	Test Lakefield - Rock Crushed though Jaw Crusher & 2 sets of Rolls in closed circuit with 28 M Ton-Cap Screens.

MACHINES USED

1 - Jaw Crusher - Hadfield 8" X 12"
2 - Symons - 20" Shorthead - Fine Bowl
3 - Rolls - Allis-Chalmers - 24" Dia x 14"
4 - Gyratory - Austin No. 103
5 - Hammer Mill - Sturtevant No. 00 - 3400 R.P.M.
6 - Rod Mill - 3' x 6' Marcy - Low Discharge 31 R.P.M.
7 - Screen - 3' x 5' Hummer

LEGEND
GRINDING

Test No.	
18	Rock Crushed through Jaw Crusher Set 1½" Through Symons Set ¾" - Feed Rate 2880 p.p.h. Through Rod Mill - Wet - In Closed Circuit With 26 Mesh Ty-Rod Screen #9902
14	Rock Crushed through Jaw Crusher Set 1½" Through Symons Set ¾" - Feed Rate - 1760 p.p.h Through Rod Mill - Dry - in closed circuit with Tyler Standard - 26 square mesh
15	Rock crushed through jaw & Symons to ¾" through Rod Mill - Wet - in closed circuit with Tyler Standard - 26 square mesh screen Feed rate 2970 p.p.h. Note - Break in curve due to screen change
21	Duplicate Test 18 - Gravity flow to screen Feed rate - 3720 p.p.h.