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UPGRADING OF A LOW-GRADE URANIUM ORE FROM AGNEW LAKE MINES LIMITED, ESPANOLA, ONTARIO

by

D. Raicevic

Mineral Processing Division

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SUMMARY OF RESULTS

The average grade of the ore was 1.25 lb U_3O_8 per ton of ore.

Laboratory Results

Between 53 and 72% of the ore by weight was rejected when applying heavy-media separation and jigging (latter to simulate heavy-media cycloning). This resulted in losses of 17.6 and 33.3% of the U_3O_8 in the ore respectively. The grades of the preconcentrates obtained ranged between 2.26 and 3.02 lb of U_3O_8 per ton of the concentrate.

Pilot-Plant Results

The pilot-plant upgrading applying the same procedure as in the laboratory testing rejected 51.0 and 56.8% of the ore by weight losing 23.0 and 32.0% of the U_3O_8 in the ore respectively. The grades of the preconcentrates were 1.96 and 1.98 lb of U_3O_8 per ton of the preconcentrate.

Upgrading of the ore by jigging alone rejected 63.8% of the ore by weight losing 38.7% of the U_3O_8 in the ore. The grade of the jig concentate was 2.06 lb of U_3O_8 per ton.

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*Research Scientist, Non-Ferrous Minerals Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

INTRODUCTION

The upgrading of uranium-bearing ores has been a target since the beginning of the uranium industry for possible savings in grinding and extraction costs, and to make the low-grade uranium ores economically treatable by increasing their grades. This is accomplished by rejecting the non-uranium bearing material (waste) from the ores. To make this treatment feasible the uranium content in the waste material should be small and the cost of the upgrading must be low.

There are four major methods for rejecting the waste material from these ores:

- Sorting of individual lumps of the ore on basis of their uranium content
- High-intensity magnetic separation
- Flotation
- Gravity concentration (jigging, tabling, spirals, heavy-media separation, cycloning, etc.)

A considerable amount of laboratory and pilot-plant work on upgrading uranium ores has been done by applying some of these methods (1)(2)(3)(4). Some of them were more or less successful, but so far, no serious attempts have been made by the Canadian uranium producers to apply any of these methods in practice, despite successful application of heavy-media separation to the uranium ores in Australia, Sweden and South Africa (5)(6), and to base-metal and iron ores in Canada.

Purpose of Investigation

In his letters of September 17, 1969 Mr. F.C. Lendrum, company's consultant, requested the Mineral Processing Division to crush this low-grade uranium ore to minus 1/2 inch and then upgrade it by rejecting about 75% by weight of the material applying heavy-media separation. No specific grade of pre-concentrate or uranium recovery was requested.

Location of Property

This property is located in the Agnew Lake area about 15 miles north of Espanola, Ontario or about 65 miles west of Sudbury.

Ore Shipment

About 10 tons of material designated as "development ore" was shipped to the Extraction Metallurgy Division of the Department of Energy, Mines and Resources on September 23, 1969. About one ton of this sample was sent to the Mineral Processing Division for this investigation. The uranium content in this one-ton sample was 1.25 lb U_3O_8 per ton of ore.

Analyses

All analyses in this investigation were done by the Analytical Laboratory of the Extraction Metallurgy Division. All sampling (feed and products) was done on minus 1/2-inch sizes from each original fraction.

MINERALOGY

A summary of the mineralogical investigation (7) done on the ore from this area is summarized below.

Uranothorite and monazite are the major radioactive minerals in the ore from the Agnew Lake area but minor amounts of brannerite are also present. The radioactive minerals occur in the quartz-sericite matrix of a conglomerate, and are randomly disseminated or concentrated in thin seams which also contain rutile, pyrite and occasionally pyrrhotite. The grains of uranothorite appear to be mainly between 48 and 65 mesh in size, and those of monazite between 35 and 48 mesh. The rare-earth content is due primarily to the presence of monazite. Brannerite commonly occurs as an intergrowth in grains of rutile. Pyrite is the chief sulphide mineral but some pyrrhotite is also present.

DETAILS OF INVESTIGATION

Size Analysis of Crushed Ore

The one-ton ore sample was crushed to minus 1/2 inch and a screen analysis obtained (see Table 1).

Results of this table showed that 18% of the ore by weight was in the minus 28-mesh (fine) fraction with a calculated assay of 0.091% U_3O_8 while the assayed value of the same fraction was 0.092% U_3O_8 (Tables 2 and 3). This fine fraction, containing 25.6% of the U_3O_8 in the ore, is therefore sufficiently upgraded by crushing alone and can be sent directly to grinding and/or sulphuric acid leaching circuit without further upgrading.

TABLE 1

Size, Assay and U_3O_8 Distribution in ½-Inch Crushed Ore

from Agnew Lake Mines Ltd.

Crushed Ore Size	% Weight	% U_3O_8 Assay	% U_3O_8 Distn
-1/2+3/8 in.	7.6	0.043	5.1
-3/8 in.+3 mesh	15.9	0.058	14.4
-3+6 mesh	27.7	0.058	25.3
-6+10 mesh	16.4	0.061	15.7
-10+20 mesh	10.1	0.059	9.4
-20+28 mesh	4.3	0.066	4.5
+28 mesh fraction (calcd)	82.0	0.058	74.4
-28 mesh fraction (calcd)	18.0	0.091	25.6
-28+ 35 mesh	3.1	0.058	2.8
-35+ 48 mesh	2.2	0.065	2.2
-48+ 65 mesh	2.6	0.087	3.5
-65+100 mesh	1.9	0.097	2.9
-100 mesh	8.2	0.11	14.2
Head (calcd)	100.0	0.064	100.0

Methods of Upgrading

The plus 28-mesh fraction, comprising 82% of the ore by weight, assaying about 0.058% U_3O_8 and containing 74.4% of the U_3O_8 in the ore, was upgraded on a laboratory (batch) scale and on a pilot-plant (continuous) scale applying the following methods:

(1) Heavy-Media Separation
(2) Heavy-Media Separation and Jigging
(3) Jigging

Laboratory Tests

The laboratory upgrading of the plus 28-mesh fraction of the ore was done applying the HMS method alone and in combination with jigging.

(1) Upgrading of Plus 28-mesh Fraction of the Ore by Heavy-Media Separation

Using pulps of galena as media, having specific gravities ranging from 2.60 to 2.85, sink-and-float separations of this fraction of the ore were performed in buckets. Results are recorded in Table 2.

TABLE 2

Laboratory Results of Upgrading Crushed Ore by Heavy-Media Separation

Feed				Sink			Float		
Fractions	% Wt	Assay, % U_3O_8	Method of testing	% Wt	% U_3O_8 Assay	% U_3O_8 Distn	% Wt	% U_3O_8 Assay	% U_3O_8 Distn
-½"+28 mesh -28 mesh	82.0 18.0	0.058 0.092	HMS 2.85 Untreated	2.0 18.0	0.59 0.092	18.5 26.0	80.0 -	0.043 -	55.5 -
Total (calcd)	100.0	0.064		20.0	0.142	44.5	80.0	0.043	55.5
-½"+28 mesh -28 mesh	82.0 18.0	0.057 0.092	HMS 2.80 Untreated	5.5 18.0	0.42 0.092	36.4 26.2	76.5 -	0.031 -	37.4 -
Total (calcd)	100.0	0.063		23.5	0.168	62.6	76.5	0.031	37.4
-½"+28 mesh -28 mesh	82.0 18.0	0.052 0.092	HMS 2.75 Untreated	6.5 18.0	0.27 0.092	29.6 28.1	75.5 -	0.033 -	42.3 -
Total (calcd)	100.0	0.059		24.5	0.139	57.7	75.5	0.033	42.3
-½"+28 mesh -28 mesh	82.0 18.0	0.058 0.092	HMS 2.65 Untreated	26.2 18.0	0.114 0.092	46.5 25.8	55.8 -	0.032 -	27.7 -
Total (calcd)	100.0	0.064		44.2	0.105	72.3	55.8	0.032	27.7
-½"+28 mesh -28 mesh	82.0 18.0	0.055 0.092	HMS 2.60 Untreated	30.0 18.0	0.096 0.092	46.8 27.0	52.0 -	0.031 -	26.2 -
Total (calcd)	100.0	0.062		48.0	0.095	73.8	52.0	0.031	26.2

(2) Upgrading of Plus 28-mesh Fraction of the Ore by Heavy-Media Separation and Jigging

For this test work, the plus 28-mesh portion of the ore was separated into two fractions: minus 1/2-inch plus 6-mesh (coarse) fraction and minus 6- plus 28-mesh (middle) fraction. The coarse fraction was upgraded by HMS at specific gravities ranging from 2.60 to 2.85. In the iron industry, the middle fraction would be upgraded by heavy-media cycloning. Since HM cyclones were not available, it was felt that jigging of the middle fraction would give results similar to those that would be produced by the HM cyclones, i.e., jigging would simulate the heavy-media cycloning. The jigging was done using a 1-M Denver laboratory jig under carefully controlled conditions as recorded in Table 3.

TABLE 3

Conditions of Laboratory Jigging

Feed: Minus 6- plus 28-mesh fraction

Size of jig (screen area)	1 1/4 in. x 1 1/2 in.
Speed	260 rpm
Stroke	1/4 in.
Ràgging - type	steel balls
- size	1/4 in.
- weight	90 grams
Water - cc/min	980
Separating screen - mesh	4
Feed rate - 40 g/min	400

Results of these tests are recorded in Table 4.

Summary of the laboratory results obtained by using heavy-media separation alone (Table 2) and in a combination with jigging (Table 4) are recorded in Table 5.

The graphical presentation of the summarized results is given in Figure 1 (page 7).

TABLE 4

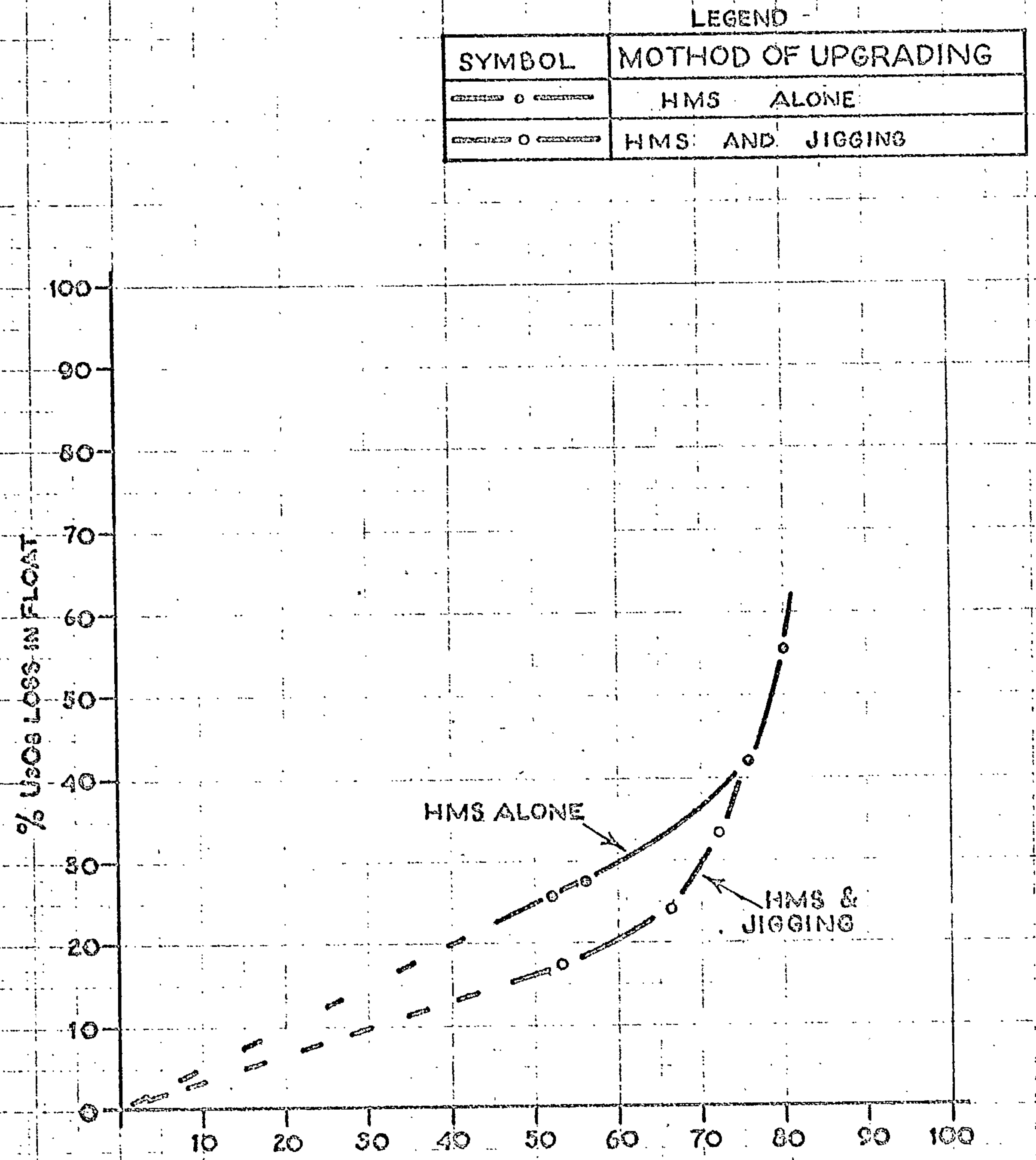
Laboratory Results of Upgrading Crushed Ore by Heavy-Media Separation and Jigging

Feed				Sink			Float		
Fractions	% Wt	Assay, % U_3O_8	Method of Upgrading	% Wt	% U_3O_8 Assay	% U_3O_8 Distn	% Wt	% U_3O_8 Assay	% U_3O_8 Distn
-½"+6 mesh	50.2	0.061	HMS @2.85	2.2	0.68	23.5	48.0	0.033	24.7
-6+28 mesh	31.8	0.052	Jigging	7.9	0.14	17.3	23.9	0.023	8.6
-28 mesh	18.0	0.092	Untreated	18.0	0.092	25.9	-	-	-
Total (calcd)	100.0	0.064		28.1	0.152	66.7	71.9	0.030	33.3
-½"+6 mesh	50.2	0.060	HMS @2.70	7.5	0.27	32.0	42.7	0.023	15.5
-6+28 mesh	31.8	0.052	Jigging	7.9	0.14	17.5	23.9	0.023	8.7
-28 mesh	18.0	0.092	Untreated	18.0	0.092	26.3	-	-	-
Total (calcd)	100.0	0.063		33.4	0.143	75.8	66.6	0.023	24.2
-½"+6 mesh	50.2	0.062	HMS @2.60	21.0	0.12	39.3	29.2	0.020	9.0
-6+28 mesh	31.8	0.052	Jigging	7.9	0.14	17.3	23.9	0.023	8.6
-28 mesh	18.0	0.092	Untreated	18.0	0.092	25.8	-	-	-
Total (calcd)	100.0	0.064		46.9	0.113	82.4	53.1	0.021	17.6

TABLE 5

Summary of Laboratory Results

Method of Upgrading	Density of Medium	Pre-concentrate			Waste		
		% Weight	% U_3O_8 Assay	% U_3O_8 Distn	% Weight	% U_3O_8 Assay	% U_3O_8 Distn
HMS alone	2.85	20.0	0.142	44.5	80.0	0.043	55.5
HMS alone	2.80	23.5	0.168	62.6	76.5	0.031	37.4
HMS alone	2.75	24.5	0.139	57.7	75.5	0.033	42.3
HMS alone	2.65	44.2	0.105	72.3	55.8	0.032	27.7
HMS alone	2.60	48.0	0.095	73.8	52.0	0.031	26.2
HMS + Jigging	2.85	28.1	0.152	66.7	71.9	0.030	33.3
HMS + Jigging	2.70	33.4	0.143	75.8	66.6	0.023	24.2
HMS + Jigging	2.60	46.9	0.113	82.4	53.1	0.021	17.6



$\%$ U_3O_8 LOSS IN FLOAT

% WEIGHT OF FLOAT

FIG.1 SUMMARY OF LABORATORY RESULTS

Pilot-Plant Testing

(1) Upgrading of Ore by Heavy-Media Separation and Jigging

The pilot-plant testing was done using a pilot-size HMS machine manufactured by The Ore and Chemical Company and/or by a 4 x 6-in. Denver jig.

A cross-section diagram of the OCC machine is presented in Figure 2.

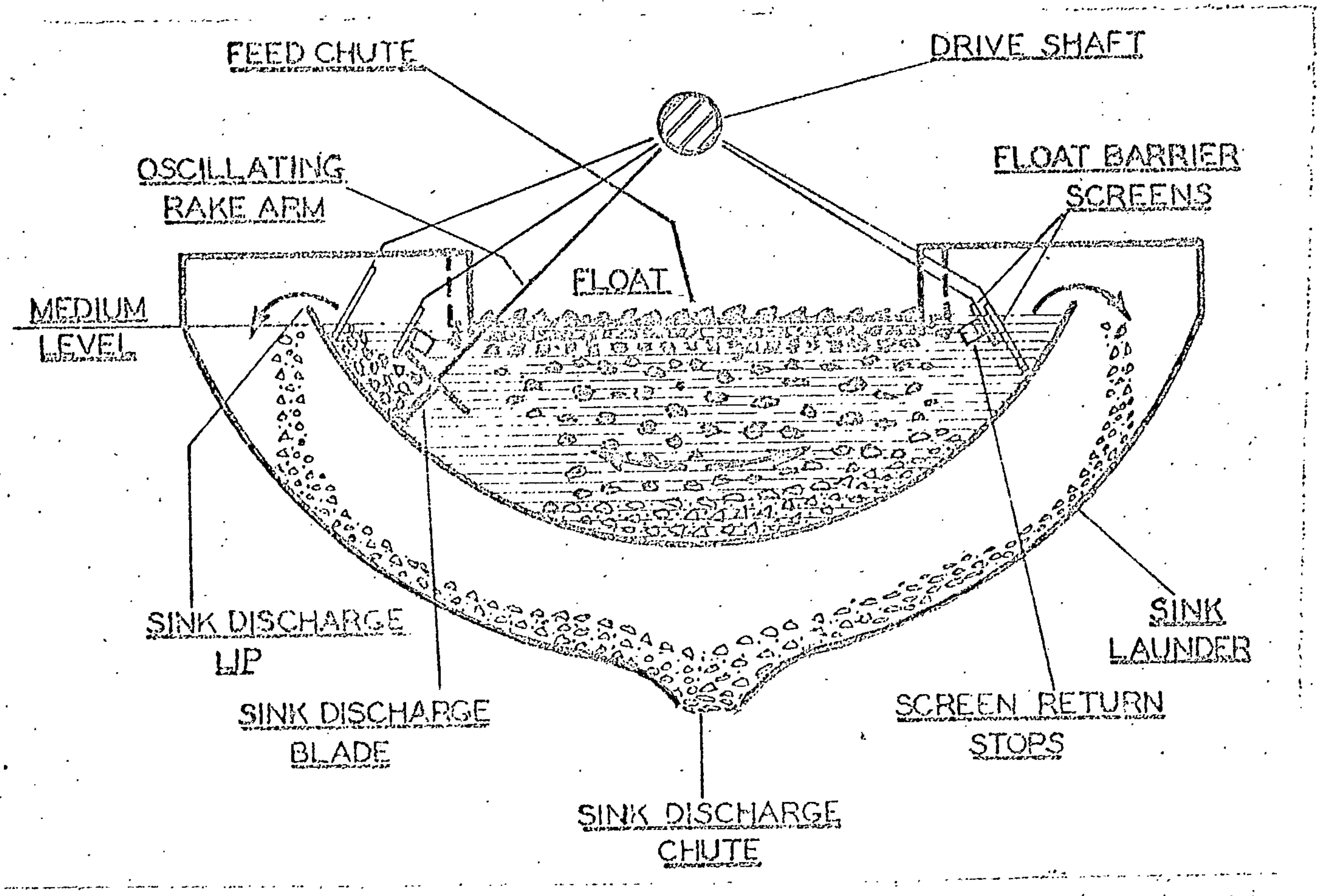


Figure 2. Diagram of OCC Machine.

This is a tub-type HMS machine. Feed is introduced to the back of the machine at the surface level of the medium where the ore is separated into float and sink. Float material is carried with the medium over the front weir of the machine into a chute. The sink, which drops to the bottom of the machine, is removed by means of an oscillating rake that alternately carries sink to the discharge lips at each side of the machine. From here, sink material slides to the sink-discharge chute. Both the float and the sink carry a certain amount of medium at the discharge points, the float much more than the sink. To recover most of this medium, both float and sink are sent over two vibrating screens which are finer than the feed and coarser than the medium so that the products are collected as screen oversize, and medium passes through the screens to the pump and is re-circulated by adding it at two points at the back of the machine.

The flow diagram of this arrangement is presented in Figure 3.

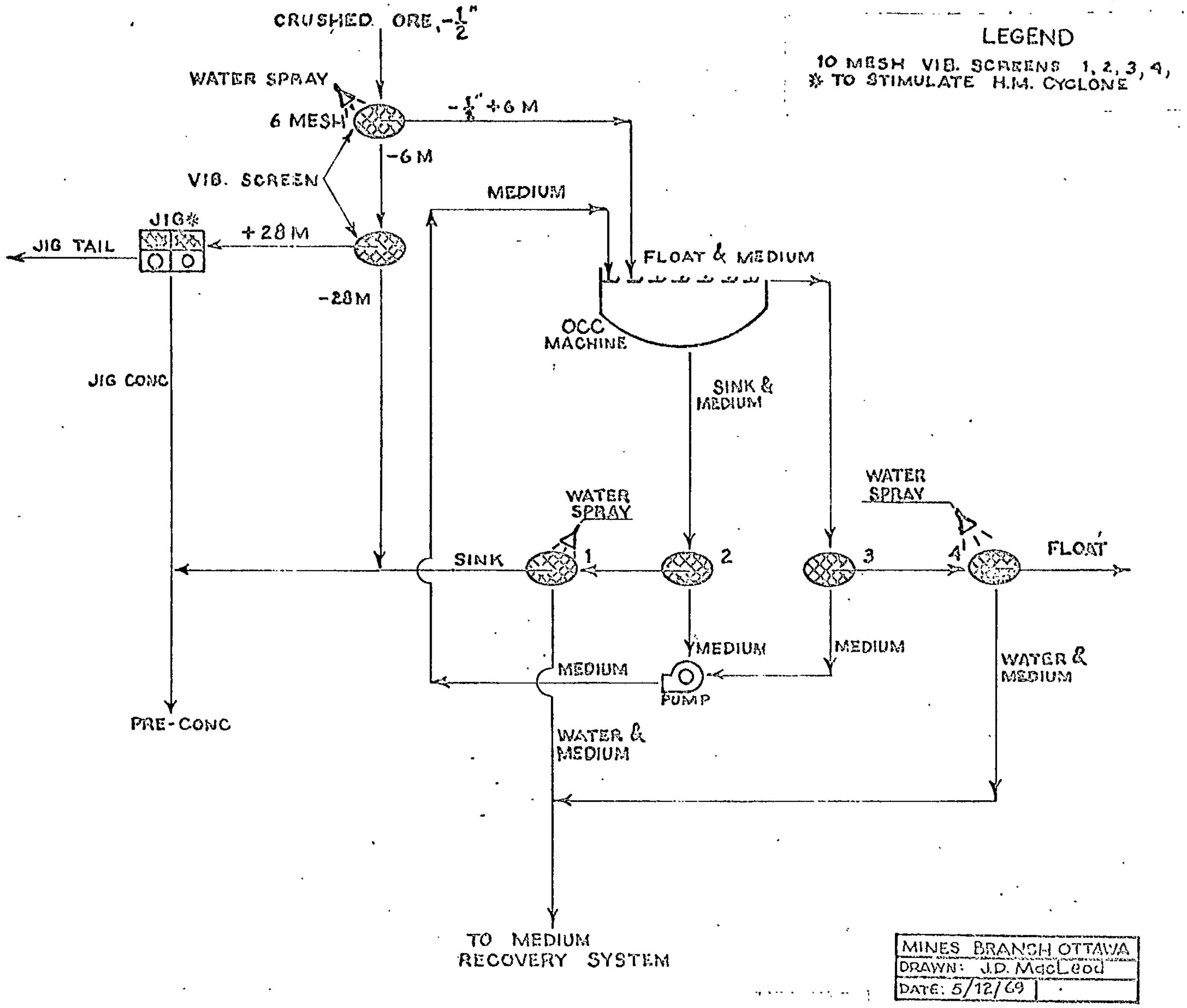


Figure 3. Pilot-Plant Flow Diagram

The ferrosilicon used for this testing had a fineness of 98.4% minus 200 mesh or 72.8% minus 325 mesh.

An effort was made to treat the minus 1/2-inch plus 28-mesh portion of the ore by the heavy-media separation, i.e., the minus 6 plus 28-mesh fraction was included in the HMS feed. This procedure would eliminate the HM cyclones. Many problems were experienced such as maintaining the proper densities, high loss of the media, improper rejection of materials resulting in high U_3O_8 losses in the float, etc. As a result, the use of this feed to the HMS machine was discontinued and only the coarse fraction (minus 1/2-in. plus 6-mesh) was treated by the OCC machine. The densities (at the floats) ranged from 2.80 to 3.06.

The minus 6- plus 28-mesh fraction was jigged by a 4-in. x 6-in. Denver pilot-plant jig with the conditions recorded in Table 6.

TABLE 6

Pilot-Plant Jigging Conditions for Upgrading -6 + 28-Mesh Fraction of the Ore

Size of jig (screen area)		4 in. x 6 in.
Stroke		1/4 in.* and 3/16 in.**
Ragging - type		Steel balls
	Weight and size	72 g of 1/4 in. diam
	Weight and size*	1122 g of 3/8 in. diam
	Weight and size**	1224 g of 3/8 in. diam
Water		2.0 US gal/min
Separating screen - mesh		3

*at 90 lb/hr feed rate
**at 125 lb/hr feed rate

The pilot-plant results of upgrading the coarse fraction of the ore by HMS and the minus 6 plus 28-mesh fraction by jigging are recorded in Table 7.

TABLE 7

Pilot-Plant Results of Upgrading Crushed Ore by Heavy-Media Separation and Jigging

Pilot-Plant Feed				Sink			Float		
Fraction	% Wt in Ore	% U_3O_8, Assay	Method of Upgrading	% Wt in Test	% U_3O_8 Assay	% U_3O_8 Distn	% Wt	% U_3O_8 Assay	% U_3O_8 Distn
-½ in.+6 mesh	50.2	0.066	HMS @2.80	56.5	0.098	84.2	43.5	0.024	15.8
-½ in.+6 mesh	50.2	0.059	HMS @2.90	47.7	0.098	78.9	52.3	0.024	21.1
-½ in.+6 mesh	50.2	0.060	HMS @3.06	36.0	0.10	59.7	64.0	0.038	40.3
-6+28 mesh	31.8	0.053	Jig @90 lb/hr	22.6	0.12	51.5	77.4	0.033	48.5
-6+28 mesh	31.8	0.055	Jig @125 lb/hr	24.5	0.095	42.3	75.5	0.042	57.7

These results showed that HMS, at the density of 3.06, gave a fair rejection of the waste material but the U_3O_8 loss in the float was considerably higher than at the density of 2.90. The latter resulted in a lower rejection of the waste material.

Both these densities gave acceptable grades of concentrates for the conventional H_2SO_4 leaching process.

The jigging results from Table 7 showed a similar trend, i.e., the test carried out at the feed rate of 125 lb/hr resulted in a considerably higher U_3O_8 loss than the test done at 90 lb/hr, making the latter test more acceptable.

A summary of the results obtained by treating the ore by combined HMS (at 2.90 and 3.06 densities) and jigging (at 90 lb/hr) is recorded in Table 8.

TABLE 8

Summary of Pilot-Plant Results
From HMS and Jigging Combined

Fraction	Feed % Wt	Feed % U_3O_8, Assay	Feed Method of Upgrading	Sink % Wt	Sink % U_3O_8 Assay	Sink % U_3O_8 Distn	Float % Wt	Float % U_3O_8 Assay	Float % U_3O_8 Distn
-½ in.+ 6 mesh	50.2	0.059	HMS @2.90	23.8	0.098	37.3	26.3	0.024	10.0
-6+28 mesh	31.8	0.052	Jigging @ 90 lb/hr	7.2	0.12	13.9	24.7	0.033	13.0
-28 mesh	18.0	0.092	Untreated	18.0	0.092	25.8	-	-	-
Total (calcd)	100.0	0.063		49.0	0.098	77.0	51.0		23.0
-½ in.+ 6 mesh	50.2	0.060	HMS @3.06	18.0	0.10	28.3	32.2	0.038	19.2
-6+28 mesh	31.8	0.052	Jigging @ 90 lb/hr	7.2	0.12	13.9	24.6	0.033	12.8
-28 mesh	18.0	0.092	Untreated	18.0	0.092	25.8	-	-	-
Total (calcd)	100.0	0.063		43.2	0.099	68.0	56.8	0.036	32.0

(2) Upgrading of Ore by Jigging

Ore was crushed to 1/4 inch and separated on a 28-mesh screen. The minus 28-mesh fraction assayed 0.090% U_3O_8. The plus 28-mesh portion was jigged using the 4 x 6-in. Denver jig under conditions recorded in Table 9.

TABLE 9

Pilot-Plant Jigging Conditions for Upgrading
Minus 1/4-In. Plus 28-Mesh Fraction of the Ore

Size of jig (screen area)	4 in. x 6 in.
Stroke	5/16 in.
Ragging - type	Steel balls
Weight and size	500 g of 3/8 in. diam
Weight and size	700 g of 1/2 in. diam
Water	2.2 US gal/min
Separating screen - mesh	4
Feed rate	125 lb/hr

The results obtained are given in Table 10.

TABLE 10

Pilot Plant Results of Upgrading Crushed Ore by Jigging Alone

Fraction	Feed		Sink			Float		
	% Weight	% U_3O_8, Assay	% Weight	% U_3O_8 Assay	% U_3O_8 Distn	% Wt in Test	% U_3O_8 Assay	% U_3O_8 Distn
-1/4 in. + 28 mesh	80.0	0.054	16.2	0.12	31.8	63.8	0.037	38.7
-28 mesh*	20.0	0.090	20.0	0.09	29.6	-	-	-
Total (calcd)	100.0	0.061	36.2	0.103	61.4	63.8	0.037	38.7

*Untreated.

It was observed that lesser amounts of the acid-consuming materials (diabase and argillite) were present in the preconcentrates obtained from the pilot-plant tests than in the preconcentrates obtained from the laboratory tests.

CONCLUSION

Satisfactory grades of the preconcentrates and fair rejections of the waste material from the ore were obtained from both the laboratory and the pilot-plant investigations but uranium recoveries were low.

ACKNOWLEDGEMENT

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