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REVIEW OF SINK-FLOAT PRECONCENTRATION OF ELLIOT LAKE URANIUM ORES

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W. R. Honeywell* and S. Kaiman**

INTRODUCTION

In Canada, uranium has been extracted from its ores by either an acid or basic leach process. It has, however, been realized that preconcentration, ahead of leaching, by some physical means such as by sink-float, flotation or gravity concentration procedures might be employed to advantage if it effected savings in the capital cost of the plant and in processing costs.

A study of the mineralogy of the Elliot Lake ores indicates that a certain proportion of the conglomerate ore is barren of uranium and accordingly if it could be removed from the ore by the sink-float process, considerable savings might be effected. In the last fifteen years several samples of Elliot Lake ore from different properties have been subjected to sink-float test work on a laboratory scale at the Mines Branch, Ottawa. This report is a summary and review of the results of this test work.

MINERALOGY OF ELLIOT LAKE URANIUM ORES (1)

In the Elliot Lake district of Ontario, economic concentrations of uranium minerals occur in a quartz-pebble conglomerate with most of the uranium minerals occurring in the matrix. The mineralogical characteristics of the ore conglomerates of the district are remarkably uniform. The ratio of quartz pebbles to matrix has been estimated to be approximately 2 to 1. The matrix consists principally of quartz, sericite, feldspar, chlorite, pyrite, and the uranium-containing minerals brannerite, uraninite and monazite, with minor amounts of thucholite, uranothorite, coffinite and pitchblende. In typical ore conglomerate, the quartz pebbles are closely sized and range from 0.5 to 1.5 or 2 inches in diameter. The pebbles consist mainly of silica. Except for rare occurrences in fine pyritized fractures in the pebbles, most of the radioactivity is present in the matrix.

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The mineralogy indicates that the sink-float process should be carried out on ore crushed to minus 1 inch and at a specific gravity of from 2.66 to 2.69. Dana's Textbook of Mineralogy gives the specific gravity of quartz crystals as 2.65 to 2.66.

EARLY MINES BRANCH INVESTIGATIONS

In the period between 1953 and 1958, several samples from different Elliot Lake uranium mines were tested at the Mines Branch by static sink-float procedures using heavy liquids. After a few preliminary tests that indicated that a specific gravity of 2.68 would produce an approximately acceptable tailing from the ore being treated, nine detailed tests were done at an average specific gravity of 2.68 using a mixture of acetylene tetrabromide and carbon tetrachloride. Samples treated ranged in particle size from 1 inch to 4 mesh down to as fine as from 10 to 65 mesh. The undersize was not treated in these tests, and it was assumed that in a commercial operation it would be added to the sink portion to form the concentrate.

The results obtained from this early work on six ore samples from three mines in the Elliot Lake area are given in Table 1. Examination of these results shows that all the results are quite similar except in the case of a sample from Algom Uranium Mines Limited (SR 283 / 54, Test 8) where a very low-grade sample, which was not representative of the ore, was investigated. However, even in this instance, the uranium grade of the float was of the same order as most of the higher-grade samples investigated. An overall average of all the results excepting those of Test No. 8, shows that 34.4% of the ore could be rejected at a grade of 0.015% with a uranium loss of 6.1%. The average weight rejected as float would be 45.1% of the sink-float feed.

In 1958 a series of sink-float tests was carried out on Northspan ore crushed to either minus 6 inch, or minus 1 inch[1]. The separations were made at three specific gravities, and the results are shown graphically in Figure 1.

Figure 1 shows that this ore should be crushed to minus 1 inch to obtain satisfactory results. The curve for the 1-inch to 4-mesh fraction shows that at a specific gravity of about 2.68 approximately 40% of the weight could be eliminated with a loss of 5 % of the uranium. Expressed another way, the sink product plus the untreated fines would contain 60% of the weight and 95% of the uranium.

TABLE 1

Summary of Sink-Float Tests on Elliot Lake Ores

Source of Sample	Report Number*	Head Assay U_3O_8 %	Mesh Size	Specific Gravity of Medium	Float				Test No.
					Based on Sink-float feed Wt %	Based on Whole Ore			
						Wt %	U_3O_8 %	U_3O_8 Loss %	
Pronto Uranium Mines Ltd.	SR*-210/53	0.13	-10+65**	2.66	60.0	40.0	0.02	6.3	1
Pronto " " "	SR-224/54	0.081	-$\frac{3}{4}$"+10	2.70	30.0	26.7	0.014	5.9	2
Pronto " " "	SR-224/54	0.081	-$\frac{1}{2}$"+10	2.72	40.6	34.1	0.016	8.9	3
Pronto " " "	SR-224/54	0.081	-$\frac{1}{4}$"+10	2.72	45.2	30.8	0.016	7.8	4
Pronto " " "	SR-449/56	0.13	-$\frac{1}{2}$"+65	2.67	37.3	34.7	0.009	2.2	5
Algom " " "	SR-251/54	0.087	-5/16"+10	2.67	48.8	30.6	0.017	6.4	6
Algom " " "	SR-251/54	0.087	-5/16"+35	2.67	49.6	42.3	0.015	7.8	7
Algom " " "	SR-283/54	0.027	-1" +35	2.67	73.4	71.2	0.016	39.4	8
Northspan " " "	Ref. (2)	0.11	-1" +4	2.67	49.1	35.6	0.009	3.3	9
				2.68	45.1	34.4	0.015	6.1	Average

*SR reports are Special Reports of the Radioactivity Division, Mines Branch

** This test was carried out on 10 to 65-mesh material. The minus 65-mesh material was not treated but was combined with the concentrate. This method applies to the other screen sizes listed in this column.

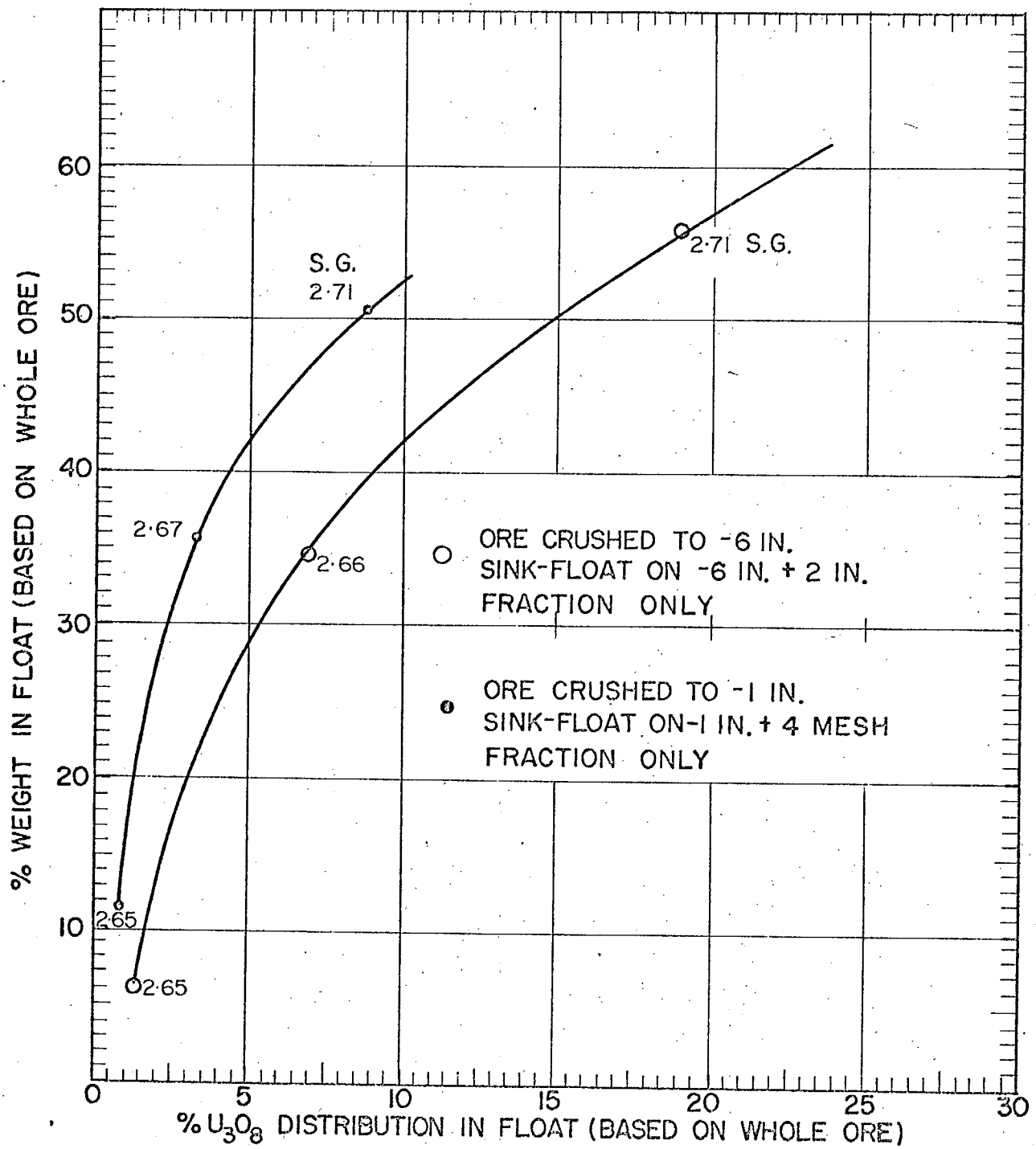

Figure 1. Results of Sink-Float Tests on Ore From Northspan Uranium Mines Ltd.

Leach tests were carried out on the whole ore as well as on the preconcentrate produced, with about 93% extraction of uranium in each case. On the other hand, preconcentration by sink-float followed by leaching effected an overall acid saving of 30 lb H_2SO_4 per ton ore on this particular sample [2].

RECENT MINES BRANCH INVESTIGATIONS

In 1964 a new investigation was conducted with the object of developing a process in which sink-float could be applied economically to Elliot Lake ore. In this work a sample of ore from Denison Mines Limited was used as feed material and the test work involved sink-float tests followed by bacterial leaching of float products. A consideration of previous sink-float test results led to the conclusion that the loss of uranium to the float fraction made preconcentration by sink-float unattractive. However, this objection to sink-float preconcentration would be overcome if the float fractions were amenable to bacterial leaching.

In this work on a sample of Denison ore containing 0.11% U_3O_8 the sample was crushed to minus 1 inch with the sink-float work being done on the minus 1-inch plus 4-mesh and minus 4 plus 10-mesh fractions. The minus 10-mesh fraction represented 12.7% of the weight and was not treatedby sink-float. As in the earlier work it was assumed that the minus 10-mesh fraction would be combined with the sink fractions to make the preconcentrate for conventional acid leaching. The sink-float work was done at specific gravities of 2.69 and 2.76.

The results of the work on the Denison ore are given in Table 2 and Figure 2. These data show that with a heavy medium having a specific gravity of 2.69, 44% of the weight and 7% of the uranium was rejected. The uranium analyses of the preconcentrate (sink plus untreated minus 10 mesh fraction) and reject (float) were 0.18% U_3O_8 and 0.017% U_3O_8 respectively. When the specific gravity of the heavy media was increased to 2.76, about 64% of the weight and 23% of the uranium was rejected. These latter results are not considered to be of practical interest since a sufficiently high recovery of the uranium in the rejects could not be obtained by bacterial heap leaching. The results of the bacterial leach tests done on the rejects showed that only 34% of the uranium in the rejects could be recovered by this means.

Some of the data from the sink-float tests done on the Northspan ore (Figure 1) are repeated on Figure 2 so that they may be more easily compared with the results obtained on the Denison ore. Figure 2 shows that the sink-float results on the two ores are very similar.

TABLE 2

Sink-Float Results on Denison Ore after Crushing to -1 inch

Products and sp gr of Separation	Fraction Wt %	Overall Wt %	U_3O_8 Assay %	Content	Fraction U_3O_8 Dist. %	Overall U_3O_8 Dist. %
2.69 sp gr						
-1 + 4 m Float	49.74	30.90	0.016	.0049	9.5	4.5
-1 + 4 m Sink	50.26	31.23	0.15	.0468	90.5	43.2
-4 +10 m Float	52.40	13.18	0.021	.0028	8.0	2.6
-4 +10 m Sink	47.60	11.97	0.27	.0323	92.0	29.8
-10 m (untreated)		12.72	0.17	.0216		19.9
Orig. Ore		100.00	0.11	.1084		100.0
-1 + 4 m Float		30.90		.0049		4.5
-4 +10 m Float		13.18		.0028		2.6
Tailing		44.08	0.017	.0077		7.1
-1 + 4 m Sink		31.23	0.15	.0468		43.2
-4 +10 m Sink		11.97	0.27	.0323		29.8
-10 m (untreated)		12.72	0.17	.0216		19.9
Preconcentrate		55.92	0.18	.1007		92.9
2.76 sp gr						
-1 + 4 m Float	74.07	46.02	.057	.0262	31.1	19.4
Sink	25.93	16.11	.36	.0580	68.9	42.9
-4 +10 m Float	75.29	18.94	.03	.0057	19.5	4.2
Sink	24.71	6.21	.38	.0236	80.5	17.5
-10 m (untreated)		12.72	.17	.0216		16.0
Orig. Ore		100.00	.135	.1351		100.0
-1 + 4 m Float		46.02	.057	.0262		19.4
-4 +10 m Float		18.94	.03	.0057		4.2
Tailing		64.96	.049	.0319		23.6
-1 + 4 m Sink		16.11	.36	.0580		42.9
-4 +10 m Sink		6.21	.38	.0236		17.5
-10 m (untreated)		12.72	.17	.0216		16.0
Preconcentrate		35.04	.30	.1032		76.4

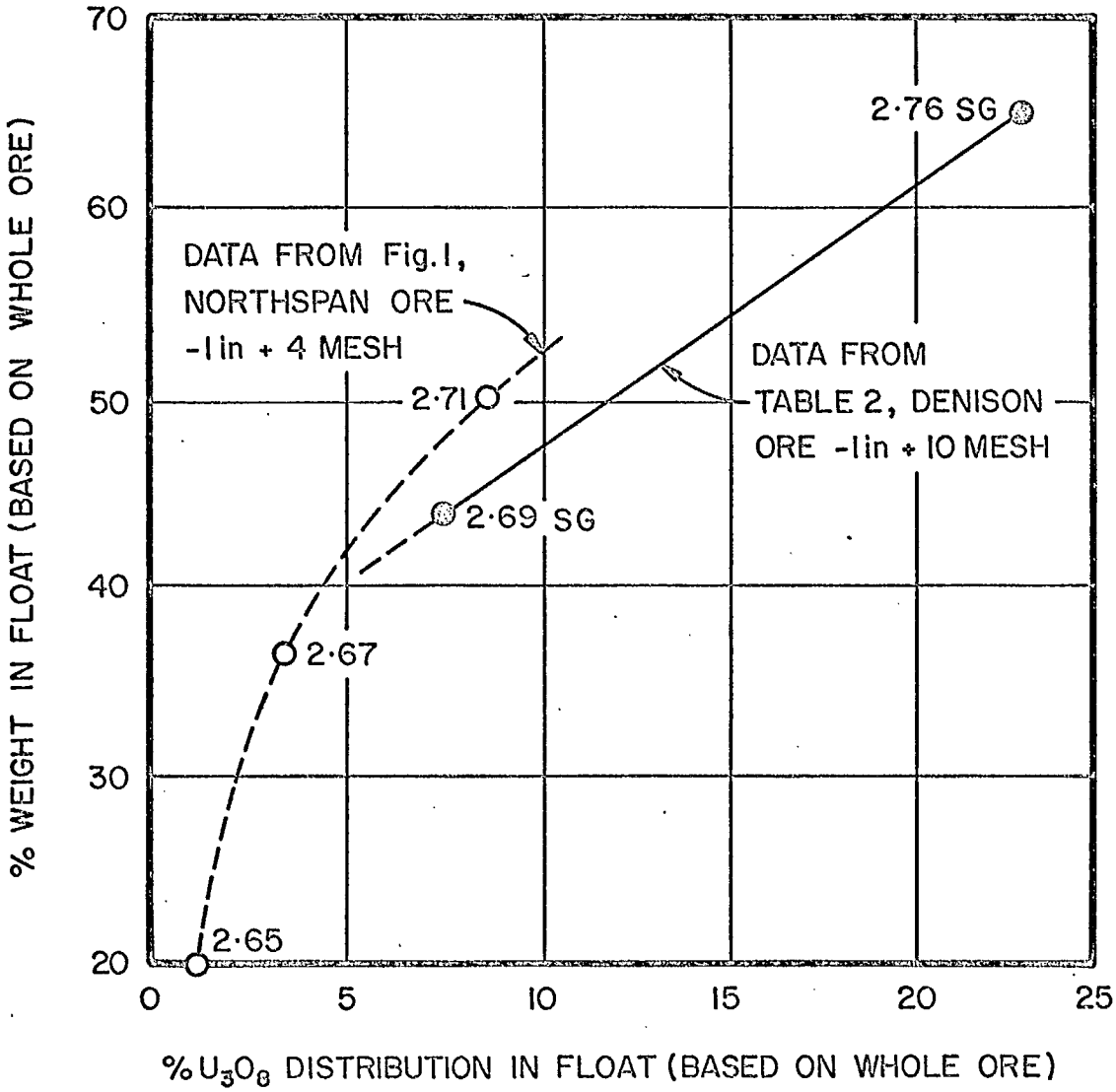

Figure 2. Results of Sink-Float Tests on Ore From Denison Mines Limited

In 1966 further heavy-liquid fractionation tests were undertaken on sized samples from the Nordic Mines of Rio Algom Mines Limited [3]. It was hoped that the data obtained could be used as a basis to predict maximum degree of concentration that might be expected from gravity-separation techniques. Two series were carried out, the first on closely sized fractions of a sample crushed to all minus 20 mesh, and the second on closely sized fractions of a sample ground for 25 minutes in an Abbe ball mill which produced a product containing about 55% minus 200 mesh. The sized fractions were separated in heavy liquids at specific gravity 2.90, 2.80 and 2.70 using 125-ml separatory funnels and a centrifuge. All sizes were treated except the minus 10-micron material which was too fine to be fractionated.

The results of the work on the Nordic ore are given in Table 4 and Figure 3. Almost identical results were obtained at a specific gravity of 2.70 on both feed materials. At this specific gravity (2.70) neither the amount of ore rejected nor the uranium rejected in the float was affected by the degree of fineness to which the ore was ground ahead of sink-float treatment. Figure 3 also shows that the amount of uranium lost to the float fraction was about 5 % and was dependent only on the specific gravity of the heavy medium and was not affected by the particle size of the ore. Further evidence of the independence of uranium loss and size is given by the data on Figures 1 and 2 where it can be seen that the uranium loss to the float at a specific gravity of about 2.70 with the ore crushed to minus 1 inch is almost the same as that resulting from the treatment of the much finer ore (Figure 3) at a specific gravity of 2.70.

The per cent weight rejected in the float fraction is dependent on both the specific gravity of the heavy medium and the particle size of the feed material. A study of all the sink-float results given in Table 1 and Figures 2 and 3 shows that if the feed particle size is minus 1 inch, 35 to 45% of the weight will be rejected at a medium specific gravity of about 2.70 (Figure 2). If the feed is crushed to minus 20 mesh or finer 60 to 70% of weight is rejected at a specific gravity of 2.70 (Figure 3).

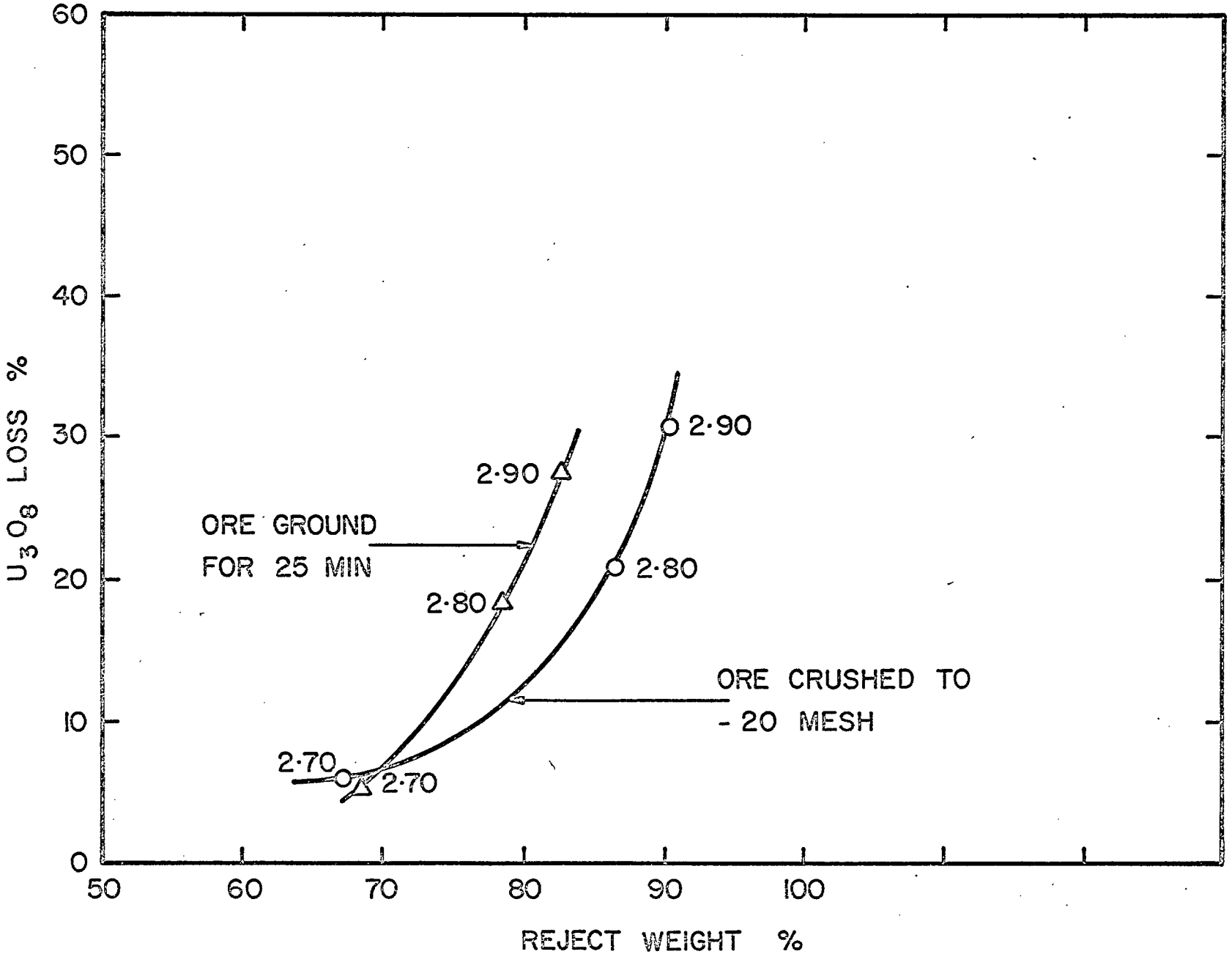

Figure 3. Sink-Float Results On Algom Nordic Ore

TABLE 4

Sink-Float Rejects on Algom Nordic Ore

Specific Gravity	Reject Wt,%		Loss U_3O_8,%		Ratio of Conc.	
	-20 mesh feed	55% -200m feed	-20 mesh feed	55% - 200m feed		
2.90	90.2	82.7	30.9	27.7	10.2	5.8
2.80	86.9	78.7	20.8	18.7	7.6	4.7
2.70	67.5	68.7	6.0	5.3	3.1	3.2

CONCLUSIONS

On the basis of sink-float studies done on a wide selection of uranium-bearing ores from the Elliot Lake area over the past fifteen years it can be concluded that:

1. Satisfactory sink-float treatment of the Elliot Lake ores requires that the ores be crushed to at least all minus 1 inch (Figure 1);

2. With Elliot Lake ore crushed to all minus 1 inch or finer, the specific gravity of the heavy medium should be between 2.67 and 2.70 if excessive uranium losses to the float fraction is to be avoided;

3. The ore throughout the Elliot Lake ore body is similar in the way it reacts to sink-float separations. With ore crushed to minus 1 inch 35-45 % of the ore can be rejected at a specific gravity of 2.69-2.70 with a uranium loss in the float of 5-7 %. With the ore crushed to all minus 20 mesh, and treated at a specific gravity of about 2.70, the weight rejection would be about 60 % while the uranium loss would be 5-7 %, as it would be with coarser feed material.

4. Any attempt to reduce the loss of uranium below 5-7 % will only result in an impractically low weight rejection (Figure 1, specific gravity 2.65).

REFERENCES

1. W.R. Honeywell and S. Kaiman, "Flotation of Uranium from Elliot Lake Ores". Canadian Mining and Metallurgical Bulletin, 59, No. 647, 347-355 (1966).

2. W.R. Honeywell and H.H. McCreedy, "Investigation of Uranium-bearing Ore from Northspan Mines Ltd., Lacnor Property, Elliot Lake, Ontario". Mines Branch Investigation Report IR 58-191, October, 1958.

3. S. Kaiman, work previously referred to in the Proceedings of the Fall Meeting of The Canadian Uranium Producers' Metallurgical Committee, October 14, 1968.

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