RI 8846

Bureau of Mines Report of Investigations/1984

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UNITED STATES DEPARTMENT OF THE INTERIOR

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With an Economic Evaluation by D. A. Kramer

UNITED STATES DEPARTMENT OF THE INTERIOR
William P. Clark, Secretary

BUREAU OF MINES
Robert C. Horton, Director

Library of Congress Cataloging in Publication Data:

Foot, D. G. (Donald G.)

Evaluation of methods for recovering potash from carnallite ore.

(Report of investigations ; 8846)

Includes bibliographical references.

Supt. of Docs. no.: I 28.23:8846.

1. Potash. 2. Carnallite. 3. Flotation. I. Huiatt, J. L. II. Title. III. Series: Report of investigations (United States. Bureau of Mines) ; 8846.

TN23.U43 [TN919] 622s [622'.3636] 83-600310

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°Bé	degree Baumé	lb/d	pound per day
d/wk	day per week	lb/h	pound per hour
d/yr	day per year	Mgal	thousand gallons
h	hour	min	minute
h/d	hour per day	MMBtu	million British thermal units
in	inch	pct	percent
kW·h	kilowatt hour	ton/d	ton per day
lb	pound		

EVALUATION OF METHODS FOR RECOVERING POTASH FROM CARNALLITE ORE

By D. G. Foot, Jr.,[1] and J. L. Huiatt[2]

ABSTRACT

The Bureau of Mines investigated two methods for recovering potash from carnallite ore in continuous 100-lb/h flotation units. In the insoluble-slimes flotation procedure, insoluble slimes were removed by flotation prior to potash flotation. In the direct flotation method, insoluble slimes were depressed and the potash floated directly without prior removal of the insoluble slimes. Seventy-three percent of the potash in the ore was recovered in a leached final KCl product containing 59.1 pct K_2O using the insoluble-slimes flotation method. The direct flotation method recovered 74.5 pct of the potash in a final product containing 60.2 pct K_2O. The rate of return on the investment was calculated at 13 pct for the insoluble-slimes flotation method and 15 pct for the direct flotation method, based on a Bureau economic evaluation.

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INTRODUCTION

The Bureau of Mines conducted research on techniques for recovering potash values from high-insoluble-slimes-bearing domestic carnallite ores. In the first phase of the study, two techniques were devised: (1) a method where the insoluble slimes were depressed during potash flotation and (2) a method where insoluble slimes were removed by flotation prior to potash flotation. Reports of the first phase of the research[3] described batch- and locked-cycle, bench-scale testing of the two techniques. This report describes results of the second phase of the research: (1) operation of a continuous 100-lb/h flotation unit designed to technically evaluate the two methods and (2) an economic evaluation of the two methods.

Potassium is one of three basic chemical ingredients used for promoting plant growth. Refined potash salts, obtained from either ores or brines, are the only economically significant sources of potassium used in fertilizers. Current domestic demand for potash is 6.0 million tons of K_2O. However, only approximately 1.8 million tons of K_2O are produced in this country. The balance of the domestic demand is supplied by Canadian exports.[4] About 84 pct of the domestic production is from bedded deposits in the Carlsbad, NM, area. This area has been a source of high-grade sylvinite (a mixture of KCl and NaCl) ores during the last 40 years. Depletion of high-grade ores makes low-grade sylvinite and carnallite ores major potash sources. Insoluble slimes in these ores create processing difficulties. Discarded insoluble slimes occlude valuable potash minerals and adsorb significant amounts of amine collectors used in flotation. Methods compatible with existing commercial potash processes must be devised to remove or treat these insoluble slimes before potash flotation to improve potash recoveries and reduce processing costs.

ACKNOWLEDGMENT

The authors wish to acknowledge cooperation from the National Potash Corp., Carlsbad, NM, for providing the carnallite samples used in this investigation.

SAMPLE DESCRIPTION

Over 25 tons of minus 4-in, run-of-mine ore was received for testing in the continuous flotation unit. A partial chemical analysis of the ore is given in table 1. Petrographic and X-ray diffraction analysis of the carnallite ore indicated that halite (NaCl), carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), and sylvite (KCl) were the most abundant minerals. Minor amounts of kainite ($KCl \cdot MgSO_4 \cdot 3H_2O$), leonite ($MgSO_4 \cdot K_2SO_4 \cdot 4H_2O$), and polyhalite ($MgSO_4 \cdot K_2SO_4 \cdot 2CaSO_4 \cdot 2H_2O$) were also present. The

TABLE 1. - Chemical analysis of carnallite ore

	wt pct
K_2O	12.8
Na	23.4
Mg	4
Ca	.2
SO_4	2.5
Cl_2	46
Water insolubles	3.5

[3]Foot, Jr., D. G., and J. L. Huiatt. Direct Flotation of Potash From Insoluble-Slime-Bearing Sylvinite and Carnallite Ores. Pres. at AIME Annual Meeting, Chicago, IL, Feb 22-26, 1981, preprint 81-74, 8 pp.

Foot, Jr., D. G., C. E. Jordan, and J. L. Huiatt. Direct Flotation of Potash From Carnallite. BuMines RI 8678, 1982, 11 pp.

[4]Searls, J. P. Potash. Sec. in BuMines Mineral Commodity Summaries, 1983, pp. 118-119.

water-insoluble fraction of the ore contained abundant magnesite, chlorite, and illite. Some carnallite and sylvite contained minor amounts of occluded hematite, which gave the minerals a distinct red color.

Carnallite ore was prepared for feed to the continuous flotation unit by crushing through 3/4-in size using a hammer mill. The ore was screened at 10 mesh, the liberation size for the sylvite and carnallite minerals. The oversize was processed in a rod mill. Dry screen analysis of the crushed ore, given in table 2, indicated that 23.4 pct of the total weight was coarser than 10 mesh.

CONTINUOUS FLOTATION UNIT DESIGN AND OPERATION

DESIGN FOR INSOLUBLE-SLIMES FLOTATION

Circuit design was based on data obtained from bench-scale, locked-cycle testing. The flow diagram presented in appendix figures A-1 through A-5 was adopted for the method using insoluble-slimes flotation. Minus 3/4-in material was fed to a 10-mesh vibrating screen. Screen oversize was processed in a rod mill operating at 50-pct-solids pulp density. The screen undersize was slurried with saturated brine and mixed with rod mill discharge. The combined slurry flowed to a carnallite decomposition tank. Because carnallite must be decomposed to KCl to produce a feed material for potash flotation, approximately 400 lb of fresh water per ton of the carnallite ore was added to dissolve the $MgCl_2$, leaving a solid KCl product. Approximately 9 pct of the potassium in the carnallite was dissolved in the brine during the 5-min decomposition leach. (A portion of this potash could be recovered by solar evaporation of the excess plant brine.)

Slurry from the carnallite leach decomposition step was diluted to 27 pct solids for the insoluble-slimes flotation circuit. Insoluble-slimes flotation reagents (Superfloc 127 and Aeropromoter 870)[5] were added ahead of flotation in a Denver No. 7 Sub-A flotation machine. No conditioning was required. Total insoluble-slimes flotation time was approximately 10.5 min.

TABLE 2. - Screen analysis of carnallite ore

Screen size, mesh	wt pct
Plus 10	23.4
Minus 10 plus 20	19.2
Minus 20 plus 35	14.6
Minus 35 plus 65	15.6
Minus 65 plus 100	8.7
Minus 100	18.5

Deslimed pulp was conditioned for 2 min with MRL-201 insoluble-slimes blinder and an emulsion of Armeen TD and Barrett's oil. Conditioned pulp was fed to a bank of three Denver No. 5 Sub-A flotation machines. Potash rougher flotation time was 10.5 min. The potash rougher concentrate was upgraded further by a 3.5-min single-stage cleaner flotation and 3.5-min recleaner flotation without additional reagents. The recleaner concentrate was water-washed to remove fine NaCl and filtered to recover the entrained brine. Less than 0.5 pct potash was lost during final product leaching. Pan filters were used for final debrining of all products in the flotation unit. Potash cleaner and recleaner tailings were recycled to rougher and cleaner flotation circuits, respectively.

Insoluble-slimes concentrate and salt tailings from potash rougher flotation were combined and thickened in a spiral classifier. The clear brine was recycled, while the thickened solids were filtered to recover additional brine. New equilibrium brine, made from the ore, was used in the flotation unit for initial startup only. Brine was recycled as completely as possible during operation.

[5]Reference to specific products does not imply endorsement by the Bureau of Mines.

The recycled brine from classifier and filtered products was pumped to a recycle brine tank. This tank served as a surge tank for process brine, which was metered to various points in the flotation unit.

DESIGN FOR DIRECT FLOTATION

This circuit, shown in appendix figures A-6 through A-9, was similar to the insoluble-slimes flotation circuit except (1) the insoluble-slimes flotation circuit was eliminated, (2) slurry from the carnallite decomposition was pumped directly to the potash flotation circuit, and (3) the slimes were flocculated with Superfloc 127 and depressed with MRL-201 in the potash flotation circuit. Figure 1 shows an overall view of the continuous flotation unit.

OPERATION

The reagent schemes described in table 3 were used in the operation of the insoluble-slimes flotation and direct flotation units. These represent optimum dosages determined during operation. Most of the data were obtained during 12-h runs; however, 48- and 96-h runs were also conducted. The major problems encountered were (1) production of minus 100-mesh fines in the rod mill and (2) generation of excessive froth during potash flotation.

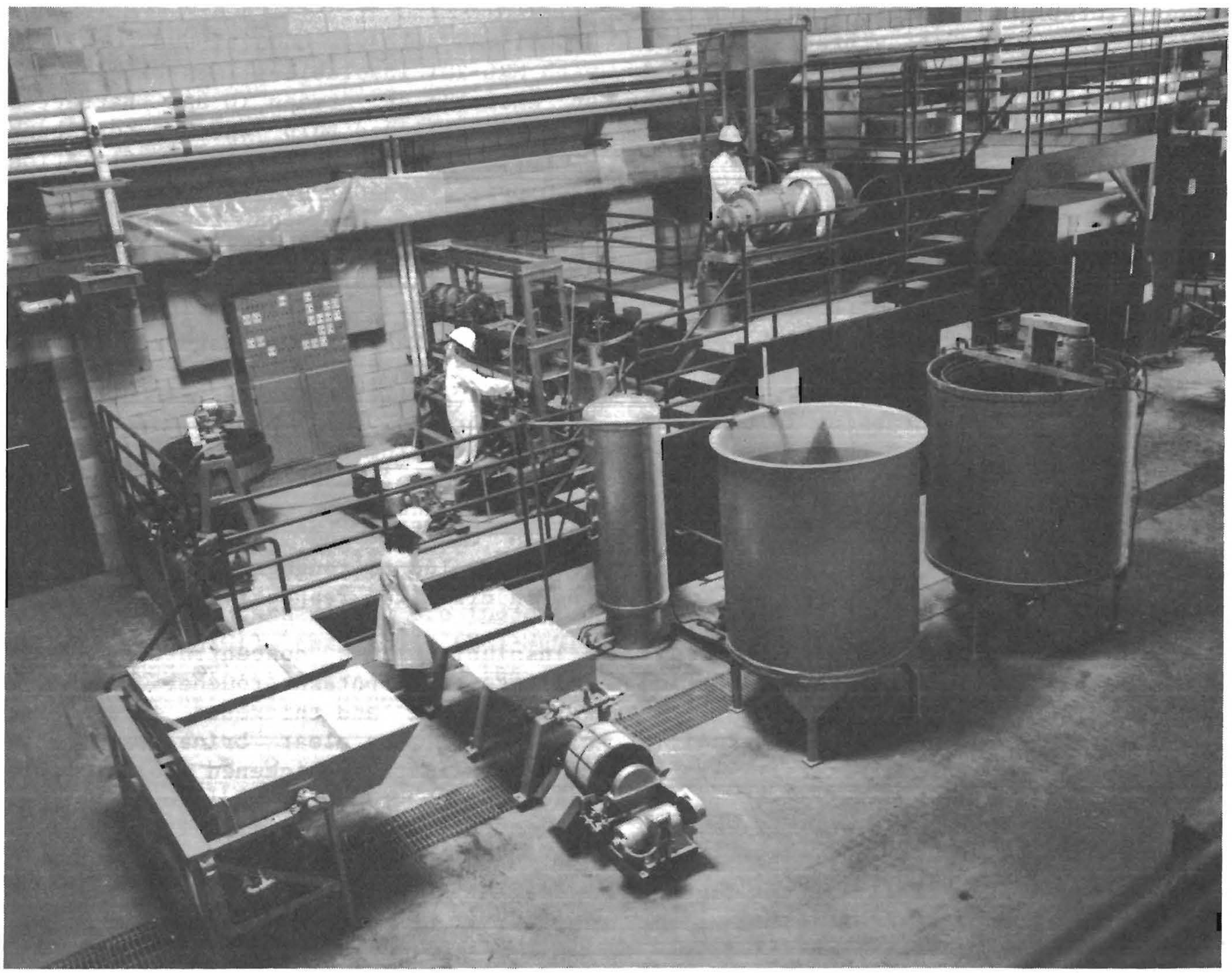


FIGURE 1. - Overall view of continuous flotation unit.

TABLE 3. - Reagent schemes used in continuous flotation unit

Reagent	Total reagent addition, lb/ton	
	Insoluble-slimes flotation	Direct flotation
Superfloc 127...	0.05	0.08
Aeropromoter 870	.20	0
MRL 201.........	1	1
Armeen TD and Barrett's oil..	.3	.4

During insoluble-slimes flotation, fine sylvite reported to the insoluble-slimes concentrate, thus increasing potash losses. When operating either flotation unit, fine halite reported to the potash concentrate, thus lowering the grade and requiring a final water wash to raise the grade to a marketable 60 pct K_2O. The water wash was performed at an optimum 4-to-1 ore-to-water ratio.

SAMPLING AND DATA ANALYSIS

During operation of the insoluble-slimes flotation unit, samples of the plant feed, rod mill overflow, insoluble-slimes concentrate, potash recleaner concentrate, insoluble-slimes tailings, salt tailings, and recycle brine were taken every 4 h for a complete material balance. The samples were filtered, dried, and assayed for potassium, sodium, and water insolubles. During operation of the direct flotation unit, the same samples were taken except for the insoluble-slimes concentrate. Complete mass balances of potassium, sodium, and water insolubles are shown in figures A-1 through A-9.

EXPERIMENTAL RESULTS

Results of the flotation operations for both procedures are shown in table 4. These are results under the optimum conditions listed in table 3.

When treating the carnallite ore by the insoluble-slimes flotation method, 73 pct of the potash in the plant feed was recovered in a leached final KCl concentrate containing 59.1 pct K_2O. Almost 80 pct of the insoluble slimes and 12 pct of the potash in the feed reported to the insoluble-slimes concentrate. Decomposition leaching of the carnallite and water washing of the potash recleaner concentrate dissolved 9.7 pct of the potash.

When treating the ore with the direct flotation method, 74.5 pct of the potash in the feed was recovered in a leached recleaner concentrate containing 60.2 pct K_2O. The final salt tailings contained nearly 77 pct of the insoluble slimes and 16 pct of the potash. Decomposition-leaching of the carnallite and water washing of the potash recleaner concentrate dissolved 9.8 pct of the potash.

TABLE 4. - Flotation results for continuous flotation unit

Product	Assay, wt pct			Distribution, pct		
	K_2O	Na	Water insolubles	K_2O	Na	Water insolubles
Insoluble-slimes flotation:						
Final KCl product...........	59.1	0.8	2.9	73.0	0.5	12.3
Final salt tails............	1.3	26.9	5.8	5.5	64.9	8.3
Insoluble-slimes concentrate	11.9	25.5	22.8	11.8	13.9	79.4
Loss to brine...............	ND	ND	ND	9.7	20.7	ND
Direct flotation:						
Final KCl product...........	60.2	.3	3.9	74.5	.2	17.1
Final salt tailings.........	2.9	25.9	4.4	15.7	76.6	82.9
Loss to brine...............	ND	ND	ND	9.8	23.2	ND

ND Not determined.

Screen analysis of the concentrates obtained under optimum conditions are shown in table 5. Over 28 pct of the weight was in the minus 100-mesh fraction. Limited testing indicated that the material could be pelletized readily to increase particle size and thus improve market value.

TABLE 5. - Screen analysis of final KCl products, weight percent

Product size, mesh	Insoluble method, slimes	Direct method
Minus 35.............	28.7	29.4
Minus 35 plus 10......	42.7	39.2
Minus 100............	28.6	31.4

Potash lost to the insoluble-slimes concentrate was predominately minus 100-mesh material, while potash lost to the final salt tails was predominately plus 35-mesh material. Both plus 35-mesh and minus 100-mesh material were lost to the final tailings when using the direct flotation method. Halite contamination of the potash recleaner flotation concentrates was almost entirely minus 100-mesh material. This fine material was entrained in the froth.

MATERIAL BALANCE AND ECONOMIC EVALUATION

Flow diagrams and complete material balances for the insoluble-slimes flotation and direct flotation procedures are shown in figures A-1 through A-5 and A-6 through A-9, respectively. The material balances are for a plant designed to process 10,000 ton/d of carnallite ore of the grade described in table 1. Economic evaluations of the methods are described in tables A-1 through A-4.

Estimated operating cost for the insoluble-slimes flotation process is \$49.92/per ton of potash product, or \$0.85 per unit of K_2O; the cost for the direct flotation process is \$47.46 per ton of potash product, or \$0.78 per unit of K_2O. Based on a selling price of muriate of potash of \$1.26 per unit of K_2O, the insoluble-slimes flotation procedure yields an estimated rate of return on investment of 13 pct after taxes. Direct flotation yields an estimated 15-pct after-tax rate of return on investment.

SUMMARY AND CONCLUSIONS

Operation of a 100-lb/h continuous flotation unit demonstrated the technical and economic feasibility of recovering potash from insoluble-slimes bearing carnallite ore. Using the insoluble-slimes flotation process, where the slimes are removed by flotation prior to potash flotation, 73 pct of the potash in the feed was recovered in a leached recleaner flotation concentrate contiaining 59.1 pct K_2O. Nearly 80 pct of the insoluble slimes was recovered in the insoluble-slimes flotation concentrate.

Using a direct flotation method, where the potash is floated directly while depressing the insoluble slimes, 74.5 pct of the potash in the feed was recovered in a leached recleaner concentrate containing 60.2 pct K_2O. The final salt tailings contained nearly 83 pct of the insoluble slimes.

The processes are economically feasible, yielding, after taxes, estimated rates of return on investment of 13 pct for the insoluble-slimes flotation method and 15 pct for the direct flotation method.

APPENDIX.--ECONOMIC EVALUATION

By D. A. Kramer[1]

CAPITAL COSTS

The capital cost estimate is of the general type called a study estimate by Weaver and Bauman.[2] This type of eestimate, prepared from a flowsheet and minimum of equipment data, can be expected to be within 30 pct of the costs for the processing plants previously described.

Estimated capital costs on a first quarter 1982 basis (Marshall and Swift (M and S) index of 739.0) for plants processing 10,000 ton/d of carnallite ore are $66,317,500 and $62,166,900 for insoluble-slimes flotation and direct flotation, respectively, as shown in tables A-1 and A-2. The plants are designed to operate 3 shifts per day, 7 d/wk, 350 d/yr, except for some of the reagent preparation facilities which operate 1 shift per day, 7 d/wk. The remainder of the time is for scheduled and unscheduled downtime.

Equipment costs used in this estimate are based on informal cost quotations from equipment manufacturers and on capacity-cost data. In developing the plant capital costs, corrosion-resistant materials of construction are used where appropriate. The tanks and flotation

[1]Chemist, Avondale Research Center, Bureau of Mines, Avondale, MD.

[2]Weaver, J. B., and H. C. Bauman. Cost and Profitability Estimation. Sec. 25 Perry's Chemical Engineers' Handbook, ed. by R. H. Perry and C. H. Chilton. McGraw-Hill, 5th ed., 1973, p. 46.

TABLE A-1. - Estimated capital cost,[1] insoluble-slimes flotation

Fixed capital:	
Ore preparation section	$7,156,400
Insoluble-slimes flotation section	2,216,300
Potash flotation section	3,152,800
Concentrate debrining and drying section	6,584,200
Tailings debrining section	13,814,400
Waste pond	3,418,800
Subtotal	36,342,900
Plant facilities, 10 pct of the above subtotal	3,634,300
Plant utilities, 12 pct of the above subtotal	4,361,100
Basic plant cost	44,338,300
Escalation costs during construction	6,087,500
Total plant cost	50,425,800
Land cost	0
Subtotal	50,425,800
Interest during construction period	7,832,900
Fixed capital cost	58,258,700
Working capital:	
Raw material and supplies	1,256,400
Product and in-process inventory	2,217,500
Accounts receivable	2,217,500
Available cash	1,784,800
Working capital cost	7,476,200
Capitalized startup costs	582,600
Subtotal	8,058,800
Total capital cost	66,317,500

[1]Basis: M and S equipment cost index = 739.0.

TABLE A-2. - Estimated capital cost,[1] direct flotation

Fixed capital:	
Ore preparation section	$7,156,400
Potash flotation section	3,362,600
Concentrate debrining and drying section	6,432,000
Tailings debrining section	13,626,600
Waste pond	3,511,300
Subtotal	34,088,900
Plant facilities, 10 pct of above subtotal	3,408,900
Plant utilities, 12 pct of above subtotal	4,090,700
Basic plant cost	41,588,500
Escalation costs during construction	5,709,500
Total plant cost	47,298,000
Land cost	0
Subtotal	47,298,000
Interest during construction period	7,347,000
Fixed capital cost	54,645,000
Working capital:	
Raw material and supplies	1,178,900
Product and in-process inventory	2,067,400
Accounts receivable	2,067,400
Available cash	1,661,800
Working capital cost	6,975,500
Capitalized startup costs	546,400
Subtotal	7,521,900
Total capital cost	62,166,900

[1]Basis: M and S equipment cost index = 739.0.

cells are constructed of mild steel, but the rod mill is rubber lined to withstand corrosive properties of the chloride brine.

Working capital is defined as the funds in addition to fixed capital, land investment, and startup costs that must be provided to operate the plant. Working capital is estimated from the following items: (1) raw material and supplies inventory (cost of raw material and operating supplies for 30 days), (2) product and in-process inventory (total operating cost for 30 days), (3) accounts receivable (total operating costs for 30 days), and (4) available cash (direct expenses for 30 days).

Startup costs are estimated as 10 pct of the fixed capital costs, of which 1 pct is shown in tables A-1 and A-2. The remaining 9 pct are assumed to be first year operating costs; however, they are not shown in the operating cost table. These startup costs are used in calculating the required return on investment. Land investment is not included in this estimate.

OPERATING COSTS

The estimated operating costs are based on an average of 350 d/yr of operation over the life of the plant. The operating costs are divided into direct, indirect, and fixed costs.

Direct costs include raw materials, utilities, direct labor, plant maintenance, payroll overhead, and operating supplies. Raw materials and utility costs are shown tables A-3 and A-4. The direct labor cost is estimated on the

TABLE A-3. - Estimated annual operating cost, insoluble-slimes flotation

	Annual cost	Cost per ton muriate of potash[1]
Direct cost:		
Raw materials:		
Carnallite ore at $3.00/ton	$10,500,000	$19.71
Armeen TD at $1.03/lb	540,700	1.02
Barrett's oil at $0.24/lb	126,000	.24
Sipex EC111 at $0.48/lb	10,100	.02
Hydrochloric acid, 18° Bé, at $0.02/lb	30,000	.06
Superfloc 127 at $1.81/lb	316,800	.59
Aeropromoter 870 at $1.91/lb	1,337,000	2.51
MRL 201 at $0.50/lb	1,750,000	3.29
Replacement rods for grinding at $0.23/lb	230,900	.43
Subtotal	14,841,500	27.87
Utilities:		
Electric power at $0.060/kW•h	1,520,200	2.85
Process water at $0.25/Mgal	56,200	.11
Natural gas at $3.06/MMBtu	670,400	1.26
Subtotal	2,246,800	4.22
Direct labor:		
Labor at $8.50/h	990,100	1.86
Supervision, 15 pct of labor	148,500	.28
Subtotal	1,138,600	2.14
Plant maintenance:		
Labor	957,800	1.80
Supervision, 20 pct of maintenance labor	191,600	.36
Materials	957,800	1.80
Subtotal	2,107,200	3.96
Payroll overhead, 35 pct of above payroll	800,800	1.50
Operating supplies, 20 pct of plant maintenance	421,400	.79
Total direct cost	21,556,300	40.48
Indirect cost, 40 pct of direct labor and maintenance	1,298,300	2.44
Fixed cost:		
Taxes, 1.0 pct of total plant cost	479,900	.90
Insurance, 1.0 pct of total plant cost	479,900	.90
Depreciation, 20-yr life	2,772,300	5.20
Total operating cost	26,586,700	49.92

[1]This product is a concentrate containing potassium equivalent to 59 pct K_2O.

basis of assigning 4.2 employees for each position that operates 24 h/d, 7 d/wk, and 1.4 employees for each position that operates 8 h/d, 7 d/wk.

Payroll overhead includes vacation, sick leave, social security, and fringe benefits.

Indirect costs include the expenses of control laboratories, accounting, plant protection and safety, plant administration, marketing, and company overhead. Research and overall company administrative costs outside the plant are not included.

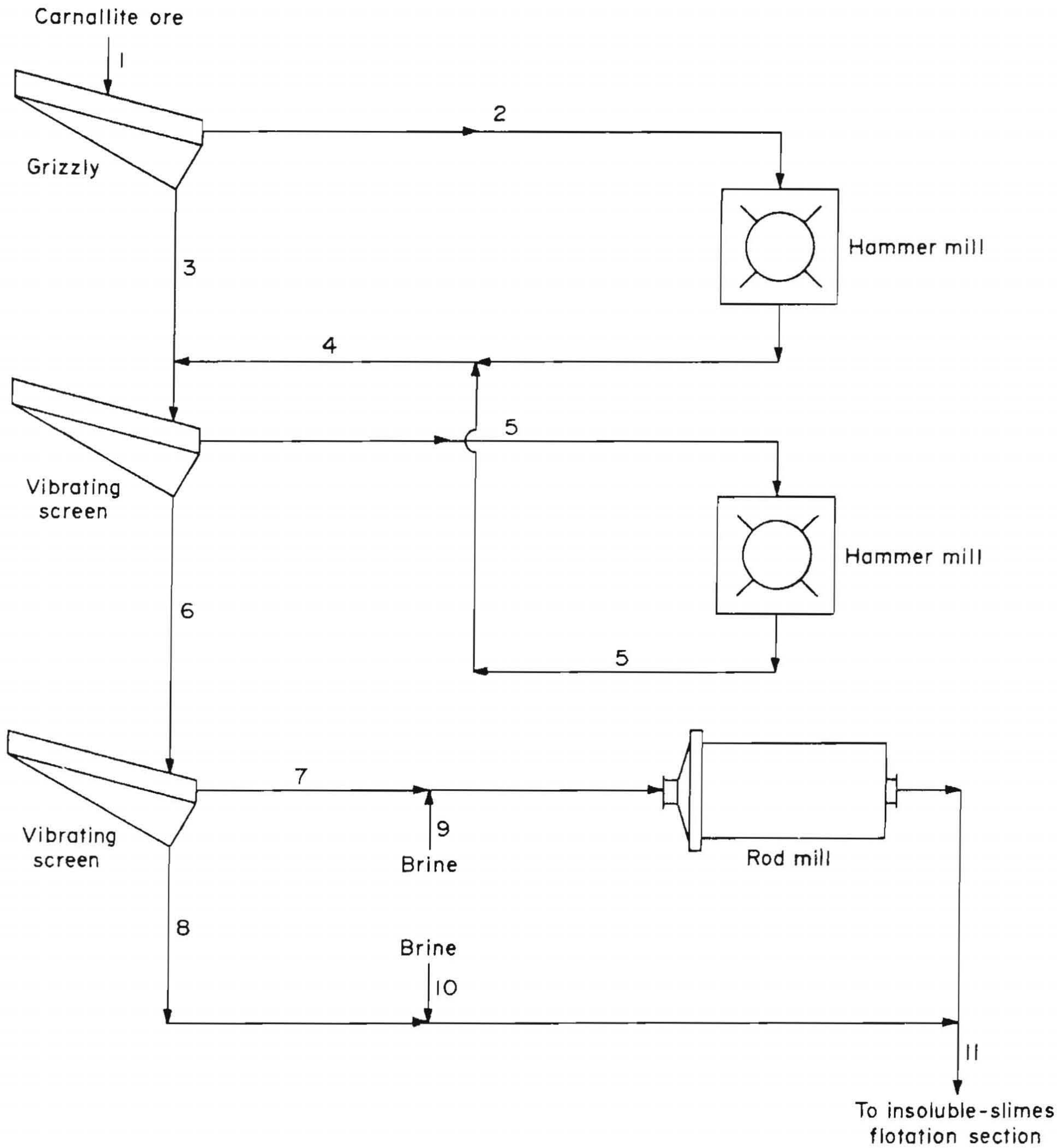
Fixed costs include the cost of taxes (excluding income taxes), insurance, and depreciation. Depreciation is based on a straight-line, 20-yr period.

TABLE A-4. - Estimated annual operating cost, direct flotation

	Annual cost	Cost per ton muriate of potash[1]
Direct cost:		
Raw materials:		
Carnallite ore at $3.00/ton	$10,500,000	$19.96
Armeen TD at $1.03/lb	721,000	1.37
Barrett's oil at $0.24/lb	168,000	.32
Sipex EC111 at $0.48/lb	10,100	.02
Hydrochloric acid, 18° Bé at $0.02/lb	40,000	.08
Superfloc 127 at $1.81/lb	506,800	.96
MRL 201 at $0.50/lb	1,750,000	3.33
Replacement rods for grinding at $0.23/lb	230,900	.44
Subtotal	13,926,800	26.48
Utilities:		
Electric power at $.060/kW·h	1,248,700	2.37
Process water at $0.25/Mgal	56,500	.11
Natural gas at $3.06/MMBtu	660,800	1.26
Subtotal	1,966,000	3.74
Direct labor:		
Labor at $8.50/h	919,400	1.75
Supervision, 15 pct of labor	137,900	.26
Subtotal	1,057,300	2.01
Plant maintenance:		
Labor	920,900	1.75
Supervision, 20 pct of maintenance labor	184,200	.35
Materials	920,900	1.75
Subtotal	2,026,000	3.85
Payroll overhead, 35 pct of above payroll	756,800	1.44
Operating supplies, 20 pct of plant maintenance	405,200	.77
Total direct cost	20,138,100	38.29
Indirect cost, 40 pct of direct labor and maintenance	1,233,300	2.34
Fixed cost:		
Taxes, 1.0 pct of total plant cost	461,300	.88
Insurance, 1.0 pct of total plant cost	461,300	.88
Depreciation, 20-yr life	2,664,700	5.07
Total operating cost	24,958,700	47.46

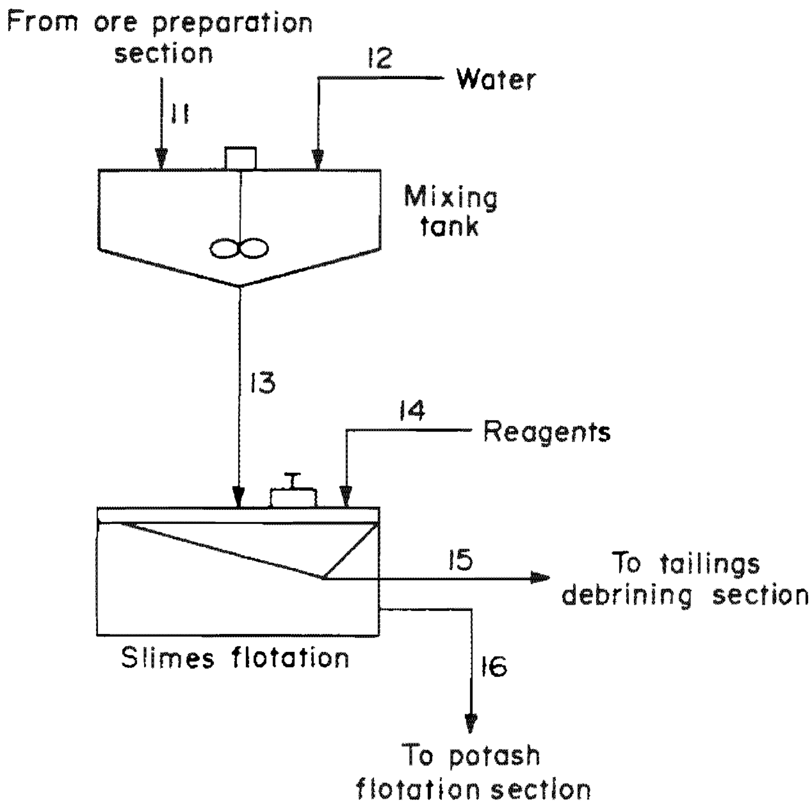
[1]This product is a concentrate containing potassium equivalent to 61 pct K_2O.

The estimated annual operating costs for a plant processing 10,000 ton/d of carnallite ore are $26,586,700 for the insoluble-slimes flotation circuit and $24,958,700 for the direct flotation circuit, as shown in tables A-3 and A-4. For the insoluble-slimes flotation circuit which produces a product of approximately 59 pct K_2O, this corresponds to $49.92 per ton of product, or $0.85 per unit of K_2O. The direct flotation circuit produces a product of approximately 61 pct K_2O, and the above operating cost corresponds to $47.46 per ton of product, or $0.78 per unit of K_2O. (One unit is equivalent to 1/100 of a ton, or 20 lb.)



Stream	1	2	3	4	5	6	7	8	9	10	11
Solids, ton/d	10,000	6,300	3,700	8,300	2,000	10,000	2,340	7,660	0	0	10,000
Brine, ton/d	0	0	0	0	0	0	0	0	2,340	18,764	21,104
Total	10,000	6,300	3,700	8,300	2,000	10,000	2,340	7,660	2,340	18,764	31,104

FIGURE A-1. - Insoluble-slimes flotation: Ore preparation section.

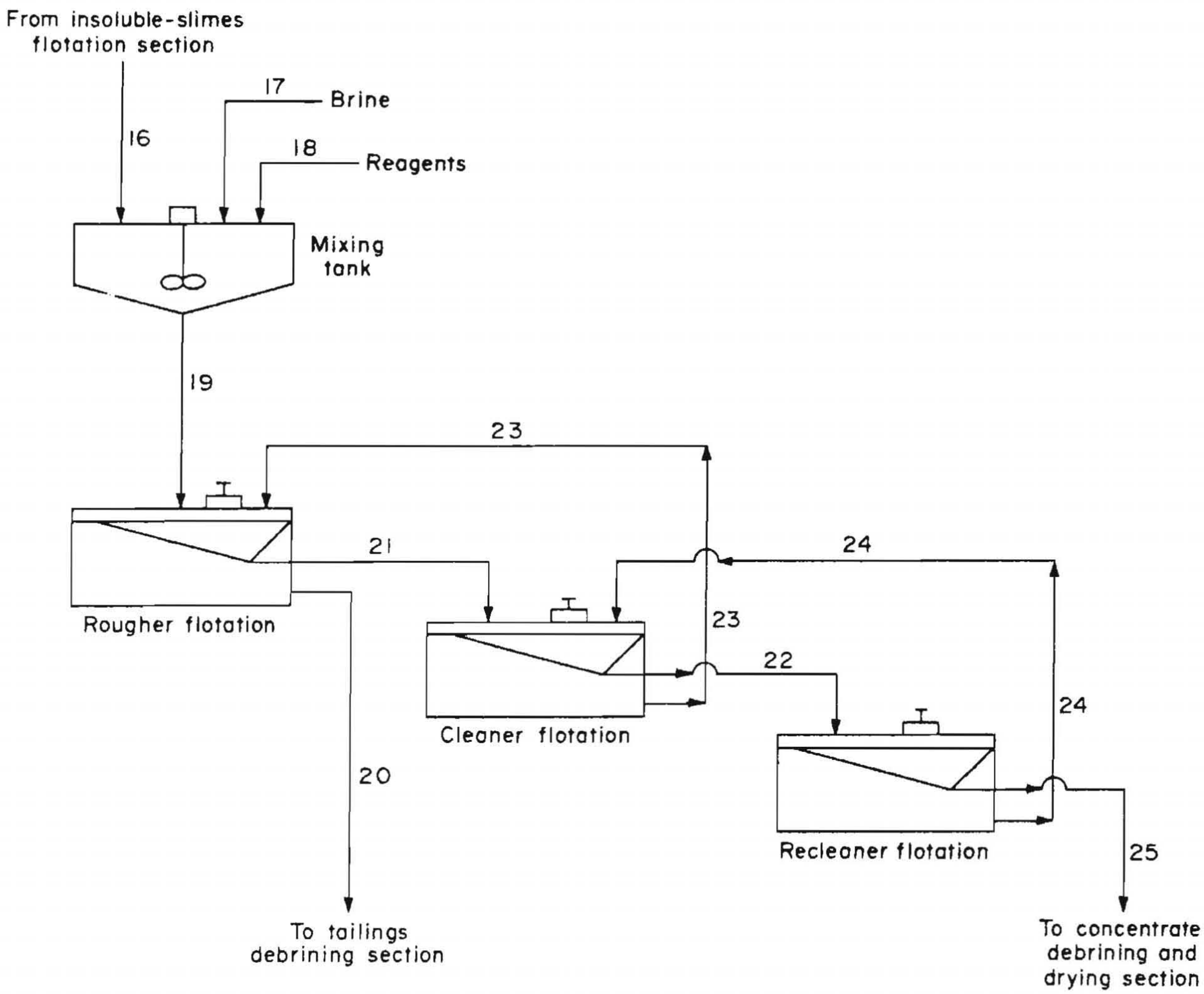


Stream	11	12	13	14	15	16
Solids, ton/d:						
Potassium ...	1,060	0	965	0	121	844
Sodium	2,240	0	1,882	0	311	1,571
Water-insolubles .	350	0	350	0	278	72
Other[1]	6,350	0	5,079	0	512	4,567
Brine, ton/d:						
K^+	967	0	1,062	0	695	367
Na^+	1,144	0	1,502	0	982	520
Other[2]	18,993	2,000	22,264	0	14,558	7,706
Total	31,104	2,000	33,104	0	17,457	15,647
Reagents, lb/d:						
Superfloc 127	0	0	0	500	0	0
Aeropromoter 870	0	0	0	2,000	0	0

[1]Calcium, magnesium, sulfate, and chloride.

[2]Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-2. - Insoluble-slimes flotation: Flotation section.

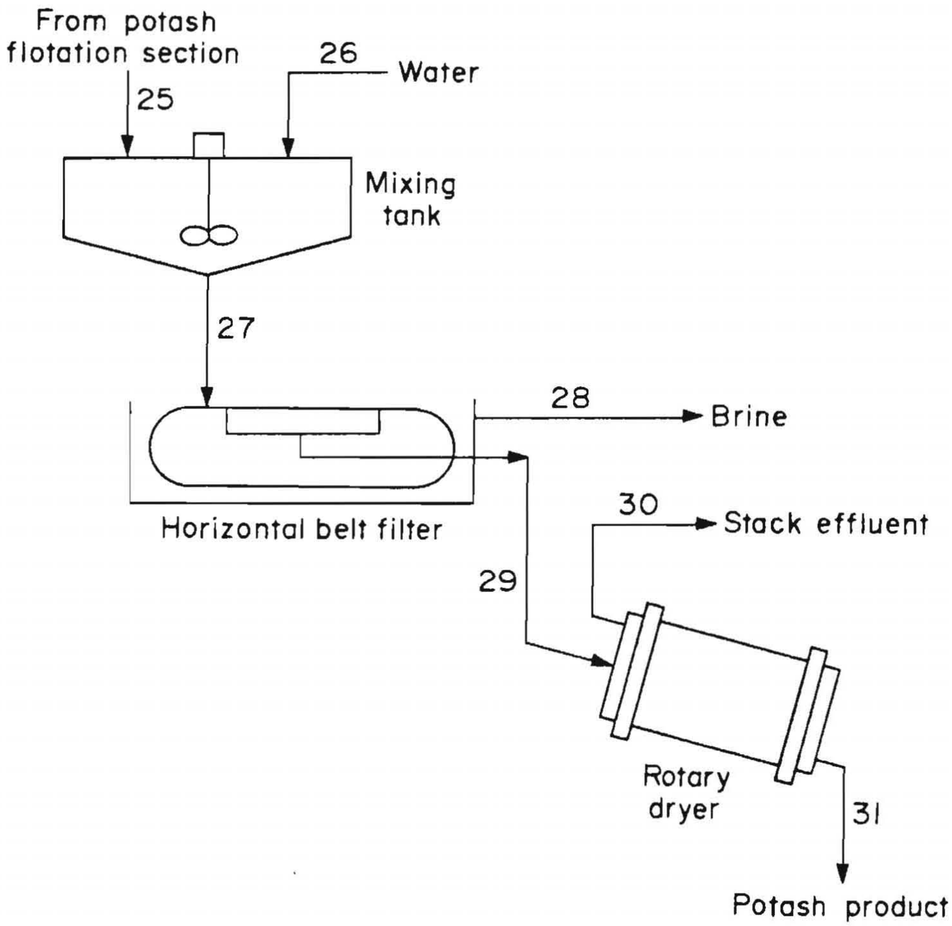


Stream	16	17	18	19	20	21	22	23	24	25
Solids, ton/d:										
Potassium ...	844	0	0	844	56	823	801	35	13	788
Sodium	1,571	0	0	1,571	1,454	141	127	24	10	117
Water-										
insolubles .	72	0	0	72	29	62	49	19	6	43
Other[1]	4,567	0	0	4,567	3,876	820	730	129	39	691
Brine, ton/d:										
K^+	367	538	0	905	763	237	178	95	36	142
Na^+	520	760	0	1,280	1,079	335	252	134	51	201
Other[2]	7,706	11,271	0	18,977	15,992	4,966	3,749	1,981	764	2,985
Total	15,647	12,569	0	28,216	23,249	7,384	5,886	2,417	919	4,967
Reagents, lb/d:										
Amine, EC111,										
Barrett's oil	0	0	3,060	0	0	0	0	0	0	0
MRL 201	0	0	10,000	0	0	0	0	0	0	0

[1] Calcium, magnesium, sulfate, and chloride.

[2] Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-3. - Insoluble-slimes flotation: Potash flotation section.

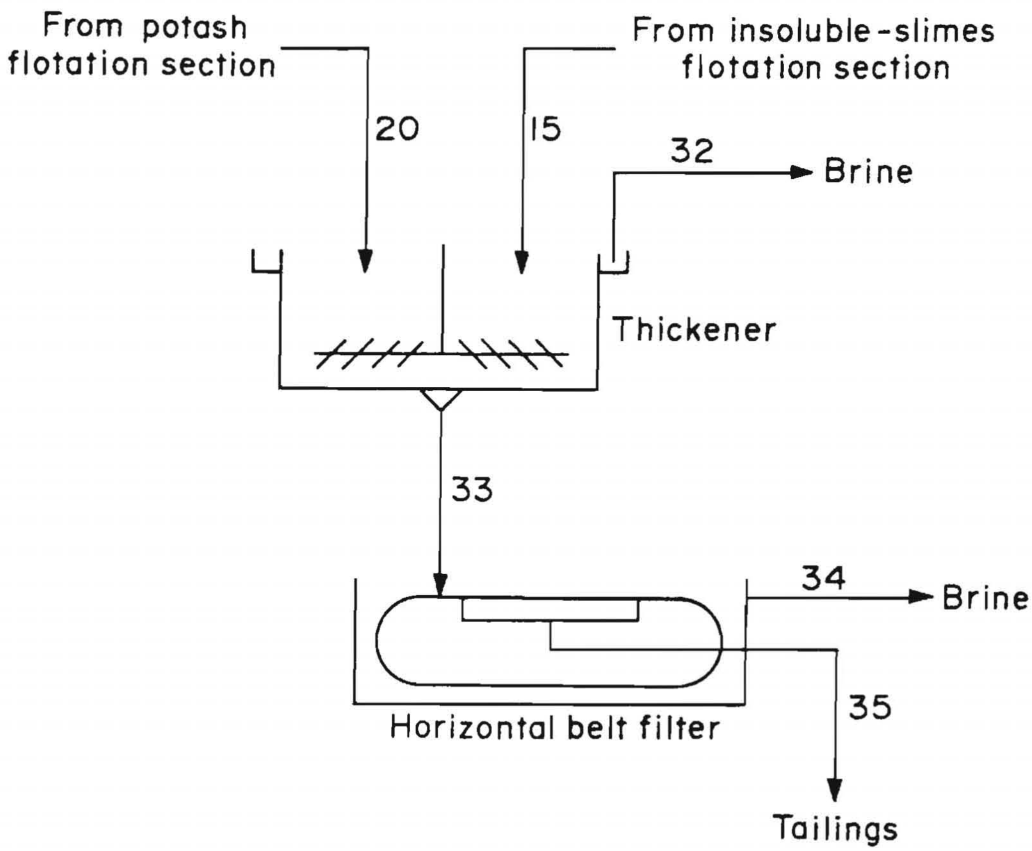


Stream	25	26	27	28	29	30	31
Solids, ton/d:							
Potassium ...	788	0	784	0	784	38	746
Sodium	117	0	12	0	12	0	12
Water-insolubles .	43	0	43	0	43	0	43
Other[1]	691	0	763	0	763	42	721
Brine, ton/d:							
K^+	142	0	146	139	7	0	0
Na^+	201	0	306	292	14	0	0
Other[2]	2,985	410	3,323	3,166	157	178	0
Total	4,967	410	5,377	3,597	1,780	258	1,522

[1] Calcium, magnesium, sulfate, and chloride.

[2] Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-4. - Insoluble-slimes flotation: Concentrate debrining and drying section.

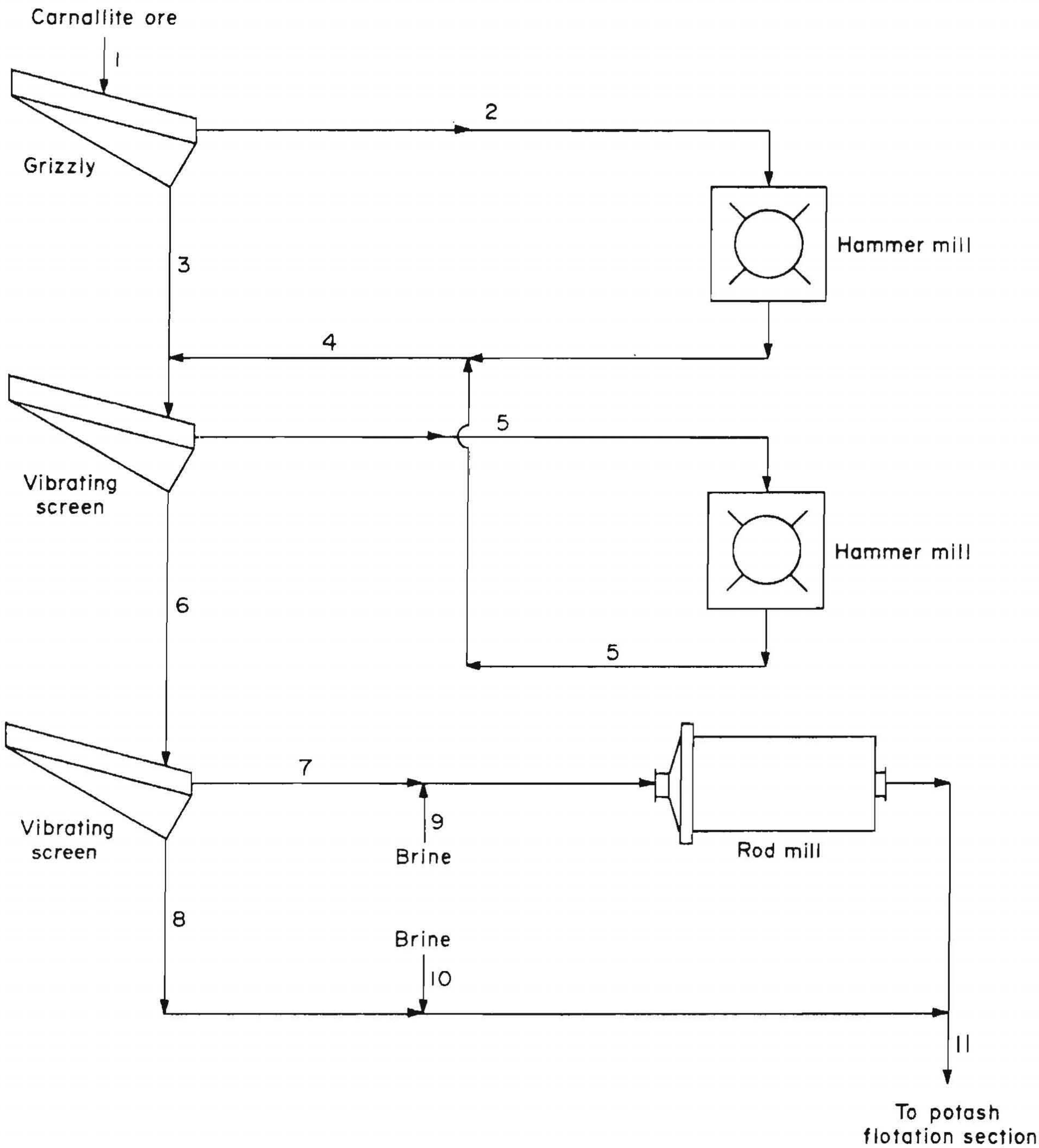


Stream	15	20	32	33	34	35
Solids, ton/d:						
Potassium ...	121	56	0	177	0	177
Sodium	311	1,454	0	1,765	0	1,765
Water-insolubles .	278	29	0	307	0	307
Other[1]	512	3,876	0	4,388	0	4,388
Brine, ton/d:						
K^+	695	763	1,049	409	263	146
Na^+	982	1,079	1,483	578	371	207
Other[2]	14,558	15,992	21,986	8,564	5,498	3,066
Total	17,457	23,249	24,518	16,188	6,132	10,056

[1]Calcium, magnesium, sulfate, and chloride.

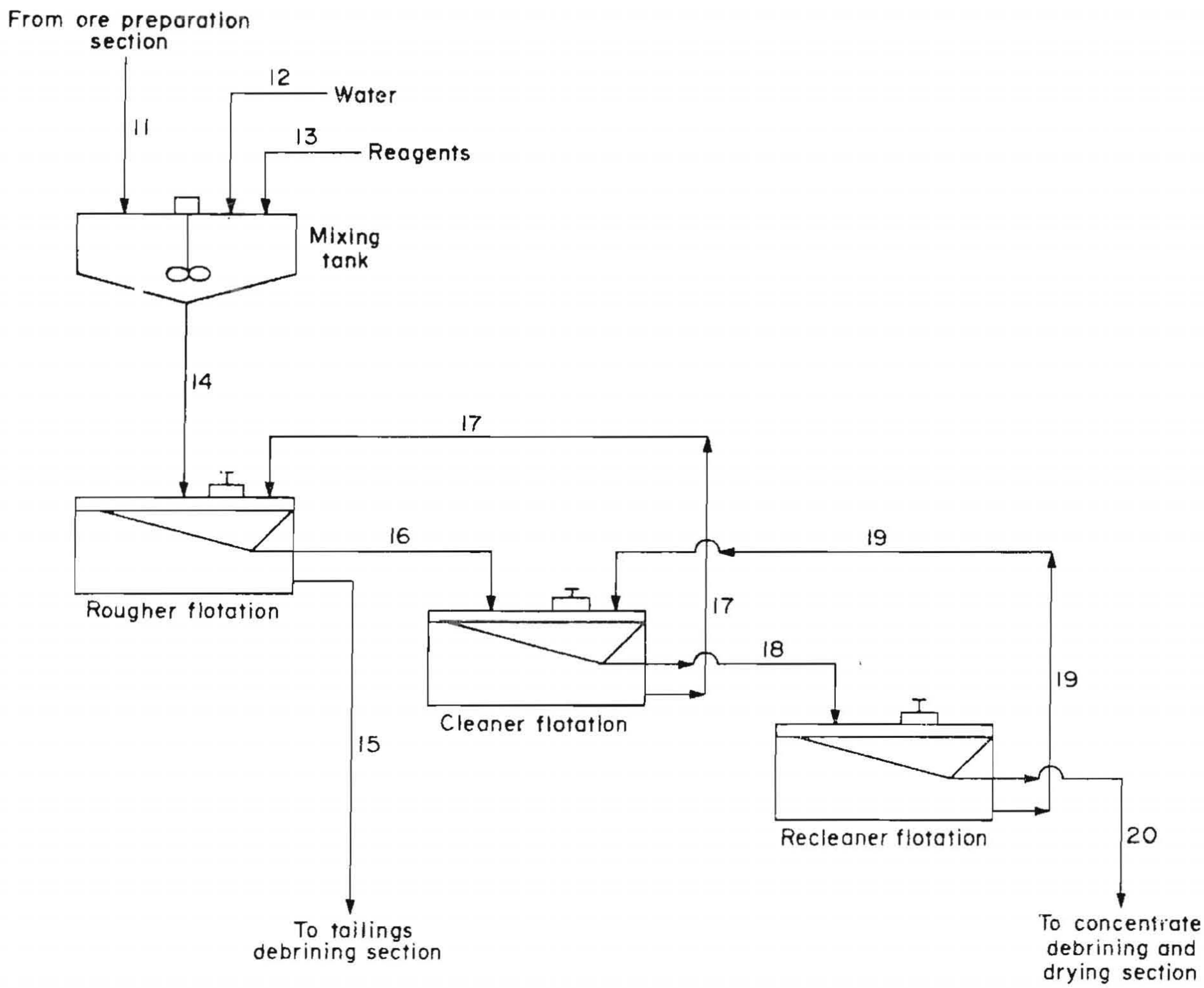
[2]Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-5. - Insoluble-slimes flotation: Tailings debrining section.



Stream	1	2	3	4	5	6	7	8	9	10	11
Solids, ton/d	10,000	6,300	3,700	8,300	2,000	10,000	2,340	7,660	0	0	10,000
Brine, ton/d	0	0	0	0	0	0	0	0	2,340	18,764	21,104
Total	10,000	6,300	3,700	8,300	2,000	10,000	2,340	7,660	2,340	18,764	31,104

FIGURE A-6. - Direct flotation: Ore preparation section.

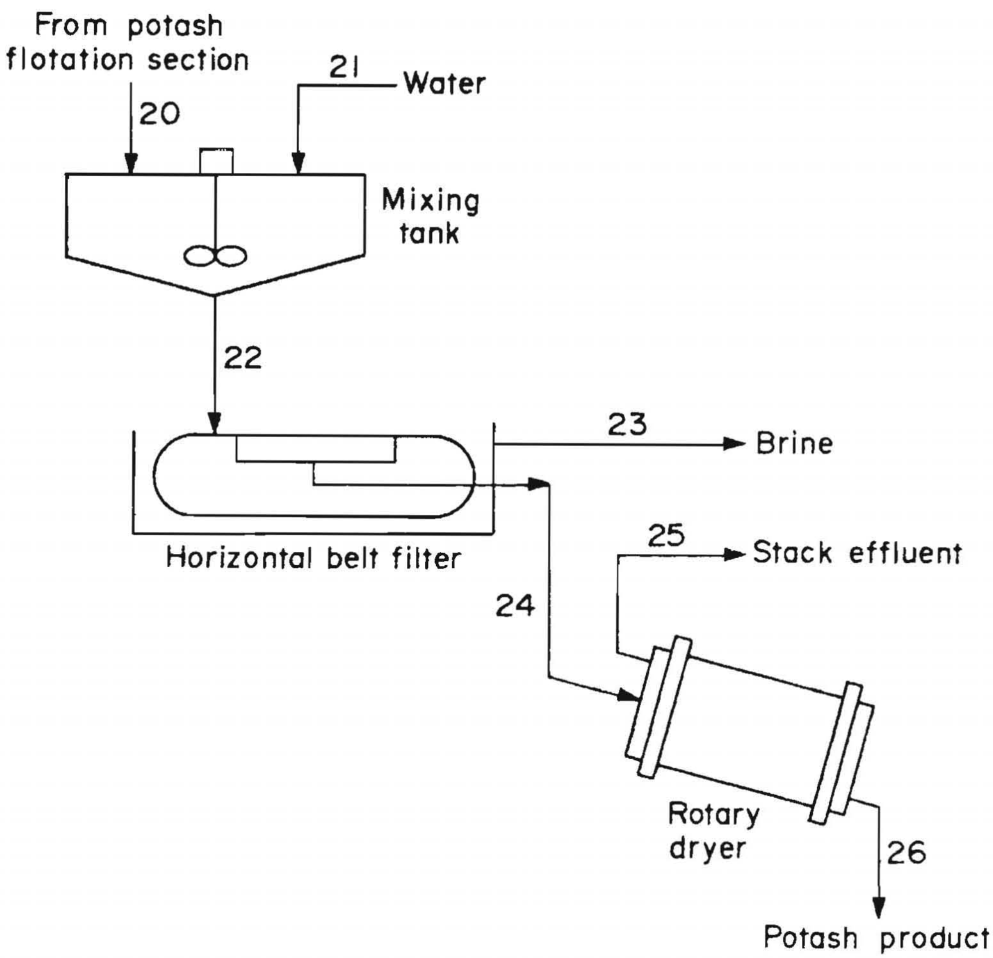


Stream	11	12	13	14	15	16	17	18	19	20
Solids, ton/d:										
Potassium	1,060	0	0	965	160	845	40	827	22	805
Sodium	2,240	0	0	1,882	1,716	204	38	182	16	166
Water-insolubles ...	350	0	0	350	290	127	67	92	32	60
Other[1]	6,350	0	0	5,079	4,334	902	157	786	41	745
Brine, ton/d:										
K^+	967	0	0	1,062	897	227	62	227	62	165
Na^+	1,144	0	0	1,502	1,268	320	86	321	87	234
Other[2]	18,993	2,000	0	22,264	18,797	4,749	1,282	4,756	1,289	3,467
Total	31,104	2,000	0	33,104	27,462	7,374	1,732	7,191	1,549	5,642
Reagents, lb/d:										
Amine-Barrett's oil	0	0	4,000	0	0	0	0	0	0	0
Superfloc 127 .	0	0	800	0	0	0	0	0	0	0
MRL 201	0	0	10,000	0	0	0	0	0	0	0

[1] Calcium, magnesium, sulfate, and chloride.

[2] Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-7. - Direct flotation: Potash flotation section.

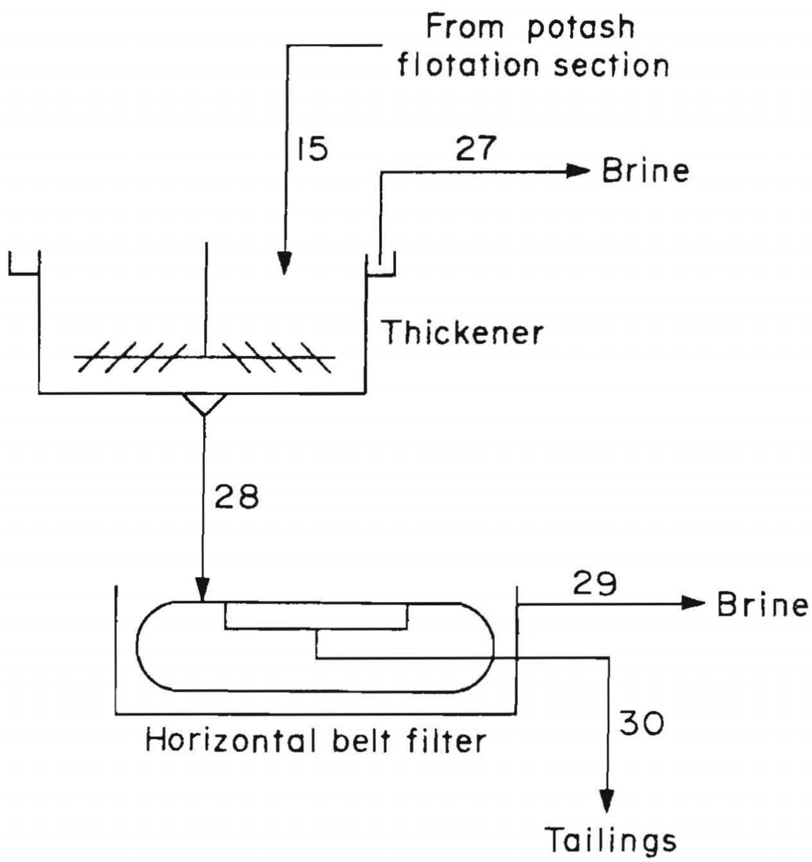


Stream	20	21	22	23	24	25	26
Solids, ton/d:							
Potassium ...	805	0	800	0	800	40	760
Sodium	165	0	5	0	5	0	5
Water-							
insolubles ..	60	0	60	0	60	0	60
Other[1]	745	0	734	0	734	37	697
Brine, ton/d:							
K^+	165	0	170	163	7	0	0
Na^+	234	0	395	383	12	0	0
Other[2]	3,467	414	3,892	3,735	157	176	0
Total	5,642	414	6,056	4,281	1,775	253	1,522

[1]Calcium, magnesium, sulfate, and chloride.

[2]Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-8. - Direct flotation: Concentrate debrining and drying section.



Stream	15	27	28	29	30
Solids, ton/d:					
Potassium ...	160	0	160	0	160
Sodium	1,716	0	1,716	0	1,716
Water-insolubles ..	290	0	290	0	290
Other[1]	4,334	0	4,334	0	4,334
Brine, ton/d:					
K^+	897	590	307	217	90
Na^+	1,268	834	434	307	127
Other[2]	18,797	12,368	6,429	4,556	1,873
Total	27,462	13,792	13,670	5,080	8,590

[1]Calcium, magnesium, sulfate, and chloride.

[2]Includes water, chloride ion, and minor quantities of other dissolved salts such as magnesium and sulfate.

FIGURE A-9. - Direct flotation: Tailings debrining section.

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