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G.M. RAO *,
N.N. SUBRAHMANYAN **

BENEFICIATION OF TUNGSTEN ORES IN INDIA — PROBLEMS, PROCESSES, APPLICATIONS, AND DEMANDS IN GENERAL ON A GLOBAL SCENE

For decades, the use of gravity separation technology has been much neglected to the advancements and interest shown in flotation. More recently, a greater interest in gravity separation has come up to improve the economies of low grade treatment with the aid of the preconcentration technology. Tungsten occurances in India, with the processing applications used, are briefly indicated. Worldwide processing plants with their adopted technology and problems in processing are summarised. A concise account of processes available and the latest developments in tungsten ore beneficiation is also presented. A salient note on the results obtained at the laboratory stage of investigations in the Indian Bureau of Mines, Ajmer is also given. It is widely known fact that the recovery of slimy tungsten is not effective by gravity methods and the necessary parameters for flotation of tungsten ores, especially wolframite, has yet to be established at a bench scale commercialisation would come at a later date.

Introduction

The world is not running out of mineral resources, but out of the mineral technology needed for their profitable production and processing. Processing new kinds of ores and low grade ores will require new and superior technology and the need is increasing day by day. The mineral processing engineer must devise new processes and improve the older ones to meet present-day demands.

Tungsten is a hard, heavy, durable and heat-resistant metal with the highest malting point among the metallic elements. It is commonly

*Superintending Officer(Ore Dressing), Indian Bureau of Mines, Ajmer, INDIA.
**Director, Ore Dressing, Indian Bureau of Mines, Nagpur, INDIA.

used for lamp filaments and electrical contacts. Its primary use is in tungsten carbide for tools and as an alloying element for tool and high temperature steels, including bits, construction and mining equipment, turbines and structural material in nuclear and space technology.

Tungsten is one of the important strategic minerals of India. Degana is the only producing mine in the country. The tenor of the Indian ores is much less than the discards of milling plants in other countries. The deposits are small and the complex nature of the ores demands complicated process technologies.

The world tungsten resources are assessed to be about 12 million tons, of which 60% is accounted for by China and the USSR. One third of the production of tungsten concentrate is also accounted for by China. India produces about 50 tons of tungsten concentrate per annum, which is hardly 4% to 5% of the country's requirement. The present requirement is on the order of 10.00 to 12.00 TPY.

Indian scenario deposits and processing

A. Reserves

India's reserves of tungsten are 1.24 million tons of ores, assaying over 0.1% WO_3. About 44 million tons of leaner ors in the assay ranges of 0.01 to 0.08% WO_3 are also available.

B. Occurances are reported from the following areas

1. Rajasthan State
   a. Degana, Nagaur District,
   b. Balda, Sirohi District,
   c. Dewa-ka-Bera, Sirohi District,
2. Maharastra State
   a. Agargaon, Nagpur District,
   b. Kuhiana.
3. West Bengal State
   a. Chendapathar, Bankura District,
   b. Minor occurances in Darjeeling District and Purilia District are also reported.
4. Karnataka and Andhra Pradesh States
   a. Kolar and Hutti Gold Fields: Scheelite is associated with gold mineralisation. The old tailing dumps of Kolar are now being worked for recovery of tungsten values (Walker dump and Balaghat dump). Scheelite content waries from 0.01% to 0.53% WO_3.

b. Tungsten occurances are cited in Khondo-lites of Burugugunda ares in Andhra Pradesh State.

5. Other Areas: Occurances of tungsten have been reported from Umphyrtha in Meghalaya, Kalimata Gaya in Bihar State, Jhu in Gujarat State and Dudatoli area of Almora and Chamoli Distrcts in U.P. State.

C. Production

The major production of tungsten has been from Rajasthan, West Bengal and Karnataka, of the order of 45 to 45 tons of concentrate.

D. Process programme

a. The Rajasthan State Tungsten Development Corporation is planning to have a concentrator of 100 TPD with gravity, flotation and magnetic separation processes. The Atomic Minerals Division is installing a 20 TPD Gravity Concentrator at Degana.

b. Scheelite from old dumps: The Walker dumps amounting to 1.7 lac tons at 0.18% WO_3, and Balaghat dumps with 8.1 lac tons at 0.04% WO_3 are processed for the recovery of scheelite. The amenabilty of these dumps has been tested by IBM, and IBM has set up a Pilot Plant on site to produce scheelite concentrate. It has been ascertained that tabling, flotation and magnetic separation processes combine to yield a concentrate of 65.0% WO_3 from a feed of 0.2% WO_3.

c. Hutti Gold Mines: The Hutti Gold Mine Company is conducting beneficiation tests on the mined ore of scheelite. Lurgi Chemie, Frankfurt, is helping them with a process of direct flotation.

World scene

Production

The tungsten trioxide produced in 1983 was only 44.000 tons. China and the USSR together account for about 50% of the world production. Other major producing countries include Australia, North Korea, Bolivia, Canada, Portugal, South Korea, Brazil and the USA. Most of the tungsten mines treat ore containing less than 1.0% but above 0.3% WO_3. China possesses about 47.0% of the world resources in tungsten.

Processing of tungsten ores

General: The important processes adopted for tungsten ore are gravity separation, where lighter gangue is discarded; magnetic separation, in which iron and iron bearing minerals are removed; flotation, in which the sulphide minerals are removed; and, finally electrostatic separation, in which less conducting minerals are removed to yield a richer concentrate of tungsten mineral.

New equipents has appeared on the scene for pre-concentration and fine particle treatment. The preconcentration equipment includes sorters, heavy media separators and spirals. The fine particle treatment is done with Reichert Cones, Bartles Mozley Tables and Sluices.

The adoption of modern technology in tungsten processing plants in the world is indicated below:

1. Mount Carbine Mina - Sorters
2. Kingisland Scheelite - Sorters
3. Panasquiere, Portugal - Heavy Media Cyclones and Bartles-Mozley Separators
4. Hemerdon, U.K. - Dynamic Heavy Media Separator
5. Climex Molybdenum, USA - Reichert Cones
6. Chojilla, Bolivia - Bartles-Mozley Separator
7. Tajishan Deposit, China - Rocking Shaking Vanners
8. Canada Tungsten, Canada - Flotation of Scheelite
9. Yxsjoberg, Sweden - Flotation of Scheelite
10. China Mount Pleasant, Canada - Flotation of Wolframite
11. Sec. Minera Puquio Cocha, South Africa - Table, Flotation and Magnetic Separation.

The metallurgical results of worldwide processing plants with the processes adopted are given in Table No. 1.

Table 1

Tungsten Processing Plants in the world and their technology

Sl. No.	Mill	Capacity	Feed	Ore type	Process adopted	Results obtain Grade	Results obtain Rec.
1.	Enramada, Bolivia	600 TPD	0.5		HMS, Jigging, Tabling, Cross Selt Mozley Separator	68.0	
2.	Mount Pleasan Mines, New Brune Wick, Canada	6.5 lacs TPY	0.4	Quartz Vein	Flotation, Conc. leached with H_2SO_4		
3.	Canada Tungsten Mining, Canada				Gravity, Flotation, leaching of concentrate	65.0	
4.	Climax Moybdenum, USA	45000 TPD		Moly tails	Spirals, Flotation, Spiral & Table, Meg. Sep., Flotation		30.0
5.	Panasquiere Portugal			Quartz lode	HMS, Table, Mag. Sep., Tables, Bartles Mozley Separator	75.0	70.0
6.	Mount Carbine, Queensland Australia		0.09	Schist, Quartz reef	a. Sorting, Jigging, Tabling b. Spiral, Jigging, Tabling, Flotation, Mag. Sep., ESS	70.0	
7.	Scheelite, Kingisland	4.0 lacs TPY	0.80		a. Spiral, Tabling, Retabling, Flotation, Magnetic Sep. b. Fines, Flotation c. Roast, Magnetic Sep. d. -75 micron, Flotation, Artificial Scheelite		
8.	Yxsjoberg, Sweden	2.0 lacs TPY	0.32	Skarn	Flotation	75.0	89.00
9.	Hemerden, UK		0.17	Granite	HMS(DWP), Jip, Tails and orginal fines, Table		
10.	Miltersill, Austria	3.0 lacs TPY	0.4 to 0.8	Amphibolic Quartz	Flotation	30.0 65.0	95.00 -
11.	Sang Dong, South Korea	7.5 lacs TPY	0.5 to 0.61	Quartz	Flotation of sulphides, Tails, Scheelite, Flotation, Table, HCL, Re-Flotation		
12.	Tajishan Deposit, China		0.25	Quartz vein	Sorting, Jigging & Tabling, Flotation leaching	70.0	86.00
13.	Xihashan, China	3000 TPD		Quartz vein	Sorting, Jigging & Tabling, Flotation, Mag. Sep., ESS	70.0	86.00
14.	Dangdong Baoshan, Mill (Skarn)		0.5	Skarn	Bulk Sulphide Tails, Scheelite, Flotation	66.0	80.00
15.	Soc. Minera Puquio Cocha, S.A.	15-20 TPH	0.18		Scrubbing, Mag. Sep., Tabling, Flotation, Magnetic Separation	70.0	-

A general list of milling plants for tungsten ores is as follows:

Tungsten milling plants of the world

Sl. No.	Country	Company	Process	Capacity TPD
1	2	3	4	5
1.	Australia	Pacific Copper Ltd Torrington operations	Sorting, Jig, Table	10000
2.	Australia	Peko Wallsend Operation Ltd, Kingisland scheelite	Table, Flotation	1150
3.	Austria	Wolfram Berbau and Hutten gesell shaft MBH	Flotation	1000
4.	Bolivia	Ambo Mining and Exploration Ltd	-	-
5.	Bolivia	Churquini Enerprises Inc. Chicole grand Mine	-	-
6.	Bolivia	Corporacion Minera De Bolivia Comibol Empress Mineral Unificada del Cerro de potosi	Flotation, Gravity, Magnetic	1210
7.	Bolivia	International Mining Company (IMCO) Chojilla Operations	Gravity, Flotation	1200
8.	Bolivia	Enarmada	HMS,Jig,Table	600
9.	Brázil	Mineraco Acquan Industrial & Comercio Barra Verde	-	600
10.	Brazil	Mineracc Tomaz Salustiño S.A. Brejui	Gravity, Mag. Sep.	-
11.	Burma	Myanma Tin and Tungsten Corpn. Hermyingyi Mine Yetanabon Mine	Mahnetic Separation	-
12.	Canada	Canada Tungsten Mining Corp. Ltd, Yukon & Nwterritionies	Gravity,	-
13.	Canada	Mount Pleasant Mine, New Bruswick	Flotation	
14.	China	Tajishan Deposit	Sorting,Jig,Table	650000 TPY

1	2	3	4	5
15.	China	Xihuashan	Gravity, Magnetic Separation	3000
16.	China	Dangdeng Baoshan Mill Skarn	Electrostatic Separation, Flotation	-
17.	England	South Crofty Ltd, South Crofty operations	Gravity	10000
18.	France	Societie Minera D' Anglade operations	-	-
19.	Japan	Nettesu Mining Co. Ldt, Kamaishi Mine	Flotation,Tabling	7000
20.	Korea	Korea Tungsten Mining Co. Ltd. Sangdongmine	Flotation,Gravity, Magnetic Sep.	260
21.	Korea	DK bang Mining Co.Ltd, By-duck Project, Ok bang	Gravity, Flotation	60
22.	Mexico	Negocia Ciones Mines de Navarro S.A. de C.V. Belfram	Gravity, Tabling	100
23.	Namibia	(South West Africa) Krantz berg Mining Co. Krantz berg Tungsten Mine	-	125 300
24.	Nevada	National Mining Ltd, Fallan operations	Gravity, Flotation	125
25.	Nevada	National Resources Development Inc. Nevada operations	-	125
26.	Nevada	Utah International Inc. Springer Mine	-	-
27.	Peru	CIA Mineral Tourmalina S.A. Tourmalina	Flotation	120
28.	Peru	Empressa Minera del Centro del peru S.A. Morococha Division, San Cristobol Division	-	1795
29.	Peru	Fermin Malaga Santolalla E. Hijos Pasto Bueno	Gravity, Flotation	600
30.	Peru	Sòc. Mineral Puquio Cocha S.A. Morococha Operations	Flotation	300

1	2	3	4	5
31.	Portugal	Beralt Tin & Wolfram (Portugal) SARL Panasqueira Mine	HMS, Gravity, Flotation	2400
32.	Portugal	Minas E. Metallurgia S.A.R.L. Plant.	-	-
33.	Sweden	A/B Statsgruvor Wigstrem Operations, Yxsjoberg Mine	Flotation	720
34.	Thailand	Laemnga Tin dreding	-	-
35.	Turkey	Etibank General Mudurlgu Volfram isletmesi MO	-	-
36.	USA	Climax Molybdenum Co. Div. AMAX Climax operations, Colorade	Gravity, Magnetic Separation, Flotation	45000
37.	USA	Holding Mine and Development Co. September Clamis California	-	-
38.	USA	Teledyne Tungsten, Straw berry Mine	-	-
39.	USA	Union Carbide Corpn. Metals Div.Bshop Plant	-	-
40.	UK	Hemerden	HMS, Jig	-
41.	Zaire	Kivumines, Bishasha Mine	Gravity	150

New projects planned for 1986

Sl. No.	Country	Location	Name of the Company
1.	Canada	MacTung, NWT	Amax
2.	Spains	Salamanca, Provinve	Promotora de Recursos/Shell
3.	India	Degana	Rajasthan State Tungsten Development Corpn. Ltd.
4.	Australia	Tasmania	McIntyre Mines
5.	Britain	Cornwall	SW Consolidated

Problems in processing

The major problems in processing are:

1. Tungsten ores are disseminated type and need fine grinding for complete liberation.
2. Since tungsten mineral are fragile, slime production is greater in comminution.
3. In gravity concentration, other associated heavy minerals such as garnet, topaz, iron oxides and sulphides, etc., join tungsten minerals and thus dilute the concentrate.
4. The presence of calcite is a problem in scheelite flotation.
5. When tungsten minerals are scheelite and wolframite, the concentration is a problem as different methods are required for these two minerals.
6. Recovery of the fine and slime tungsten is problematic.
7. An effective scheme for the flotation of wolframite has to be established.
8. In the casses of disseminated ores, the recoveries are far from satisfactory.
9. The removal of garnet and tourmaline from wolframite is not fully successful.
10. The recovery of wolframite values in the size ranges of 0-20 microns is poor by both the gravity and flotation methods.

Mineral processing technology has to change to keep up with challenges for cheaper processing methods, contend with environmental constraints and reduce energy requirements in order to economically treat the lower and poor graded disseminated ore types.

A small note on the processes available & their application

Ore beneficiation is traditionally defined as the physical treatment of mineral raw materials without altering their indentity in the course for their convertion to marketable products. Recent techological advances, the massive demand for effective treatment of new types of ores, increasingly rigorous requirements with regard to product standards, attempts to reduce production costs and improve process efficiencies, the problems of tackling low-grade ores in large masses or fine fractions, and, last but not least, environmental pressures have all extended activity in beneficiation to its physical, chemical and physico-chemical areas.

The available process are:

A1: Pre-concentration and sorting: Processing R.D.M. to eleminate unwanted minerals of coarser sizes leads to pronounced savings in cost, energy and man-power in the succeeding unit operations. This technigue will render the mining of low grade ores economical by rejecting the major waste at a much cheaper cost and processing the rest by more costly processes. Photomatric sorting and electronic sorting with the aid of various radiations like X-ray, gamma, flourescence, IR, etc., for the size ranges of 10 to 200 mm are being developed.

A2: Sluices

A3: (a) Heavy Media Separation
(b) Dyna Whirl Pool Process
(c) Tri-flo-Separator

B: Dry Separation Technology: The development of dry processing technology has not kept pace with that of wet processing, but some interest is being revived these days. The processes available are: Jigs, Tables, HMS, Magnetic & Electrostatic separators and Pinch Sluices.

C1: Gravity Unists:

(1) Jigs
(2) Tables
(3) HMS
(4) Denver Buckman Tilting Concentrator
(5) Rocking Shaking Vanner
(6) Nelson Concentrator
(7) Moving Belt Separator LBS
(8) The Bartles Cross Belt Concentrator

D1: Flotation and Shear Flocculation: To date the processing plants for tungsten are mostly gravity processes, except for the ones of Canada Tungsten Corporation in Canada, Yxsjoberg, Sweden and Miitersail of Aurstria. Lately, a lot for research is being carried out in the flotation of wolframite minerals, and several reagents are patented. For scheelite, the flotation process was established long ago, but new reagent development is still going on. Flotation has become relevant as the ores are of disseminated and very low grade, and no other processes can help is this state. The reagents so far sought for wolframite flotation ars acids of Arsonic, phosphonic, sulphosuccinamic and hydroxamic and their derivates.

D2: Shear Flocculation: This process is effective in recovering fine values in the size ranges of 1 to 40 microns by means of flocculation and flotation.

E1: Recovery of heavy minerals from fines and slimes: The processing of fine-grained ores frequently results in the production of ultrafine particles, which respond poorly to conventional physical separation techniques. The ultrafine particles, commonly called slimes, carry considerable mineral value, but are not revovered in processing by gravity methods.

One of the major problems in mineral processing is the recovery of values form slimes by gravity processes. Minerals as fine and slimes are lost on a gigantic scale; for example, one third of the phosphate mined in Florida, 1/2 of the tin mined in Bolivia and 1/5th of the tungsten mined in the world, as well as substantial amouts of tin in Thailand, Malaysia and other places. The various processes available are:

(a) Buddles,
(b) Strakes,
(c) Vanners,
(d) Sullivan deck,
(e) Round frames, and
(f) Slime Tables.

There has benn a singnificant development in the equipment designs for fine particle gravity concentration in the last two decades or so.

F1: Development of Gravity Equipments are:

(a) Denver Buckman Tilting Frame
(b) Shaken Helicoid
(c) Bartles Mozley Separators
(d) Bartles Cross Belt Separators
(e) Duplex Concentrator
(f) Slime Tables
(g) Rocking Shaking Vanner China
(h) Rotating Tube
(i) Nelson Separator
(j) Centrifugal Jig
(k) Centrifugal Separator: YX-800 China
(l) Circular Shaking Table
(m) IHC - Radial Jig
(n) American Balanced Jig
(o) Yuba Jig

Recently, interest has been shown by researchers to study the effect of the presence of electrolytes, pH and also viscocity on the performance of gravity equipment.

Incidental advances in related auxilliary processes for gravity separation, for examples, in instrumentation, classification, screening and pumping-will have an effect on the efficiency of the main processes.

A summation of the technology for processing tungsten ores with reference to developments is presented in Table No. 2.

Table No. 2

Processes available for concentration of tungsten ores

Sl. No.	Process	Size applicable
1	2	3
I.	Old Technology	
	a. Conventional Processes	
	1. Jigs	upto 10 mesh
	2. Tables	28 to 200 mesh
	3. HMS	5" to 10 mesh
	4. Spirals	20 to 200 mesh
	5. Flotation	35 to 400 mesh
	b. Pneumatic Concentration	
	1. Jigs	up-to 10 mesh
	2. Tables	28 to 200 mesh
	3. HMS	10 to 65 mesh
	4. Sluices	10 to 100 mesh
II.	New Technology	
	a. New Processes:	
	1. Bartles Mozley Concentrator	100 to 5 microns
	2. Pre-Conc & Sorting	10 mm to 20 mm
	3. HMS	upto 1/4"
	4. DWP	2" to 65 mesh
	5. Heavy Media Cyclones	upto 40 mesh
	6. Triflo Separator	
	7. Jigs	20 mesh
	8. IHC - Jigs	to still finer sizes
	9. Sluices	upto sand sizes
	10. Moving Belt Separator	Fine material -35 to 100 mesh
	11. Rotating Cone Concentration	20 to 200 mesh
	12. Denver Buckman Tiling Concentrator	upto 20 microns
	13. Rocking Shaking Vanner	minus 20 mesh
	14. Bartes Cross Belt Concentrator	5 to 150 microns
	15. Reichert Cones	100 to 30 microns
	16. Duplex Concentrator	upto 100 microns
	17. Yuba Richards Mineral Jig	1/2 to 200 mesh
	18. Flotation	upto 20 microns
	19. Shear Flocculation	40 to 1 micron

1	2	3
	20. Rotating Tube 21. Nelson Separator 22. Centrifugal Jig 23. American Balanced Jig b.* Advanced Technology for specific cases - Modyfied versions of earlier models: 1. Spirals 2. Tables 3. Jigs 4. HMS 5. Pre Concentration Technology 6. Flotation Reagents	
	*In mineral processing, most of the losses of minerals and metal values are in the fine size ranges, so considerable work has been done in recovering these values by modifying the earlier process models.	

The IBM Laboratory at Ajmer has carried out abount 20 investgation of tungsten ores, of which about 13 are from a single deposit.The salient data is presented in Table No. 3.

Table No. 3

Metallurgical Results(Tungsten Samples - Balda, Sirohi)

Sl. No.	Mineralogy			Orig. Assay %	Concentrate			Process adopted
					wt%	Assay %	Dist %	
1.	Wolframite	Quartz	Tourmaline	0.08	0.32	19.00	50.00	Table cum Mag. Sep.
2.	"	"	"	0.20	0.45	16.00	40.00	-do-
3.	"	"	Mica	0.21	0.23	57.33	50.00	-do-
4.	"	"	Turmaline	0.10	0.032	60.00	23.00	-do- and ESS
5.	"	"	Mica	0.21	0.86	15.80	68.00	Jig Cum Table Conc.
6.	"	"	"	0.21	0.92	15.30	70.00	-do-
7.	"	"	"	0.21	0.15	66.00	45.00	-do-
8.	"	"	"	0.20	0.90	13.00	57.00	-do-
9.	"	"	"	0.16	0.14	62.00	53.00	Tabling
10.	"	"	"	0.05	0.61	1.30	18.00	-do-
11.	"	"	"	0.03	1.34	0.88	33.00	-do-
12.	"	"	"	0.44	0.67	45.33	71.00	-do-
13.	"	"	"	0.03	1.50	0.84	30.00	-do-

Table No. 4

Metallurgical Results - Tungsten Samples: Degana Tungsten Project

Sl. No.	Mineralogy	Original Assay%	Concentrate			Process adopted
			Wt%	Assay%	Dist%	
1.	Wolframite Mica, Quartz Iron Oxides, Pyrite and Pyrrhotite	5 Loden - +65 mesh frabtion is richer and accounted to 80-85% of Tungsten with 80-85% by wt. and is frear than the rest.				Sizing
2.	" "	68.12	89.99	71.35	93.61	Magnetic Separation, Tabling
3.	" "	16.39	16.79	61,32	64.31	Tabling cum Magnetic Separation
4.	" "	00.20	00.06	56.85	12.65	-do-
5.	" "	63.10	85.39	72.19	93.67	WHIMS
6.	" "	54.25	80.03	65.91	93.79	Dry Magnetic Sep.
7.	" "	00.25	00.21	68.30	57.80	Tabling cum Flotation cum Magnetic Separation

It can be seen from the results that the conventional processes do not yield concentrates of the desired grade and recovery level. The losses are very high in fines and slimes. Several investigations carried out on samples from Degana Deposit have also indicated poorer results. The main reason is that the ore is poorer in grade and is disseminated. Hence, the latest technology for the recovery of fine values are suggested in addition to the flotation of very fine particles which will improve the recovery. The concentrate normally obtained by fine mineral processing is bound to be leaner and is to be further improved by chemical processing.

Conclusions

Gravity separation methods are amongst the oldest methods in mineral dressing, yet new processes are being developed and commercialised lately. For a process to get developed, tested, confirmed and commercialised, it usuelly takes a long time, and gravity separation is no exception to this rule.

Recently, researchers have been attempting improvements in gravity processes by adding different electrolytes. The advances in the auxiliary processes will also have an effect on the efficiency of gravity proccesses.

A lot of mineral values are lost in the form of fines and slimes, a in the cases of phosphates, tin and tungsten ores etc. The need for the development of specialised processes/units to recover values in the fines and slimes is much grater today, as the ores trated now are poor in grades, disseminated, with liberation at a very fine size.

This has become very essential in the case of tungsten as the richer ores are exhausted and the leaner ores are to be processed economically as a conservation step. Also, substitutes have not yst been develeloped for this mineral, making the picture very serious.

The world is not running out of mineral resources, but out of the mineral technology need for the economical exploitation of existing deposits.

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STRESZCZENIE

Rao G.M., Subrahmanyan N.N., 1986. Przeróbka rud wolframu w Indiach, Fizykochemiczne Problemy Mineralurgii, 18; 23-37.

W pracy dokonano przeglądu indyjskich i światowych źródeł rud wolframu oraz przeanalizowano stosowane technologie wzbogacania ze szczególnym uwzględnieniem frakcji mułowej.

СОДЕРЖАНИЕ

Г.М.Рао, Н.Н.Субрахманян, 1986. Переработка вольфрамовых руд в Индии. Физико-химические вопросы обогащения, 18; 23-37.

В работе проведен обзор индийских и мировых месторождений вольфрамовых руд, а также проанализированы применяемые технологии обогащения с особенным предусмотрением шламовых фракций.