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TUNGSTEN

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

Indira Bhavan, Civil Lines,
NAGPUR – 440 001

PHONE/FAX NO. (0712) 2565471
PBX : (0712) 2562649, 2560544, 2560648
E-MAIL : cme@ibm.gov.in
Website: www.ibm.gov.in

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18 Tungsten

Tungsten, also known as Wolfram, is a chemical element with symbol 'W'. In its raw form tungsten is a hard steel grey metal that is often brittle and hard to work. Tungsten is found in the minerals wolframite (iron - manganese tungstate, $FeWO_4/MnWO_4$), scheelite (calcium tungstate, $CaWO_4$) ferberite and huebnerite.

Off all metals in pure form, tungsten is one of heaviest metals and has the highest melting point of any element except carbon (3422 ^{o}C, 6192 ^{o}F), lowest vapor pressure (at temperatures above 1650 ^{o}C, 3000 ^{o}F) very high thermal creep resistance and the highest tensile strength. It is extremely resistant to corrosion and can be attacked only slightly by most mineral acids. When exposed to air, a protective oxide is formed on the surface of the metal, but tungsten can be oxidised more fully at high temperature. When alloyed in small quantities with steel, tungsten greatly increases the hardness of steel.

A significant amount of tungsten is recovered through recycling of tungsten scrap products. Old scrap consists of tungsten bearing products such as cemented carbide parts include metal cutting tools & metal forming tools. As tungsten has extremely high melting point and is ductile (can be readily drawn into wires), it is widely used in filaments of light bulbs and vacuum tubes, and for heating elements in electrical furnaces.

RESERVES/RESOURCES

The total reserves/resources of tungsten ore in the country, as per NMI data, based on UNFC system, as on 1.04.2015 have been estimated at 87.39 million tonnes with WO_3 content of 142,094 tonnes. All these resources are placed under 'remaining resources' category.

Resources of tungsten bearing minerals are mainly distributed in Karnataka (42%), Rajasthan (27%), Andhra Pradesh (17%) and Maharashtra (9%). The remaining 5% resources are in Haryana, Tamil Nadu,Uttarakhand and West Bengal (Table- 1).

At Degana, Rajasthan, WO_3 value in vein deposits varies from 0.25 to 0.54% while in gravel deposit, it is on an average of 0.04%. In Sirohi deposit, Rajasthan,WO_3 content ranges from 0.02 to 2.2%. In West Bengal, Bankura deposit contains an average of 0.1% WO_3. In Kuhi-Khobana-Agargaon belt, GSI has identified seven mineralised zones in Sakoli basin in Bhandara and Nagpur districts, Maharashtra. The analysis showed 0.01 to 0.19% WO_3 in Kuhi block, 0.13 to 0.38% WO_3 in Khobana block and 0.48% WO_3 in Pardi-Dahegaon-Pipalgaon block. The deposit contains an average of 0.17% WO_3. Gold ore at Mysore mine of BGML in Karnataka has been reckoned as a potential source of scheelite. The tailing dumps at Kolar Gold Fields contain about 0.035 to 0.18% WO_3.

EXPLORATION& DEVELOPMENT

GSI carried out exploration in Assam, Andhra Pradesh and Maharashtra for Tungsten and other minerals (Table-2).

Deposits of Wolfram, the chief ore of tungsten, are found in Degana (near Rawat Hills) in Rajasthan and Chendapathar in Bankura district of West Bengal. Seven mineralised zones in Sakoli basin in Bhandara and Nagpur districts of Maharashtra have also been identified. Haryana and West Bengal also have some deposits of tungsten.

Table –1 : Reserves/Resources of Tungsten as on 1.4.2015
(By Grades/States)

(In tonnes)

Grade/State	Reserve Total (A)	Remaining Resources							Total Resources (A+B)
		Feasibility STD211	Pre-feasibility STD222	Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
All India : Total									
Ore	**-**	**2230000**	**173063**	**19611152**	**23435954**	**25356049**	**16581246**	**87387464**	**87387464**
Contained WO_3	**-**	**3568**	**450**	**9914**	**20180.92**	**103415.15**	**4566.28**	**142094.35**	**142094.35**
By States									
Andhra Pradesh									
Ore	-	-	-	3640000	4700800	5952500	509000	14802300	14802300
Contained WO_3	-	-	-	5096	6574.64	8273.65	318.28	20262.57	20262.57
Haryana									
Ore	-	2230000	-	-	-	-	-	2230000	2230000
Contained WO_3	-	3568	-	-	-	-	-	3568	3568
Karnataka									
Ore	-	-	-	15361152	11805499	172921	9338246	36677818	36677818
Contained WO_3	-	-	-	2915	1775	142	1403	6235	6235
Maharashtra									
Ore	-	-	-	610000	5637250	1830000	-	8077250	8077250
Contained WO_3	-	-	-	1903	10304	3828	-	16035	16035
Rajasthan									
Ore	-	-	-	-	963666	17000628	5964000	23928294	23928294
Contained WO_3	-		-	-	1421.44	90171.5	2115	93707.94	93707.94
Tamil Nadu									
Ore	-	-	-	-	-	-	250000	250000	250000
Contained WO_3	-	-	-	-	-	-	50	50	50
Uttarakhand									
Ore	-	-	-	-	138000	-	520000	658000	658000
Contained WO_3	-	-	-	-	25	-	680	705	705
West Bengal									
Ore	-	-	173063	-	190739	400000	-	763802	763802
Contained WO_3	-	-	450	-	80.84	1000	-	1530.84	1530.84

Table – 2: Details of Exploration Activities for Gold, 2015-16

Agency/ State/ District	Location Area/ Block	Mapping		Drilling		Sampling (No.)	Remarks Reserves/Resources estimated
		Scale	Area (sq km)	No. of boreholes	Meterage		
GSI							
Assam							
Bongaigaon, Dhubri & Kokrajhar	Chakrashila-Nadangiri-Bhuneswar	DM	2	-	-	-	A G-4 stage investigation was taken up in 2015-16 for search of W, Sn & REE in which detail mapping of 2 sq. km has been executed.
Kamrup	Kumarkuchi-Chagaligaon	LSM DM	50 2	-	-	-	A G-4 stage investigation was taken up for W, Sn & REE. Analytical results received so far reveal that the porphyritic granite is rich in total REE as compared to other units.
Andhra Pradesh							
East Godavari	Chinnagali-Konda-Potaram area	1:2000	1.55	7	1143	384	A G-3 stage investigation has been carried out for tungsten and graphite mineralisation at Chinnagalikonda area with the objective to delineate mineralised zones for tungsten and graphite. Pitting and trenching (85 cu m) has been carried out and 43 pit/ trench samples, 103 BRS, 184 core samples, 15 PS, 15 ORM, 19 PCS and 5 EPMA samples have been collected.
Chandrapur	Lawari-Amboli area	1:5000	3	-	124	65	In Maharashtra a G-4 stage investigation has been taken up in Lawari-Amboli area, Chandrapur district with an objective to identify the zones of tungsten and associated mineralisation. Some mafic enclaves of amphibolite are observed within the gneissic rock near Amboli village. Scheelite is observed in quartz-tourmaline vein under UV lamp southwest of Amboli village. All the lithounits such as quartz-tourmaline vein, quartz vein and pegmatite vein observed in the study area are mapped on 1:5000 scale. Bedrock samples and pitting & trenching samples of quartz-tourmaline vein southeast of Amboli village were studied and checked under UV lamp. Towards southeast of Amboli village bedrock samples of quartz-tourmaline vein give W values of 339 ppm. Whereas the highest W value so far recorded is 530 ppm from bedrock sample of quartz. Pitting and

(Contd.)

Table – 2 (Contd.)

Agency/ State/ District	Location Area/ Block	Mapping		Drilling		Sampling (No.)	Remarks Reserves/Resources estimated
		Scale	Area (sq km)	No. of boreholes	Meterage		
Maharashtra							
Chandrapur (Contd.)							trenching samples of quartz-tourmaline vein of the Amboli village give maximum W value of 322 ppm. Scout drilling is carried out towards southwest of Amboli village. So far 124 m drilling has been completed. From 29.10 m to 45.50 m highly altered quartz-biotite schist with fragmented quartz vein occurring intermittently was observed. Quartz-mica schist is encountered up to a depth of 64.80 m. From 64.80 m to 73.40 m compact quartz-chlorite mica schist having little tourmaline is also observed. In this zone scheelite is encountered under UV lamp. From 73.40 m to 107.10 m biotite-rich quartz-mica schist is observed which is devoid of mineralisation under UV lamp but at places dark-coloured metallic lustre is encountered. From 107.10 to 113.20 m compact quartz-mica schist having tourmaline is observed. In this zone along boundary of quartz crystal scheelite is observed under UV lamp. Beyond this depth only quartz-mica schist is observed but no scheelite is encountered under UV lamp. Borehole analytical data were awaited. The investigation is completed.
Gadchiroli	Navgram	LSM	50	-	-	24	A G-4 stage investigation has been carried out to ascertain tungsten and associated mineralisation. Two major mineralised quartz reefs are observed near Navgram (Sitabai Dongri) and Karakapalli (Sigamodi Dongri) area. The Sitabai Dongri quartz reef is N15°W-S15°E-trending for about 4.0 km strike length and width varies from 5 m to 25 m. Sitabai Dongri reef is silicified, ferruginised, fractured and brecciated.

(Contd.)

Table – 2 (Contd.)

Agency/ State/ District	Location Area/ Block	Mapping Scale	Mapping Area (sq km)	Drilling No. of boreholes	Drilling Meterage	Sampling (No.)	Remarks Reserves/Resources estimated
Maharashtra (contd.)							
							Sulphide mineralisation is noticed in the form of specks and dissemination of a galena, chalcopyrite, sphalerite and bornite. The Singamodi Dongri near Karakkapalli area, is of about 300 m strike length and 15-25 m width and tapering on either side. In Sitabai Dongri quartz reef, 13 m length of channel is sampled at every 1 m. Chemical analysis of 6 BRS samples from quartz reef shows value of W ranging from 154 to 604 ppm, three BRS samples from quartz reefs depict value of Zn ranging from 700 to 800 ppm and eleven BRS samples from quartz reef depict value of Zn ranging from 300 to 590 ppm. Three BRS samples from quartz reef illustrate value of Cu ranging from 0.11 to 0.15% and eight BRS and PTS samples from quartz reef show value of Cu ranging from 129 to 885 ppm. Four channel samples indicate value of Au ranging from 150 to 240 ppb. Petrographic study indicates sulphide mineralisation viz. chalcopyrite with pyrite, sphalerite and galena specks. The investigation will be continued in FS 2016-17.
MECL							
Maharashtra							
Nagpur	Navgram	1:1000	0.50	7	1343	24	Detailed exploration was carried out with objective (i) to ascertain the thickness, depth and strike extension of lodes precisely at grade and thickness cut off, (ii) to increase the confidence level of resources established by GSI as per UNFC norms and (iii) to study mineralogical characteristics of ore and its beneficiation. Total resources estimated are 2.10 million tonnes of 1.16 % WO_3, Out of this total measured resources are 0.931 million tonnes with 0.158 % WO_3 and indicated resources are 1.171 million tonnes with 0.162 % WO_3 content (331/332) of UNFC. The resources estimated by MECL include the resources earlier estimated by GSI.

PRODUCTION & PRICES

There was no production of tungsten ore/concentrate during 2015-16. The past production of tungsten was reported from Degana, Rajasthan and Chendapathar, West Bengal. The domestic prices of tungsten ore and concentrate are furnished in the General Review on 'Prices'.

MINING & PROCESSING

Deposits of wolframite that were established at Degana in Rajasthan and at Chendapathar in West Bengal are found associated with quartz veins, with width that varied from a few centimetres to three metres or sometimes even more. In Degana, it is also associated with gravel beds overlain by 2.5 m thick sand.

Gravel mining was carried out in the past in selected areas where wolframite was found to be concentrated. The overburden sand was at first loosened and loaded manually and transported by tractor unit to dump sites. The payable gravel was then worked.

In case of vein deposits, the orebody was cut with chisel and hammer at convenient places, to form undercuts. At Degana, tungsten orebody occurs as vein, stockwork and alluvial deposits.

Inclined veins were developed by putting adits in the stockwork.

Degana in Rajasthan and Chendapathar in West Bengal were the only mines of tungsten in India that produced meagre quantities of concentrate. These mines, owing to economic non-viability, had to be closed down. As per the press release by NMDC dated 24th October 2016, NMDC Ltd. & Mishra Dhatu Nigam (MIDHANI) have signed a Memorandum of Understanding (MoU) to develop tungsten mines and processing technology for the metal.

USES

Tungsten is mainly used in the form of ferro-tungsten in making of special and alloy steels and military applications. Ferro-tungsten typically contains between 25% and 75% tungsten. The other principal use of tungsten is in the manufacture of tungsten carbide, one of the hardest synthetic materials used in various industries like construction , metalworking, mining and oil drilling. It is used widely in the manufacture of cutting tools & devices and in wear-resistant materials, particularly those that need to be operated at high temperatures. In making this, cobalt or nickel metal powder is used as a binder to hold together the tungsten carbide grain. Tungsten compounds are used in dyes and pigments; manufacture of paints & printing ink; and also in Ceramic Industry for producing yellow tint. Other alloys bearing tungsten have wide range of applications, i.e., ornaments, heat sinks, radiation shielding, weights & counter-weights,super alloys for turbine parts, tool steels wear-resistant alloy parts & coatings, etc. Tungsten alloys and tungsten composites are used as a substitute for lead in bullet and shot.Tungsten is used as filament in incandescent light bulbs and cathodes for electronic tubes cell phones, television set, HID lamps and other electrical consumer products. The metal is used in superalloys with copper or silver and in Chemical Industry. Tungsten carbide is often used in armor-piercing ammunition.

SUBSTITUTES

Tungsten remains essentially unsubstitutable in its use for production of filaments, electrodes and contacts in lamp & lighting applications. However, an electrodeless, non-tungsten lamp is available as alternative for commercial and industrial uses. Titanium, tantalum and niobium carbides can be used in certain wear-resistant applications. Molybdenum tool steels and tungsten tool steels are interchangeable. In some cutting tool applications, bulk ceramic is an alternative. In some applications, substitution would most often result in increased cost or reduction in product performance.

TECHNICAL POSSIBILITIES

Further development of new metal shaping methods, i.e., laser is becoming a viable proposition. Development of new cutting tool

materials coating on cemented carbide parts, that increase their useful life could reduce the usage of tungsten. Use of tungsten scrap could be increased. The recycling of tungsten bearing scrap and the recovery of tungsten from scrap materials are well established practices for a number of reasons. The value of tungsten and other metals present in the scrap, such as cobalt, columbium, copper, nickel, rhenium, silver, titanium, and tantalum, provides economic reasons to recycle. Recycling of tungsten in high speed steel is high and a typical melt contains about 60-70 % scrap, including internally generated scrap. On the other hand, recycling in such applications as lamp filaments, welding electrodes and chemicals uses is done. Recycling is more environment friendly and usually more economic than waste disposal. Tungsten compounds could be used in light-sensitive applications. Scrap recycling is an important factor in the world's tungsten supply.

POLICY

As per the Foreign Trade Policy, 2015-20, the imports and exports of tungsten ores and concentrates (HS Code 26000000) allowed free.

CONSUMPTION

The entire domestic requirement of tungsten ore/ concentrates is met by imports. Sandvik Asia Pvt. Ltd, Pune, Maharashtra,Widia (India) Ltd, Bengaluru, Karnataka, and Rapicut Carbides Ltd, Ankleshwar, Gujarat, Mishra Dhatu Nigam Ltd, Hyderabad, Andhra Pradesh and Sunflag Iron & Steel Co. Ltd, Bhandara, Maharashtra were the important consumers of ferro-tungsten for production of alloy steel. Mining Machinery Industry is the main consumer of the imported ore/ concentrates.

WORLD REVIEW

The world reserves of tungsten in terms of metal content are about 3.1 million tonnes, distributed broadly amongst China (61%), Canada (9%), Russia & Vietnam (3% each) and UK (2%) (Table -3).

Table - 3 : World Reserves of Tungsten (By Principal Countries)

(In '000 tonnes of Tungsten content)

Countrry	Reserves
World Total (rounded)	**3100**
Austria	10
Canada	290
China	1900
Portugal	3
Russia	83
Spain	32
UK	51
Vietnam	95
USA	NA
Other countries	680

Source : Mineral Commodity Summaries, 2017

The world mine production of tungsten in terms of metal content in 2015 increased slightly to 80,866 tonnes from 80,849 tonnes in 2014. China was the leading producer (80%), followed by Vietnam (6%), Russia & Canada (3% each) and Bolivia & Rwanda (1% each) (Table-4).

Table – 4: World Mine Production of Tungsten (By Principal Countries)

(In tonnes of metal content)

Country	2013	2014	2015
World: Total	**76404**	**80849**	**80866**
Austria	851	830	870
Bolivia	957	956	1116
Brazil#	494	510	500e
Canada	2762	2689	2114
China	64895	65369	65000e
Korea, Dem. P. R. of e	60	70	70
Kyrgyzstane	100	100	100
Myanmare	140	140	90
Peru	35	77	139
Portugal*	692	671	474
Russia	2982	2659	2700e
Rwanda	1344	1313	1081
Spain	487	822	835
Thailand*	161	110	39
Uzbekistan(e)	300	300	300
UK	0	0	195
Vietnam	0	4134	5123
Other countries	144	99	120

Source: *World Mineral Production, 2011-2015.*
* ***Wolframite & Scheelite.***

FOREIGN TRADE

Ammonium paratungstate (APT)$(NH_4)_{10}(H_2W_{12}O_{42}).4H_2O$ is the main intermediate and also the main tungsten raw material traded in the market.

Exports

Exports of tungsten and alloys including scrap decreased drastically to 314 tonnes in 2015-16 from 475 tonnes in the previous year. Exports were mainly to Germany (25%), USA (20%), Sweden (10%), UK and Austria (8% each). In 2015-16, exports of tungsten ore & concentrates decreased drastically to only 1 tonne as against 175 tonnes in the preceding year. Exports were solely to Nepal (100%) (Tables - 5 and 6).

Imports

Imports of tungsten ores and concentrates also decreased drastically to 78 tonnes in 2015-16 from 191 tonnes in the previous year. Imports were mainly from Singapore (67%), Rwanda (19%) & Uganda (12%). Imports of tungsten and alloys including scrap decreased to 385 tonnes in 2015-16 from 438 tonnes in the previous year. Imports were mainly from China (58%), Korea, Rep. of (11%), Austria (10%), Germany (8%) and Singapore (4%) (Tables- 7 to 9).

Table – 5 : Exports of Tungsten and Alloys Incl. Scrap (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (kg)	Value (₹'000)	Qty (kg)	Value (₹'000)
All Countries	**475385**	**1574148**	**313688**	**1196642**
Germany	214877	476776	78260	309856
USA	170179	411991	63552	162883
Poland	7988	126974	8124	127765
Sweden	27126	79684	32191	78134
Italy	8752	77955	4963	71964
Japan	3265	82362	2428	69875
France	4075	58185	3585	47158
UK	849	7319	24069	40762
Austria	11477	23672	25110	38930
Bangladesh	4685	37280	3270	37779
Other countries	22112	191950	68136	211536

Table – 6 : Exports of Tungsten Ores & Conc. (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**175**	**29666**	**1**	**391**
Nepal	-	-	1	390
Vietnam	143	27383	-	-
Italy	32	2283	-	-
UK	-	-	++	1

Table – 7: Imports of Tungsten Ores & Conc. (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**191**	**61582**	**78**	**34081**
Rwanda	10	10008	15	13200
USA	2	9146	2	10128
Uganda	35	36904	9	8996
Singapore	-	-	52	1566
Germany	++	326	++	191
France	144	5198	-	-
Other countries	-	-	-	-

Table – 8: Imports of Tungsten & Alloys Incl. Scrap (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (kg)	Value (₹'000)	Qty (kg)	Value (₹'000)
All Countries	**437833**	**1868711**	**384803**	**1591491**
China	229012	874042	224700	790689
Austria	39526	349710	36925	266864
Germany	25854	124107	29340	171139
Korea, Rep. of	42141	191181	42368	156025
Singapore	20422	54243	14197	49891
USA	47840	163241	10797	47726
Japan	10162	42548	10073	35080
Italy	3591	16822	6644	23296
UK	11948	19805	3074	12877
Switzerland	2024	5783	2183	12192
Other countries	5313	27229	4502	25712

FUTURE OUTLOOK

World tungsten supply will continue to be dominated by China's production and exports. As per Global Tungsten Market Trends, statistics and forecast 2015-20, Europe is an important market for tungsten demand. The demand for tungsten for industrial applications is expected to witness strong growth,particularly in Asia Pacific and Latin America regions. In the next few years, tungsten concentrates production from outside China is expected to increase. Some of the increase is expected to come from improved production from existing mines and some is expected to come from the ramp up of production at recently started mines and tailings operations. The consumption of tungsten in cemented carbides, which is the leading end-use sector is expected to rise in the near future.

In India, the entire demand can only be met by imports and recycling, as there is no indigenous production of tungsten concentrates. High content of WO_3 in the tailing dumps of Kolar can be worked on priority basis to meet the demand.