ITIA

Tungsten

Newsletter – June 2014

The Panasqueira Mine at a Glance

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Sojitz Beralt Tin & Wolfram (Portugal) S.A.

The main article in this Newsletter features the Portuguese tungsten mine, Panasqueira. The ITIA Newsletters in 2012 explained the basics of tungsten mining in principle and it is a logical step to go from general to specific. ITIA is most grateful to the authors and their company for this report on one of the largest tungsten mines in Europe written especially for this Newsletter.

Company's outline and profile

Sojitz Beralt Tin & Wolfram (Portugal) S.A. (SBT&W) is wholly owned by the Japanese Sojitz Corporation and is the oldest Portuguese mining Company. Panasqueira mine also is one of the largest operating tungsten mines in the Market Economy Countries (MEC). It currently employs approximately 370 people. Production quantity is variable but currently is in the range of 85,000 – 95,000 mtu WO_3 (1 mtu – metric tonne unit – is equal to 10 kg) per year, depending on the ore grade extracted from different areas of the mine. The tungsten concentrate produced has WO_3 content of 74 – 75% which is one of the highest grades available in the market.

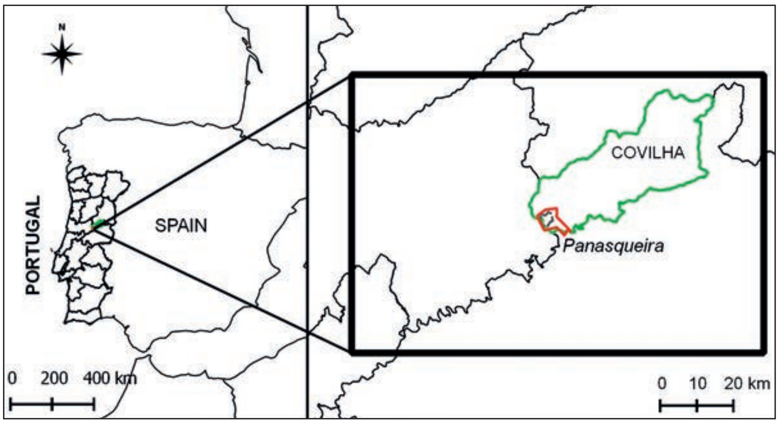
History and location

The first prospecting licence was granted in 1886 and the first reference to wolframite mineralization in the Panasqueira area reportedly dated to 1888.

The mining company was founded in 1896 to mine tungsten at Panasqueira as the industrial uses of the commodity were first being developed throughout the world. The first area where wolframite ore was recovered was from Cabeco do Piao (now known as Rio); the first areas mined near present day workings were from Vale das Freiras, Vale da Ermida and Barroca Grande. All the individual concessions were grouped into one single mining area known as the "Couto Mineiro da Panasqueira" which covers the same ground as the present day concession.

In 1904, a new mechanized treatment plant was built near Cabeco do Piao (Rio), which was situated on the Zezere River for water supply. There is a report of the delivery of 41 tonnes of ore to various buyers. The first underground drifts were opened at Rio but mining activity decreased as richer veins were discovered at nearby Panasqueira. Milling and treatment of the Panasqueira ore at Rio continued until September 1996, when the final concentration equipment began to be moved to Barroca Grande.

In 1911 the Wolfram Mining and Smelting Company was formed and purchased all the rights to the concessions including the buildings, the equipment and 125 ha of rural land. In 1912, the new company made major investments in machinery and equipment, upgrading the Rio treatment plant and installing the first aerial 5,100m rope-tramway that brought the ore from different mining sites at Panasqueira to the Rio plant. In 1912, the production of wolframite concentrates was reportedly 267 tons of 65% WO_3 mined by 244 workers from 10,791 tonnes of vein as well as 86,063 tonnes of host rock.



The mine concession (red line) is located in Covilha, in the Distrito de Castelo Branco, one of eighteen administrative regions in the country on the southern edge of the Serra da Estrela, a Portuguese mountain range approximately 300 km northeast of the Portuguese capital city of Lisbon and 200 km south-east of the port city of Porto.

World War I in 1914 saw a period of accelerated expansion and growth of the mining operation. The production rate was increased, the plant was enlarged and a furnace was installed. The number of workers at the mine increased to 800. In addition, the company allowed individuals to work small surface veins exposures workings in the concession area, an activity that involved approximately 1,000 people recovering small quantities of ore for sale back to the company. The hills surrounding the present day operation contain many old pits and shafts left from these small operations.

From the end of the World War I to 1928, the mining activity was contingent on the price of tungsten. During this period of uncertainty in the tungsten price, the search and the recovery of tin was intensified. In 1927 approximately 110 tonnes of cassiterite concentrate as well as 190 tons of wolframite concentrate were produced. In 1928, the Wolfram Mining and Smelting Ltd. reorganized and changed its name to become Beralt Tin & Wolfram Company (the name, Beralt, being derived from Beira Alta, the local region).

The tungsten price recovered in 1934 and stayed high through to the end of World War II. These were the years of peak production at the mine. Manpower increased from 750 workers in 1933 to 3,300 in 1940 and nearly 5,800 in 1943. Portugal was neutral during the war and the mine could count on a steady supply of workers and sales to both sides in the conflict. In addition, there were approximately 4,800 individual miners working the small veins on the surrounding hills.

The tungsten price fell sharply again after the end of the war and only increased in 1950 due to the Korean conflict. Steady production was maintained with increased mechanization and increased production of tin and the introduction of the recovery of copper from the plant tailings. It was also during the 1950's that the company recognized the importance of water quality and installed the water treatment plant at Salgueira, located one kilometre downstream from the main mining operations.

Panasqueira mine tailings disposal

Since 1974, the company has accelerated the mechanization of the underground operations in order to further reduce labour costs and changed the mining method from largely long wall stopeing to more mechanized room and pillar method. The opening of a new inclined conveyor shaft from the deeper Level 2 began in 1977 and the extraction of ore from Level 2 began in 1982.

In 1998 the remaining plant at Rio was moved and all milling consolidated at its present day site at Barroca Grande.

A new underground shaft connecting Level 2 with Level 3, 90 meters in depth, was completed and a new 284 kW winch was installed. The complete shaft system with automated mine car handling began operating in April 1998.

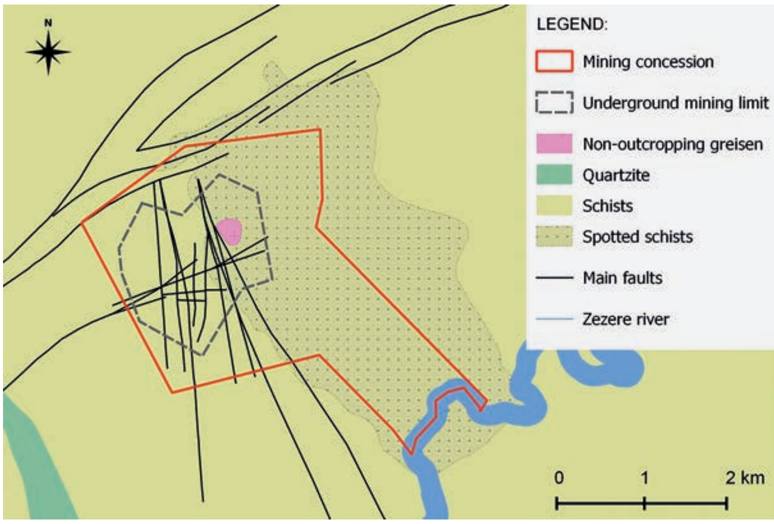
In late 2007 the Japanese company, Sojitz Corporation, acquired 100% of the shares of the Company and its name was changed to Sojitz Beralt Tin & Wolfram (Portugal) S.A..

The concession lies in moderately rugged, pine and eucalyptus covered hills and valleys with elevations ranging from 350 metres in the southeast to a peak of 1,083 metres in the north-western corner of the concession.

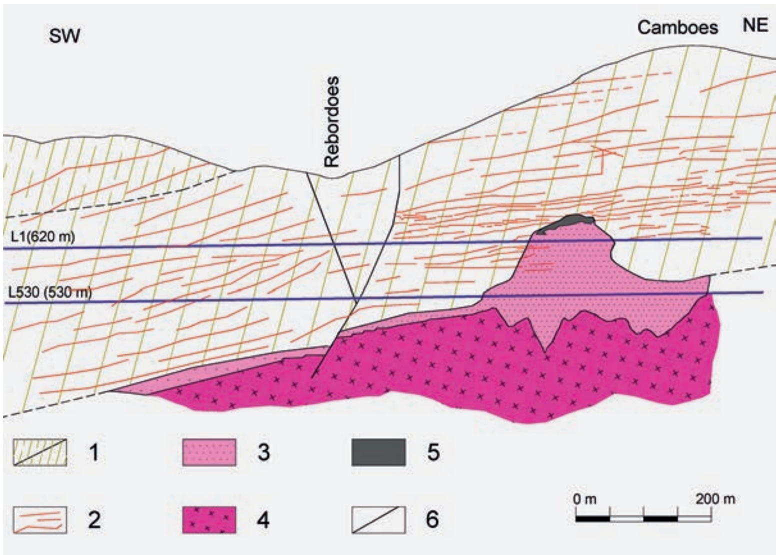
The climate is pleasant, with average temperatures of 24°C in July – August and 4°C in December. Rainfall is most common in November – January with seasonal averages of 200 mm in December to 10 mm in August. The Zezere River is the major source of water for the city of Lisbon, so the mine conducts constant water monitoring.

Panasqueira mine plant installations general view

Local population density is low. Most of the population works in agriculture (pasture, grain, timber, fruit, oil and wine), and with the mine and small service industries. The village of Barroca Grande is notable for its long history of mining, with a significant number of people being employed by Sojitz Beralt Tin & Wolfram (Portugal) SA (SBTW) and currently engaged in the activities of operation and maintenance of the Mine, Concentration Plant and Administrative Services.



Simplified geological map



Schematic section (along panel 4) of the non-outcropping greisenized two-mica granite of Panasqueira. (1) Shists/spotted schist; (2) Quartz veins; (3) Greisen; (4) Two-mica granite; (5) Silica cap; and, (6) Main fault.

Geology and mineralogy

Panasqueira mine is a world-class W-Sn-Cu vein-type deposit, located in the Central Iberian Zone of the Palaeozoic Iberian Massif (Portugal), which is one of the most important metal-logenic provinces of Europe.

The dominant lithologies in the mine concession area are a metamorphosed, pre-Ordovician, tightly folded, lower-greenschist slates – locally spotted – and greywackes (Beira Schist). Underground works intersect a partially greisenized two-mica granite, emplaced during the late-to post-tectonic stage of the Variscan orogeny. These lithologies are faulted by 2 systems of NS and EW faults.

Panasqueira is a vein-type deposit, typically consisting of sub-horizontal, hydrothermal quartz veins intruding into the Beira Schist. Average dip of mineralized quartz: 8–10°SW, and average thickness of 0.3 m (range 0.1–1.0 m).

Dimensions of ore body: 2,500m (length), 400 to 2,200m (width) and 500m (depth). The actual limits of the ore body have not been delineated, outlining the potential for additional resources in the existing mine.

The principal tungsten-bearing mineral is wolframite (ferberite), and by-products include tin (cassiterite), copper (chalcopyrite) and silver. Sixty-five different minerals have been identified in Panasqueira Mine.

Wolframite mineralization occurs as very large nugget-like crystals or large crystal aggregates, usually concentrated towards the margins of the quartz veins or, occasionally, close to the central portion of the quartz veins.

The unique geological nugget mineralization feature makes traditional resource appraisal methods irrelevant. It has led Panasqueira to develop an in-house resource estimate formula, locally called Pintas.

Sequence of sub-horizontal quartz mineralized veins: (1) Typical heal-tail morphology of the quartz veins; (2) 3 x 3 pillar with wolframite nugget; (3) Highly mineralized quartz vein with wolframite in the hanging and footwall, with sulphide rich central zone; (4) Thick vein of quartz with coarse wolframite, siderite and sulphides; (5) Crystals of wolframite growing perpendicular to the walls; (6) Sulphide rich quartz vein in the central zone; (7) Massif sulphide vein (arsenopyrite, chalcopyrite and pyrrhotite) with wolframite; and (8) Specialized miner measuring the wolframite crystals area for grade control.

Resources estimation

D9 & *Pintas* Formulas

With 100 years of operating experience, Beralt has developed internal empirical formulas to determine the grade of the deposit. These formulas have been validated by external consulting companies several times and have been considered the only one reliable method in light of the nugget mineralization of the wolframite in the vein.

Resources are estimated from a formula based on vein thickness: D9 formula. This formula is used to estimate Inferred and Indicated Resources by internal geologists. Measured resources – Virgin Area & Pillars – are estimated by measuring the area of wolframite crystals: Pintas Formula (described in detail in this article).

All resources are reduced to 84% to allow for resources left in pillars that need to be maintained because of the mining method stability. For Inferred and Indicated Resources safety factors of 40% and 60%, respectively, are applied, i.e. 33% and 50%, respectively, of recoverable resources.

For measured resources, recoverable resources are estimated to be 84% in unworked areas, 67.3% of 84% (i.e. 56.5%) in areas with 11 m x 11 m pillars and 45% of 84% (i.e. 37.8%) in areas with 11 m x 3 m pillars.

D9 Formula:
Grade in WO_3% = (A) x (B) x 0,6 / (C) x (D) x (E)

(A) Vein intercept in cm;
(B) 75% is the average proportion of WO_3 in the Wolframite;
(C) 2.2 is the average height of the stope in meters;
(D) 2.8 is the relative density (i.e. specific gravity) of the rock;
(E) 10 is a unit's conversion factor (1000/100);
The value of 0.6 is an empirical value determined from the study.

Production Sampling Method Approach

The distribution of the wolframite crystals is extremely erratic and results in a "nugget-effect" similar to what is commonly seen in high-grade, coarse gold mines. The mine does not utilize conventional sampling techniques such as channel sampling or drilling to provide material to estimate grade of the individual faces or stoped areas. Instead, an empirically derived factor is used, a formula that has proved reliable and accurate for many decades of mining. This formula is applied to the measured area, and mine grades are reported in terms of recoverable wolframite per horizontal square meter of vein, and subsequently converted to recoverable wolframite per ton of ore.

Measuring consists of measuring the area of wolframite crystals within the vein. The areas of wolframite are accumulated for a specific length of exposed vein and recorded. This system has been used successfully for decades.

Wolframite occurs as very large crystals or large crystal aggregates within the flat lying quartz veins and may be accompanied by intense alteration halos. The wolframite crystals are easily identified in the vein along with the length sampled and the average vein thickness. The current measuring has enabled the mine to develop a very unusual but effective method of grade control and resources calculation.

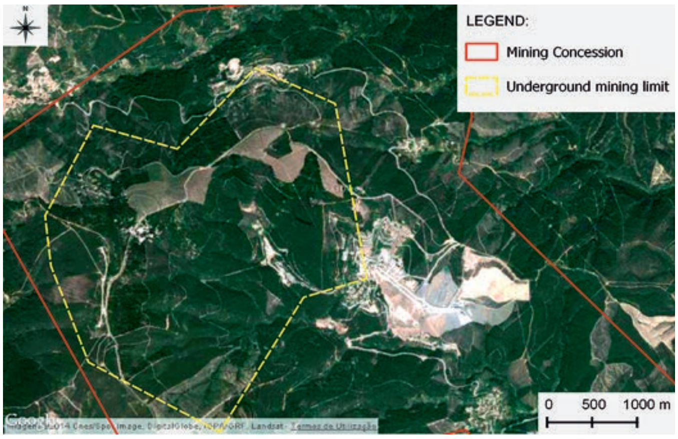
The grade of the sample is estimated in terms of kilograms of wolframite per square meter of plane area of vein. The height of the stope excavated then determines the number of tonnes (dilution) and grade of ore sent to the mill.

***Pintas* Formula:**
(A) Grade in kg/m^2 = (a) / 100 x (b) x (c)

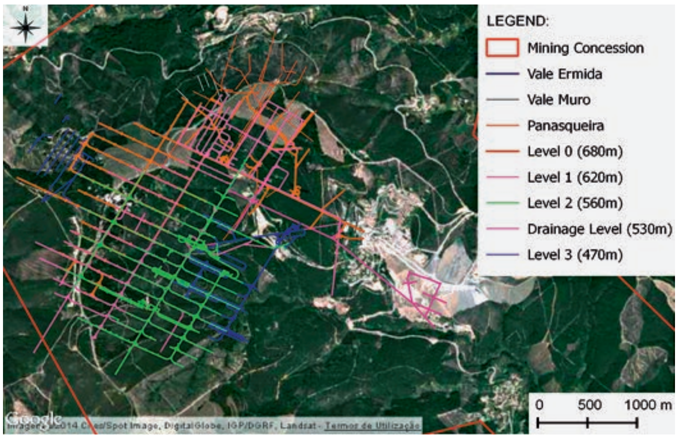
(a) Measured surface of wolframite on the exposed vein;
(b) Vein linear meters is the length of the sampled vein;
(c) 1.5 is an empirical factor (i.e. the reconciliation factor between the grade estimated at the mine and the grade measured at the plant);
The value 100 is the unit conversion factor.

Grade in WO_3% = (A) x (B) / (C) x (D) x 10

(B) 75% is the average proportion of WO_3 in the wolframite;
(C) 2.2 is the average height of the stope in metres;
(D) 2.8 is the relative density (i.e. specific gravity) of the rock;
The value 10 is a unit's conversion factor.



Bird’s eye view of operation footprint. (Google satellite image, 2014)

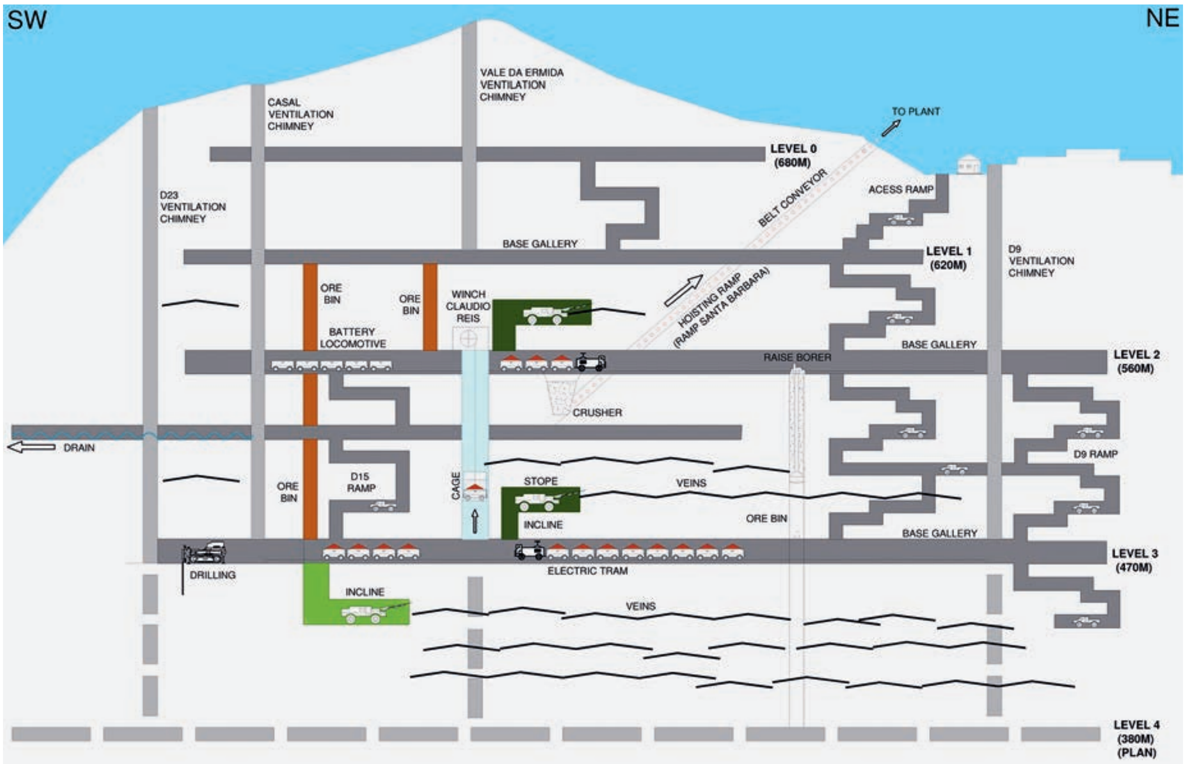


Underground mining operations. (Google satellite image, 2014)

A map is created for each vein showing all of the “samples” taken on that particular vein. As development progresses, all of the ““samples” within an individual block (a block is defined by a drive and panel and is usually about 80 m by 100 m) are averaged to provide a block grade. The individual samples are weighted according to the original length measured. When the entire block has been converted to 11 m x 11 m pillars then sampling is complete and no further changes will be made to the block grade.

Technical overview of operations

The extraction of the ore occurs exclusively underground, based on 4 horizontal levels (from level 0 to level 3) and the mine development has progressed from upper level (level 0: 680 m) down to the lower level (level 3: 470 m). Production currently operates at the Levels 0, 1 and 2. The mine entrance is located South of the underground mine and East of SBTW (Sojitz Beralt Tin & Wolfram) offices – Rebordoes.



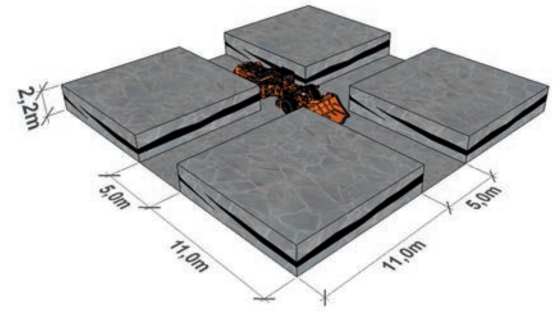
Operation map scheme. Four main levels (dark grey) connected by ramps. Water drainage level (530 m) between level 2 (560 m) and level 3 (470 m). Ore bin connecting base levels (orange). Level 3 ore transported for level 2 by vertical winch (light blue). Stope advancing between base levels (dark green) and exploration galleries (incline on light green) following sub horizontal veins. Main crusher under level 2 base connecting the plant by Santa Barbara hoisting ramp (red dots). Four main surface ventilation chimneys.

The ore is conveyed through an underground conveyor to the concentration plant at the surface. Tailings are moved to the disposal area:

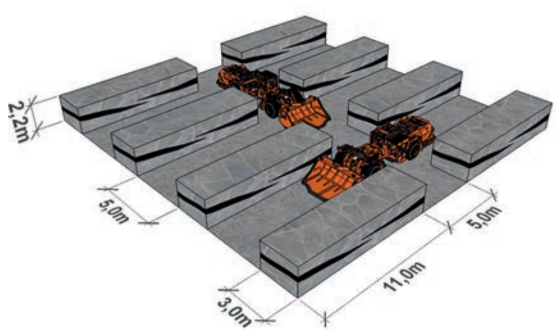
- Coarse tailings are stockpiled and sold to local companies for road works;
- Fine tailings and sands are disposed in a dedicated pond.

The water treatment unit is located downhill. Water from the mine, the plant and the tailings area is treated to be either reused in the plant or released to the river.

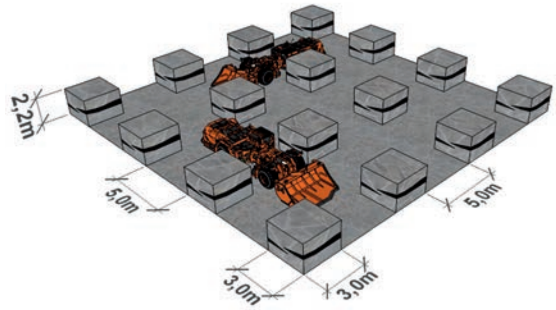
Mechanized room and pillar method. All of the schematic images correspond to a room section 5 m wide and 2.2 m high in N-S and E-W directions.



Pillars are made in a grid of 11 x 11 m (recovered resources are estimated to be 51%)



Pillars are made in a grid of 3 x 11 m (recovered resources are estimated to be 73%)



Pillars are made in a grid of 3 x 3 m (recovered resources are estimated to be 85%)

Some numbers:

- Cut-off grade: 5 kg/m^2 of WO_3 or 0.060% WO_3;
- Operation days: 230–240 per year;
- 2 shifts x 5 days;
- Effective time of work is 6.5 hour per shift;
- Run of Mine (ROM): c. 800,000 tonnes per year;
- Equipment mechanical availability: 80%;
- Equipment: 14 Jumbos, 14 LHD (load haul dumper) and other.

Extraction methodology

The mining method used at Panasqueira is a mechanized room and pillar method. Tunnels east-west oriented called drives and north-south called panels. Height of the stope is 2.1 m to 2.3 m, with a block dimension of 100 x 80 x 2.2 m^3. Economic thickness veins >10 cm.

Mineral Processing

The first step of the processing of the ore is a pre-concentration with the use of Heavy Media Separation (HMS). Here the problems that are present underground with regard to resource measurement, the “nugget-effect” and the brittle nature of the wolframite crystals, are turned to advantage. These same characteristics of the Panasqueira ore lend themselves perfectly to the use of Heavy Media Separation to remove approximately 80% of the ore which has no tungsten content.

The underground jaw crusher delivers <100 mm ore to the plant via the 1,203 m conveyer belt and three large storage bins. Separation and discarding of waste quartz and schist is the first step in the concentration process. Here the HMS system uses a hydro cyclone for separation using a dense slurry media with very fine ferrosilicon. This pre-concentrate is then fed via various crushing, screening and washing steps to the main concentration plant.

Panasqueira uses a conventional gravity concentration method followed by sulphide removal using flotation and final dry magnetic separation.

Some numbers:

- Annual Ore Production Capacity: 900,000 – 1,000,000 tonnes (ROM);
- Annual Concentrate Production Capacity: c. 100,000 mtu WO_3;
- 2 x 8h shifts x 5 week days;
- Mine Call Factor (MCF) of 150% due to mine and process plant different grade assessment.

Mine operations: (1) Raise-borer; (2) Low profile loader; and (3) Jumbo.

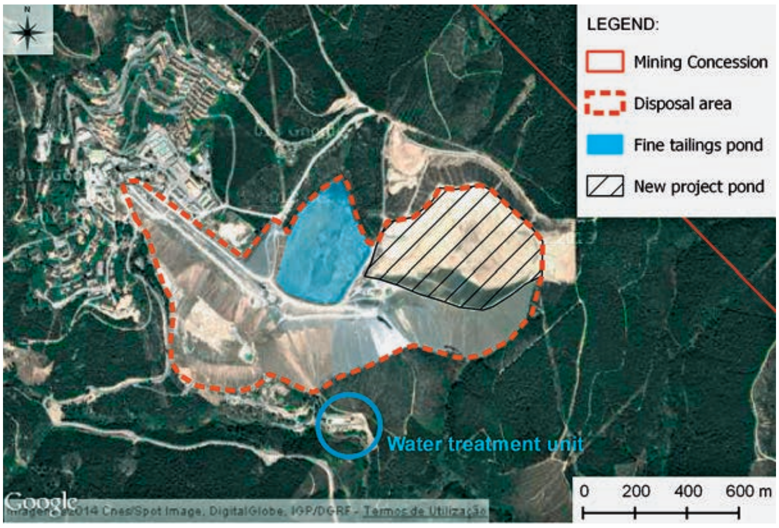
The plant produces a high quality tungsten concentrate with 74% to 75% WO_3. It also benefits from tin and copper by-products (tin 30t/year and copper 200t/year) and a stable WO_3 recovery rate at 80%.

The plant enjoys strong performance indicators:

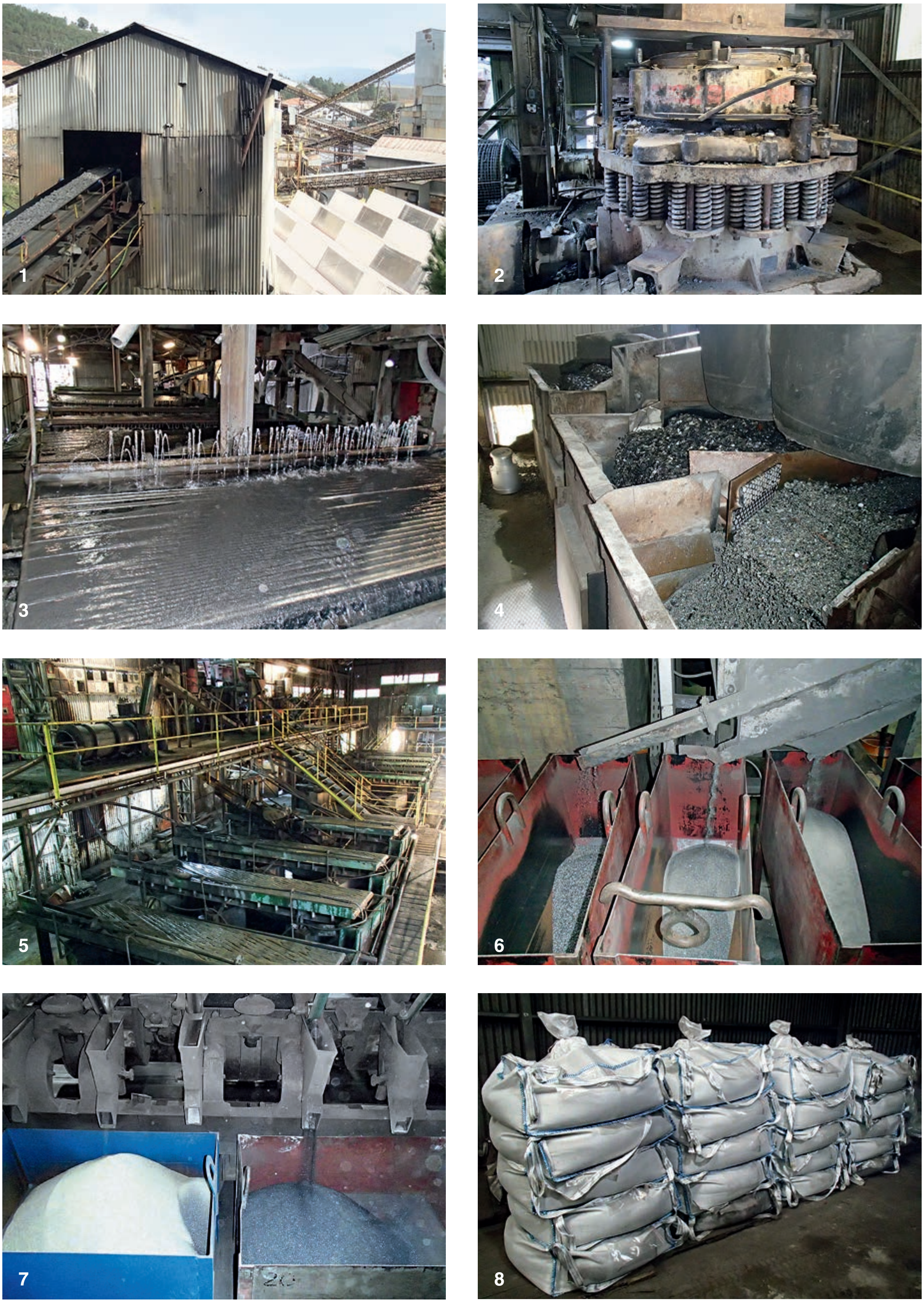
- Recovery rate significantly improved for Tin & Copper recently;
- 72t of tin concentrate at 72% Sn in 2013, from 46t in 2012;
- 350t of copper concentrate at 28% Cu grade in 2013, from 240t in 2012;
- Electro-mechanical availability of the plant: over 90%

On-site laboratory

Beralt has an on-site laboratory to test tungsten concentrate grades as well as contaminant levels in the water quality samples. The laboratory uses a gravimetric analysis to assess tungsten oxide (WO_3) and total sulphur content. It uses a titration analysis to assess the grade of by-products (tin, copper, arsenic, and phosphorus). The analyses performed by SBTW on site are comparable to the analysis performed by SBTW main customer's laboratory. Beralt delivers concentrate systematically at, or above, requested rate.



Satellite view of the disposal area. (Google satellite image, 2014)



Mineral Processing: (1) ROM getting in the Plant by conveyor belt; (2) 4.25 foot Symons short head cone crushers; (3) Coarse gravity shaking table (type Hercules); (4) Allis Chalmers 16´x 6´ screens discharge for concentrate and tailings in HMS; (5) General view of Final Concentration (Pre-Concentrate flotation on tables - type James - to remove sulphides); (6) Screening of concentrate before feeding Dry High Intensity Magnetic Separators cross belt; (7) Dry high-intensity magnetic separation of magnetic minerals (siderite and wolframite) from non-magnetic minerals (cassiterite and pyrite); and (8) Wolframite concentrates packed in one tonne big bags.

Environment

Beralt is strongly committed to environment preservation.

Mine Closure Plan and Site Rehabilitation
Beralt complies with Portuguese environmental law and International Environmental Standards relative to mine closure plans, as defined by the EU Commission.

The closure plan of Beralt establishes and ensures the creation and constant updating of a Closing Process for Panasqueira (for when the mine eventually closes). During the operation of the mine, it guides all decisions and actions of the management to safeguard the future of the natural environment, public health and safety of people. This ensures that the land would be available for alternative usage, appropriate for the region and sustainable in the long term. Socio-economic impacts due to the closing will be minimized as much as possible.

Beralt has prepared a mine closure plan since 2011 for the preparation of future mining operation achievement. The Mine Closure Plan covers all infrastructures and facilities and has involved all authorities (local, regional and national) and all stakeholders (affected groups and local organizations). Calculated costs for the closure plan assume 2038 as a hypothetical closure date. The plan and costs of implementation will be reviewed at intervals of five years (2017, 2023, 2028, etc.).

Other environmental items
Beralt holds all necessary environmental licenses:
- Environmental Permit (valid until 2014, to be re-applied for and renewed in the course of the year);
- License for using water resources (valid until 2016);
- License for rejecting wastewater (valid until 2016).

Beralt is strongly dedicated and continuously investing in the protection of its local environment:
- Improvement of water management by installation of a new thickener and lime dosing system in 2012 resulting in manganese release conforming to EU regulations;
- Ongoing construction of a new tailing disposal.

Ongoing construction of a new tailing disposal
After completion of construction work, only the geomembrane remains to be installed.

On–site disposal installations include:
- Sand and slimes tailings are disposed of in a dam built into the Northern section of the heavy media separation reject stockpile;
- Tailings pond also receives sludge from the water treatment plant.

Ongoing construction of a new tailing disposal (October 2012)

In anticipation of the saturation of the tailings pond (1 year of capacity left), the management started the construction of a new pond:

- In order to match construction of the required volume for fine tailings storage with the availability of supporting landfill construction coarse waste material, the work was planned to be carried out in 3 phases;
- Solution for tailings storage construction allows a total storage volume of about 1,726,500 m^3 or ~ 30 years given the current volume:
    - 164,500 m^3 during the 1^{st} phase ~ 3 years
    - 510,500 m^3 during the 2^{nd} phase ~ 9 years
    - 1,051,500 m^3 during the 3^{rd} phase ~ 18 years
- Estimated cost 6,219,000 €.

However, construction and operation of the pond will follow the mine storage needs and cash-out to come is limited. The new pond has already been built (hole dug).

Capex amounts to 1,500,000 € and only the geomembrane for phase I remains to be installed in 2014 (cost c. 400,000 €).

Beralt benefits from the EU tailings ponds Directive:

- Ponds can be used until the end of their useful life;
- No obligation to immediately cover a pond that reached the end of its useful life.

Water treatment plant

Water treatment plant is fully operational, with cost saving measures being implemented. The Salgueira water treatment plant treats used water from the mine and the tailings area.

Salgueira new water treatment unit

Lime conditioner of the mine drainage

The Salgueira treatment plant was designed in 1957. It consists of two treatment tanks, a multi-level building, and a lime storage and hopper system. A new unit has been added in 2011.

The plant collects water from several sources. Water is treated with the addition of lime, precipitate sludge is pumped to the tailings pond, and treated water is then discharged to the creek channel adjacent to the plant or pumped to holding tanks for later use in the mine.

The sources of used water include mine water drainage, surface accumulation on the old tailings area (Barragem Velha), water from the new tailings pond (Barragem Nova) and seepage from the base of the tailings.

The most significant flow to the plant is from the mine discharge. Lime is delivered to a loading area above the plant, fed by gravity to the treatment plant below, mixed with a small volume of water and then fed to the treatment tanks. The sludge generated during treatment is pumped to the Barragem Nova tailings pond. Treatment reportedly requires approximately 40 tonnes of lime each month, four to five operators and power to operate the plant and pump the sludge up to the pond.

The management has taken steps to increase the water treatment capacity and to reduce costs. For example the milk of lime (solution) used for water treatment that used to be purchased externally will in the future be produced on site from local lime powder. The mine has obtained a waiver on the maximum pH of waters to be released in the river (level of 10 instead of 9) and Mn.

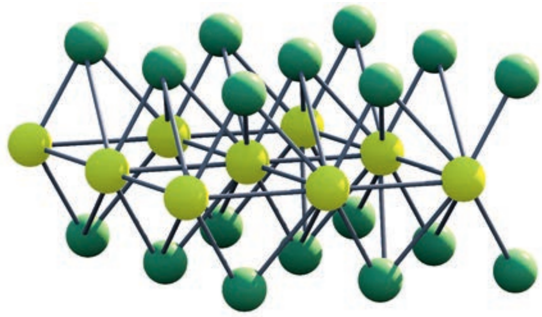
All images courtesy of Sojitz Beralt Tin & Wolfram (Portugal) S.A.

Editor's Footnote

From the foundation of the company to current ownership, from prospecting to actual production, from technical peculiarities to environmental aspects, the management of Panasqueira has provided an article which elaborates on each and every aspect of what it takes to run a tungsten mine and the challenges which are, despite many similarities, often unique to individual mines, including their special geology, geographical location and environment. Backed by the knowledge of the basics from the 2012 Newsletters, it is easy to appreciate the efforts required to mine tungsten in today's socio-economic environment.

Atomically Thin Solar Cells made from Tungsten Diselenide

Ultrathin layers made of Tungsten and Selenium have been created at the Vienna University of Technology. Experiments show that they may be used as flexible, semi-transparent solar cells.



Crystal structure of tungsten diselenide (WSe_2); tungsten atoms in the middle with a top and bottom layer of selenium.

The above headline attracted the interest of ITIA's Technical Consultant, Prof Wolf-Dieter Schubert, and together with the Secretary-General, Burghard Zeiler, he paid a visit to the Photonics Institute to see Prof Thomas Müller and to learn more about a potential new application for tungsten.

Thomas Müller began by explaining that, at the Vienna University of Technology, they had now succeeded for the first time in creating a diode made of tungsten diselenide. Experiments showed that this material could be used to create ultrathin flexible solar cells and even flexible displays could become possible.

One of the key observations in recent years was that ultrathin layers are different from regular crystals. At least since the Nobel Prize in physics was awarded in 2010 for creating graphene, these "two dimensional crystals" made of carbon atoms have been regarded as one of the most promising materials in electronics. In 2013, graphene research was chosen by the European Union as a flagship-project, with a funding of one billion euros. Graphene can sustain extreme mechanical strain and it has good opto-electronic properties. With graphene as a light detector, optical signals can be transformed into electric pulses on extremely short timescales.

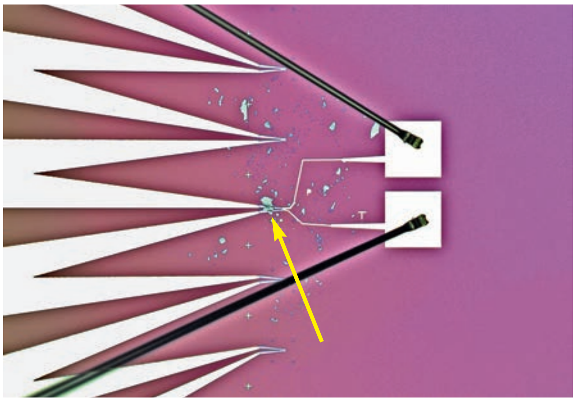
For one very similar application, however, graphene is not well suited: for building solar cells. "The electronic states in graphene are not very practical for creating photovoltaics", said Thomas Müller. He and his team therefore started to look for other materials which, similarly to graphene, can be arranged in ultrathin layers, but have even better electronic properties.

The material of choice was tungsten diselenide (WSe_2) which consists of one layer of tungsten atoms connected by selenium atoms above and below the tungsten plane. The material absorbs light, much like graphene, but in tungsten diselenide, this light can be used to create electrical power.

Thomas Müller explained some technical details, which may be the foundation to the production of the world's thinnest solar cells. The layer is so thin that 95% of the light just passes through, but a tenth of the remaining five percent, which is absorbed by the material, is converted into electrical power. The internal efficiency is therefore quite high. A larger portion of the incident light can be used if several of the ultrathin layers are stacked on top of each other – but sometimes the high transparency can be a useful side effect. "We are envisioning solar cell layers on glass facades, which let part of the light into the building while at the same time creating electricity", Thomas Müller enthusiastically explained.

Today, standard solar cells are mostly made of silicon and are rather bulky and inflexible. Organic materials are also used for opto-electronic applications, but they age quickly. "A big advantage of two-dimensional structures of single atomic layers is their crystallinity. Crystal structures lend stability", said Thomas Müller.

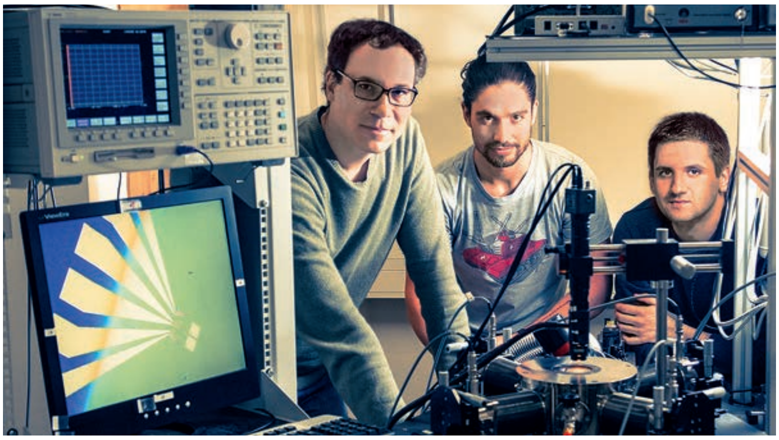
The results of the experiments at the Vienna University of Technology have now been published in the journal "Nature Nanotechnology" [1]. The research field is extremely competitive: in the same issue of the journal, two more papers were published, in which very similar results are shown. Researchers at the MIT (Cambridge, USA) and at the University of Washington (Seattle, USA) have also discovered the great advantages of tungsten diselenide. There seems to be little doubt that this material will soon play an important role in materials science all over the world, much like graphene has in the last couple of years.



Tungsten diselenide sample (light blue mono layer crystal in the centre (yellow arrow)) connected to electrodes (white, with black contact wires) to measure electrical properties. Surface area of the WSe_2 crystal is approximately 10 µm^2.

Currently, researchers all over the world are showing renewed interest in transition metal dichalcogenides (TMDs), such as tungsten disulfide (WS_2), tungsten diselenide (WSe_2), molybdenum disulphide (MoS_2) and molybdenum diselenide ($MoSe_2$) [2]. WS_2 and MoS_2 are abundant in nature and are widely used in industry, for example as an additive in lubricants. WSe_2 and $MoSe_2$ have to be produced synthetically.

Thomas Müller explained: "Two-dimensional TMDs, such as tungsten diselenide, have distinct advantages over traditional three-dimensional semiconductors, such as silicon, and are considered by many scientists as the electronic materials of the future". Researchers have already succeeded in creating electronic devices such as low-power transistors [3], electrical circuits [4], solar cells [1], and light emitters [1].



On the left, Thomas Müller, Professor at the Photonics Institute of the Vienna University of Technology, in his lab together with fellow researchers Marco Furchi and Andreas Pospischil (middle and right).

After this exciting news, we were most interested to hear about the practical challenges awaiting gifted researchers and engineers in their endeavors to turn the scientific findings into industrial products and to find viable ways for their commercialisation.

"The key for the success of tungsten diselenide in real-life applications is to find a reliable and commercially feasible technology to produce large-area two-dimensional crystals with reproducible properties and desired geometrical shape", Thomas Müller told us. For the production of two-dimensional sheets of TMDs, scientists currently rely on a technique that is called mechanical exfoliation: a piece of adhesive tape is used to peel off thin layers of material from a bulk crystal. The tape is then pressed on to a target substrate. Among the particles that remain stuck on the substrate, one can find atomically thin layers that are used to realise proof-of-principle electronic devices, which is a truly time-consuming endeavor. Who would have thought that adhesive tapes play a key role in today's cutting edge research?

Currently, the growth of two-dimensional crystals is in its infancy and has just started to develop. However, the research field progresses extremely fast and several research groups have reported promising results. As previously shown for graphene, chemical vapor deposition of TMDs on metallic and insulating substrates has been demonstrated [5]. To obtain large quantities, liquid-phase exfoliation of TMDs seems to be promising [6].

Basic research has prepared the ground for technologists to take over the challenge and to create a new application for tungsten. As it is "just" two-dimensional layers, a break through in this technology may not create a new major application for tungsten in terms of tonnage, but an interesting and beneficial one in any case. We wished Thomas and his colleagues all the best for their research and promised to keep the tungsten community posted of future developments in this field.

References:

[1] Pospischil et al., Nature Nanotechnology 9, 257 (2014)
[2] Wang et al., Nature Nanotechnology 7, 699 (2012)
[3] Radisavljevic et al., Nature Nanotechnology 6, 147 (2011)
[4] Wang et al., Nano Letters 12, 4674 (2012).
[5] Huang et al., ACS Nano 8, 923 (2014).
[6] Coleman et al., Science 331, 568 (2011).

All images courtesy of Vienna University of Technology

ITIA news

27th Annual General Meeting, 21–24 September, Toronto, Canada

The 27th AGM will be held in the Westin Prince Hotel in Toronto from Sunday 21 to Wednesday 24 September and will be jointly hosted by Member Companies in Canada and the US including Kennametal Inc, Almonty Industries Inc, Federal Carbide Co, Mi-Tech Metals Inc, North American Tungsten Corp Ltd and Tungco Inc who have invited delegates to a dinner on Tuesday evening. The event will be followed by optional plant visits kindly offered by two Member Companies in the US: Global Tungsten & Powders Corp's plant in Towanda, PA on Thursday 25 September and Federal Carbide Co's plant in Tyrone, PA on Friday 26 September.

As always at these AGMs, the chance is taken to hear updates from experts in the principal market sectors as may be seen from the list of papers and speakers below:

- **China Tungsten Market Update**, Mr Xiao Wenqiang, Manager of Powder Materials Department, Zhuzhou Cemented Carbide Works Import & Export Company
- **Update on the Japanese Tungsten Market,** Mr Furkhat Faizulla, Deputy Director, Advanced Material Japan Corp
- **Tungsten Recycling: Technology, Potential and Limits,** Prof Wolf-Dieter Schubert, ITIA Technical Consultant, and Dr Burghard Zeiler, ITIA Secretary-General
- **European Tungsten Market Update,** Mr Wolfgang Budweiser, Director Sales EMEA, HC Starck GmbH
- **The Tungsten Industry Conflict Minerals Council (TI-CMC),** Mr Steffen Schmidt, Board Member of TI-CMC
- **US Tungsten Market Update,** Mrs Stacy Garrity, Director of Sales & Marketing, Global Tungsten & Powders Corp

Toronto landscape with the CN Tower in the foreground. © Imel900-Fotolia.com

- **US Tungsten Market Update,** Mrs Stacy Garrity, Global Tungsten & Powders Corp
- **Summary of Tungsten Market, Trend of Tungsten Mining Costs and Project Update,** Mr Robert Baylis, Managing Director, Roskill Information Services Ltd

Papers and speakers are subject to change. For the full programme, registration forms, hotel reservations and visa advice, readers should go to the ITIA website.

ITIA membership

Welcome to:

Betek GmbH & Co KG (Germany), a producer of tungsten carbide tools and wear parts (previously a member from 2003 to 2009)

Blackheath Resources Inc (Canada), exploring tungsten mines which had produced in the past in Northern Portugal

For a full list of ITIA members, contact details, and products or scope of business, please refer to the ITIA website – www.itia.info.

ITIA tungsten consortium

Compliance with REACH – a service from the ITIA

Among all update requests on Joint-Submission Part of Registration Dossiers received in 2013, the following updates were agreed by the Consortium and have been successfully submitted to ECHA by the Lead Registrants on behalf of relevant Co-Registrants:

Substance	Descriptions of Updates on Dossier including Chemical Safety Report
Sodium Tungstate	To include laboratory reagent and fine chemicals downstream use
Tungstic Acid (dihydrogen wolframate)	To include new uses of: • Use of tungstic acid in research and development • Use of tungstic acid in the production of catalysts containing tungsten trioxide
Tungsten Carbide	Composition change to cover impurity levels ranging 1% to 20%. *Note: the original default value of each impurity was less than 0.1%, however, impurities such as O_2, free C and/or W_2C are possibly exceeding 0.1%*
Tungsten Metal	• Modifying description on production of tungsten-containing steels and super-alloy articles. The updated text reflects correctly that tungsten powder is not used in the production of steel/alloy ingots. • Modifying GES 4: Production of tungsten-containing steel and super-alloy articles. New descriptor codes to include description on ingot route for article production.

The Consortium Secretariat will continue to prepare updates to the Technical Dossiers when necessary. Members of the Consortium and/or SIEFs can send their update requests for inclusion. Details and request forms for Dossier updates can be found on the Consortium's SIEF website – sief.tungstenconsortium.com.

SCMG Europe GmbH, a German company, has joined the Consortium this year.

For further details of the Consortium work programme, a list of members, conditions of Membership and purchase of Letters of Access and Recyclers Agreements, please refer to the Consortium websites – www.tungstenconsortium.com and www.sief.tungstenconsortium.com.

Dr Burghard Zeiler
Secretary-General