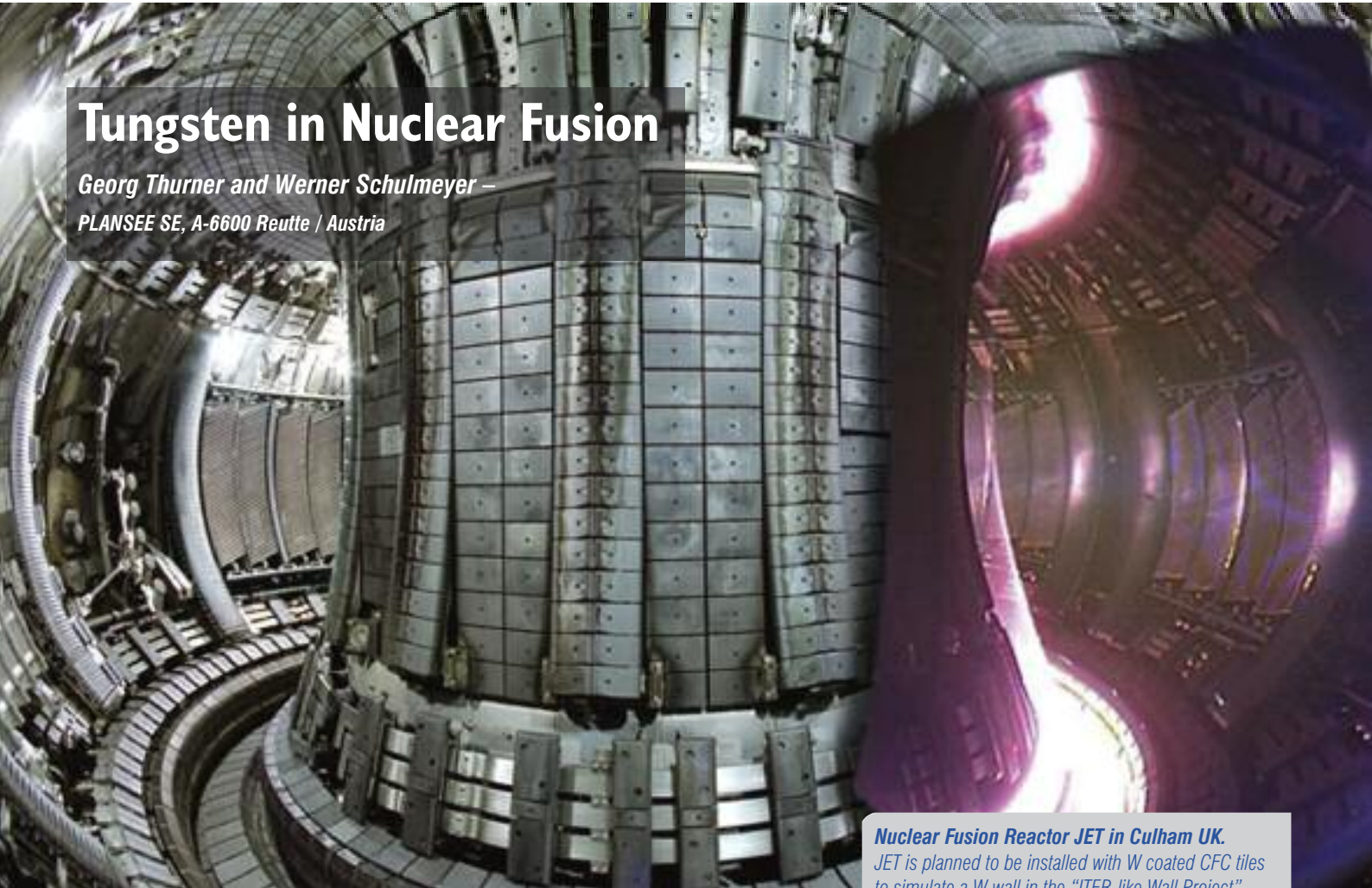




## Tungsten in Nuclear Fusion

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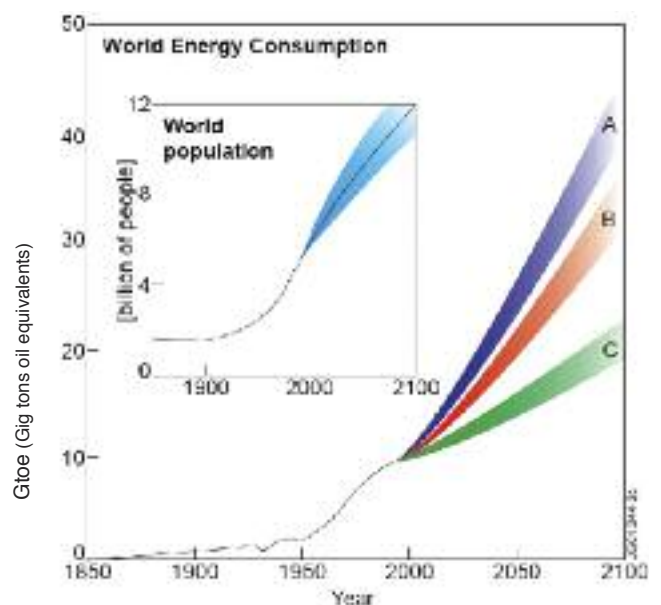


**Nuclear Fusion Reactor JET in Culham UK.**  
JET is planned to be installed with W coated CFC tiles to simulate a W wall in the "ITER-like Wall Project"

The following article is based on a paper presented at the ITIA's AGM last September and has been kindly edited for this Newsletter by Dr Georg Thurner, Head of Quality-Safety-Environment Management and Corporate Security at Plansee SE, Austria.

### Why do we need Nuclear Fusion?

The world population will further increase throughout the next decades. At the same time, the energy consumption will grow accordingly. Currently experts are discussing three different scenarios, depending on economic growth and technological improvements (Fig. 1). Scenario (A) is a high growth scenario with high economic growth and impressive technological developments. Scenario (B) represents intermediate economic growth and less ambitious technological improvements and Scenario (C) is an ecologically driven scenario which represents a rich and green future. No matter which scenario will commence, each case will lead to an extensive growth in energy consumption.



**Fig. 1: Scenarios for increasing energy consumption**  
(Source: J. Ongena, G. Van Oost, Fusion Sci. Technol., 2006, 3-15)

Today three groups of energy sources are used: fossil energy (85%), renewable energy (13%) and nuclear fission energy (2%). To cover the huge energy needs which are predicted for the next generations, the actual energy sources seem to be inappropriate. Fossil energy is limited in resources and produces carbon dioxide emissions, which account for global warming. The share of renewable energy sources will further increase, but their potential to replace all fossil energy sources as a reliable primary power supply is questionable. Nuclear fission is associated with limited resources, the burden of highly radioactive waste and the risk of uncontrolled reactions leading to potentially severe accidents. What we need to overcome these limits is an energy source which is safe, reliable, independent from natural boundary conditions (daytime/seasons, wind) does not disturb the environment, and has unlimited and uniformly distributed resources. An answer to that could be nuclear fusion, the energy of the sun.

## Nuclear Fusion – basic principles

Energy conversion by nuclear fusion is based on the effect that the mass of an atomic nucleus is smaller than the sum of the masses of its constituents (the so-called mass defect). If light elements, like hydrogen, are fused to heavier elements, like helium, the mass balance is converted into energy according to the equation

$$E = mc^2.$$

To combine the positive charged hydrogen nuclei, one has to overcome the high repulsive electrostatic forces. Inside the sun this happens because of high gravitation and a temperature of about 15 million °C. On earth gravitation is much lower and we have to increase the temperature to about 100 million °C to give the hydrogen nuclei sufficient kinetic energy to allow for nuclear fusion.

In nuclear fusion experiments the Deuterium-Tritium reaction (**Fig. 2**) is preferred as it means the most efficient reaction having the highest mass defect:



The heavy hydrogen isotopes Deuterium (2.01 AMU) and Tritium (3.02 AMU) are fused to form Helium (4.00 AMU) and a high energetic Neutron (1.01 AMU). The mass balance of 0.02 AMU is converted into 17.6 MeV of energy.

During normal chemical reactions like combustion of fossil fuels the amount of energy conversion is in the range of electron volts per molecular unit. In nuclear fusion it is a million times higher (mega electron volts) giving the immense potential of nuclear fusion.

## Nuclear Fusion – Fuels

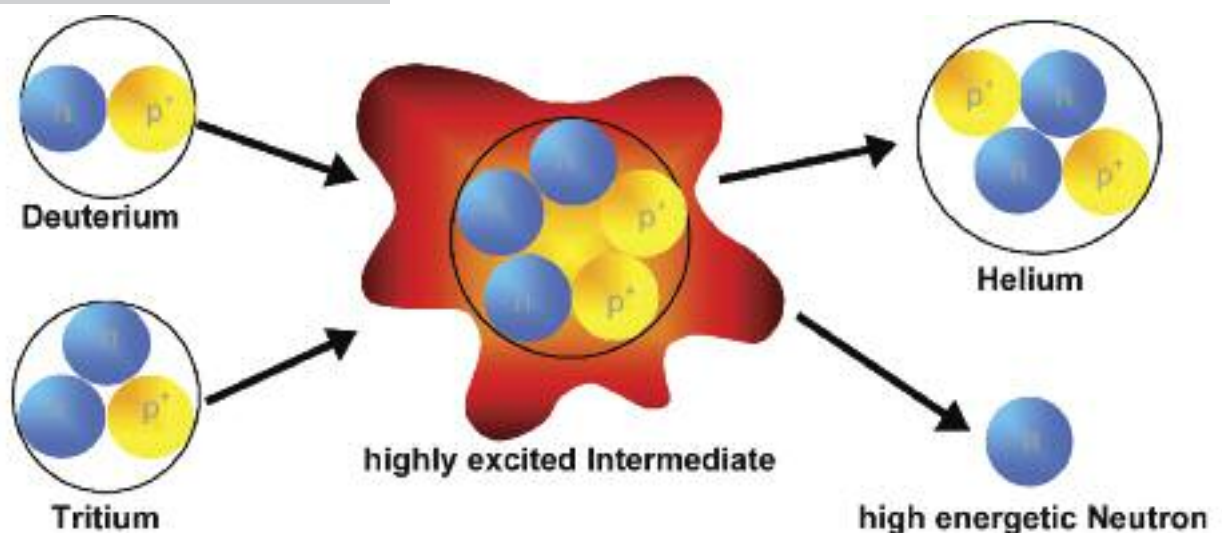
As mentioned before the most suitable fuels for nuclear fusion are Deuterium and Tritium. Deuterium occurs in ordinary water, having 33g of Deuterium in one metric ton of water. Tritium does not occur naturally, nevertheless it can be bred out of Lithium, according to the reaction:



Lithium is a constituent of rocks and therefore as widespread as it is easily accessible.

As a conclusion, the primary fuels for nuclear fusion, water and rocks, are inexhaustible. The annual fuel consumption of a family would be 2litres of water and 250g of rock.

**Fig. 2: Deuterium-Tritium Reaction**

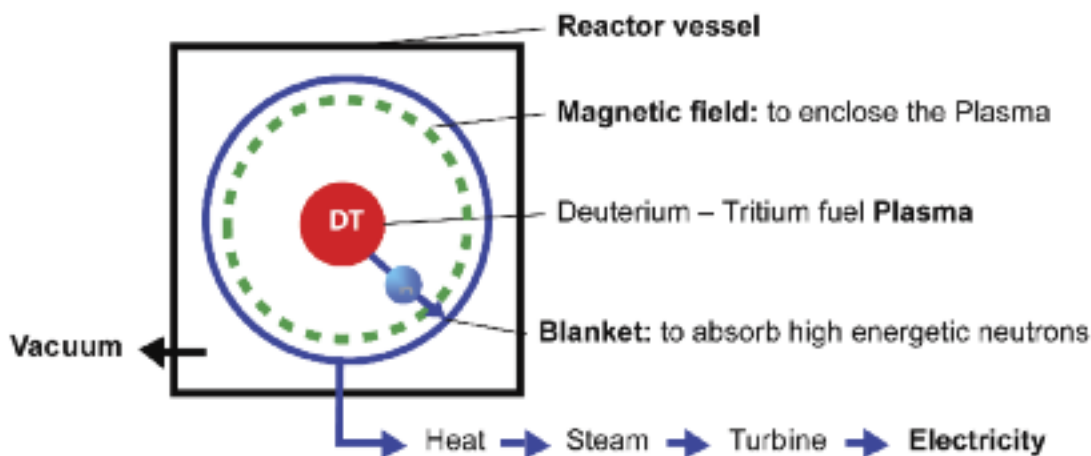


## Nuclear Fusion Reactors

**Fig. 3** shows the basic principle of a nuclear fusion reactor.

The vessel of a nuclear fusion reactor is a vacuum chamber in which the Deuterium-Tritium plasma is enclosed by a strong magnetic field to contain it and to thermally isolate it from the surrounding walls. The Deuterium-Tritium reaction yields high energetic neutrons which are used for heating by absorption within the so called blanket. Subsequently the heat within the blanket is converted into steam and finally electricity by a conventional heat exchange and turbine system.

**Fig. 3: Basic principle of a nuclear fusion reactor**

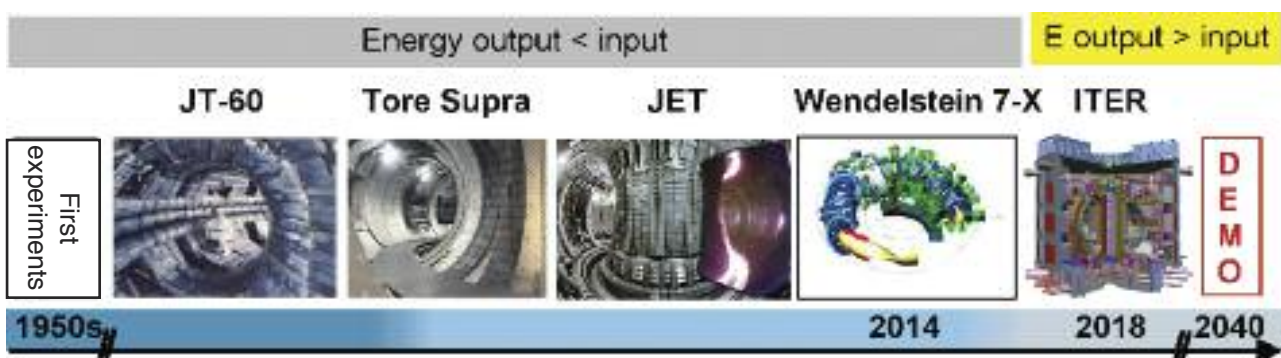


Most nuclear fusion reactors are designed according to two different basic options, depending on the geometry of the magnetic field. The Stellarator has very complex magnetic field geometry but enables a continuous operation. In comparison the Tokamak reactor has much simpler magnetic field geometry but can be operated only in a pulsed manner.

Energy output of all experiments was (and still is) lower than the energy input. The international thermonuclear experimental reactor ITER, which is planned to start its operation in 2018, is aiming to become the first nuclear fusion reactor to achieve a positive energy balance by a factor of 10. The first prototype of a commercial nuclear fusion reactor, the so-called DEMO reactor, is expected to go live in 2035. See **Fig. 4**

The first experimental nuclear fusion reactors were built in the 1950s. All nuclear fusion experiments so far had the goal to demonstrate the feasibility principle of the fusion reaction in a manmade reactor.

**Fig. 4: Development of nuclear fusion reactors**



## Material Challenges

So far feasibility of controlled nuclear fusion in principle has successfully been demonstrated in a number of experiments. One of the biggest challenges in the further development of nuclear fusion reactors is to develop appropriate materials for the plasma facing components due to the extreme operating conditions and required lifetimes (Fig.5). For example plasma temperatures exceed 100 million °C. One of the most exposed components, the so-called divertor, is a high performance heat exchanger which has to withstand thermal fluxes up to 20 MW/m<sup>2</sup>, high temperature gradients (up to 1,500 °C/cm), numerous thermal cycles, as well as high neutron irradiation and ion bombardment.

## Tungsten – the preferred material for plasma facing components?

Applicable materials for such high performance heat exchangers are Carbon Fibre Composites (CFC) and Tungsten (Fig.6).

The behaviour for CFC at plasma facing conditions is well known based on its traditional use for more than 50 years in nuclear fusion experiments. One of the disadvantages of CFC is its high retention of Tritium due to its porosity. This leads to a radioactive contamination of the plasma facing components, which is unacceptable for a commercial power plant.

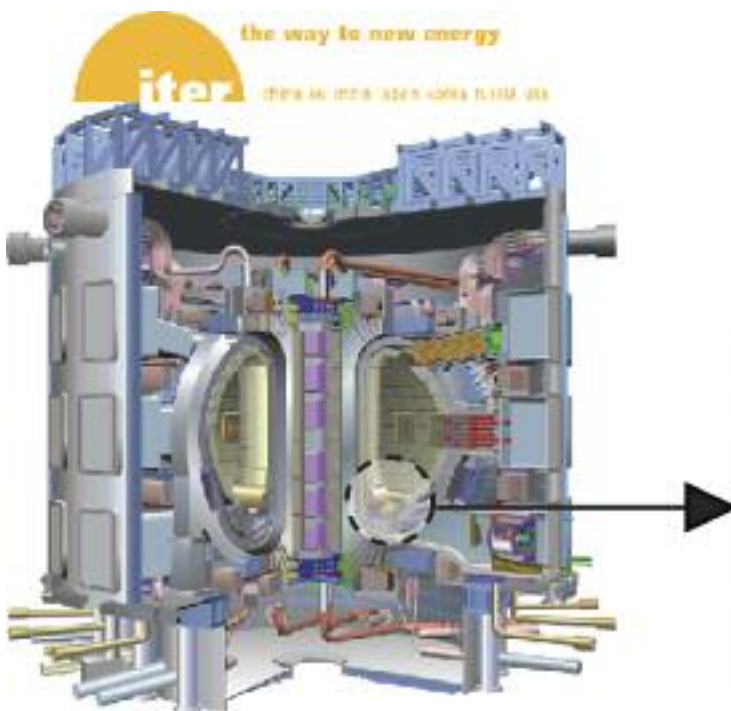


Fig. 5: Plasma facing components in ITER

Full-scale model of a divertor

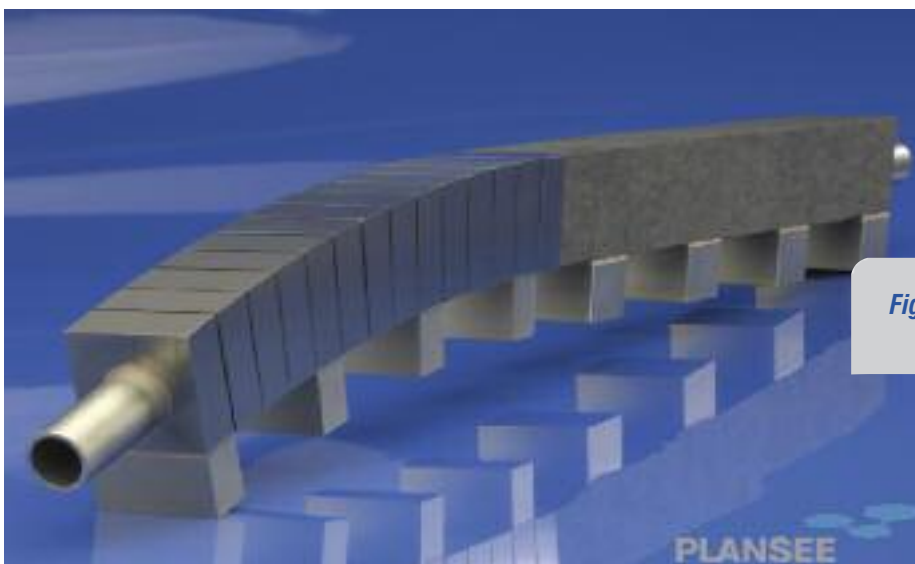


Fig. 6: Divertor Plasma Facing Unit with W and CFC monoblocks

Plasma facing components made from dense Tungsten do not show Tritium retention and therefore no radioactive contamination. As the use of Tungsten in nuclear fusion is fairly new its interaction with the plasma has yet to be fully explored. Nevertheless Tungsten is the most promising material for plasma facing components so far.

## Next steps

Currently an extensive development of Tungsten divertor prototypes is in progress. A number of high level skills are required in this effort: Manufacturing of complex composites based on new joining technologies, high end quality assurance technologies, as well as handling of comprehensive project management.

**Fig. 7** shows an ITER Qualification Prototype. CFC and Tungsten Monoblocks are joined to a CuCrZr cooling tube constituting three plasma facing units (PFUs) on top. The PFUs are then connected to a 316L steel heat exchanger element via adapters.

Prototypes as shown in **Fig. 7** allow for investigation of behaviour and properties of Tungsten and CFC by testing under near plasma facing conditions.

## Summary

Nuclear Fusion is a promising energy source for the future. Extreme conditions (plasma temperatures of above 100 million °C) require high performance materials for the plasma facing components for which Tungsten is one of the most promising materials. Further development is required to demonstrate the usability of Tungsten in this application.

## Further Information

<http://www.iter.org>

<http://www.plansee.com/power-engineering-nuclear-fusion.htm>



**Fig. 7:** ITER Qualification Prototype

## Membership

Welcome in 2009 to:

- ▶ **Geodex Minerals Ltd**, a Canadian based resource company, with a focus on the development of its flagship project Sisson Brook, an open-pit tungsten-molybdenum deposit in New Brunswick, Canada
- ▶ **Hazelwood Resources Ltd**, an Australian company, is aiming to become a tungsten producer in 2010 at its Big Hill Tungsten Project.
- ▶ **Newcrest Mining Ltd**, an Australian company, has identified a significant tungsten deposit in Western Australia in close proximity to its existing Telfer Gold Mine, where extensive infrastructure already exists.

and, in 2010, to

- ▶ **Wogen Resources Ltd**, a UK company, trading tungsten ores and concentrates, various tungsten oxides and tungstates, metal scrap and ferro tungsten.

## Elections to the Executive Committee

The AGM unanimously approved the election of:

- ▶ **Bernard North**, Chief Engineer, Kennametal Inc
- ▶ **Gao Bo**, Deputy General Manager of Tungsten Department, China Minmetals Corp

in place, respectively, of David Landsperger and Wang Lixin

## Appointment of HSE Consultant

The ITIA has retained the services of **David Landsperger**, formerly Director of Metallurgical Operations at Kennametal Inc (and a long-standing member of the ITIA Executive Committee) before his retirement at the end of 2008, to manage and co-ordinate our HSE work programme, in conjunction with the HSE Committee, and to supervise the activities of all consultants used by ITIA in connection with HSE. Not least amongst his aims will be an improvement in the method of reporting to members – clear, brief non-technical summaries.

Landsperger's reputation in, and knowledge of, the industry is second to none. Whilst his expertise may not be specifically in HSE, he has many years' experience as a director and manager; his ability to deal with government departments in the USA and his wide knowledge of the problems facing the US tungsten industry from the regulatory authorities bring an invaluable asset to ITIA. These comments may appear US-centric, but it is currently in the USA where the focus is on tungsten, often adversely, and Landsperger will liaise regularly with members and organisations in other countries, visiting as necessary.

He will also assume the same role in supervising the work programme of the Tungsten Consortium.

## 22nd Annual General Meeting, 14-18 September 2009, Vancouver

Generously hosted by North American Tungsten Corp, the Association's 22nd AGM was held in the Marriott Pinnacle Hotel in Vancouver and, despite the harsh economic climate, was attended by over 200 delegates.



**Jesper Gullberg**, Lead Buyer with Sandvik Tooling, was elected President of the Association at the 21st AGM in 2008 in Xiamen. He is seen here on the right with Steven Leahy (on left), Chairman and CEO, North American Tungsten, elected at the same time as Vice-President.

Welcoming delegates to the 22nd AGM, Gullberg recalled that not only was Vancouver a city steeped in history – there was evidence that people had lived there for over 2,000 years – but that it was in Vancouver that the ITIA itself was conceived in 1987, arising from the ashes of the tungsten producers' association. Reviewing the activities of the Association over the last year, he noted the continuing emphasis on the HSE work programme to which 60% of the budget was allocated and expressed appreciation to the HSE Committee for enduring the heavy work-load. The Committee had been ably led for many years by Carmen Venezia (Global Tungsten and Powders) supported by Georg Thurner (Plansee) as Vice-Chairman and now by David Landsperger as HSE Consultant (see separate section).

Although a separate entity, the Tungsten Consortium had occupied a great deal of everyone's time to ensure that its work programme progressed according to plan. The Consortium had been formed on the initiative of the ITIA which had taken a clear role in making certain that all deadlines were met.

The highlight this year was the publication of the new Tungsten Brochure (see separate item) and thanks were due to all those who had contributed material to bring about its success.

Gullberg concluded by thanking North American Tungsten and Steven Leahy for hosting the AGM and allowing the visit to the Cantung mine; to EMC Metals and the Yukon government for co-hosting the dinner with NATC on Wednesday evening; and to Bernard North and the plant manager, Johnny Martin, of Kennametal for arranging the visit to their Langford plant on Vancouver Island.

Each year it becomes more difficult to match the high quality of the speakers and their presentations and the following list explains why the meeting-room was full at all times.

- ▶ **An Update on HSE Issues, Carmen Venezia, Global Tungsten & Powders Corp**
- ▶ **Tungsten Carbide in Oil and Gas Drilling Applications, Dan Scott, Baker Hughes Inc**
- ▶ **Tungsten in Nuclear Fusion, Georg Thurner, Plansee SE**
- ▶ **Update on the US Tungsten Market, Kevin Blasi, Global Tungsten and Powders Corp**
- ▶ **The Mactung Project, Stephen Leahy and Britt Reid, North American Tungsten Corp**
- ▶ **The Background and Analysis of Relevant Policies and Reforms to China Tungsten Industry, Huang Guoping, China Minmetals**
- ▶ **O'Callaghans Project, Brian Kinsella and Li Tao, Newcrest Mining Ltd**
- ▶ **Latest Situation in the Japanese Tungsten Market, Motoki Nishino, Advanced Material Japan Corp**
- ▶ **Electroplating Tungsten Alloys and its Applications, He Fengjiao, Hunan University**
- ▶ **Tungsten in Russia, Denis Gorbachev, Wolfram Co CJSC**
- ▶ **Review of Projects and Reserves, Mark Seddon, Roskill Information Services Ltd**

Delegates turned their attention to less serious affairs in the evenings, notably at a delightful dinner in Stanley Park where North American Tungsten was joined as the host by EMC Metals Corp and the Yukon Government. The humorous speech by the Minister of Energy, Mines and Resources, the Hon Archie Lang (see pic), will be a model for dignitaries on future occasions.



Led by Steve Leahy (see pic), two chartered planes just managed to beat the weather and take 36 delegates on a visit to North American Tungsten's Cantung underground scheelite mine high in the wilderness of Canada's Northwest Territories.



Back at sea-level, Kennametal Inc was kind enough to invite some 45 delegates to take the ferry to Vancouver Island and tour its Langford plant which manufactures tungsten carbide special parts. Bernard North, Chief Engineer at Kennametal, hosted the visit (front row far right).



## **Tungsten Consortium ..... Compliance with REACH - a service from the ITIA**

### **Six more companies have joined the Consortium**

- ▶ **Albemarle Catalysts Company BV, Belgium**
- ▶ **Cronimet Holding GmbH, Germany**
- ▶ **Element Six GmbH, Germany**
- ▶ **Intermetal Compagnie Des Metaux AG, Liechtenstein**
- ▶ **HC Starck GmbH, Germany**
- ▶ **Technogenia SA, France**

(To view the full list of Consortium members, please refer to the Consortium website – [www.tungstenconsortium.com](http://www.tungstenconsortium.com))

Improvements were introduced to the website for Consortium members, notably to enable members more easily to track progress on the completion of the scientific dossiers which will supply the data required for registration of tungsten substances with the European Chemicals Agency (ECHA). The Consortium Technical Committee shouldered the heavy burden of this vital activity.

Extensive work took place to set up Substance Information Exchange Forums (SIEFs) for each substance, having established "sameness of substances" and having agreed Lead Registrants (LRs) for each of the ten compounds under the aegis of the Consortium. The SIEF websites went live in July 2009.

It is understandable that some companies with only a limited interest in the tungsten market have chosen not to join the Consortium but to purchase a Letter of Access at a later stage. A Letter of Access will be essential for each substance and for each separate company entity intending to register one of the substances covered by the Tungsten Consortium. So companies with several legal entities may decide that membership of the Consortium, even with a 10%

surcharge for joining late, may be a more economical option. If a company manufactures or imports a tungsten substance not so covered, it is possible that read-across data from sodium tungstate will suffice and the Consortium will be happy to discuss this on a case by case basis.

A Letter of Access will give the registrants of the tungsten substances the right to refer to all the information as provided in the Lead Registrant's registration dossier and will provide registrants with the registration token allowing them to register.

A final decision about costs and other details is expected by end April 2010 after a survey has been conducted. The Consortium recognises its obligation to assess the cost in a fair, transparent and non-discriminatory fashion and this exercise will help us to do so.

Whilst the Secretariat will co-ordinate and complete as much work as possible on behalf of Consortium members, registration itself has to be effected by individual companies with ECHA. As an aid, ITIA is providing a guide to IUCLID 5 (the complicated on-line process to register), using professional help and seminars.

The next meeting of the full Consortium Committee will be held in Vienna on Wednesday 29 September 2010 on the occasion of ITIA's 23rd Annual General Meeting.

## ITIA 23rd AGM, September 2010, Vienna

CERATIZIT and Wolfram Bergbau-und Hütten will co-host the ITIA's 23rd Annual General Meeting in Vienna and the provisional outline programme is as follows:

Date	Meeting/Function
<b>Sunday 26 Sept</b>	- Consortium Technical Committee
<b>Monday 27 Sept</b>	- Consortium Technical Committee - Consortium Steering Committee
<b>Tuesday 28 Sept</b>	- Joint meeting of HSE and Executive Committee - Executive Committee - ITIA Reception (all delegates)
<b>Wednesday 29 Sept</b>	- AGM - Consortium Committee - Dinner hosted by CERATIZIT and Wolfram Bergbau
<b>Thursday 30 Sept</b>	- AGM - Depart for optional visit to the Mittersill mine and overnight stay in Salzburg
<b>Friday 1 October</b>	- Visit mine - Return to Vienna

Further details of this annual event, at which the worldwide industry gathers, will be posted to our website in late May, including a registration form. Companies which are not ITIA members may attend the AGM (there is a fee) and receive presentations on a variety of industry and general topics.

*Apologies to readers who noticed that there was no June 2009 issue. The editors and art designer had to give priority to ensuring the new Tungsten Brochure was ready for distribution to delegates attending the AGM in September 2009.*

**For a full list of ITIA members, contact details, and products or scope of business, please refer to the ITIA website – [www.itia.info](http://www.itia.info).**

## Tungsten Brochure

Essential reading..... A brand new Tungsten Brochure has been published by ITIA. This one is 134 pages compared with 33 pages of the 1997 version and contains fascinating text about the Past, the Present and the Future of Tungsten and a rich compendium of illustrations. Each brochure contains an electronic version in the form of a CD. Send an email to [info@itia.info](mailto:info@itia.info) with your postal address for a free copy.

The principal authors were Dr Erik Lassner and Dr Wolf-Dieter Schubert who make up the ITIA's Technical Consultancy Service. Sadly for the Association, Erik Lassner has decided to retire for the second time and, at the age of 80, one has to admit that he is entitled to call it a day.

Born in 1930, Lassner studied chemistry at the Technical University in Graz, Austria. He worked for Metallwerk Plansee as Laboratory and R&D Manager between 1956 and 1975, before joining Wolfram Bergbau as Plant Manager and becoming a Director. He retired in 1993 and is the author of many technical and scientific publications.

As Jesper Gullberg, ITIA President, said in his opening address at the AGM, Lassner had always been a great supporter of the ITIA and, with his wide experience in the field of tungsten, he had provided technical and scientific support to the organisation since 2003; his expertise will be sorely missed.

