The Crucible

Cobalt Market Report

Finnish Mining Update

INSIDE THIS ISSUE

As part of a process of enhancing and improving the value of MMTA membership, we have devised a short survey. Please help us to raise the value of your membership by completing the below short (2 minutes) survey.

Membership Survey

MMTA WAREHOUSE UPDATE

The MMTA's rules are determined by the Members of the MMTA. If the Directors are petitioned by a significant number of Members to reconsider any particular MMTA Rule, then the Directors have a duty to consider possible amendments to the MMTA Rules and put those amendments to a vote of the Members.

The MMTA Warehouse Rules require that: "The company shall be neutral, not owned or associated with any trading company".

The MMTA Warehouse Rules were debated extensively in October 2011, when 97% of warehouse using Members voted not to change the above requirement.

The MMTA Warehouse Rules were again discussed at the AGM on 25 April 2013. One Member spoke in support of change and one Member spoke against in an otherwise low key debate. Despite an invitation from the chair, no other warehouse using Member has petitioned either the MMTA Directors or the MMTA Executive requesting that the existing Warehouse Rules be amended.

The MMTA Warehouse Committee reported at its meeting on 11 June 2013 that the MMTA had received two Warehouse Approval requests from Pacorini Metals and one from CWT Commodities. Following the initial expression of interest from NEMS, no formal request for Warehouse Approval has been received.

Pacorini Metals is in a group that includes Glencore Xstrata; CWT Commodities is in a group that includes Marc Rich Investments and NEMS is in a group that includes Trafigura.

The MMTA Warehouse Committee has concluded that as Pacorini Metals and CWT Commodities are each in a group that includes a "trading company", they do not meet the criteria within the MMTA Warehouse Rules and therefore cannot be given Warehouse Approval by the Committee. This is in no way a reflection on any other aspects of the businesses of the companies concerned. The warehouses in question are used by some Members. They simply do not meet the criteria for approval determined by the Membership of the MMTA.

The Warehouse Committee has passed this issue to the MMTA Directors for a final determination.

As a result of conflicting business commitments of a number of Directors, the MMTA Directors' meeting scheduled for 18 June 2013 did not take place and is to be rescheduled in September 2013 after the holiday period.

MMTA Members are reminded that they are free to use any warehouse they choose, MMTA Approved or not. In many instances Members choose to use warehouses that are not MMTA Approved.

The only reference to use of MMTA Approved Warehouses is in the Trade Regulations, which is a form of contract provided for the convenience of Members which they are free to use for trade with a counterparty if both parties wish to do so. Its use is not required and indeed many, if not most, members will use their own contract terms when conducting business.

The Trade Regulations provide that:

"The usual basis of trade in respect of these Terms and Conditions shall be "in warehouse" and, unless otherwise agreed at the time of concluding each contract, shall be in a warehouse currently listed in the Association's List of Approved Warehouses."

Members and others can therefore use the Trade Regulations and still agree to use a warehouse that is not MMTA approved.

The MMTA is an association of Companies involved in all aspects of the minor metals trade who have over time determined clear rules of best practice for the safe undertaking of transactions in minor metals for all parties involved. These historically determined rules based on good intentions and the vast experience and wisdom of the Members are embodied in the MMTA Rules including the MMTA Warehouse Rules.

Roy Walton, MMTA Chairman

NEW MMTA OFFICE IN CENTRAL LONDON

It is with enormous pleasure, and a great deal of relief, that I am able to announce that the MMTA has recently taken residence in its new offices at 3 Whitehall Court, in the heart of London, and only a minute's walk from the Embankment Gardens and the River Thames.

The new office is at Embankment Tube (Northern, Circle and District lines), and is within easy walking distance of Waterloo and Charing Cross main train stations. Other mainline train stations are only a short journey away.

You may be aware that it has been our goal to move to more centrally located offices, which will enable Members to make use of dedicated office and meeting space when visiting London.

Whether you are travelling to the UK from abroad, or simply 'in town' for a few hours, we invite MMTA Members to make use of our new offices. We can accommodate up to 16 in our meeting room, or you can just book the office to work in. There is free guest wi-fi, and use of a flipchart, projector and screen are also possible on request.

Equally, if you need us to arrange catering for a meeting, please speak to either Maria or Emma.

This is a free member benefit—all you need to do is contact the MMTA executive team, who will be happy to reserve the space for you.

Maria Cox, General Manager, MMTA

MMTA NEW OFFICE WELCOME DRINKS RECEPTION—17TH SEPTEMBER 5.00PM

The MMTA Main Committee invites Members to join them at the MMTA's new offices in 3 Whitehall Court to celebrate our relocation. After a viewing of the new office, drinks and snacks will be provided at the Farmers' Club upstairs with views of the Embankment Gardens and River Thames.

DIARY DATES

- **Wogen vs MMTA Cricket Match, Networking Social Event, London, UK** Sold out
- **Site Visit—Campine NV, Beerschot, Belgium, 2 September** Sold out
- **MMTA New Office Welcome Drinks Reception, MMTA, London, UK, 17 September**
- **Arbitration 1/2-day Seminar, London, UK, 18 September**
- **MMTA's 40th Anniversary Dinner, Intercontinental Hotel, London, UK, 8 October**
- **New York Dinner, Waterclub, New York, USA, 12 December**
- **Christmas Lunch, Pewterers' Hall, London, UK, 18th December**

JOB VACANCIES

Trainee Metal Trader:

situated North Midlands area

To work in a small but busy office environment

Liaise directly with customers and suppliers

Will be expected to learn all aspects of metal trading and associated administration

A clean driving licence is essential

Package; Car and benefits

Salary: circa £30 - 35k + bonus, dependent upon experience

Works Manager:

situated North Midlands area

Working in warehouse/ processing environment alongside workforce

Responsible for all aspects of receipt, processing and despatch

Work to customer deadlines and quality demands

Must be numerate and have good organisational skills

Experience within the Metals industry helpful but not a necessity

Salary: circa £26k + bonus

Interested parties should contact maria@mmta.co.uk

in the first instance.

METALS PRO CLIMATE DIALOGUE, BRUSSELS

The MMTA recently had the opportunity to attend the Metals pro Climate Dialogue held in Brussels on 5th June. The evening's discussion focussed on the objectives, scope and challenges of environmental and resource efficiency productivity indicators, and Metals pro Climate, along with co-hosts Eurometaux and the Nickel Institute, were joined by speakers from the European Commission and Parliament, as well as from the OECD to discuss this important and very current topic.

By way of an introduction to the topic, Metals pro Climate points out that 'the use of resources – including mineral and non-mineral, food and energy – and the impact of resource use on the environment is being increasingly discussed. Consequently, Resource Efficiency has been moving up the political agenda sharply for some years now. The European Union wants to decouple economic growth from the use of resources by 2020 and develop indicators to measure resource efficiency. Some days ago, the EU Commission ... published a Communication on the single market for Green products proposing two new tools to measure the environmental performance of products (PEF) and organisations (OEF). In addition, EU-Commissioner Potočnik set up a European Resource Efficiency Platform (EREP) with the mandate to develop policy proposals to increase resource efficiency by 2013'.

All protagonists agreed that 'Europe is highly dependent on raw materials in different forms. Hence, the transformation to more resource- and energy-efficient production and consumption is highly complex and affects almost all economic and policy areas'. Speakers were keen to point out that there is a shortage in materials' production, which is not only of importance with regard to energy efficiency, but the shortage of raw materials is also a barrier to economic growth, hence the importance of the 'Reduce, Reuse, Recycle' mantra.

There is a need for a balanced and transparent discussion to ensure an international level playing field, and it is essential for data being collected to also accurately reflect end of life recycling rates, in order to allow a comprehensive assessment of metals' availability. It was made clear that balanced solutions can only be achieved with the input of industry. The group discussed in some detail what the most appropriate targets might be and highlighted the

Photo from WV Metalle, by Alexander Louvet

importance of the ongoing discussion on resource efficiency to give direction to policy and feed into both European and wider international strategies on green growth.

It was highlighted during the debate that Europe is uniquely impacted by import dependency, particularly with its aging and dense population, but that since the economic crisis, the topic has not really been at the forefront of debate; however, in the same way as Europe's resource use dependency was at the heart of the economic crisis, it must also be at the heart of any solutions for growth. This is not just about environmental concerns, it needs to be fundamental to industry.

Metals play an enormous role in underpinning all aspects of a strong, competitive Europe, given their importance not only in such sectors as energy, electronics, construction, aerospace, but also in less obvious ways, for example, metals play a huge role in such sectors as food, through transport and logistics.

Within companies, it was also highlighted that resource efficiency is simple, good housekeeping, as cutting waste cuts direct business costs, and increases competitiveness.

On the subject of competitiveness, there was significant concern expressed about the financial and legislative burdens placed on EU businesses, which decrease competitiveness when compared with non-EU countries. The cumulative effect of high taxes on such elements as labour, and disproportionate lack of taxation on energy use and waste production send a strong global message. There was much controversial debate on different taxation models which could be used to strengthen and support the value added within Europe, with general agreement that Europe's strength is in the field of innovation, and that EU legislation needs to support this, in order to maximise the growth potential across the continent.

Maria Cox, General Manager MMTA

LETTER FROM NORTH AMERICA

Dear Members

Whilst I'm sure it comes as no real comfort to those of you currently facing incessant rain in Europe, it has recently been absolutely foul here in New York. Indeed, last week we had a record 4.17" of rain in one day: it was wet. And we're promised more of the same tomorrow, and the next day, and...

Although it was 'published' in January of this year, the US Department of Defense's *Strategic and Critical Materials 2013 Report on Stockpile Requirements* was actually only available some little time after then. And it has really only garnered cursory coverage in the mainstream press.

Should you have the time, it is very well worth wading through, especially to pick up snippets such as the fact that "Base Case" assumptions (during the modeled conflict year) include, amongst others: "*(1) response to a catastrophic attack in the U.S.; (2) deterring and defeating regional aggressors...*", and "*...a homeland recovery program to replace lost assets of at least $100 billion in private and government spending over the three regeneration years*". It is fortunate, I suppose, that the "*DoD believes that the NDS* [National Defense Stockpile] *planning process provides reasonable assurance that the stockpile will be able to supply the military, industrial, and essential civilian needs of the United States during national emergency.*" If nothing else, one has to commend the DoD on its optimism!

So, what in the report is of potential interest to MMTA members?

To produce its report, the DoD studied some 76 different materials (28 metals, excluding precious metals and rare earths, seven precious metals (including rhenium!), 11 ores and compounds, seven miscellaneous non-metals, three alloys and 16 rare earths) to see whether, in the aforementioned Base Case, they exhibited shortfalls, i.e. "*insufficient reliable production to meet demands.*" This turned out to be the case in 23 instances.

The DoD then assessed the applicability, benefits and costs of four different types of mitigation strategy, in short, federal inventories (including stockpiling), substitution, extra purchases from (reliable) foreign suppliers, and "*reductions in Government guarantees of shortfall materials contained in or used in the production of exported goods.*"

Having done all this, the DoD concluded that, out of these 23 materials, in 12 instances stockpiling was recommendable in combination with, where relevant, (except, in one instance, beryllium), the other mitigation strategies above.

And those materials were:

Antimony[9]	Dysprosium[4]	Germanium	Thulium[1]
Beryllium	Erbium[2]	Silicon Carbide[8]	Tungsten
Bismuth[5]	Gallium[3]	Tantalum[6]	Yttrium[7]

The "*priority ranking*" for stockpile acquisition (excluding beryllium, which, being militarily vital, is treated separately) is indicated by the associated numbering. Both tungsten and germanium are covered by existing inventory.

Finally, it is very interesting to note that, for the first time that I know of, the DoD actually looked at "*buffer stock inventory*" as an alternative to stockpiling. There is an entire, albeit short, appendix (No.8) dealing with "*Inventory Methods and Approaches*". In relation to the situation in the U.S., as a choice, buffer stocks could be a very attractive alternative, falling, as they do, outside the ambit of the plethora of rules and regulations governing acquisitions by the NDS.

Anyway, fellow members, just a few observations there on what the DoD, rather than the NSA, is up to! I trust they were of interest.

With best wishes, as always, from New York, to MMTA members everywhere.

Tom Butcher, June 7th 2013 *Hard Assets Investor*

NEW MMTA MEMBER

The MMTA welcomes its newest members:

Aaron Ferer & Sons Co Ltd

ESTABLISHED 1886

Aaron Ferer & Sons Co. is a 127 year old metal trading company headquartered in Omaha, Nebraska. With over 115 years in the scrap metal industry, and 50 years of international trading, we pride ourselves on strong relationships forged by working closely with our customers and honoring our commitments.

We are physical traders/ merchants of minor metals, non-ferrous metals, ferrous metals, chemicals, ores, concentrates, residues, and precious metals; including Ag, As, Au, Bi, Ca, Ca/Al, Cd, Cr, Cu, Fe, In, Mg, Mn, Na, Pb, Red P, Sb, Se, Si, Sn, Te, Yellow P, as well as Stainless Steel and Steel scrap. With two offices in China, an office in Peru, and by utilizing warehouses throughout the world, we excel in global logistics and are able to meet customers' requirements on short notice.

Contact: Mr. Whitney Ferer
Email: afsco@ferer.com

NEW MMTA MEMBER

The MMTA welcomes its newest members:

Cronimet Central Africa AG

CRONIMET Central Africa AG supplies 'Conflict Free' mineral concentrates, Tantalite, Wolframite and Cassiterite from Rwanda. We process and upgrade our mineral concentrates at Minerals Supply Africa Ltd in Kigali, which is a wholly owned subsidiary of CRONIMET Central Africa AG and from there supply the world's largest smelters and refiners with certified 'Conflict Free' minerals, enabling them to pass the EICC audits. We are full members of the iTSCi traceability scheme and are part of the OECD multi stakeholder steering committee.

Contact:

Miss Candida Owens

Email:

candida.owens@btinternet.com

Website: http://www.cronimet.de/en/locations/europe/switzerland/steinhausen/cronimet-central-africa-ag/

Phone: +44 7721 092692

Address: Allmendstrasse 11, CH-6312 Steinhausen / Switzerland Telephone direct +41 41 748 51 34, Telefax +41 41 748 50 48

Metals: Tantalum, Tungsten, Tin.

COBALT MARKET REPORT

Properties:

Cobalt is a hard, shiny and greyish metal, appearing in the first long period of the Periodic Table between iron and nickel. Today, cobalt has many strategic and irreplaceable industrial uses as a result of its unique properties; a high melting point (1493°C) and retaining its strength to a high temperature; being ferromagnetic with a high thermo-stability and being multivalent, thus enhancing catalytic action. Cobalt is the 33rd most abundant element in the earth's crust and global reserves are estimated at around 7 million tons.

Occurrence and Resources:

Cobalt is not found as a native metal but in nickel-bearing laterites or nickel / copper sulphide deposits. This means that cobalt is usually produced as a by-product of nickel and copper mining activities. Of current production sources, approximately 66% of cobalt production is copper related, 31% is nickel related and only 3% is produced by primary cobalt operations. The main reserves are found in the southern part of the Democratic Republic of Congo (DRC), an area commonly known as the copper belt and which currently holds close to half of the world's cobalt reserves. Australia, Cuba, Zambia, New Caledonia, Canada, Russia and Brazil hold much of the balance of global cobalt reserves. In 2012 approximately 64% of refined global cobalt output was originally mined, concentrated and, in some cases, semi refined in the DRC before being exported to refiners elsewhere in the world.

Supply:

Although the majority of the world's cobalt supply is originally sourced from the DRC, only a fraction of this is actually refined within the country itself. Primary export markets for DRC's production of unrefined cobalt ores, concentrates and cobalt intermediates (primarily in crude hydroxide and carbonate form) are China, Finland, Zambia and Belgium. Here, these materials are either refined into cobalt metal (cathode, coarse powder etc) or into downstream chemical products (cobalt salts) or specialty materials (fine cobalt powders). In 2012, global refined cobalt output was approximately 77,000 MT. An estimated 53% of this output was in the form of chemicals or specialty products, 39% in solid metal form and approximately 8% in the form of coarse cobalt powder.

Following five consecutive years of production increases, global refined cobalt output declined in 2012 after production peaked at just over 80,000 MT in 2011. Falling market prices drove primarily Chinese refiners to scale back production and cobalt operations in the DRC were hampered by power disruptions. The reduction in Chinese output ended a five year production boom period during which China more than doubled its output. A decade of fast economic growth and a structural change to the global cobalt market transformed China into the single largest producing country in the world, contributing just over 30,000 MT or 40% to global refined output in 2012. Following a short but intense period of industry consolidation fewer than ten producers account for over 80% of China's total refined cobalt output. Having little cobalt resources of its own, China imports over 90% of its cobalt raw material requirements from the DRC.

Other major supply sources of refined cobalt are Freeport Cobalt's refinery in Finland (previously OMG), ENRC's metals refinery Chambishi located in northern Zambia, Sherritt's metals refinery in Canada and Umicore's refining operations in Belgium.

In 2013, supply increases are expected to come from Sherritt's Ambatovy operation in Madagascar where a successful production ramp up may bring anywhere between 2,000-3,000 MT of refined cobalt metal to the market. By the end of 2013 Sumitomo Metal Mining will have completed its Taganito Nickel Project in the Philippines, allowing it to increase cobalt metal production at its Niihama refinery in Japan from early 2014. However, it is expected that these production increases will be largely off-set by additional cut backs in African production

resulting from a structural power shortage. All in all no significant net increase is expected in refined cobalt output until 2014.

The below table provides a breakdown of global refined cobalt production in 2012:

2012 Refined cobalt sources
(metal, cobalt chemicals and powders)

Producer / refiner:	Country	Products	2012
Various	China	Chemical, Metal, Powders	30,200
OMG	Finland	Chemical, Powders	10,547
Chambishi	Zambia	Metal	5,435
Umicore [1]	Belgium	Chemical, Powders	4,200
ICCI / Sherritt	Canada	Metal	3,792
Xstrata	Norway	Metal	2,969
Sumitomo	Japan	Metal	2,542
Minara	Australia	Metal	2,400
QNPL	Australia	Chemical	2,369
Norilsk	Russia	Metal	2,186
Katanga Mining	DRC	Metal	2,129
Vale	Canada	Metal	1,890
Votorantim	Brazil	Metal	1,750
CTT	Morocco	Metal	1,314
Various	South Africa	Powders	1,100
Kasese	Uganda	Metal	556
Various	India	Chemical	600
Eramet	France	Chemical	326
Mopani Copper	Zambia	Metal	230
Ambatovy	Madagascar	Metal	450
Total Refined Cobalt:			**76,985**

Source: Darton Commodities Ltd. / Cobalt Development Institute

Uses:

Cobalt has a diverse range of important metallurgical and chemical uses which varies from aircraft engines to rechargeable batteries. It is also found in industrial chemical processes where its unique catalytic properties can be used for such applications as desulphurisation of hydrocarbons, the removal of nitrous oxide and the emerging technology of converting natural gas to liquid hydrocarbons. Base industry also utilises the advantages that cobalt can bring to the hard metal industry, where hard wearing metals and alloys allow the manufacture of highly effective cutting tools for a broad range of industrial applications. The high temperature resistance, hardness and wear characteristics of cobalt when alloyed with other metals can also be put to good use not only in gas turbines but also as hard surfacing in critical applications where working environments are aggressive. By improving wear and durability, this can also improve operating efficiencies by extending the operating life and reducing friction. Furthermore, cobalt's versatile physical and chemical properties make it a vital ingredient in the colouring of pigments and ceramics, electroplating and the manufacture of vehicle tyres, paint driers, permanent magnets, synthetic diamonds and animal feed.

Demand:

Global consumption of refined cobalt was estimated at approximately 74,000 MT in 2012, almost 50% up from the levels seen a decade earlier. Booming demand for rechargeable batteries in laptop computers, tablets, mobile phones and other portable electronics has been the biggest growth driver for cobalt consumption. For many years the battery industry has been making significant efforts in substituting cobalt with lower cost materials, reducing the overall content of cobalt in battery cathode materials. However cobalt cathode chemistry continues to be the product of choice for applications requiring thin, flexible and high energy density

NEW MMTA MEMBER

The MMTA welcomes its newest members:

Zhuzhou Keneng New Material Co Ltd

Zhuzhou Keneng New Material Co. Ltd. has been authorized by Zhuzhou Administration for Industry and Commerce, specializing in the manufacture of minor and rare metals. It is one of the licensed indium exporters in China, registered in JINSHAN SCI-TECH PARK OF ZHUZHOU with the self-run import and export license, the company mainly deals with processing, import and export of minor metals. Owning factories in Hunan Province and Yunnan Province, its main products include In, Bi, Ga, Te, Sb etc and have passed the ISO9001: 2008 quality system certification, ISO14001: 2004 Environmental System Certification and OHSMS18000:2001 Occupational Health and Safety System Certification.

Our company concentrates all its energy on exploiting the production of various minor metals, and then exporting our products to Japan, South Korea, Europe, the United States, Hong Kong, Taiwan and other countries and regions, in order to meet the rising demand for mobile phones, LCDs, wireless semiconductors and the optical fiber industry.

We have established a long term, continuous and stable business relationship with our clients throughout the world.

Contact: Xianghua Tang
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Fax: 86-731-22498117
SKYPE: amic8711
E-mail: zzknsales23@zzkeneng.com
Website: www.zzkeneng.com

MMTA WEBSITE ADDITION

We are constantly making small changes and additions to the MMTA website to make it more user-friendly and effective for your use.

Industry Events:

The MMTA executive team receives lots of notifications of events, meetings, courses, and other activities that may be of interest to members, so we will be listing these wider industry events on a new page on the website for your information.

Click here to view Industry Events.

Improvement to online payments:

Some members have experienced problems with the way UK vat is displayed on the online bookings form. This has now been addressed.

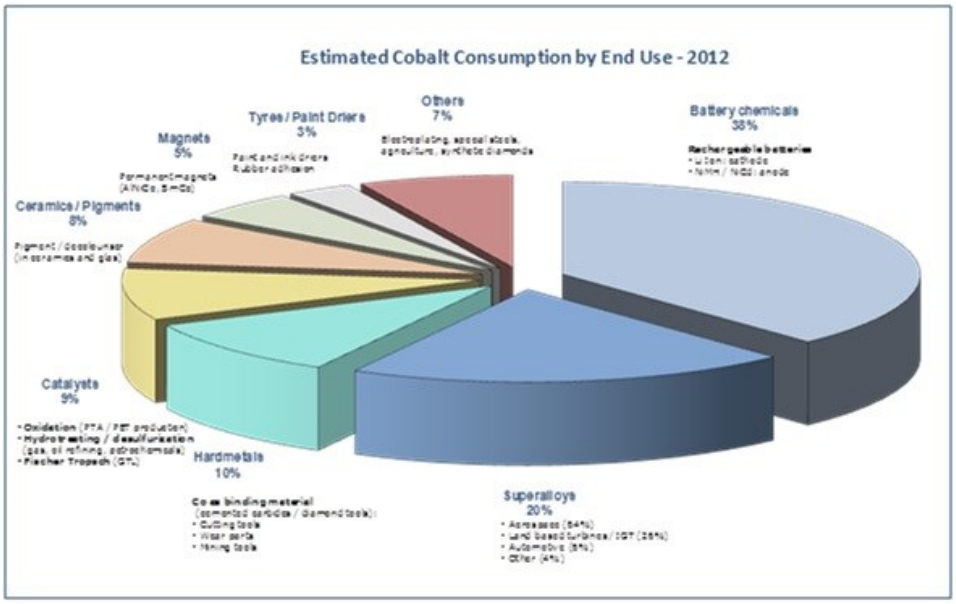
Thank you for bringing it to our attention.

COBALT MARKET REPORT, CONT'D.....

batteries with the best possible cycle life. Strong demand growth estimates for portable electronic devices suggest that cobalt will continue to see healthy consumption increases from this industry. Furthermore, automotive related demand for cobalt containing battery materials is expected to rapidly increase in the coming years as the market adaptation of (plug-in) hybrid electric vehicles starts to accelerate.

The superalloy industry is the second largest cobalt consuming market after the battery sector and in 2012 these two industries jointly accounted for an estimated 58% of global cobalt demand. Consumption in the superalloy sector has benefitted from a buoyant aerospace sector where airplane and engine build rates remain high. With airplane manufacturer order backlogs accumulating to more than eight years of production the demand outlook for cobalt from both the new and replacement engine market is expected to remain healthy.

Demand growth for cobalt from other, more mature consuming industries tends to be of a more cyclical nature, following general economic and industrial production growth trends. Consumption in sectors which are heavily dependent on downstream demand from industries such as automotive, construction and mining, has therefore seen a negative impact from the economic slowdown that has hit a number of key markets in recent years. The anticipated recovery in GDP growth in some of Europe's main geographic markets should in turn result in renewed consumption growth.



Source: Darton Commodities Ltd.

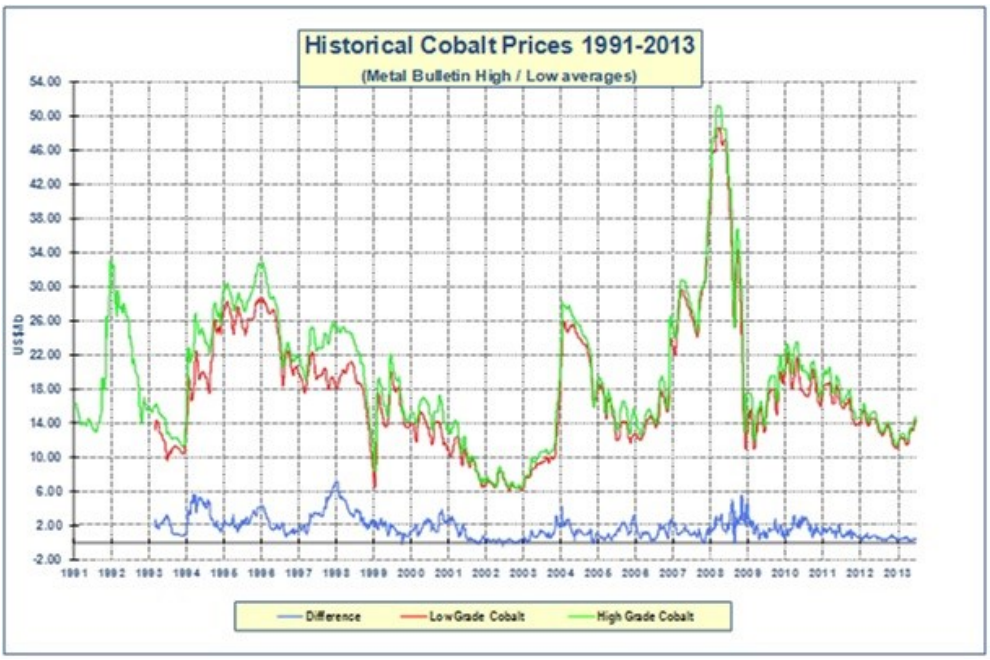
Prices

Until the early 1990's when cobalt metal production was largely dominated by producers in the Congo (Gecamines) and Zambia (ZCCM), the African Producer Price was the only published price reference available to the market. With supplies from non African sources growing and free market prices becoming increasingly volatile, Metal Bulletin introduced a cobalt metal price quotation in 1991. Initially this was a single 99.8% quotation which was followed by the introduction of a 99.3% quotation in 1993. Metal Bulletin cobalt quotes are established through price discovery, using telephone surveys to obtain current spot price information from traders, producers and consumers. For many years Metal Bulletin quotes have been the default pricing benchmark for cobalt with the majority of long-term supply contracts priced basis a formula linked to Metal Bulletin price quotations.

In February 2010 the London Metal Exchange launched the world's first cobalt futures contract, followed by a cash contract in May that same year. Whilst the

contract initially suffered from a structural lack of liquidity preventing the contract from gaining greater market acceptance, the LME cobalt contract has started to gain traction as traded volumes have gradually but consistently increased. There appears to be a growing consensus amongst producers and consumers that the LME contract will eventually be accepted by the industry as the next benchmark for cobalt pricing.

Historically, cobalt prices have been characterized by strong volatility, with the peaks and troughs usually correlating to specific supply and demand related events. Cobalt metal prices dropped to a historic low of US $ 6/lb. by early 2003, to be followed by an all time high five years later when prices peaked at US $ 52/lb in April 2008. The financial and economic crisis that hit the market that same year sent cobalt prices crashing down, reaching a low of US $ 9/lb. only 7 months later. Market prices subsequently recovered to levels above US $ 20/lb by early 2010 and have since seen a fluctuating but continuous downward trend as the market moved into structural oversupply. Global cobalt production increased a stunning 30% that year following a surge in Chinese output and the restart of operations that had previously been idled due to poor market conditions. The market rapidly moved into surplus as China in particular accumulated massive stocks of both raw material and downstream products. These surpluses continued to overhang the market during the following two years, eventually driving prices down to the $10/lb. level by December 2012. During the first half of 2013 cobalt prices recovered again gaining some 40% and reaching $14/lb at the beginning of July. With market surpluses having been gradually absorbed by the market, power shortages hampering DRC production and a ban on the export of cobalt raw materials from the DRC taking effect in July, further price increases are anticipated during the second half of the year.



Source: Metal Bulletin

Darton Commodities Ltd.

For a more detailed Cobalt Market Review please visit:
www.dartoncommodities.co.uk

THE MMTA IS 40 YEARS OLD THIS SUMMER

MMTA's 40th Anniversary Dinner

InterContinental, London Park Lane

Tuesday 8th October






Join MMTA Members and guests at the 40th Anniversary Dinner, at The InterContinental on London's Park Lane.

Last year we greeted over 250 industry professionals at the largest Anniversary Dinner ever, and we are expecting another successful event this year.

The evening will begin with an

'MMTA Founding Members' Drinks Reception'

from 6.45pm

kindly sponsored by the 3 current MMTA founding member companies – AMC Plc, Lambert Metals Intl. Ltd. & Wogen Resources Ltd.

AMC Group

Lambert Metals International Ltd.

wogen

At 8.30pm guests will sit down for a 3-course dinner served with plenty of wine!

Last orders at the bar will be 01.30am

Bookings for this event are now being taken.

Tickets cost £95 for MMTA Members/£140 for non-members (+ VAT where applicable)

Tables of 10 or 12 can be booked.

Please contact Maria Cox or Emma Newman for more details, or to register for the event.

The cut off date for bookings is Wednesday 2nd October.

Dinner Sponsors

AVON

Charity Raffle Sponsor

RC INSPECTION






mmta
Minor Metals Trade Association

INTERCONTINENTAL
LONDON PARK LANE

THE CHANGING FACE OF COMMUNICATIONS IN THE MINOR METALS SECTOR

My first exposure to the MMTA was in 1979 when I joined Cominco as a junior trader. I can remember being very impressed that the LME dealing desk would allow me to call a broker in New York at the touch of a button. Unbelievable as it may seem today, this was the cutting edge of technology at a time when communication was limited to land line and telex.

Since that time we have seen the introduction of the fax and the mobile phone and subsequently the growth in e-mail and the Internet.

Technology has let us communicate more quickly and more efficiently and it has changed the minor metals business.

When I first joined the industry there was an active inter-merchant market, indeed there were some traders who claimed never to have dealt with a producer or a consumer!

That market thrived on there being imperfect market knowledge, producers didn't know consumers and vice versa and price changes could take up to 24 hours to travel around the world.

Now all market participants have almost instant access to market knowledge and the role of the trader's trader has disappeared. Everyone in the business now needs to provide some value to survive.

I believe that technology will continue to drive change in the minor metals industry and we will all need to adapt to survive.

Looking forward, I believe that online networking will be embraced by the industry, we will see the onset of online trading of some minor metals and that published prices will be based on real transactions rather than reported business.

Nigel Tunna, Metal Pages

AIR POLLUTION IN SELEBI-PHIKWE, BOTSWANA

In the north eastern corner of Botswana in the Central district lies a little copper-nickel mining town, Selebi-Phikwe. Although Bamangwato Concessions Limited (BCL) did give us a chance to thrive in our small town, this gift came at a price: our health and at times some of our other means of earning a living, through selling crops.

Time and time again we had a massive cloud of smoke hovering over the city, those who were asthmatic gasping for air at times and those who weren't asthmatic still struggling to breathe, with improvisations for gas masks coming in the form of smears of *Vaseline* or *Vicks Vaporub* seen just under the nostrils of almost every student and all those aware that these 'reduced' the sulphur dioxide's choking sensation. BCL did little, though, to prevent this air pollution and a lot of people, including people of my generation, eventually left Selebi-Phikwe with the situation still unchanged. The little sprouts we tried growing were often devoured by the sulphurous acid resulting from water on leaves of plants reacting with the sulphur dioxide in the air.

A mass statement was sent out, though by whom, I don't know, advising people not to water their plants in the mornings but only in the evenings when the sulphur cloud had disappeared. It seemed the pollution was going to be stopped or at least reduced to a certain extent, but it continued for many years, with this year making it 40! But there have been reports recently of a possible solution to the problem that has for decades marred Selebi-Phikwe's living conditions: the sulphur dioxide is to be somehow trapped and turned into sulphuric acid to then be sold to companies for cleaning nuclear materials.

Bonno Matale, Sheffield University, MMTA Intern

MMTA ON THE ROAD

On Wednesday 3rd July, the MMTA set out for Firth Rixson in Glossop. At FR we were greeted by Deborah Stott who gave us a presentation on FR, which was followed by an overview of the properties of superalloys and the role minor metals can play in determining their characteristics.

It became evident that a combination of many minor metals is required to create their unique compositions. Further, it is not simply adding what is needed, but it is also important to keep out degrading elements (e.g. oxygen), and with ever tighter specifications being demanded by end-users, this is an increasingly important consideration.

It was interesting to learn that the demands placed on the superalloys (used for turbines) are now so great, that to withstand the great forces applied, they are forged from a single crystal. This advancement is to mitigate against creep that can occur along grain boundaries. I was comforted to know that this helps make me safer when I fly!

With this information in mind we were taken on a factory tour. After putting on safety gear and fluorescent vests, we were ready to see first-hand how these complicated superalloys are created.

I would like thank everyone at Firth Rixson, Glossop, for taking the time to show MMTA its operation.

Alex Lewis, MMTA Intern

ADDITIONS TO MMTA MAIN COMMITTEE

It is with great pleasure that the MMTA Main Committee would like to announce that David Gussack of Exotech Inc, based in Florida, USA,

and Chris Edler of Lambert Metals International Ltd, based in London, UK,

were unanimously appointed to join the MMTA Board of Directors.

David is currently a member of the Business & Social Events Committee, and Chris is part of the Conference Committee.

UK TRADE MISSION TO FINLAND

Group visiting FQM Kevitsa open pit mine

Since the early 2000s, the Finnish mining industry has been booming. UK Trade & Investment (UKTI) works with UK-based businesses to ensure their success in international markets, and encourage the best overseas companies to look to the UK as their global partner of choice. In order to learn about the opportunities around the rapidly growing Finnish industry, promote UK mining expertise, network with relevant stakeholders and to enhance collaboration, UKTI in Helsinki organised a mining cluster trade mission to Finland in March 2013. The British delegates came from the Association of Mining Analysts, Association of British Mining Equipment Companies, British Water, Imperial College London and Mineral Industry Research Organisation. Together the UK organisations represented over 600 individual companies, involved in mining related products and services from different sides of the cluster.

"Finland is the most attractive country in the world for mining investments..."

According to the annual survey conducted by the Fraser Institute (2013), Finland is the most attractive country in the world for mining investments, mainly due to the rich mineral potential, availability of geological data, strong infrastructure, political stability and transparency. There are at the present 12 metallic mineral mines, five of which are gold mines, and 31 industrial mineral mines operating in Finland. The metallic mineral mine projects for the next five years indicates EUR 3 – 4 billion direct investments in to mine expansions and new construction. The Finnish geology offers excellent prospects for mining and the probabilities for new discoveries are especially good in Northern and Eastern Finland. Finnish mining projects have included the excavation of iron, chromium, copper, nickel, zinc, gold, vanadium, titanium, lead, cobalt, silver, tungsten, and molybdenum ores, along with ores containing rare earth elements. The potential to find new high-tech metal deposits is high, especially for platinum group metals, lithium, rare earth elements, titanium and cobalt. In 2010, about 30 tons of cobalt was produced in Finland, niobium is expected to be produced at Yara's Sokli phosphate mine, Mustavaara vanadium-iron-titanium mine is going back into production in 2017 and the Norwegian Nordic Mining is developing several new lithium deposits in the prospective areas of central Finland.

Kevitsa AG grinding mills hard at work

Approximately EUR 87 million was spent on mineral exploration in 2012, slightly up from the year before. Some 50 exploration companies are currently operating in Finland. Besides the recent environmental problems at the Talvivaara nickel mine and some conflicts between mining and tourism, namely in the municipality of Kuusamo in Northern Finland, the general mood towards mining in Finland remains neutral. At the moment, mining contributes around 0.5 % of Finland's GDP, a share which by all accounts is set to increase in the future. Regionally the impact is already significant. Mines create jobs in sparsely populated high unemployment regions that need and welcome the jobs. For example in the municipality of Kittilä in Northern Finland, mining is already as

UK TRADE MISSION TO FINLAND, CONT'D...

important as tourism, the other big source of income for the region.

Indications are that one job created at a mine creates three to four other jobs around the economy. As a response to the sore points and the industry's growing importance, a common objective has been agreed by different stakeholders and the Finnish government to raise Finland's profile as a leader in sustainable extractive industry. Led by the Ministry of Employment and the Economy, the plan – introduced in April 2013 – includes measures to be taken by the industry to obtain society's support for its activities. Proposals for improving the operating conditions for the industry were made with regard to administration, training, infrastructure, and more active, open dialogue.

During the week, the British delegation met representatives from over 20 public and private organisations. First in Helsinki, Geological Survey of Finland introduced our visitors to mining in Finland, followed by discussions over the mineral policy and the mining cluster with the Ministry of Employment and the Economy and about the environmental aspects of mining with the Ministry of the Environment. As an overarching theme, education and the demand for new skilled labour was discussed on several occasions during the week.

Each load leaving the Kevitsa mine pit can weight over 200 tons

After spending two days in Helsinki our delegation travelled north to Rovaniemi, Lapland, "the home of Father Christmas". The focus at this point turned more practical, intended to illustrate the cluster in action, and we had the opportunity to visit the recently operational First Quantum Minerals Kevitsa nickel-copper mine in Sodankylä. Another overarching theme, that of mining and the environment, and especially water issues, was brought up on several occasions and remains a hot topic in the public discussion as well. From an industry perspective, also ensuring the positives and benefits are communicated leaves room for improvement. Other top issues that emerged during the week included the need for international collaboration and as for financing, it is no secret that at the moment it is difficult, if not impossible, to find Finnish funding for junior companies.

Our key message to the Finnish stakeholders was that the UK offers a unique selection and network of mining operators across the whole spectrum of the cluster. Many of the world's natural resource focused investment funds and banks are UK headquartered, as are many of the world's mining houses. The UK offers world-class mining equipment manufacturers, state of the art engineering services that cut across the whole life cycle of mines and the UK's mining related training and research capabilities are some of the best in the world. The UK's and the City of London's financial services with the London Stock Exchange and AIM have created a natural pull for mining operators to gather their know-how and expertise within the UK. For a sector already in dire need of professionals, such as mining engineers, providing services in education and training presents a clear opportunity for the service sector. Consulting and collaborative research & development projects, especially in environmental aspects of mining such as waste handling and water treatment, presents another clear prospect for the UK expertise. In mineral exploration, in addition to the other 50 or so companies, several UK juniors are already exploring the region. Finally, there is always a demand for high-class innovative mining equipment solutions and the potential to engage in joint-ventures with Finnish companies to gain a foothold within the international mining supply chain.

Eero-Matti Salminen, UK Trade & Investment

MMTA ON THE ROAD

Upon arrival at Alfred H Knight's premises, I was introduced to Paul Chew, who gave an introduction to AHK outlining their ethos and operations. I was surprised to learn they currently have over 35 offices worldwide. Soon we were taken on a tour of their laboratories.

The tour started at sample arrival and followed a logical progression through to preparation and analysis. Samples are coded and tracked through the entire process to ensure traceability. It was interesting to learn that this site alone receives hundreds of samples a week, from all over the world.

During the tour we were taken through preparation and melting. It was fascinating to see the pouring of the first melt (>99% metals are extracted), and the slag which is processed further to collect any remaining metal.

As the tour progressed, it became clear that assaying is a complicated procedure and cannot be rushed! Throughout the tour we were taken to many departments, each an important process in the chain. Samples are taken through a circuit, and should a sample not adhere to strict criteria, it is not advanced to the next stage, but is reprocessed.

Overall I was struck by the friendly office culture and approachability of all the staff. I am grateful to everyone at AHK for an informative and exciting visit, and a special thank you to Neil for tolerating all of my questions!

Alex Lewis, MMTA Intern

Would you like to contribute to the Crucible?

Do you have a little time to get involved with one of the MMTA projects?

Does your company have a good news story you would like to share, or a vacancy you would like to advertise?

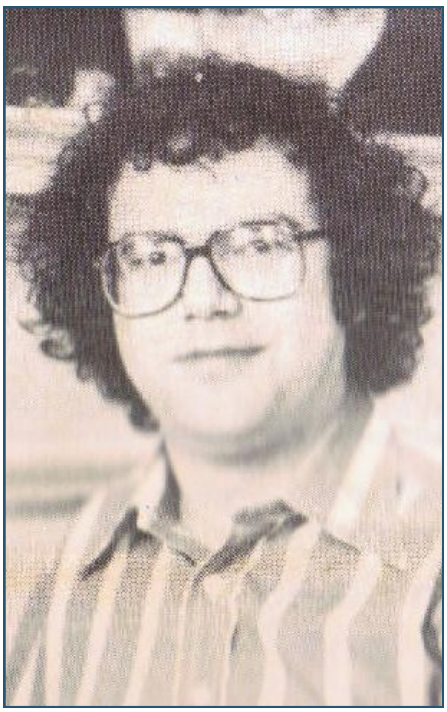
Get in touch with the MMTA executive team.

Email: maria@mmta.co.uk

Tel: +44 (0)207 833 0237

mmta
Minor Metals trade association

EARLY DAYS: GROWTH OF THE MMTA



Peter Robbins

When Victor Hugo coined the phrase 'an idea whose time has come', he wasn't thinking about a bunch of minor metal dealers meeting for a booze-up in London. But the speed at which the MMTA developed from the first get-together in the early 1970's fits Victor's snappy term to a T.

Demand for strange metals was beginning to boom in the electronics, chemical and the aerospace industries. Established metal trading companies hadn't yet realised that minor metals, with exacting technical properties, had to be traded differently from base metals. And most minor metal traders were young and had a lot in common with each other.

Getting together, however informally, was, people realised, exactly what was needed. It was a way of identifying ourselves outside the companies we worked for and establishing a forum where we could discuss the issues that concerned us most. So what were these issues?

Contractual arrangements at that time were a problem. My company issued modified London Metal Exchange contracts but many traders were not members of the LME. Did the seller's or buyer's contract rule? It was all a bit of a mess and the only we could operate effectively was by goodwill and trust.

The first thing I was told, rather pompously, when I started work in the City was that the maxim that guides all trade in the square mile is 'My word is my bond'. The second thing I was told was that, if you have any sense, you should take the bond. But I was always surprised by how few disputes there were considering how many details needed to be agreed in a deal – quantity, quality, origin, delivery location, insurance status, ETA, etc. We tried to settle disputes amicably because we needed to continue trading with each other. If I give something away on this deal the other guy is more likely let me off the hook on the next deal.

But there is another characteristic of minor metals' trading that could test trust to the limit. If a consumer, let's say, wanted a large quantity of antimony, you couldn't ask them to hang around for a few days to get firm offers from other suppliers, in order to do a risk-free deal. You had to decide quickly either to sell the consumer your stock or go short. In other words, you had to trade from position. In other words, you had to gamble. And this was the beginning of a long bullish period in which prices for some minor metals changed more rapidly than for any other traded commodities. It was a great temptation to try to get out of a sales contract when the price of whatever you had sold had doubled since you did the deal. An agreed contract was clearly needed; as was an arbitration service.

I was pleased with the success of our party in the Thames-side pub and a date for another get-together was quickly agreed. More far-sighted traders than I, however, instantly saw the merit of institutionalising our trading activities. It became clear that what we wanted was a trade association. There are hundreds of trade associations in Britain alone. There's one for bankers another for basket makers and another for dental implantologists – why not one for us?

There was a long debate over what we should call ourselves. The word 'minor', it was pointed out, could imply that there was a bigger and better association dealing with metals. 'Special' sounded a bit superior. 'Rare' might be confused with rare earth metals. 'Strategic' might imply armaments, and so on. 'Minor' was

EARLY DAYS, CONT'D....

agreed more through exhaustion than inspiration.

I should confess that I would have been very satisfied if all our future meetings were kept to informal social occasions, but I was pleased enough to see my fellow members forming several sub-committees, appointing officers and opening bank accounts. The London Chamber of Commerce led us all quickly and inexpensively through the legal and technical hoops and the MMTA was born.

Forgive me if I forget some names but I seem to remember that it was Brian Morgan, Howard Masters, Peter Pemberton, Angus Kinnear, Robbie Lichtenstern and the late Len Hillyard who acted as the main midwives of the new association.

As I saw it, one of the merits of forming an association was that it would be able to carry a great deal more weight in any debates we had with government or regulatory bodies than individuals or individual companies.

An anomaly in the UK's import tariff system at the time became the guinea pig we decided to use to test our new-found strength. Nearly all the UK's magnesium was imported from Norway through a single agent and it attracted little or no import duty. They had a semi-monopoly. Russian magnesium, however, was plentiful but carried a huge import duty. This meant that us traders were denied a chunk of business and that British consumers were paying through the nose for their magnesium. So, the arrangements were, albeit in a small way, harming the country's economy.

Len Hillard and I wrote to the Department of Trade and Industry under an MMTA letter heading and we swiftly received a reply inviting us to a meeting with a senior civil servant. We were courteously received and offered a cup of tea before the civil servant rose from his chair and pointedly closed the door of his spacious Whitehall office. In a cut glass accent he wearily explained that there was very little he could do to help us. 'Well', he drawled, 'you can guess what happens in cases like this. A minister is button-holed by someone at a cocktail party; promises are made, and these arrangements fall into place without much discussion I'm afraid. Magnesium is not exactly a big issue in the great scheme of things'. So in our very fist fixture it was Unfathomable Bureaucracy 1, MMTA nil.

We didn't want to make too much of a fuss, especially as this was in the middle of the Cold War with Russia, and we were very busy doing other things - but at least we road-tested our new facility.

Within a few months of its formation the MMTA went global and increased its membership enormously. I turned up to many of its social functions which became increasingly up-market and prestigious. I left the business to work for the UN in the 1980s and have sadly not been close to the MMTA ever since, but I thought that current members might be interested to know how their institution grew from its very humble beginnings.

Peter Robbins, founding MMTA member.

Do you have an MMTA story to tell?

If so, we want to hear it.

Please send your contributions for the 40th Anniversary edition of the Crucible to

maria@mmta.co.uk

HELP THE MMTA PROMOTE YOU

The MMTA executive team receives many hundreds of calls and emails a year enquiring about potential new business contacts. We refer enquirers to the MMTA Members' Directory, where they can search by metal or company.

Is your member listing up-to-date?

Please take a few minutes to check your website contact and other details to ensure they are as you would like to see them:

Are contacts current?

Do we have all the metals listed that you are involved in?

We have expanded our database to allow visitors to the site to search by ferro-alloys as well as pure metals.

Contact emma@mmta.co.uk if you would like to make changes.

MMTA SEMINAR

How to Use Arbitration to Resolve International Disputes

When: Wednesday 18th September 2013 9.30—12.00

Cost: £75 for MMTA Members / £120 for non-members

- What are Litigation and Arbitration
- Advantages of arbitration explained
- How arbitration works
- Which arbitration rules to use
- Alternatives including mediation

The seminar will be presented at the MMTA Office by Donald Lambert and Nicole Finlayson of Penningtons Solicitors LLP

To register, please contact emma@mmta.co.uk

SUPERALLOYS

Super—a prefix occurring originally in loanwords from Latin, with the basic meaning "above, beyond." Words formed with super-, have the following general sense: "to place or be placed above or over".

The superalloys continue to be of significant interest to the metals' trade, primarily due to the myriad of business opportunities presented by the extensive range of alloying additions. The diversity of elements utilised can be seen in a breakdown of the chemical composition of two common Nickel base superalloy families; CMSX and Rene (Figure 1). Each addition plays a specific role in satisfying a service requirement and alloy development can be seen as a 'series of compositional modifications designed to improve specific properties without adversely affecting others'. Before investigating the metallurgy in greater detail, let's take a look at why this group of alloys deserves the prefix 'Super'.

Alloy	Co	Cr	Mo	W	Re	Ta	Al	Ti	Nb	Hf	C	B	Y
Second Generation Single Crystals													
Rene N5	7.50	7.00	1.50	5.00	3.00	6.50	6.20	0.00	0.00	0.15	0.05	0.004	0.01
CMSX-4	9.00	6.50	0.60	6.00	3.00	6.50	5.60	1.00	0.00	0.10	0.00	0.00	0.00
Third Generation Single Crystals													
Rene N6	12.50	4.20	1.40	6.00	5.40	7.20	5.75	0.00	0.00	0.15	0.05	0.004	0.01
CMSX-10K	3.30	2.30	0.40	5.50	6.30	8.40	5.70	0.30	0.10	0.003	0.00	0.00	0.00

Figure 1

The Rolls Royce Trent 1000 was introduced into service underneath the wing of the Boeing 787 Dreamliner in October of 2011; it is one of the most fuel efficient gas turbines ever produced, has a specific thrust in excess of 30 metric tons and yet produces 20% less CO_2, 40% less NO_x and 50% less noise than the previous generation of engines. The Trent 1000 owes its performance to nickel base superalloy blades in the high pressure turbine (HPT), which are subjected to temperatures in excess of 1,500°C whilst each converting up to 800HP from the gas flow into torque, the equivalent power of a formula one engine. At 10,000 rpm the HPT blade tips are encroaching on the speed of sound, imparting a centrifugal loading analogous to hanging a double decker bus from each of the ~100 palm sized blades, and yet incredibly they can travel over ten million miles before requiring replacement. Super? Justifiably so.

What came first, the chicken or the egg? The modern jet engine and the latest generation of superalloys owe their existence to a mutual partnership dating back to conception in the late 1930's, with advancements in one field spurring on an almost chronological development in the other. The fundamentals of gas turbine performance are described by the 'Brayton Cycle', a thermodynamic framework that details three interrelated variables; temperature, pressure, and volume. The realisation that high temperature materials would be essential for gas turbine operation occurred long before Frank Whittle first conceived his turbojet, and the relationship between increased operating temperature and improved efficiency is still an inescapable fact. It should not be forgotten that superalloys find considerable use in the petroleum and petrochemical industries, space vehicles, nuclear reactors, steam power plants as well as primary metals' production, but the prime reason for their existence is their outstanding strength over the temperatures at which gas turbine components operate.

The term superalloy formally applies to an alloy developed for high temperature service, usually based on group VIIIA elements i.e. iron, cobalt and nickel. It may be surprising to learn that the refractory alloys actually offer superior mechanical performance at high temperatures, as can be seen in Figure 2, but they have very high densities, poor ductility at low temperatures and are extremely susceptible to oxidative degradation, so much so that their use is limited to inert environments until reliable coatings can be developed.

The standout feature of the superalloys is their *combination* of oxidation resistance and creep strength, and many

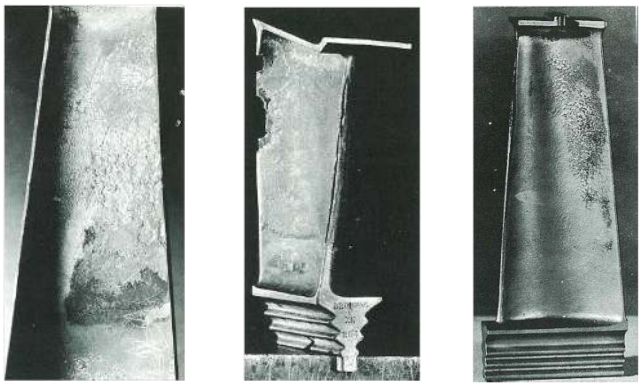
Alloy	1100°C	1320°C	1540°C	1760°C
	Ultimate Tensile Strength (MPa)			
Superalloys	350	#	#	#
Niobium alloys	350	168	119	#
Molybdenum alloys	630	385	252	182
Tantalum alloys	560	364	210	105
Tungsten alloys	700	420	280	210
Chromium alloys	315	119	#	#

Figure 2

(15-20%) have been developed for utilization in corrosion-resistant applications alone.

Corrosion or oxidation resistance is vital since the gaseous surroundings of many high temperature components often contain sulphur, chlorine and sodium, which although present in small quantities have noticeable effects on the surface stability of the alloy. Figure 3 shows turbine blades with varying degrees of surface degradation due to hot corrosion; in most instances this will have little effect on immediate performance (except for aerodynamic efficiency) but will dramatically decrease the time to fatigue failure and increase the creep rate.

Figure 3



Creep is the gradual 'permanent plastic deformation' (elongation) under a constant stress at a load *below* the yield stress of the material. Creep rate always increases with temperature, hence the importance of suitable creep strength in high temperature alloys. To give an example of the problem: turbine blades operate most efficiently when the gap between the blade tip and the casing is at a minimum (typically 2% of the blade width), with such tight tolerances even creep in the order of tenths of a millimetre will result in contact with the casing and ultimately failure.

Iron base superalloys are the least expensive of the three families but have the lowest useful temperature ceiling at around 800°C, cobalt base alloys offer superior hot corrosion resistance and higher temperatures still but development was discouraged by the cobalt shortage of the 1970's and they are not used widely. Nickel base superalloys are the most complex, most widely used for the hottest parts, and to many metallurgists the most fascinating of all of the superalloys. The current state of the art is seen in a single crystal turbine blade made from a 3rd-4th generation nickel superalloy, a component that demonstrates the developments made in both metallurgy and process engineering.

Figure 4 shows a conventionally cast turbine blade that has had an acid etch applied to the surface so that the microstructure is visible, it can be seen that the casting is not one continuous solid but is in fact made up of a series of individual crystals or 'grains'. Almost all conventionally cast metals are 'polycrystalline' (multi-grain), the boundaries between grains form as a result of misalignment between atoms as they struggle to order themselves uniformly upon cooling from liquid to solid.

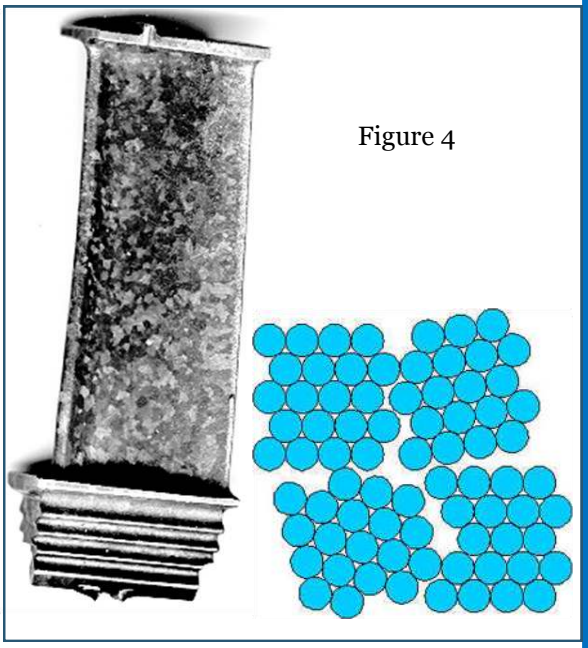


Figure 4

Grain boundaries are regions of atomic mismatch and less dense atomic packing, at elevated temperatures the strength of

METAL EVENTS LTD PRESENTED WITH QUEEN'S AWARD

On Thursday 30th June, the MMTA was invited to attend the presentation of Metal Events' Queens Award for Enterprise for Outstanding Achievement in International Trade 2013 at the Marriot Hotel, County Hall, London.

The Mayor of Lambeth was present to witness the event, but it was Rosi Prescott DLL, on behalf of Her Majesty, who presented the award to Jill Fitzgibbon and Rachel Carnac, Co -Directors of Metal Events Ltd.

The Queen's Awards for Enterprise are presented on the recommendation of the Prime Minister and with Her Majesty the Queen's approval. The Awards were inaugurated in 1966 and are awarded to businesses for outstanding achievement in international trade, innovation and sustainable development.

Congratulations to Metal Events Ltd on this achievement.

IMAGE FROM WASHINGTON DC

Paine overseeing the installation of Graft. Photo by Rob Shelley

Stainless Steel Tree—Graft, (2008-2009) by American sculptor Roxy Paine can be seen in the Sculpture Garden of the National Gallery of Art, Washington DC.

The stainless steel structure is 45ft high and 45ft wide, is made from over 8,000 components and weighs over 16,000 lbs.

SUPERALLOYS, CONT'D....

the boundary is *lower* than the strength of the grain. Grain boundaries are primary sources of creep, due to the mechanisms of 'grain boundary sliding' (the sliding of grains past one another), and 'grain boundary diffusion' (the movement of atoms along the gaps in the grain boundary).

The development of production methods to remove grain boundaries such as DS (Directionally Solidified) and SC (Single Crystal) was a major breakthrough that resulted in dramatic increases in creep strength. An example of a directionally solidified blade that has been etched is shown in Figure 5; the casting consists of a small number of large longitudinally grown grains and the relatively small number of boundaries remaining are all orientated with the loading direction to eliminate sliding. The principle behind the process involves cooling the alloy from the melt at an extremely slow rate by minimising the temperature gradient; this gives the atoms longer to arrange themselves and the starter grains are effectively 'grown' upwards. The use of a 'grain selector' is an advanced modification to the process that allows for production of castings that are completely free of grain boundaries; the casting is grown from one single crystal (grain) Figure 6. Single crystal alloys therefore have excellent creep strength, and can operate at temperatures circa 30°C greater than DS.

Figure 5

Figure 6

On a metallurgical level Nickel base superalloys derive their properties primarily due to the relationship between two phases; Gamma (γ) and Gamma Prime (γ'). A phase is a region that differs in structure and/or composition from another region, and is defined by the atomic bonding and arrangement of elements in a material. For a simple alloy of metal 'A' and metal 'B', the phases could consist of: Pure A, Pure B, and many permutations of A+B.

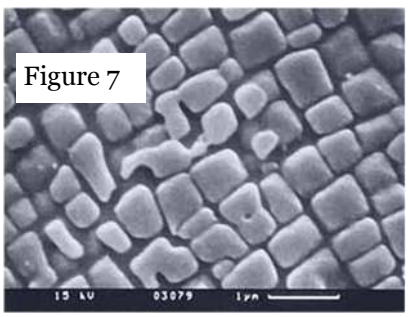


Figure 7

Figure 7 shows the microstructure of a Nickel base superalloy when viewed under an electron microscope, the magnification is 13,000x putting the true width of the image at approximately 0.00001m. The dark background is the Gamma phase or 'matrix', this can be thought of as the amalgam within which the light grey Gamma prime phase precipitates are distributed.

Nickel initially seems like a poor choice for a superalloy base, as it has mediocre creep properties, however it has an excellent tolerance for alloying, making it a favourable choice for the Gamma matrix. Chromium, molybdenum and tungsten all act as potent strengtheners to the Gamma phase and are added in high percentages; iron, cobalt and vanadium fulfil the same role in certain compositions, but are less effective. At temperatures above 60% of the alloy melting point, strengthening of the Gamma matrix is dependent on how easily atoms can move or 'diffuse' through the metal. Molybdenum and Tungsten are the most potent strengtheners here, due to

their high densities. Nickel also has the tendency, with chromium additions, to form rich chromium oxide and aluminium oxide protective scales, which provide the majority of the oxidation and hot corrosion resistance to the alloy. Chromium is typically present at 10-20%wt, but with the development of effective thermal barrier coatings the environmental exposure of the alloy itself has been reduced, resulting in lower loadings in modern alloys.

The Gamma Prime phase plays the most important role in the final properties of the alloy and has a remarkable strengthening effect; it is most unique in that its strength increases with increasing temperature. Gamma Prime forms as a regular array within the Gamma matrix, in the case of Figure 7 as cuboidal precipitates but can also be found as spheres or plates (Figure 8).

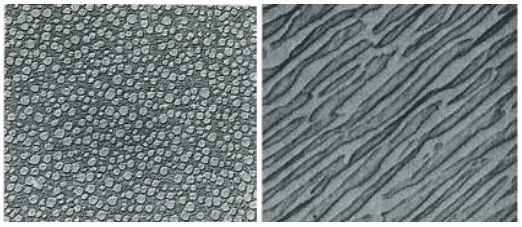


Figure 8

Gamma Prime consists primarily of $\mathbf{A_3B}$ compounds with Ni_3Al making up the majority, although it is common to add at least as much titanium to the alloy as aluminium. Of the other elements already in the Gamma matrix, small amounts of cobalt, chromium and moly can substitute for **A** in the Gamma Prime, whereas additions of hafnium, columbium and tantalum can substitute for **B**.

As the principal strengthening phase in superalloys the quantity of Gamma Prime has steadily been increased; in modern single crystal alloys it makes up about 60% of the volume. The strength of Gamma Prime has also been increased by adding refractory elements; Tantalum, tungsten and rhenium, with their higher melting points, have been found to be more effective strengtheners than columbium, and molybdenum.

Boron, carbon and zirconium are important additions to conventionally cast or directionally solidified alloys, as they segregate to the grain boundaries; here, thanks to their odd atomic sizing, they both act to 'pin' the boundaries preventing sliding, and also fill the gaps that allow for the movement (diffusion) of other atoms. In addition to improving oxidation resistance, hafnium was found to be very effective at improving the stability of the grain boundaries. This allows for easier casting of the alloy; without it the grain boundaries tend to 'tear' as the metal shrinks upon solidification from the melt. In a single crystal alloy the grain boundaries have been removed as a source of weakness altogether, so these elements are typically absent or found in low levels. Another feature of the latest single crystal alloys is the addition of yttrium, which is thought to increase the stability of the surface aluminium oxide scales further improving oxidation resistance.

Obviously due to the vast number of superalloy compositions available and the varying performance requirements based on application, the above constitutes a very basic overview of the metallurgy. A condensed summary of the preferential location and role of the various elements can be seen in Figure 9.

Elements	Ni	Co	Fe	Cr	Mo	W	Re	Cb	Ta	Ti	Al	C	B	Zr	Hf
Gamma	X	X	X	X	X	X									
Gamma Prime							X	X	X	X	X				
Grain Boundary												X	X	X	X
Oxide Scale				X							X				

Figure 9

A discussion about candidate materials for the potential replacement of superalloys is beyond the scope of this article, but both GE and Rolls Royce have committed to the use of Ceramic Matrix Composites in certain gas turbine components in the near future. The gas turbine industry is incredibly risk adverse; a mature technology will spend thousands of hours on a demonstrator rig, followed by thousands of rigorous flight hours in a military program, before even being considered for commercial applications. Given the risk inherent in replacement of a material that has over 80 years of development and experimental data behind it, it is likely that the phase in will be extremely gradual. Remembering that current engines have thirty years of operational life remaining, during which they will require replacement superalloy components, and that superalloys are used across a wide range of applications with broad performance requirements, the next 20+ years should be considered transitional rather than revolutionary.

Will Parry-Jones, AMC plc

INFORMAL DRINKS & INTRODUCTION TO METALLURGY COURSE

NEW YORK, USA

Thanks to those MMTA members and guests who joined us for a pleasant after-work drink on 26th June. It was a hot, humid evening, but those who were there had the opportunity to catch up with fellow MMTA members, as well as make some new contacts.

The following day, a group of us went back to the classroom for an Introduction to Metallurgy, delivered by Tom Glasgow, former NASA metallurgist, who gave attendees a grounding in why metals act the way they do, as well as the reasons for selecting different combinations of metals for different applications.

If you were not able to attend the course, but would like to register your interest, we will let you know when we are able to run it again.

Please contact maria@mmta.co.uk

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The MMTA promotes essential elements that add quality, safety and enjoyment to our lives.

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