MOLYREVIEW
INTERNATIONAL MOLYBDENUM ASSOCIATION
January 2009

Miners move mountains with moly

Molybdenum is an indispensable ingredient in the steels used in mining equipment. It adds strength and wear resistance to the machines used to dig and process ore. It brings corrosion resistance to the chemical processes used in many mining operations. It even finds its way into the lubricants that keep the machines from breaking down. Here we focus on molybdenum in the machinery that digs, shovels, hauls, crushes, grinds and mills the rock to extract valuable raw materials.

Nearly everything we use in our daily lives was once a resource in the ground, often present in miniscule percentages. However, Mother Earth does not give up her treasures easily! Someone has to find that resource, extract it from its home in the earth and enrich it in order to create a useful raw material for material suppliers. To do this, miners dig, crush, grind and mill enormous quantities of rock, stones and dirt and transport them from place to place in the process. The quantities of material and its hardness place great stresses on the equipment used. All along the chain of converting dirt to useful raw materials, moly plays an important role. It adds service life to the equipment used throughout the mine and plant, lowering the cost of production and bringing into everyday reach materials and products that we consider indispensable.

Getting the ore out of the ground

Operators do not commission a new mine on a whim. Before anything else happens, someone must find and characterize an ore deposit. This is where the exploration geologists come in, with their drilling, sampling and analysis equipment. They extract many long samples of the earth (core samples) in order to determine the location and concentration of ore throughout a potential site. Only after engineers thoroughly analyze the data can they plan a mine.

Article continued on page 6 →

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The longest X80 pipeline in the world

In recent years gas consumption in China has increased sharply, and so it has become critically important to improve the energy supply throughout the country. To accomplish this, China is accelerating exploitation of domestic resources and importing oil and gas from nearby Russia and Central Asia. For the transmission of gas from the west of the country to the southeast, the China National Petroleum Corporation (CNPC) is building the Second West–East Gas Pipeline.

This gas pipeline has a total length of 8,660 km (5,381 miles), consisting of one main pipeline and six branch pipelines. It passes through 13 provinces from Huoerguosi in Western China to Shanghai, Guangdong and Guangxi province in south-eastern China. It is an important pipeline which will connect gas resources in Central Asia, Talimu, Zhungeer, Tuha, Changqing and Longgang with the markets in south-eastern China.

The pipeline is initially designed to provide 30 billion cubic metres (1,062 billion cubic feet) of natural gas annually from Central Asia. In a release, CNPC said the trunk line will use 2.8 million tonnes of X80 grade steel pipe, consisting of 2 million tonnes of spiral submerged arc welded (SSAW) pipe and 800,000 tonnes of longitudinal submerged arc welded (LSAW) pipe. The branch lines will use 1.6 million tonnes of X70 grade steel pipe. China's leading SSAW pipe maker Baoji Petroleum Steel Pipe Co. has supplied 328,000 tonnes of pipes for the project. Baosteel and Heibei-based Julong Steel Pipe are the main domestic LSAW pipe suppliers. CNPC also imports LSAW pipes from foreign producers, mainly located in Japan and South Korea.

Around 10,000 tonnes of moly to be used

High Strength, Low Alloy (HSLA) steel grade X80 pipes with a diameter of 1219 mm (48 in) will be used along the full length of the main line. The pipeline will be divided into two parts, one section with a pressure of 12 MPa from Huoerguosi to Zhongwei, the other with a pressure of 10 MPa from Zhongwei to Guangzhou. According to operating pressure and area class, six kinds of pipe with a thickness from 15.3 mm (0.60 in) to 33 mm (1.30 in) will be installed. The branch lines and the connecting lines will use X70 line pipes with 10 MPa internal pressure.

Several major Chinese steel companies have developed X80 hot strip and plate products for spiral pipe and longitudinal pipe production, respectively targeting a 60% domestic steel supply to the project. The low carbon, high niobium base metallurgical concept provides high strength and excellent toughness due to the acicular ferrite microstructure that is typical for such alloys. Between 0.2% and 0.3% Mo is added to the steel to retard the formation of primary ferrite and pearlite and to compensate for an insufficient cooling rate, especially when heavy gages are to be rolled. For this mammoth project 4,400,000 tonnes of moly-grade steel will be required, containing in the order of 10,000 tonnes of molybdenum.

Record-breaking pipeline

The Second West–East Gas Pipeline is unprecedented among the world's X80 pipelines. It is the longest X80 pipeline in the world, crossing all kinds of terrain and geographic and weather conditions in China. The western section of the pipeline ➔

Content

Moly Review

Publisher:
International Molybdenum Association
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London W4 5RG, United Kingdom

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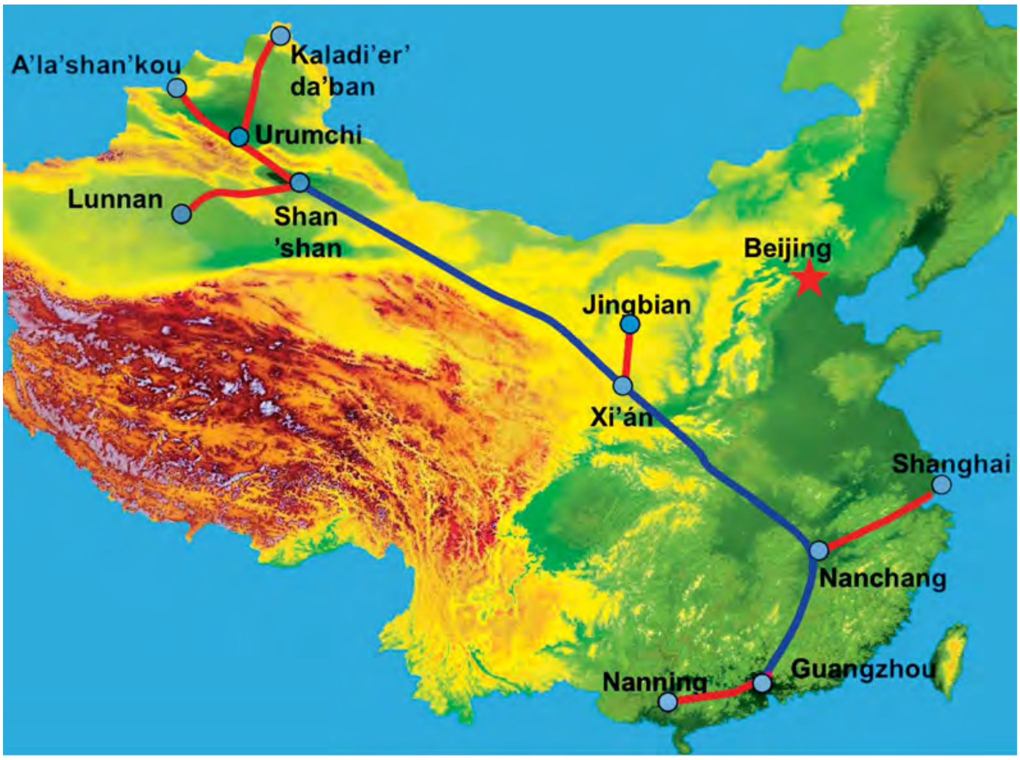


The Second West–East Gas Pipeline is the longest X80 pipeline not only in China but also the world, crossing all kinds of terrain and geographic and weather conditions in China. Chart: NiobelCon.

will be constructed from February 2008 to the end of 2009 and the eastern section will be constructed from September 2008 to June 2011. The project is scheduled to be completed by the end of 2011.

CNPC will import natural gas via the 1,818 km (1,130 miles) long Central Asia–China gas pipeline, which is being built from Turkmenistan and Kazakhstan to Xinjiang Uygur Autonomous Region in the north-west of China where it connects to the Second West–East Pipeline. According to CNPC, the inflow of Turkmen gas will significantly help China in meeting its energy demands and will stabilize the country's overall consumption structure. Turkmenistan will diversify its energy exports by delivering gas eastward as opposed to its current deliveries to Europe via the Russian Federation.

The pipeline, the second after China's first West–East natural gas pipeline, which went into operation in 2004, is considered significant for improving China's energy consumption mode. The government plans to raise the ratio of natural gas in its energy consumption structure by 2.5 percentage points to 5.3% by 2010. According to estimates by CNPC, the full operation of the Second West–East Pipeline will raise its ratio by one to two percentage points, while replacing 76.8 million tonnes of coal and reducing emissions of sulfur dioxide by 1.66 million tonnes and carbon dioxide by 150 million tonnes.

The first West–East pipeline, which pipes gas from the Tarim Basin of Xinjiang to Shanghai, transmits 12 billion cubic metres (425 billion cubic feet) of natural gas annually. Very recently it was decided to build a second string parallel to the Second West–East gas Pipeline that would double the capacity and secure an additional 30 billion cubic metres (1,062 billion cubic feet) of gas per annum for Chinese consumers and industry.

Sources: NiobelCon, Tubular Goods Research Centre of CNPC

For this mammoth project 4,400,000 tonnes of moly-grade steel will be used, requiring about 10,000 tonnes of molybdenum. Photo: NiobelCon.

Moly-grade stainless steel makes waves at Middle Eastern airport

The world's largest stainless steel roof is being built at the New Doha International Airport in Qatar. Shaped in a billowing, wave-like form, it symbolizes the Gulf emirate's aspiration to be a gateway to the world and sets new standards of elegance, comfort and convenience in air travel. The roof of the passenger terminal is made of a moly-grade lean duplex stainless steel.

New Doha International Airport passenger terminal approach. Image: Qatar Airways.

With a massive, boldly innovative expansion of its airport facilities, Qatar is literally reaching for the skies. New Doha International Airport (NDIA) promises to be an international gateway to the region that will showcase the cultural, technical and environmental achievements of this small but wealthy Gulf state. Located about 4 km east of the existing airport (which it will eventually replace), NDIA will comprise a new passenger terminal, an Emiri (royal) terminal complex, Qatar Airways' new headquarters, a public mosque, an 85-metre high control tower, cargo terminal buildings, hangars and other buildings. With two of the longest commercial runways in the world, the new airport will be among the first to accommodate the Airbus A380 double-decker "super-jumbo", the largest commercial aircraft ever built. When finished, NDIA will be about two thirds the size of Doha and 12 times larger than the current Doha international airport. It is expected that the new airport will generate additional commercial activity. For this reason a huge complex will be built alongside the airport: an area of over 100 hectares (about 10.8 million square feet) have been reserved for a hotel, an office and business park and a retail mall.

The airport is being built on 22 square kilometres (about 8.5 square miles) of land, nearly half of which was reclaimed from the sea. 50 million cubic metres (almost 1.8 billion cubic feet) of landfill and four large dredgers were used for the reclamation, which was completed in 2005. A reinforced seawall 13 km (8.1 miles) long was built to protect the area. A large-scale environmental clean-up was also carried out, with 6.5 million cubic metres (about 229.5 million cubic feet) of waste being moved to a new purpose-built facility.

Surrounded by sea, the airport incorporates water motifs in its design. The approach road for arriving passengers is flanked by water; the Emiri terminal

New Doha International Airport passenger terminal – interior view. Image: Qatar Airways.

is shaped like sailboats; undulating metal roof structures can be found in support facilities and on the stainless steel passenger terminal roof. When it reaches its definitive form after 2015, the entire passenger terminal complex will be the largest building in Doha. Designed by US architects HOK (Hellmuth, Obata & Kassabaum), it sets new standards in elegance, comfort, smart technology and environmental consciousness. Moving walkways will help passengers move around the building, and CO_2 and heat occupancy sensors will regulate air intake.

But the terminal's most striking feature is its undulating roof, said to be the largest stainless steel roof in the world. Several factors had to be taken into account when selecting the stainless steel grade. The most important of these was the airport's closeness to the sea. The roof had to resist not only the heat and humidity found everywhere in the Middle East, but it also had to withstand salt corrosion on top of these other problems. Other factors included cost and a favourable strength-to-weight ratio.

Another important consideration was that the roof should not reflect too much sunlight, which would not only cause discomfort on the ground but also distract the pilots. Texture and appearance were therefore vital not only for aesthetic but also for practical reasons. To get these two factors right, Contrarian Metal Resources applied its proprietary InvariMatte® finish to the duplex stainless steel sheets. This non-directional, low-gloss, uniformly textured stainless steel finish is especially suited to surfaces where low reflectivity is required. The end result is extremely consistent, like paint, but, as there are no coatings to deteriorate, it can last much longer, without much maintenance.

Lean duplex stainless steel roof

Although this type of matte finish can be applied to stainless steel Types 304(L) and 316(L), it was a duplex stainless steel that was specified on this occasion. Contrarian Metal Resources turned to a local supplier of global renown, Pennsylvania-based ATI Allegheny Ludlum. The company's AL 2003™ lean duplex stainless steel (1.8% Mo, 21.5% Cr, 0.17% N, 3.7% Ni) turned out to have exactly the right properties for the task in hand. The manufacturers have stated that this grade has a substantial strength advantage over Type 316L, allowing thickness reductions and therefore lighter weight; this translates into significant savings in raw material costs. Also, the corrosion resistance of this grade can be superior to 316L, even in as-welded condition. Especially where weight-to-strength ratio and chloride pitting resistance are important, certain grades of duplex stainless steel can be more suitable than 316L. AL 2003™ has in fact replaced 316L in some applications: for example, the pipes supporting the canopy for a Washington DC metro station, flexible flowlines for the Kikeh oil and gas project offshore Malaysia, and laser-welded tubes for a geothermal condenser.[1]

New Doha International Airport from the air. Image: Qatar Airways.

AL 2003™ is the only lean duplex grade that contains moly in significant amounts. In this grade, moly is an indispensable ingredient in combating corrosion. This is vital in a region notorious for its hot, humid and saline atmosphere – especially as the airport site is virtually surrounded by sea.

1 John J. Dunn and David S. Bergstrom (ATI Allegheny Ludlum), "AL 2003™ LDSS (UNS S32003) as a substitute for Type 316L", Stainless Steel World 2006 Conference, Texas, 14 November 2006 (www.alleghenyludlum.com/ludlum/Documents/AL%202003%20as%20a%20Substitute%20for%20Type%20316L.pdf)

NDIA passenger terminal roof: facts and figures

Architect	HOK (Hellmuth, Obata & Kassabaum)
EPC services for NDIA	Bechtel
Construction of passenger terminal	Sky Oryx (Taisei Corporation)
Area of terminal	219,000 square metres (c. 2.3 million square feet), with 40 gates (2011); expanded to 416,000 square metres (c. 4.5 million square feet) with 80 gates from 2015
Area of terminal roof	2.1 million square feet (about 195,000 square metres)
Opening date	2011
Capacity	24 million passengers and 750,000 tonnes of cargo per year (phase 1); will expand to 50 million passengers from 2015
Estimated cost	US$ 9 billion
Material	AL 2003™ lean duplex stainless steel
Quantity	3.5 million lb (1587.6 tonnes)
Mo content	1.8%, or 63,000 lb (28.576 tonnes)
Supplied by	Allegheny Technologies Inc.
Fabricated by	Contrarian Metal Resources (using InvariMatte® matte finish)
Project website	www.ndiaproject.com/main.html

Continued from page 1

Miners move mountains with moly

Once mining commences, enormous amounts of earth must be moved simply to reach the ore deposit. In open-pit mines, building-sized shovels scoop up gigantic volumes of earth to fill trucks that haul from 70 to 400 tonnes of earth in a single load. The amount of rock and earth that requires processing results in veritable trains of these trucks shuttling around the mine 24 hours a day. Very large tunneling machines bore deep into the earth to create underground mines. The loads carried by this equipment are enormous, so it must be constructed of high-strength materials if it is to be energy-efficient and strong enough to handle the work without breaking down. Equipment manufacturers strive for a maximum load/vehicle-weight ratio, because every pound taken from the vehicle structure increases the amount of payload and decreases the operating cost per pound of ore.

Critical components in shovels and trucks are built with moly-grade steels for safe and efficient operation. Photo: Kennecott Utah Copper.

Moly-grade, high-strength constructional steels are used to build these machines. These materials have much higher strength than standard low-carbon steels, can be welded to fabricate large structures and are available in plate form from a variety of manufacturers.[2] Moly improves the hardenability of these steels, allowing hardening throughout thicker sections than would otherwise be possible. High-strength steel castings containing moly are used in cast components like yokes, axles, hubs, casings and steering parts. Components where strength and toughness are paramount, like pivot pins used on dump bodies and hydraulic cylinders, employ higher-alloy steels like the AISI 4300 series.

High loads and stresses on the equipment are not the only factors working to break this equipment. Digging, scooping, drilling, dumping and transporting the material for processing creates a large erosion and wear problem. Ore bodies typically contain large quantities of hard, abrasive rock, which can wear away the toughest materials. Friction, abrasion and heat build-up occur as the machines dig or grind their way through the earth. This combination is devastating to steels and irons, and this is where moly makes its mark. It increases the strength, hardness and wear resistance of the low carbon steels found in these applications. Shovel bucket liners, bulldozer blades and dump truck liners all benefit from moly's ability to increase hardness and toughness.

2 Alta / Steel, American Alloy Steel, Arcelor, Bradken, Esco and Titus Steel, to name only a few.

The Chuquicamata mine in Chile is one of the largest open-pit copper mines in the world. A truck operating in this mine illustrates the scale of equipment used in the mining industry. Larger and larger equipment places more stress on components. Moly-grade steels meet the strength challenges posed by the equipment size.

A "truck train" hauling large amounts of rocks from the bottom of the mine to the top at Chuquicamata. Trucks run around the clock, and must be reliable if economies of scale are to be exploited.

The use of wear-resistant steels in these applications helps to increase the intervals between overhauls and replacement, thereby increasing efficiency of the operation and keeping costs low. Abrasion-resistant (AR) steels, again containing only a few tenths of a per cent of moly, provide the requisite resistance to wear in these materials.

Turning dirt into useful material

Digging the ore out of the ground is only the beginning. Ore bodies contain the material of interest in quite low percentages, along with enormous amounts of rock having little or no commercial value. Some miners have more than one material contained in their ore body, which can provide cost synergies (think of those copper mines that produce economically useful quantities of both moly and rhenium in addition to copper).

Tunneling machines are typically used in hard rock mining. The discs on the machine's face cut into the rock face, pulverizing the rock and allowing the machine to bore into the rock. Photo: The Robbins Company.

Table 1. Typical moly-grade steels used in mining equipment

Application	Class	Product examples	Moly content
Structures	High-strength structural steels	TMCP* rolled plate (YS**: 420–500 MPa) Quenched & tempered plate (YS**: 500–1100 MPa) Hot-rolled seamless tube	0.10–0.70%
Wear Surfaces	AR steels	Quenched & tempered plate (YS**: 400, 450, 500 MPa)	0.20–0.80%
Highly loaded components	Heat-treatable alloy steels	AISI 4300 series	~0.25%
Hubs, housings, axles	High-strength steel castings	ASTM A487, DIN17205	0.15–0.30%
Breaker ball mills, hammer mills, pump parts	White cast iron	A-532 and GJN-HV600 (Ni-Hard)	0.50–3.0%

* TMCP: thermomechanically controlled process
** YS: yield strength

Gyratory crushers act as primary crushers, the first to receive blasted material from the mine or quarry. Photo: Metso Minerals.

To convert millions of tons of rock into millions of pounds of useful raw material requires the rock to be crushed and ground ever finer, so that the ore can be liberated from the surrounding rock (or gangue as the miners call it). Friction and wear are powerful adversaries in these operations! While the equipment is busy fracturing and eroding the rock, it wears itself away at the same time.

The initial steps must process large rock fragments, and human imagination has devised a number of different approaches. Gyratory cone crushers fracture the rock between two converging cones; jaw crushers are exactly what they sound like: they "chew" the rock into smaller pieces; roller crushers (out of favour in recent years because of their lower throughput) break up the rock between sets of rotating rolls. These machines turn large rocks into small rocks that must be still further refined, and process tens to hundreds of tonnes of rock per hour. →

Small pieces of rock are still far too large to be useful, since the ore itself is usually distributed in fine particles within the rock. This is where the grinding and milling processes play their part. Rod and ball mills grind the rock inside large rotating cylinders filled with either hard balls or rods; autogenous or semi-autogenous (SAG) mills use large particles of the rock itself to replace part or all of the grinding medium, a clever approach that eliminates or reduces the need for balls or rods.

The scale of the equipment in these ore processing operations is enormous (the SAG mills in the picture below have a diameter of 32 feet or almost 10 metres) because of the volume of material that must be processed. Here again moly comes to the rescue. The same wear-resistant properties it imparts to the steels used to dig the ore are critical in these operations. Moly is found in steels and cast irons used in crusher main frame liners, grinding mill liners, grinding balls, separating screens, bin and hopper liners, impact walls and plates, chute and transfer point liners, and other applications. Even with the improved wear properties of the moly-grade steel, these components are considered consumable. For example, grinding media in SAG and ball mills wear out at a rate of about 0.6–0.8 lb (0.72–0.36 kg) of balls per ton of ore processed. At a processing rate of 150,000 tons per day, that makes 90,000–120,000 lb (c. 41,000–54,000 kg) of steel biting the dust each day. Using a reasonable estimate of 0.1% Mo in the components leads to an estimate of 90–120 lb (41–54 kg) of Mo consumption daily in each mill.

According to one expert, crushing, grinding and milling equipment uses steel with the following moly contents:

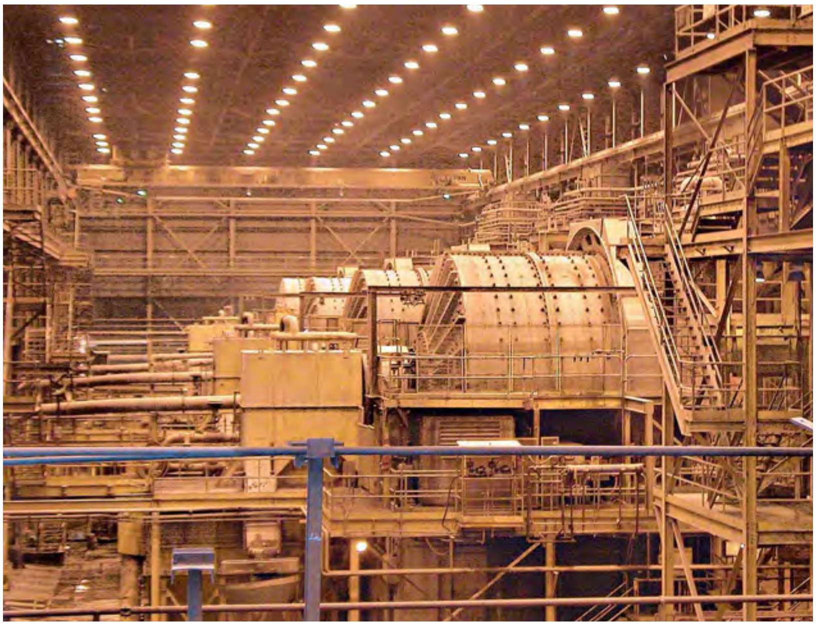
SAG mill liners	0.35%
Ball mill liners	2.6%
Crusher concaves	1.3%

Semi-autogenous (SAG) mill at the Climax Henderson mill. These huge machines use the rock itself and moly-grade cast iron balls to do the grinding, subjecting internal components to an extreme wear environment.

Summary

Mining operations involving the removal, transportation, crushing and fine grinding of enormous amounts of ore and rocks place great demands on the steels used for equipment. Molybdenum imparts strength and hardenability to these materials, allowing the construction of lighter and more efficient structures with longer service life and fewer unscheduled repairs, therefore improving the costs of mine operators.

The mill at Climax Henderson. The huge volume of rock processed to extract the molybdenum ore requires this gallery of machines, busily grinding away both the rock and their internal components. Moly-grade steels help to reduce the metal loss due to wear and erosion.



Internal view of the liner of a semi-autogenous grinding (SAG) mill. Designed to resist significant impacts from the ore being ground, the liners are made of CrMo steels. Photo: Polysius.

Moly keeps mining equipment running

Lubricants containing moly provide long-lasting lubrication of equipment operating in severe environments and whose components are inaccessible after assembly.

There's nothing like moly for lubricating moly! Or more precisely, for lubricating moly-grade steels. Moly is well known to the mining and oil industries as an alloying element in steels and irons in their equipment. In these alloys, moly confers resistance to corrosion and chemical attack, enhances abrasion and wear resistance and increases strength and toughness, resulting in robust and reliable equipment. Moly-containing alloys are found in many of the machines used to dig, drill, crush, grind, pump, convey and transport the products of these industries. All this equipment is subject to rough working conditions, whether extracting bituminous shales in Alberta, drilling for petroleum deep under the Gulf of Mexico, digging for coal in Silesia, or mining uranium in Kazakhstan. Reliability of the equipment used in these heavy industries is critical no matter where they are located. But remote locations and challenging environments create great difficulties when having to replace a component that has seized up! For these cases, the best antidote is still … molybdenum, or more exactly, molybdenum disulfide (MoS_2).

Conveyor for nickel ore in New Caledonia, stretching 1.2 km (0.75 miles) into the sea (total length: 1.8 km, or 1.13 miles). Subject to a strongly saline atmosphere, to shocks and to jolts, the quality of its lubrication is essential for its reliability. Photo: Eramet-SLN.

A highly compatible lubricant

Molybdenum disulfide is an excellent dry lubricant because its lamellar structure has a very low coefficient of friction between its layers and because it readily adheres to other materials. Usually dispersed into a thermoplastic resin or added to a paraffin mixture to improve adherence to the components being lubricated, it has excellent anti-seize and anti-friction properties. It is resistant to the effects of dust and fine abrasive particles, and is completely inert to water. It is extremely stable over time.

It is capable of lubricating equipment at temperatures up to 400 °C and pressures up to 30 t/cm^2, which a traditional oil or grease cannot withstand. Finally, it is compatible with practically all the alloys and materials used in mining and oil drilling, whether they are used on the surface, under the surface or under the sea.

Mining and drilling equipment's "best friend"

These qualities make it the lubricant of choice for components that are inaccessible after assembly, or which would be too time-consuming and complicated to dismount. An example of such a component is a deepwater drill head.

Therefore, molybdenum disulfide lubricant is present in most mining equipment: examples are the crown gears and pinions of cranes, gears, transmission chains, piston compressors, mechanical shovels, crushing machines, conveyors, bearings … the list goes on and on. In these applications, more than 5% MoS_2 is used as an addition to petroleum-based lubricants to enhance their capabilities. For example, molybdenum disulfide helps maintain the lubricating film in cases of seize-up in cold temperatures, protecting the equipment from premature failure.

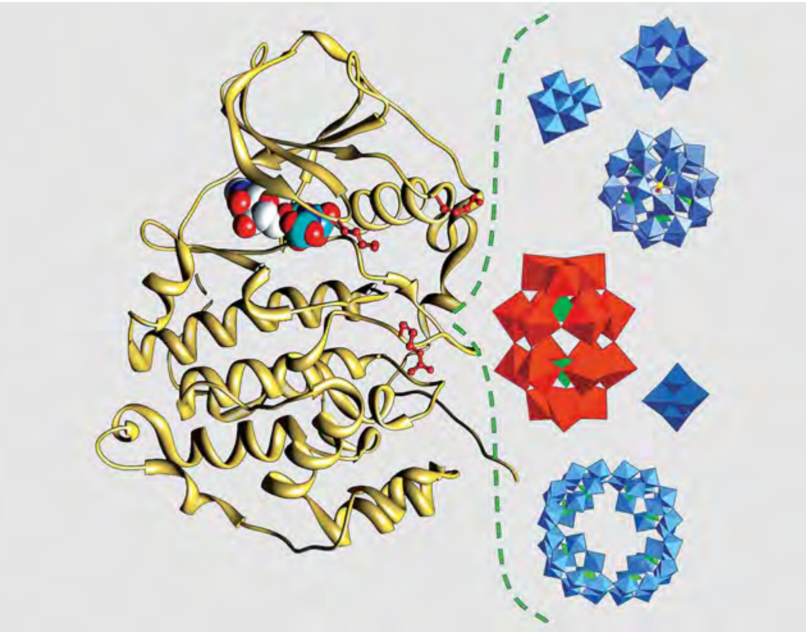
Because of its unique ability to provide long-term reliable lubrication in challenging operating environments, molybdenum disulfide dramatically extends the life of mining and drilling equipment. Moly disulfide is truly mining and drilling equipment's best friend!

Molybdenum to treat cancer?

A team of chemists and biologists has discovered that polyoxomolybdates can inhibit the deregulated enzymes that cause cancers. Could a metal known for its industrial applications help to cure cancer?

Cancer-inhibiting compound

The discovery took the researchers by surprise. Life sciences research biologists of the CEA (a French research institute) and chemists of the Pierre and Marie Curie University in Paris had teamed together to take a close look at compounds called polyoxometalates which are aggregates of metal ions (molybdenum, tungsten and vanadium) and oxygen. In doing so they stumbled on a property they had not been looking for: they discovered that the compounds had a powerful inhibiting effect on the CK2 human protein kinase, an enzyme that, when deregulated, is active in many cancers, including leukemia, lung cancer and prostate cancer. The highest inhibition was observed for the phosphomolybdate $K_6[P_2Mo_{18}O_{62}]$. This enzyme is receiving close attention from biologists who, in their quest for inhibitors, test millions of molecules per year from the combinatorial libraries of specialized institutes.



Targeting the protein kinase (left) with polyoxometalate (right). Photo: CNRS Photothèque / Bernold Hasenknopf.
Source: Renaud Prudent, Virginie Moucadel, Béatrice Laudet, Caroline Barette, Laurence Lafanechère, Bernold Hasenknopf, Joaquim Li, Sébastian Bareyt, Emmanuel Lacôte, Serge Thorimbert, Max Malacria, Pierre Gouzerh and Claude Cochet, "Polyoxometalates as protein kinase CK2 inhibitors," Chemistry & Biology 15 (2008), 683–692.

Serendipity

The results of the research were unexpected. Claude Cochet, Research Director of the CEA and a biologist, said: "While inhibiting molecules mostly result from organic syntheses, this is the first time an inorganic compound has demonstrated an inhibiting effect." And Bernold Hasenknopf, from the Paris Institute of Molecular Chemistry, commented: "This discovery is, as is often the case, the result of a happenstance. This purely biological application of a polyoxomolybdate is entirely new, for we were above all exploring the traditional application of these molecules, in particular for catalysts or materials." The polyoxomolybdates are compounds of molybdenum in its highest oxidation state, molybdenum(VI). They are soluble in water, giving an aqueous solution that can be used by biologists. The next steps in the research will consist of cellular tests and the first experiments on animals. The research opens the way to new approaches in the design and application of future anti-cancer drugs.

First stainless steel lined swimming pools in France

The Vichy Water Sports Centre, located in France's famous spa resort, was opened to the public this summer, and is the first centre constructed in France equipped with 100% stainless steel pools. Chlorine content was a decisive factor in the choice of corrosion-resistant moly-grade materials. In addition to simple maintenance, stainless steel allowed the architect to use his imagination in shaping the pool's design. Now, dozens of local communities have shown interest in using stainless steels to refurbish their pools.

Nearly 40 years ago Austria opened its first all stainless steel swimming pool. Since it was first filled with water, it hasn't needed any refurbishment. Now France is following suit, opting for the innovative, economical and sustainable solution offered by stainless steel for the renovation and construction of its water sports centres. After the refurbishment of a pool for the commune of Saint Bonnet de Mure, Rhône in March 2008, the city of Vichy opened a new outdoor Olympic-size swimming pool, along with indoor amusement, learning and wading pools. In total, 2,150 square metres →

(23,142 square feet) of water surface are enclosed by more than 65 tonnes of stainless steel. The stainless steel is made of about 70% recycled material. Moly-grade austenitic stainless steels were chosen for their superior corrosion resistance in the chlorine-rich environment. The walls and bottoms of the pools and areas exposed to splashing or warm indoor humidity, such as handrails and ladders or the amusement pool's slides, are all made from Type 316 stainless steel, supplied by ArcelorMittal.

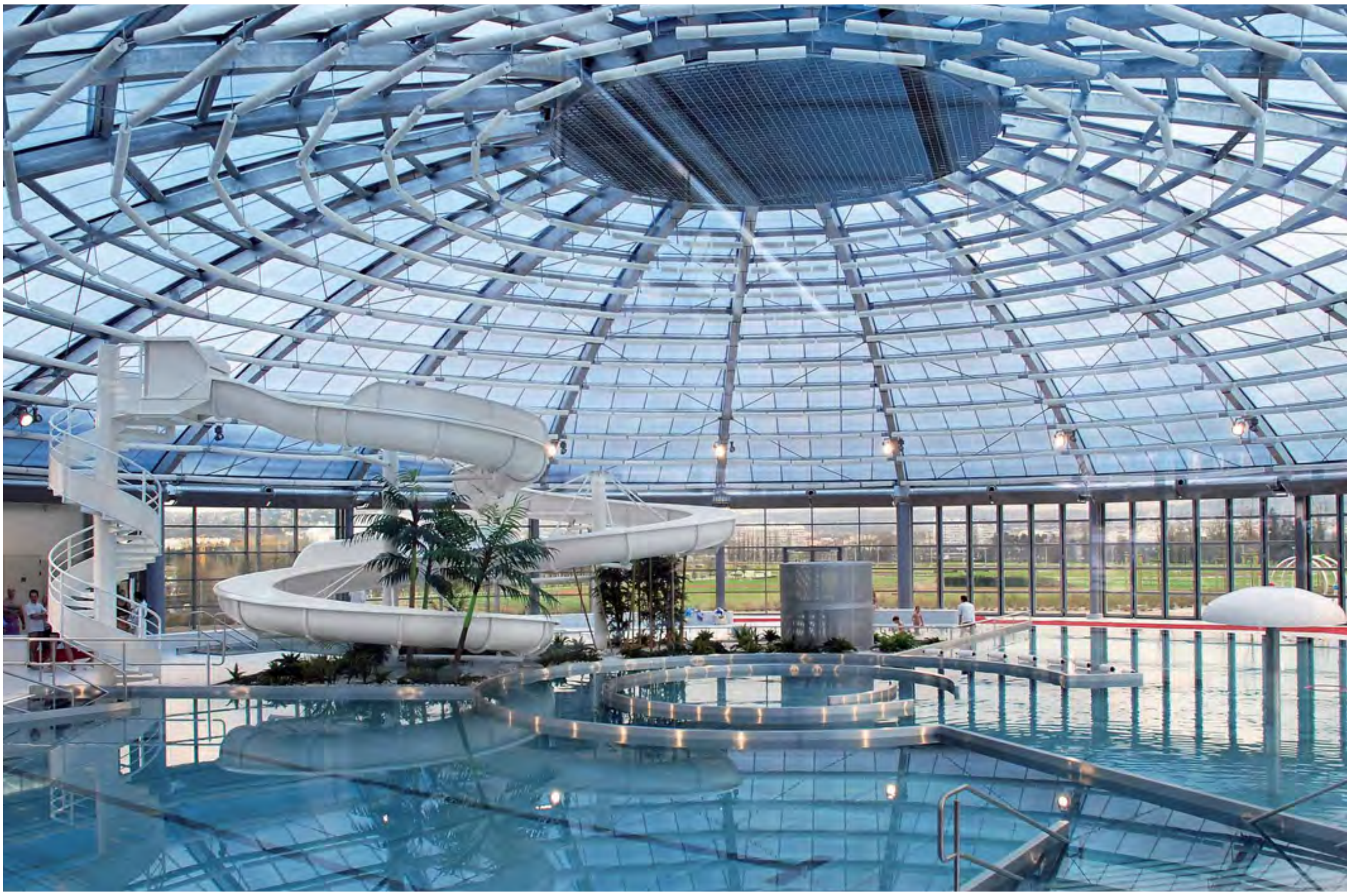
Vibration of light

Architects have long been interested in using stainless steels in swimming pools, but it was the change in swimming pool material regulations that finally enabled these first two projects to move ahead in France. Jacques Rougerie, designer of the Vichy pools, heads a practice specializing in futuristic marine architecture, and water-related design is clearly his vocation. His commitment is almost lyrical: "Stainless steel contributes to setting a new scene with its "vibration of light" phenomenon that enables us to rethink the design of the place itself. It provides colour and expression like no concrete swimming pool can. For an architect, this is fabulous! For example, we capped the indoor pool with a blue-tinted polycarbonate dome that is reflected on the submerged metal surfaces, thus giving swimmers a sensation of incomparable weightlessness. Stainless steel also provides more flexibility in imagining highly varied forms."

A giant pot

But a solid and rational technical argument follows immediately: "All pools have leakage problems. With a stainless steel pool, the water is contained much like water in a cooking pot! Furthermore, project execution is much simpler and shorter than with traditional tiled concrete. Finally, the gain in terms of sustainable development is incontestable: →

The Bellerive-sur-Allier swimming pool, Vichy. It was the first Olympic-size swimming pool in France ever to be built of stainless steel. Photo: Jacques Rougerie.



The Bellerive-sur-Allier swimming pool, Vichy. The stainless steel lining allows the designer to create complex shapes that are difficult to realize with other building materials. Photo: Jacques Rougerie.

a hygienic, ecological (recyclable) material that requires less maintenance than conventional solutions, and is much longer-lasting." But the architect knows how to be modest: "It is the advice and recommendations of the pool manufacturer that convinced me of the advantages of the material." Since the inauguration, dozens of French local authorities have expressed an interest in using stainless steels in swimming pools, both for renovations and for new projects.

Vichy Water Sports Centre fact sheet

Commissioned by	Vichy Val d'Allier
Designer	Jacques Rougerie (www.rougerie.com)
Execution	Baudin Châteauneuf and HSB France (a subsidiary of the Hink Group, Austria)
Grades	1.4404 (316L), 1.4571 (316Ti) and 1.4401 (316) recycled stainless steel
Supplier	ArcelorMittal

A dose of moly can go a long way

People thought steel was out of the race in cycling performance. But nothing could be further from the truth, thanks to a hidden dose of molybdenum that puts the muscle in new bicycles.

The Parisian Velib'. The renaissance of all-steel bicycles comes with the development of city fleets.

In the ultra-competitive world of professional cycling, doping may allegedly help a competitor to propel the pedals forward, but many have come to regret that choice. By contrast, in the everyday world of recreational and commuter cycling, a little "doping" of the steel used in these bikes brings benefits to all.

To be sure, carbon fibre is the material of choice in the racing world, especially in international races like the Tour de France. Light, strong, and flexible, it's a sure winner in this esoteric world. However, its price puts it out of reach for most users. Outside the professional cycling world, new types of stronger bicycles have been developed for extreme uses: these include mountain bikes which have to withstand the bumps of off-road trails, the "'teen" version BMX for skate parks and dirt tracks, and especially the free-service bicycles now appearing in cities like Brussels, Paris, Lyon, Montreal and Melbourne. Bikes are back and are vying for position with the automobile on the streets of our cities.

A highly effective anti-fatigue potion

With this need for stronger bikes, moly-grade steel is also back as a bicycle frame material. Why? Its relative lightness, flexibility, lower price than its all-carbon or aluminium competitors, and its proven robustness combine to make it an ideal material. In fact, chrome-moly steel has become the standard material for city bike fleets designed to resist the hazards of urban riding and improper handling by the occasional rider.

The most highly performing grades (for example CrMo 4130, also called "Cromoloy,") combine chromium, manganese and molybdenum. With 1% Cr and just under 1% Mo, 4130 offers the best combination of performance and cost for components requiring resistance to fatigue failure caused by the repeated shocks of heavy use. It is found in well-known applications like the handlebars (nearly indestructible, curved, ribbed inside, and heat-treated) and the frame. It also replaces aluminium in many other parts where its small weight penalty is less important than price and reliability. This is the case for components like the crankset with its chain wheel; the fork; the brake and gear cables; the chain, bolts, and spokes. Wheels and spokes are the parts most highly stressed and most subject to shock and corrosion, so moly's benefits are most appreciated here.

The comeback of the "All-Steel Bicycle"

So thanks in part to a magic formula containing molybdenum, alloy steel is once again racing ahead in bicycle technology, even if cycling champions aren't ready to trade in their carbon-fibre bikes. Mo is found mostly in the new-look bicycles of city fleets, mountain bikes or BMXs. They are on their way to giving British manufacturer Raleigh's catchphrase "The All-Steel Bicycle" new meaning. But not just any steel is used: it is moly steel we speak of, the only one that really makes the grade.

Stainless steel moulded to the goldsmith's imagination

Andrew Nyce is a retired metallurgist with a PhD in material sciences. Formerly the owner of an R&D company specialized in high-performance metals and ceramics, he now fashions rings and pendants with Types 304 and 316 stainless steel rods and flat bars.

As we follow the guiding theme of Andrew Nyce's creations, there is no room for doubt: he's a man of metal! Holding a PhD in material sciences and metallurgy, Andrew Nyce founded and headed for 43 years a research and development company in high-performance metals and ceramics, Gorham Advanced Materials Institute (GAMI). Though retired since 2003, Andrew is busier than ever, working with his hands to design and create original jewelry – made of metal, naturally!

New applications for an ancient technique

Andrew Nyce qualified as a goldsmith after receiving a thorough training at the Portland College of Arts (Maine, USA) and carrying out hundreds of hours of practical work in the shop. Thanks to his initial training and career entirely dedicated to metals, he naturally turned to the materials he knew best for his creations: precious metals like gold, silver or platinum, and also industrial alloys processed from powder metallurgy, in particular different grades of austenitic and martensitic stainless steels.

Andrew combines knowledge of modern alloys with a fascination for Damascus steel (see box below), an ancient process, originally from India and later widely adopted in the Middle East, for fabricating high-carbon (1.5–2%) steels into swords, knives, tools and the like. To make his jewelry, he procures Damascus stainless steel in rods and bars made in Sweden by Erasteel Kloster and Damasteel. After machining the steel billets, he subjects the rough shapes – rings and bracelets – to acid etching to obtain the desired effect. Then he circles the rings with gold, silver or platinum. "The molybdenum present in 316 stainless steel," he says, "is a key component of this grade, which forms the best possible combination in terms of corrosion resistance and durability. This is particularly important for bracelets and rings that would otherwise risk oxidizing in contact with skin and detergents."

A growing craft

While he has identified only four or five specialists in his field throughout the world, Andrew Nyce underscores that other applications are developing, for example for musical instruments (saxophones), clasps and leather accessories (suitcases, handbags etc.). Not only have the variety and elegance of his artwork attracted many buyers, they are also inspiring young people to seek training in his workshop.

About Damascus steel

Damascus steel was brought to Europe by the European crusaders, who admired the swords of the Sultan's troops. The original Damascus pattern is obtained by fusing together bits of iron, steel and carbon in a ceramic crucible. Carbides resulting from the precipitation of the high carbon content form lines on the surface of the steel, creating a specific pattern, the famous "watering effect". After they have been twisted, cut or coiled by the smith, the objects obtained can be etched with acid which attacks the hard and soft steels to different degrees, thus creating spectacular coloured motifs of networks and surfaces.

Today, Damascus steel is obtained from powder metallurgy, whereby alternating layers of two different kinds of stainless steel powders (304 and 316) are hot isostatically pressed. This technology allows the welding together of multiple layers, varying from a few dozen to a few hundred, depending on the effects sought. Etching then reveals the distinctive patterns of the layers.
For more information, see **www.andrewnycedesigns.com** and **www.damasteel.com**

Tiered Sea Breeze Damascus Stainless Steel Ring circled with gold or silver. Photo: Andrew Nyce Designs.

Symbol of hope crowns Belfast Cathedral

St Anne's Cathedral, the Anglican cathedral of Belfast, Northern Ireland, has a new, strikingly unconventional feature that it has been awaiting for over one hundred years. The Spire of Hope, which won the 2008 Royal Institute of British Architects award, soars 39 metres (almost 128 feet) above the cathedral. The exterior is constructed of Type 316 stainless steel and is designed to be maintenance-free for 100 years.

Belfast Cathedral is widely regarded as the centre of Anglican worship in Northern Ireland. The cathedral is built on the site of the parish church of St Anne, consecrated in 1776. The current cathedral has been evolving as a structure, built in stages as funds have allowed, since its foundation stone was laid in 1899. With the completion of the Spire of Hope in 2007, another chapter is written in the history and evolution of this icon of Anglican worship.

The cathedral had long lacked a crowning feature reaching heavenward. The notion of completing such a crown gained a new urgency as the cathedral approached its centenary. A stately spire had been included in the cathedral's original design but it remained just an idea on paper throughout the cathedral's life. With a new wave of prosperity coming to Belfast, and new development springing up around the cathedral, the cathedral community was concerned that this stately Romanesque building might be nudged into the background. The Cathedral Board formed a panel in 2003 to prepare a request for designs and undertake a design competition among architects under 40 years old from across the Emerald Isle. In the summer of 2004, the panel convened to review 23 submittals for the opening round of the competition. From this group, the panel selected three finalists and came to a consensus on the design that was to become the Spire of Hope. The winning design came from Box Architects of Belfast.

Now that the panel had agreed on a concept, the next two years brought the hard work of bringing the spire to life: detailed design of the structural support, computer modelling of the spire's behaviour in the wind, and selecting a fabricator with the skills and the dedication necessary to turn a bold vision into a luminous reality. The project became a wonderful collaboration between the cathedral, the designers and the fabricators. The design is a long "spike" reaching 39 metres (almost 128 feet) skyward above the church and extending downward through a large glass skylight 15 metres (almost 50 feet) into the church above the choir. The spike is round in cross-section, tapering from 1.2 metres (almost 4 feet) in diameter at its widest point to 4 mm (0.15 in) at the tips of the spike.

The original design was for a carbon steel skeleton covered with titanium plates. This design raised some concerns for the selection panel. Among the concerns, there was a worry about electrolytic action between the titanium skin and the carbon steel skeleton not being able to meet the 100-year maintenance-free design criterion, and a concern that the design, with openings between the titanium plates, might "sing" when the wind blew across it, much like a flute. The stainless steel solution addressed both of these concerns. Moly-grade Type 316 stainless was selected for the outdoor portion of the spire to withstand corrosion in the coastal, urban environment and the fully welded skin eliminated the gaps that might cause the "singing". It also eliminated the need for an internal skeleton. The spire is hollow and self-supporting.

The round cross-section of the spire gave the design team some concerns about the dynamic response when subjected to wind. ➔

The Spire of Hope: facts and figures

Length	54 metres (c. 177 feet)
Maximum width	1.2 metres (almost 4 feet)
Weight	40 tonnes
Material	Stainless steel Type 316 (exterior); stainless steel Type 304 (interior). About 600 kg of molybdenum were used in the outdoor part of the spire
Glass	2½ tonnes of triple-layered glass spanning 6½ metres (about 21 feet) across the opening through which the spire enters the building
Designers	Colin Conn Architects; Robert Jamieson Architects (Belfast)
Structural engineers	Ramboll Whitbybird (London); Taylor and Boyd (Belfast)
Fabricators	Tuchschmid (Frauenfeld, Switzerland)
Project manager	WH Stephens (Belfast)

The Belfast Cathedral Spire of Hope, view from the interior. Photo: Todd Watson.

These concerns led them to engage the School of Aeronautical Engineering at Queens University in Belfast to develop computer modelling of its behaviour. This modelling resulted in some redesign to "tune" the plates of the structure and provide enough structural damping to prevent the spire from moving excessively, even when subjected to hurricane-force winds. The modelling also revealed that the fins anchoring the spire into the building required some additional stiffening. The structure is still quite dynamic, nearly always vibrating mildly. This led the designers to specify replacement of over 500 structural bolts in the building framing to guard against any possible loosening due to this mild vibration.

Every generation of designers makes its mark on the world bringing new ideas, new sensibilities, new materials to the craft. This project represents a realization of striving to produce new architecture that complements the existing structure without copying it, of juxtaposing the old and the new to create a new and unique whole. The spire is illuminated by 12 outdoor lights and eight interior lights. Rising over 70 metres (almost 230 feet) above the ground, and visible throughout the city, this triumph of design and construction has secured the cathedral's place in the skyline of Belfast for many years to come.

The Belfast Cathedral Spire of Hope. Photo: Todd Watson.

IMOA's 20th AGM

2008 marked IMOA's 20th anniversary, which was celebrated in fitting style at the AGM in Chile. The meeting provided the opportunity to look back on the Association's past achievements and forward to its exciting plans for the coming year. It was also the year in which the Association's Secretary-General, Michael Maby, was succeeded by Tim Outteridge.

Over 150 delegates gathered at the coastal resort of Viña del Mar, Chile, for IMOA's 20th AGM, generously hosted by Codelco. In his welcome address Victor Perez, Marketing Director of Codelco and IMOA President, began by reminding everyone that IMOA had reached its 20th anniversary, and he encouraged members to celebrate in a manner appropriate to this important milestone. Later, it transpired that nothing less than an entire vineyard had been dedicated to this purpose, and members dutifully obliged.

Sustainability and stewardship

Turning to the Association's business, Perez praised the "flexible, bright and talented staff" and the "high degree of membership commitment" which had enabled the Association to assimilate the challenges of the EU's REACH legislation and respond to regulatory issues around the world. The investment IMOA had made in developing its data had given the association an arsenal of arguments to show that, from an environmental standpoint, molybdenum is a very low-risk metal. Perez went on to say that the conceptual frameworks of sustainability and product stewardship were here to stay and that the Association's commitment must be maintained in order to ensure that IMOA is prepared for the future challenges presented by the trend to extend producer responsibility "beyond the gates".

Promotion

Reviewing the Association's market development programme, Perez noted IMOA's ➔

Members arrive at Viña Indomita and take in (not literally) their surroundings.

From left: Tim Outteridge, Victor Perez, Hans Imgrund, Michael Maby and Dave Thornton. Hans Imgrund and Dave Thornton are past IMOA Presidents.

continued efforts in the promotion of stainless steels, particularly in architecture, building and construction, and the influence of such activities on decision makers all over the world. He went on to draw attention to the Molybdenum Technology Platform, which had elicited a large number of quality proposals for new molybdenum-related research. Finally he announced that IMOA had earmarked record funding for market development in 2009, underpinning a very ambitious future programme.

New Secretary-General

The 20th AGM was the last for IMOA's long-serving and highly respected Secretary-General, Michael Maby, who had earlier announced his retirement. Maby was at the helm from the very inception of IMOA in 1989, steering the association through its formative years. He was instrumental in the evolution of IMOA to the established, dynamic and successful organisation it has become. Many gave tribute to Maby for his excellent and dedicated work over 20 years. Commenting on his tenure Maby

Victor Perez and Rose Maby (IMOA staff, "retiring" along with her husband).

said: "It has been a pleasure to work with IMOA from the very beginning, knowing there was always a supportive and friendly membership through bad times and good." Quoting the Epicureans, he contemplated a retirement "free from disturbance". However, he may have to wait a while for that, as he plans to continue in his parallel role as Secretary-General to ITIA for a few more years, much to the delight of his colleagues and friends in the tungsten industry. Maby passes the baton to Tim Outteridge, a former IMOA Executive Committee member and Vice President who returns to the moly industry after a break of some eight years.

Presentations

The presentations at the 20th AGM (see box) maintained the same high quality as in the past and ensured a full auditorium at all times.

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IMOA 20th AGM presentations

- **Health, safety and environment issues** Guido Provoost and Sandra Carey
- **Moly Tech Platform** Fernando Lund, Director of Centre for Advanced Interdisciplinary Research in Materials (CIMAT)
- **Molybdenum as a by-product** Juan Carlos Guajardo, General Manager of CESCO
- **Molybdenum in life (including medical uses)** Philip Mitchell, Emeritus Professor of Chemistry at the University of Reading
- **The potential of moly in high-strength carbon steel for structural, pipeline and automotive applications** Hardy Mohrbacher, Managing Director of NiobelCon bvba
- **Molybdenum applications in China** Hardy Mohrbacher, Managing Director of NiobelCon bvba
- **Preliminary results of SMR survey for IMOA** Werner Bulla, SMR GmbH
- **Stainless steel in South America** Carmen Silva, ILAFA
- **Other issues** Nicole Kinsman, IMOA Technical Director