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Mining Magazine

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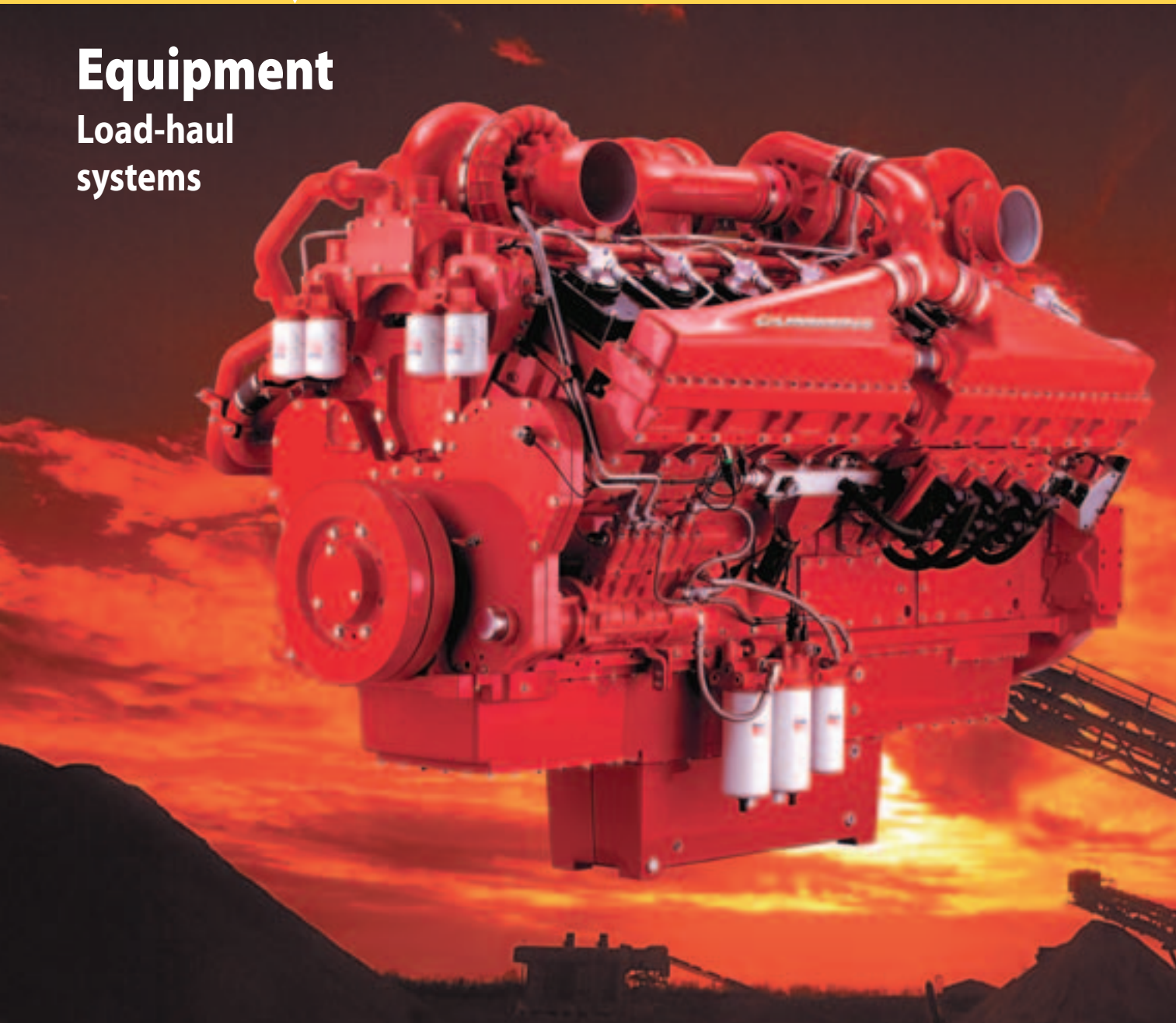
Load-haul systems



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APRIL 2006 • VOL 194 • NO 4

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Matte tapping at the Fortaleza nickel smelter, Mineracao Serra da Fortaleza Ltda, Brazil

The characteristics of tailings and their ability to mobilise metal constituents are of great, and growing, concern

in this issue

FRONT COVER

Cummins' latest QSK50 is sure to be one of the main engine attractions on view at the Paris Intermat show (April 24-29). Purpose-designed for haul trucks, excavators and loaders, the 50-litre V16 engine offers up to 1,567 kW (2,100 hp) and is one of the first mining engines meeting EPA Tier 2 emissions. Evolved from the industry-standard K2000E, the engine incorporates Cummins Modular Common Rail fuel system, reducing noise by up to 80%. Other features include individual cylinder health-monitoring and high-durability FCD pistons, extending engine life-to-overhaul by 17%.

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*In Africa, new technology Warman slurry pumps (post 1991) from Weir Minerals are sold as Envirotech pumps

Wild west

THE private-sector investment arm of the World Bank, the International Finance Corp (IFC), will this month implement a new set of environmental and social standards. They will replace the existing guidelines (adopted eight years ago) in all IFC-sponsored projects and are likely to be incorporated into the Equator Principles (the guidelines followed by a group of leading financial organisations; see p4).

With appropriate timing, Citigroup Global Markets Inc has just published a report which concludes that mining risk is company, rather than country, dependent. The report, 'Towards Sustainable Mining', postulates five factors of sustainable development that have the potential to add, or destroy, value for metals and mining companies globally: commodity and country exposure, mine development, and the corporate responsibility factors of sustainable governance and of HSEE (health, safety, employment and environment).

By combining these factors, Citigroup has created a Sustainability Mining Index (SMI) to evaluate how companies are conducting their businesses. Among the conclusions is the observation that, while commodity exposure can have some impact, it is the country exposure that causes most variation in company scores. This, however, can be exacerbated by corporate management when it comes to mine development, and by control of HSEE and sustainable governance at the operating level.

Citigroup notes that the sustainable development agenda presents companies with only two choices (assuming that they do not want to continue operating in the old ways in a new world, and go out of business):

First, they seek out low-regulation, low-cost environments for their future developments (the so-called 'riding with the cowboys' option).

Second, they develop a new business model that places a premium on environmental responsibility (the 'hanging with the sheriff' option).

Citigroup's SMI ranks 17 of the world's largest mining companies based on its five broad measures of sustainable development. The mine-development measurement takes into account the impact of corruption, mine closures, access to land and stakeholder engagement levels, while the country-risk measurement takes into account a region's bond rating, the threat of terrorism, political interference and the vulnerability of the supply chain. A company's commodity exposure can encompass recycling, emissions, energy use, health, safety and environmental impacts.

The report maintains that the companies that react most effectively to emerging business risks and opportunities will outperform their less-conscious rivals. Sustainable practices, it says, have "the potential to add or destroy value for metals and mining companies, and thereby for investors". In this regard, Citigroup recommends that investors buy Alcoa Inc, BHP Billiton plc, Rio Tinto plc, Anglo American plc and Alumina Ltd.

Of more importance to *Mining Magazine* readers are Citigroup's observations on the importance of mine development on determining value for the operating company. The report states, not surprisingly, that "gaining mineral rights and ensuring access to land are key elements of the mine-development process". However, Citigroup adds that the 'softer' skills, around stakeholder consultation and environment-impact assessment, "can also be critical".

Indeed, Citigroup concludes that the project 'pipeline' that secures the future growth prospects of mining companies depends as much on a company's ability to manage social and political risk as on its project management or technical expertise.

To help measure such competences, Citigroup selected five tangible indicators: government relations, local community engagement, managing corruption, environmental assessments and closure planning, and a company's track record and reputation. For each indicator, Citigroup rated companies according to five levels of performance. Under 'local community engagement', for example, the performance ranged from 'Some charitable contributions' (scoring just 1), through 'Coherent community policy' (worth 3), to 'Sector leading and innovative' (worth 5). Only Rio Tinto and Anglo American top-scored in this category.

Whatever the individual corporate scores, and indeed the merits of such rankings, investors are reminded that, in reality, cowboys are farmers who tend cattle, and it is only in the movies that they ride wild, and shoot people.

"Riding with the cowboys, or hanging with the sheriff"

... with Dr Chris Hinde

Intermat is near

THE International Exhibition of Equipment, Machinery and Techniques for the Construction and Building Materials Industry (Intermat) opens its doors this month, and almost 1,500 exhibitors are expected, with 200,000 visitors.

Intermat is one of the world's biggest construction shows, and this year's event will include at least seven national pavilions (Korea, Spain, US, Finland, the UK, Italy and China). The show will also include a large outdoor demonstration area presenting a range of crushing/grinding, drilling, boring and laser guidance equipment under actual working conditions.

The mining and quarrying industries are well represented. The sector is being hosted in a dedicated area, with a special discussion forum, and some major new equipment launches. We featured the most significant launches and events for Intermat in last month's *Mining Magazine* (*MM*, March 2006, p30); for details, please visit our website (www.mining-journal.com).

Intermat is being held at the Paris Nord Exhibition Centre in France on April 24-29.

Lonmin PGM expansion

LONMIN plc has commissioned a US$10 million feasibility study to increase its PGM smelting and refining capacities in South Africa.

The proposed de-bottlenecking and expansions across the company's PGM refining chain are expected to increase the company's previous PGM production forecast, of 2.5 Moz/y by 2010, to 3.5-4.0 Moz/y. Lonmin said: "This has the potential to be an attractive brownfield expansion project opportunity for Lonmin at a capital cost expected to be of the order of US$330-350/oz of PGM produced annually, approximately one-third of the cost of new greenfield capacity." The cost of the expansion is estimated to be US$300-350 million. The feasibility study will take about 12 months to complete. Lonmin's PGM output in the December quarter of last year came to 363,737 oz.

Bucyrus' oil-sands award

SYNCRUDE Canada Ltd has bought its third 495HF electric mining shovel from Bucyrus International Inc. The shovel is for the company's Aurora mine, which ordered two 495HF shovels last year.

The shovel is equipped with a field-proven lower-works design that carries 3.2 m-wide crawler links, giving the shovel the ability to operate in the soft underfoot conditions found in oil-sands applications. In addition, the 495 High Performance shovels carry the new Bucyrus SuperCab, which is specifically designed for operator comfort, efficiency and work-face visibility.

IFC's environmental standards get tough

THE private-sector investment arm of the World Bank, the International Finance Corp, has adopted a new set of environmental and social standards, with implementation expected once the new rules have been approved by the board of the IFC this month.

The new standards will replace the existing guidelines – adopted in 1998 – in all IFC-sponsored projects (and not just in mining). As were the existing guidelines, the new standards are likely also to be incorporated into the Equator Principles.

The Equator Principles are a set of environmental and social guidelines announced nearly three years ago by a group of leading financial organisations. The number of organisations signed up to the Equator Principles now totals 40, covering about 80% of project financing worldwide.

The IFC's executive vice president, Lars Thunell, described the new standards as "stronger, better and more comprehensive than those of any other financial institution working with the private sector. We aim…to increase the development impact of the projects in which we invest. We also seek to give companies operating projects in emerging markets the capacity to manage fully their environmental and social risks."

The new standards contain additional requirements in several areas, including community health, the contentious issue of the use of security forces and pollution abatement and prevention. The last-named will include the requirement that a project's greenhouse-gas emissions are quantified.

The standards comprise six documents. Three will be formal policy of the IFC: the Sustainability Policy; the Performance Standards; and the Disclosure Policy. The other three will be for advisory and reference purposes: Guidance Notes; the Environmental and Social Review Procedure; and the Environment, Health & Safety Guidelines.

Boddington gets the go-ahead

THE partners in the Boddington gold-mine redevelopment project in Western Australia have decided to proceed with construction.

Boddington is owned by Newmont Mining Corp of the US with 66.7% and South African-based AngloGold Ashanti Ltd with 33.3%. The go-ahead follows the announcement in February of the acquisition by Newmont of the 22.22% share held by Newcrest Mining Ltd for A$225 million.

Based on Newmont's estimated share of US$0.9-1.0 billion, the total capital cost will be in the range US$1.3-1.5 billion, which will result in a mine producing 1.05 Moz/y over the first five years of operations. Average output over the expected 15-year mine life is expected to be 900,000 oz/y, at an operating cost of US$210/oz net of by-product credits.

Boddington lies just over 100 km southeast of Perth. The redevelopment will exploit the Wandoo basement resource.

The initial mine plan is based on proven and probable reserves totalling 403 Mt, at an average grade of 0.89 g/t Au and 0.12% Cu, for contained reserves of just over 11 Moz and 480,000 t of copper. Newmont anticipates copper recovery of 83%.

There are additional resources of 144 Mt measured and indicated, at 0.58 g/t Au and 0.08% Cu.

DBT sells transport arm

AS PART of a decision to focus on its core coal-mining activities, Lünen-based DBT GmbH has sold its subsidiary DBT Maschinenfabrik Scharf to the Aurelius Group, a private-equity company headquartered in Munich.

Maschinenfabrik Scharf, with its subsidiaries Transporttechnik Saar and Scharf Polska Sp, is a leading manufacturer of underground transport systems for men and materials. The product line includes overhead monorail systems and rail-mounted systems used for handling loads of up to 30 t.

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Ferrominera Orinoco awards processor work

VENEZUELA'S Ferrominera Orinoco has approved a US$219 million contract to Duro Felguera for work on its iron-ore concentrator in Bolívar, bringing the total awarded to date to the Spanish company for work on the plant to US$453 million.

The contract, via Duro Felguera's local subsidiary, Plantas Industriales, will involve designing, manufacturing, supplying, erecting and commissioning the various processes to bring the iron content of the concentrated ore up to 68%. The installed processes will also reduce the percentage of silica.

The delivery's first phase, in November, will include the stockyards; the second phase, in December 2008, will incorporate all systems forming the process plant.

The concentrator will process 12 Mt/y to yield 8 Mt of concentrate. The stockyards will be designed for a throughput of 26 Mt/y as the plant will also handle raw iron ore from the nearby Cerro Altamira mine, which will not undergo concentration as it already has sufficiently high iron content. The project also includes a marshalling yard for 2 km trains, with corresponding loading and unloading stations.

The plant will increase the life of the mine by at least 40 years as it will allow Ferrominera Orinoco to process low-grade iron-ore reserves. The installation, 110 km from Puerto Ordaz, will employ up to 850.

Volvo scores mammoth order from China

VOLVO has received its biggest-ever sales order from China.

Volvo Construction Equipment China (VCEC) is to delivery 36 A40D articulated haulers and six L220E wheel loaders to Changsha Design & Research Institute of Nonferrous Metallurgy (CINF). The 40 t haulers and 11 t loaders will be utilised in the Chinese bauxite operations of Guangxi Hua Yin Aluminum Co, with delivery scheduled by the end of November.

Siemens wins Zambia deal

SIEMENS has received an order worth €15 million (US$1=€0.82) from Equinox Copper Ventures Ltd to equip two ore-grinding mills at the Lumwana copper mine in Zambia with gearless Simine drive systems. The mills are due to start operating at the end of 2007.

Siemens is supplying gearless ring-motor drive systems supplied with power via cyclo-converters. The SAG mill, 11.6 m in diameter, will be equipped with a 18 MW drive system, while the 8 m mill will have a drive output of 16 MW.

The variable-speed drives are controlled with Siemens' patented transvector system, which reduces wear and, due to the lack of any gears, the cost of maintenance is considerably lower than for conventional drives.

A 'frozen charge shaker' will be used for the first time for the ore-grinding mills envisaged for Zambia.

The procedure (which utilises defined forward and reverse movements of the mill) is used for the controlled detachment of frozen (hardened) charge stuck to the inner wall of the mill shell.

LionOre gives DMS plant go-ahead

LIONORE Mining International Ltd is to add a 1.7 Mt/y dense-media-separation (DMS) plant to the ore-processing circuit at the Phoenix open-pit nickel mine, part of the company's 85%-owned Tati Nickel operation in Botswana.

According to LionOre, the plant will stabilise the ore grade through the main concentrator plant, thus increasing nickel production by 590 t/y. Commissioning of the plant is expected by the end of July. LionOre has also given the go-ahead for a 'bankable' feasibility study (BFS) to build a second, US$70 million DMS plant at Tati, with a throughput capacity of 12.5 Mt/y. The BFS is due for completion by July, with construction to begin in August and commissioning expected by December 2007.

The BFS will interface with LionOre's BFS to introduce its Activox processing technology at Tati currently under way.

Zimbabwe tables state control of mining firms

THE Zimbabwean Government has proposed changes to the country's Mines and Minerals Act that would result in the state taking a 51% interest in certain foreign-owned mining companies.

In a statement to the industry body the Chamber of Mines, the mines minister, Amos Midzi, said the cabinet had approved measures for the government "to indigenise 51% in some instances of all foreign-owned companies".

According to Mr Midzi, this would involve the government taking 51% in energy, precious metals and diamonds, of which 25% would be non-contributory and transferred as soon as the changes become law, and the balance of 26% would be earned over five years.

In the gold and emerald sectors, the government plans to take a 51% stake in conjunction with local investors.

Vulcan bit's trial success

FOLLOWING recent drilling trials at the James Bay site in northern Quebec, Mercier Drilling reports that it reached over 1,000 m with Fordia Group's Vulcan 16 mm bit.

Jean-Claude Gendron, Mercier's vice president of diamond drilling, described his drillers as being "amazed by the extended bit life".

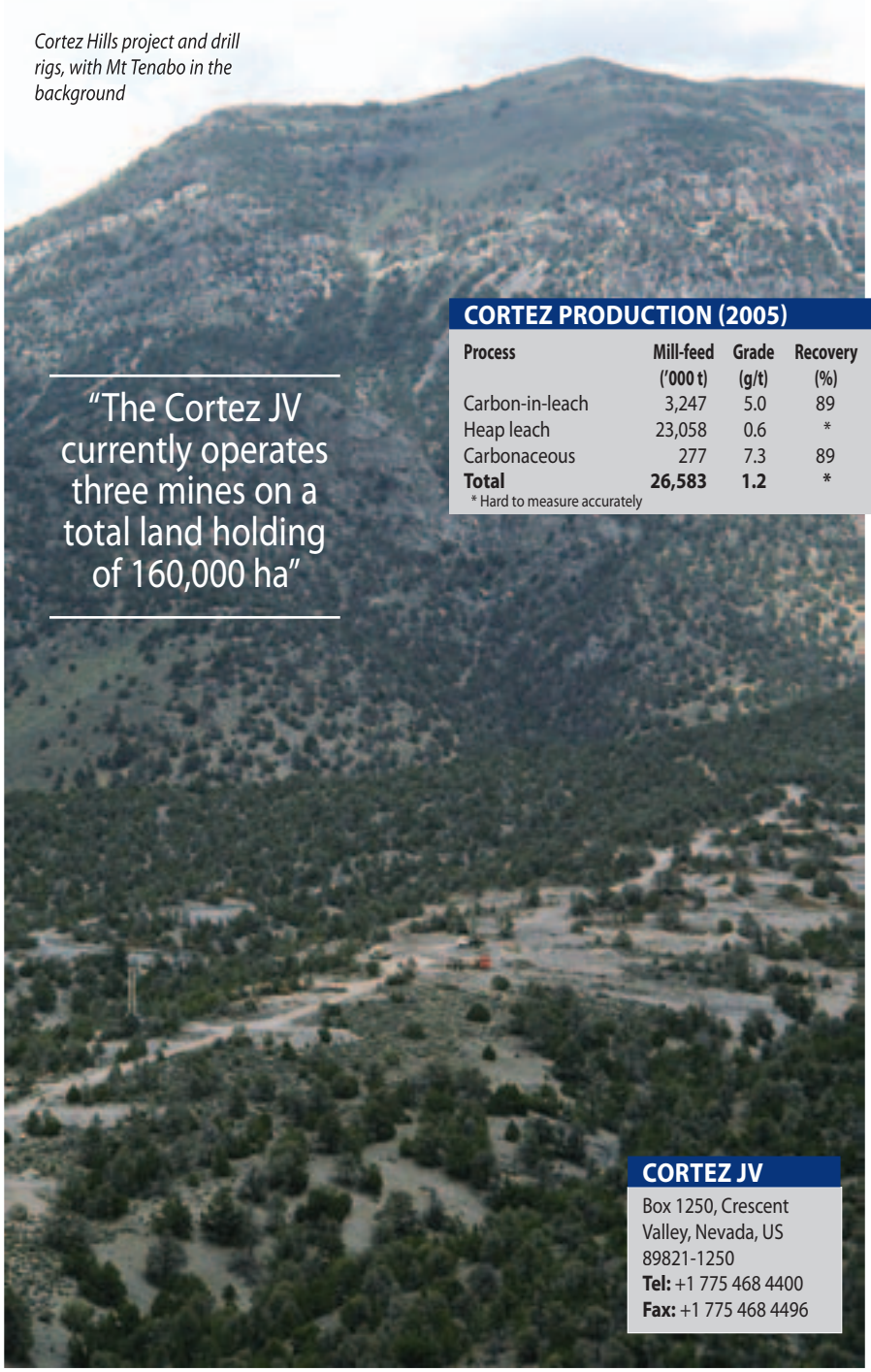
Fordia promotes the Vulcan 16 mm bit as offering up to 33% longer bit life when compared with a 12 mm drill bit. During heavy drilling applications, the reduced pull-outs to replace the drill bit ensure that drill sites are able to realise significant improvements in productivity.

The drill bits' critical gauges are protected with thermally-stable polycrystalline diamonds, which offer "unsurpassed durability", according to Fordia. The bridge structure, which does not restrict drilling-fluid circulation, is composed of the same material as the matrix and wears along with it.

This creates a system that distributes the highest torques equally on all segments.

Expansion mode

Six months ago, the partners in the Cortez gold joint venture in northeastern Nevada gave the go-ahead for a US$455 million project expansion



Cortez Hills project and drill rigs, with Mt Tenabo in the background

"The Cortez JV currently operates three mines on a total land holding of 160,000 ha"

CORTEZ PRODUCTION (2005)

Process	Mill-feed ('000 t)	Grade (g/t)	Recovery (%)	Production (oz)
Carbon-in-leach	3,247	5.0	89	466,900
Heap leach	23,058	0.6	*	378,320
Carbonaceous	277	7.3	89	58,400
Total	**26,583**	**1.2**	*	**903,620**

* Hard to measure accurately

CORTEZ JV

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IN SEPTEMBER 2005, Placer Dome Inc (60% owner and operator) and Rio Tinto (40% owner through Kennecott Minerals Co) announced the go-ahead of the Cortez Hills project, which comprises the Cortez Hills deposit itself and the Pediment deposit. At that time, the proven reserves were said to amount to 37.5 Mt at 3.3 g/t Au, and the probable reserves a further 27.2 Mt at 1.8 g/t. Placer Dome reported that total contained gold in the project amount to almost exactly half of the 11.1 Moz total in the entire Cortez JV.

Unfortunately for Placer Dome, it will not be able to enjoy the fruits of its expansion project as an independent producer. March 8 was the last day of trading in the company's shares (on the Toronto and New York stock exchanges) following the takeover by Barrick Gold Corp in January (the company secured a 100% stake in Placer Dome on March 20 following compulsory acquisition of the remaining shares).

The takeover by Barrick has inevitably injected an element of uncertainty into the Cortez Hills project, with senior officials having been replaced, and a review taking place of Placer Dome's mines and projects to ascertain how they will fit into a new corporate structure (at the moment, the operation is held through Cortez Gold Mines, which is described as a division of Barrick). A company spokesman told *Mining Magazine* that "while we do not expect any significant changes to the development plans at Cortez, specific details may, or may not, change in the near future". *Mining Magazine* will publish details of any changes in a forthcoming issue.

ORIGINAL PLANS

Under Placer Dome's proposal, the ore from the Cortez Hills project will be treated at the existing Cortez mill (which treats ore from the Pipeline deposits) and some at a new leaching facility to be constructed near Cortez Hills/Pediment. The new operation, assuming it goes ahead, will yield 4.6 Moz over the seven-year project life, at a cash operating cost of about US$170/oz.

The capital cost of the original project includes US$50 million for a decline to be driven, over the next four years, from the existing open pit to beneath the planned Cortez Hills open pit to evaluate an underground extension.

HISTORY

Mining has taken place in this part of north-central Nevada since the 1860s, and a number of abandoned mines and ghost towns lie in the area.

The partners in the Cortez JV, which centres on the Crescent Valley, 120 km southwest of Elko, began exploration activity in the area in 1968. This came five years after Newmont Mining had identified a 3.0 Moz gold deposit in the Carlin Trend. Newmont opened its first mine on the Trend in 1965, and subsequent discoveries have included Barrick Gold's

39 Moz Betze-Post deposits (worked as an open pit) and the 10 Moz Meikle deposit (worked as an underground mine). Nearby is Newmont's Gold Quarry mine.

Placer Dome discovered the Pipeline deposit in 1991, and the South Pipeline deposit shortly afterwards. The Pediment deposit was discovered in 1998, followed by the South Pipeline Extension deposit in 2000. The Cortez Hills deposit was uncovered in 2003, with an initial estimate putting the resource at 3.0 Moz. By June 2004, the Cortez Hills deposit was estimated to contain 7.5 Moz of gold in proven and probable reserves.

The mineralisation has similarities with the nearby Carlin Trend discoveries, being sedimentary rock-hosted and consisting of micron-sized free gold particles that are disseminated throughout the host rock, commonly in association with secondary silica, iron oxides or pyrite. The geochemistry is also similar, and there is a low silver-to-gold ratio.

The Cortez Hills discovery is a few kilometres from the original Cortez mine, which operated as an open pit from 1969 until the early 1990s. The adjacent mill was shut in October 1999, and a new processing plant entered operation in 1996. The Cortez JV currently operates three mines (Gold Acres, Pipeline and Pipeline South) on a total land holding of 160,000 ha, and has joint ventures with Coral Gold and Idaho Mining Corp on contiguous properties.

South-looking view of the Pipeline/South Pipeline Pits

COSTS

The costs at Cortez are affected by royalties on the property.

These include a sliding royalty held by Royal Gold and a 1.5% royalty held by Idaho Resources, which once held the claims for the Cortez site. The average royalty and production taxes account for US$53/oz, according to Placer Dome.

MINING ACHIEVEMENTS

Cortez received the *Mining Journal* award for 'Mining Operation of the Year' (sponsored by the London Stock Exchange) in 2004 for its high-volume, highly-efficient, capital-intensive operation. The three open pits, concentrator and several heap-leach pads have a combined capacity of some 70 Mt/y using conventional open-pit mining methods.

A worker on a haulage truck at Cortez

The pit wall varies from 35° to 50°, and mining is carried out with electric and hydraulic shovels and haul trucks. Almost US$50 million was spent in 2004 on a new equipment fleet (including new 400 t Liebherr trucks). This increased capacity is designed to counter a transition into lower-grade areas of the Pipeline and South Pipeline deposits.

According to the mine sequencing plans, Pediment will not be mined until after 2010, while the Pipeline and South Pipeline operations will start to slow down in 2008-10. In the year to end of December 2005, Cortez achieved a mill feed of 26.6 Mt at 1.2 g/t to yield 903,620 oz (just failing to achieve an above-nominal capacity of over 1 Moz/y for the eighth year in a row). The 14% decline was due to a reduction in throughput. Average cash costs rose to US$206/oz (US$162/oz in 2004) with total costs of US$242/oz.

PROCESSING

Cortez utilises carbon-in-leach and oxide heap-leach gold-recovery processes.

The existing Pipeline plant, which has a throughput capacity of 10,000 t/d, will expand by 50% to accommodate the new material. Fortunately, the plant was designed to handle various types of oxide ore (initially from the Pipeline and South Pipeline orebodies) and comprises primary crushing, autogenous/ball mill grinding, carbon-in-leach (CIL) and carbon-in-column (CIC) gold-recovery systems, together with carbon stripping, reactivation and gold-refining facilities.

The CIL circuit consists of eight tanks, 16 screens and eight carbon-forwarding pumps. Retention time varies from 44 hours (for the 9,300 t/d throughput rate) to 54 hours (for the South Pipeline ore at 7,500 t/d). The CIC circuit consists of six carbon columns with a retention time of 18 minutes.

After stripping the carbon (using a pressurised Zadra process), the gold is recovered by electrowinning on to stainless-steel cathodes. The filter cake is dried, fed into an induction furnace and poured into doré bars (assaying 90-94% Au and 3-6% Ag).

The low-grade, run-of-mine oxide ore is heap-leached, with gold-bearing carbon from this section being returned to the main concentrator for gold recovery.

In announcing the go-ahead decision last September, Placer Dome's chief executive, Peter Tomsett, described Cortez Hills as "an exciting opportunity for the company", adding that the project "demonstrates our ability to create value from our exploration programmes. We expect to be in the Cortez trend for many years and this project is another significant development that underscores the value of the land package the joint venture has acquired around the mine."

Recent geotechnical analysis and re-engineering has resulted in shallower pit-wall angles being adopted to ensure appropriate factors of safety, and therefore a shallower overall open-pit depth.

As a result, a portion of the mineral reserve was reclassified as a mineral resource, and the high-grade mineral resource that now sits below the bottom of the open pit will be investigated as part of the underground mine development project.

The new proven reserves were given as 87.5 Mt at 2.0 g/t, with probable reserves of some 147 Mt at 1.1 g/t.

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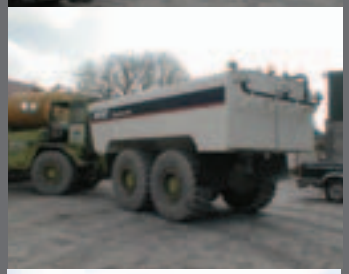


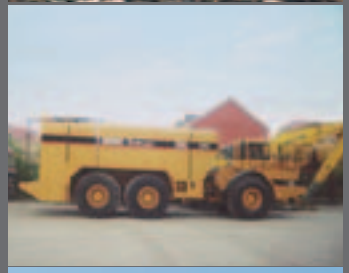


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Riding on a supercycle

ACTIVE MINING TRUCK POPULATION

Size-class	Operation numbers End-2003	End-2005	Change (%)
90-110 t	4,983	6,411	29
140 t	1,726	2,065	20
154-190 t	2,937	3,141	7
220 t	2,349	2,919	24
290 t+	497	711	43
Total	**12,492**	**15,247**	**22%**

Source: Mobile Mining Equipment Database (The Parker Bay Co)

Dave Porter, who introduced the term 'Ultra Class' into haul-truck weight designation, provides an exclusive analysis of product developments in the loading and haulage sector

A LOT has changed in the more than two years since the last *Mining Magazine* report on loading and hauling. At that time (*MM*, December 2003, p27), the world's economies were still recovering from post-9/11 despair and the metals prices had only just started its long recovery.

Metals price appreciation, the early closure of some higher-cost mines, falling stockpiles and expectations of economic recovery have all been contributing factors in the recovery of the century for the heavy-equipment sector.

The market for trucks remains dominated by the big five manufacturers: Caterpillar, Hitachi, Komatsu, Liebherr and Terex (Unit Rig). But while the names remain the same, unit sales have increased dramatically over the past few years (even in the best years, truck shipments were measured in hundreds but we are now counting truck sales in thousands).

Despite the serious problems caused by the shortage of off-road tyres (*MM*, December 2005, p20), truck sales are booming. The number of 90-110 t trucks in operation at the end of last year was 29% higher than the number working at the end of 2003 (see table above). The number of 140 t trucks was 20% higher, and there were 7% more trucks operating in the 154-190 t weight range. While the 220 t truck group was an impressive 24% greater, the clear winner has been the Ultra Class' trucks (290 t-plus), with an increase of 43% compared with the end-2003 situation. According to The Parker Bay Co, a total of 711 Ultra Class units were operating at the end of last year, compared with only 497 such trucks at the end of 2003. The market for these is shared between Caterpillar, Hitachi, Komatsu and Liebherr.

Overall, this is a very respectable 22% increase, providing for a substantial and, in many instances, overdue replacement of older trucks. Indeed, according to Parker Bay, orders for mining trucks (units of over 90 t) nearly tripled between 2003 and 2005, with shipments up from just 570 in 2003 to 1,586 in 2005.

Currently, the T282B is unsurpassed in payload capability. If equipped with a special lightweight body, this further increases payload to 378 t (416 ton), and achieves this with an unloaded weight (ULW) of around 232 t and a gross machine weight (GMW) of just 592 t

TRUCK DEVELOPMENTS

Caterpillar upgraded its 797 in 2003 to the model B (rated at 345 t, with increased power output from its dual-block 24-cylinder 2,600 kW engine). Fleets of 797B trucks are now operating successfully in the Alberta oil-sands mines, at Escondida and in Australia, with a total of about 200 units in operation worldwide.

However, from the point of view of maximum payload, the 797B cannot match the 363 t (400 ton) payload capability of the current Liebherr T282B. If equipped with a special lightweight body, this further increases payload to an unsurpassed 378 t (416 ton) and not only does the T282 carry the greatest payload, it achieves this with an unloaded weight (ULW) of around 232 t and a gross machine weight (GMW) of just 592 t.

Caterpillar is due to announce shortly the next (F) generation of upgrades to its heavy construction and quarrying trucks (under 100 ton), starting with the 777F. However, the announcement will be eclipsed by the

Continued on page 12

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first public declaration, due to be made in late March (after *MM* went to press) of the company's diesel-electric drive programme (see later).

Liebherr is contracted to Siemens for its drive systems, but, for at least two years, Liebherr has been manufacturing its own planetary reduction gearing. So it will come as no surprise that the company will soon introduce its own proprietary drive system, which will be eventually integrated into the T282B. Early next year (and Bauma could be a good opportunity), we could see another new Liebherr product with the re-emergence of the Innovative Lightweight Truck (ILMT).

The original ILMT design concept was a hybrid, incorporating several weight-saving features plus a new divided rear-axle arrangement. This led to the TI-272, and a number of units went into service. Unfortunately, the concept was not accepted by an overly conservative mining market. However, the second-generation machine (the TI-260) will be an entirely different prospect, incorporating design changes that will again include the company's own inverter drive system, along with a completely redesigned rear-axle assembly.

Because of its contractual agreement with Siemens, Liebherr has no truck product below 400 ton, so the design of smaller-capacity trucks remains a high priority. With Liebherr fully committed to its ILMT design, it is likely to form the basis of all future truck products.

Liebherr has around 110 T282s in operation currently, with orders for at least 37 more (depending on tyre availability). Mt Arthur Australia is running 21 T282s, Codelco has 16 in operation (with a further seven units on order), Syncrude has 17 (12 on order) and Cortez has eight (with 16 on order; see p8). Asarco in Tucson has requested a quote, but precise numbers have not been secured to date.

The next all-new truck product from Komatsu since the introduction of the 830EAC in 2004 is the much-anticipated 960E. The first units are almost complete after what has been one of the most intensive application-evaluations of any new truck product to date.

Rated at a tyre-dependent capacity of 360-380 ton, the first 960E unit completed its shakedown at the company's Tucson proving grounds. But to undertake the second phase of operational evaluation, it was moved to the Powder River Basin in Wyoming. With this second stage of testing nearing completion, a new unit (03) will be built in Peoria (modified to include different planetary gearing), then shipped to an Alberta oil-sands operation for final testing. Unit 01 will remain in Tucson.

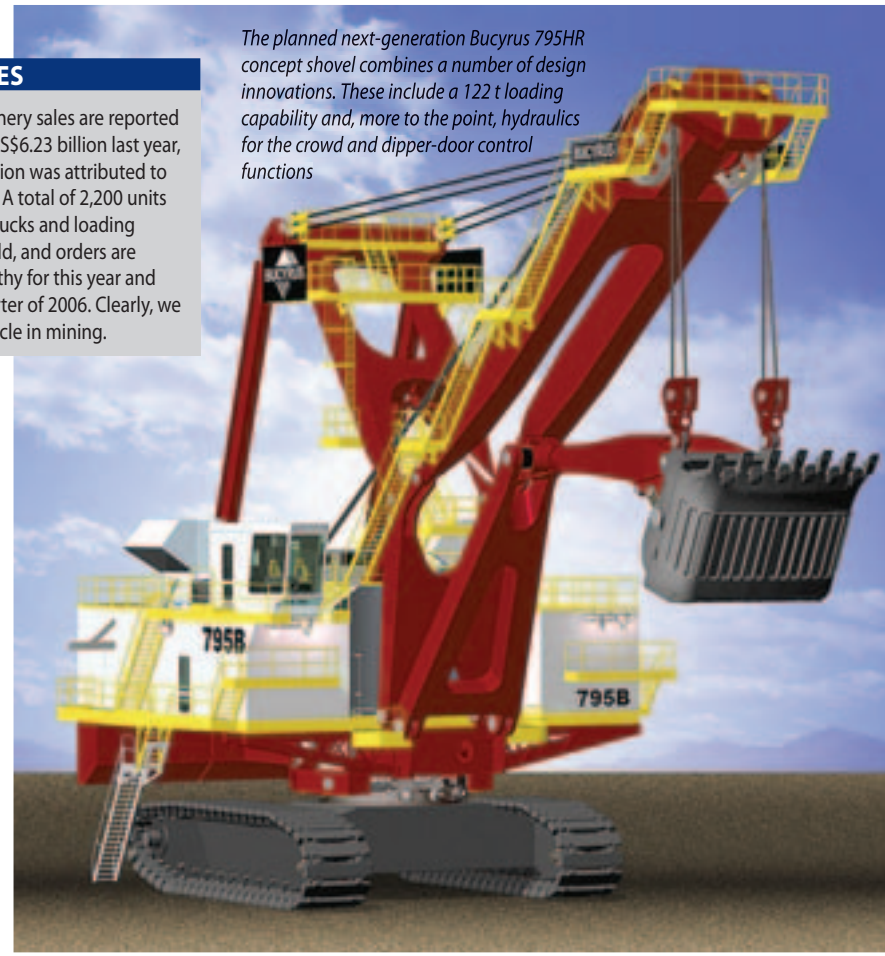
While Liebherr is locked into an agreement with Siemens for drive systems, this is not the case with Hitachi. When it took full control of the Euclid product line, it included both General Electric and the new Siemens drives, and this arrangement continues today.

There are currently four mining trucks in the Hitachi mining range (below 100 ton is generally considered to be in the quarrying and heavy construction sector). Hitachi's largest rigid-frame haul truck, the EH5000, is based on the design of its predecessors: the R280AC and EH4500. Equipped with the

Continued on page 14

SURFACE SALES

Total mining machinery sales are reported to have exceeded US$6.23 billion last year, of which US$3.5 billion was attributed to surface equipment. A total of 2,200 units of surface mining trucks and loading equipment were sold, and orders are reported to be healthy for this year and into the March quarter of 2006. Clearly, we are riding a supercycle in mining.



The planned next-generation Bucyrus 795HR concept shovel combines a number of design innovations. These include a 122 t loading capability and, more to the point, hydraulics for the crowd and dipper-door control functions

The EX8000 was developed as a response to the growing size of dump trucks, and is a perfect match for 300 ton trucks. North American Contractors Group ordered two units: one is already in full operation, with unit two under construction

Hitachi	Engine-rated power (kW) SAE J1349	Load capacity (m^3) SAE heap 2:1	Payload (t)	Gross machine weight (t)
EH3000	1,304	102	140	279
EH3500	1,414	115	171	324
EH4500-2	1,939	159	254	480
EH5000	1,939	196	284	528

Continued from page 12

Hitachi standard heavy-duty body, it has a maximum payload capacity of 284 t (312 ton) and a maximum GMW of 528 t (1.16 Mlb). According to Hitachi, the actual payload capacity can range from 320 ton to 360 ton, depending on body size and weight, as well as the particular application and material density.

Following the EH5000, speculation is high that the company is designing two new trucks. First, a 190 ton unit (that could be called EH4000) and, because Siemens does not manufacture small-capacity drives, this unit would normally have incorporated a GE drive. However, this is not to be the case, as the introduction of the EH4000 will be the first unit to feature a proprietary drive system designed and built in Japan.

There is also much speculation that a larger version of the EH5000 is under consideration. A unit with a capacity of at least 400 ton (called EH5500 or EX6000). Along with significant changes in construct-

First of the super-sized hydraulic excavators, the O&K RH 400 is seen loading one of the first Unit Rig MT-5500AC trucks. The second-generation 360 ton machine will be called MT-5900 and could be introduced late this year

units, a truck of this size would require wider 59/80 R63 tyres, and so the design will require changes to the chassis, including a new rear-axle assembly.

ELECTRIC DRIVES

The market is changing for electric-drive systems (*MM*, December 2005, p28), with Caterpillar announcing the incorporation of its proprietary electric-drive technology into selected mining products. Just ten years ago, General Electric held over 90% of the electric-drive truck market, and all of the major truck original equipment manufacturers (OEMs) incorporated technically-identical GE systems.

The choice of motive power was mainly limited to just two engine manufacturers; so each truck OEM had its work cut out proving competitive advantages, where, in many cases, none existed. Reliability, service support, chassis/dump body construction and material choice in critical areas, all became the name of the boardroom presentation game.

GE still produces the largest and most diverse range of DC and AC-drives, and the market in electric-drive mining trucks is dominated by Komatsu, Liebherr, Terex Unit Rig and Hitachi. The emergence of AC-drive technology provided a much-needed spark into the truck industry. However, Komatsu did not just want to be the first into this lucrative market, but wanted the new drive incorporated into an all-new haul truck.

The other manufacturers, which realised that truck capacity had reached its limit under DC technology, assumed that any significant drive-system developments by GE would be shared with all truck OEMs.

The 300 ton-plus Ultra Class truck market was conceived directly as a result of a symbiotic relationship between Komatsu and GE. Komatsu needed the new AC-drive system for its planned 290 t 930E truck. This was a design based on the ideal four-pass loading by most existing shovels (such as the P&H 4100A and Bucyrus 495HR). This truck-shovel combination proved very successful, with over 450 units sold. Liebherr and, more recently, Hitachi, clearly understood the advantages of a four-pass shovel-truck combination, and subsequently developed 300 ton-plus trucks of their own.

Understandably, it was not very long before the rift created by the Komatsu-GE alliance spurred interest from other suppliers. Siemens Energy and Transportation Inc, which saw the opportunity for development, has won 45% of the large-drive market. However, the company has no plans to develop smaller drives, so GE remains the dominate player in that sector.

While the market trend is away from DC drives in favour of the inverter drive, one OEM that has clearly benefited from maintaining a very close relationship with GE is Terex Unit Rig. The company has been hugely successful at manufacturing cost-effective trucks to the less mature markets, such as China and India, where expertise in AC drives is limited.

Interestingly, while the first Komatsu 960E (unit 01) incorporated the latest, and largest, GE drive, the second test unit has been configured for a Siemens drive. It will be interesting to see how each drive system performs in what will be the first directly-comparable performance evaluations.

HYDRAULIC EXCAVATORS

The first mining-class hydraulic excavator that was intended to compete directly with conventional rope shovels was the O&K RH400, followed by the Hitachi EX5500. These were eclipsed by the EX8000 and Komatsu's new P8000 series. The first EX8000 is in operation in Alberta, with a second under construction and a third due for shipment to Australia.

The EX8000 was developed as a response to the growing size of dump trucks, and is a perfect match for 300 ton trucks. The EX8000 exceeds the operating weight and shovel-loading bucket capacity of the EX5500-5 by 270 t and 11 m^3, respectively. The unit provides more than adequate power, with a crowding force of 2,870 kN and a bucket capacity of 40 m^3.

ELECTRIC ROPE SHOVELS

Super-class shovels (with capacities of 90-100 t) remain the loading equipment of choice for large mining operations, and the market is still dominated by the Bucyrus 495HR and P&H 4100XPB (Barrick Gold Corp's Goldstrike mine in Nevada ordered a 4100XPB last month to join four 2800 models on site).

Besides gaining physically larger profiles and footprints, the external appearance of electric mining shovels has changed very little over the years, but dramatic changes are evident internally. When P&H Mining introduced the Centurion shovel control system on its electric shovel line in 2004, it injected new

Continued on page 16

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WHEEL LOADERS

There are three main OEMs in this market sector, which is primarily used for secondary loading. Komatsu offers, for example, the WA900 and WA1200, Caterpillar the 992 and 994, and (for diesel electric) LeTourneau offers the L-1000, L-1100 and L-1850.

When higher-capacity loading is coupled with the need for greater mobility, wheel loaders with payloads of around 40 t (such as Komatsu's WA1200, Caterpillar's 994 and LeTourneau's L-1850) can be used as the primary loading tool.

For sheer size, nothing beats LeTourneau's L-2350. However, while the trucks and shovels have eased off in terms of capacity, the L-2350 may have been a step too far. Only two units have been built, and the market for this size of machine is very small.

Most recent introductions have been smaller-capacity units – for example, LeTourneau's Pit Bulls, the L-950 and dozer version D-950. These units incorporate the company's new Switched Reluctance (SR) drive (not currently available on the larger machines), which is somewhat like a cross between DC and AC. The heart of the technology is a simple motor design; no brushes, no magnets and no commutator. Routine maintenance is limited to replacement of two end-bearings every 20,000-30,000 hours.

Left: the LeTourneau L-950 Pit Bull loader incorporate the company's new Switched Reluctance (SR) drive, which is somewhat like a cross between DC and AC. While this system has a number of advantages over conventional DC drive, currently it is not available on the company's larger machines

"Centurion is much more than a sophisticated control system; it is a platform for integrating advanced technologies well into the future"

Continued from page 14

meaning into the billing that P&H shovels are looking to the future where 'Bigger, Faster and Smarter Machines' will be the order of the day.

Increases in speed and smart capability are largely the product of the Centurion's AC800 controller. The AC800 performs both the process control functions of an I/O system supervisor as well as the drive networking function of a drive controller.

In addition to its speed and intelligence, however, the Centurion represents multi-generational product planning. Mark Hardwick, vice president of P&H MinePro Services Americas North, said: "Centurion is much more than a sophisticated control system; it is a platform for integrating advanced technologies well into the future."

With ten times the processing capacity of its forerunner (the Electrotorque Plus control system), Centurion handles much larger volumes of software applications and data. The smart I/O system runs on a fibre-optic network providing over 20 times the throughput, and with advanced diagnostics at each I/O point, including error checking and internal and external fault detection, the system is quick and reliable. The closed-loop control and communications network monitors more than 200 I/O points and helps the operator optimise all phases of the digging cycle.

NEXT GENERATION

The industry has entered into a period of rationalisation, from the standpoint of overall engineering design and from the availability of cost-effective components.

It would seem that the race to the next truck-weight class is on hold. While mining companies understand better than anybody the need to lower

> "Systems are currently being developed that will allow a shovel operator to set the digging and loading parameters for the next few hours, and then leave the unit to work on its own"

costs, the target is not so much the need to increase single-unit capacity, but rather the need to increase reliability and reduce life-cycle costs.

So is bigger better? To gain some perspective, we need to understand where we are in the current market. Today's 4100 XPB and Bucyrus 495HR have swing-bucket capacities of 109 t (120 ton), compared with the first 4100 shovels, which were developed with a payload of just 73 t (80 ton) to three-pass load 218 t (240 ton) trucks.

These large-cable shovels have been widely accepted in the mining industry; over 150 of the 4100 series shovels have been sold to date.

But, while we may consider larger as 'better', these units might not necessarily be the most cost-effective solution. Faster control systems, with reduced swing times, might enable trucks to be loaded more efficiently. Then there is the question of semi-autonomous or fully-autonomous operation.

Systems are currently being developed that will allow a shovel operator to set the digging and loading parameters for the next few hours, and then leave the unit to work on its own. Working together with close-proximity devices, a truck would be detected within the shovel's area of operation, it would be identified (including its rated payload), the provisions accepted and the truck positioned and loaded.

While running large numbers of fully-autonomous trucks looks highly complex and very difficult to implement fully, especially into a mixed fleet of conventional operator-driven trucks, intelligent loading by shovels and draglines looks relatively simply by comparison.

The loading of the very largest trucks introduced some problems as the bodies are higher and wider, so P&H (in co-operative studies with truck manufacturers) developed Optima 7Plus 100, a new dipper and bail configuration providing greater height for loading.

The planned next-generation Bucyrus 795HR concept shovel combines a number of design innovations. These include a 122 t loading capability that would three-pass a 400 ton truck and four-pass the next generation of Ultra Class truck (which will have an expected 500 ton payload). In developing the 795HR, Bucyrus has created a new breed of mining shovel by incorporating field-proven designs such as Hook Rollers (from the Bucyrus 680W Dragline) and the Knee-Action (pivotal knuckle) front end from its stripping shovels.

New to the electric rope shovel is the use of hydraulics for the crowd and dipper-door control functions. The use of hydraulics for the crowd is said to eliminate boom stresses and also the maintenance challenges associated with traditional crowd machinery. The use of hydraulics to control the dipper door allows the 795HR to soft-dump the passes to a haul truck. Initial drop impacts are controlled to levels similar to smaller-capacity shovels, which is important when 240 ton trucks are two-pass loaded.

The 795HR design also offers the benefits of an AC electric-drive system. In fact, it makes use of an IGBT (Insulated Gate Bipolar Transistor) system, which is currently used on the 495BI and 495BII shovels and has been applied extensively in other industries.

Both the 795HR and other shovel concept designs could be the first step in the next generation of electric mining shovels.

Given time, and the introduction of second-generation Ultra Class trucks, larger loading machines will then be introduced. The question, however, is will customers be willing to pay for the development of that machine?

Sales growth at Duratray

MELBOURNE-BASED Conymet-Duratray International Ltd, which has Chilean origins, has announced strong growth in sales during the past year. More than 80 new Duratray suspended dump bodies for large mine dump trucks have been sold.

Clients include Escondida in Chile (bodies for Caterpillar's 797B), CVRD in Brazil (Cat-793 and Terex MT4400), Barrick in Argentina and Phelps Dodge at Morenci (both for Cat-793s), Anglo American (for Komatsu's 930E), Grande Cache Coal in Alberta (for Komatsu's 830E), Cambior in Guyana and Suriname, and Inco for the Voisey's Bay operation (all for Caterpillar's 777), plus three additional units to North American Palladium (for Komatsu's 730E trucks).

Duratray claims that its suspended dump body offers "significantly extended wear life in hard abrasive conditions", as well as the "virtual elimination of carry-back material in the trays in wet, softer conditions". These factors are combined with significantly reduced shock and vibration on the equipment and the operator, hence both truck availability and operator acceptance are very high, according to Duratray.

Conymet-Duratray's second product line, the all-steel high-efficiency HE-series trays for large off-highway dump trucks has also experienced a surge in sales.

More than 70 new units have been sold, including sales to Codelco-Chile (for Liebherr's T282B and Komatsu's 930E), to AngloCopper Chile and BMA Coal Australia (both for Komatsu's 930Es) as well as to many other clients for the smaller Caterpillar 789 trucks through Roche Mining Australia, and for Komatsu 730E trucks through Macmahon Contractors Australia.

Conymet bought Duratray, a chute manufacturer for large-scale mining operations, from Pacific Dunlop three years ago. These chutes consist of suspended rubber platforms, which prevent corrosion while ensuring the impact from the cargo is targeted directly towards the suspension system of the trucks involved.

255 m³ Duratray for Caterpillar's 797B Ultra-Class truck

Flameproof Paus

FOR years, Paus's MinCa has been acknowledged as a reliable and versatile mining car. Featuring four-wheel-drive, it can be used as platform for various applications, with a payload of almost 3 t. This well-proven platform has now been designed as a flameproof unit (according to the new ATEX regulations).

Minca is powered by a Perkins 1104C-44T (71 kW; 2,300 rev/min) engine. The flameproof system is controlled by sensors and automatic shutdown procedures. All relevant values (including temperature and pressure) are permanently monitored and, in the event of failure, the engine will automatically shut down.

The exhaust gas system includes a catalyst for reducting exhaust gases, and the cooling system keeps surface temperatures below 150°C and exhaust gas temperatures below 70°C. Flame arrestors, both on the fresh air and exhaust side, ensure that no combustion leaves the engine. In case of gas ingress from the air filter into the engine, the system will automatically close the air inlet valve, and shut off the engine.

For more details, please visit: www.paus.de

Volvo premieres hybrid technology

Development of Effpower prototype batteries

THE Gothenburg-based Volvo Group has announced a hybrid solution for heavy vehicles which it claims offers fuel savings of up to 35% and a reduction in maintenance costs through reduced wear on braking systems.

The Swedish group, which includes Volvo Construction Equipment, said the hybrid concept provides maximum fuel-saving effects in transport operations with frequent braking and acceleration.

A vital part of Volvo's hybrid solution is designated I-SAM (Integrated Starter, Alternator Motor), which comprises a combined start motor, drive engine and generator. I-SAM works together with an automatic, converted mechanical transmission; an electronic control unit; conventional diesel engine; and batteries that are charged by braking energy.

By linking the electric motor and diesel engine in parallel, they can work to operate the vehicle. As such, the capacity of the hybrid power system increases substantially compared with series hybrids, which are the standard solutions currently being tested in heavy vehicles. I-SAM provides enough power resources to start and accelerate even heavy vehicles to an appropriate speed without assistance from the diesel engine. This also reduces the vehicle's noise level.

Volvo claims these advances have been made possible because of the group's experience in developing diesel engines, electronics and transmissions. Volvo is also participating in development of a new type of battery, Effpower, which is based on proven lead-acid technology. Through this new technology, the power output has been doubled, while Volvo claims that manufacturing costs for the batteries can be significantly reduced compared with alternatives on the market.

Also based in Gothenburg, Effpower was formed in 1999 to commercialise a breakthrough development in bipolar battery technology. The company's principal shareholders are Volvo Technology Transfer (a venture-capital company in the Volvo Group), Industrifonden (a state-funded venture-capital company) and the Gylling family (founders of the Optima Battery business).

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Tier-3 Komatsu loader

KOMATSU America Corp has introduced its new WA600-6 wheel loader, the first Komatsu wheel loader equipped with a Tier-3-compliant engine.

WA600-6 is designed primarily for quarry, sand and gravel, industrial and smaller mining applications. It offers improved productivity, lower fuel consumption and increased reliability over the WA600-3.

The WA600-6 is powered by a Komatsu Tier-3, SAA6D170E-5 six-cylinder engine, producing 370 kW (502 hp) at 1,800 rev/min, a significant increase in power over the previous model.

The engine is equipped with an electronic control system, a heavy-duty high-pressure common-rail fuel injection system, a new combustion system for reduced noise and fuel consumption, a cooled exhaust gas recirculation system and an air-to-air charge air-cooling system.

The WA600-6 boasts a breakout force of 39.5 t (87,230 lb), a straight static tipping load of 36.6 t (80,645 lb) and a 40°-turn tipping load of 30.5 t (67,210 lb). The standard bucket is 6.4 m^3 (8.4 yd^3).

Terex offers Caterpillar engines 'for simplicity'

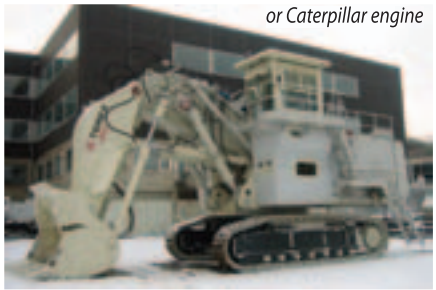
TWO years ago, Terex O&K entered into an agreement with Caterpillar dealers to sell and service their large hydraulic shovels within specific regions of the world (*MM*, December 2005, p28). Last month, Terex O&K announced it is to introduce Caterpillar engines into the product line as an option "to simplify the after-market service".

The first RH120-E with a Caterpillar C18 engine recently left the plant in Dortmund, Germany. The two 18-litre-displacement units deliver a total of 1,044 kW (1,400 hp) and fulfil the Tier-3 emission regulations (like the standard Cummins QSK 19 C engines).

The RH120-E contains twice the drive train of the RH40-F using the same engine, gearbox and pumps. The O&K twin-engine concept allows units to continue operating, with reduced speed, if one engine fails but, thanks to a stable pressure in the hydraulics, the digging forces remain constant and all functions are workable.

Terex O&K said the RH90-C will be the next model to be fitted with Caterpillar engines, due for mid-year.

The 280 t RH120-E is now available with either a Cummins or Caterpillar engine



Enter Caterpillar's medium excavators

CATERPILLAR has introduced three new mid-sized hydraulic excavators to launch its D-series. The machines (324D L, 324D L and 330D L) feature "greater performance, flexibility and versatility", according to Caterpillar, than the C-Series machines they replace.

The new excavators also deliver the lowest engine emissions ever by using Cat engines with ACERT technology. A new, spacious cab and new styling also set the D-Series apart from previous machines.

Each of the excavators has more engine power and increased hydraulic pressure for increased breakout force and greater lift force, which create faster cycle times and superior productivity. The heavy-lift circuit is now standard on D-Series models.

For expanded versatility, many factory-installed options are also available. The D-Series excavators feature a range of factory-installed auxiliary hydraulic systems, including a one-way, high-pressure, high-flow circuit for hammers and vibratory plate compactors. Another option is the Tool Control System, which is exclusive to Caterpillar and allows operators and technicians to set auxiliary hydraulics flows and pressures by using the monitor in the cab instead of using expensive service tools.

To aid in machine management, Caterpillar offers Product Link. This optional system provides information on machine location, service hours and machine health via wireless communications. For enhanced security, the optional Machine Security System controls the time when the machine can be operated, and it requires a machine-specific key to deter theft (see software feature, p42).

HYDRAULIC EXCAVATOR SPECIFICATIONS

	324D L	325D L	330D L
Operating weight (t)	24.79	29.24	36.15
Engine model (Cat ACERT)	C7	C7	C9
Net power (kW)	140	152	200
Bucket dig force (SAE; kN)	163	176	189
Max reach (m)	10.5	11.2	11.7
Max digging depth (m)	7.3	7.8	8.2
Track length (m)	4.63	4.86	5.02

The Caterpillar 324D

Still unacceptable

Despite considerable effort, mining remains one of the most hazardous occupations when the number of people exposed to risk is taken into account

Workers return to the Sago mine, near Buckhannon, West Virginia, on January 9 Photo: Bloomberg News

THE International Labour Organisation (ILO) calculates that an amount equal to 4% of the world's gross domestic product is lost every year from workplace-related injury, death and disease.

The ILO reports that there are some 2.2 million work-related deaths every year. Of these, the vast majority (some 1.7 million) are from work-related diseases, with a further 158,000 being commuting fatalities. Of the 350,000 deaths from workplace accidents, over 15% are at construction sites (ie a death every ten minutes somewhere in the world).

Although only accounting for 0.4% of the global workforce, mining is responsible for over 3% of the fatal workplace accidents (more than 10,000 per year, ie a rate of well over one death per hour). No reliable data exist for mining injuries but the level is high, as is the number of workers affected by occupational disability (such as pneumoconiosis, hearing loss and the effects of vibration).

Coal mining accounts for a significant share of the total, and the ILO has convened a meeting of experts next month to review its 20-year-old Code of Practice on safety and health in underground coal mines.

The existing code was adopted in 1985, and much has changed since in the coal-mining industry. Twenty-four experts (including government officials from Australia, China, Germany, India, Poland, the Russian Federation, South Africa and the US) will meet in May to review a new draft code, which is due to be posted on the internet this month for comments.

GLOBAL IMPROVEMENT

Accident rates in the international mining industry have improved steadily over the years but national safety standards still vary dramatically.

South Africa, for instance, where mines are deep and operations labour intensive, still has a much higher fatality rate than mining in Australia and the US, although it has managed to halve the total number of deaths over the past ten years.

China remains a blot on the mining industry's safety record, with some 6,000 mine workers still losing their lives every year (60% of the world total, and an average of over 16 deaths per day, most in gas explosions). In 2003, the fatality rate per million tonnes of coal produced in China was an extraordinary 40,000 times higher than in the US or Australia.

Safety standards are not much better in India. The World Health Organisation (WHO) reports that there are a total of 330 million workers in India, and that there are some 35,000 workplace fatalities per year. This annual rate of 11 deaths per 100,000 workers is twice that for workers in Europe, and the death rate on India's mines is almost four times the country's overall average.

In its 'Digging Deeper' mining report in 2003, PricewaterhouseCoopers (PwC) reported that there is limited data available for direct comparisons for international accident statistics. However, some countries could be compared based on their reported Fatality Injury Frequency Rates (FIFR; the number of fatal injuries per one million man hours worked). The mining figures in the report included:

MINING FIFR	
South Africa	0.34
Canada	0.21
US	0.13
Chile	0.12
Mexico	0.12
Australia	0.03

Australia as a whole has halved its workplace fatality rate during the past ten years, with only 2.3 deaths per 100,000 workers in 2003/4. However, mining remains one of the most dangerous occupations within the country, with some five deaths per 100,000 workers. The Australian Government reports that around 30% of the fatalities are caused by falling objects, 20% in vehicle-related accidents, 12% by falls and 7% each from workers being hit by an object or being overcome by gases. The remaining one-quarter of fatal accidents were caused mainly by workers being trapped between objects, contact with electricity or chemicals, drowning or by explosions (visit: www.worksafe.gov.au).

US TRAGEDY

Underground mining is the second most-dangerous occupation in the US (after a category that includes farming, forestry and commercial fishing). In its report, PwC noted that the mining FIFR of 0.13 in the

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SAFE SOCIETY

The International Society of Mine Safety Professionals was founded to promote the development of health and safety professionals throughout the international mining community. Saving lives and reducing injuries through better leadership, planning and practice are described as the primary goals of the society.

The society's website (www.ismsp.com) provides the latest in safety developments, links to other safety-related sources and many other communication opportunities with peers, consultants and suppliers of services and information.

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Mining to Success

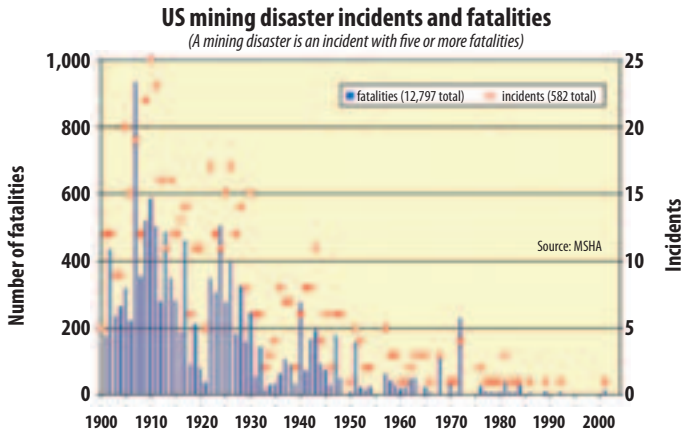
Continued from page 22

US was still substantially higher than the country's all-industry average of 0.08 deaths per million man hours (as reported by the US Department of Labor).

However, the US mining industry has been improving its safety record since the Mining Safety and Health Act was signed in 1977 (stimulated by the deaths of 425 miners in 1970). Since 1990, US mine injuries have declined by 51% and fatalities by almost 67%, and last year saw the lowest number of mining deaths for ten years (22 coal miners were killed, each in a separate incident).

Despite the recent improvements, the explosion at the Sago mine in January has sparked calls for an urgent review of how safety regulations are enforced. The deaths of 12 miners in West Virginia was the deadliest coal-mining accident in the US for more than four years (and brought the State's coal-mining deaths in January to 14), and has already had a profound effect (not least in media coverage: a Google search on 'Sago Coal Mine' returns 276,000 hits).

Within days of the Sago tragedy, lawmakers in West Virginia had passed a bill that requires mining companies to use electronic devices to track trapped miners and to stockpile oxygen to keep them alive until help arrives.



In the legislation (initiated by West Virginia's Democratic Governor Joe Manchin), coal companies in the US's second-largest coal-producing state will need to provide improved underground communications, faster emergency-response times and the storage of additional air supplies. Meanwhile, in Washington, senators at a hearing on mine safety pledged to step up federal oversight of the nation's coal mines.

Also, for only the third time in its history, the US Labor Department's Mine Safety and Health Administration (MSHA) has issued an emergency temporary standard (ETS) to improve protection of miners during and after underground coal-mine accidents and evacuations. The ETS became effective immediately upon its publication in the Federal Register (on March 9).

David Dye, the acting administrator for mine safety and health, said: "This year's tragic mine accidents in West Virginia require immediate action to put in place additional safety requirements to help miners successfully evacuate a mine when an emergency occurs." He added that "MSHA is moving forward on every front to improve protection for miners' safety and health".

The ETS contains provisions (applicable to all underground coal mines) on self-contained self-rescuer (SCSR) storage and on the use, installation and maintenance of lifelines. In particular, the ETS covers the availability of supplemental SCSRs to increase the supply of oxygen; added lifelines to guide miners along evacuation routes when visibility is poor; more frequent evacuation drills to condition miners to escape quickly, and proper training on how to transfer from one SCSR to another.

The ETS also includes requirements for immediate

accident notification applicable to all underground and surface mines. Mine operators must notify MSHA within 15 minutes after determining an accident has occurred so that co-ordination of appropriate mine rescue or other emergency response can begin as soon as possible.

Public hearings on the emergency temporary standard are scheduled for April 11 in Charleston, West Virginia; April 24 in Denver, Colorado; April 26 in Lexington, Kentucky; and April 28 in Arlington, Virginia. Written comments are being accepted until May 30 (visit: www.regulations.gov).

April 28 every year is World Day for Safety and Health at Work.

Industry experts are also studying whether new technology can help to prevent future fatalities. Professor Larry Grayson, of the Mining Department at the University of Missouri-Rolla, commented that the mining industry has been "lulled to sleep" by decreasing accident rates. Keith Pauley, chief executive of Mid-Atlantic Technology, Research & Innovation Center, is quoted as saying that investment in mine-safety technology has lagged for years, partly because the government has not pushed for improvements. He claims that mining regulations focus on training and accident prevention, with little attention to rescue.

The National Mining Association has asked Professor Grayson, a former coal-mine manager, to head an independent commission on mine safety. Part of the commission's work will be to examine which technologies could help.

One company with much to contribute is NL Technologies (NLT), a leading provider of underground lighting and communications systems, which has developed a software suite for asset/personnal tracking as part of its Northern Light Digital brand. The latest initiative is part of a joint venture with AeroScout Inc (see software feature, p44).

NLT also recently announced a partnership agreement with Embigence GmbH, a pioneer in multimedia networked automation, to deliver intrinsically-safe access points for hazardous underground environments. The solution, already installed in coal mines in Europe, is designed to help prevent accidents and enhance emergency response.

Ansul's fire extinguishers

NLT was chosen recently by AMCI's Carborough Downs operation in Queensland's Bowen Basin to supply communications and lighting products for its new underground mine. NLT will deliver wireless-fidelity tracking equipment for personnel and equipment, environmental monitoring and two-way messaging using its 'ultra-light' cap lamp.

SAFETY RESEARCH

Among its various roles, the National Institute of Occupational Safety and Health (NIOSH) reports on trends in mining-related fatalities and traumatic injuries. The organisation is involved in co-ordinating research projects, and its activities include consultation in the formulation of research questions, study design, data collection and statistical methods to support laboratory research.

NIOSH identifies the main hazards in mining as workers' exposure to electricity, diesel exhaust and dust, and to accidents related to explosions, fires and rock falls.

Blasts in underground mines and surface-processing facilities are caused by accumulations of flammable gas and/or combustible dust mixed with air in the presence of an ignition source. Explosions can therefore be prevented by minimising methane concentrations through methane drainage and ventilation, by adding sufficient rock dust to make the coal dust inert, and by eliminating ignition sources. The effects of explosions can be mitigated by using barriers to suppress propagation.

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Fires remain a significant hazard to the safety and health of mine workers. There are two areas of concern. The first is the immediate danger of being burnt. Fortunately there are now numerous products available to mitigate this risk. A full suite is available, for example, from Kidde plc, which is one of the global leaders in fire and safety products. The company also serves the aerospace, defence and consumer markets.

Another supplier of fire protection and suppression equipment is Tyco Fire & Security through its Ansul brand. Products include fire extinguishers and hand line units; fire detection/suppression systems and a complete line of dry chemical, foam and gaseous extinguishing agents.

Formed in 1915 (as Ansul Chemical Co), the company held a fire school in 1940 to train its employees, and became part of Tyco International Ltd in 1990. Ansul's vehicle-fire suppression systems, introduced in the 1960s, are now used to protect a wide range of mining equipment.

The second concern from underground fires is an indirect one: the smoke and toxic products carried throughout the mine make escape through confined passageways difficult and time-consuming.

NIOSH reports that rock falls injure over 500 miners each year in the US alone but that improvements in technology (such as the use of personal bolter screens) is reducing the incidence of rock falls and resultant injuries.

ENGINEERING CONTROLS

In terms of engineering controls to improve mine safety, NIOSH has three main categories: equipment design, ground control and ventilation.

1. Equipment design: Machines pervade the mining industry. They greatly reduce the level of manual labour and increase productivity but are also the cause of a huge number of mining accidents. There has also been a rapid growth in the development of new mining technologies (including remote control, continuous haulage and automation) but NIOSH warns that these new technologies need to be carefully monitored as they introduce the potential for new types of health and safety risks.

Design influences on improving underground safety range from whole new systems to individual components. Regarding the latter, few things are more important than brakes.

> "Regarding individual components, few things are more important than brakes"

The first disc brakes were installed over 70 years ago on mine winders built for Phelps Dodge Corp in Arizona. It was not, however, until the late 1950s when the automotive industry discovered the advantages of using disc brakes that the technology became widely recognised. This, in turn, led to the introduction of advanced braking systems and the use of advanced materials for friction linings.

Twiflex, which claims to be the leading suppler of industrial disc brakes, boasts a long record of innovation. Formed in 1946 (as an engineering research company, trading as Compression Ignition Ltd), Twiflex patented an automatic, torsional vibration-limiting, flexible clutch coupling in 1947 that was adopted by several navies. Twiflex first introduced disc-brake technology for industrial applications in 1951. The popular and widely-used MR caliper was launched in 1954 and is still manufactured today.

Svendborg Brakes Group markets industrial hydraulic disc-brake systems, electronics, couplings and machinery (produced in Denmark, Germany and Spain). Svendborg comments that, although braking is a mechanical science, hydraulics and electronics play major roles and will only increase in importance. It is within the latter field that the company sees major growth, as the role of advanced hydraulic systems become more and more important.

The original company was founded in 1893 but it was not until 1989 that it began to specialise in braking systems, coinciding with Svendborg's acquisition of the rights to produce industrial disc-braking systems from Hägglunds Drives.

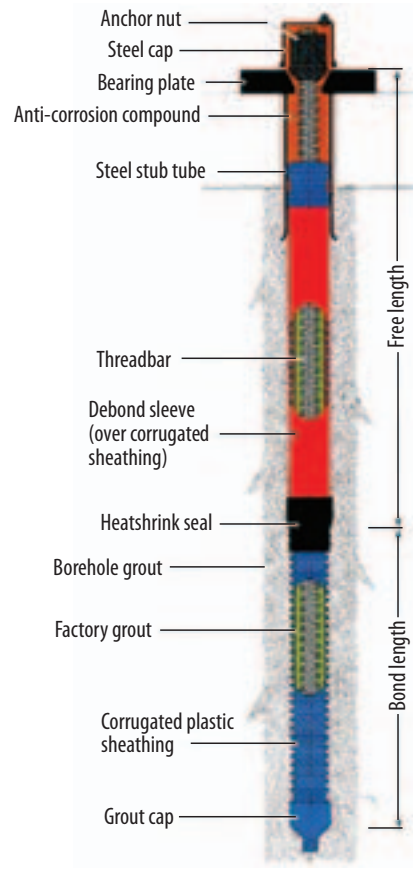
The company currently offers two main types of disc brake: Failsafe, for example the BSFH 500 series, which is a spring-applied and hydraulically-released brake with a clamping force up to 250,000 N; and Active, for example the BSAB 120, which has a clamping force of up to 430,000 N.

Controlled braking is an important feature for disc brakes to reduce the stress on mechanical components, and in 1998 Svendborg introduced its Soft Braking Option. The SOBO Controller offers 'intelligent braking' regardless of the load on the drive unit, and has been used on hundreds of installations, including conveyors and ventilation systems.

In the past 15 years there has been significant development in tunnelling technology, especially in the use of full-face excavators.

To improve efficiency and safety, Cavotec Specimas has developed a range of special tunnelling reels to power this equipment.

The company's motorised cable reels include hydrodynamic systems, torque motors, permanent and electro-magnetic clutches and, for the largest reels, direct torque control.



Cross-sectional diagram of a Dywidag anchor

2. Ground control: Ground-control safety issues include improving roof support performance, maintaining safe escape routes, optimising pillar design, controlling multiple-seam workings and predicting roof conditions. Engineering design to match the appropriate geological and mining factors is necessary, and a range of computer software programs are available to help ground-control monitoring and design.

At the moment, the US Mine Safety and Health Administration is soliciting comments relating to safety standards for roof bolts in underground mines; contributions are required before the end of April.

One company that will have a role to play is Dywidag-Systems International (DSI). This international network of companies is focused on developing and applying post-tensioning, geotechnical and stay cable systems for the construction and mining industries. The group offers various services relating to roof control, including 'proving tests' on trial anchors, and on-site 'suitability' and 'acceptance' tests.

DSI has been expanding recently, and acquisitions during the past year have included France's Artéon SA (September 2005) and Canada's Stewart Mining (February 2005). Last month, DSI announced the acquisition of Mexicana de Anclas Mineras, a Mexican producer of a wide range of mining products, such as slotted-tube friction bolts, cement cartridges, thread bolts and fibreglass scaling bars.

Founded in the mid-1980s, Anclas Mineras also produces pneumatic installation machines for cement cartridges and tools for the easy installation of bolts. The business will operate as DSI-Anclas Mineras.

3. Ventilation: As well as the hazards associated with flammable gas and combustible dust atmospheres, prolonged exposure to airborne contaminants can result in adverse health effects. As *Mining Magazine* reported last year (*MM*, August 2005, p15), the concentration of methane and other airborne contaminants underground can generally be controlled by dilution (ventilation), capture before entering the host air stream (methane drainage) or isolation (seals and stoppings).

GIA Industri AB, founded back in 1884, is heavily involved in the ventilation business. Through GIA SwedVent, the group offers complete systems for underground ventilation, including high-pressure axial fans and flexible ducting. GIA SwedVent also undertakes ventilation system design.

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OMEGA- BOLTS

PLATES
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MATS & MESH
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Filling the void

Typical tailing material

Hydraulically backfilling underground voids left after mining provides an opportunity to reduce above-ground tailings dumps and improve safety

BY THOMAS LAUTERBACH

FILLING underground voids is of importance because of the safety benefits of providing support to the roof and improving ventilation circuits. There are also increasing advantages due to the shortage of acceptable dump sites for tailings on the surface.

Filling voids stabilises the rock mass by preventing the loosening of roof layers and results in lower rock movements. Efficient packing will absorb strain from the rock and evenly distribute stresses. The filling will also improve mine ventilation by eliminating air leakage.

Backfilling can be separated into packing with and without bonding material, and also according to the particle sizes and the method of placement. A distinction is usually made between dump stowing, pneumatic packing and hydraulic packing. Hydraulic transportation with Putzmeister high-density solids pumps is examined in more detail below.

SLURRY AS A SAFETY MATERIAL

For hydraulic transportation to be utilised successfully, two problems have to be addressed:

1. The material must be transported (with as low a water content as possible) at controllable pressures over large distances.
2. The installed fine-grain material must be drained.

Draining of the material can be minimised if it can be successfully transported over large distances with little water content and the fluid can be bonded. Fluid bonding is possible by adding hydraulically-bonding materials, such as cement.

The skill in hydraulic transportation is to find the optimum recipe for the material composition. This will vary depending on the granule size and, if achieved, will lead to a controllable flow pressure that does not result in blockage if a pump fails.

For this purpose, extensive tests with Putzmeister piston pumps have been carried out in the German ore-mining industry. If larger solids, for example residues from wall rock, are added to fine-grained suspensions, a 'bearing' effect occurs in the suspension, which (along with a lubricant on the pipe wall) leads to good flow properties and low pressure losses.

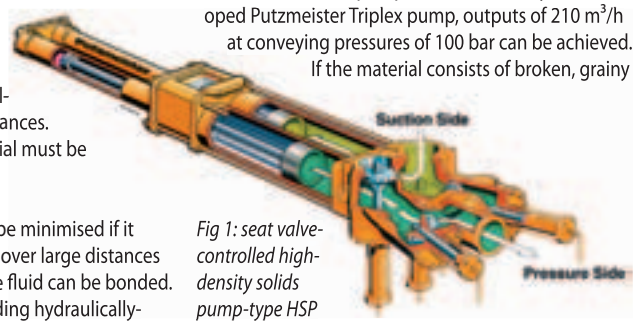

Fig 1: seat valve-controlled high-density solids pump-type HSP

PUMP SELECTION

The choice of the high-density solids pump is of decisive importance. If very fine material is involved, Putzmeister used its hydraulically-controlled seat-valve pumps (fig 1). These high-pressure pumps are designed for fine-grained materials and for materials that are difficult to pump. With the recently-developed Putzmeister Triplex pump, outputs of 210 m^3/h at conveying pressures of 100 bar can be achieved.

If the material consists of broken, grainy material with individual large foreign bodies, then transfer-tube-controlled high-density solids pumps without valves (KOS pumps) should be used (fig 2). The characteristic feature of the KOS series is the S transfer tube.

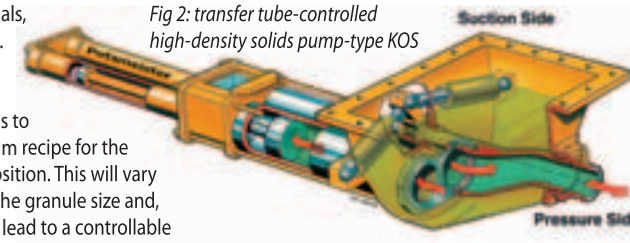

Fig 2: transfer tube-controlled high-density solids pump-type KOS

The alternation between the intake and pressure cylinders guarantees almost continuous operation with an unobstructed delivery passage. Foreign bodies in the packing material can be conveyed up to a particle size of 80% of the outlet diameter. Conveying quantities of up to 500 m^3/h at 30 bar (or 16 m^3/h at 100 bar) can be achieved.

Using piston pumps to install packing in underground voids from an above-ground station has the following advantages:

- Different packing materials can be stored in silos and mixed as required.
- The material can be conveyed to the packing location via pipelines.
- After the packing pipe is installed, disused mine openings can be sealed.
- With the piston pump being above-ground, the only underground equipment is the pipes.
- Piston pumps allow transportation over up to 12,000 m.

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INSOLUBLE MIXTURE

As a watery mixture of insoluble matter, there are many slurry-transportation applications in the mining industry. Indeed, the movement of crushed rock and water is almost ubiquitous in mineral processing, with partially-processed material often being in slurry form as it moves between stages. For example, pumps are needed to move slurried coal through the washing process (which removes impurities and upgrades the heating value of the coal).

In the mining industry, dredging probably involves the largest quantities of slurry (with capacities at individual sites of up to 18,000 m^3/h) but the transportation distances are quite short.

Slurry pumping distances are longer (typically around 10 km) at the open-pit phosphate mines in Florida, which pump huge amounts of slurry. Also in North America, Syncrude has refined hydro-transport technology for its oil-sands mining operation. In this process, the oil sands are made into a slurry and transported to the processing plant via pipelines rather than on the traditional and more expensive conveyor belts.

Much longer distances are involved at some mining operations around the world. For example, the Alegria mine in Brazil pumps its iron ore (as a 70% solid) down a 396 km pipeline to a pelletising plant on the Atlantic coast (*MM*, February 2006, p8). Two pump and valve stations maintain an average flow of 6 km/h with a flow rate of some 1,200 m^3/h (a slurry delivery of over 15 Mt/y).

Cia Vale do Rio Doce (CVRD) is building a 250 km pipeline to transport 8 Mt/y of bauxite concentrate from its Miltônia mine in northern Brazil to its Alunorte plant in Pará. CVRD awarded the pumping and valve contracts to Weir Minerals and Valvtechnologies Inc (www.valv.com), respectively, with the infrastructure designed by Pipeline Systems International (see p30). The system will comprise a 610 mm-diameter pipeline, five Geho TZP pumps (plus one on standby) and valves ranging in size from 25 mm to over 600 mm.

In the mix

The first long-distance slurry pipeline was constructed 50 years ago, and millions of tonnes of material are now transported every year by this bulk-transport system

QUITE apart from whether the material being transported is ore, concentrate or waste (whether to tailings dams or as underground backfill), the broad classification for slurry is whether or not the constituent material will settle.

[Please note that the distribution and management of slurry as tailings on the surface is examined on p33, and as underground backfill as part of this month's feature on safety on p28].

The size distribution (from a few microns to several millimetres) and the overall solids content will play a significant role in determining the settling behaviour of the mixture. However, 'non-settling' slurries are something of a misnomer, as everything will settle given sufficient time. Nevertheless, slurries where the particle size is sufficiently fine will give the appearance of remaining homogeneous.

Settling slurries need to be transported at higher velocities to avoid deposition, and subsequent blockage, and this clearly impinges on the overall design of the pipe and pumping system. For this reason, a key design factor is the likely variation in content that must be accommodated. Where concentrates are being transported, the material is likely to be consistent. However, if ore or tailings are being carried, there is likely to be a considerable variation in feed. Both are likely to vary, in particular, according to the rock/mineral type (eg the area of the orebody being mined) and the mill performance.

The resultant slurry is normally defined by its shear stress and viscosity, and, for design purposes, the flow must be at least equal to that which will keep all solids in suspension (termed the Stationary Deposit Velocity). The design velocity will be above this level to allow a suitable margin of safety but with turbulent flow, which is inevitable with different particle sizes, pipeline wear rates will increase considerably as the velocity is increased.

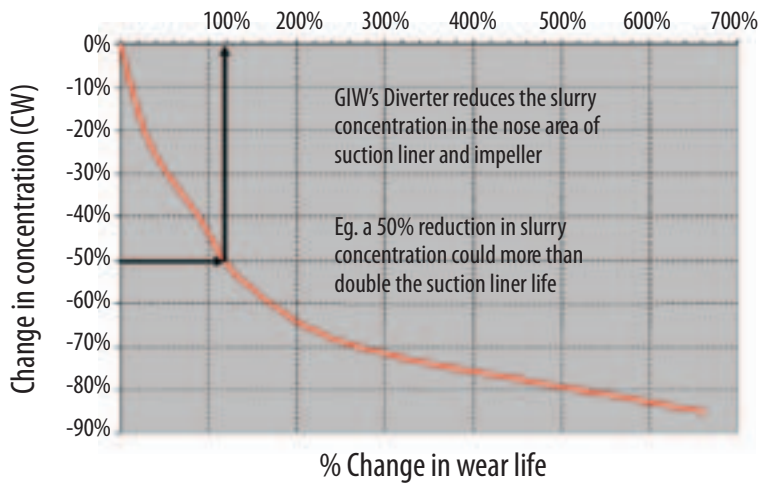
A Grindex slurry pump in action

Slurry systems can be designed using modern modelling techniques but practical experience from similar operations is still a valuable part of the decision-making process. Whatever approach is taken, it is crucial that every aspect of the system is considered together, including the pipe diameter, pump capacity, pipe gradient (where a choice is available) and the distance between pumping stations.

PUMP CHOICE

As *Mining Magazine* noted in its examination of pumps last year (*MM*, November 2005, p21), centrifugal units, which are suitable for low-head, high-flow applications, are the most popular pumps in mining. However, for long-distance pipelines (especially if the slurry is viscous), it is often necessary to use positive-displacement (rather than dynamic) pumps, which produce a constant flow regardless of the intake or outlet pressure. The flow rate from these pumps is relatively insensitive to changes in pipeline resistance but they generate a relatively low overall flow rate, and so must usually be installed in parallel.

Whatever type of slurry pump utilised, employing



technologically-advanced materials has dramatically improved the life of the units, and some pumps are now equipped with sacrificial zinc anodes.

The biggest cost in owning and operating a pump is usually the energy consumption, and the recent rise in energy prices has placed greater emphasis on the efficiency of pumps.

Several companies are involved in developing new, more efficient pumps. For example, Stockholm-based **ITT Flygt**, founded in 1901, conducts extensive research on slurry flow behaviour and pumping techniques. The company recently transferred some of this expertise onto a new website (www.flygt.com/sludge). On this portal, the company provides guidance on pump selection, design recommendations and educational videos (apart from its own product information).

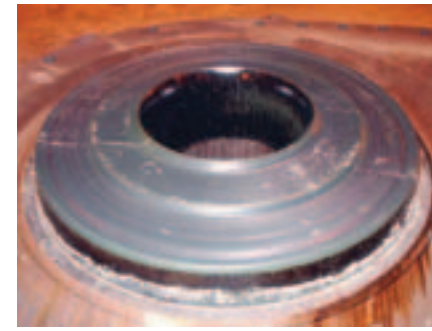
GIW Industries (www.giwindustries.com) has been designing pumps and moving slurry for over 90 years, and describes itself as being in the 'transportation' business, saying that it can "move just about any material you specify". The company's pumps have been used to pump phosphate rock in Florida, tar sands in Canada and hundreds of different materials in between.

Grindex's slurry pumps include the Tuff Line series

GIW recently introduced a 'Slurry Diverter', described as a "revolutionary design to increase suction liner and impeller wear life". The company says that if particle contamination can be excluded from the pump's 'nose gap', wear life can be dramatically improved.

Research has shown that internal velocity and pressure gradients between the impeller shroud and the pump casing can allow particles to migrate toward the suction eye. These solids contribute to the wear-induced degradation of the gap between the suction liner and the impeller. As this gap grows, wear rates increase and pump efficiency is reduced (see figure on p30).

By 'diverting' particles away from the casing wall, their flow direction can be reversed. GIW has integrated a 'step' into both the suction liner and impeller clearing vanes to provide a physical and hydraulic block in the particle path. This transfers the solids from the pump wall into the higher-velocity flow path created by the clearing vanes, where they are returned to the process fluid.



An impeller and suction liner from GIW's Slurry Diverter

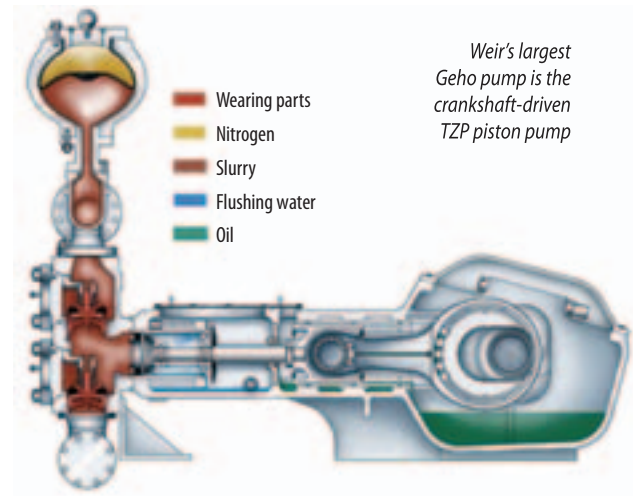
Grindex AB (www.grindex.com), another Stockholm-based company, was founded in 1940 and started designing and producing submersible pumps in 1960. Grindex's slurry pumps include the Tuff Line and Bravo series; the latter is particularly recommended for highly-abrasive solids.

Pennsylvania-based **Red Valve** (www.redvalve.com), founded in 1953, offers products for a variety of applications and industries worldwide. The company's high-quality elastomeric components are described as being ideal for abrasive and corrosive installations, and the "unique non-clogging" designs of its pumps are claimed to be perfect for all types of slurries.

Weir Minerals (www.weirminerals.com) has a product range that incorporates brands that cover virtually any slurry pump, valve, hydrocyclone or wear-resistant lining application. The company's slurry pumps centre on the Warman centrifugal (in horizontal and vertical configurations) and Geho positive-displacement brands (in Africa, the Warman slurry pumps are sold as Envirotech pumps).

Weir's largest Geho pump is the crankshaft-driven TZP piston pump, which has a 800 m^3/h capacity at a pressure of 120 bar. This pump can handle moderate abrasivity, medium viscosity (< 8,000 MPa), mild corrosivity, and up to 8 mm particle size with a 75% solids content.

Larox Flowsys (www.larox.fi/flowsys) offers extensive experience in developing solid/liquid separation solutions after what it describes as "decades of continuous investment in research and development in meeting the filtration needs of the mining and metallurgy industries worldwide".



Weir's largest Geho pump is the crankshaft-driven TZP piston pump

Designing a better system

Slurry pipelines have proven themselves to be a safe and cost-effective way of transporting large tonnages of minerals over long distances

BY RAMESH GANDHI, JAY NORWOOD AND YUEGUANG CHE

OVER the past 40 years, slurry pipelines have moved from being an intriguing, but rather risky, possibility to becoming a highly reliable alternative to conventional methods of transportation.

A typical slurry-transportation system can be split into particle preparation, the pipeline itself and the dewatering facility. The optimum particle size distribution (PSD) for hydro-transport is a balance between the grinding and pumping considerations, the necessary pipe dimensions and the thickening/filtering costs, as well as the delivery requirements.

Within limits, the finer the grind, the easier it is to transport solids by pipeline (reducing the pumping power required and the erosion rate of the pipeline). However, this comes at a price.

Finer slurries tend to be transported at lower solids contents, increasing the volume to be transported and stored. The lower slurry velocity requires a larger-diameter pipe for any given flow rate, and that may increase capital costs. A finer grind also requires a larger mill and consumes more power and grinding media, and filtering becomes more difficult.

The slurry concentration should be as high as possible in order to reduce the amount of water transported with the solids. Slurry concentration is selected such that the friction loss in the pipe is not very high.

The slurry flow rate depends upon the solids throughput, solids density and slurry concentration.

TYPICAL SLURRY PARTICLE-SIZE DISTRIBUTION

Concentrate	% -65 Mesh (210 µ)	% -325 mesh (44 µ)
Coal	50-60	20-30
Bauxite	95	40
Copper Tailings	70-90	30-50
Phosphate	65-85	35-50
Copper	97-100	55-85
Zinc	100	60-80
Iron	100	60-80
Gold Tailings	100	60-80
Nickel Laterite	>95	60-90

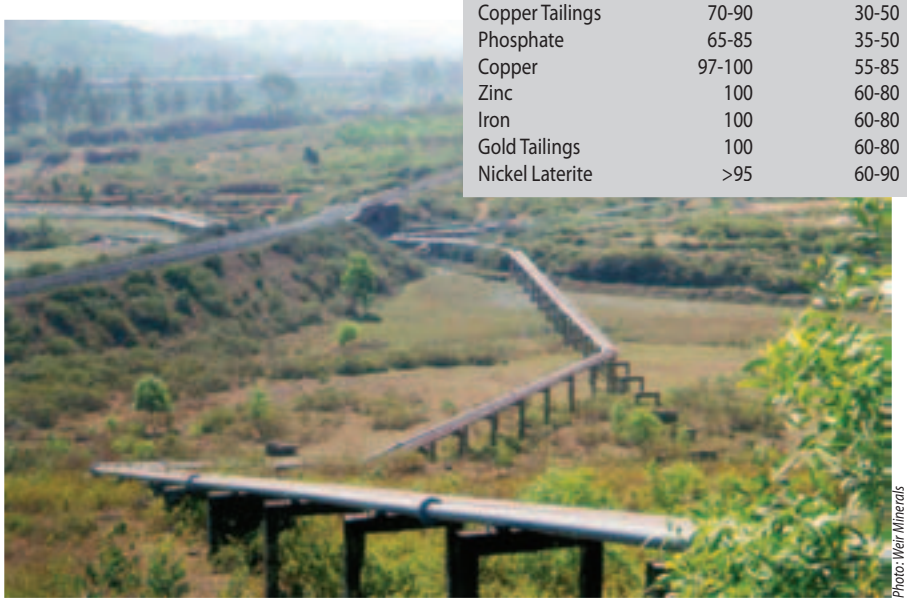


Photo: Weir Minerals

Pipeline Systems Inc designed a 171 km pipeline to transport of 2.3 Mt/y of refined iron ore from a mine in Yunnan province, China, to the pelletising plant at Anning. Long-distance slurry pipelines commonly are the lifelines to a process plant. They are complex and the selection of the best pipeline design and equipment is essential

The mass flow rate of slurry is obtained by dividing the solids throughput by the slurry concentration, and the mass flow rate of the liquid (water) is obtained as a difference between the slurry mass flow rate and the solids mass flow rate. The volumetric flow rate of slurry is obtained by adding the volumetric flow rates of solids and water. The volumetric flow rate is obtained by dividing the mass flow rate by the density of the material.

For example, if 5 Mt/y of solids are to be transported, and assuming an operating availability of 8,322 hours per year, the solids throughput will be 600 t/h. Assuming a slurry solids concentration of 50% (by weight), the mass flow rate of slurry will be 1,200 t/h. Assuming a solids density of 2.65 t/m^3, and a water density of 1 t/m^3, the slurry flow rate will be 826 m^3/h.

Flow behaviour is defined by plastic viscosity and yield stress. The latter is a function of particle surface area. For a given volume of solids, particle surface area increases when the particle size is reduced.

Slurry particles can break down and generate fines when subjected to shear, and so the yield stress of slurry traveling via a long-distance pipeline can be significantly higher than that of a fresh slurry sample.

The friction loss in a pipeline depends upon the flow regime. In laminar flow, friction loss depends upon yield stress as well as plastic viscosity. In turbulent flow regime, the friction loss is governed by plastic viscosity.

SYSTEM DESIGN

A key design parameter in any slurry pipeline system is the operating velocity range. In a conventional (turbulent) system, the line velocity must be high enough to maintain turbulence and to prevent deposition of the coarse particles. However, if the operating velocity is too high, pressure losses and pipeline wear rates can become too high for the system to be economic.

For a long-distance, cross-country pipeline, the minimum operating velocity should be higher than the laminar-turbulent transition velocity and the deposition velocity. In general, viscous slurries (ie ones with a higher solids concentration and/or fine particles) will be 'transition velocity'-limited. Dilute slurries, and/or coarse slurries, will be 'deposition velocity'-limited.

As the solids concentration of any given slurry rises, the transition velocity will increase and the deposition velocity will decrease. As a rule of thumb, the most economical concentration with which to run a long-distance pipeline is where the two values are equal. The particle size distribution and slurry concentration are selected such that the deposition velocity and laminar turbulent transition velocity are less than 1.5 m/s.

This allows the long-distance pipeline to be designed at a velocity in the range of 1.5-2 m/s. The pipe diameter is selected such that the desired velocity of flow is obtained at the design throughput.

The pumping requirements depend on the friction loss through the pipeline, as well as the static head required due to changes in elevation between the

PUMP CHOICE

The discharge pressure controls the basic decision of whether to use centrifugal pumps or positive-displacement (PD) pumps.

Centrifugal slurry pumps can handle large flow rates, but are limited to about 40 m head per pump. These pumps are less expensive and easy to maintain. When higher pumping heads are needed, the pumps can be arranged in series. Normally, the maximum pumping pressure is limited to about 5 MPa (725 psi).

PD pumps have a limited flow capability (about 300 m^3/h) per pump, but can develop very high pressures. Pumps capable of producing 25 MPa (3,650 psi) have been used in long-distance slurry pipelines. Pumps can be arranged in parallel to achieve higher flow rates.

For discharge pressures below 5 MPa (725 psi), the installation of centrifugal pumps normally provides an economic advantage over PD pumps, especially when large flow rates are encountered. However, the total cost of a centrifugal-pump system can sometimes be more expensive than the equivalent PD-pump system as spare pumps are needed to achieve high system availability.

Two types of impellers and liners are used for centrifugal slurry pumps. Wear-resistant, metal-lined pumps are used when handling coarse particles. Rubber-lined pumps are used when handling fine slurries.

The following types of PD pumps have been used for high-pressure pumping systems: piston, plunger and piston-diaphragm pumps (*MM*, November 2005, p21), and the hydro-hoist (lock-hopper) pumping system. The latter consists of two or more pipes arranged in parallel, and the chambers are alternatively filled with slurry and pumped out, using water under high pressure, by synchronising the opening and closing of valves.

mine site and the delivery site. In a long-distance pipeline, the pumping pressure may be such that more than one pump station is needed. The pipe-wall thickness requirement depends on the pressure in the pipe, and this pressure is reduced when more than one pump station is used. Therefore, the cost of pipe will decrease, but the cost of pump stations will rise with an increase in the number of pump stations.

This article is based on a paper written by the authors, who may be contacted at: Pipeline Systems Inc, 5099 Commercial Circle, Suite 102, Concord, California 94520, US. Website: www.pipesys.com

Handling your tailings

Not surprisingly, the physical and chemical characteristics of tailings and their ability to mobilise metal constituents are of great and growing concern

BY JON ENGELS

TAILINGS consist of ground rock and process effluents that are generated in a mine processing plant. Mechanical and chemical processes are used to extract the desired product from the run-of-mine ore and produce a waste stream known as tailings.

This process of product extraction is never 100%-efficient, nor is it possible to reclaim all reusable and expended processing reagents and chemicals. The unrecoverable and uneconomic metals, minerals, chemicals, organics and process water are discharged, normally as slurry, to a final storage area commonly known as a Tailings Management Facility (TMF), or Tailings Storage Facility (TSF).

Tailings are a waste product with no financial gain to a mineral operator at that particular point in time. It is therefore imperative that tailings should be stored in the most cost-effective way possible to meet regulations and site specific factors. Dams, embankments and other types of surface impoundments are by far the most common storage methods used today and remain of primary importance in tailings-disposal planning. The particular design of these retaining structures is unique to a particular environment and mining operation.

The first stage in determining the most applicable type of tailings storage method is to look at various alternative handling options. These are:

- Disposal to disused mine pits, underground backfill and/or offshore disposal.
- Practical use of the tailings (eg as construction or restoration material).
- Feasible alterations in the plant to make storage safer and more environmentally friendly (eg dewatering, pollution control and independent waste streams).

The recycling and reuse of water in the processing plant is an important issue in reducing the environmental impact and the freshwater requirements. The toxicity of the tailings and associated effluents can have a dramatic impact on the environment

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and should be considered when designing a TSF. Storage of process water in a tailings facility creates water-management challenges and, in the event of a breach in the retaining-wall, the water can act as a transport mechanism for the escaping tailings.

Once the scale and complexity of the required storage facility is estimated (eg taking into account the predicted tailings tonnage for the estimated life of the mine, the tailings properties, plant water-storage requirements, and regulations/company policies constraining the design of a tailings facility), an assessment can be made to determine the suitability of a TMF's location and the various storage options.

The fundamentals of a tailings storage facility are that it should remain perpetually stable, have little or no impact on the environment and surrounding residents, and that it can be rehabilitated once closed. Combining this with early planning and the development of a suitable management strategy will ensure successful tailings storage.

BRIEF HISTORY

Historically, tailings were routinely discharged directly into the nearest surface water course. This is still practised in parts of the world, particularly in areas of high rainfall and steep and unstable terrain.

The OK Tedi mine in Papua New Guinea and the Grasberg mine in Indonesia are just two examples of large mining operations that dispose of their tailings and waste rock directly into the local water course. This type of storage method creates vast environmental liabilities and costs associated with remediation and reclamation. It has also generated substantial opposition that has contributed to the general negative public perception of the mining industry, thus harming its reputation.

The figure below shows tailings deposition from a gold mine in the early 1900s in the Cortez Hills of Nevada (see p8 for a description of a more recent mine on the site). The tailings have been deposited as a slurry from the processing plant (where the image was taken) and then allowed to flow down the side of the valley creating extensive damage to the environment.

It is reported that the impact of uncontrolled tailings disposal were being recognised as early as the 1900s. Plugging of irrigation ditches and contamination of downstream areas were becoming more common, thus creating conflicts between land and water use, particularly where agriculture interests existed. By about 1930, a complete cessation to this type of tailings disposal was enforced in the Western World, creating the first benchmark regulations on mine-waste management. It should be only a matter of time before mines like OK Tedi and Grasberg are restrained from disposing their tailings uncontrollably.

TAILINGS STORAGE

Tailings stored on the surface are usually deposited within purpose-built retaining embankments. Storage in conventional impoundments are the most common method, and these normally have higher embankments than thickened, paste and dry-stack storage facilities (*MM*, December 2005, p14).

Embankments for conventional storage facilities are designed to retain tailings and water, whereas thickened, paste and dry-stack facilities contain embankments designed to retain runoff, bleed water and fines rather than the weight of the tailings mass itself.

In-pit, co-disposal and offshore are alternative tailings discharge methods that are not widely practised but can be useful under certain circumstances. In-pit storage involves filling mined-out open pits with tailings. Generally, no liner systems are used and the tailings are stored above groundwater level. Co-disposal is a mixing of tailings and coarse mine waste to produce a single waste stream. This method of tailings storage is most suitable to the backfilling of voids (underground and open pit), the covering of conventional tailings storage methods and the construction of elevated waste heaps (providing that a water containment system is in place).

IN-PIT

To a degree, the design of the retaining embankment is independent of the type of impoundment layout. The only considerations are costs associated with starter dyke and subsequent raised construction, the volume of material required to establish a particular height, the tailings properties and the water storage requirements of the facility. Ideally, topographical depressions are more advantageous for tailings storage as the volume of fill material required and the subsequent embankment heights are reduced.

Offshore tailings disposal is the discharge of tailings to natural bodies of water. Submarine Tailings Disposal (STD) is perhaps the most common offshore disposal technique and involves the deepwater discharge of tailings to the sea.

The layout of a surface tailings storage facility depends on natural land forms as well as man-made engineered features. The three main layout types for slurry impoundments are:

- Ring dykes (paddocks or cells).
- Valley impoundments: cross valley, side-hill and valley bottom.
- In-pit.

TAILINGS DISCHARGE METHODS

Tailings can be discharged using subaqueous (below water) or subaerial techniques (above the water line, on the ground or on the tailings beach). The choice between these methods can dramatically affect how the tailings deposit and settle within the impoundment. Tailings characteristics can also influence the behaviour of the tailings once discharged.

Generally, as the tailings deposit, they flow away from an outfall and natural segregation occurs. The degree of this segregation essentially depends on the particle size range of the tailings, the pulp density of the slurry and the speed of flow of the tailings. As the degree of thickening of tailings increases, there is less slurry to carry the coarse fraction and the tailings begin to stack closer to the discharge point. Further thickening eventually results in a non-segregated

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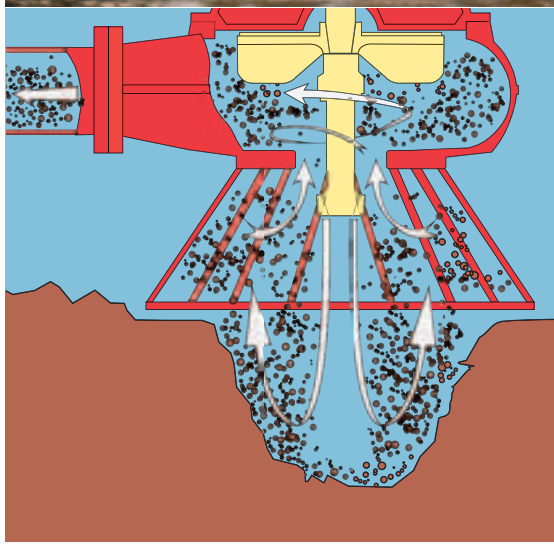

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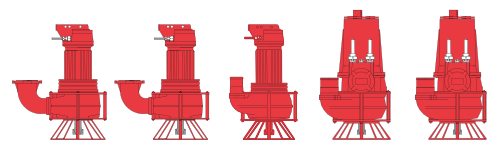
The BRAVO pumps complete Grindex existing drainage and sludge pumps for professional users worldwide.



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slurry due to the high pulp density of the depositing tailings. When this stage is reached, the voids in the coarse fraction of the slurry are filled with the fines, resulting in a homogeneous mixture.

For low pulp densities, the coarse fraction of the tailings settle closest to the discharge point, while the finer material (slimes) is carried furthest away. For subaerial deposition, this results in a beach sloping downwards from the spigot towards the supernatant pond. For most tailings types, the expected beach slope grade is 0.5-2.0% within the first 100 m, and that the higher the pulp density and/or the coarser the gradation of the tailings, the steeper the beach slope.

ALTERNATE STORAGE OPTIONS

Thickened tailings, as the name suggests, involves the mechanical process of dewatering slurries with a low percentage of solids. This is normally achieved by using compression thickeners or a combination of thickeners and filter presses. Thickened tailings are defined as tailings that have been significantly dewatered to a point where they will form a homogeneous non-segregated mass when deposited from the end of a pipe. When placed layer by layer, the thickened tailings will dry to near its shrinkage limit and become dilative under dynamic shaking, thus preventing the possibility of liquefaction.

The idea of Thickened Tailings Disposal (TTD) is to stack the pulp to form a self-supporting conical pile, thus reducing the height and retention forces of the containing perimeter embankments. The tailings are generally discharged from topographical high points within the tailings storage facility or by riser towers or central ramps. Water remaining after deposition and any surface runoff is collected in a pond at the toe of the pile. Typical slope angles of 1-3.5º can be achieved to create a landform which is self-draining and thus is easy to restore and rehabilitate.

Paste tailings are defined as those that have been significantly dewatered to a point where they do not have a critical flow velocity when pumped, do not segregate as they deposit and produce minimal (if any) bleed water when discharged from a pipe. The increased viscosity of the tailings as a result of high dewatering requires the use of positive displacement pumps to transport the paste. This limits the distance to which the paste can be economically transported.

Dewatering tailings to higher degrees than paste produces a filtered wet (saturated) and dry (unsaturated) cake that can no longer be transported by pipeline due to its low moisture content. These filtered tailings are normally transported by conveyor or truck, deposited, spread and compacted to form an unsaturated tailings deposit. This type of tailings storage produces a stable deposit requiring no retention bunding and is referred to as 'dry stack'.

TAILINGS MANAGEMENT

Tailings management strategies can vary greatly between mine sites as a consequence of site-specific factors. Different climates, plant-water conservation requirements, tailings properties, topography, geotechnical and geological conditions, and the hydrology of an area are just a few of the key parameters that influence the complexity of tailings management for an individual tailings facility. With this in mind, it is difficult to have a generic management manual that can apply to a range of different sites to mitigate the many risks and environmental impacts associated with tailings storage.

> "Tailings management is becoming one of the criteria by which a mineral operator's environmental performance is judged"

The past ten years have seen a dramatic rise in the number of regulatory agencies establishing prescriptive or rigid tailings storage guidelines. Mining companies are also becoming more vigilant by implementing environmental policies and management systems to take more control over their tailings storage practices.

Major mining companies employ internal and external experts to audit their tailings facilities and management systems frequently. This is not surprising considering that tailings management is becoming one of the criteria by which a mineral operator's environmental performance is judged. Thickening, paste and dry stacking of tailings offer a real alternative to tailings management that is consistent with the expectations of the mining industry and the increasing regulator and public concerns.

The operating stage of a tailings impoundment requires the most management (in the form of inspections and monitoring). Diligent inspections, the use of operating manuals and a dedicated team

Continued on page 38

The new force in dewatering

The new 2600 series from ITT Flygt sets the standard in dewatering pump technology. Featuring cutting-edge design with new materials and the patented Dura-Spin™ hydraulic system, these pumps deliver unmatched wear resistance and consistent performance over time. All of which contributes to the lowest possible cost of ownership. And with our outstanding support and worldwide presence Flygt helps keep your operations moving.

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ITT

Engineered for life

Continued from page 36

of tailings operators are the requirements for successful tailings management to achieve minimal and acceptable impacts on the environment. Thus, an operating manual is a key requirement of a tailings management system and should be well-structured, define responsibilities, be implemented effectively and be continually revised to maintain its validity.

All individuals involved in storing tailings should be aware of site-specific operations and their roles and responsibilities as documented in the tailings management system. Personnel should be aware of their actions and the consequences of not following their required responsibilities. A lack of awareness can lead to misjudgements, inconsistency in application and an inability to identify problems that may develop into high-risk situations.

This raises the point that no matter how well structured a tailings-management system is, it can only ever be effective if implemented correctly. It is therefore essential that the individuals of a tailings-management system are well-trained, competent and will not lose confidence in their own decisions.

TAILPRO

Tailings research recently carried out at the Department of Mining, Quarry and Mineral Engineering at the University of Leeds (as part of the EU-funded TailSafe project: EVG1-CT-2002-00066) has produced an interactive database to increase the knowledge and awareness of tailings storage practices, the daily management requirements and the associated risks of operation.

> "Most of the operational content of TailPro is specific to conventional tailings storage impoundments"

This database has been developed further as a result of the success of www.tailings.info (a website designed to present a very basic overview of tailings storage practices and to increase public awareness). The database, known as TailPro, is a risk-management tool accessible online (www.tailpro.com) and is designed to allow easy navigation through a vast amount of knowledge on tailings storage from anywhere in the world.

The development of TailPro has been prompted by the lack of information available to personnel involved with the operation and management of tailings storage facilities. Industrial feedback has played an important role in the design and presentation of TailPro, which aims to enhance tailings management by focusing on the key parameters associated with reducing risks and preventing spills.

The management practices for identifying and evaluating risks (along with their control, intervention actions and mitigation measures) are also presented. The database has been designed to allow a range of different disciplines associated with tailings management to find relevant parameters quickly and easily.

Most of the operational content of TailPro is specific to conventional tailings storage impoundments (which, from a management perspective, are far more problematic than the thickened, paste and dry-stacking alternatives). However, the management aspects and some of the operational parameters of TailPro can apply to any type of surface tailings storage facility.

It is hoped that TailPro will be recognised by the mining industry as a tailings training resource for employees, and that it will continue to improve through user feedback.

Jon Engels has just completed his PhD thesis on tailings management, and was one of the leading contributors to the TailSafe project (which finished in November 2005). Contributing authors to this paper are Dr Darron Dixon-Hardy, who is a lecturer in mining engineering at the University of Leeds and who co-ordinated the Tailsafe project; and William Birch, who is head of the Blasting & Environmental Research Group and is a lecturer in surface mining at the University of Leeds

Problems melt away

Historical processing methods are out of favour because of ever-tighter environmental restrictions, leaving the way clear for development of new hydrometallurgical and pyrometallurgical techniques

MANY of the orebodies currently available for development are of low grade or comprise mineral combinations from which the contained metals are relatively difficult to liberate. As a result, processing techniques are increasingly important in determining whether, or not, a deposit can be economically developed.

However, environmentally-unfriendly processes are out of favour and, for example, the smelting of concentrates containing arsenic using historical techniques is now unacceptable. It has also become necessary to clean up any gas emissions (and ever-tighter regulations on heavy metals may make any gas-releases prohibitively expensive in the future). Indeed, the historic smelting procedures are synonymous with the old 'smokestack' industries, and are becoming unacceptable as sustainable techniques.

As a result of the increase in costs and the tighter environmental regulations, metals producers have been forced into improving existing processing methods or finding alternative techniques.

Xstrata Technology's ISA process won the *Mining Magazine* Editor's Award in 2005 (*MM*, January 2006, pA16). The permanent stainless-steel cathode system allows automation of the process, increased labour efficiencies and lower power consumption. The technology accounts for more than one-third of the world's refined copper.


Technology behind ISA Process gains more recognition


One of Metso Minerals' rotary dryers

PYROMETALLURGICAL PROCESSES

Pyro processing is used to increase the economic value of ores, minerals, waste and related materials by changing their mechanical and/or chemical properties through the addition or removal of heat.

Pyrometallurgical techniques include Outokumpu Technology's flash-smelter process and the ISAsmelt/Sirosmelt processes. The Outokumpu flash-smelter process represents an efficient low-cost process for the large-scale production of copper and nickel, in particular. For smaller throughputs, the Sirosmelt process is probably more appropriate.

Outokumpu Technology recently announced the sale of a flash-smelting plant for Konkola Copper Mines plc (KCM) in Zambia. The contract is worth €20 million (US$1=€.0.82). This is the fifth flash-smelting licence sold by Outokumpu Technology since mid-2005. The new smelter, commissioning of which is expected next year, will use Zambian concentrates, mainly from KCM's own mines, as raw material to produce 300,000 t/y of copper.

Outokumpu Technology's scope of supply covers the flash-smelting licence, basic engineering for the whole smelter (including drying, flash smelting, slag cleaning and also the cobalt-recovery system) as well as process gas cleaning, delivery of proprietary equipment for an advanced direct-to-blister flash smelting furnace and a TM-16 anode casting shop.

Tapani Järvinen, president and chief executive of Outokumpu Technology, said in January: "We have continuously developed the flash-smelting technology to reduce process steps and improve environmental and safety performance. The direct-to-blister technology, currently used in two smelters in Poland and Australia, and now designed for this Zambian smelter, eliminates converting and thus molten metal transports in a smelter." He added: "This deal shows that flash smelting is clearly the leading and the most economical technology for copper smelting plants."

In the 1970s, researchers at Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia developed the Sirosmelt process to improve the smelting of metals. The process involves injecting gases into a molten slag bath at 1,200ºC. The gases work most efficiently if injected below the surface of the slag bath through a lance, and the technology protects the steel lance from melting in the extreme temperatures.

Sirosmelt has been hugely successful in producing a diverse range of metals (including lead, zinc, copper and iron), and global production capacity is now in excess of 3 Mt/y. The technology also offers environmental benefits, including cleaner smelting, greater efficiency, and the treatment of wastes to yield valuable products.

Based on the Sirosmelt lance, ISAsmelt is a modern bath-smelting process for producing non-ferrous metals that was developed by Mount Isa Mines (MIM, now a subsidiary of Xstrata) and CSIRO. ISAsmelt utilises a simple refractory lined furnace and operates with a single submerged combustion lance to create a highly turbulent bath. More than 2.0 Mt/y of copper concentrate are smelted each year in these furnaces, and an ISAsmelt furnace currently under construction in China will treat a further 600,000 t/y of copper concentrate.

Metso Minerals offers engineering services, equipment and systems to cover the entire thermal process, including drying and cooling, materials handling and combustion. For example, the company designs and supplies both direct-fired and indirectly-fired rotary kilns (which are used to heat solids to the point where a required chemical reaction takes place) for variety of applications (ranging in size up to 7.6 m in diameter and 190 m in length).

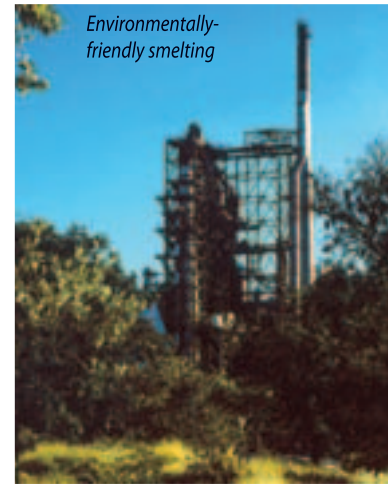
Environmentally-friendly smelting

Photo: Xstrata Technology

Metso is the only company that has the original drawings, specifications and calculations for pyro-processing systems that were installed under the following trade names: Allis-Chalmers, Allis Mineral Systems, Boliden Allis, Kennedy Van Saun (KVS), MPSI/Hardinge, Stansteel and Pyrotherm.

Kumba Resources Ltd and Samancor Ltd recently announced a deal to use a new technology, developed by Kumba, for the production of manganese alloys.

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The deal will see both companies co-operate globally on projects that utilise Kumba's new AlloyStream technology.

The companies said they plan to launch a joint study to assess the feasibility of building a 200,000 t/y high-carbon ferromanganese plant in South Africa – with first production slated for 2009. The technology was successfully demonstrated last year and allows manganese alloy to be produced directly from fine manganese ore and non-coking coal. As such, it allows the beneficiation of ores that would have previously been of limited use.

HYDROMETALLURGICAL PROCESSES

Hydrometallurgy is the process of winning metals in solution without gas emissions. The process, scaleable from small to large projects, can handle ores that are high in arsenic, very complex sulphide ores and concentrates, or low-grade ores. This field is developing very quickly, and is probably the future for the processing of concentrates.

Hydrometallurgical processes are increasingly favoured for polymetallic ores and complex concentrates (including copper, lead, zinc and nickel combinations). These techniques usually involve pressure oxidation followed by solvent extraction, and provide the ability to separate copper, nickel and cobalt.

The roast-leach electrowinning (RLE) process, for example, is popular for zinc recovery. RLE consists of four basic steps:

- Roasting of the zinc concentrate.
- Leaching of the zinc oxide.
- Purification of the leach liquor.
- The electrolytic recovery of the zinc metal.

To achieve a reasonable recovery of zinc, a significant amount of iron is leached along with the zinc, and must be removed from the solution before a marketable zinc product can be produced. The most common approach is to precipitate the iron using an alkali (such as sodium, potassium or ammonia) to produce the insoluble jarosite.

Last August, South Africa's Mintek, in association with partners from industry and other research organisations, announced that it had embarked on a research programme aimed at extending existing tank-bioleaching technology (which has already been commercialised for refractory gold and demonstrated for copper sulphides) to the processing of zinc concentrates.

Zinc concentrates are conventionally treated by RLE but many plants have excess electrowinning capacity, and the successful development of a bioleaching route would enable existing facilities to expand their output without installing additional roasters. A further advantage would be the ability to accept a broader range of concentrates, including those unsuitable for roasting – for example, those with high copper levels.

> "Hydrometallurgical processes have the necessary flexibility in the treatment of complex ores"

COMPARISON

In comparing pyrometallurgical and hydrometallurgical processes, there are various notable differences. For example, the capital cost of most pyrometallurgical processes increase at a faster rate for a decreasing recovery of metal than do hydrometallurgical operations. As a rule of thumb, at a capacity of 25,000 t/y, the capital cost of hydrometallurgy, in most cases, becomes more favourable than that of pyrometallurgical processs.

The labour component for hydrometallurgical plants can be as low as half that of pyrometallurgical plants. A significant unit-price advantage can be realised when operating at less than full production, making hydrometallurgical processes more competitive than pyrometallurgical techniques for variable-feed operations.

Hydrometallurgical processes have the necessary flexibility in the treatment of complex ores and, in addition, assist in the recovery of by-product metals (which, when dealing with low-grade porphyry deposits, can often be detrimental to a project's economic viability). High overall revenues for by-products more often than not have significant influence on overall process economics, which would make the hydrometallurgical process option extremely attractive.

It has been demonstrated in several instances that hydrometallurgical processing can be used to treat low-grade ores, whereas pyrometallurgical refining methods would be prohibitively expensive. Low-grade uranium ores, for example, are now being exploited (albeit on a limited basis) in Texas by methods that involve pumping sodium carbonate (leachant for uranium ore) directly into the deposit without bringing the ore to the surface. Field tests of this technique are also under way in Wyoming, New Mexico and Colorado.

Hydrometallurgy can be less energy-consuming when applied to low-grade ores or to run-of-mine ore. Moreover, the process operates at relatively low, often ambient, temperatures, compared with temperatures as high as 1,500°C that are typical in pyrometallurgical furnaces. Much of the heat utilised in pyrometallurgy is difficult to recover.

Hydrometallurgy has been suggested, too, as an alternative to traditional pyrometallurgical processes to reduce pollution, especially air pollution caused by smelter emissions of sulphur dioxide.

Hydrometallurgical plants, however, do require sophisticated control schemes to maintain satisfactory operation, as they tend to operate more like chemical plants. The engineering of hydrometallurgical plants is also more complex, and requires a full understanding of 'scaling' relationships as well as processing requirements.

In relation to the consumption of process materials, fuel and electric power, hydrometallurgical processes are much more demanding than the pyrometallurgical equivalent because the latter uses mostly oxygen (using air drawn from the atmosphere) as a reagent and sulphur (present in the ore) as a heat source.

The complexities involved in hydrometallurgical processes swing many developers toward pyrometallurgy, whereas, from an environmental perspective, they might otherwise be drawn to hydrometallurgy. Looking at each process from an operating cost perspective, hydrometallurgy has a lower labour component but this advantage is offset by the additional costs in relation to the consumption of process materials, fuel and power.

In summary, there are distinct differences between both hydro- and pyrometallurgical processes; neither seems to have a distinct advantage over the other.

ISASMELT PROCESS

The ISAsmelt reactor is an upright cylinder and the key feature of the process is the lance, which drops through the top of the furnace into the molten slag below. The feed reacts with air and oxygen from the lance.

The off-gases from the furnace pass up through a waste boiler, where the contained heat is captured to make steam and the cooled gases pass through an electrostatic precipitator (for the removal of dust) before the gases go to an acid plant.

A frozen layer of slag on the outside of the lance protects it from the heat of the furnace. The submerged lance can be raised and lowered automatically so that its tip is always in the best place just below the surface of the slag. The products of the smelting process (matte/metal and slag) are taken from the bottom of the furnace through a water-cooled taphole. The matte/metal and slag then flow into a settling furnace, where the matte/metal separates from the slag.

Photo: Xstrata Technology

ISAsmelt treats a variety of raw materials. Pictured is the stacker-blending copper concentrate

This article is based on a contribution by Chris Jordinson, who has been involved in the mining industry for over ten years and is chief executive officer of Copper Resources Corp. CRC's assets include porphyry copper deposits in the Philippines and Namibia, and a recently-acquired high-grade copper deposit in Congo's Katanga Province






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Screen control

In the last of a three-part series of features on computer software, we focus on programs that facilitate efficient mine and plant operations

HAVING already looked at the companies that provide orebody-modelling and mine-planning computer programs, attention is turned to the systems that are used in the day-to-day mining and processing of minerals.

There is, of course, a huge array of software available to improve operating control and efficiency, and many of the programs listed here are an integral part of much larger computer systems (most of the companies highlighted have already been mentioned in the past two issues of *Mining Magazine*).

At the centre of the mining process is the moving of material, often utilising heavy equipment. One of the companies offering computer software to help in this work is Carlson Software Inc, whose products include the Grade, Productivity Tools, Truck Pro and Dragline programs.

In the Carlson programs, terrain models can be fed to the heavy equipment by radio link. **Carlson Grade**, released in March 2005, can then offer drill navigation solutions, along with the logging of blastholes and an excavator interface for monitoring overburden and ore removal. Points can be logged by the equipment to update the geologic model through either real-time links or by office personnel through radioed data transfer. This radio link is managed by two pieces of software: Telescope, a 900 MHz, spread-spectrum linkage; or Stargazer, a high-speed wireless-fidelity (wi-fi) linkage.

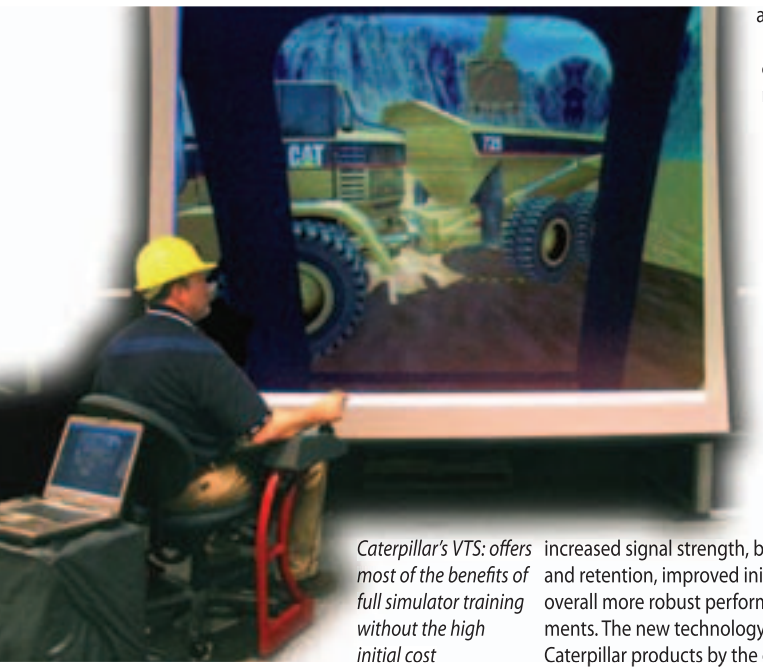
Carlson's **Productivity Tools** program analyses the production rates for all heavy equipment, while **Carlson TruckPro** is a newly-developed program for truck loading and haul management. TruckPro includes despatch features and an office component for viewing truck locations and status. Peer-to-peer communication enables viewing of all trucks by all operators. Truck information is also analysed in the Productivity Tools program. Carlson's **Dragline 3D** program offers swing monitoring and productivity feedback.

Many equipment manufacturers offer computer software to improve the efficiency of their products. Caterpillar, for example, is implementing new technology on several of its control and guidance products to provide customer access to a broader range of GPS frequencies. Caterpillar is providing this technology to take advantage of recent enhancements to the US Navstar GPS system, as well as Russia's renewed commitment and improvements to the Glonass satellite constellation.

This broader range of positioning frequencies will allow Caterpillar products, such as AccuGrade, CAES and the Aquila Drill and Dragline systems, to use Navstar's L5 and L2C frequencies, as well as Glonass's G1 and G2 signals. Caterpillar notes that this enhanced access to satellite constellations demonstrates its continuing commitment to provide users with the greatest uptime and availability.

Caterpillar claims that customers in the world's northernmost and southernmost regions, such as northern Canada, Australia and southern Africa, will benefit most by the new release, and should experience "dramatic productivity improvements". In addition, those working in areas where line-of-sight to the sky is difficult, such as deep open-pit mines, will witness improved uptime and capabilities.

Customers worldwide will apparently see increased signal strength, better signal acquisition and retention, improved initialisation time, and an overall more robust performance in difficult environments. The new technology will be available on Caterpillar products by the end of this year.



Caterpillar's VTS: offers most of the benefits of full simulator training without the high initial cost

KEEPING IN TOUCH

Equipment simulation is an increasingly important part of improving operating efficiency. To help meet the growing need for qualified equipment operators, Caterpillar's Equipment Training Solutions group is developing "cost-effective, easy-to-use and reliable" PC-based simulators for training entry-level operators. The company's **Virtual Training System** (VTS) is designed to train inexperienced operators from basic control orientation through to complex application tasks. The training can be used as a self-study tool or as part of an instructor-led programme.

The VTS is already available for hydraulic excavators, and VTSs for off-highway trucks, wheel loaders, backhoe loaders and tractors will be introduced later this year. Systems for motor graders and skid-steer loaders are due to be released in 2007.

Caterpillar claims that the VTS offers most of the benefits of full simulator training without the high initial cost. Specifically, the system minimises the use of production machines for training and reduces exposure of trainees and instructors to hazards in the field. The system also allows flexible scheduling and location of training, and provides measures of trainee performance, which is difficult to assess in real situations.

One of the hardest things for a software engineer to model in the past has been the interaction of broken dirt and excavating tools. However, Immersive Technologies (IT) claims to have overcome these difficulties, and the company's business-development manager, Oye Obe, said VirtualGround Technology (the result of more than seven years of research and engineering) represents a "quantum leap beyond existing ground/tool simulation technologies in the earthmoving industry".

Established in 1993, IT has 65 Advanced Equipment (AE) Simulators deployed in 14 countries around the world, and has now incorporated VirtualGround Technology into its new **Dragline Simulator** program (introduced as a tool for Australian coal mines last November). According to IT, this new generation of ground/tool simulation technology allows complex operating processes and digging tool/ground interactions to be realistically simulated for the first time. The dragline simulator is

February saw the launch in Europe of a new system from Komatsu called **Net Connection**, which seeks to facilitate the equipment manufacturer's delivery of technical assistance to customers. The system enables users to be connected at all times to Komatsu's headquarters and to receive real-time assistance regarding troubleshooting and technical training.

A global remote-monitoring system for compressors and generator sets has been introduced by Atlas Copco. **Cosmos** provides information on service schedules, operational history and utilisation data, and on the location of the machine. Visits, for example, can now be organised more efficiently, with technicians at the appropriate on-site location at the right time.

While Cosmos is not an anti-theft system, it does allow machines to be located at any time, creating added value for customer logistics and service planning. It may also reduce insurance fees.

Left: Atlas Copco's Cosmos: a global remote-monitoring system for compressors and generator sets

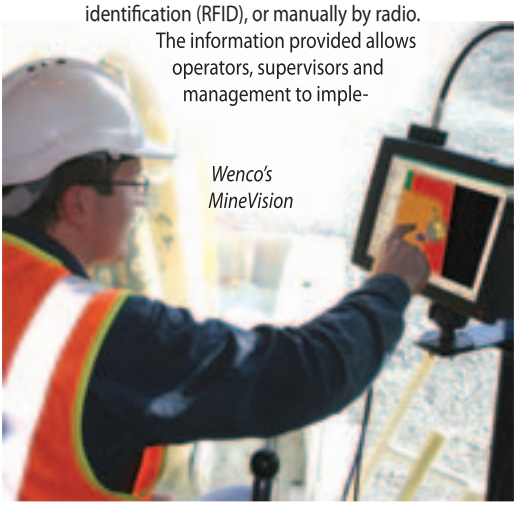
expected to help alleviate the 'skills constraint' on productivity.

According to Anglo Coal Australia (ACA), which partly funded development of Dragline Simulator, the shortage of skilled dragline operators is acute in Queensland's Bowen Basin, which has the largest operating dragline fleet of any single coal-producing region in the world.

ACA runs a fleet of seven draglines in central Queensland, including two units at the Callide mine southwest of Gladstone, where the first IT Dragline Simulator will be used to train new operators, test prospective operators and in coaching of more experienced drivers.

Matthew Little, senior mining engineer at Callide, said ACA's existing use of IT's AE Simulator technology for dump truck, excavator, loader and dozer operator training (and positive results from limited exposure of trainees to basic mechanical-scale models) had created high expectations of the Dragline Simulator. He believes the use of simulators can halve the typical training time of up to six months for new operators.

Efficient vehicle control and despatch plays an important part in improving operating profits. Micromine, for example, offers the **Pitram** system for production management and control. The system records operations automatically using GPS, data telemetry and tagging through radio-frequency identification (RFID), or manually by radio.



Wenco's MineVision

The information provided allows operators, supervisors and management to implement industry-standard management techniques, including corrective action and risk-management techniques, as well as accident prevention, down time, waste minimisation, grade optimisation and stockpile management strategies.

At the end of shifts, the program's Shift Processing module is used to update the central database to maintain an historical record of site activities. Reports can be configured to meet site-specific needs. The Grade Control module allows for multiple ore types, multiple waste and fill types, and maintains a snapshot of an operation at the end of each period. In an automated Pitram system, all trucks and loaders are fitted with a Mobile Hub and a Mobile Display Unit, and GPS data can be used to confirm the location of all equipment.

TireMax is offered as part of Wenco's fleet management system

Wenco International Mining Systems Ltd (www.wencomine.com) has been providing relevant mine-management systems since 1985. The company's products range from GPS-based fleet tracking and reporting software to sophisticated auto-despatch programs.

Wenco notes that its systems "combine a powerful database, advanced radio network communications and intuitive user interfaces". Wenco products include:

- WencoDB: the core database.
- MineVision: dynamic representation of vehicle position and status.
- BenchManager: automated guidance for digging units.
- Fleet Control: a despatcher interface.

BenchManager uses a combination of software, broadband radio communications, on-board computers and GPS equipment to determine the unit's track elevation (to an accuracy of less than 5 cm). This elevation is then compared with a Digital Terrain Model (DTM) and the result displayed to the operator.

Arm Geometry Sensors are an add-on component to BenchManager for shovels and loaders, and determine bucket positions by measuring joint angles with accelerometers. Measurements are taken every fraction of a second to provide bucket positions that are accurate to within 20 cm, which Wenco claims is the most precise technology on the market.

At the operational level, only fuel costs more than tyres, and, with the tyre shortage expected to continue into 2007, mines are focusing on preserving their current stocks by improving and maintaining road conditions. As part of its Fleet Management system, Wenco offers **TireMax**.

The program includes a basic inventory system, calculates and displays each tyre's usage and assists in preventive maintenance. Working with tyre manufacturers, Wenco uses specific calculations from Bridgestone, Firestone, Toyo, Michelin and Goodyear to calculate each individual tyre's status and compare it against the manufacturer's maximum recommendation.

These calculations include ambient temperature, fractional tyre weight (loaded and empty), and average work-day speeds. This indirect measurement is in direct contrast to the expensive alternative of individually-mounted on-board tyre sensors.

Maptek Ltd is one of the world's largest suppliers of mining software, and its programs include the Vulcan modelling and mine-planning suite (with a new version, 7.0, due for release later this year) and the **MineSuite** vehicle despatch system (*MM*, February 2006, p14).

Mintec Inc has released the latest version of **MineSight** (3.50-02), which it claims contains several key components. These include the **acQuire** program for blasthole data management. Some 45 mines are reported to be using MineSight.

In mid-March, Toronto-based Geosoft announced the creation of a new **Enterprise Solutions group**, which will focus on the design and delivery of exploration data management (EDM) solutions. Troy Wilson, vice-president of marketing, said Geosoft's EDM solution will work "intuitively and seamlessly, and is a cost-effective means of connecting the people in an organisation with all of their data and

Orica Mining Services is a leading provider of systems to improve explosives utilisation. Two years ago, the company introduced the i-kon **Surface Remote Blasting System** (SURBS). This allows quarry and surface mining operations of all kinds to initiate their i-kon electronic blasts conveniently and remotely from a central point, well away from the hazard of fly rock or other blast effects (*MM*, September 2004, Orica profile).

Using remote-firing hardware with the existing i-kon system, SURBS offers increased flexibility for mining operations where firing time delays are critical and pit closures must be minimised. SURBS can handle up to 2,400 detonators (using 12 loggers) and uses coded radio signals (on an assigned frequency).

Continued on page 44

Continued from page 43
applications". Geosoft recently added a new, interactive, map template to its Oasis montaj program, and has enhanced its 3-D visualisation technology (*MM*, February 2006, p14).

UNDERGROUND MINING

In January, AeroScout Inc and NL Technologies (NLT, a division of Levitt-Safety Ltd and a leading provider of underground lighting and communications systems) announced a partnership to deliver an **advanced real-time location solution** (RTLS) for the underground mining industry (see also p25). The partners are using standard wireless-networking technology and wi-fi RFID tags to provide "an immediate and accurate tracking of personnel for improved safety and efficiency".

The partners claim that AeroScout's IP-based RTLS is a "compelling solution for underground mine operators, providing advanced asset and personnel tracking functionality over standard wireless networks" and "delivers on the ability to utilise data, voice and location services over a single network".

Through joint development efforts, NLT has integrated AeroScout's wireless real-time location system into its Northern Light Digital Network. AeroScout's long-range active RFID tag is installed into the Northern Light GII Model cap lamps, providing Wi-Fi based location tracking capabilities.

The latest releases from MineMax include **iGantt 3.1**, an update of the company's production scheduling software for open-pit and underground operations. Features include activity-based or resource-based scheduling of production activities, easy-to-use charts and 3-D visual scheduling.

The iGantt Auto-Scheduling module takes into account tonnage and grade targets, while simultaneously balancing and maximising resource utilisation. Heading development rates are automatically adjusted to ensure maximum equipment utilisation, and the program can limit the number of concurrent development headings and interrupt development when a higher priority heading becomes available.

PROCESSING

Modern process plants consist of perhaps only one-third of the items of equipment compared with equivalent traditional installations but have complex dynamics. With pressure on plant managers to reduce production costs, deliver a consistent product, improve recoveries and observe demanding safety and environmental regulations, process-control systems have become a critical means to improve plant efficiency and business performance.

South Africa-based Mintek emphasises its role in this regard, and is proud of its history of technological innovation, particularly with regard to carbon-in-pulp gold processing, uranium recovery, gold refineries, DC arc furnaces, plant-control systems and bio-leaching.

Mintek's metallurgical plant-control systems include computer programs for submerged-arc furnaces (**Minstral**), milling (**MillStar**), flotation (**FloatStar**) and leaching (**LeachStar**). These are coupled with Mintek's monitoring and control equipment to provide an overall platform for efficient plant operation.

Control is facilitated by 'in-stream' analysis systems, which provide continuous assay information for the measurement and control of materials, in wet and dry states of concentration and refinement. These systems, which output data in graphical or numerical forms, can be integrated with plant-control equipment to meet the needs of metallurgists and plant operators alike.

Invensys Process Systems has been selected by Iron Ore Co of Canada (IOC) to implement a new automation system for its concentrator in Labrador City. By connecting with several existing **Foxboro** systems, the beneficiation plant will come under central control.

IOC's Labrador City concentrator is Canada's largest such operation, with a production capacity of 16 Mt/y, 75% of which is processed into pellets on-site and the balance shipped to sinter-feed customers. Invensys will implement the latest I/A Series (version 8.X) hardware and software, including the CP270 family of control processors and a range of I/O modules. The system will replace outdated equipment that was used to control the magnetite recovery and spiral processes, and will integrate with existing I/A Series systems that are used for controlling the grinding area and hematite plant.

The generic ETAP software (www.etap.com) is the most comprehensive analysis tool for the design, simulation and operation of industrial power systems. Three months ago, Operation Technology Inc (OTI) announced that PT Newmont Nusa Tenggara (NNT), operator of one of Indonesia's largest copper-gold mines, had deployed its **ETAP Real-Time** solution to reduce production losses due to faults caused by a variety of environmental disturbances.

NNT is also using the software to monitor, control and optimise power generation and transmission at its facilities throughout Indonesia's Sumbawa Island.

NNT's installation of ETAP Real-Time employs two primary products: ETAP Intelligent Load Shedding and ETAP Power System Monitoring & Simulation. Together, these products provide a fully-integrated system to optimise electrical power management, resulting in lower generation cost and less lost time.

US-based Smart Screen Systems Inc manufactures high-frequency screens for the mining industry, which have 'smart' electromagnetic motors (as one might expect from the company's name). This is claimed to provide more efficient separations, minimal maintenance (and no lubrication requirements) and a reduction of up to 70% in energy consumption. Smart Screen notes that the 19th-century design of eccentric-shaft technology cannot offer these same benefits because of the inherent disadvantages of using brute force to generate the vibration.

CASE STUDY: SANDVIK'S CENTRAL CONTROL

Sandvik manufactures its products in many different locations around the world, and this decentralised model presents enormous logistical challenges.

Sandvik Mining and Construction is a global manufacturer of high-technology mining and construction equipment. Its product range is large and comprehensive, including drill rigs, boring equipment, extraction tools, loaders, crushers and utility vehicles.

Each of Sandvik's nine product groups has its own unique manufacturing requirements. For example, a machine designed for boring large-diameter tunnels might encompass 10,000 mechanical parts, and its manufacturing specification will be significantly different to those for a high-technology drill.

Sandvik has responded to this logistical pressure by investing in advanced information technology. Since the mid 1990s it has been using enterprise resource planning software from Geac Computer Corp*. The software, called System21, is now installed in 35 production, distribution and sales sites around the world to provide an integrated view of the group's manufacturing, inventory and finance.

System21 provides essential, controlled, data-access to Sandvik's staff, customers and suppliers via a browser-based portal. The central control is at the Swedish company's head office in Sandviken, and provides a consolidated view of inventory and production.

Sandvik claims that the system has reduced lead times significantly, from two weeks to just a few days, and it has also taken dozens of people and unnecessary discussions out of the information chain.

The next stage of Sandvik's supply-chain development will be the centralisation of its high value, infrequently ordered, parts inventory, such as engines and transmission systems. Sandvik expects to reduce its worldwide inventory of these by 40% (representing millions of dollars saved annually) by consolidating its distribution centres for these high-value items.

**Geac was acquired last month by Golden Gate Capital, and has been reorganised into two companies: Infor (whose assets include the System21 software products) and Extensity (which will focus on financial applications)*

GENERAL MANAGEMENT

Mincom launched the latest version of its enterprise asset-management program, Ellipse 6, last October. New to the package is a fully-integrated reporting and business intelligence solution, **Mincom Ellipse Reporting**.

Paul Beesley, head of research and development at Mincom, noted that as well as supporting all the typical enterprise reporting requirements, Ellipse 6 allows users to identify trends in operational data, access real-time information, and analyse and optimise business performance. The program was available for general release in February.

Mincom also offers the **Work Planner** program to support maintenance planning. The software has specific tools that allow users to balance asset availability against the costs of supporting that asset. It provides consolidated graphical views and easy-to-use organising and scheduling capabilities.

Datamine International's range of products includes **Ore Controller**, which is a flexible modular system that can be implemented at any open-pit or underground mine using standard modules (with customised modules added where necessary). The software offers periodic reconciliation routines to validate the interpretation, modelling and design processes used.

Ore Controller is being implemented at the Geita gold mine in Tanzania to help increase ore throughput to 6.5 Mt/y without increasing the number of geologists. Datamine claims that a valuable add-on benefit for Geita (see photo, right) will be a 5% reduction in the number of holes that need to be drilled for grade control; an annual saving of US$100,000, apparently.

The Nyankanga open pit at the Geita operation

Last August, Vancouver-based Gemcom Software International Inc announced the release of **In-Site**, what it described as "the next-generation production-information management solution for open-pit and underground mines".

Gemcom's executive vice president, Omid Ejtemai, said that In-Site will integrate with Gemcom's GEMS geological modelling and mine-planning software (*MM*, March 2006, p18).

In-Site is described as a production-management business-intelligence solution that "delivers analytical and reporting tools to provide accurate and timely decision-support in all phases of the mining value-chain. Integrating with mine-planning databases, mining equipment systems and enterprise resource planning systems, In-Site provides a unified view of information from across single or multiple operations in near real-time."

Runge's products include the XERAS, Talpac and DragSim programs. **XERAS**, mentioned in *Mining Magazine* last month (*MM*, March 2006, p21), incorporates financial modelling, advanced budgeting and maintenance forecasting. The company claims that the product allows easy revision of various stages of the business plan, and easy re-working of scenarios during management reviews.

Talpac has over 300 licensees worldwide and is claimed to be the industry standard for determining the productivity and economics of truck and loader haulage systems. Within Talpac, the haul route for the truck can be specified, the truck type selected and operating limitations set (including speed limits).

Runge is well known for its dragline planning expertise, having been involved in the analysis and simulation of dragline operations in Australia, South Africa and North America for over 20 years. The company's **DragSim** program facilitates both short- and long-term planning of dragline operations, and allows users to calculate productivity, unit costs and rehandled volumes. Blasting and additional stripping and mining equipment can also be incorporated into the analysis to emulate the actual operating conditions more effectively.

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Achievements rewarded

This tiny, land-locked country, sandwiched between Russia and Turkey, has achieved an unprecedented double-digit economic growth rate for the past five years

ARMENIA'S foreign investment rose by 33% in 2004 to US$306 million, and foreign direct investment (FDI) jumped 48% to US$227 million, one-third of the latter attributed to privatisation deals.

The mining sector has benefited from a radical overhaul of the regulatory environment; indeed, the country won *Mining Journal*'s 'Country of the Year' award (sponsored by Barrick Gold Corp) in 2003 for its rapid improvement in investor conditions. Mining's share of FDI inflow was 17%, and mainly concerned payment for shares in Armenia's biggest mining company, Zangezur Copper Molybdenum Combine.

Armenia has significant deposits of copper, molybdenum and gold, as well as smaller deposits of zinc, lead and silver. Copper-molybdenum and polymetallic ore deposits are rich in elements such as bismuth, tellurium, selenium, gallium, indium, thallium, rhenium and germanium. Armenia also has significant deposits of construction materials such as granite, basalt, travertine, gypsum, diatomaceous earth, limestone, and raw materials for cement production.

There are 17 mining and metallurgical companies active in the country, mainly concentrated in two provinces, and most of them either extract and process ores of copper and molybdenum, or extract gold from tailings.

Armenia's gold reserves and resources are estimated at around 230 t. The Zod and Meghradzor hard-rock mines exploit the largest deposits in the country and are operated by Ararat Gold Recovery Co (100% owned by Sterlite Industries Ltd), which also operates a gold-processing plant at Ararat.

Global Gold Corp is establishing a major presence in north-central Armenia. It recently acquired the Toukhmanuk gold property adjacent to its Hankavan property, and, in August 2005, Global also acquired 51% of the Armenian company Mego-Gold llc. It will acquire the remaining 49% within two years. The Toukhmanuk mine was estimated by Armenia's National Reserve Committee (NRC) to contain 3.3 Mt of ore averaging 6 g/t Au and 15 g/t Ag.

Above: view of the Zod operation, operated by Ararat Gold Recovery Co

In August 2005, Global Gold also formed a joint venture with Iberian Resources Ltd to develop the Litchkvadz-Tei and nearby Tereterasar gold-copper-silver deposits in southern Armenia. These properties are situated among several significant past and present producing mines, such as the Kajaran, Agarak and Kapan copper mines.

Armenia's largest mining asset is the Kajaran deposit, in the southern Syunik region, which is described as being among the ten biggest copper-molybdenum deposits in the world, and contributes 3% annually to global molybdenum output. Kajaran Copper Molybdenum Combine was privatised in December 2004. A consortium of companies led by the German company Cronimet has acquired 100% of the holding company, Zangezur CMC, and expected to produce 18,000 t of copper and 4,000 t of molybdenum concentrates from Kajaran in 2005. The consortium plans an extensive initial investment to upgrade the mine and plant.

Based on a contribution to Mining Annual Review *by Tigran Sukiasyan*

Correction

In our recent 'spotlight' on Russia (*MM*, February 2006, p40), we inadvertently referred to Rio Tinto having a stake in Peter Hambro Mining, rather than it having a joint-venture agreement.

Mt Aragats: the highest peak in Armenia at 4,090 m

Silver boosts Mexico

THERE is still no end in sight to the current bull commodity market, with Macquarie Bank noting in mid-March that "it is unlikely that an end to the current cycle is near, and high metals prices are set to stay with us in the foreseeable future".

Although many metals are flying high at the moment, it is silver that caught the eye during March. The metal reached a new 22-year high of US$10.50/oz last month, after the Securities and Exchange Commission approved Barclays Global Investors' new silver exchange-traded fund.

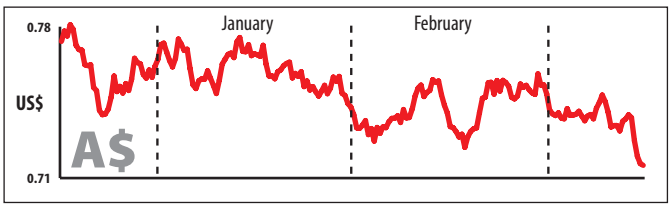
The EFT will act like a tracker fund for the underlying metal, and is seen as a way for investors to have exposure to silver without having to buy the actual metal. Silver has now risen by more than 40% since Barclays Global proposed the silver-backed EFT last November.

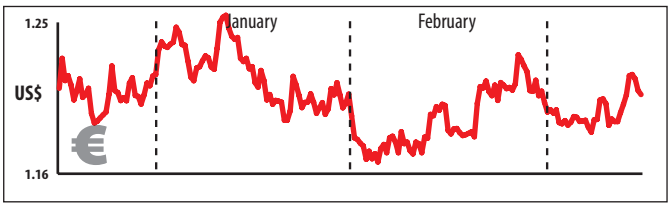
Meanwhile, money is rolling into the world's leading silver-producing country, Mexico. Silver has been mined in Mexico since colonial times, and production was some 90 Moz in 2005. Over half of this total is produced by Peñoles SA de CV, which is the world's leading producer and operator of the richest silver deposit (the Fresnillo mine in Zacatecas, which yielded 35 Moz last year).

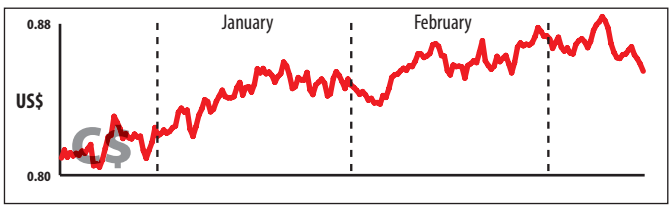
Mexico has several other silver producers, including Vancouver-based Endeavour Silver Corp, Pan American Silver Corp and Gammon Lake Resources Inc.

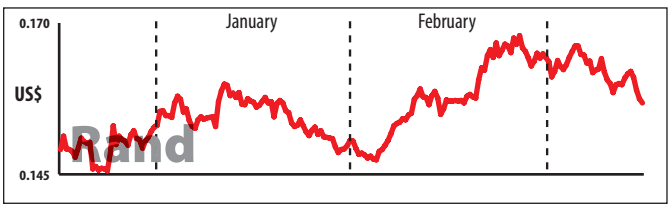
Mexico is diversifying into a host of other metals, and expects a record US$1 billion in mining investment this year.

However, despite all the good news, Mexico still faces a challenge in encouraging sufficient foreign investors. Fortunately, the government is aware of the need to sell the country abroad, and to market its royalty-free mining regime. Of course, the price of silver will help.



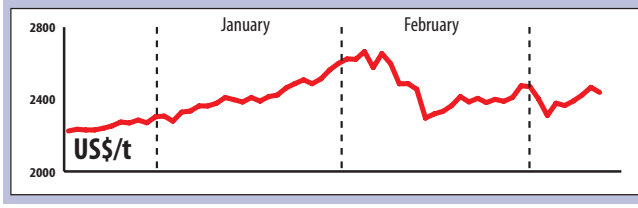






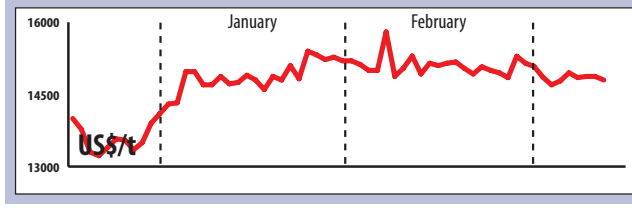
ALUMINIUM

The Indian Government has cut import duties on alumina, aluminium, copper and zinc from 10% to 7.5%, and those on ores and other concentrates from 5% to 2%. Meanwhile, Chinese alumina capacity is forecast to climb to 13 Mt/y by the end of this year, compared with only 10.5 Mt/y at the end of 2005. Aluminium Corp of China Ltd should account for two-thirds of this capacity.



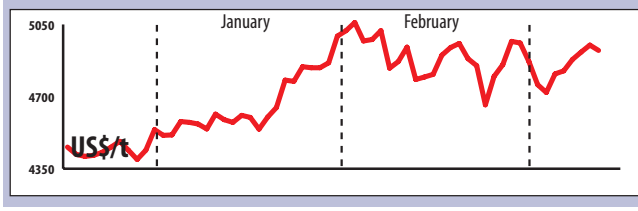
NICKEL

Metal prices have remained relatively stable during the past two months, just short of the US$15,000/t mark. Two projects in the news are Western Area NL's Flying Fox deposit in Western Australia, where a feasibility study was completed on the T5 orebody recently, and LionOre Mining International Ltd's decision to add a dense-media-separation plant at its Phoenix nickel mine in Botswana.



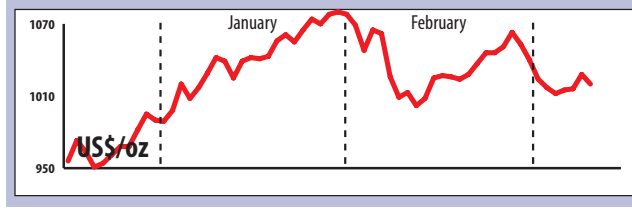
COPPER

China has raised its export tax on refined copper and copper alloys from 5% to 10%. The move is expected to reduce Chinese exports of copper from 2007. Copper prices weakened at the end of February following news that stocks on the London Metal Exchange had reached their highest level (109,400 t) but recovered in early March.



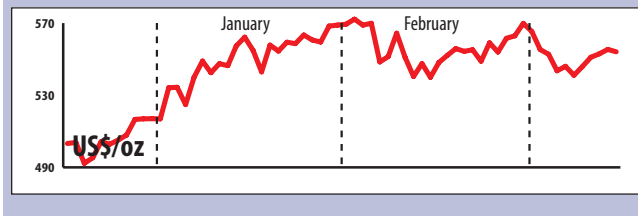
PLATINUM

Prices have see-sawed recently around US$1,050/oz. Two projects made the news in March: a new accord has been signed between Rusina Mining NL and the holder of the mineral production-sharing agreement for the Acoje nickel-platinum project in the Philippines, while a preliminary resource estimate has been compiled for Platinum Australia NL's Smokey Hills project in South Africa.



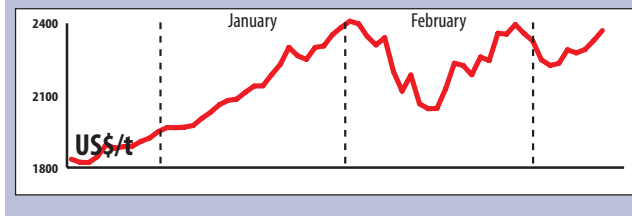
GOLD

Commodity funds have renewed their interest in bullion, encouraged by the relatively stable prices and the growing perception that, like platinum, the price risks are weighted to the upside. Meanwhile, the authorities have reported that Australian gold output rose slightly to 263 t in 2005, while South Africa's production fell by more than 13% to 296 t.



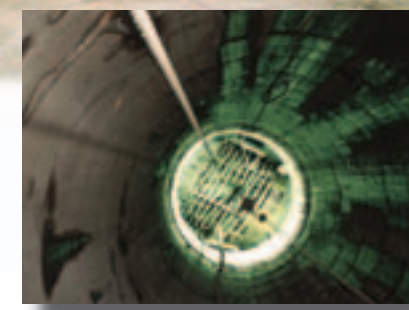
ZINC

As we go to press, three-months zinc has broken through the US$2,400/t barrier to reach a record high despite two production hikes. Korea Zinc Co plans to raise its refined zinc production by 5% to 430,000 t this year, and Chinese zinc smelter Huludao is to begin production from its lead-zinc facility in June, which will raise its zinc output by 40% to 390,000 t/y.



KOPEX – ZZM Group

New Quality for the World Market



A SIGNIFICANT new market player has joined the world's elite mining companies. The company has been created by Warsaw Stock Exchange-listed KOPEX SA (a general contractor of industrial projects, manufacturer of machinery and coal-mining equipment) and joint-stock company Zabrzańskie Mechanical Works SA (ZZM; Poland's leading manufacturer of mining long-wall equipment).

By purchasing 65.06% of KOPEX stock, ZZM has created the greatest Polish manufacturing and commercial mining group, and the third largest mining-equipment group in the world.

The group will focus on hard-coal mining, open-cast mining, metal ore mining and other mining sectors, as well as specialised mining services. The group will develop the best of both companies – the highest quality of produced and delivered goods and services, as well as carrying out of complex industrial projects in the international mining market.

The constituent companies include:
KOPEX – general contractor of investment projects
ZZM – manufacturer of mining shearer-loaders
Wamag – supplier of coal preparation equipment
Kopex-Famago – manufacturer of complete systems for open-cast mining
Przedsiębiorstwo Budowy Szybów – shaft construction services
Tagor – supplier of mining supports
Dozut-Komag – manufacturer of seals for power and control hydraulics and pneumatics
Bremasz – provides overhaul and repair services for mining supports.

This group is able to undertake every size and complexity of mining project, from design, through production and delivery of equipment and technological systems, to construction, development and modernisation of mines worldwide. Such ability is limited only to the best from the best.

The trump cards in this mining 'game' are machinery, equipment and mining technology. The group is in first place in this regard, with its technology 'ace' being Dozut-Komag's environment-friendly anticorrosion coating for the sliding surfaces of hydraulic equipment. This technical solution was awarded a medal in 2002 during the Brussels Fair, and followed many years of research by specialists from Zabrze.

The group will be active in many areas of the world - with Russia and India being particular targets. Europe will remain the group's most important market, followed by South America. Four mining contracts are being finished by KOPEX in Argentina, and co-operation with some other countries is planned, eg with Chilean partners in the modernising of non-ferrous ore mines.

The group is going to increase delivery of equipment for open-cast mining in Germany, Czech Republic, Slovakia, Turkey, as well as Serbia and Montenegro.

KOPEX and ZZM have both reported good export achievements in these countries.

In the opinion of market analysts, the Polish group is making significant contributions to the international mining sector by providing quality equipment and services, and giving new and interesting solutions to its commercial partners.

In the past few years, ZZM has invested nearly US$40 million in the development of modern technologies, while KOPEX represents an experienced, well-known contractor, which has valuable contacts in the international market.

Joint logistics, marketing and financial activities will bring an improvement in remuneration by increasing the power and potential of the group, which is already competitive with the best companies worldwide.

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Positive markets

Supply and demand for cadmium have come back into balance

PRIMARY cadmium metal output has continued to decline from the highs reached in 1997, with production originating predominantly from Asia (China, Japan and Korea) and the Americas (Canada and Mexico), with only small production from Europe and Australia. African cadmium production, which was always quite small, has now virtually disappeared.

Although primary cadmium supply has been decreasing (and is currently around 16,500 t/y), secondary cadmium supply has been increasing steadily, and an estimated 3,500 t/y is now produced from the recycling of spent NiCd batteries.

Cadmium and cadmium compounds are utilised in five major product areas, which include NiCd batteries, pigments, stabilisers, coatings, and minor uses such as specialised alloys and electronic compounds. Cadmium consumption has always been difficult to establish accurately but is believed to be some 20,500 t/y at the moment.

The consumption figures generally reported are those for conversion of cadmium metal into cadmium oxide or cadmium sulphide, the direct use of cadmium metal for electroplating and coatings, and usage for production of cadmium-containing alloys and specialised chemical salts. The problem is that cadmium oxide is often used as the starting material for other cadmium products, and that cadmium oxide is the primary material used in NiCd batteries. Thus, there is the danger that cadmium consumption figures may include double counting.

There is little doubt that the future of the NiCd battery market rests with its use in cordless power tools. The power-tool market has been growing at very rapid rates in recent years and, in spite of claims that NiMH batteries will replace NiCd batteries in power tools, the power manufacturers that have evaluated both chemistries indicate that NiMH systems lack the characteristics necessary for use in power tools.

Current cadmium prices are now above the all-time historical average price for cadmium of US$2.00/lb and are generally above the production or disposal costs of cadmium for most primary zinc producers. However, some large primary cadmium producers have permanently shut down capacity, and others may be fearful that the current higher prices for cadmium may only be short-lived.

> "There is little doubt that the future of the NiCd battery market rests with its use in cordless power tools"

Article based on an extensive contribution by Hugh Morrow of International Cadmium Association for Mining Annual Review

WITH KEN GOODING

Tough at the top

Clifford: "something different"

LEIGH Clifford, Rio Tinto's chief executive, is giving notice that at the end of next year he will be available to take on one of Australia's top jobs – just as long as it is not in the mining industry.

He grabbed the chance during an appearance on Australia's 'Nine Network Business Sunday' programme to remind the audience that he is rapidly approaching 60, the age when Rio's executive directors retire. He would, he said, be returning to Australia at the end of 2007 with his family, and would then do "something different".

There seems to be a shortage in Australia of executives of Mr Clifford's stature and experience. So we can assume that a number of big non-mining companies, with top management succession in mind, are now looking to see how they can fit him into their futures.

Mr Clifford's reminder of his impending retirement has also set people ruminating about who will become Rio's next CEO.

But first, let's look at Mr Clifford's little problem. Not so long ago Rio's policy was to have the CEO move up to the chairmanship, first in an executive role and then as a non-executive. This route is not open to Mr Clifford because of changes to the UK's corporate governance policies. These now insist that it is bad practice to have an executive director move into the chairman's office.

That's why Mr Clifford's predecessor, Sir Robert Wilson, quit the group after reaching 60 in 2003, and instead has been installed as chairman at the BG Group (formerly British Gas) and at the Economist publishing group.

Some observers suggest Rio is still reeling from the body blow of losing "the two Bobs" is quick succession. The other Bob, Bob Adams, director of planning and development, died suddenly early last year. Admirers suggest the two Bobs were primarily responsible for the strategy that, for ten years at the end of the 1990s, made Rio the world's most successful and respected mining group.

So, when he took over from Sir Robert, Mr Clifford had a lot to live up to, particularly as he was seen by some observers as an 'operations man' rather than someone who was interested in 'the big picture'.

The consensus is that up to now Mr Clifford has done a good job as CEO, helped by soaring commodity prices and the fact that Rio has never hedged. Although Rio's 2004 accounts showed Mr Clifford was paid US$3.09 million, including a US$1.29 million cash bonus, he has worked for Rio since 1970 and has not obviously had the chance to make mega-bucks like Brian Gilbertson, ex-BHP Billiton CEO, or Xstrata's Mick Davis, or some executives at junior exploration companies that have made major discoveries.

Mr Clifford has been a non-executive director of the UK-based Barclays banking group since 2004, but he would almost certainly appreciate another few years of heavily remunerated employment in his native Australia.

Mr Clifford was born in South Australia and gained his BSc in Mining Engineering and then a Masters in Engineering Science at Melbourne University. His first job with Rio was at Broken Hill in New South Wales. He had various operations and marketing roles in Rio's coal and metalliferous operations.

He first appeared in London as group mining director, before returning to Melbourne in 1996 as managing director of Rio Tinto Australia. He became CEO of Rio's global energy product group, based in London, in 1999. Before he took over from Sir Robert, Mr Clifford was credited with masterminding Rio's astute takeover of North Ltd, the Australian iron-ore group, in the face of a rival bid from Anglo American.

So who will take over when Mr Clifford leaves? At present the odds seem heavily in favour of Guy Elliott, Rio's 51-year-old finance director. He is British – with an MA from Oxford University and an MBA from INSEAD in France.

After joining Rio Tinto in London in 1980 he held a number of commercial and headquarters positions. These involved him in industrial minerals and in the marketing of energy products in Asia, Europe and the US. He was president of Rio Tinto Brasil from 1996-99, in charge of Rio Tinto's Brazilian investments in gold, nickel, iron ore and coal.

Immediately before becoming finance director, Mr Elliott was head of business evaluation, a position he held between 1993 and 1996, and again from 1999-2001. In this capacity he led the team responsible for the evaluation of all Rio's major capital expenditures, and the execution of business development transactions and mergers and acquisitions.

> "Almost every analyst agrees that it would be a great shock if Rio brought in an outsider as CEO"

Not everyone agrees Mr Elliott will be a shoo-in. One observer doubts Mr Elliot has the ruthless streak needed for the job.

He says: "He is a lovely bloke, just the kind of person you would want as a next-door neighbour. You can't say that about Leigh Clifford."

Besides Mr Elliott, another potential CEO candidate is Oscar Groeneveld, also a long-time Rio employee – 29 years – and well grounded in the group's culture. Some say he seems to have been on something of a fast track up through the ranks in recent years.

Mr Groeneveld has qualifications in engineering, science and management. He has had senior roles in Rio's coal, aluminium and technology operations, and was copper group CEO from 1999-2004, when he switched to become CEO of Rio's aluminium group.

Almost every analyst agrees that it would be a great shock if Rio brought in an outsider as CEO. But, whoever takes over will have the immense benefit of no longer having to live with the legacy left by Sir Robert. Whereas Mr Clifford was Sir Robert's appointee and was expected to follow the strategies Sir Robert laid down, the next CEO, if he wants to, can strike out in new directions.

Meanwhile, I leave you with a favourite memory of Mr Clifford. Just after he had been appointed to Rio's main board, he was at the group's annual meeting, one that was attended by some particularly rowdy environmental protesters. At one point a man at the front stood on his chair and started shouting at the top of his voice. He then made a dash for the stage on which the directors were arranged.

Not knowing what the protester had in mind, most of the directors cringed back, some disappearing behind their table. But not Mr Clifford, who is a very tall, very well-built man.

Instinctively, he was on his feet, chest thrust forward and a clenched fist drawn back ready to tackle the protester. Then Mr Clifford suddenly remembered where he was – at the annual meeting of one of the UK's major public companies – and, rather sheepishly I thought, dropped the fist to his side and settled back in his seat.

Which goes to show that the Australian group that eventually hires him, will not only be getting someone who is tough-minded. It will be getting someone who actually is tough through and through.

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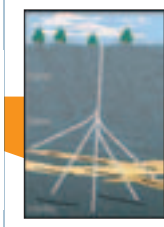

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Forthcoming...

- **Mine of the month - Boddington, Western Australia**: Newmont Mining and AngloGold Ashanti gave the go-ahead last month for a US$1.4 billion redevelopment of this gold mine (see p4). We look at the history of the operation, and recent developments.
- **Contractors v own staff**: An overview of the numerous issues facing mine managers when deciding how to resource on-site projects.
- **Generating electrical power**: With mines and projects often remote from established infrastructure, we examine the alternative power sources available.
- **New drilling technology**: Exploration activity is continuing apace around the world, and equipment manufacturers are developing new machines and technology to facilitate the search for metals and minerals.
- **Precious-metals processing**: We take a look at the latest developments in the processing of gold, silver and the platinum group metals.
- **Germany and central Europe**: A *Mining Magazine* round-up of the leading equipment manufacturers in this important region.

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