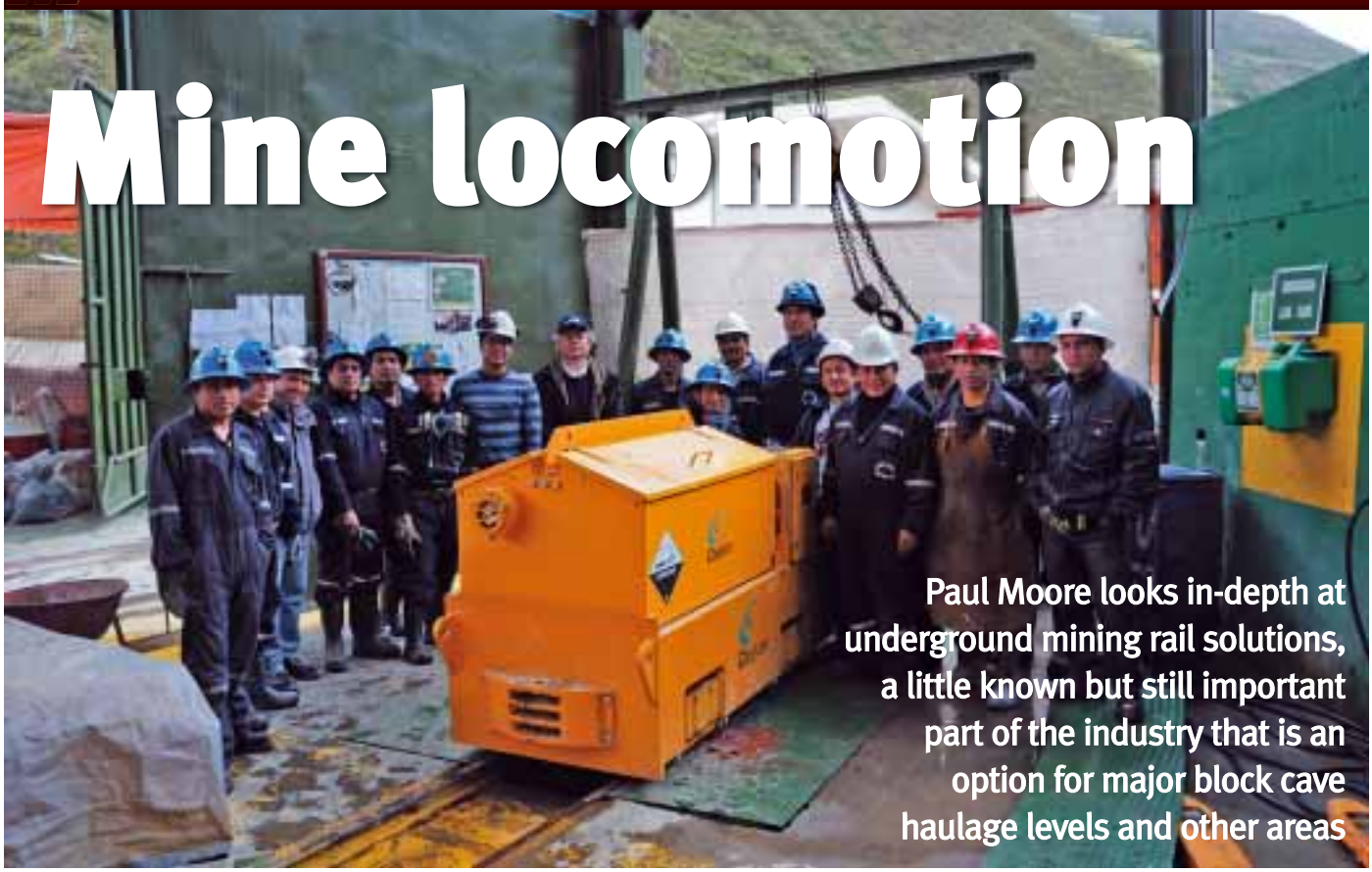
Mine locomotion



Paul Moore looks in-depth at underground mining rail solutions, a little known but still important part of the industry that is an option for major block cave haulage levels and other areas

Commissioning of one of three 3.5 t Clayton battery locomotives in January 2012 for Marsa gold mine in Peru. Although simple in design these modern locomotives with solid state electronic controllers replace 20 year old Clayton locos with dated mechanical controllers

In commodity terms, large tonnage hard rock mines (mainly copper, gold, nickel) and coal mines dominate the use of underground rail in mining; with South and Central America, Canada, China and South Africa probably the major regions applying rail solutions. As with other market niches, China has its own suppliers of mine locomotives and rolling stock, including groups like Xiangtan Electric Locomotive Factory, Baoji China Railway Construction Machinery and others, though to date their influence has yet to be felt to any extent outside the domestic Chinese market – that said, the Chinese market for mining locos and rail solutions is very large.

Elsewhere in the world there is an electic group of mining rail solution suppliers, from local groups focussing mainly on rebuilds and refurbishment of old locos and rolling stock; to those offering both this type of service as well as new equipment. While the number of companies involved is small, as it is such a niche area, the potential rewards are high when large mining rail contracts and tenders do come up. It is also the case that most of these companies offer solutions for both mining and tunnelling, and in recent years the tunnelling market has been larger and more profitable for them.

The refurbishment market is large – this is due to the robust build nature of mining locos, the high degree of customisation, and their often relative simplicity in design terms. There are also companies that specialise in rolling stock solutions and different ore car designs and unloading systems: these include Nordic Mine Technology in Canada, as well as Galison and Octa in South Africa. There are also a lot of famous mining locomotive brands which are no longer available as new machines but where there are a lot of examples in the field that could be rebuilt.

Market players include Brookville, Irwin Car (owner of Balco brand) and Mining Equipment Ltd (MEL) in North America; and Trident in South Africa, which acquired the global manufacturing and distribution rights for all new Goodman equipment in 2003 having already retained the African rights. Trident then developed entirely new locos in its own right – such as the Millennium and New Era models. In November 2010 Trident became part of the MOGS, a subsidiary of Royal Bafokeng Holdings. Most recently the company has been involved in a project to produce a fuel cell-based solution.

In the UK, Clayton Equipment is a well known global supplier, as are Schalke and Schoema in Germany; and GIA in Sweden, just acquired by Atlas Copco. As stated the hard rock sector, the market is divided into mining and tunnelling rail solutions, though with a number of large mines now looking at large access tunnels and the use of TBMs and other continuous mining methods in mine development, this market demarcation may become more blurred. Stillwater and OK Tedi are good examples.

In the coal market, there are also a number of groups offering monorail solutions, such as SMT Scharf, Becker Mining Systems, Pioma, Ferrit, GTA and others. These are solutions for personnel and transport of non-mined materials rather than for the haulage of waste or overburden itself, which in coal mining is almost exclusively carried out by conveyors, either alone or in conjunction with shuttle cars or battery haulers. However, some of these suppliers are also actively marketing their products for ore haulage.

Present and future

In terms of the present market structure and what the future holds for mining rail, Clayton Managing Director Steve Gretton comments: “Development of rail haulage systems is never static and as technology advances so too does the application of this technology within the industry; striving for increases in productivity, efficiency and safety. Currently motive power is delivered via either conventional diesel or electric power systems; diesel systems offering variants of either diesel hydrokinetic or diesel hydrostatic drives whilst the electric variants provide power via storage traction batteries or overhead catenary systems for non group 1 environments. Certainly for underground applications electric systems are preferred; given zero emissions leading to reduced ventilation requirements and functional simplicity hence lower maintenance activity provides the end user with reduced operational

Mining Equipment Ltd 25 t diesel locomotive pulling 15 m³ capacity roll-over muck cars through a dump at OK Tedi mine, Papua New Guinea

costs. The electric preference will further strengthen as mines go deeper in pursuit of high grade ore."

He adds: "Advancements in battery technologies, particularly the lithium ion battery, are making the electric option even more attractive; with faster charging rates and greater efficiencies improvements in the electric locomotives flexibility and range have been made. For the non-flameproof market making the unit an electric/electric hybrid, effectively a battery/trolley combination, also significantly improve the machines flexibility allowing onboard battery charging from the overhead catenary whilst on the main haulage loop, switching the locomotive to battery power once off the catenary and into the development headings. Fuel-cell and ultra-capacitor technology have made real advancements in recent years however given the current high cost of the fuel-cell technology it will be several more years before it finds its way into mainstream mining locomotive production." A new development in the fuel cell mining rail story is outlined later in this article.

In terms of mining applicability, Paul Moore spoke with Sandy Watson, Vice President - Mining, US & International, at Stantec, which has conducted a number of design and implementation studies for mining rail projects and so is well placed to comment on some of the broader reasons why rail is still competitive. He agrees that there is still very much a place for rail in the underground mining industry and it is always a consideration. He told ***IM***: "This is especially the case with larger tonnages, such as mines that are moving 30,000 t/d to 160,000 t/d of material. Haulage levels in block caves in particular are candidates for rail. This is partly because a lot of capital is committed up front and given the level of forward planning required, suppliers are often given life of mine contracts." In addition, specifically for where there is haulage to a primary underground crusher, loading conveyors with LHDs or underground trucks (via ore chutes) may not be an option due to the size of some of the rocks the conveyor would have to cope with, ie they should only be considered where the expected fragmentation will allow it. Generally, a conveyor needs to be three or even four times the width of the largest ore blocks. At the existing DOZ mine at PT Freeport Indonesia (PTFI), Caterpillar AD55 trucks deliver ore to two 54-74 primary gyratories; once the ore is crushed it is conveyed to the mill via a ramp. For the Deep Mill Level Zone (DMLZ), which will handle 80,000 t/d, the mine is looking at using trucks but as stated below, the Grasberg Block Cave itself will use rail haulage.

For smaller drill and blast operations moving only a few thousand tonnes per day and with shorter hauls, rail becomes less of an option, just because this level of infrastructure and capital spend is not required. These smaller mines tend to already have the facilities in place such as fuel bays and underground shops to service diesel rubber tyred vehicles so it makes sense for them to stick with that system without having to put it additional service capability for rail.

Sandy Watson at Stantec adds: "The obvious advantage with rail in large projects is the reduced operational cost compared to use of diesel underground trucks. Rail can have 10% of the operational cost of trucks in some situations. The savings are most marked where rail haulage can be used and in terms of the reduced manpower requirements. Many new projects, for example, involve automated haulage trains."

One of the largest planned rail projects in mining is at PT Freeport Indonesia (PTFI) at the Grasberg minerals district in West Papua. As part of the Grasberg Block Cave underground project, a rail system hauling up to 160,000 t/d is to be installed. This will consist of locos from Schalke and 30 t ore cars which PTFI are currently sourcing.

Schalke will supply 38 t locos for the haulage level with two locos per train. The Grasberg open pit is expected to complete mining by mid-2016 and the Grasberg Block Cave will ramp-up to full production of 160,000 t/d by 2022. Each train will consist of twenty 30 t cars for a total load of 600 t per trip. In a high tonnage mine such as this, which will arguably be one of the largest underground mines in the world, the benefits when making a comparison with having to use underground trucks are obvious in terms of reduced maintenance and manpower. This is particularly the case given the difficulty of sourcing skilled mechanical and electrical engineers as well as operators.

Large underground mines generally are looking at practical alternatives to having to use large fleets of mechanised underground trucks and LHDs and rail is one option. Rail is one option being considered at Resolution Copper, while in the Philippines, Atlas Consolidated Mining is looking at using rail in the restart of the Carmen Copper block caves.

Ventilation is another potential benefit of rail underground. When compared with diesel LHDs and trucks, emissions are far reduced therefore the necessary ventilation infrastructure is reduced. This could include less or smaller fans, smaller ventilation openings/shafts. In addition, rail can mean smaller heading cross sections can be used, meaning lower ground support costs.

Locomotive developments

In addition to the mentioned Grasberg Block Cave project that is in development, in July 2010, the worldwide leading copper producer Codelco (via Ferrostaal) placed an order with Schalke for the delivery of further locomotives for El Teniente. Before the end of 2009 Schalke had already sold 18 130 t locomotives to the operation but the 2010 order covered three diesel-electric service locomotives with a total locomotive mass of 90 t and a diesel motor performance of 1,350 kW. On the transport level of Teniente 8 the service locomotives will be used for supporting mineral transport as well as for maintenance and cleaning purposes and for towing other machines in case of failures and emergencies.

Also in 2010, LKAB placed an order with Schalke for the delivery of three 108 t trolley wire locomotives and further locomotives of this kind are to be ordered up until the year 2016. The new 108 t Schalke locomotives will haul a non-braked load of up to 1,600 t from the production area to the bunker system on the main haulage level KUJ 1365 at Kiruna. During this transport the locomotives are not only hauling along tunnel sections that are completely automated but are also covering the

GIA mining rail projects include Boliden in Sweden

whole loop starting from the loading area, leading to the discharge area and back again.

The company states that its experience with supplying the 130 t locomotives to El Teniente, which are also operating completely automated, served as a reference for the ambitious new transport concept at LKAB.

Mining Equipment Ltd (MEL) has been supplying the mining and tunnelling industries with quality rolling stock for more than 30 years. It supplies diesel and battery locomotives up to 35 t, including Plymouth, Schoema and Balco designs. A complete line of non-propelled rolling stock including muck cars, flat cars, personnel cars, segment car and concrete agitator cars is also offered. Recent orders include fifth wheel dump muck cars for Stillwater Mining in Montana, which are being used to haul muck out of a new TBM-mined tunnel. Another recent project for Mining Equipment was the New Irvington Tunnel in northern California. Explosion proof, 12 t diesel locomotives were supplied as well as a large spread of fifth wheel dump muck cars, flat cars and personnel cars. MEL is based in Durango, Colorado with a primary shop in Farmington, New Mexico. It also have a fabrication facility near Shanghai and an office in North Bay, Ontario. Paul Moore spoke with Matt Pope, Vice President about the market: "It is true that refurbished and rebuilt locos are very common in the market and we offer this service, however, more and more mines come to us with very customised needs that can only be offered with new equipment. Rebuilds can also be relatively expensive an in terms of operating cost, it can pay for the customer to get exactly what they want." He also reiterated the point about the bonus for rail in the increased level of tunnelling type work in mines – MEL supplied locos for the new TBM tunnels at OK Tedi as well as the mentioned work at Stillwater. Other orders have been supplied to the Superior copper mine in Arizona and the Elliot Lake uranium mine in Quebec.

Clayton Equipment has been established for over 80 years. Initially the company manufactured mainline locomotives until the early 1960s when it began to specialise in narrow gauge locomotives predominantly for mining applications. Business Development Manager Matthew Pearson told ***IM***: "The key to the success of the company in the 1970s to 1990s was the development and manufacture of rubber-tyred locomotives which ran on conventional rail track. A conventional steel tyred locomotive could not operate on gradients much beyond 1 in 15 with very limited loads, but the rubber tyred locomotives with far superior adhesion managed to negotiate gradients of 1 in 10 with large loads. This breakthrough enabled coal mines in particular to follow the coal seams and work with haulage routes on much steeper gradients. Today Clayton remains the only manufacturer of rubber tyred locomotives." In

A Clayton 30 t rubber tyred flameproof loco during tests in its UK factory

2009 Clayton produced the world's largest rubber tyred machines for a coal mining project. These high speed 30 t machines are capable of hauling large loads on very steep gradients. Clayton exports locos globally, from simple "low tech" locomotives to fully automated state of the art machines with PLC control and touch screen drivers interface. The majority of the locomotives produced are for the mining industry but a reasonable percentage of machines manufactured are destined for the tunnelling market. Clayton also caters for the industry's demand for used equipment through refurbishment and modernisation works to existing locomotives.

Schoema is a leading global manufacturer of tunnelling locomotives and other rail vehicles that also have mining applicability. The product range includes vehicles in a weight class up to 80 t and with an engine power up to 700 kW. This covers the full spectrum of diesel-powered tunnel locomotives, in the range of 5 to 60 t and with an engine power of up to 400 kW. Schoema locomotives are customised to meet any project requirements; when performing the technical design, extreme requirements are often considered such as narrow tunnel cross-sections; tight curve radii; high performance requirements; safety requirements; and extreme gradients. In addition to diesel-powered locomotives, it offers environmentally compatible battery-powered tunnel locomotives in the range of 5 to 15 t and track gauges from 600 to 900 mm. The electrical drive power varies from 30 to 70 kW. Schoema battery locomotives provide a convincing operating duration of at least 8 to 10 h without any need for battery replacement or recharging.

Clayton polymer tyred solution

The latest offering from Clayton provides the end user with a fully ATEX-certified 28 t work horse delivering a tractive effort in excess of 10,000 kg all with high efficiency, reliability and safety as standard. The zero emissions locomotive consists of a double bogie, three axles per bogie design, built to operate in gaseous mines (group 1 environments) on gradients of up to 10%. The locomotive is fitted with urethane tyred wheels with differential axles to enable it to negotiate horizontal curves as small as 8 m in radii. Clayton states: "Using a polymer tyre fully exploits the use of the machines tractive weight, significantly increasing the friction coefficient at the rail/wheel interface." Conventional steel tyred machines on average enjoy a friction coefficient of μ=0.18 within the mine environment; but the polymer equivalent generates an average friction coefficient of μ=0.45 under the same mine conditions. This 150% increase in grip at the rail likewise translates to a 150% increase in useable tractive effort derived from the machine weight. The result, say Clayton, is significantly more pulling power for the same weight of locomotive when compared against its steel wheeled counterpart giving greater scope and flexibility within the haulage environment.

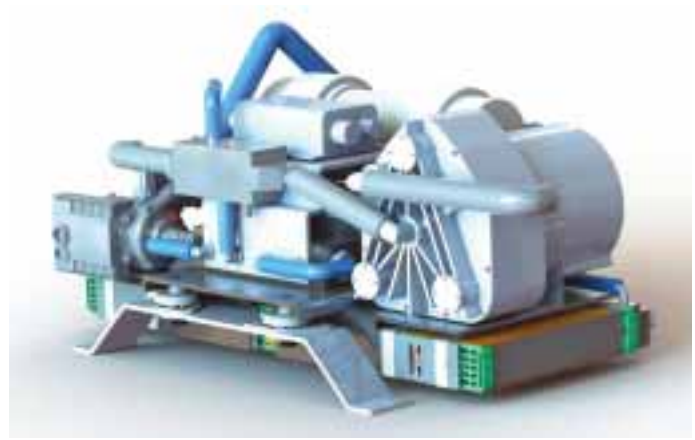
Likewise this additional grip improves the braking performance of the locomotive. The stopping distance being a function of the square of the velocity is non-linear, this non-linear function gives a varying percentage improvement in stopping distance dependant on vehicle speed; as an indication with the locomotive transporting a 24 t roof support down a 5% grade at 12 km/h, a 67% improvement in stopping distance is achieved over that of a steel wheeled equivalent machine. Utilising more of the available tractive weight through the use of polymer tyres also has positive implications on the rail infrastructure as the locomotive weight needs to be 2.5 times lighter than the steel tyred equivalent, given an identical haulage demand, resulting in reduced track maintenance and operating costs.

The machine is designed to offer fast face to face transfers halving the salvage time between face changes by efficiently transporting two roof supports per face to face journey. This is achieved through a unique multiple working configuration allowing a train consist of lead locomotive, trail locomotive and two chock transporters. Once the train has been mechanically coupled an intrinsically safe multi-pin connector electrically connects the two locomotives; the lead machine then has total control over the tailing locomotive thereby eliminating the need for an addition driver in the trailing machine. Quick release pneumatic connections are provided to automatically control rolling stock brake systems directly from the lead locomotive as a result of the locomotive brake demand requested from the driver.

The driver/maintainer interface is simple, with two onboard computers controlling machine functionality; one dedicated to traction drive circuits and one dedicated to machine operation and safety monitoring. For driver and maintainer alike all information is displayed on a Human Machine Interface (HMI) eliminating the need for traditional instrumentation.

The traction drive equipment utilises solid state microprocessor and power electronics based technology to control the locomotive traction motors. Control of the 112 kW install power is achieved by applying pulse width modulation techniques to power semiconductors (IGBTs) in conjunction with diodes to control the supply voltage applied to the series wound traction motors. The 200v DC power supply is delivered via two 150 kWh lead acid traction batteries giving a 300 kWh power base for the most arduous shift patterns.

The loco is also equipped with multiple safety features designed to protect personnel, the mine infrastructure and itself. This includes a deadman's device built into the traction power joystick which once released cuts power to the drive circuits and automatically applies the emergency brakes. During an emergency stop to ensure optimum braking performance, sand is also automatically deployed to condition the rail/wheel interface, maximising the friction coefficient and thus minimising the train stopping distance. Speed monitoring is crucial to the safe operation of the locomotive and train and the machine is equipped with a programmable automatic overspeed setting which if breeched would again cut drive and automatically apply the emergency brakes.



CAD models (not to same scale) of VP reversible metal-hydride storage system (left) and fuel cell powerplant (right)

Additional safety features include earth leakage detection, remote CCTV viewed on the HMI, long range LED lighting, battery switch-fuse isolators, midpoint isolators, and thermal protection monitoring in control system and traction motors. A high level of computing power allows for onboard brake testing and track condition monitoring; providing the end user with vital operational information to satisfy health and safety obligations together with critical infrastructure condition monitoring information for maintenance staff.

The loco is designed to operate within a temperature range of -20°C to +50°C with user adjustable control functions being average current limit in drive; current limit in braking; acceleration rates; creep speeds, programmable speed limits and overspeed limits. The control package provides several standard features including traction control, peak current limit, average current limit, IGBT saturation detection and thermal overload protection. Control parameters are adjusted using a hand held programming terminal, this device is also used as a fault diagnostic tool and displays the operator's inputs to the controller.

Enter the fuel cell

Vehicle Projects (VP) of Golden, Colorado and Anglo American Platinum (Amplats) in South Africa, have just announced that they are collaborating on a project to build five fuel cell mine locomotives to be demonstrated in mid-2012 at Amplats's Dishaba underground mine in Limpopo province. The purpose of the innovative vehicles is to mine platinum in a more economical, energy-secure, and environmentally-benign manner. The locomotives will not require any electricity from the grid to function, and will not emit any noxious gases.

VP, as prime contractor, is executing

Does any magazine in the mining world travel as far as International Mining? In the past two or three years, *IM* editors have travelled to, among other places:

Country	Operations reported on
AUSTRALIA	Pilbara iron ore
	Beta Hunt nickel
	Gwalia Deeps gold
	Northparkes copper and gold
	Ridgeway copper
	Kanowna Belle
BRAZIL	Cuiaba gold
CANADA	Williams gold
CHILE	El Teniente copper
	Minera Florida gold, silver zinc
CHINA	Tianjin (China Mining) and Beijing (ChinaCoal)
	Shendong coal
	Buertai coal
	Cuncaota coal
	Daliuta coal
DRC	Banro's gold projects
	Mukondo cobalt
	Luita copper/cobalt
FINLAND	Talvivaara nickel
	Fennoscandian Mining & Exploration
	Pyhasalmi copper and zinc
FRANCE	Narrow vein mining
GERMANY	Mibrag lignite
	Garzweiler lignite
GUYANE (FRENCH GUIANA)	
	Auplata and Goldplata gold
INDONESIA	Grasberg copper and gold
MEXICO	Fresnillo silver
	Penasquito gold
	Las Cuevas fluorite
MONGOLIA	Oyu Tolgoi copper and gold
RUSSIA	Moscow Metals and Minerals Summit
SLOVAKIA	VSK Mining's Gemerská Poloma talc
SOUTH AFRICA	Finsch diamond mine
	Burnstone gold
	Central Rand Gold
	South Deep gold
SWAZILAND	Water powered drill project
SWEDEN	Aitik copper (twice)
	Garpenberg polymetallic
	Kiruna iron ore
USA	Doe Run lead
	Henderson molybdenum
	Generating solar power from Arizona tailings

International Mining's website www.im-mining.com is a lively presentation of 'hot' news, with a primary focus on technology developments. Longer feature articles are also to be found there. We pride ourselves on bringing the news to readers immediately, unlike some other websites, one of which, in mid-November, was headlining: *Trapped Chilean Miners Face Long Wait for Rescue!* www.im-mining.com reported on the extraction of the miners on the day it happened, and has subsequently reported on a number of the technical innovations and services that played important roles in that miraculous rescue. Also John Chadwick was interviewed on the subject on BBC World TV.

CAD image showing how power plant will look in the Trident Era loco

engineering design, fabrication, and testing of the fuel cell power plant and reversible metal hydride storage system in its state-of-the-art facility in Golden. VP's hybrid fuel cell power plant employs Ballard proton-exchange membrane FCvelocity-9SSL V4 stacks and K2 Energy lithium-ion batteries. Continuous fuel cell net power is 17 kW, and together with the traction battery, maximum net power is 45 kW for approximately 10 min. The power plant will fit within a 0.1 m^3 box, and the volume of the powerplant plus battery is 0.5 m^3. Low-temperature waste heat from the power plant is the source of energy to store, release, and distribute hydrogen in the vehicle. The VP-designed reversible metal-hydride storage unit provides hydrogen-dense, energy efficient, ultra-safe storage of hydrogen for underground operations. It is designed to store 3.5 kg of hydrogen (50 kWh electrical output at the fuel cell) and be refueled underground from 20 bar hydrogen in 10-20 min. During refueling, either waste mine water or ambient mine air will cool the hydride bed. Operating hydrogen pressure is only 10 bar gauge. The storage unit will fit within a 0.3 m3 box.

The entire power-dense locomotive power module – fuel cells, batteries, hydride storage, cooling system, and power electronics – requires only 1 m3 of volume. Upon completion of testing of the power module (expected in March - April 2012), the unit will be shipped to VP's locomotive project partner Trident in Johannesburg, for integration into a Trident 10 t New Era locomotive. Integration, locomotive testing, and demonstration, initially at the Trident surface test track, will be assisted by VP's project partner Battery Electric in Johannesburg.

Amplats is funding the project and will serve as the end user of the developed fuel cell mine locomotives. Vehicle Projects develops turnkey prototype fuelcell vehicles that solve problems of environmental quality or energy security. It is best known for developing and demonstrating the world's largest hydrogen-fuel cell land vehicle, a 130 t locomotive.

Ore car solutions

Nordic Mine Technology, based in North Bay, introduced the first design of an in-line chute for the LKAB Kiruna mine in 1968/1969. The company continued to operate under the LKAB Canada name until 1987, when Eric Nylund took over the company and changed the name to Nordic Mine Technology. Between 1987 and 2006, Nordic went on to design, fabricate and install 18 rail haulage systems and over 250 chutes of various different sizes to mines in Canada, the USA, Peru, Mexico, Ghana, South Africa, Sweden, Australia and Indonesia. In 2006, Ronald Elliot of Minesteel Fabricators purchased Nordic, which continues to focus on latest technology underground loading, unloading and haulage solutions. Ore cars are custom designed and sized to suit every application. They feature impact and wear resistant material, large diameter wheels, TBU taper roller bearing assemblies, very low rolling resistance to the car (less than 0.2%), a high degree of reliability, low maintenance costs, and continuous loading without spillage along with continuous dumping.

The company also supplies dual action

A Nordic Mine Technology 5 m^3 end hinge mine ore car

chutes, which are pneumatically or hydraulically powered for in-line or side loading of mine cars or trucks, with variable throat opening and active lip for total-flow control of any muck handled. Train or truck cycle times are greatly improved and spillage can be virtually eliminated since the chute lip is lowered to the top of the vehicle when loading. The chute is supplied in sections for ease of installation and can be reused in new stope or ore pass locations. The solutions can include optional chute control, manual control from the chute platform, pendant remote control from a truck or train compartment or TV-remote control from a control room. Chute arrangements include in-line continuous loading of mine cars and in-line loading of trucks. Side loading of mine cars or trucks is also offered, which has very low maintenance requirements, ease of installation and a minimum of concrete work. The system is also easy to dismantle and re-use at new locations. Similarly, unloading stations use little concrete work with a very low maintenance requirement and allow continuous dumping and reversing of empty trains. Side thrust rollers and car, lower and upper, roller guides keepside hinged car from climbing on dump rollers. They are configurable for auto start and shutdown when an ore train approaches and exits the station.

Finally, Nordic has developed a hydraulic re-railing system that can be towed with the train or stored in a maintenance shop on a flat car. Using heavy duty cylinders the mine car or cars can be lifted and pulled back, even with the track, and gently lowered into place. To support

Aside from the developing Grasberg work, recent deliveries include LKAB Kiruna KUJ1365, for which 20 17 m³ mine cars were supplied, as well as an inline hydraulic loading chute and a full testing facility including running dynamics and loading unloading tests. At Coeur Alaska's Kensington mine, Nordic supplied two side loading chutes with hydraulic cylinders and controls, including truck mounted remote controls. The company has also worked on contracts with a number of other mines in recent years including Levack, Fresnillo, Stillwater and Hemlo.

GTA's floor rail haulage system with pinion, the RP 250

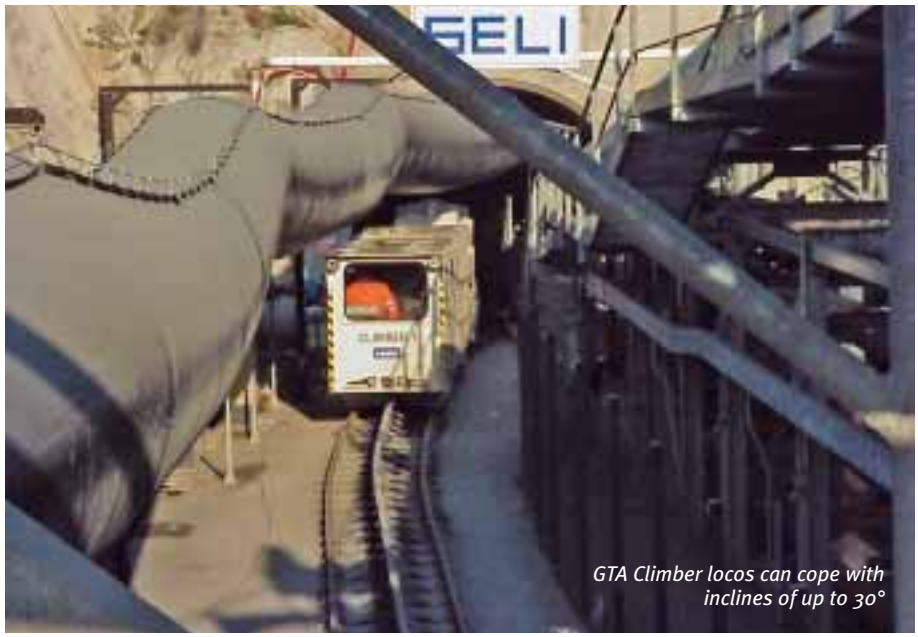
Monorails

The SMT Scharf Group develops, builds and maintains rail-bound railway systems for mining and tunnels. The trains are used all over the world, primarily in hard coal mines, but also in underground mining for platinum, gold, diamonds, copper and nickel. They are used to transport materials and personnel with working loads of up to 48 t. According to the company, rail-bound trains are the only means of transport that can be used underground on branching lines to cope with inclines of more than 13º.

SMT Scharf presented the development of a rack and pinion driven diesel-train to the specialist public for the first time in November 2007 and since that time has received all necessary licenses for use in underground mines in the most important underground coal mining regions. Installations have been made in Europe, China and Russia. The mines required systems which are especially designed for steep inclinations up to 30º and for high payloads up to 50 t. The train configuration, consisting of drive unit, brake car and transport trailers, can run safely and trap-guided along prefabricated and easy to install rail tracks.

The company told ***IM***: "The special design of the rolling stock and rail system makes this product safe of derailments. It can be used on a complete and independent rack-and-pinion rail network as well as for the transport of common mine rail cars with flanged wheels in steep inclinations. This floor-mounted transport system in 600 mm to 900 mm gauge can be easily converted into a diesel-powered monorail system. The diesel power unit can be suspended from a monorail installation and can be used to operate monorail drive units for the transport of personnel, material and equipment. An additional advantage thus is that the service and spare-part business can be optimised. There is a big intersection of parts for both monorail and duo-rail systems which is highly welcomed by our customers to enable them to realise lower service costs."

For wet and slippery rail environments, the rack and pinion drive solution by means of the interlock device ensures that the forces can be safely transferred into the rails. In addition this combined drive technology offers cost advantages as the rack and pinion rails only have to be installed in the wet areas of the inclination. In the straight areas the machine will run in normal friction-wheel mode. Besides



GTA Climber locos can cope with inclines of up to 30°

the self-propelled diesel locomotive SMT Scharf offers also rope-driven transport systems with 500 mm and 800 mm gauge.

The machines are designed for use in explosive atmospheres with a CH_4 content of up to 1.5%. SMT Scharf monorail locomotives are equipped with long-life and robust Liebherr motors with 80 kW and 130 kW rated capacities. This is the best basis for lowest service cost over the life-time of the machine.

For use in ore haulage, the company's EMTS (electric monorail transport system) system is stated as being the most optimal system. Electrical drives with high torque make it easy to meet transport challenges. The company comments: "Today's standard in many mines is to use rubber tyred vehicles for the transport of ore. However changing the view to use EMTS offers a significant benefit for the mine owner. Smaller cross sections of the galleries, faster access to the ore body by steeper inclinations, reduced cost due to lower air-conditioning for the electrical driven machines the ROI is fast and makes this technology interesting for future mine developments."

Also based in Germany, GTA is another major monorail solutions provider for mines. The company states: The efficiency of these heading and supporting devices very much depends on the reliability of the logistics infrastructure, ie the transport system of the mines. As the transport systems were far from being perfect, GTA started about ten years ago with its own activities in designing and manufacturing transport systems."

Its experience in the field of monorail systems came as a by-product of upper level machine operations, leading to the development of a GTA monorail loco with a number of improvements. Know-how in floor operated transport systems was gained with the acquisition of the company inTrak, successful specialists in design and operation of tunnelling transport systems, mainly floor operated. The combination of the different but similar technical solutions and the exchange of know how between the engineers, finally led to the present range of GTA Transport Systems. Today GTA and inTrak offer a range solutions for underground transportation tasks. All GTA / inTrak machines are available in both, flameproof and non-flameproof versions.

All GTA / inTrak machines are available in both, flameproof and non-flameproof version. The actual scope of machines includes on the upper level; the monorail system MR 08, with a diesel drive; monorail systems with electric drive; the hydraulic shunting trolley AKS H; pneumatic shunting trolley model AKS P and lifting beams. On the mine floor the RP Floor Rail Haulage system and climber locomotives are available which contain a variety of kinds of drive including diesel, electro-hydraulic and pneumatic. They are moved on different types of rails including standard floor rails, standard monorails, rack monorail, rack on floor or a special Climber rail; with traction transmitted by standard wheels, friction wheel systems and pinions & sprockets.

GTA's latest development is the floor rail haulage system with pinion, the RP 250. This innovative transport system is equipped with two high torque gear boxes with 2 x 125 kN push/pull force. The installed diesel engine power starts at 83 kW and reaches up to 300 kW. The system is designed for transport of heavy loads in inclined areas, where the abilities of monorails are not sufficient. Assembling and/or disassembling of the rail racks can be done fast and easily. The loads that can be transported with this system include personnel, roof support sections, heading machine elements, heavy elements of face conveyors, drum shearers and other mining equipment. The climbing ability is up to 30°. The Climber locomotive is designed for tunnelling applications but its power and climbing ability also make it an interesting product for mining. The climber loco rolls on standard rails, but is driven by diesel-hydraulic friction wheels on a special centre rail of the monorail kind. The friction drives can be installed on the loco and on different trolleys or cars. The Climber 200 with a 200 kW diesel engine is able to climb 20° with a load of 20 t.

The MR 08 monorail can be supplied with two different Diesel engine types: 83 kW or 135 kW. It is equipped with up to six hydraulic friction drives. The climbing ability is between 18 and 25° with a maximum speed of 2m/sec. The minimum width of the MR 08-4 is 750 mm, while that of the MR 08-6 is 900 mm. It can be used for all standard transport jobs of material and staff.

The GTA shunting trolley AKS- 9300 is equipped with two high torque hydraulic motors, developing a push / pull force of 20 kN. Two of these can be used as a duo trolley with single hydraulic control. Within the monorail structure of mines there are many different smaller transport tasks, which can be managed with this system. The company also offers the shunting trolley AKS-P 9500, which is equipped with two pneumatic motors. ***IM***

SMT Scharf rack-and-pinion Duorail system