Finding technology solutions to combat operator fatigue

Mining boom leads to increase in Greenfield Operations

Steady and straightforward approach drives Ravensworth to success

Component Rebuild Centers: The flexibility of a service shop with the process consistency of a manufacturer

Asphalt reclamation paves way for efficient underground haulage

Coal: Solution for an energy-dependent world
Welcome to Viewpoint, a magazine produced by Caterpillar to address the issues facing our mining customers today—and to share what we’ve learned from our industry partners around the world.

As always, our primary focus is on safety. In this issue we address operator fatigue—one of the most prevalent causes of accidents within the mining industry and the focus of a new study by Caterpillar. We share practical advice for operators and report on some promising new technologies that help mining companies manage this important safety issue.

This issue includes two articles focusing on one of Caterpillar’s most important markets: Coal. Our mine profile features Xstrata’s Ravensworth mine, located in the coal-rich Hunter Valley in New South Wales, Australia. And our energy story highlights coal’s critical role in meeting the growing global demand for power.

We head underground for a feature story on CVRD Inco’s Coleman McCreedy East mine in the Sudbury Basin of Ontario, which shares best practices for building and maintaining roads in these challenging conditions. Our story on a new Component Rebuild Center (CRC) operated by Cat® dealer Sotreq in Brazil shows how CRCs help mine sites achieve optimum component life and reliability. And finally, we learn about the obstacles and advantages to starting a greenfield operation, featuring the best practices exhibited by Newmont in its startup mines in Ghana.

Thank you for the positive response to Viewpoint. This magazine is for and about you—so please continue to share your feedback.

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Viewpoint is a publication of Cat Global Mining, producer of the mining industry’s broadest line of equipment and technology. Caterpillar serves the worldwide mining community through its vast dealer network and a single division called Caterpillar Global Mining, headquartered in Peoria, U.S.A., with additional offices worldwide.
Exploration programs in recent years have yielded rich discoveries of mineral deposits. With commodity prices strong and sustained, mining companies are opening greenfield operations in remote areas. The current boom has led to new operations in the gold mines of Mali, Tanzania, Commonwealth of Independent States (CIS) and Ghana; the copper belts of Africa and Mongolia; the coal fields of Mozambique and Botswana; and the diamond mines of Angola, Democratic Republic of Congo and CIS.

**The challenges**

“There are serious considerations that go into a company’s decision to mine in remote environments,” says Caterpillar’s Gregory Gardner, an account manager in the Global Mining division. “Sometimes it means developing infrastructure and support for equipment and staff in a part of the world that hasn’t been exposed to the financial, environmental and population impact of a high volume mining operation.”

Greenfield operations in remote areas face a host of challenges:

- **Transportation issues.** Remote locations often lack adequate infrastructure and are far from major cities—resulting in higher transportation costs.
- **Care for workers and their families.** In remote locations, mining companies may need to build schools, medical facilities, sanitation facilities, shopping areas, etc. In some cases towns must be relocated.
- **Lack of necessary skills.** Local work forces generally lack technical skills and education. Mining companies must provide training to develop equipment operators, technicians and plant workers and often provide basic education for local communities to develop the language skills necessary to understand operating and safety instructions.
- **Pilferage.** Fuels, minerals, tools and spare parts may not be secure on site. This creates major expenditures on local security and additional infrastructure costs.

Greenfield developments in remote locations are usually welcomed by the local community instead of being criticized for their effect on the environment,”

**Newmont is moving toward success in Ghana**

For companies that can overcome the drawbacks to development of a new site, there are significant advantages to mining in these remote environments. **“Greenfield developments in remote locations are being developed may experience very low or very high temperatures, high or very little rainfall, high altitudes, dust and wind.”**

**Harsh conditions.** The geographies where greenfield mines are being developed may experience very low or very high temperatures, high or very little rainfall, high altitudes, dust and wind.

**Unstable governments.** Corruption, inefficient bureaucratic administrations and civil unrest are key deterrents to investment and corporate compliance requirements.

**Assessments and permitting.** The development of new mines requires elaborate studies of the potential environmental and social impacts before a permit is issued, covering topics such as:

- Reclamation
- Air and water quality
- Noise and vibration
- Animal and plant life
- Cultural aspects
- Safety and health
- Compensation
- Relocation and resettlement

Mantrac Ghana Ltd. has been the Caterpillar equipment dealer in Ghana since 1937. The dealer also shares challenges when working with new mines in remote locations.

“Certain government sectors can hinder operations,” says Andy Sarson, managing director of Mantrac Ghana Ltd. “Our company, compared to U.S. or European Cat dealers, holds very high inventories due to delays in customs and excise procedures—making it very costly to operate because of high working capital requirements. Equipment will simply stand idle if we do not have stock.”

Skilled staff shortages also are a problem. “We have two major mining contracts in Ghana that employ over 250 staff members—of which 80 percent were newcomers to the business,” says Sarson. “We face major challenges in recruiting and training.”

**The benefits**

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**Hiring local workers is a priority for Newmont, which provides training to help workers perform their jobs in the mining operation as well as to develop marketable skills that can be transferred to other jobs when operations close.”**

The world’s voracious appetite for the products of mining is sending companies to the four corners of the Earth to develop new deposits. Developing new sites not only allows mining companies to expand their operations; it also creates opportunities to improve the quality of life in undeveloped communities.
Africa is rich in mineral resources, including gold, diamonds, platinum, copper, coal, bauxite, iron ore, zinc and manganese. In Ghana, the main resource is gold with small operations in the bauxite, manganese and diamond industries.

Newmont reports that exploration success at both of its Ghana projects has been exemplary. Reserves have grown from a combined 94,000 kilograms (3.3 million ounces) in 2002 to 575,000 kilograms (20.3 million ounces) at year-end 2006.

The Ahafo mine poured its first gold on July 18, 2006, and commenced commercial production in August 2006. Ahafo sold 5,700 kilograms (202,000 ounces) of gold in 2006 and is expected to produce between 11,700 kilograms (410,000 ounces) and 12,800 kilograms (450,000 ounces) in 2007 as the mine enters its first full year of production and optimization.

Newmont currently operates two open pits at Ahafo. The process plant consists of a conventional mill and carbon-in-leach circuit. Ahafo reserves as of Dec. 31, 2006, were 357,000 kilograms (12.6 million equity ounces).

Caterpillar dealers help mining companies with many considerations:
- The number and types of machines to achieve production targets.
- Order and delivery scheduling so machines are ready to work when needed.
- The range of support equipment needed.
- National, local and site regulations that drive modifications to the machine, including emissions, environmental, ergonomic, operator comfort and safety.
- How the terrain and climate will affect equipment.
- How Cat Financial and Cat World Trade can play a role in equipment and project financing.
- What facilities are necessary to support and service mining equipment.

With the dealer being responsible for the maintenance and repair of the mining equipment, that allows the customer to do what he does best—mine materials,” says Sarson.

Newmont raises native plants in preparation for land reclamation and reforestation.

• How to build and operate a safe site.

SUSTAINABLE DEVELOPMENT
While Newmont is pleased with achievements so far and confident in future success, leaders are most proud of the strong relationship the company has built with the local community.

“I want Newmont to be one of the first gold mines in history to have a successful partnership with the community,” says Chris Anderson, director, corporate and external affairs.

Newmont has partnered with a number of government and social organizations to improve the quality of life in Ghana today—and to prepare its citizens to maintain their improved community long after the mine has closed.

Collaborations and partnerships with community development experts continue to focus prominently in Newmont’s programs. These partnerships have led to programs that are transforming the lives of people within the mining communities by promoting agribusiness growth, improving quality of life through resettlement and relocation, and partnering in a community health and well-being initiative.

“I want us to be known as a good neighbor, a good corporate citizen in Ghana and as one of a new breed of mining companies,” says Gordon Nixon, managing director and vice president of African Operations for Newmont Ghana Gold Ltd.

“The involvement Newmont Ghana to the highest possible levels in all areas; safety, financial return, production, environmental stewardship and social responsibility,” Nixon continues. “Specifically, in the near future, our vision is to bring to fruition at least one other project as big as Ahafo and eventually produce two million ounces a year out of West Africa. We are developing a strong management team of Ghanaians to take us further into the future as Newmont Ghana in Africa.”

Newmont raises native plants in preparation for land reclamation and reforestation.
As economies boom and the quality of life improves in developing countries, the demand for energy grows at a staggering rate. At the same time, the world is searching for energy sources that are plentiful, secure and have minimal impact on the environment.

A variety of new energy and fuel sources are under development—and in some cases being put to use in limited applications at sites around the world. Researchers are having success converting natural gas and biomass to liquids. Photovoltaics (solar) and wind energy are becoming viable for selected markets. Nuclear energy may see a resurgence. And new oil supplies are being uncovered around the globe.

But to meet the energy needs of many areas of the world, one source continues to make compelling sense: Coal.

“Much of the world’s continued economic progress depends on maintaining coal as a secure, reliable and low-emissions source of energy,” says Chris Curtfman, president of Cat Global Mining. “Coal often gets a bad rap in debates about climate change, but we simply don’t have the option of turning away from such an abundant energy resource. Instead, we must continue to find ways to process and use coal cleanly and efficiently. It’s time to apply the same focus and intensity that we did for the ‘space race’ in the 1960s—speeding technology development and deployment to ensure coal’s future viability.”

**SOLUTION FOR AN ENERGY-DEPENDENT WORLD**

**A COMPELLING CHOICE TO HELP MEET THE GLOBAL ENERGY DEMAND**

**FACING FUTURE CHALLENGES**

Like other energy solutions, coal faces some major challenges, explains Darrin Johnston, a project team leader in the Advanced Power Systems group at Caterpillar Inc. He calls these three challenges potential game-changers:

- Increasing demand for energy and associated higher prices
- National energy security concerns
- Regulations to reduce emissions of greenhouse gases

“Coal directly addresses the first two of these energy challenges,” Johnston says. “And a number of new technologies will help coal meet the third.”

**Increasing demand for energy and associated higher prices**

Rapid economic growth has resulted in a rising demand for energy resources in countries like China and India, and projections are that the growth will continue as these countries’ economies expand. In its World Energy Outlook 2006, the International Energy Association (IEA) reports that global primary energy demand is projected to increase by just over half between today and 2030—an average annual rate of 1.6 percent—and to increase more than one quarter between now and 2015. More than 70 percent of the increase in demand will come from developing countries—with China alone accounting for 30 percent of that growth.

Fossil fuels will continue to dominate energy consumption and its growth—accounting for 85 percent of the increase in world primary energy demand over the next 10 years. Renewable energies are growing fast but from a small base—and by 2030 are expected to meet 14 percent of total energy demand, according to IEA, up from 1.1 percent in 2006.

As demand grows and countries become increasingly dependent on imports, they become vulnerable to disruptions in supply and resulting price shock. “A small group of countries with large oil reserves can increase market dominance and their ability to impose higher prices,” says IEA.

Johnston says coal can address both the demand and the rising prices. “There’s a lot of it—and it’s relatively inexpensive.”

“World reserves of coal are enormous,” says IEA. Coal makes up 60 percent of the world’s fossil fuel reserves and is much more widely and evenly dispersed than other fossil fuels. At current rates of consumption, there is enough coal in the world to last about 230 years.

Coal is mined in more than 50 countries and extensive reserves are present in many countries—particularly those that will see their own energy demands substantially increase. IEA reports proven reserves of coal worldwide are estimated to exceed 1 trillion metric tonnes (1.1 short tons). In comparison, current reserves of oil are projected to last about 40 years and natural gas reserves are projected to last about 65 years.

In addition to abundant supply, coal is one of the world’s least expensive energy sources. “It costs about a third of the cost of natural gas on a per-unit energy basis,” says Johnston. “Compared to petroleum, it’s about an eighth of the cost.”

Generating electricity from coal is also highly cost-competitive compared to other sources, reports the Centre for Energy and Economic Development (CEED), a U.S.-based organization that works with regional and state policymakers to fashion public policies that balance the need for a growing supply of affordable, reliable electricity with the responsibility to protect our environment.

**Energy security concerns**

As countries grow increasingly dependent on imported fuel, they become more vulnerable to disruptions in supply. Embargoes, permanent loss of fuel sources, soaring prices, and events and catastrophes that affect energy sources on a global basis can threaten the energy security of countries.
that lack indigenous energy supplies or have tenuous relationships with supply countries. Energy resources are essential to sustain the world population, improve the quality of life and help developing countries. “In today’s world, energy means life,” says Phil Hansen, a Caterpillar Inc. commercial mining manager. “If you take away energy, you’re not just making people uncomfortable; you are taking away a basic element of survival. We can’t sustain this population without efficient and effective energy.”

To achieve energy security, countries need a source of energy that is stable in price and reliable in supply. “Widespread, indigenous sources of coal provide energy security for many countries,” says Johnston. “And some of the largest energy users in the world—the United States, India and China—have the largest reserves.”

In addition, coal is a flexible energy source. “Today, it’s primarily used for electric power,” Johnston says. “But it can be converted for other uses. New technologies give coal the potential to reduce or replace oil imports. Coal can be converted to synthetic gasoline, diesel, hydrogen or other mobile fuels.” In South Africa, for example, years of oil embargoes forced the country to use the energy source it had—coal—to produce the fuels it needed. “We can’t sustain this population without efficient and effective energy.”

A variety of regulatory compliance policies already have been implemented or are being considered to control carbon emissions. For example, the Kyoto Protocol, ratified in 2005, now covers 164 countries globally (more than 60 percent) in reductions of carbon dioxide and other greenhouse gas emissions. The protocol requires companies to emit less carbon dioxide than their target or buy carbon permits to make up any shortfall. The goal is a 5 percent reduction in carbon emissions between 2012 and 2012 from their emissions base in 1990. Other countries have instituted or are considering similar policies or emissions regulations. “What we need to do is get businesses to develop their own solutions,” says Gerry Shahen, Caterpillar Group President. “We know climate change legislation is coming, which means we’re all going to have to operate in a carbon-constrained world.” Shahen said in a speech green to the National Mining Association (NMA). “And we believe we can help ensure that legislation is good for the environment and the economy.”

CATERPILLAR:
WORKING TO ENSURE VIABILITY OF COAL

In early 2007, Caterpillar Inc. joined some of the world’s largest corporations to form the U.S. Climate Action Partnership (USCAP)—an alliance of 35 major business and leading non-governmental organizations (NGOs) that have come together to call on the federal government to enact legislation requiring significant reductions of greenhouse gas emissions. Some of the 32 corporate members of USCAP include DuPont, BP America, General Electric, Duere, Company, General Motors and Rio Tinto.

Why would Caterpillar join an organization that wants to drastically reduce greenhouse gas emissions—much of which are the result of large stationary power plants that burn coal? “So we can be in the game while the rules are being decided,” says Gerry Shahen, Caterpillar Group President.

“By joining USCAP, we have put ourselves on the line to support the coal industry. If we don’t come together to support policies and technologies and funding for clean coal now, we won’t have this argument in 15 or 20 years. We won’t have a coal industry to argue about.”

In a coal-to-liquids plant and it was profitable today, it would still take years to recoup that investment,” he explains. “And if oil prices dropped, that plant could become unprofitable. If governments decide that coal-to-liquids plants are an integral part of their energy security strategies, they may need to enact policies to protect investors from this possibility.”

Regulations to reduce emissions of greenhouse gases Environmental impacts associated with energy consumption must be addressed as society demands cleaner energy and less pollution. “This is a new political reality,” says Johnston. “It appears highly likely that greenhouse gas legislation will be increasingly adopted in developed nations, and legislation could occur in developing nations as well.” He estimates developed nations will aim to reduce total greenhouse gas emissions 20 percent by 2020 and between 50 to 80 percent by 2050.

CEED says it is imperative that mining and power generation companies move forward on researching and deploying technologies that control emissions to protect the viability of coal. “New investments in research, development, demonstration and deployment will make coal use possible in a carbon-constrained environment,” says CEED. “A global focus on this issue is essential.”

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“Although CO2 emissions from coal-fired power plants are currently higher than other power sources on a per-unit-of-electricity basis,” says Johnston, “there are a number of solutions that will enable dramatic reductions, enabling coal to meet emerging regulations. We believe these developments will ensure the environmental and economic sustainability of coal as an energy source.”

CLEANER COAL

New technologies address these emerging environmental challenges—such as particular greenhouse gas emissions—as well as improve the performance of coal as an energy source.

“Cleaner coal can be competitive if oil prices stay above US$40 to US$50 a barrel.” If someone made the investment then distributes the rights to allowed emissions. Importantly, from Caterpillar’s perspective, a federal approach is preferable to a patchwork of separate state climate regulations—something that already is occurring around the country.

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Johnston points out two key ways to reduce carbon emissions: Increasing the efficiency of coal-fired power plants, and developing and implementing CO2 sequestration technologies.

Improving power plant efficiencies Retrofitting and building new facilities in line with state-of-the-art technologies that increase efficiency will make a measurable difference in carbon emissions, Johnston says. For example, supercritical and ultra-supercritical pulverized coal plants operate at temperatures and pressures above the critical point—resulting in significantly higher efficiencies and lower emissions.

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“Coal can be the big winner in meeting the growing energy needs for the future,” he says. “We understand the emissions challenges of current coal technology but applaud intensified industry efforts to design and implement cleaner technology. This is essential to the future viability of coal.”

Richards is a proponent of expansion of the use of fuels based on the supply of coal for gasification or liquefaction. “These technologies have very high potential,” says Richards. “And in addition to power generation, these fuels can be made available for various types of mobile and stationary applications.”

Transformation of coal can produce hydrogen, methane and synfuels—designer fuels that can be customized based on the product and application needs of the future. “Even with improved power plant efficiencies, we still must manage CO2,” Richards says. “And sequestration is an increasingly viable option. Sequestration means the storage of CO2 to prevent its escape into the atmosphere.”

A study by the Massachusetts Institute of Technology (MIT) identifies Carbon Capture and Sequestration (CCS) as the critical enabling technology that would reduce emissions significantly while also allowing coal to meet the world’s pressing energy needs.

CO2 capture can be done pre-combustion at gasification/liquefaction plants, or post-combustion at conventional power plants. Gasification and liquefaction are generally considered the most promising technologies because they reduce emissions before coal is used for energy—transforming coal to gas, in particular hydrogen, and using this as the primary fuel source in power stations instead of burning coal directly.

Investigations are under way for various storage solutions. Underground storage options include injecting the carbon underground to enhance the recovery of coalbed methane, into depleted oil fields to generate additional oil production, or into deep saline aquifers. These methods show promise, but significant development is needed to overcome issues that could slow their adoption. One key issue may be the regulatory structure. To date there is no definitive study on the long-term stability and viability of these various sequestration sites. Additionally, long-term site monitoring, compliance, and liability/ownership responsibilities are yet to be determined.

Richards says the ideal sequestration solution will offer high CO2 storage capacity without the threat of leakage and will render the stored CO2 permanently benign.

“Rock weathering sequestration is a fascinating emerging concept targeted to meet these expectations,” says Richards. “It is based on mineral carbonation through a process called Accelerated Rock Weathering (ARW).”

The key to ARW is magnesium silicate. This mineral, commonly used for construction fill and road gravel, naturally reacts with CO2 in the atmosphere. As it absorbs the CO2, the mineral is converted from a pebble form into powder.

“The earth has an abundance of this mineral,” says Richards. “In fact, there’s nearly 60 times more of it than there is coal in the world. Using it at a 1:1 ratio to absorb CO2 from coal, there’s enough of it to be feasible for all future use of coal.”

“The downside with ARW is that these carbon capture and sequestration processes have not yet been perfected and made financially viable,” he says. “Some technologies need to be developed—and talented people around the world are working on them.”

To be successful, we must integrate broader systems-thinking that involves the transformation of coal into useful energy supplies and resolves the corresponding CO2 capture and sequestration,” Richards says. “An integrated system can be the solution for the growing world hunger for energy.”
Combine a good coal deposit, the right approach to mining it, and a skilled and stable workforce—and you get a long-lived successful coal mining operation. Xstrata Coal’s Ravensworth Mine in the upper Hunter Valley of New South Wales, Australia, makes the most of its resource by employing the low-cost productivity of draglines aided by a more flexible truck and shovel team and completed by a highly mobile large wheel loader to load out coal.

“Ravensworth first started mining coal in 1972,” says Terry Flynn, mine manager. “There is a very good resource here, and it is a tribute to the people who have worked here over the years that it remains a strong and vibrant supplier of coal to the local power stations. Many of the current employees have worked here for more than 20 years. Four individuals have more than 30 years’ service.”
1/ Draglines remove 80 percent of the overburden at Ravensworth.
2/ This dragline bucket will soon be filled with overburden from one of Ravensworth’s two pits.
3/ An electric shovel pre-strips overburden to set the stage for dragline operations. The shovel works with the same trucks that haul coal.
4/ Sitting on the spoil side of the pit, the dragline operator commands a 55-cubic-meter (72-cubic-yard) bucket.

The relatively small work force of 121 racks up high productivity marks and impressive safety performance. The miners produced 4.3 million metric tonnes (4.7 million short tons) of coal last year as they mined seams ranging from 0.3 to 5.5 meters (1 to 18 feet) in thickness with a stripping ratio that averaged 6.1. Including office staff and maintenance technicians, the average amount of material moved per employee in 2006 was about 213,000 bank cubic meters (280,000 bank cubic yards). Equally impressive, the work force has experienced no lost time injuries since May 2006.

“We strive to make safety an integral way of how we do our work. It is not an add-on or a stand-alone issue,” Flynn explains. “Risk management principles are a consideration at all steps of our process including planning, completing and reviewing tasks.”

A team approach and a strong sense of responsibility held by each miner and staff member also contribute to good production and safety. Tony Galvin, operations manager, points out, “It’s a close-knit team. Maintenance and production teams work together, and the WesTrac (Caterpillar dealer) team works closely with us. We work toward the same goals.”

“There is a strong sense of ownership of performance in all aspects of the operation,” Flynn says.

MOVING ROCK AND COAL

Ravensworth operates two pits, each featuring a large dragline for the majority of overburden removal. A P&H 2300 electric shovel with a 20.6-cubic-meter (27-cubic-yard) bucket teams with Caterpillar® 790C trucks to pre-strip overburden before the draglines take over. In the process, the truck-shovel team moves about 17 percent of the 24 million cubic meters (11 million cubic yards) of overburden moved annually by the entire fleet of machines.
The versatility of the truck-shovel operation levels areas for optimum dragline productivity. But the geology is predictable with the main types of rock being sandstone, soapstone and carbonaceous mudstone. “We have minor faulting and some dikes, but nothing that has a big impact on mining,” says Mark Williams, mining engineering and projects superintendent.

The 2-kilometer-long (6,500-foot-long) Narama pit hosts a Bucyrus 1570 dragline equipped with a 55-cubic-meter (72-cubic-yard) bucket. The single dragline handles half of the total overburden moved annually mine-wide. Some material is cast during blasting, but that material is included in the dragline production figures. The dragline makes three passes from the spoil side and one pass from the highwall side to dig the full 42-meter (138-foot) depth and 55-meter (180-foot) width of the pit.

A Bucyrus 1370 dragline equipped with a 50-cubic-meter (65-cubic-yard) bucket is king of the West pit and annually moves about 30 percent of all overburden. The 1.4-kilometer-long (4,600-foot-long) pit is about 30 meters (100 feet) deep. Currently the dragline is doing spoil side stripping. The West pit has a public road near one end; as a result, dust control and blasting schedules get special attention. To avoid any potential hazards that might be created by dust emanating from blasting, the road is closed temporarily when blasting in the West pit.

The Bucyrus 1370 dragline is key to Ravensworth’s mined land rehabilitation as it produces long term and productive landscapes compatible with the surrounding countryside and flora and fauna. In practice, Ravensworth beneficially uses mined material to the original contour, and revegetation for a mix of pasture and forest. Caterpillar grading is the primary land use.

Ravensworth emphasizes mine haulage road construction and vigilant road maintenance.

The mobility of the wheel loader enables it to handle all coal loading tasks. Both pits are served by a single haulage ramp, which simplifies truck assignment and scheduling. Last year Ravensworth purchased the loader and a fleet of five Cat 789C trucks with target payload of 177 metric tonnes (195 short tons) to do both overburden and coal hauling. A single truck from the previous fleet remains to comprise a total of six.

A Caterpillar 994F wheel loader, working with Cat® 789C trucks, primarily loads out coal. But the loader-truck team sometimes assists in stripping overburden and removes interburden that averages 1.0 meters (3.3 feet) thick. The loader accounts for 3 percent of all overburden moved.
To keep truck productivity high, Ravensworth managers pay particular attention to the long-life haulage roads. Coal hauls average 4.9 kilometers (3.0 miles) one way and pre-stripe hauls are about 1.8 kilometers (1.1 miles) one way. Williams explains, “Main coal haulage road segments that are relatively permanent are built from mine spoil with effective embankments for drainage, and they are sheeted with imported crushed gravel. This ensures that coal haulage can be done in all weather conditions.”

Cat 16H and 16G motor graders maintain the roads. Each shift normally operates a water cart and a grader for routine road maintenance. Generally only one loading unit is operating each shift, so major road repairs are scheduled for when the road is not in use.

The trucks carry coal to a crusher that reduces coal size to less than 50 millimeters (2 inches). The crushed coal feeds into a 5,000-metric-tonne (5,510-short-ton) bin, which feeds an overland conveyor operated by Macquarie Generation. The conveyor takes the coal to two nearby power stations—Liddell and Bayswater. The two plants total 4,400 megawatts of generating capacity and are the sole customers for Ravensworth coal.

**Keeping Machines Working**

The Ravensworth maintenance team of 28 people focuses on the draglines, shovel and older mobile equipment and coal handling facilities while the on-site WesTrac team of seven maintains the new Cat equipment—the five 789C trucks, 994F loader and 16H motor grader—under a maintenance and repair contract (MARC).

“The MARC keeps our work force to a minimum in these times of high demand for mechanics,” says Galvin. “The MARC also allows us to more accurately predict costs.” Galvin also is quick to point out that the WesTrac project manager, Dave Bull, is on site and attends the daily planning meeting at the mine. The WesTrac maintenance functions are carried out as part of the entire Ravensworth team.

“The Ravensworth work force, management and WesTrac have good working relationships.” Bull says. “We are proud of the contribution that the Caterpillar fleet and the MARC have had on helping the mine meet its KPIs (key performance indicators). The 789C fleet has met and exceeded the productivity requirements and has averaged more than 95 percent contract availability during the past 14 months.”

All of the maintenance crews work out of a large 10-bay shop featuring four bays set up for efficient preventive maintenance work. A fully equipped tire maintenance center and a fueling station are located adjacent to one end of the shop. A field crew handles refueling and in-field lubrication of some machines, such as the pair of diesel-powered blasthole drills, using two fully equipped field service trucks.

Maintenance staff members aim to identify problems before they cause failures. “We make use of all available technology,” Galvin says. All machines are monitored with fluids analysis—the MARC machines using Caterpillar SOS. The maintenance technicians frequently use non-destructive testing techniques, such as radiography and vibration analysis, especially when assessing the condition of dragline structures and components. And the maintenance department has run noise testing on most machines for both operator exposure and spectator exposure.

The maintenance and operations departments coordinate their efforts to maximize tire life. Weekly tire pressure checks, occasional tire temperature checks, a monthly report on haulage road conditions, and an investigation of any tire events are all components of the program. The attention to tires is paying off with truck tire life of about 7,000 hours.

Despite apparent success, the maintenance department is restructuring to better define responsibilities and improve planning. The culture of continuous improvement lives at Ravensworth. Google that approach with a good resource of low-sulfur coal plus steady, low-cost production, and you see continued success for Ravensworth.
Caterpillar machines are designed so that components can be rebuilt several times over the life of the machine—allowing customers to benefit from maximum performance and reliability throughout the life of their equipment.

Component Rebuild Centers (CRCs) help Caterpillar customers achieve optimum component life and reliability through world-class rebuild practices. Equipped to rebuild and test all major components of the largest equipment Caterpillar produces today, CRCs meet the same safety, quality and contamination standards as a Caterpillar factory. “Customers have options when it comes to repairing and rebuilding components,” says Patrick Mohrman, a Caterpillar product support manager. “But there isn’t another repair option that can provide what a CRC does. It’s 100 percent Caterpillar.”

Dealers and Caterpillar work together at all stages—sizing the facility, determining the right equipment, providing all the necessary specifications and tooling, and training the technicians who work there. “Dealers build CRCs to provide their customers with the least cost to rebuild, a quick turnaround, better quality through standardization, improved contamination control and the latest updates for Cat equipment,” says Mohrman. “And we believe CRCs do all these things.”

USING QUALITY TOOLS
Certified Component Rebuild Centers are large investments for Cat dealers. In addition to the large square footage required for a facility, a CRC also contains a number of high-tech tools necessary to assess the condition and rebuild all major equipment components. CRCs are equipped for general machining as well as outfitted with specific tools to rebuild and test engines (including blocks, cranks, heads and cylinder packs), powertrains, torque converters, transmissions, differentials, wheel stations and more.

FOLLOWING QUALITY PROCESSES
Each rebuild follows a Cat-approved process—beginning with a thorough cleaning of every component and ending with rigorous testing to ensure quality.

“Everything gets looked at,” says Caterpillar product support manager Mike Staley. “For example, engines are completely stripped to the bare block and checked down to the bolts. Then they’re re-assembled with whatever parts make the most sense. They may be new, they may be parts rebuilt from the same machine, or they may be exchange parts from another rebuild. You use all these components to do it in the fastest and most economical way.”

Dealer CRCs are continually audited for cleanliness and must meet stringent standards set by Caterpillar. Many CRCs meet Caterpillar’s Five Star Contamination Control standards. Paying attention to contamination control enhances productivity, increases component longevity and results in decreased downtime.

DEVELOPING EXPERT TECHNICIANS
“CRC technicians are trained by Caterpillar experts to rebuild Caterpillar components—and only Caterpillar components,” says Mohrman. “And they’re trained for their area of expertise. Whether it’s a fuel system or a transmission, they become experts in the rebuilding of that specific component. They do it day in and day out.”

ADDING VALUE IN BRAZIL
With customers in nearly every state in Brazil, Cat dealer Sotreq knows the value of providing major component rebuilds that offer quality repair, fast turnaround and maximum value. That’s why, in 2000, Sotreq decided to invest in a 3,200-square-meter (34,000-square-foot) Component Rebuild Center designed to restore engine and drive-train components to factory standards. An 820-square-meter (8,800-square-foot) addition is in progress. Sotreq’s newest CRC is centrally located in Contagem, the third-largest city in the Brazilian state of Minas Gerais. Rebuild activities at this facility complement those of two smaller Sotreq CRCs, one in Belem, Para, and the other in Sumare, Sao Paulo.

“We know that having access to our CRCs helps our clients to reduce downtime,” says Sinval Colares Nassau, manager of the Sotreq CRC. “We value our strong business partnerships with all our clients and we work with all of them to satisfy their expectations in terms of quality, reliability and availability.”

“Our objective is to fully serve customer machine, service and maintenance needs, so that customers can concentrate on core business needs.”

MANAGING COMPONENT LIFE
Planned component rebuild intervals can be based on a number of factors, including past experience, condition monitoring, fuel consumption, oil analysis or even arbitrary target hours. Mine site conditions can change over time and impact component life. Deeper pits, longer hauls, overloading, etc., can have a negative impact on component life. Positive changes can come from continuous improvement initiatives like contamination control, fluid cleanliness, application and payload management, and better maintenance and monitoring.
Meeting the Need

Sotreq built its newest CRC to meet the needs of a booming mining industry as well as to meet customer demand for improved contamination control practices. “Our decision to build this newest CRC was motivated by the increasing number of mining machines and volume of powertrain components in our territories,” says Sinval Colares. “We needed the additional capacity to better organize our work flow—and offer our customers the full advantages of contamination control and rebuild certifications.”

Ten of Sotreq’s major mining customers and more than 1,000 traditional dealer customers have taken advantage of the new facility.

Component rebuilds completed so far for mining machines have included 777, 785, 789 and 793 mining trucks; 990, 992 and 994 wheel loaders; D9, D10 and D11 track-type tractors; and 16H and 24H motor graders. Smaller machine components—from 950 wheel loaders, 320 hydraulic excavators, 416 backhoe loaders and D6 track-type tractors—are also repaired at the CRC. Warranty repairs and partial rebuilds take place there, too.

Sotreq’s largest CRC is designed to move material systematically from receiving to initial, external cleaning. Following that are disassembly, component cleaning, inspection, component reconditioning, re-assembly, testing, painting and shipping.

“We have 20 work areas just to assemble powertrain components,” says Sinval Colares. “We also have six areas for disassembly and two for testing. We have two dynamometers, one that we use to test 3400 and smaller engines and another larger one to test 3500 engines. We also have two hydraulic/transmission tests that we use to evaluate hydraulic pumps, hydraulic motors, transmissions and torque converters.”

“Currently, we’re operating in two shifts, but because of volume increases, we’re planning to add a third,” he says. “With this new shift, we will be able to increase our annual production around 20 percent the first year and 30 percent the second year. We also plan to improve our hydraulic test and relocate the hydraulic area so that we can increase our capacity from 1,400 to 2,000 large components. All these improvements will allow us to offer customers even faster turnaround on rebuilds and repairs.”

More than 120 technicians are responsible for quality rebuilds within the CRC. Sotreq operates its own mechanical training school and offers on-the-job training by experienced technicians who mentor less-experienced employees.

Sotreq insists on high standards for contamination control as well and has received Five Star Contamination Control certification from Caterpillar. “We are pleased to have earned this highest certification rating from Caterpillar,” says Sinval Colares. “We set high standards to maximize our competitive advantage in the service capability area. In addition, we know that reducing contamination has clear benefits for our customers, including longer component life, lower owning and operating costs, reduced service rework and lower warranty costs.”

“All this contributes to increased profitability for our customers.”
Using cold mix asphalt paving technology more commonly used in highway construction, one of CVRD Inco’s Canadian underground mines quickly created a smooth and durable roadway for its truck fleet. The innovative approach to building underground roads minimized production interruptions, solved potholing problems and created a smoother surface for enhanced truck productivity.

The truck haul ramp at the Coleman McCreedy East mine, on the northwest rim of the Sudbury basin in Ontario, is a critical link in moving nickel ore out of the mine. The truck haulage system is effectively an extension of the hoisting shaft as the ramp extends a distance of about 6 kilometers (3.7 miles) from the 1,000-meter to the 1,700-meter level. All production below the 1,000-meter (3,370-foot) level is hauled by truck. At the 1,000-meter (3,370-foot) level, ore is delivered by conveyor to the shaft and then skipped to the surface.

Since 1997 mining crews have stabilized the surface of the ramp with asphalt emulsion in efforts to provide a smooth, hard and dust-free surface. The construction method created a quality roadway, but the smoothness and durability did not live up to expectations. As a result, the engineering staff conducted a thorough review of the existing ramp design and construction methods. Ultimately, the staff determined that full depth reclamation (FDR) with asphalt emulsion was the way to meet the demands placed on the underground highway.

ROADWAY CONSTRUCTION EVOLVES

The design of the mine necessitates truck haulage. Truck travel distances from the two ore bodies to the hoisting shaft now range from about 2.5 kilometers (1.5 miles) to nearly 6 kilometers (3.7 miles) on ramps with a nominal grade of 14 percent. Production averages 3,200 to 3,600 metric tonnes (3,500 to 4,000 short tons) per day.

The initial road design used crushed waste rock placed in a subbase and base layer. The layers were 25 centimeters (10 inches) and 20 centimeters (8 inches) thick and used minus 7.5-centimeter (minus 3-inch) and minus 3.2-centimeter (minus 1.25-inch) material, respectively. The 46-centimeter (18-inch) thick roadbed could be graded as required to provide a smooth riding surface.

Dust rising from the roadbed quickly became a serious problem. Road maintenance crews experimented with a variety of dust suppression products including calcium and magnesium chlorides and lignin. All of the products provided some level of success in controlling dust, but they tended to become slippery and created safety concerns.

In 1996 the mine investigated asphalt as a means to handle the dust problem. Asphalt is a semifluid at ambient temperature and does not readily mix with aggregate in this state; however, it can be liquefied easily by heating, by adding a petroleum solvent, or by emulsifying it in water. Hot mix asphalt was not logistically viable in the underground environment, and, similarly, the underground environment precludes the use of petroleum solvents in large quantities.

Liquefying the asphalt by creating an asphalt emulsion was the choice for underground roadway paving. This process involves milling asphalt into microscopic particles, 1 to 10 microns in size, and dispersing them in water. A small amount of chemical emulsifier is also added to keep the asphalt droplets in stable suspension. The resulting asphalt emulsion contains approximately 60 to 65 percent asphalt and 35 to 40 percent water. The asphalt particles stay suspended in the continuous water phase until the emulsion is mixed with the aggregate on the roadway surface. After mixing, the water and asphalt separate. The asphalt bonds the aggregate particles together and the water is brought to the surface by the use of compaction equipment. Once the water completely evaporates, the system is said to have cured. The result is a stabilized hard surface that does not generate dust.

The initial methods used to apply asphalt emulsion to the truck ramp achieved penetration and mixing of the asphalt with the base aggregate to a depth of about 38 millimeters (1.5 inches). But the thin asphalt layer was susceptible to potholes created when the trucks ran over spilled rock and ore and pushed it through the surface layer. The puncture holes were then prone to raveling into larger holes. In addition to the pothole problem, the ramp was not as smooth as needed. The construction process required nearly perfect grading of the base, which was very difficult to achieve.

ROADBED DESIGN

“The mine managers recognized that a smooth road was necessary to help the mine reach production targets,” says Andy Charsley, leader of the project team. “So we reviewed different roadbed designs, including developing methods for constructing new sections of ramp as well as methods for improving the existing ramp.”

Any proposed recommendations would be constrained by available capital, and the method selected must cause only minimal interruptions to production haulage.

A detailed investigation of roadway layer design and surface alternatives revealed opportunities to reduce aggregate base thickness and to make changes in material sizes.

“The review team concluded that the asphalt-stabilized layer could be improved,” says Charsley, “by using the most up-to-date road construction techniques and asphalt pavement design methodology for both existing pavement and new construction.”

The initial design of the roadbed called for 46 centimeters (18 inches) of crushed material in layers typical of designs for surface roads built on soft subgrade. But in the case of underground hard rock mines, the subgrade is bedrock, which does not deflect significantly under load. As a result, the purpose of using aggregate as a base in the mine is for grading a smooth road and, if needed, for handling drainage. At a minimum, the layer must be thick enough to fill in the undulations in the blasted rock surface and to form the thickness of the pavement when mixed with asphalt emulsion.

Undulations in the rock are about 15 centimeters (6 inches) above and below the desired grade. The proposed pavement thickness is 10 centimeters (4 inches). For practical purposes the design team chose a granular layer thickness of 30 centimeters (12 inches) — a 33 percent reduction in base thickness compared to the previous design.
We agreed that a single, homogenous layer of aggregate would perform well,” says Charsley. “Eliminating the two-layer system offers a further reduction in placement time, because finish grading is required only once.”

The design team also determined that aggregates sizes should fit a tight size range so that the material would offer good compaction characteristics and would be highly stable when mixed with asphalt emulsion. The gradation selected was granular A, an Ontario provincial standard for roadways.

The base material was to be crushed from mine waste rock on the surface at the mine. The waste rock makes an ideal roadway aggregate because it is very hard and abraded resistant. In addition, the rock is 100 percent fractured and is angular, which adds to the high stability of the final product. Stability is defined as resistance to lateral deformation due to imposed loads.

The design team also considered the layout of the ramp. Despite many curves, the roadway did not have supereleverved curves, which are important because they reduce lateral tire forces, reduce truck frame stress and reduce the amount of spillage. At a truck speed of 16 kph (10 mph) and a minimum curve radius of slightly more than 30 meters (100 feet), 7 percent banking would result in zero net lateral force on the tires. The design team compromised and called for supereleverved curves with a minimum radius of 30 meters on a 4 percent lateral slope.

ASPHALT STABILIZATION AND RECYCLING

The use of asphalt emulsion at the mine had evolved into a spraying and raking process. The hydraulically driven rake mixed asphalt and aggregate and provided about 38 millimeters (1.5 inches) of asphalt stabilization and Recycling

The process involves pulverizing the full depth of the existing pavement and a portion of the underlying material. That material is blended and mixed with a stabilizing additive to provide a uniform material. When the technique is used with new granular material, the process is known as base stabilization. The only difference is the amount of asphalt emulsion added to the mix. For recycling, 1 to 4 percent asphalt emulsion by weight is typically required, and 6 percent by weight is required for new construction.

Construction

In situ asphalt recycling has grown in popularity as the availability of cold planing equipment has grown. Replaceable tungsten carbide milling tools make the machines even more productive. A Caterpillar RM-250C reclaimer was used for this project.

The reclaimer pulverizes and mixes in a single pass to a depth of 100 millimeters (4 inches). Asphalt emulsion is mixed in at the same time to provide a homogeneous mixture of asphalt and aggregate. The asphalt emulsion was added at a rate of 9 liters per square meter (2 gallons per 1.2 square yards), which correlates to 3.8 percent addition by weight.

To assess road surface smoothness, the design team conducted a full survey of the roadway to collect data for calculating the International Roughness Index (IRI). “We found that even though the ramp was very good by underground mine standards, the ride was poor compared to acceptable surface roughness standards,” says Charsley. “The ramp had an IRI average of 8 with a range of 4 to 14.”

To meet the goal of creating a 100-millimeter thick (4-inch-dyck) durable pavement that was very smooth, the design team was charged with finding a method or methods to rehabilitate the existing roadway and to construct new roadway.

We identified full depth reclamation as such a construction method,” says Charsley. “Asphalt recycling and reclaiming reuses the existing asphalt and granular material, significantly reducing costs compared to other road improvement alternatives. In situ reconstruction also minimizes haulage interruptions.”

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In the case of new construction, the process is the same, but the asphalt emulsion addition rate is 14 to 15 liters per square meter (3.7 to 4 gallons per 1.2 square yards), correlating to an addition rate of 6 percent by weight.

Once mixing is complete, a single drum vibratory roller does initial compaction. The roller used had an operating weight of 6,550 kg (14,440 lbs). Following initial compaction, a modified underground Caterpillar 120G motor grader blades the material to provide the specified profile. Recognizing that the life expectancy of pavement surface is 15 to 20 years, smooth grading of the recycled surface is essential.

Following grading, final compaction is completed on the recycled layer. A Caterpillar CB-335D combination steel drum and pneumatic tire roller provided a smooth finished surface and compacted the top layer of pavement. The roller has an operating weight of 6,320 kg (7,980 lbs).

Finally, the recycled layer was swept and sealed to prevent raveling. A spray application of CSS-1H asphalt emulsion was applied at a rate of 0.45 to 0.70 liters per square meter (1 to 1.5 pints per 1.2 square yards) and diluted with water at 1.5. The sweeping and fog sealing were done from one to three days following the recycling operation.

The construction crews typically completed 200 to 305 meters (650 to 1000 feet) of ramp rehabilitation daily in the 6-meter (20-feet) wide drift. The crew completed a maximum of 535 meters (1,750 feet) in one 10-hour day.

Good Results

“Asphalt recycling provides an economical solution by reusing all the existing roadbed aggregate and asphalt,” says Charsley. “The total depth of roadbed was reduced by a third for an additional cost reduction. Another benefit is that in situ construction keeps interruptions to traffic flow to a minimum since the stabilized material can be driven on immediately following grading.”

Superelveled corners, improvements in asphalt smoothness, and greater roadway durability also add to the sustainability of the project. An emulsion rate of 0.5 percent provides a minimal asphalt content of 3.5 percent.

A similar mix design was prepared for areas of new construction. An emulsion rate of 0.5 percent provides a minimal asphalt content of 3.5 percent.

Compliance with the engineered mix design is critical to the durability of the recycled layers. The main areas of quality control to monitor are percentage of asphalt addition, homogeneity of mixing, depth of stabilization and compaction.

Now the McCreedy East Mine has a haulage ramp capable of meeting future production targets while achieving maximum truck utilization and availability,” says Charsley.

The authors included in this article are Andrew D. Charsley, M.A.Sc., P.Eng., Garson Mine, CVRD Inco Limited, Copper Cliff, Ontario; John J. Emery, Ph.D., P.Eng., President, John Emery Geotechnical Engineering Limited, Toronto; and Gerry J. Prevost, Operations Foreman, Ontario Operations, CVRD Inco Limited.

ASPHALT MIX DESIGN

Once the design team identified asphalt recycling as the best alternative for doing the job, an engineered asphalt mix design was required. An asphalt design laboratory used samples taken from the ramp and mixed portions at material with five varying amounts of asphalt emulsion to determine the optimal mix.

- Emulsion added was CSS-1H in increments of 0.5 percent from 2.0 to 4.5 percent by weight. All five mixtures exhibited high stability.
- The final recommendation was to use CSS-1H at 3.0 percent addition.
- The identifier denotes cationic stone mastic asphalt. The cationic charge on the asphalt creates an attractive force to the aggregate, which has a natural anionic charge.
- The resulting stabilized layer will have residual asphalt content of 3.5 to 4.0 percent.

- A similar mix design was prepared for areas of new construction. An emulsion rate of 0.5 percent provides a minimal asphalt content of 3.5 percent.

The ramp reclaeration uses a rotary mill equipped with concave-backed blades to grind up existing asphalt and aggregates and to re-use it with asphalt emulsion.

The ramp reclaeration uses a rotary mill equipped with concave-backed blades to grind up existing asphalt and aggregates and to re-use it with asphalt emulsion.
Around-the-clock operations are commonplace in the mining industry. The search is on to help those who experience the fatigue that goes along with shift-work. Operator fatigue is proven to be one of the most prevalent causes of accidents within the mining industry. In the surface mining industry alone, some 60 to 65 percent of truck haulage accidents are directly related to operator fatigue.

Mining companies have long been aware of the dangers of fatigue and have tried to manage the situation through policies and procedures, and through various education, training, scheduling, diet and motivational efforts.

“There are two techniques all help deal with the root causes of fatigue,” says David Edwards, P.E., an ergonomics research engineer who studied operator fatigue in Caterpillar Inc.’s Technology and Solutions Division before joining the new Caterpillar Safety Services Division.

“At the end of the day, there are still people falling asleep,” says Edwards. “That’s why everyone in the industry is desperate for a new solution—a technology solution—to help better manage fatigue.”

THE COST OF FATIGUE

Sleep deprivation, fatigue and drowsiness decrease awareness, diminish attention spans, and increase reaction time—all significant factors that contribute to accidents. The UK reports over £52 billion in fatigue-related accident costs. Australia’s Transport Safety Bureau reports that 30 percent of all fatal crashes are linked to fatigue. Commercial on-highway truck collisions due to fatigue are estimated to account for 1,200 deaths and 76,000 injuries a year in the United States, at an estimated cost of US$12.4 billion to the commercial trucking industry. Fatigued drivers often are not aware of their condition, frequently driving for up to 30 seconds with their eyes totally closed—a situation known as micro-sleeps. Studies show that driving drowsy is equivalent to being under the influence of alcohol or drugs and that drowsiness impairs the ability to make decisions. Signs of fatigue include:

- Sleepiness/difficulty keeping eyes open
- Excessive yawning
- Blurred vision/loss of focus
- Irritability
- Becoming quiet and more withdrawn
- Inability to concentrate
- Inability to remember activities of the last five minutes
- Lacking motivation to do the task well

Studies in the mining industry indicate that fatigue affects even those with the best training and years of experience. Human error due to fatigue is not fundamentally a behavioral problem—it’s primarily a problem of human physiology.

MANAGING THE SITUATION

Ergonomic improvements in the operator environment have helped lessen fatigue. Education, training and biocompatible scheduling have also proven to be important tools.

“Miners can learn the importance of a good diet—what foods to eat to keep them alert and help them maintain energy levels,” says Bill Strous, senior vice president of Circadian Technologies, Inc., a leading international research and consulting firm that assists shift-working companies. “Workers also can learn the right behaviors at work and at home that help minimize drowsiness.”

A lot of sites have started educating the families of employees about how to best support their family members for shift-work. More and more companies are also converting to user-friendly work schedules to alleviate as much of the physical stress of shift-work as possible. Strous says.

In conjunction with Circadian Technologies Inc., Caterpillar will introduce a CD/DVD designed to educate supervisors, operators and their families on things they can do to lessen fatigue. “Caterpillar used its resources to create an educational tool that we can share with every mine site,” says Edwards.

While an educational video will be helpful, Caterpillar customers have made it clear that they’re looking for additional solutions—innovations that take advantage of technology to detect the onset of fatigue and interface with the operator and dispatcher to elicit a response.

“There has been a major effort to develop technologies to monitor fatigue, but they have been primarily for automotive use—particularly with on-highway trucks,” says Edwards. “There isn’t one technology that has come to the forefront for use in the mining industry.”

Caterpillar and mining companies have tried to leverage existing automotive technologies to adapt them for mining, but have met with little success. “We started thinking we would have more success if we can get to the source and get them interested in mining,” Edwards says. “Then we could develop a technology that is focused on mining from the beginning.”

Caterpillar is providing funds and access to mining equipment that allows research and development groups to work on a fatigue management solution for the industry.

“We want these researchers to see the differences between on-highway trucks and large mining trucks and their environments,” Edwards says.

“We need to increase awareness in the scientific community that there is a need for them to provide solutions to help miners and mining companies mitigate the effects of fatigue.”

ADVANCE EXISTING TECHNOLOGIES

Caterpillar recently partnered with customer BHP Billiton to study existing technologies and promote the advancement of the most promising solutions. Results of that study will be published and shared with the world to advance the cause, says Edwards.
“Along with Circadian Technologies, we evaluated all known technologies that are commercially available or will be emerging in the next three years,” Edwards says.

The goal of the study was to:
- Identify the most promising technologies
- Develop an objective assessment tool
- Score each technology
- Examine the feasibility of incorporating the best technologies into mining applications

“We came up with a list of 35 technologies in all industries, and shortened that list to the 21 we felt were the most viable,” Edwards says. “We then tested the leading technologies through driving simulation studies and field trials.”

Two main types of technology exist: “fitness for duty” tests that check operator fatigue levels prior to their shifts, and systems that measure operator and machine behavior during operations. These technologies measure:
- Machine behavior
- Lane deviation
- Steering wheel movement
- Pedal usage
- Machine movement
- Operator physiological conditions
- Eye behavior (blink and pupil response properties)
- Heart rate
- EEG
- Operator behavior
- Head nodding
- Mental and physical reaction times

Fitness-for-duty tests have been in use for some time to check operators for drug and alcohol usage. New technologies are being employed to test for fatigue, including:
- Pupilometry—measures eye reflexes, pupil constriction and the speed of eye movement
- Pedal usage
- Lane deviation

Degradation of reaction times can indicate impairment.

Psychomotor Vigilance Tests—evaluate reaction times and hand/eye coordination. Using a computer mouse, trackball or joystick, operators must follow a target and maintain their position.

“These units are not cost prohibitive,” says Edwards. “They range from US$5,000 to US$10,000 per unit and they are rock solid for drugs and alcohol. We’re still evaluating how well they work for fatigue, or more precisely, impaired alertness.”

Systems that monitor operator activity in the cab as well as vehicle activity also show promise. These systems monitor the operators around the clock, sometimes sending information to dispatchers as well as accumulating long-term data about the behavior of an operator or his or her machine.

On-board technologies include:
- In-dash cameras or eyeglasses with sensors that monitor eye movement and blink speeds—both indicators of fatigue.
- In-dash systems can have difficulty with vibration or motion in the cab, making the glasses a more viable option, Edwards says. The eyeglass system, called Optalert™ and made by Sleep Diagnostics Pty Ltd., costs about US$19,500 per truck. The price includes three pairs of glasses and system hardware.
- Monitors that measure steering wheel and machine movement. When operators are awake and alert, they maintain consistent position within their lane. When they get drowsy, movements are more erratic and machines sway and weave. The leading system of this type is ASTiD made by Pernix Ltd. and costs less than US$50,000 per truck. Unlike the eyeglasses, this system is passive to the operators.
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MANAGING INFORMATION
One of the technology systems investigated helps mine sites manage the information gained through monitoring—a feature Edwards can see as the future of fatigue management technologies. Data goes to a dispatcher, who has a log of the operator’s habits and can suggest a break or recommend the operator end his shift.

Edwards says it’s important to make someone other than the operator aware of any fatigue issues. “An operator who is fatigued is the worst judge of how tired he really is,” he says. “That’s like asking a drunk person if they believe they are too intoxicated to drive.”

Studies suggest that users strongly prefer systems that require as little personal monitoring and contact with the technology as possible. The preference is for systems that monitor vehicles instead of people.

“There are a lot of confidentiality issues, in particular with the operator measurements.”

MANAGE YOUR ENVIRONMENT
- Make the environment as dark as possible or wear eye shades because even low levels of light can keep people awake or disrupt sleep.
- Use a fan, air filter or other white noise machine to block outside noises or wear earplugs.
- Keep the environment at a cool temperature and well ventilated.

MANAGE YOUR DIET
- Be aware that while alcohol may cause drowsiness, it can make sleep less restful and restorative.
- Avoid heavy caffeine use, which can cause less or poor quality sleep.
- Consult a doctor before using sleeping pills; they are not a long-term solution.
- Try warm milk, decaffeinated herbal teas or herbs like valerian and kava to induce sleep.

MANAGE YOUR HOME LIFE
- Identify and resolve family and social problems when they arise.
- Talk with your family regularly to discuss problems, resolve issues and plan ahead.
- Keep a calendar and plan ahead as much as possible.
- Map out “recovery days” to allow you to catch up on sleep and get back into a regular daytime lifestyle.

MANAGE YOUR WORKPLACE
- When eating late at night, avoid fatty and fried foods, pastries and dairy products to alleviate gastrointestinal problems.
- Eat small meals through the night shift, including pasta, bread, fruits, vegetables and low-fat dips and spreads.

How to get better sleep

- Eat lean protein and complex carbohydrates for your main meals to increase energy levels.
- Elevate your heart rate for 20 to 30 minutes several times a week.

MANAGE STRESS
- Try to identify and eliminate the causes of stress.
- Learn to control what you can and stop worrying about things that are beyond your control.
- Exercise.
- Take time for yourself.
- Spend time with family and friends.
- Slow down and eliminate extra activities if you can.
- Avoid excessive amounts of toxins and stimulants.

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- Map out “recovery days” to allow you to catch up on sleep and get back into a regular daytime lifestyle.

How to get better sleep

- Eat lean protein and complex carbohydrates for your main meals to increase energy levels.
- Elevate your heart rate for 20 to 30 minutes several times a week.

MANAGE STRESS
- Try to identify and eliminate the causes of stress.
- Learn to control what you can and stop worrying about things that are beyond your control.
- Exercise.
- Take time for yourself.
- Spend time with family and friends.
- Slow down and eliminate extra activities if you can.
- Avoid excessive amounts of toxins and stimulants.

MANAGE YOUR HOME LIFE
- Identify and resolve family and social problems when they arise.
- Talk with your family regularly to discuss problems, resolve issues and plan ahead.
- Keep a calendar and plan ahead as much as possible.
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**Recommendations**

“Good technologies exist and we think they are viable,” says Edwards. “The question is, ‘How do you create a technology that deals with the world, and works for all?’ The answer is, ‘You can’t.’ We know we must have multiple solutions because all current technologies exhibit shortcomings when the application range is too broad. In other words, they don’t work everyone in every situation.”

“The most important aspect of a successful fatigue management program is taking responsibility. We must ensure that people recognize and take responsibility for their own fitness for work,” says Michael Farmer, global practice leader for fatigue management at BHP Billiton. “Frontline supervisors must understand and manage their workgroups, and companies must develop a culture that encourages workers to report and take action on drowsiness and fatigue risks.”

“Edwards says he is proud of Caterpillar’s focus on this important topic. “We’re working to meet the mining industry’s needs, the customer’s needs and to energize the research community to care,” he says. “We’ll share this with the world and hopefully all companies can benefit. And we can make the world a safer place to live and work.”

**Powertrain Simulators Put New Mining Trucks to the Test**

Caterpillar recently put its next generation of large mining trucks to the test with rigorous powertrain simulator testing. Engineers at the Caterpillar Technology and Solutions Division have designed and constructed three full-scale powertrain simulators—two for mechanical drive and one for AC electric drive—to help integrate and validate the Cat® engine and the drive train components. Caterpillar relies on full-scale simulation to optimize component interaction for performance and durability.

**CAT LOGISTICS OPENS CENTER IN MOSCOW**

Caterpillar Logistics Services Inc. will open its first parts distribution center in China as part of a long-term strategic plan to support manufacturing growth in China and at its operations around the world, executives with Caterpillar recently celebrated the grand opening of new manufacturing operations in Wuxi, China. Located in Jiangsu province in East China, the Wuxi campus includes nearly 19 hectares (47 acres) and will be home to Caterpillar (China) Machinery Components Co. Ltd. (CCMC), a wholly owned Caterpillar company. CCMC will manufacture a range of components to be used primarily in Caterpillar machines and to be sold to select original equipment manufacturers (OEMs). CCMC is part of Caterpillar’s Motion & Power Control Division, which has facilities located around the world.

**CAT ACQUIRES EUROPEAN REMANUFACTURING COMPANY**

Caterpillar has completed the purchase of Eurenov S.A.S. (Eurenov), a remanufacturer of engines, transmissions and components for leading European automotive manufacturers. Caterpillar Remanufacturing Services (Cat Reman) recently concluded the two-phase purchase process. Eurenov operates its primary facility in Chaumont, France, and another facility in Radmol, Poland. The acquisition will allow Cat Reman greater access to the European automotive and industrial engine and transmission remanufacturing market with expansion into eastern Europe.

**CAT AND RIO TINTO REACH AGREEMENT ON DRILL AND DRAGLINE SYSTEMS**

Caterpillar Inc. and Rio Tinto recently reached a three-year agreement for the Cat CAES and Aquila Drill and Dragline systems to be the preferred standard at the mining company’s open pit operations worldwide. The agreement covers nine Rio Tinto business units operating more than 30 mines in Australia, the United States, Canada and Namibia. The Caterpillar high-precision GPS mining technology products provide machine guidance and operator assistance as well as data collection of multiple production parameters. Rio Tinto is expected to order more than 200 Caterpillar high precision systems over the life of the agreement. In addition, the agreement includes a multi-year support contract.