Well over 10 billion tonnes of bulk materials are transported worldwide annually, a significant proportion of which are bulk minerals and concentrates. During transport, all of this material is placed in a stockpile and reclaimed at least once, with most materials being stockpiled and reclaimed several times during their journey from origin to final destination. The storage of mined products and concentrates at minesites, ports and other stockpile areas is an important part of the industry, with a range of companies involved in supplying solutions, from stacker reclaimer systems to covered mineral storage domes and conveyors. From Richards Bay Coal Terminal in South Africa to the Tubarao iron ore port, Vitoria, Brazil; these bulk handling technologies and solutions help to make the global bulk minerals trade possible.

Both bulk mineral ports and vessels are getting larger all the time for the main bulk minerals traded including coal, iron ore, salt and potash. At the same time, for metallic concentrates eg nickel, copper, alumina, zinc, lead as well as certain industrial minerals, there remain smaller specialist ports and storage facilities tailored for those products.

The different parts of the market are summed up in a paper by PICOR’s Tony Walker entitled Modern Bulk Material Storage and Reclaim Methods. The basic open stockpile system consists of a pile of bulk material resting on the ground with stockpiling and reclaiming being performed manually with machinery such as front end loaders. This has the advantage of being low in capital cost and in having an unlimited storage capacity. The system is a zero live storage system, at no point can the material be reclaimed simply by gravity; a mechanical action is required for this system to operate. Operational cost can be very high as well depending on the cost of labour and the equipment used. Due to the manual nature of this system it does not scale well for operations needing anything over a minimal feed rate.

An open stockpile over a reclaim tunnel with reclaim ports consists of a stockpile resting on top of a reclaim tunnel with ports in the tunnel feeding a reclaim mechanism, usually a conveyor. This configuration can consist of a single or multiple reclaim tunnels. This is an improvement on the basic stockpile in that a certain amount, generally less than a third of the stockpile, can be reclaimed by gravity. The balance of the material must be pushed into the reclaim ports. Pushing bulk material is faster and less costly than lifting it as in the basic open stockpile. While reclaiming by gravity, the reclaim rate of this type of system can match the capacity of the reclaim transport device, usually a belt conveyor. This configuration can consist of a single or multiple reclaim tunnels. This is an improvement on the basic stockpile in that a certain amount, generally less than a third of the stockpile, can be reclaimed by gravity. The balance of the material must be pushed into the reclaim ports. Pushing bulk material is faster and less costly than lifting it as in the basic open stockpile. While reclaiming by gravity, the reclaim rate of this type of system can match the capacity of the reclaim transport device, usually a belt conveyor. The operating cost of this type of system is generally less than that of the basic open stockpile, but is still high and its capital cost is higher. The reclaim rate is also limited to the pushing rate. For this reason, many open stockpiles over reclaim tunnels which require high reclaim rates are sized to hold approximately three times the capacity of the transport device to be loaded.

At large mineral storage areas in key mineral ports, millions of tonnes of coal, iron ore and other materials have to be handled efficiently, and this is normally achieved using the next level of set-up, open storage with large stacker reclaimer systems. Key players in this areas include AUMUND and its subsidiary Schade, Bruks, Sandvik, Takraf, FLSmidth, ThyssenKrupp, AMECO, TAIM Weser, FAM, Metso and others. IM spoke to four of the leading players about the design and delivery of this key equipment.

The machines are mobile and mounted on a rail track alongside the piles of bulk material, offering the potential to selectively stack and reclaim materials in different stockpile sections. This is carried out in two directions, sometimes referred to as quadrants, on both sides of the track. Four-quadrant reclaiming is possible with units featuring tripper-trailers that can be uncoupled. Active stockpiles may be stacked and reclaimed within the traveling limits and operating radius - up to the boundary zone of the storage area on the boom side of the machine. On the trailer side, a clear space, or box cut, is provided, which permits the bucket-wheel to cut into a free end face of the pile. Both stacker and reclaimer systems are tailored to the material handled and in particular the reclaimer must be specified for the precise range of materials with regard to...
density, abrasion, lump size, flow characteristics and behaviour in storage. Natacha Chapon, Vice President of Sales and Marketing, South Asia for AMECO commented: “The type of commodity has a clear impact on the material handling equipment design. Each commodity or type of bulk material has specific features such as density and angle of repose, granule size, material humidity, stickiness, dust generation, and resistance to degradation by mechanical handling. AMECO’s Design & Engineering Team has to take all these parameters into consideration to be able to create the adequate equipment that is able to pile or drag bulk material into the outgoing belt conveyor at a specific tonnes per hour capacity required by the plant management team.”

As an example, the material density has a technical impact on the boom conveyor belts on the stacker and reclaimer, while the material humidity rate will necessitate adjustments to the chain blades of the reclaimer or scraper arms. For fragile granular materials, a mechanical hoist will often be used to luff the stacker instead of a hydraulic one. The granule sizes, density and angle of repose will also generate a different pile form and as a consequence the stacker or reclaimer size will be adjusted. Moreover, hazardous materials, weather sensitive materials, dust generating and corrosive products will all require a different approach.

The volume of the commodity will also have an obvious consequence on the machine size, and on the belt speed and width to reach the required capacity. Thomas Jabs, Sandvik Vice-President TechCenters Materials Handling adds: “The handling rate of the bulk material influences greatly the design of the stacker reclaimer. Smaller handling rates below 2,000 t/h are typical, for example, in sulphur and urea systems and often employ circular stacker reclaimers. The same system is also often applied for thermal coal storage facilities at power plants. Capacities above 2,000 t/h typically require a longitudinal stockyard. The stacker reclaimers chosen here are then the cantilevered type, typically in applications between 2,000 and 6,000 t/h. Beyond these capacities it usually proves advisable to change to a rocker type upper structure of the stacker reclaimer to keep the movement of the centre of gravity of the machine in an acceptable range and therefore also keep the corner loads at the undercarriage within the desired magnitude. Keeping the movement of the centre of gravity of a balanced machine in the lowest possible limit decides about the size and the stability of the undercarriage, and also the rail gauge, ultimately influencing the overall capex significantly.”

Automation is increasingly used in the bulk handling equipment control system. For the effective management of the stockyard and in
particular the blending facility there is a great deal of automation to ensure the equipment is properly positioned and maximum utilisation of stockpile capacity and blending function is achieved. For blending systems the key to the homogenisation of the stored material during reclaim is the creation of a layered stockpile such that at any point along the length of the stockpile a section through would yield samples of every material grade delivered to the blending bed. This requires full automation of the stacking and blending functions as an integrated system with both parts operating simultaneously but in different sections of the stockpile.

Most systems involve collection of data from remote instrumentation and connection by either wired link or wireless computer network to a central control room where the equipment functions are displayed on computer monitors. The operator may use the stockpile program to determine the working parameters and the stockpile zones to be laid or reclaimed and once set in motion the operation will continued unattended. The same systems are used to monitor the machine functions, drives and hydraulic equipment plus associated safety systems. There have been great achievements in the area of automation in the recent years. A lot of terminals for bulk minerals have no operators on the stockyard, only on the ship loader.

The components and monitoring of stacker reclaimers systems is another important area. Leading drive solutions player, Hägglunds, has been part of Bosch Rexroth since 2008. Uno Sundelin, Industry Sector Director for Mining and Materials Handling at Bosch Rexroth comments: “We’ve worked very successfully with solutions for bucketwheel reclaimers for several years, focusing on using Hägglunds drive systems for the bucketwheel. By exploiting all the resources of Bosch Rexroth, we can now supply solutions for all the primary functions of these machines, including slewing, lifting and lowering the boom, rotating the bucket wheel rotation as well as moving the machine itself. We develop package solutions that integrate all these functions in collaboration and consultation with end users and OEM customers.”

Several other package solutions are also popular with users and OEMs. The Bosch Rexroth solutions for active tensioning of long conveyor belts and complete systems for railway car tipplers are other examples of solutions that are often requested. Strainstall Marine has launched a new system for monitoring the tension in chains used in industrial conveyor belts, including those employed in bulk handling. The chain monitoring system provides operators with data on the tensions in the chains, and should the loads reach pre-set limits, the system has the facility to decrease/increase tension in the chain, generate alarms to warn operators to take corrective action before any breakdown occurs or stop the conveyor. This avoids the possibility of chain failure resulting in machine downtime. The system utilises proven Strainstall load pins or compressive load cells (depending on the application) to measure the tension in the conveyor drive chain, with the resulting data transmitted to an electronic display. Specifically designed to operate in extreme temperatures and resistant to high moisture levels, abrasive materials and vibration, both the load pins and load cells are idea for use in the harsh conditions found in the mining, marine and quarrying industries. The load pins are also resistant to the effects of metal fatigue, a condition caused by being subjected to repeated cyclic loads. The systems can also include custom designed software to suit the needs of the individual customer and a range of display options to provide a fully bespoke solution.

Stockpile shape and blending
In general there are three types of mineral storage – rectangular storage (one or two rectangular piles), circular storage, or storage in a tank or silo. The storage type in turn generates different forms of stockpiles. The most common ways to pile the commodity are the chevron

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technique, the cone shell or the windrow type. The shape of the storage area and the pile creation method will impact on the machine design. For example, in the case of two rectangular storage piles, two portal reclaimers would be needed to be able to drag the material, along with one slewing stacker to pile material on both sides. If the storage is circular and a chevron technique is being used to mix different qualities of materials, a circular homogenising stacker reclaimer would be used to enable to a circular stacking movement, with the blending and reclaiming movement achieved by a harrow connected to the reclaimer arm of the machine. The sweeping movements will cause the material to slide on the pile base. In some machines, a double harrow feeds a fixed scraper conveyor long enough to reach across the full pile and is attached to the reclaimer bridge.

Barry Woodbine at AUMUND comments: “There are basically only two alternative shapes, which are the longitudinal stockpile and the circular storage. Both are generated by travelling stackers that follow a pre-determined path but the longitudinal stockpile may be recovered either by a bucketwheel or chain scraper reclaimer design; whereas in circular storage only the chain scraper type is used. Both longitudinal and circular formats may also be blending beds but for blending purposes the chain scraper is uniquely employed along with a reciprocating harrow to bring down elements of every material layer laid down when the stockpile was formed.”

Circular storages offer the greatest stored capacity per unit area of total footprint and are generally simple to enclose using a geodesic or similar dome, which are discussed later in detail in this article. Longitudinal stockpiles have the advantage that they may be easily extended but a much larger footprint for the same storage capacity and are consequently more expensive to enclose.

Very often longitudinal stockpiles will be used at the export terminal and circular storages used at a modern import terminal or power plant as these often represent a single or small group of customers but either solution may be employed. For a central coal preparation plant a circular blending bed will be used to homogenise the incoming materials with longitudinal stockpiles employed to stack out the washed coal ready for rapid transfer to a train or barge.
AUMUND supplied a circular storage facility at the Blackwater mine complex in Australia, an example of how the market is moving towards high performance centralised coal preparation plant supporting a number of individual mine sites within its local catchment area. At Blackwater, six major opencast mining operations feed the new central preparation plant using a combination of heavy haul trucks, belly dumpers and eight triple sided dumper rigs.

The mines are owned by the BHP Billiton Mitsubishi Alliance (BMA). Medium volatile hard coking coal, medium volatile weak coking coal and medium volatile thermal coal is exported from the site to Japan, Asia, South America, Europe and the Middle East plus thermal coal is also sold to the domestic market. Proven reserves are greater than 800 Mt and the new preparation plant is designed to produce some 14 Mt/y. This project was Australia’s largest ever turnkey design and construct coal handling and preparation plant contract.

In the case of India as another example, coal blending is often needed. Some 70% of the total installed capacity of electricity generation in the country is from coal based thermal power plants, but the quality of coal is deteriorating gradually. Large-scale non-selective mechanical mining is also causing further deterioration of coal quality. Only 20% of total coal transported to the power plants is of superior grade with ash content 24% or less. The average ash content of the coal fired to the generating units is in the range of 35-45% with a calorific value of only 2,800-3,800 Kcal/kg. Increased dependence of power sector on the inferior quality of coal (high ash laden coal) not only poses environmental problems but also causes poor plant performance and high cost for ash disposal. One of the solutions to improve the quality of inferior grade coal is blending of available coal with low ash, high calorific value imported coal. This is one of the options for improving coal quality instead of coal washing. This operation is directly done in the storage area.

Normally, coal is crushed and screened before blending; the ROM coal is delivered to large hoppers and then extracted by apron feeders to a number of crushers to reduce the size for easy conveying.

Thomas Jabs at Sandvik adds: “There are certainly differences in the blending strategy of a product. Power plants may receive shipments from different mines, even different countries or continents. In this case the blending is required at the port of import or at the power plant. The same may be required with imported iron ore. But iron ore itself may also be pre-blended, and example being Rio Tinto Iron Ore’s Pilbara Blend, an iron ore blend from different mines in West Australia, blended at the points of export, such as Dampier or Cape Lambert. Other bulk materials, especially synthetic bulks such as sulphur or urea, are a readymade product and do not require special blending.”

**Capacity and machine size**

The capacity required by the client will impact the belt width and speed of the equipment boom conveyors, as well as on the machine size, which includes both the boom length and the gantry structure size necessary to support a greater weight. For a single stockpiling area, the existing capacities for mineral storage systems can reach 20,000 t/h with bucketwheel reclaimers. Sandvik has a single 10,000 t/h stacker reclaimer handling iron ore in Saldanha, South Africa. The company has also recently installed some of the biggest examples operating worldwide at Kooragang Island in Newcastle, Australia for the Newcastle Coal Infrastructure Group with a 62.5 m boom length and 8,500 t/h capacity.

There is no direct relationship between bucket size and capacity or boom length and capacity. However, machines with ultra large capacities beyond 8,000 t/h tend to have longer booms. The reason for this is that an increasing width of the stockpile usually leads to an increase of efficiency in the reclaim process, provided that the width to length ratio of the stockpiles is within a range of about 1 to 10. On
the other hand, larger capacities often require larger undercarriages and wider rail gauges. This again requires longer booms. The bucket sizes are often dependent on the material that is handled. Softer material like coal is easier to penetrate, so the cutting edge of the buckets in contact with the material can be larger. Conversely, the buckets in iron ore are smaller.

However, the capacity is not equal in all stages of the logistical set-up. A typical coal blending system may have a stacking and reclaiming rate of 2,000 t/h, which would also be the work rate of the stackers delivering coal to strategic stockpiles. From the strategic stockpiles the coal will be recovered more quickly at around 4,000 t/h, allowing for very fast train loading, eg a standard 7,000 t train in only 1.4 h. For heavier materials such as iron ore the relative density would allow for faster work rates.

Barry Woodbine at AUMUND comments: “For Schade the reclaimer boom length is a function of the rail centres for longitudinal machines and at present the largest machines have a rail to rail distance of 65 m. For circular stockpiles the maximum stockpile overall diameter delivered thus far is 120 m with a live holding capacity of 200,000 m³ but new designs are in progress to extend this to a diameter of 150 m which effectively doubles the live capacity. Bucket or shovel size is a function of output rate and material density, with the largest machines having a shovel width of 3 m.”

When it comes to the actual shiploaders, the equipment features and capacities depend on the vessels size and the port activity, i.e. the scheduled number of vessels to be loaded. A 50,000 DWT (deadweight tonnes) vessel will be loaded in 24 h with a 2,500 t/h shiploader. When vessel capacity reaches 350,000 DWT, the shiploader capacity is obviously designed in order to cope with this. Different shiploader chute solutions are possible depending on the commodity type, the type of ship and the rate of loading. Sandvik states that in recent years it has been following very closely the developments in vessel engineering. The largest Valemax and Chinamax bulk vessels with capacities up to 400,000 DWT require a different approach in ship loading. Ship loading rates of up to 20,000 t/h are not uncommon anymore.

This capacity is achieved either with long travelling and telescoping bridge ship loaders, or with a long travelling, slewable and luffable ship loader. However, these very large bulk vessels are mainly limited to iron ore and some coal trade. Most large coal and ore shipments are in Capesize vessels, mainly in the range of 130,000 t, and smaller Panamax vessels.

The loading rate for any size of ship is a function of its capacity and loading period – a 130,000 t vessel with a four day loading window would need a loading rate of 2,000 t/h to account for lost time due to trimming and vessel/machine movements. For this size of vessel, most terminals would use a dedicated rail mounted ship loader connected to the storage by a system of permanent belt conveyors. For smaller ships, more mobile equipment is a possibility.

In smaller ports or where clients demand a fast track flexible solution the mobile Stormajor by AUMUND’s B&W Mechanical Handling has proven a popular alternative to fixed systems.

Typically minerals may be imported from gearered vessels using grab fitted cranes or a mobile harbour crane may be employed discharging the bulk cargo direct to mobile Eco-Hoppers – this is a dust controlled hopper system from B&W designed to minimise risk of wind-blown fugitive dust pollution. From the Eco-Hopper the cargo may be loaded to tipping trucks and then ferried to an open storage area, or maybe to an existing warehouse, often just outside the port complex to be stacked out using the mobile Stormajor. Material would be recovered from the stockpile using a rubber tyred loader and transferred often to rail wagons for shipment inland.

The stacker reclaimer is also not the only solution for high tonnage stockpile reclaim and blending. The AUMUND Rotary Discharge Machine can recover materials from stockpiles and using multiple units, may mix material in varying ratios to create a blended output. For example Samarco, last month’s Operation Focus, recently ordered four such units for reclaiming iron ore from its stockpiles; at a rate of over 1,800 t/h for each unit.

The Walker Reclaimer is another possibility for high tonnages. It consists of one or more square conical surfaces, each sloped down toward an opening in its centre. Each conical surface consists of a steel plate supported by a support system and lined with a low friction surface. In the centre of the conical surface is a reclaim opening fitted with a PICOR flow control gate. Attached to the underside of the conical surface are a number of vibrators. When the PICOR flow control gate is opened, material flows by gravity onto the reclaim conveyor. The flow rate through the opening is matched to the conveyor capacity by the PICOR flow control gate. When a flow channel is established in the stockpile, a number of vibrators around the reclaim opening are energised. Since the density of flowing bulk material is significantly less than that of static material, the vibration energy introduced into the static material around the flow channel causes the flow channel to widen. The material on the conical surface around the reclaim opening will migrate into the reclaim opening causing the flow channel to widen further. As material is reclaimed, the depth of material on the conical surface decreases causing the flow channel to widen further. As the reclaim channel widens, more vibrators are energised toward the perimeter of the conical surface causing all the remaining material on the conical surface to migrate into the reclaim opening.

The Walker Reclaimer combines the attributes of the stockpile over a reclaim tunnel and the vertical storage silo. Since it is an enclosed system the stored material is protected from the environment and the environment is protected from the material. The conical surfaces can be arranged to provide an unlimited amount of storage for bulk materials. Due to the design of the conical surfaces, materials can be stored on adjacent conical surfaces without mixing and without sacrificing storage volume.

This system can also be used to reclaim bulk materials from large, circular, domed structures. This allows the storage of more material in a limited area but the cost of storing the material is increased and the foundation loads are increased.

In 2011, Tenova TAKRAF was awarded several contracts that include bridge type bucketwheel reclaimers for the BHP Billiton Mitsubishi Alliance-owned Caval Ridge coal operation in Australia, the EuroChem Kvodar iron ore mine in Russia and the Vale Apolo iron ore mine in Brazil. A bridge type bucketwheel reclaimer consists of a moveable bridge with an incorporated belt conveyor, one or two bucketwheel trolleys that travel back and forth on the bridge. The bridge type bucketwheel reclaimer reclaims material from the
stockpile's face. It is also suitable for homogenisation of various material qualities over the full stockpile cross section. The 3,000 t/h machine for Kovdor features one of the largest rail gauges worldwide (59.9 m) for a machine of its kind. It will operate at temperatures down to -40°C. The 12,700 t/h Apolo bridge type bucket wheel reclaimer will be the most powerful machine of its kind in the world. Special attention was laid to the design of the 12 buckets and their attachment system in order to reverse the buckets in place.

An automatic bucket reversing system was developed and patented for the 4,900 t/h Caval Ridge bridge type bucket wheel reclaimer. Thus, downtimes for changes of travel direction of the machine will be reduced, which will result in a considerable reduction of operating costs. Additionally to the bridge type bucket wheel reclaimer, a bucketwheel 58 m boom reclaimer will operate on the stockpile at Caval Ridge. The bucket wheel has have a diameter of 11 m with 12 buckets. The reclaimer's belts are 2,200 mm wide, and the machine will reclaim coal at a capacity of 6,000 t/h.

Currently Tenova TAKRAF is also commissioning a bucketwheel 47 m boom reclaimer for lumpy iron ore at the Kumba Sishen iron ore mine in South Africa. The reclaimer's nominal capacity is 5,000 t/h, with a maximum capacity of 7,500 t/h. The bucketwheel has a diameter of 9.2 m. Nine buckets are mounted on the bucket wheel, with a volume of 1.4 m³ each.

**Bulk system contracts**

In the largest scale bulk mineral port projects, a consortium of companies is often involved. The port authorities will be present in most cases, as well as the company using the terminal facilities. In terms of mineral ports, this could be a mining group, steel industry company, a fertiliser company or a private group operating in bulk material imports or exports. EPCM contractors are more and more the norm for large turnkey solutions, with the exception of cement manufacturers, which often tend to select vendors by themselves. For high capacity storage systems at a large export or import terminal or processing or power plant the stacker and reclaimer equipment will be part of the much larger EPCM contract. For example for the huge 50 Mt/y Abbot Point X50 coal terminal expansion, North Queensland Bulk Ports (NQBP), the port owner, commissioned Aurecon in joint venture with Hatch to complete all engineering design and tender procurement for the project. Within this, John Holland built the shiploader, while G&S Engineering undertook the structural and mechanical erection of four new FAM-designed stacker/reclaimers.

Typically the main contract for an export terminal may involve, for example, a railcar dumper plus conveyors to a rail mounted travelling stacker, followed by a portal reclaimer to recover the material from stockpile plus conveyors and a rail mounted shiploader to discharge material to the bulk vessels. The contract may also include all the associated civil works, jetty and electrical and marine works as a complete turnkey contract.

For mobile equipment used for stockpiling or shiploading then there is unlikely to be an EPCM contractor involved since each item of equipment is free standing and not necessarily linked to any other plant or fixed port infrastructure. The mobile plant may simply be rolled into the port and put to work.

Thomas Jabs at Sandvik comments: “We receive contracts from all three parties, however, it has proven to be extremely effective to involve OEMs like Sandvik in the early planning stages, as a lot of the factors required to develop a highly efficient terminal or stockyard can only be provided by the OEM. We have been very successful in the last years cooperating with all large mining houses and EPCMs to achieve exactly this and we are looking forward providing this service also in the future.”

**Railcar unloading**

Mineral materials also have to be delivered to the stockpile site and in the case of mineral ports, this often involves railcar dumpers. Metso is a leading player in this area, and it is now over 25 years since it installed its first rail car dumper system in China. Since then, growth has been significant and has been reflected both in the number and type of dumper systems supplied over recent years, as well as the way in which contracts were executed. This growth has been mainly in the developing port cities of northeast China where the need for high throughput high integrity dumper systems is required for the fast transfer of coal arriving by train from the mines in central China. Most of this coal is transhipped to southern China to feed the ever increasing coal fired power needs in this area. There are two types of rail car dumper systems operating in the world today, for handling different train configurations. The first is known as a random train where the cars are uncoupled prior to dumping and the second is known as a unit train where the cars are fitted with rotary couplers and rotate around the centre line of the coupler and therefore negate the need for uncoupling. Random trains have a slower throughput than unit trains, but have the advantage of being able to handle a range of wagons. Unit trains consist of all cars of the same length, although it is possible with the use of platform extensions to handle trains with cars of differing lengths.

According to Metso, in the early years, the main types of dumper systems supplied into China were of the open sided “crescent” type. These dumpers were deigned to tip two wagons at a time, in tandem formation, and were used for handling random trains, where the wagons are uncoupled in pairs, before being moved onto the dumper platform. An integral part of the dumper system is the train moving devices. These are rail mounted machines called
indexers or positioners that run parallel to the main track on the entry side of the dumper. They are driven by a series of vertically mounted planetary drive units that engage with a land mounted rack. The number of drive units depends on the size of the train and the required throughput speed. For random train systems, a secondary device is sometimes used called a charger that runs parallel and adjacent to the dumper platform and is used to position the two lead wagons on the dumper platform whilst the other machine (indexer) is moving the loaded train forward ready for the next cycle. This has the effect of speeding up the operation and today the company can achieve throughputs in excess of 64 cars per hour.

Unit train railcar dumper systems are the largest in the world with the capability to tip three or even four cars at one time. The Metso triple dumper systems tip three 100 t rail cars on a single platform, while its quadruple dumpers tip four 100 t rail cars using two tandem cages operating simultaneously. These systems are designed for high throughput and typically handle trains of 200 cars long. The train handling system uses a large positioner for indexing the train through the dumper driven by 12 x 90 kW drive units.

A typical scope of supply would involve Metso providing the engineering and supervision services and supplying the high tech proprietary equipment such as electrics and control systems, mechanical drives and hydraulics. A local partner would be responsible for steelwork fabrication, installation and supply of ancillary equipment.

**Domes and storage silos**

Covered storage of minerals is also very common, with a wide range of designs from geodesic domes to teepee shapes and, rectangular structures and cylindrical tanks. In

South Asia and Africa, for example, coal has to be stored in shed/closed storage area to protect it from heavy rain. Some fine bulk materials are sensitive to wind, and others to sunlight, or there are specific environmental rules aimed at avoiding bulk material dispersion around the storage area. Metal concentrates also need protecting from the elements.

In the case of a tank, there is a vertical silo with a single or multiple reclaim ports underneath that feed a reclaim conveyor. With proper design, this method has the advantage of being a totally gravity fed system, as no mechanical forces are required for the full reclaim of the stored material. This method is especially applicable in situations where facility space is at a premium. While the capital cost of the vertical silo method is high, the operational cost is low. However, blending of material in vertical silos must be performed prior to the storage of material, or different materials can be stored in separate silos and blended when the material is reclaimed. Due to the high capital cost of vertical silos, their storage capacity is limited and silos of over 70 m in height are rare. Key players in the dome storage market include Geometrica, Dome Technology, Triodetic and CST Covers. Geometrica’s geodesic domes are made with strong and corrosion resistant galvanised steel or aluminium. The light, prefabricated domes are containerised and shipped globally. Construction may proceed before, during or after material handling equipment is installed, and, frequently, the domes are built over existing live material stockpiles with minimal or no downtime.

The most recent mine delivery was to the San Cristobal silver/zinc/lead mine in Bolivia. In early 2010, Bolivian contractor Carlos Caballero responded to a bid request for a stockpile containment solution. Minera San Cristobal had sought to prevent the release of dust from its stockpile into the environment as well as protect the material awaiting transport to the mine’s ore processing facility. Caballero teamed with Geometrica to propose a customised containment solution for the mine. Caballero served as the main contractor and installer of the dome, while Geometrica as a subcontractor engineered, manufactured and supplied the dome. Key factors in the decision to employ a Geometrica dome solution for the site included the capability to build around an operating stockpile and the capability to follow an irregular shape for the supports.

The finished stockpile containment structure is a Geometrica dome 140 m in diameter and 59 m in height anchored by concrete foundation; the largest dome of its kind in South America. The foundation, which accommodates a 9 m change in elevation over 140 m, is fitted to the terrain. The dome is designed to withstand wind speeds of up to 150 km/h and an ice load of 110 kg per square metre. The dome is made up of more than 88,000 galvanized steel tubes...
organised and inserted into aluminium hubs to form the structure. The Geometrica system requires no welding, as the prefabricated tubes slide easily into the aluminium hubs and hold fast. The precise yet simple assembly process allowed the mine to continue to operate in the midst of dome construction and made it easier to assemble the building in an environment subject to high winds. A ventilation lantern is located at the top of the dome and additional armature on the side of the dome can support dust removal equipment. The interior includes a system for lowering the material-conveyor pulley for maintenance, and a catwalk circling the dome interior. Three 13 m x 10 m doors allow simultaneous access by up to two off-road vehicles to the interior of the dome. The finished building is clad in galvanised and painted metal sheets and translucent skylights provide natural light. Material is transported from the dome to the mine’s ore processing plant via an existing underground tunnel.

Geometrica has created more than 15 bulk storage domes for mining projects located in the Andean region of South America, including at the Zaldívar, Mantos Blancos and El Tesoro operations in Chile. Globally, mining clients include BHP Billiton, Anglo American, Barrick, First Quantum, Fluor, Sumitomo and Codelco.

Another leading player in storage domes is CST Covers, which was created by CST Industries acquiring Temcor and Conservatek, two leading aluminium structure companies, in 2009 and 2010.

The company states that geodesic aluminium domes are popular as aluminium is inherently corrosion resistant versus other alloys. It will last the lifetime of the structure and will not need to be painted or repainted for protection from the atmosphere. With no corrosion or the need to repaint to protect the structure over time, there are little to no maintenance costs associated with an aluminium dome. The lightweight characteristics also allow for larger clear-span cover capability than structures utilising steel, concrete and other materials. Creative design and lightweight components provide for installation in a third of the time it takes to install other cover systems, while aluminium’s excellent strength-to-weight ratios and creative component design yield covers and structures that cannot be achieved with other materials.

CST Covers domes have been designed for snow loads of up to 165 lb/ft² and the company has the ability to design domes up to 1,000 ft in diameter.

On the tank storage side, CST also designs, manufactures and installs factory welded silos and bolted smooth wall silos available for dry bulk mineral applications. These BulkTec solutions are smooth walled bolted panel tanks are manufactured out of carbon steel, stainless steel or aluminium with various hopper and outlet configurations. A proprietary factory-applied, baked-on coating system promotes flow and resists abrasion. CST can also provide silo and storage tanks with customer specified components already installed in the tank. These can include pumps, level indicators, bin vents, lights, heaters, material handling valves, aeration systems and control panels.

Plaintree Systems recently announced that its Specialty Structures Division, Triodetic, has received a contract for the engineering and manufacture of a 130 ft galvanised steel industrial dome structure with painted steel cladding for a gold mine in northern Ontario. Manufacturing of the dome will be at the company’s new state-of-the-art plant in Atrio, or the new plant boasts high end presses, CNC machining capabilities, laser cutters, laser welders and other precision machinery. Earlier in 2011, the company announced the completion of another dome, a 94 m stockpile cover in Chile for Teck’s Andacollo copper mine.

Dome Technology has been constructing industrial storage domes since 1976. Its design is based on a thin shell concrete dome with reinforced double curvatures, known as the DomeSilo design. The group believes that this solution is much stronger than a traditional silo or other types of storage structure. The dome is designed to both cover and contain the product. Because of the dome’s inherent strength, product is generally loaded high on the dome wall. The dome is capable of handling asymmetrical loads while loading or unloading product from the dome. Grupo Cementos de Chihuahua (GCC) selected Dome Technology’s DomeSilo to store 125,500 t of clinker at its Pueblo, Colorado cement plant with an apex loading of over 500 t over a span of 73 m, including a five-story head house transfer tower. A comparative traditional structure would require significantly more construction material at a higher cost to handle to support the span.
and load. The ability to accommodate loads imposed by the stored materials loaded against the interior wall of the dome even includes high density materials such as nickel concentrates. Point loads may be placed at locations on the dome shell to support the loading conveyor and large or small openings may be located anywhere on its surface allowing flexibility when considering material handling, truss or equipment support.

The entire exterior of a DomeSilo is covered by a mould resistant UV-protective resin coating on both sides of a single-ply PVC waterproofing membrane that provides a continuous-sealed 100% water-proof barrier. The membrane is made of a strong, durable, and long lasting high tension fabric. The membrane sections are radio frequency welded to provide continuous strength and water-tightness over the entire exterior surface. Rivets fasteners or other mechanical connections found in other structures are not used, thus eliminating potential sources for leaks.

In traditional structures, temperature fluctuations causing cyclical thermal stresses fatigue and destroy conventional concrete and steel silos over time. In contrast, the outer continuous polyurethane foam insulation in a DomeSilo structure, in combination with the inner concrete layer, provides an insulated thermal mass that minimises temperature fluctuations in the structure. The insulation also minimises internal condensation and vapour drive from moisture found in some stored products.

The integrated ring foundation system provides rigidity that distributes loading uniformly and consistently often reducing or eliminating the need for deep foundations.

A DomeSilo can be built in most parts of the world any time of the year, allowing flexibility in construction scheduling. The molybdenum storage dome at Climax Molybdenum’s Henderson mine was constructed at an elevation above 3,300 m in only three and a half months. The dome is 100 m x 32 m. The inflated dome envelop protect construction activities carried on inside its moderate environment.
The DomeSilo can be designed to accommodate various mechanical systems such as simple pay loader, mass or funnel flow gravity reclaim, stacker reclaim, rotary plows, and pneumatic floors. The entire handling and storage configuration, including above or below-ground reclaim tunnels, can be design-built by Dome Technology using a diversity of shapes including low profiles and hemispheres with or without stem walls, or even long elliptical configurations.

Norseman Structures provides an alternative building solution for mine site operations. The clear-span interior of a Norseman building provides flexibility to maximise storage space based on site needs and allows operators to manoeuvre equipment without difficulty. Translucent fabric covers reduce energy costs in the form of lighting and create a bright and pleasant working atmosphere. Bulk mineral storage is one area where the product has had success. The company recently introduced its new F-Series Commercial building, a wide span premier engineered building solution for large scale mine site operations. Available in 90 ft to 130 ft widths; the design can be manufactured to any length. The use of an I-beam leg allows for various overhead door and side entrance options, while the straight sidewall design allows users to utilise complete square footage and store oversized items and materials directly against walls. The straight sidewall design permits various exterior finishes, such as metal cladding.

In tank storage, Tank Connection offers the RTP smooth-wall bolted tank design. RTP (rolled, tapered panel) tank construction is a precision bolted tank design that features a smooth-wall interior (no ledges), exact manufacturing tolerances and a top rated powder coat process. Tank Connection also provides complete turnkey field installation service, utilising direct factory crews. Field installation is accomplished utilising a synchronised, hydraulic screw jack process that allows field crews to install large tanks at grade level.

Hopper gravity discharge is available in a variety of configurations including skirt support tanks, drive-through skirted tanks, tanks on structures, tanks supported on load cells and tanks elevated on structural steel. Hopper bottom designs are available in sizes ranging up to 150,000 ft³ of storage. IM

Construction of Tank Connection silo tank for limestone storage