

Impumelelo coal mine is home to the world's longest belt conveyor

by Michael Thompson and Andrew Jennings



Conveyor Dynamics Inc. completed the Impumelelo conveyor in South Africa. It is 28 km (16 miles) long.

For a third time in its history, Conveyor Dynamics Inc. (CDI) has designed and commissioned the longest conveyor in the world. CDI's first record-setting conveyor was Zimbabwe Iron and Steel Co's 15.6-km (9-mile) overland conveyor between the Ripple Creek Mine and the Orco plant (du Toit & Fletcher, 1997). CDI subsequently surpassed this distance in 2007 with the design and commissioning of the 20-km (12.7-mile) Curragh conveyor near Westfarmers, QLD, Australia (Steven, 2008).

The company has built upon the experience and expertise gained from these previous record-setting successes to design and commission the most recent record-setter, a 26.8-km (16-mile) long Impumelelo conveyor near Secunda, South Africa.

The principal contractor for this project was ELB Group (ELB), based in Johannesburg, South Africa. ELB provides engineering services, construction services and equipment supply in the South African market and throughout sub-Saharan Africa.

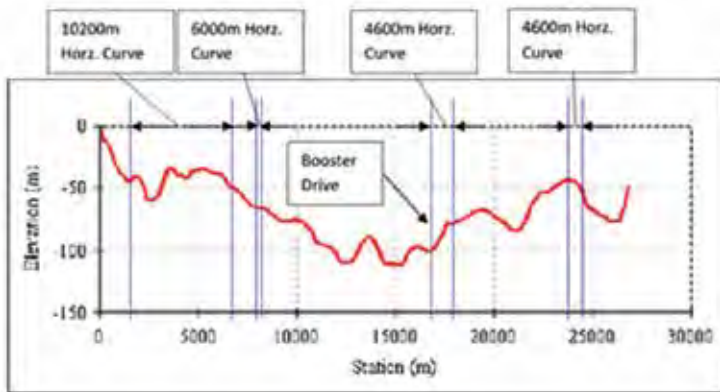
CDI, based in Bellingham, WA, USA, specializes in the design of long-distance overland conveyors (OLC). The company designs trough and pipe conveyors, transfer chutes and control systems as well as forensic engineering services. The company also develops software for the bulk material handling operations on every continent except Antarctica.

CDI was engaged by ELB to do the basic mechanical engineering design and a large part of the detail design for the Impumelelo overland conveyor. Additionally, CDI provided

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Coal

Figure 1
Conveyor profile.



the mechanical design for the principal underground incline conveyor that brings the coal from the underground storage bunker to the mine head storage silos above ground.

Description and location

CDI developed the basic mechanical and control system design with its proprietary in-house software BeltStat and BeltFlex (Nordell & Ciozda, 1984). Figure 1 contains an elevation

view of the OLC and Fig. 2 shows the map of the conveyor route. The conveyor runs from the Impumelelo mine site to SASOL's Brandspruit coal-to-diesel conversion plant. It has an overall horizontal length of 26,816 m (87,980 ft), with a total change in elevation between the tail pulley and the head pulley of -50 m (-164 ft).

Except near the tail and head end transfers, the conveyor is at or near ground level for its entire length. The OLC follows the general contour of the local terrain and includes 54 vertical curves and four separate horizontal curves (Fig. 1).

The original route included a transfer tower shown between station 18,000 and 19,000 on the map. This would have resulted in a two-flight conveyor system, with lengths of about 18.5 km and 9.5 km (11.8 and 5 miles), respectively. CDI designed the in-line booster drive and tripper chute station that eliminated the transfer tower. This reduced the cost of the civil and structural works, reduced the visual impact of the conveyor, and increased the conveyor reliability by removing a chute that could have plugged if the 18.5-km (11.8-mile) conveyor took longer to

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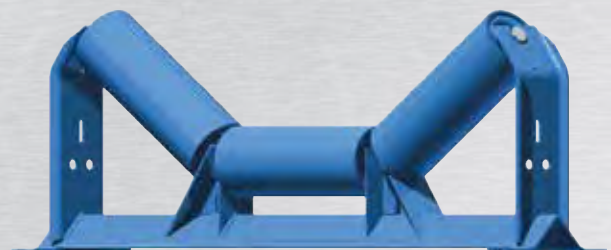


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stop than the 9.6-km (5.1-mile) conveyor.

Design considerations

At peak tonnage, the conveyor transports 2.4 kt/h (2,600 stph) of coal at a maximum speed of 6.5 m/s (21 ft/sec). However, operators can reduce the conveyor speed to save power when they transport less tonnage. The motors are able to start the fully loaded belt at the lowest ambient temperature recorded for this location: -5° C (23° F).

To reduce the operating expense required, CDI specified a special low-rolling resistance (LRR) bottom

rubber compound and special low-rolling resistance precision idlers. CDI also designed stringers with long span lengths between idler sets on the carry and return side. The large idler spacing, reduced CAPEX, noise and maintenance time. Idlers from several idler manufacturers were tested to prove they met CDI's low drag and SASOL's low noise specification.

To reduce windborne dust losses and emissions, the entire length of the cover is covered, and the idler tables are specifically designed to shield the carry side of the conveyor belt from the wind.

Project timeline summary.

- November 2012 — Contract negotiations between ELB and CDI finalized.
- February 2013 — Basic mechanical design completed and delivered to ELB.
- December 2013 — Detail engineering completed and delivered to ELB.
- May 2014 — ELB commences construction of Impumelelo overland conveyor. CDI begins programming work for the overland conveyor's motor and brake control system.
- May 2015 — Control system development completed.
- October 2015 — Completion of construction of the overland conveyor by ELB. The conveyor was dry (no load) commissioned with CDI's assistance almost immediately after construction was completed.
- October 2015 — Wet (loaded) commissioning completed by ELB.

Conveyor belt

The super low rolling resistance (SLRR) belt was imported from Aneng, China and produced by Goodyear Veyance (now Contitech). The critical belt parameters appear in Table 1. The belt manufacturer originally offered 500 m (1,640 ft) reels of belt for this project. CDI insisted they manufacture and

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Coal

Figure 2

Map of Impumelelo conveyor route across Mpumalanga province, near Secunda, South Africa.



transport 1,000 m (3,280 ft) reel and, after review, Veyance agreed (Fig. 3). This increased shipping costs but provided substantial splicing cost and time savings.

The entire belt was pulled and spliced at an average rate of 1 km/day (0.62 mile/day), the installation was performed with the assistance of Conveyor Belt Technologies of Vancouver, BC, Canada and could have been completed

Table 1

Belt specs.

Width	1200 mm
Strength	ST-2000 N/mm
Cover thickness (top x bottom)	7.0 x 5.0 mm
Weight	33.3 kg/m
Total belt length installed	54,033 m
Cable Diameter	5.2 mm
# of cords	86

in 60 days, if the crews had pulled the belt continuously.

Control system

Figure 4 contains a schematic of the system pulley layout. There are a total of 4 x 1,000 kW and 2 x 500 kW (4 x 1,340 hp and 2 x 670 hp) VFD controlled motors at three separate locations: the head, the booster station and the tail. Drives 1-4 are 1,000 kW (1,340 hp) and drives 5 and 6 are 450 kW (603 hp). Belt

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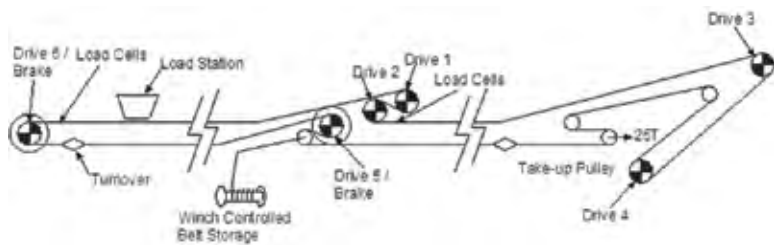
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Figure 3
1,000 m (3,280 ft) belt reel.



Figure 4
Pulley schematic.



speed, and belt slip conditions are monitored using special analog tachometers designed and manufactured by CDI. (Unlike counter cards, CDI's analog tachometer is accurate for both low and high speeds.) Belt tension for motor control purposes is measured at selected locations using a specially designed array of idlers and strain gauge load cells.

The control system for this conveyor is similar to the control system that CDI created for the Essroc conveyor (Jennings, Perrone, & Cornet, 2013). When the conveyor is running, the torque supplied by Drive 1 and Drive 2 is determined by a belt tension feedback loop. The belt tension is measured by a series of special idler rollers and strain gauge load cells along the carry strand just after Drive 2. Drive 3 is speed controlled and Drive 4 follows Drive 3's torque. Drive 5 follows the torque produced by Drive 6. Drive 6 produces enough torque to maintain a constant tension at the tail.

The OLC accelerates to full speed in 670 seconds, including a 70-second dwell period at 5 percent of full speed. The dwell stretches the belt prior to applying full torque for the main

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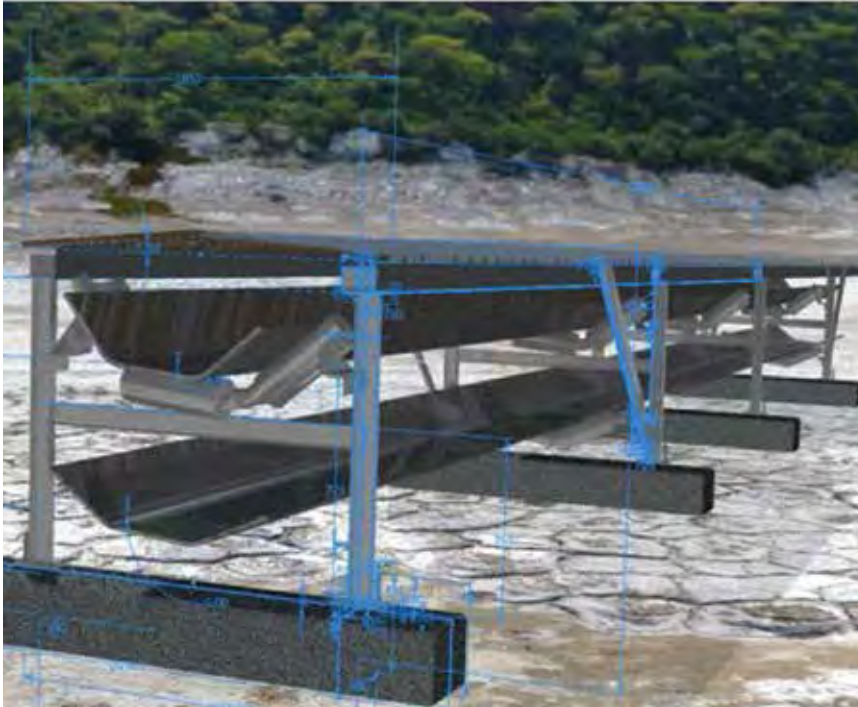


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Coal

■ **Figure 5**

3-D rendering of Inventor model of idler support structure with banked idlers.



acceleration ramp.

Using a combination of the drives and the brakes, the belt takes 100 seconds to come to a fully controlled operational stop.

Belt stretch is removed by a 22-t (25-st) gravity take-up located at the head end of the conveyor. This take-up incorporates a capstan brake in the take-up reeving to reduce the severity of take-up motion during emergency stops (Jennings, Perrone, & Cornet, 2013). Since the tape length of the belt is 54 km (33 miles), a second take-up, or “belt storage loop,” was added to the booster drive station to take up the slack created by permanent elongation out of the belt as it stretches over time. This take-up is static and is only adjusted when the dynamic take-up at the head end is observed approaching its travel limits.

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Figure 6

Idler support structures - as built.



drag and SASOL's noise reduction requirements. To reduce drag, CDI specified lower viscosity grease than is typically supplied by the idler bearing manufacturers. The idlers consist of a steel inner shell with polypropylene outer covers. The plastic outer covers reduce the idler noise and make it easier to achieve a low TIR, making the idlers roll easier and with less vibration.

The idler spacing was chosen to minimize the idler count while maintaining belt sag at or below 1 percent during normal steady-state running conditions. Due to the large variation in belt tension along the length of

Idlers

The idlers were provided by Lorbrand of Pretoria, South Africa, and were tested by Tunra in Australia to ensure that they met CDI's

the conveyor, it was impossible to find a single idler spacing that prevents belt flap resonance effects. To prevent belt flap, the carry and return side idlers are on a staggered spacing. The carry

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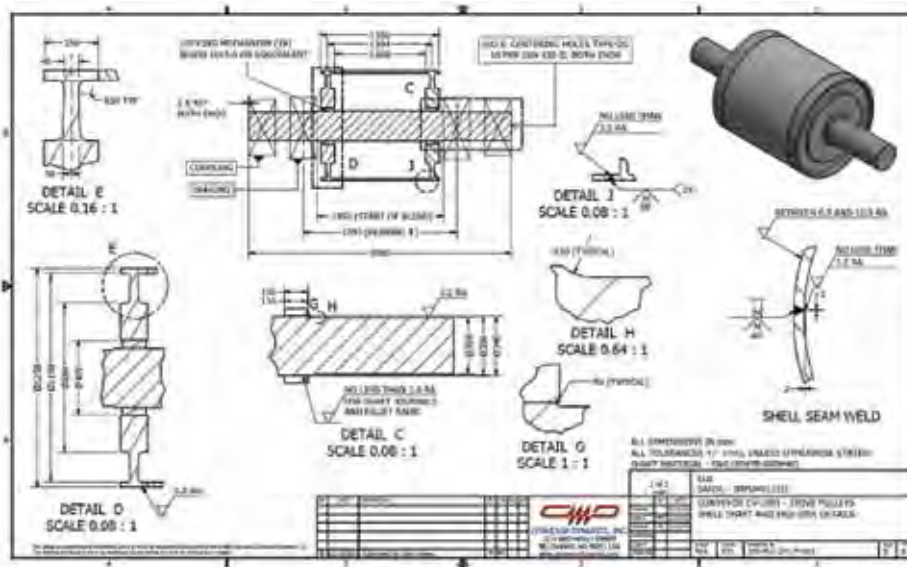
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Figure 7
Detail design of drive pulley.



side spacing alternates between 4 m and 5 m (13 ft and 16 ft). The return side spacing alternates between 8.25 m and 9.75 m (27 ft and 32 ft).

Trough angles on the carry side varied between 35° in the straight sections of the conveyor and 45° in the

horizontal curves. The return idlers were also troughed at 30° to assist in belt tracking and to further reduce the probability of belt flap.

During the design process, there was some concern about the potential for damaging the belt due to the long idler spacing. CDI has a dimensionless index called the idler junction pressure index (IJPI). Using this index, CDI ensures that its wide idler spacing designs will not damage the belt.

CDI chose an idler spacing that is three times wider than the idler spacing recommended in the handbook published by the Conveyor Equipment Manufacturer's Association (CEMA). CEMA's rules were developed for conveyors that are much smaller than 27 km (16.7 miles). In general, the take-up tension required to avoid drive slip on shorter conveyors is less than it is on longer conveyors. Since the belt tension is lower on shorter belts, shorter belts have shorter idler spacing to avoid excessive sag. Short conveyor designers could increase the take-up tension to resolve their sag problems. But on short belts, increasing take-up often entails increasing belt strength which is more costly than adding additional idlers. On long belts, the high take-up tension required to avoid drive slip allowed CDI to use larger idler spacing without introducing excessive sag. This is one of the many situations where the standard rules did not apply and where CDI's experience optimizing conveyors dramatically reduces the capital expenditure as well as time required to install and maintain a conveyor.

Idler support structures

Figure 5 shows a rendered view of the idler support. CDI provided ELB with detail drawings and structural analysis for this assembly. The idler support structure is identical everywhere along the conveyor except for the elevated sections above the turnovers and drives. This standardization made the manufacture of the 9-m (29-ft) long

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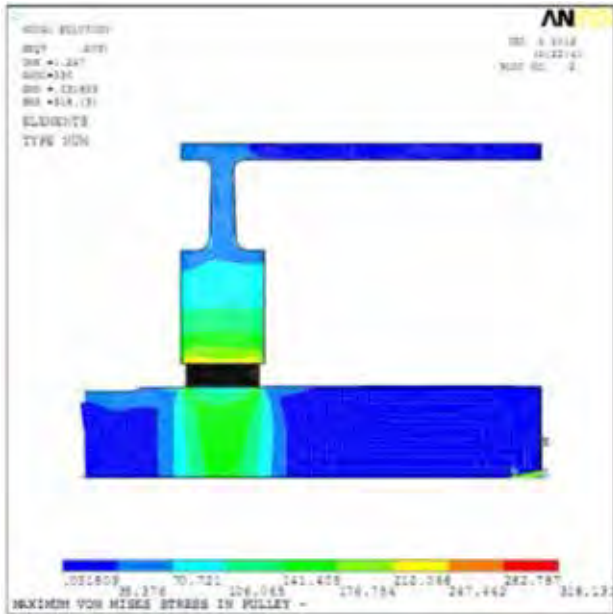
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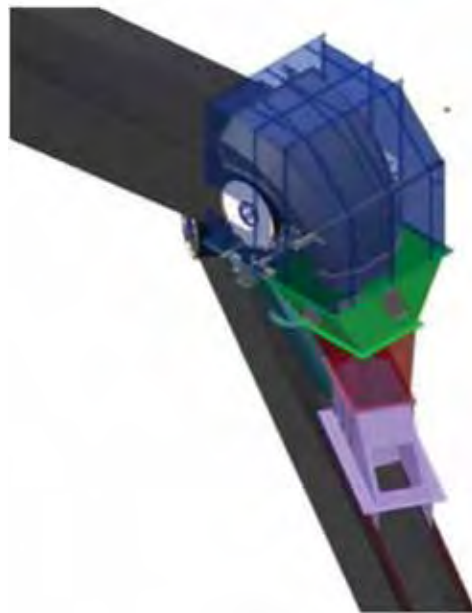
Figure 8
FEA analysis of drive pulley.



support structures more cost effective than it would have been if there were different support structures in the horizontal and straight sections of conveyor. After optimizing the structural members with FEA, the weight of the idler support structure was 17 kg/m (excluding the idler frames and hood covers). The structure can support more than 2,400 kg/m, and wind pressures of up to 880 Pa (880 N/m²).

CDI also provided the majority of the coordinates used to locate each idler support structure along the conveyor route, including adjustments for the anchor bolt connections,

Figure 9
3D model of tail chute.



and shim pack thicknesses for each idler transom frame. ELB carefully surveyed each support point and erected the structure to within +/- 0.5 mm (Fig. 6).

Pulleys

CDI also designed the engineer class pulleys for both the Impumelelo overland conveyor and for the underground incline conveyor (Fig. 7). These pulley designs were severely constrained by the following design considerations:

- Conservative deflection, stress and

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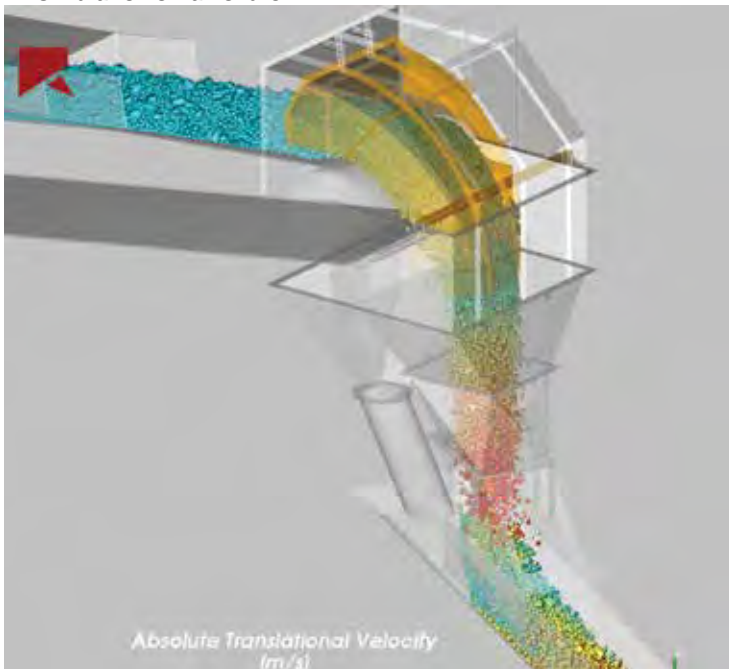
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Figure 10
DEM simulation of tail chute.



- fatigue limits.
- 300 percent motor torque ratings on the shaft locking rings.
- Requirement to use only locally readily available steel shaft material, in order to expedite rapid replacement of pulley shafts.
- EN8 steel material similar to AISI 1040 steel.
- Restrictions on pulley shell diameters created by standardization of pulley sizes and gear reducer ratios at the SASOL plant.

The combination of these constraints resulted in pulley shafts that were larger than CDI would have designed using less conservative stress limits, lower locking ring torques, and higher strength steel for the shafts. This, in turn, limited the amount of flexibility that could be designed into the end disk profiles to reduce the fatigue stresses in the end disks to acceptable levels.

Using CDI's proprietary pulley design software, PStress, CDI was able to quickly iterate through the available design variables to develop a pulley design that met these exacting specifications (Qiu & Sethi, 1993). After arriving at a suitable design, CDI modeled the pulleys with ANSYS FEA package to demonstrate the validity of PStress's calculations (Fig. 8).

Due to the complexity of the final pulley designs, CDI reviewed the production operations and quality control procedures of several pulley manufacturers located in Johannesburg to ensure the quality of the fabrication met the design intent. All of the pulley manufacturers surveyed in the process had excellent design, fabrication and quality control, and any of them could have produced these pulleys. ELB selected Lorbrand as the pulley manufacturer, based on CDI's recommendations and other factors.

Chutes

CDI also provided conceptual and detail design and DEM analysis of the tail feeding chute and the booster station tripper chute. DEM simulations were performed with Granular Dynamics International's Rocky DEM software.

The DEM simulation requires a calibration of the material in terms

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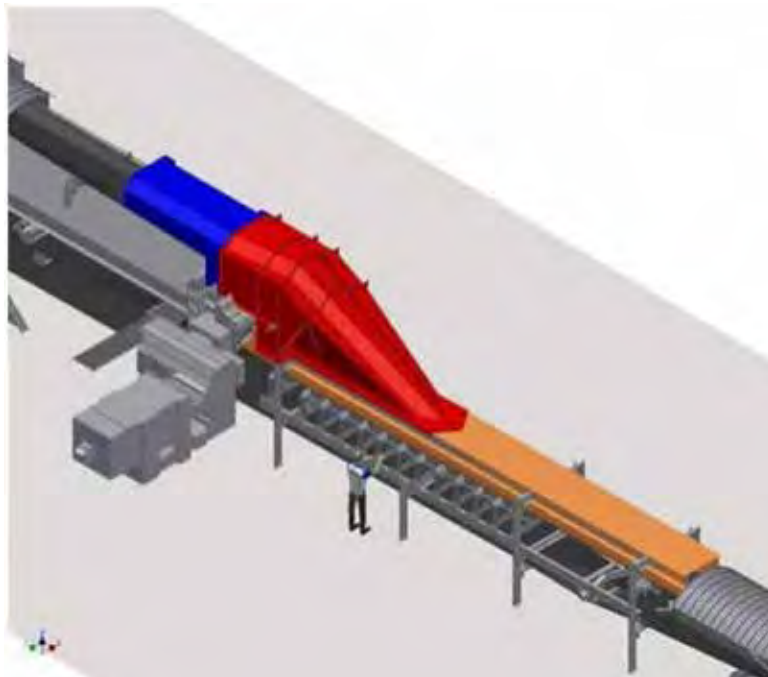
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Figure 11

3D model of booster station.



of its bulk density, particle size distribution, moisture content and other factors. Critical factors incorporated into the chute design are the material's natural trajectory and the need to direct the material so that it is correctly centered on the receiving belt. One must also attempt to minimize impact forces (low vertical velocity), and create a tangential velocity that closely matches the belt speed. Proper chute design can prolong belt life by a considerable degree, up to a factor of 10 in some cases (Nordell, Palabora Installs Curved Transfer Chute in Hard Rock to Minimize Belt Cover Wear, 1994).

Figure 9 shows the completed 3-D model of the tail feed chute. Figure 10 shows the DEM simulation of steady-state material flow through the tail chute at the design tonnage.

This chute uses a curved hood deflector to consolidate and direct the material flow toward the center of the receiving belt. A curved receiving spoon takes the impact of the falling material and redirects the flow stream to be tangential to the belt motion. The drop height between the head pulley on the discharge conveyor and the belt determines the material speed as it exits the receiving spoon.

Figure 11 shows the completed 3-D model of the booster station chute. Figure 12 shows the DEM simulation of steady-state material flow through the chute at the design tonnage. The interior of the chute includes two separate impact and material speed control surfaces: an inclined launder section with no curve to keep the material from hitting the belt at low speeds, and a lined hood section with converging sidewalls which reduces the material speed during the drop to the belt and centers the material on the receiving belt.

All the chutes were carefully designed to keep dust entrained in the main material flow and include settling zones where dust entrained in the air settled back onto the belt before the air exhausts into the environment.

Booster station structure

Figure 11 shows the chute end of the booster station structure CDI designed. This design also included an extended ramp to bring the belt line up to the level of the Drive 1 pulley. CDI provided the structure design and determined the foundation loads for



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Figure 12

DEM simulation of tripper chute.

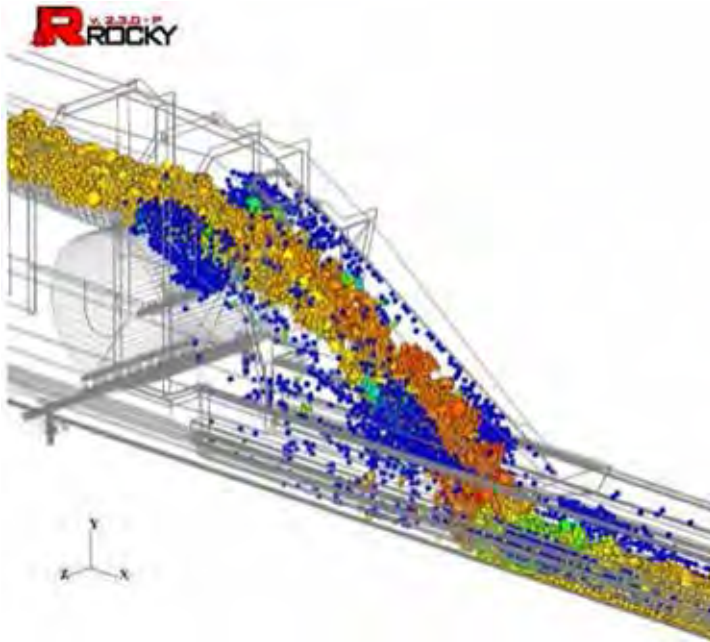


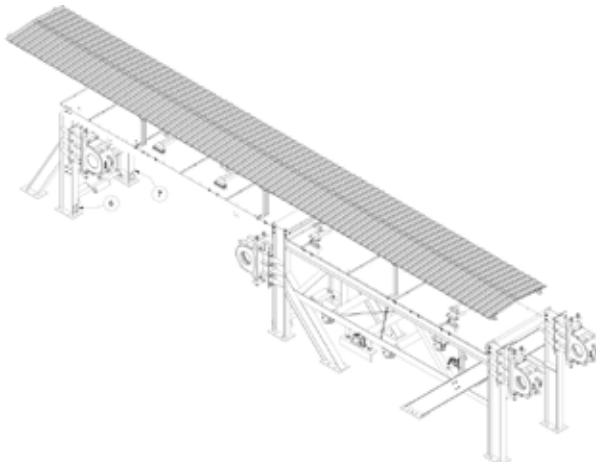
Figure 13

Booster station approach ramp.



Figure 14

Drive frame.



the entire booster station.

CDI sectioned the structural assembly into easily fabricated modules that fit in hot-dip galvanizing tanks, are easy to transport and assemble in the field. The design includes three main assemblies: an approach ramp, the drive frame and the skirt board frame.

The “approach ramp” (Fig. 13) is 138-m long x 2.4-m high x 3.8-m wide (453-ft long x 7.11-ft high x 12.5-ft wide), the ramp sits on an inclined slope with a ground level rise of 3.6 m (12 ft). Access walkways were included on both sides of the ramp. The belt storage loop, with its stationary take-up trolley and winch and the rail system it runs on are mounted underneath the ramp.

The drive frame (Fig. 14) is 15.7-m long x 3.3-m tall x 2.2-m wide (51.6-ft long x 11-ft tall x 7.3-ft wide). This structure supports three drives: Drive 1, Drive 2 and Drive 5. It also supports the tail end of the tripper chute.

The “skirt board frame” is 9.2-m long x 2.2-m high x 2-m wide (30-ft long x 7.3-ft high x 6.6-ft wide) (Fig. 15). This structure supports most of the tripper chute weight as well as the skirt board, impact idlers, and the material and belt loads.

Summary

The capital and operating expenses associated with long overland conveyors are substantial. However, significant cost savings are achievable when the designer understands that many of the rules of thumb that apply to short conveyors do not apply to long belts. Long belts differ from short conveyors in several ways including: high tensions that lead to less belt sag, longer time to complete a belt rotation leading to longer belt life, and large operating costs that justify low rolling resistance belting and idlers. The large investment in construction materials and time on long conveyors justifies devoting significant engineering hours to optimizing the conveyor assemblies. Even small differences in ground module weight and erection time lead to large savings when 27 km (16.7 miles) of ground modules are needed.

At Impumelelo, CDI utilized the most advanced technology available to optimizing the system. It reduced the number of transfer towers, reduced the structural steel weight, reduced the number of idlers and pulleys, reduced the installation time, cut the operating costs, and improved the availability of the system. CDI also reduced the noise, reduced the visual impact of the system, reduced dust emissions.

This paper highlights the complexity of

Figure 15

Skirt board frame.

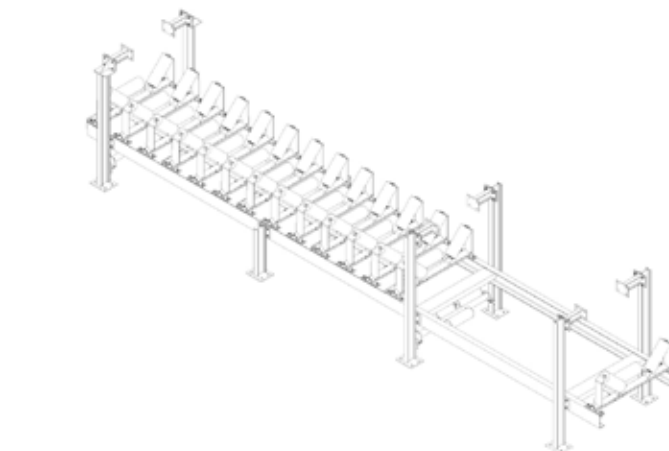
optimizing an overland conveyor to maximize the reliability and availability of a conveyor while reducing its cost. It is a flagship for state of the art conveyor engineering that clearly demonstrates the advantages of using modern engineering tools and a strong understanding of the science of conveying to design overland conveyors. ■

Acknowledgments

The author would like to acknowledge the substantial work others contributed to the Impumelelo project including CDI's former president Lawrence Nordell, CDI's Jason Aldrich, who led our drafting team, ELB's project manager Manny Marques, ELB's engineers Douw de Necker and Adi Frittella and Conveyor Belt Technologies' Larry Kuzik who led the team that pulled and spliced the belt.

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Report confirms struggle in coal country; About 50 percent of jobs in 2011 have been lost in five years

A NEW REPORT FROM Standard & Poor's found that the number of coal jobs in the United States has fallen by nearly 50 percent from its peak in 2011.

The report found that the hardest hit communities were Boone County, WV; Pike County, KY and Campbell County, WY.

The statistics confirm the difficulty that many in the industry have struggled with as the price of coal hit a 30-year low. But the numbers might also suggest that coal companies are adjusting to a new normal, finding a balance with fewer employees and lower production, the report said.

There is uncertainty about whether the drop in employment in places like Campbell County is a short- or long-term phenomenon. The issue hinges on whether this bust is a temporary dip in the commodity cycle or a permanent shift in the way the United States receives its electricity, *The Wyoming Tribune Eagle* reported.

Future restrictions on greenhouse gases underline the fact that coal will face more than just a market battle in the coming decades. That will cut into profits and pose a risk

to communities that rely on coal for their livelihoods.

The U.S. Energy Information Administration projections of how coal will weather the Clean Power Plan are not promising.

Under the plan, the administration reports, coal production in the West will decrease by 140 Mt (155 million st) between 2015 and 2040.

Powder River Basin coal, which benefits from its low mining costs and low amount of sulfur, accounts for about two-thirds of that production.

Last year, the West accounted for 55 percent of the nation's coal production. Under the Clean Power Plan, that could drop to 52 percent.

Moreover, natural gas continues to be a major competitor for coal, both in terms of emissions and its relatively cheap price, thanks to new drilling technologies, analysts say.

Despite market pressures, Campbell County remains the strongest producer of the 25 counties in the report, with 46.5 Mt (51.3 million st) of coal mined in the second quarter of this year. That's approximately half what was mined in the fourth quarter of 2011. ■