

# Boddington gold mine's expansion project includes overland conveyor

By Todd Hollingsworth and Tyler Harris

The Boddington gold mine is located near Perth in Western Australia in the Saddleback Greenstone Belt, a fault-bounded sliver of Archaean volcanic and shallow level intrusive rocks, surrounded by granitic and gneissic rocks. The mine began operations in 1987, producing about 7.7 t/a (250,000 oz/year) until mining ceased in 2001. Built on the footprint of the original mine, the Boddington gold mine expansion project involved open-cut mining from two large pits. Expected gold production is around 31 t/a (1 million oz/year) for the first five years. It will be the largest gold mine in Australia. The mine has proven and probable reserves of more than 622 kt (20 million oz) of gold and has an expected life of more than 24 years. The mine is currently solely owned by Newmont Gold Corp., the world's second-largest gold mining company, employing around 28,000 people worldwide.

The conveyor and belt feeder contract for the Boddington gold mine expansion project was awarded by Aker Kvaerner Clough Murray Roberts (AKCMR) to FLSmidth Conveyor Engineering Inc. in August 2006. The contract involved the design and manufacture of 15 conveyors and 17 belt feeders with belt widths ranging from 450 mm to 2.4 m (18 in. to 96 in.) and conveyor lengths from 16 m to 2,172 m (52 ft to 7,125 ft). The total motor power added up to more than 16,700 kW (22,400 hp). The total length of all belting was almost 11.5 km (7.1 miles), and the total fabricated steel weight was approximately 3.7 kt (4,100 st).

## Overland operation and drive technology

The overland conveying circuit starts below two gyratory crushers where the primary crushed ore is carried up through a tunnel on a 2.2-m- (86-in.-) wide acceleration conveyor that discharges onto the overland conveyor. With a capacity of 8 kt/h (8,880 stph), the overland conveyor's 1.8-m- (72-in.-) wide belt runs a distance of 2,172 m (7,125 ft) with a rise of 120 m (394 ft) up to the top of 40-m- (131-ft) high stockpile. Dual 2,800-kW (3,745-hp) motors drive the conveyor at almost 4.5 m/sec (900 ft/min).

A dynamic analysis was performed by Overland Conveyor Co. to determine starting, stopping and upset condition tensions as well as to define the starting and stopping characteristics for the motor control system. The drive system selected to control the starting and stopping was a wound rotor motor and liquid resistance starter that controlled the amount of torque applied to the drive pulleys.

A closed loop starting sequence that varied the torque of the wound rotor motor was used to control the starting time. By controlling the starting torque and time, the overall peak starting belt tensions were minimized. First, the drive system brought the pulley rpm to 10 percent of full speed. A velocity PID loop then took control

**Figure 1**

Boddington overland conveyor.



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# Conveyors

## Design parameters

Material gold ore:	
Capacity	8 kt/h (8,800 stph)
Width	1,800 mm (72 in.)
Speed	4.471 m/s (0.459 ft/s creep)
Conveyor length	2,162.8 m (7,095.8 ft) (horizontal)
Conveyor length	2,172.7 m (7,128.2 ft) (along belt line)
Conveyor lift	120.6 m (396 ft)
Belt	Contitech ST4500
Carry idler space	1,500 mm (59 in.)
Installed power	2 x 2,800 kW (2 x 3,755 hp) primary 2 x 75 kW (2 x 100 hp) creep
Operating temp.	-5.7 to 45.6° C (21.7 to 114° F)
Counterweight	36.7 t (40.4 st)

and held the 10 percent speed for 15 seconds. This 15-second dwell time allowed the entire length of the belt to break away and start moving. Finally, the drive system brought the conveyor up to full speed during an additional 65 seconds.

Stopping the fully loaded conveyor by simply removing power from the drives could create a tension wave that could have an adverse affect on the system. While the conveyor was designed to handle this tension wave, a controlled stop that minimized this tension wave was preferred. For this reason, two stopping modes were defined. Mode 1 was used if the full speed running torque of the conveyor was greater than 50 percent torque. In this mode, the drive system would gradually reduce torque to 30 percent over 30 seconds. At the end of the 30-second ramp, the drive system would disengage and allow the conveyor to coast to a stop. Mode 2 was used if the full speed running torque was less than 50 percent torque. In this mode, the drive system would disengage and allow the conveyor to coast to a stop.

The dynamic analysis showed that the tension

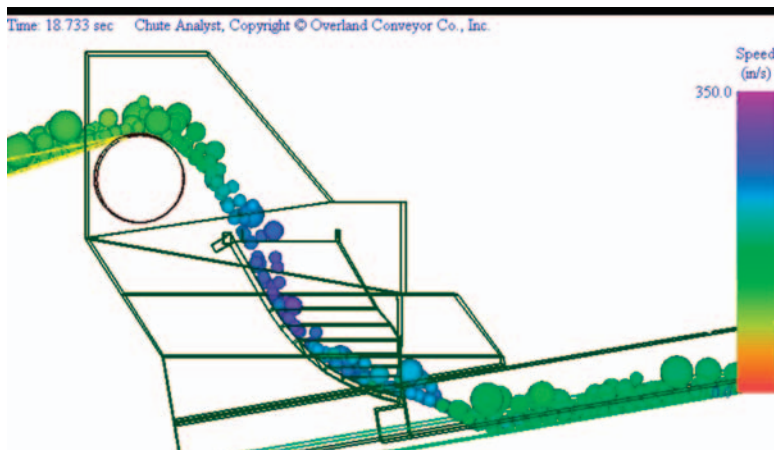
wave created by an aborted start would cause excessive belt sag near the tail of the conveyor. With the overland conveyor being an uphill demand conveyor, conventional design called for the drive and gravity take-up systems to be located at the head end of the conveyor. As the gravity take-up moved to compensate for the tension wave, a secondary wave would be created. This pattern would build upon itself, creating an unstable condition that resulted in the excessive sag near the tail. This predicted sag at the tail was enough to cause possible failure of the carry idlers and to pose a potential safety hazard for mine personnel. To control this situation and prevent a safety hazard, the following solutions were discussed:

- Flywheels – to dampen the primary tension wave by extending the stop time.
- Winch take-up – to eliminate the secondary tension waves by locking the take-up pulley.
- Capstan – to eliminate the secondary tension waves by locking the take-up during an aborted start.
- Relocation of the gravity take-up to the tail area – to allow better reaction by the gravity take-up to the tension wave.

Due to the overall dynamic operation of the overland, the preferred take-up system was a gravity take-up. Therefore, the winch take-up was immediately removed from the list of possibilities. Of the remaining options, the simplest and most cost effective option was to relocate the take-up to the tail area. By doing this, the take-up could react quickly to the dynamic tensions at the tail. The final dynamic analysis indicated that, while secondary tension waves would still be induced into the system, the tail location for the take-up would not cause an unstable or hazardous condition.

## Figure 2

### DEM model of transfer onto the overland conveyor.



### Transfer chute design

Since the belting was the most costly component of the system, it was important to maximize the belt life. To do this, an analysis of the transfer onto the overland was performed using discrete element modeling (DEM). The DEM analysis aided in the placement of the chute walls and wear surfaces in order to direct the material properly onto the belt (Fig. 2). The final design used a curved loading chute to place the material onto the belt, minimizing the possibilities of cut and gouge damage, abrasion damage and impact damage from the large rock being conveyed.

The primary disadvantage of the curved chute design is a high wear rate on liners. Three liner

types were considered for the project: abrasion resistant (AR) plate, clad overlay plating and ceramics. Samples of all three were sent to TUNRA at the University of Newcastle for wear testing. The AR plate showed the highest wear rate, while the clad overlay and the ceramic tiles wore at about the same rate. The next step was to compare the capital costs and cost per millimeter of wear for a 300 x 300 square piece of liner. The capital cost for the AR plate and the clad overlay were very similar, while the ceramic liners were about 11 percent more expensive. However, the cost/mm wear for clad overlay was three-fourths the cost/mm wear of AR plate while the cost/mm wear for ceramics was one-third that of AR plate. Ultimately, ceramic liners were chosen for the project based on their cost/mm savings.

To aid in liner maintenance, a quick-change chute design was developed. This design included a fixed internal frame with three sections of liner walls (back, left and right) that could be quickly and easily lifted out of the top of the chute. Once the walls with worn liner were removed, a second set of liner walls could then be lifted into place and the conveyor system could be restarted. The walls with the worn liners could then be taken to a maintenance shop for liner replacement, while the conveyor was operational.

## Overland components

A concerted effort was made to source as much equipment as possible from within Australia. However, due to the sheer size and specialized nature of some of the equipment, the project became international in scope. Major components were sourced from within Australia as well as from Greece, Belgium, the U.S., Denmark and Taiwan.

## Steel fabrication

When the project fabrication began, the steel industry in Western Australia was booming. To meet the steel delivery milestones for the project, the fabrication was split between two Western Australian fabricators. The limiting factor then became a single painting contractor being used by both companies. A significant effort was put forth in order to monitor the fabrication and painting processes and keep the completed steel moving out of the shops.

## Motors

The motors were purchased from Teco



Taiwan through a single source contract between Teco and Newmont Boddington Gold Mine. Both squirrel cage induction motors with VFD's and wound rotor motors with liquid resistors (LRS) were considered for controlling the starting and stopping of the overland. The final design of the overland conveyor was based on wound rotor motors due to their capital cost savings. The LRS were selected and supplied by AKCMR through an Australian supplier. The LRS were used to vary the motor torque during starting and stopping. This varied torque allowed for extended soft starts and stops that minimized dynamic tension waves during these transient conditions.

The dual 2,800-kW (3,755-hp) motors performed load sharing by means of trimming resistors. Once the motors reached full speed, the main LRS system was bypassed and fixed trimming resistors were used to tune the motor output torque. The tuning of these trimming resistors was done by the LRS supplier during commissioning of the overland conveyor.

Liquid resistors use a solution that creates a resistance between electrodes. The resistance changes as the electrodes are inserted and/or withdrawn from the solution. This, in turn, creates a change in the available motor torque from the wound rotor motor. One drawback to liquid resistors is that the torque characteristics can change dramatically with the temperature of the solution. An increase in solution temperature from 15°C (59°F) (cold start) to 60°C (140°F) (hot start) would increase the initial starting torque from 60 percent to 130 percent. To compensate for this, a closed loop control system was used during starting. The control system monitored the speed of the conveyor and increased or decreased the torque by raising or lowering the electrodes, so that the conveyor would follow a

**Transfer onto the overland conveyor.**

# Conveyors



**Overland conveyor drive system.**

predefined speed curve. In addition to the closed loop controls, heat exchangers were installed to maintain as consistent a temperature as possible in the solution.

## **Gear reducers**

Parallel shaft floor mount reducers from Hansen Belgium were used as the primary reducers on the overland conveyor. These main reducers were coupled with a creep drive unit installed on the high-speed shaft. The creep drive was used to allow for low-speed inspection of the conveyor while running empty.

The wound rotor motors could have been used to provide the creep operation of the conveyor. However, the heat generated during high-slip, slow-speed operation in the LRS fluid would have required a much larger cooling system. Therefore, a simple secondary creep drive with a low-voltage VFD was used for slow-speed creep operation.

**Overland conveyor drive motors.**



If the primary motor was to be energized while the creep drive was engaged, the creep drive motor would go into an extreme over speed condition and potentially fail, creating a hazardous condition to any individuals and equipment near the system at the time of the failure. A manual clutch with a Fortress Trapped Key system was used to engage and disengage the creep drive. The Fortress Trapped Key system ensured that the primary motors could not be energized while the creep drive clutch was engaged.

## **Backstops**

Backstops from Marland USA were used as the primary system to prevent the conveyor from rolling backward. Since there were dual drives, a load sharing system designed and supplied by Marland was employed to prevent either backstop from being overloaded. The backstop torque arm was supported on a set of cushions that would deflect when load was applied. This deflection allowed a slight rotation in the pulley that, in turn, allowed the second backstop to engage. The net result was a load-sharing effect between the two backstops.

Australian safety code required a secondary backstop system to be installed on the conveyor. To satisfy this requirement, failsafe high-speed brakes from Svendborg in Denmark were installed on the high-speed shaft of each drive unit. Under a normal stop, the brakes were held in the released position until the conveyor speed dropped below 10 percent. The full brake torque would then be applied in a parking brake mode. A backup system with delay timer was included in the brake controller in order to mechanically apply the brakes safely in the event of a power failure.

## **Pulleys**

Pulleys were purchased through Tefco, Australia. The designs included turbine type end discs, with both running and starting tensions being evaluated in order to produce an infinite life design for the pulley and shaft.

The pulley bearings included a dual seal arrangement, with a V-ring outer contact seal and triple labyrinth inner seal. This arrangement was selected in order to provide protection from dust and water ingress without having the added grease points of an independent “taconite” type seal.

Both drive pulleys included ceramic lagging consisting of ceramic tiles embedded in a base rubber. The ceramic lagging increased the available friction of the drives and decreased the amount of counter weight required at the take-up. This, in turn, allowed for lower overall belt tensions in the system.

## Belting

Steel cord belting was purchased through Contitech's IMAS facility in Greece. Due to the shipping roll sizes, race track cassettes were used for the belting instead of standard rolls. The steel cord belting included inductive rip detection sensors that were monitored at the loading station to alert the control system and shut down the conveyor if a belt rip occurred.

## Idlers

Idlers were purchased through Tyton, Australia. The project specification required that the idlers be designed for an L10 life of 100,000 hours. Also, because the overland conveyor was located between the two main ore pits at the site, the idlers were required to have contact seals to protect the bearings. The seal selected included an outer contact seal, two grease-filled chambers and two inner contact seals. This was deemed the best solution to keep the highly abrasive dust found at Boddington away from the idler bearing and to maximize the idler bearing life. Since the most significant component of the conveyor power and tension calculations was the force required to lift the material from the loading point to the discharge pulley, the extra seal drag did not appreciably affect the overall power and tensions.

## Take-up

The take-up tower was designed with a continuous wire rope that started at the take-up structure, reeved through the take-up carriage, then through the take-up weight and terminated at a take-up winch. This design allowed mine personnel to lower the take-up weight to the ground during maintenance without the need for a crane.

Since the winch was directly connected to the active working cable, the winch safety factor had to include the dynamic tensions that could be realized in the cable. This resulted in a winch rating of 25.5 t (28 st) with a minimum M6 classification.

## Pull wire and belt alignment safety switch monitoring

There are 94 pull wire switches and 32 belt alignment switches distributed along the 2.17 km (1.3 mile) length of the overland conveyor. Smart switch technology was used at each of these 126 locations to minimize wiring, yet allow the control room to know the status of each individual switch. The switch addressing system and its associated master control panel were designed and supplied by Austdac, Australia and incorporated Dupline safety relay components. The specific system selected for the Boddington overland carries a SIL 3 safety rating. A SIL 3 rating indicates that



the system can be used in place of a hardwired safety circuit.

Each pull wire switch included a built-in safety relay module. The belt alignment switches were purchased from a separate supplier and were wired to external safety relay modules. The safety relay modules communicated to Austdac's master control panel through an addressing system. The addressing system indicated the status of each switch and opened an emergency stop relay in the master control panel if any emergency stop switch was activated. The plant control system was then hardwired directly to the emergency stop relay.

## Conclusion

The overland conveyor system was successfully completed and operational as of April 24, 2009. It was one of the first systems to come online at the mine. In the months that followed, the remainder of the plant was completed and, in September of 2009, the Boddington gold mine expansion project poured its first bar of gold and shipped its first truckload of copper concentrate to the port. ■

**Overland conveyor backstop (top) and take-up area (bottom).**