Unique Hybrid EPB Design for use in Coal Mine Drifts

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1. Introduction

The history of mechanized tunneling for mine exploration and access tunnels started more than fifty years ago with the Steep Rock Iron Mine in northwestern Ontario, Canada. The use of Tunnel Boring Machines (TBMs) in mines continued through the 1960s and 1970s, achieving high rates of excavation in soft rock, but their applicability was limited and their costs too high. Despite the drawbacks, their fast rates made them an attractive option and TBMs continued to be used sporadically in mines, particularly in Europe. Between the 1970s and 1990s, over 100 km of tunnels were bored by Robbins machines in European hard rock mines.

In the last two decades, with further technological advancements and increasing awareness of the potential benefits, several mining projects have seen the successful application of TBMs. The projects feature variable ground conditions from harder to less-competent to heterogeneous rock, from open-face machines to earth pressure balance TBMs.

In the growing mining industry, demand for rapid excavation, along with the highest quality and safety standards (to develop new ore bodies faster and reduce development costs and risks) seems to justify the higher capital investment associated with a TBM.

The switch to mechanized mining becomes even more beneficial as ore bodies are becoming deeper and more complex, requiring design and development of very large underground mines, and with that tunnels and shafts.

Today, the versatility of TBM technology has been extended to the unique demands of the Australian mining industry, where ore bodies are already being identified in deep locations. In Australia, road headers were once the most popular choice for decline tunnels to access coal seams, but TBMs are primed for a revival.

2. Grosvenor Coal Mine: Main Project Features

The Grosvenor Decline Tunnel is an ASD $1.95 billion Greenfield metallurgical coal project owned by Anglo American in Moranbah, Central Queensland, approximately 180 kilometers southwest of the coastal port city of Mackay and about 1000 kilometers north of Brisbane. Located just south of the Moranbah North coal mine, it targets the same Gonyella Middle coal seam as the Moranbah mine, and it is expected to produce five million tonnes of coal per annum from its underground long wall operation over the next 26 years.

The Grosvenor Coal Mine has a planned expansion in which two decline tunnels will be required for mine access to the coal seam at the shallowest depth of 130 meters. Longwall panels are planned to be 300 meters in width with lengths up to 6200 meters. The first decline tunnel (Conveyor Drift) will transport the coal from the long wall to the stockpiles area on the surface; the second decline tunnel (Transport Drift) is designed for people and equipment to access the underground once the mine is operational.

For the first time in the Queensland coal industry, a TBM methodology has been developed to excavate both drifts and contribute to construction of the “world-class long wall mine” envisioned by Anglo American. Stability, safety, quality and schedule have been the key factors in the selection of this technology.

Construction on the Grosvenor project started in July 2012, with more than 3,000,000 cubic meters of earthmoving, more than 13,000 cubic meters of reinforced concrete and a team of 700 people at work on a 24/7 schedule. Commissioning of the long wall is targeted for late 2016 and the coal will be processed through the existing Moranbah North coal handling and preparation plant and train loading facilities.

3. Drift Geology and Layout

Geology along both drifts’ alignments consists of varying soil and rock conditions. The soft ground portion consists of sand, sandy clay, clay and conglomerate. The mixed face/rock portions consist of siltstone, coal, sandstone and basalt. Rock hardness ranges from 20 to 120 MPa with an average of 90MPa UCS in the sandstone portions (see Figure 1).

Both decline tunnels are approximately 1,000m at a grade of 1:6 or 16.7% (Conveyor Drifts) and 1:8 or 12.8% (Transport Drift). Except for the vertical curve between the assembly area on surface and the launching tunnel (400 meters radius) there are no curves along both drifts’ alignments (see Figure 2).

The geology along both alignments changes from soft clays and soil (in the first 300 m) to sandstone and basalt as the tunnels extend down the decline. Methane gas is present along the alignments with higher concentration in some intermediate coal layers and at pit bottom. The possibility of high water inflows is low.

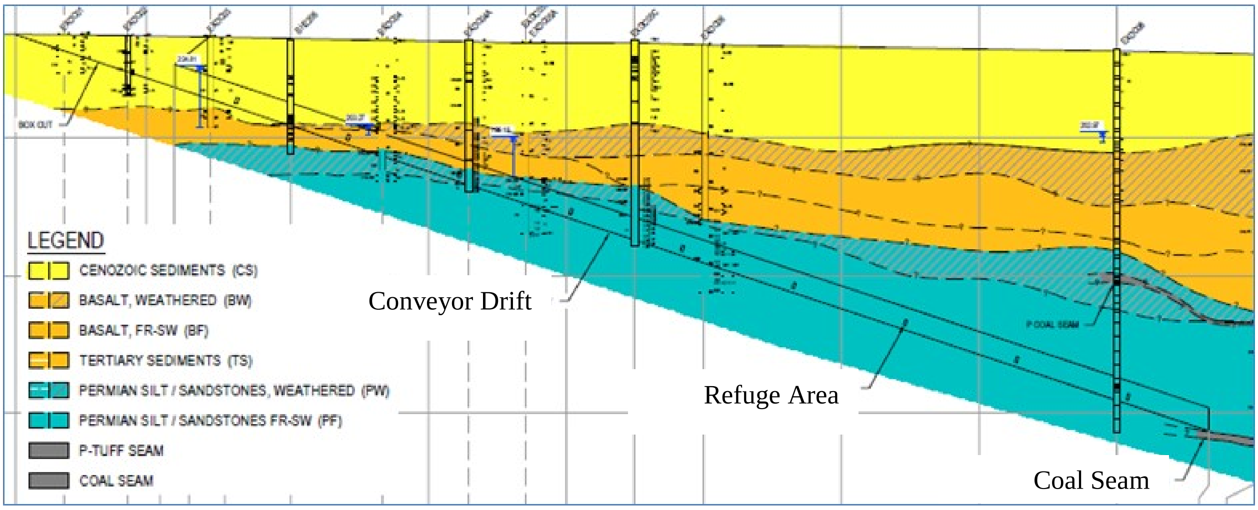


Fig. 1 Grosvenor Coal Mine – Conveyor Drift Geotechnical Long Section

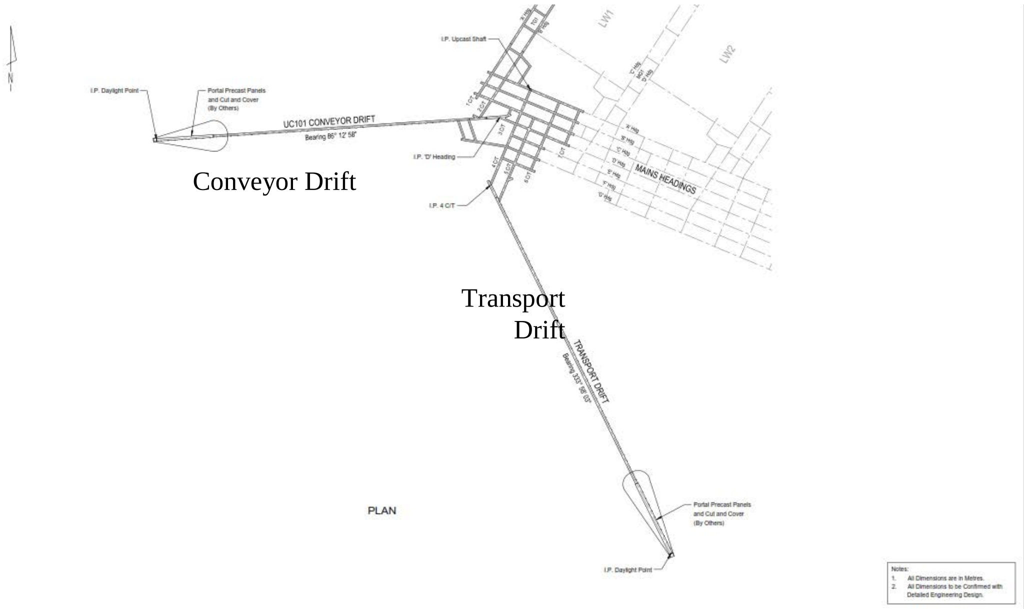


Fig. 2 *Grosvenor Coal Mine – Conveyor and Transport Drifts plan view*

Each drift will have an internal diameter of 7.0 m and consists of a steel-fiber-reinforced concrete segmental lining (universal ring in 5+1 segments). A special flat segment placed on the I.D. of each ring, at the invert level, allows Multi Service Vehicles (MSVs) to transit along the tunnel (see Figure 3).

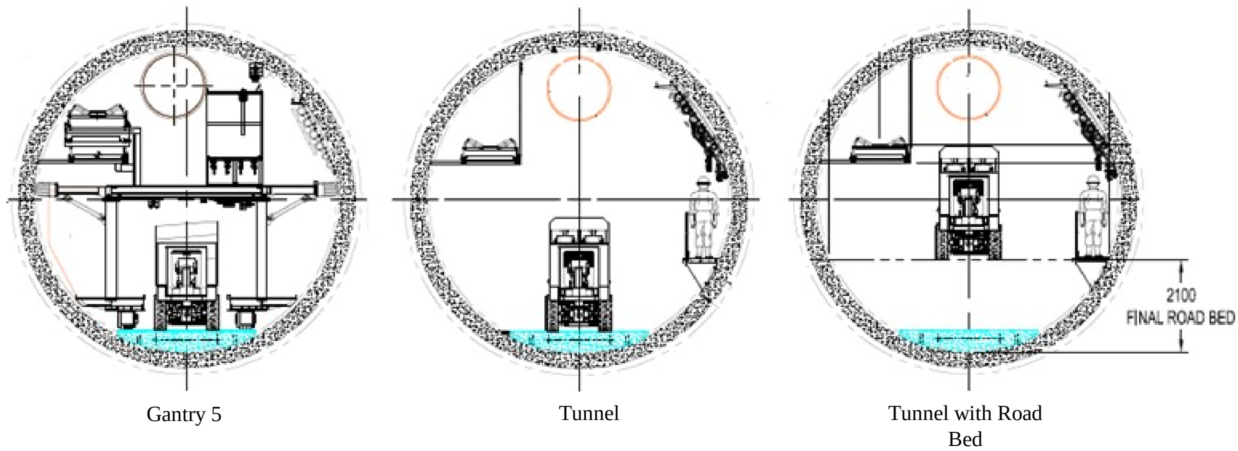


Fig. 3 *Tunnel Cross Section showing Invert Segments*

After completion, an additional 2.1m of concrete will be cast on top of the flat invert to raise its level and increase the width of the road to approximately 6.4m meters. This will allow transit of larger production and service vehicles during the coal production stage (see Figure 4).

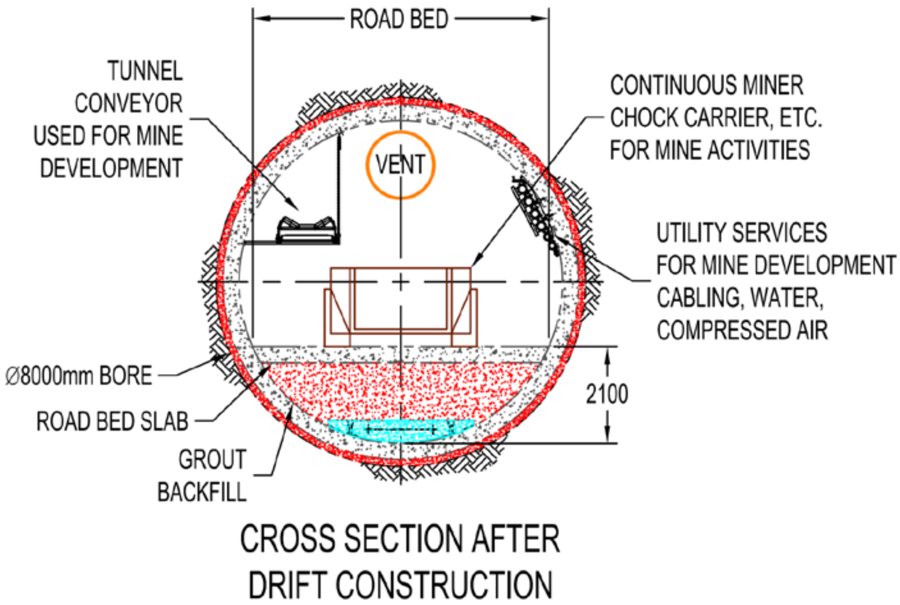


Fig. 4 Tunnel Cross section during the Coal Production Stage (6.4m wide x 4.9m high)

4. TBM Design Criteria and Special Features

In August 2012 Anglo American awarded the contract for the supply of TBM, Back-up equipment and Tunnel Conveyor system to The Robbins Company.

Any of the existing standard design TBMs commonly used for civil works would not have been appropriate for the Grosvenor coal mine application, due to the variable geology and gassy conditions. For this reason a “purpose built” machine with special features was designed and built by Robbins not only to efficiently bore mixed face conditions while installing pre-cast concrete segments as final lining, but also to:

- operate safely in the coal mine environment with the possibility of methane gas;
- build multiple decline tunnels within the same coal mine development.

Risk assessments performed with the project team (Client, Contractor and Equipment supplier) provided the basis for critical TBM design and tunnel construction decisions.

Risk Assessment, design and production processes were jointly reviewed on a weekly basis with the Underground Mine Manager (UMM), Electrical Engineering Manager (EEM) and Mechanical Engineering Manager (MEM) responsible for acceptance and compliance of the machine to the QLD coal mine requirements.

4.1 TBM General Description

The Grosvenor TBM is a Robbins 8.0 m High Performance (H.P.) Rock/Mixed Face Convertible Shield TBM. The hybrid TBM is capable of conversion between a pressurized, EPB mode, and a non-pressurized, Single Shield mode. Because of the requirement to swiftly build two blind tunnels while maintaining full ground support, the machine was also designed for quick disassembly so that it could be re-launched on a second tunnel. The TBM is fitted with a back-loading cutterhead (for use with Robbins 17-inch Wedge Lock disc cutters) powered by 12 x 330 kW explosion proof electric motors for a total installed cutterhead power of 3,960 kW (see Figure 5).

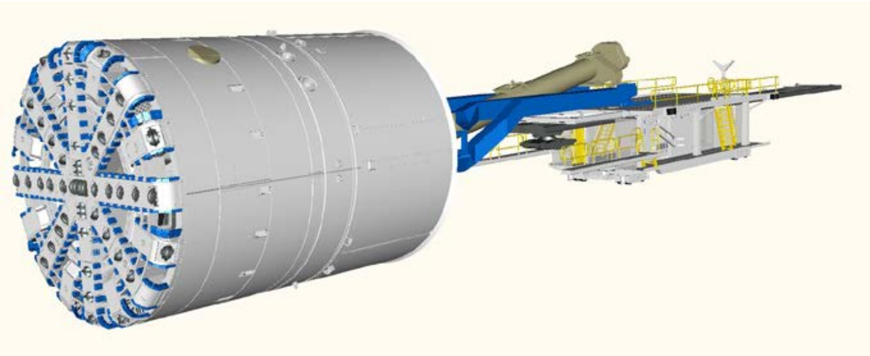


Fig. 5 *Isometric view of the Grosvenor TBM fitted with disc cutters.*

The cutterhead is designed to operate in different modes, depending on the type of ground being cut. First, it can be used in EPB mode with cutting bits, a relatively open mixing chamber, and a screw conveyor for muck pick-up. Second, it can be operated in rock mode by changing out the knife bits with disc cutters, the scrapers with bucket lips, adding modular radial loading plates into the mixing chamber, sliding forward the hopper built into the center bulkhead, and extending the screw conveyor forward into the mixing chamber, underneath the hopper.

The screw conveyor consists of two augers (front and rear) mounted in series and articulated at the junction by a spherical joint to allow for movement in tunnel curves. Both screws are driven by two hydraulic drives delivering up to 115kNm each. Also the screw conveyor is designed to operate in the changing ground conditions and cope with potential gassy conditions. The mixing chamber and the screw conveyor form a sealed chamber. Methane gas may be contained within the excavated material flowing through the screw conveyor, which will escape and be removed at the conveyor discharge by the snuffing box (a steel frame bolted to the discharge gate). The suction created at the screw conveyor discharge draws the methane inside the main duct and out of the tunnel.

Injection ports are installed along the screw conveyor that can be used to inject ground conditioning to facilitate the flow of material and prevent sparks generated by the friction of rock/rock and metal/rock.

The forward shield consists of two concentric steel rings (inner and outer shields). The inner shield is made of 4 pieces + 1 key segment for easy disassembly from the first tunnel, to be re-used in the second drive. The outer shield is made of two pieces, lower and upper, with the same thickness as the segment ring to allow for lining continuity after the inner ring is removed. The outer shield, once grouted and left in place as final tunnel support, also allows for safe disassembly of the machine core with no work under exposed rock.

The rear shield is also designed in two concentric rings to fulfill the same requirements. All shield platforms, bridges, walkways and back-up installations account for the tunnel gradient with equipment and frames tilted at the same angle. See figure 6 and Table 1 for more detail.

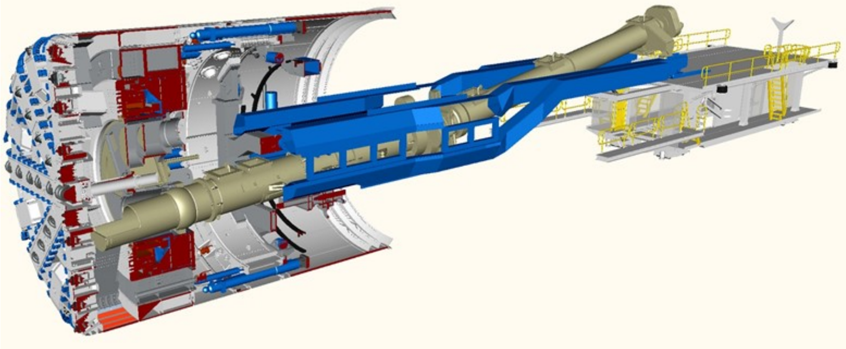


Fig. 6 *Cutaway view showing screw conveyor setup.*

Table 1. Technical Data for the Robbins Hybrid/Dual Mode TBM

MACHINE TYPE	**Dual Mode EPB/Rock TBM**
Design Parameters	
Bore Diameter	**8.0 m**
Total length	**135 m**
TBM weight	**994 tonne**
TBM core weight	**399 tonne**
Back-up system weight	**552 tonne**
Number of segments	**5+1 key +1 flat invert**
Segment width	**1,400 mm**
Segment thickness	**350 mm**
Curve radius (vert. and horiz.)	**400 m**
Gradient	**1:6 and 1:8**
UCS	**Max 100 MPa**
Hydrostatic Pressure	**3 bar**
TBM Specifications	
Cutterhead	**Mixed ground, convertible**
Cutters	**17” disc cutters, back-loading**
Cutterhead Power	**12 x 330 kW = 3,960 kW**
Cutterhead Speed	**0-6.4 RPM**
Breakout Torque	**17,344 kNm**
Maximum Thrust	**22,619 kN**
Screw Conveyor Type	**Double, shafted, hydraulic drive**
Methane Monitors	**6 locations**
Explosion-Proof EPB Sensors	**10 locations**
Segment Backfill	**Bi-component grout**
Probe Drill/Grout	**18 peripheral ports; 1 drill**

4.2 Operation in Gassy Conditions

Not only was the TBM to operate as a hybrid design capable of swift disassembly, but also as an explosion proof unit. Excavation of the drifts was to start in soft ground formations at the surface, then continue into rock as the drift got deeper, then finish when the TBM intercepted the target coal seam. Because of the varying strata, and the expectation of hard and abrasive basalt in the deeper sections, the TBM was set up as a “convertible EPB” style machine, or hybrid TBM. The machine could operate in Open Mode or Closed Mode, as described below. Some hybrid machines use an interchangeable screw or belt conveyor when switching modes. In the Grosvenor case, the screw conveyor was kept for both modes as it was thought that the screw and closed bulkhead would help contain any methane liberated at the face. The screw was made with abrasion and spark resistant materials and with a suction duct at the discharge hood, to safely channel and extract gas if encountered. Operational features in the different modes are described below.

CLOSED/EPB MODE

- Closed bulkhead, Earth Pressure Balance (EPB) operation with pressure maintained at the face
- Cutterhead fit with bi-directional scrapers for muck pickup
- Control of shield body roll by alternating CW/CCW cutter head rotational direction
- Ground treatment additives injected via CH nozzles, via the bulkhead, or via ports in the screw conveyor
- Screw conveyor position within the muck chamber set by casing spacers. Screw conveyor protrudes slightly in front of the closed bulkhead. EPB pressure helps feed material into the screw
- EPB pressure within the chamber maintained by adjusting the TBM advance rate, screw rotary speed, and screw discharge gate opening size.

OPEN/ROCK MODE

- Bulkhead fitted with suction ports to draw air/gas from the top of the chamber
- Cutterhead fit with single-direction muck pickup buckets and loading plates
- Control of shield body roll by slew adjustment of thrust cylinders
- Ground treatment additives only needed for spark prevention, dust control on the tunnel conveyor, and for wear reduction
- Screw conveyor extended further into muck chamber by adjusting casing spacers
- Gravity loaded hopper formed by extension of the bottom half of the screw casing (forming a “trough”) and by extending hopper panels through the bulkhead
- Screw operates only partially filled, without any “plug”

4.3 Operation in Coal Mine Environment: Compliance to Coal Mine Regulations

As the geology consists of soft soils to hard rock with sections of mixed face and potential gassy conditions, an EPBM type machine is used to maintain a positive face pressure for the excavation of the soft material and also to contain the methane gas where it can then be diluted or removed from the heading.

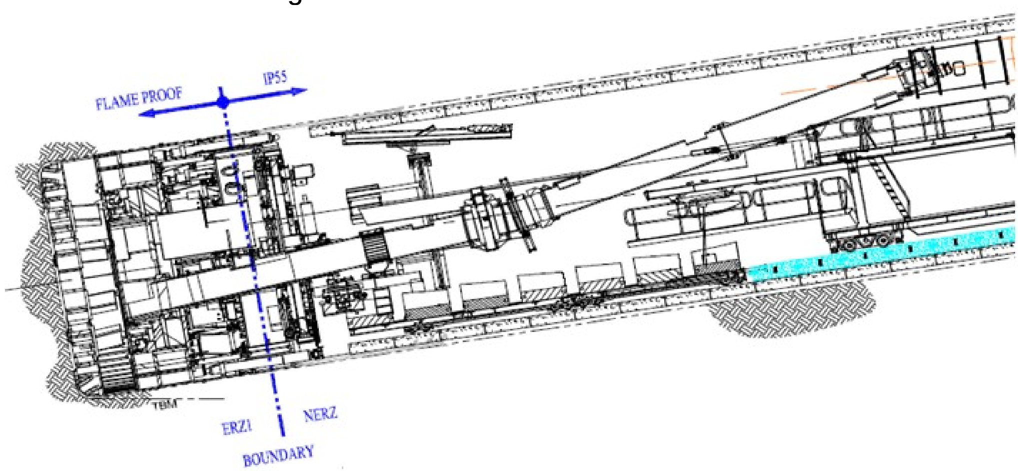
At the very beginning of the design process (August 2012) an extensive risk assessment was conducted by owner, contractor and OEM on the proposed machine layout, to determine the potential areas (zones) of accumulation and flow of methane gas.
In accordance with the Queensland Coal Mine Standards, these zones are classified as:

- NERZ (Negligible Explosion Risk Zone) with methane concentration <0.5%;
- ERZ1 (Explosion Risk Zone) with methane concentration between 0.5 and 2.0%;
- ERZ 0 with methane concentration >2.0%.

In order to trace the potential flow of methane, the drifts have been divided into seven separate sections with different potential energy release mechanisms. The release mechanisms within each section were then analysed and recorded together with the preventive and mitigation controls:

- Cutterhead and TBM power interlocking when methane gas detected exceeds the predetermined CH4 levels;
- Gas management as per Trigger Action Response Plan (TARP);
- Extraction ventilation (snuffing box at discharge of screw conveyor and extraction from into the shields);
- Foam injection system;
- Flame proof cutterhead bulkhead/main drive and screw conveyor;
- Gate valves on both sections of the screw conveyor;
- Fan station interlock to the TBM power supply.

In consideration of the potential gas leakage paths, operating scenarios and above controls, the NERZ-ERZ1 boundary was located 1 meter behind the probe drill/grout injection ports in the TBM shields as shown in Figures 7-8.



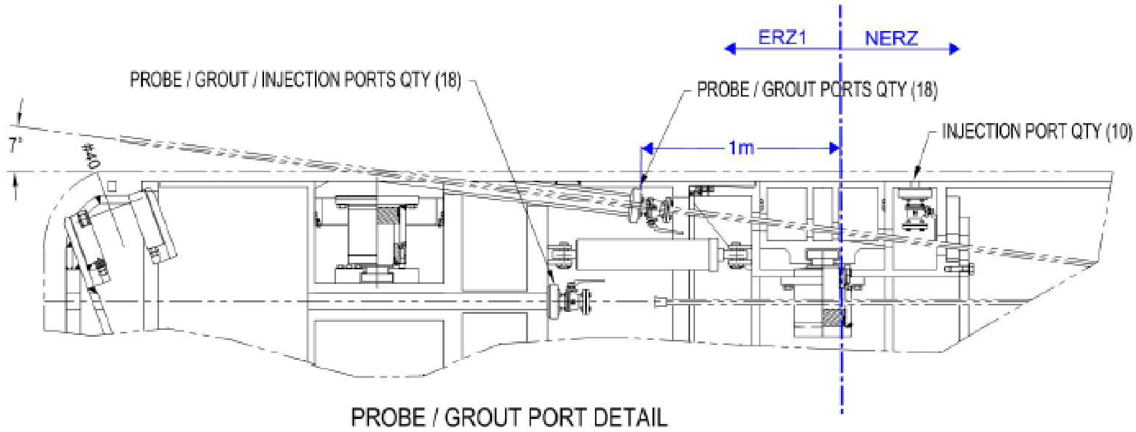


Fig. 7 *ERZ1 and NERZ Boundary (blue line).*

Fig. 8 *TBM shields - ERZ1/NERZ boundary.*

The TARP defines a minimum set of actions required by site personnel in response to the deviation in mine conditions from normality.

Based on this plan, when methane gas is detected and prior to TBM power shutdown level being reached, the following mitigation measures must be implemented:

- Reduction of advance rate (up to 12mm/min);
- Screw gates activation;
- Higher foam concentration.

When cutterhead and screw conveyor shutdown level is reached (>1.0% in ERZ1):

- The ERZ controller and mining coordinator determines the period required to ventilate the methane gas;
- The TBM is allowed to restart with reduced advance rate and increased foam concentration.

When TBM shutdown level is reached (>0.5% in NERZ):

- The crew has to evacuate the TBM to reach the designated assembly area;
- The ERZ controller has to determine the restarting process

In addition to this, specific design and procurement guidelines (Anglo American Guidelines, NSW Mining and Design guidelines, QLD Recognised Standards) have had to be followed in order to deliver a compliant product. Some of the most recurrent restrictions throughout the whole process were:

- maximum allowed content of combined magnesium and titanium in exposed aluminum alloy (6%),

- material (hoses, belts, wheels, straps, cable coatings, cylinder pads, etc.) required to be Flame Resistant and Anti-Static (FRAS),
- surface temperature of any operating equipment not exceeding 150 degrees Celsius,
- no hot works allowed and no work allowed where temperature higher than 29.4 degrees Celsius

Standard operating procedures from the Grosvenor Safety and Health Management System have been strictly followed by all personnel involved in TBM assembly and operation, with an extensive induction process initiated months in advance (on hazard identification and risk management, isolation and tagging, PPE, working at height, manual handling, equipment and personnel interaction, environmental management, slinging and lifting, fatigue management, etc.).

4.4 Quick Demobilisation / Re-Mobilisation

The TBM decline tunnels at Grosvenor Mine are both designed to be “blind headings”, i.e., excavation ceases when the TBM reaches the coal seam. Then, the TBM must be retracted back up the slope through the PCC lined tunnel it has just completed (7m I.D.). The TBM must be retracted quickly so that continuous mining machines can access the coal seam to begin the follow-on mine development work. And, the TBM is needed immediately to begin excavation of the second drift. Both drifts need to be completed and cleared to allow effective mine development work to proceed. The Grosvenor EPB TBM design incorporated special features to allow quick demobilization in a “blind heading”, without the need of a large disassembly chamber and without any hot work. Underground disassembly would have been very difficult and time consuming due to the mine’s strict roof support requirements for such a chamber, and the long time needed to fit lifting tackle and to do the TBM disassembly. Disassembly on the steep gradient would have made the process even more complicated.

The Grosvenor TBM cutterhead was designed with an inner/outer bolted construction (see Figure 9). At the end of the first heading, the TBM was backed up 600 mm to provide access in front of the head so that bolts in the circular inner/outer joint could be removed. Before any personnel entered this area, roof support consisting of rock bolts and shotcrete was applied from within the safety of the cutterhead structure to provide a safe 600 mm wide working area. Then, the outer cutterhead segments, consisting of two 180 degree sections, were “parked” in the invert and rock bolted to the face. The outer cutter head sections were recovered from the parked position later, after the TBM “Core” was removed from the heading.

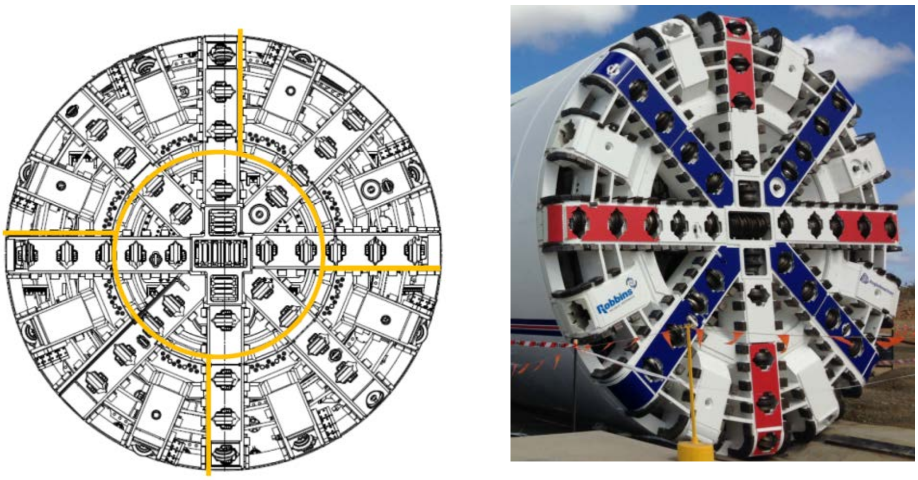


Fig. 9 *Cutterhead (inner/outer bolted construction).*

The cutterhead core and cutterhead support were designed to fit back through the 7000 mm ID of the lined tunnel. After removal of the outer cutterhead segments, the TBM “core” (cutterhead core, cutterhead support, main drives, screw conveyor, segment erector, bridge) and backup (in total almost 1000 tonnes) were retracted as a self-propelled single unit up the 1:6 slope. This unit was propelled up the slope by a special “walking dolly” system. Although simple in concept, the walking system was complicated by the limited space beneath the TBM core, and the need to distribute the 1000 tonne weight over seven precast segments, to prevent damage to the tunnel liner. The system consisted of three dolly units, working in unison to distribute the load. The backup gantries were fitted with lift jacks to provide anti-slide. This was an integral part of the walk-out system. All controls were linked for fail safe walking up the steep slope (see Figure 10).

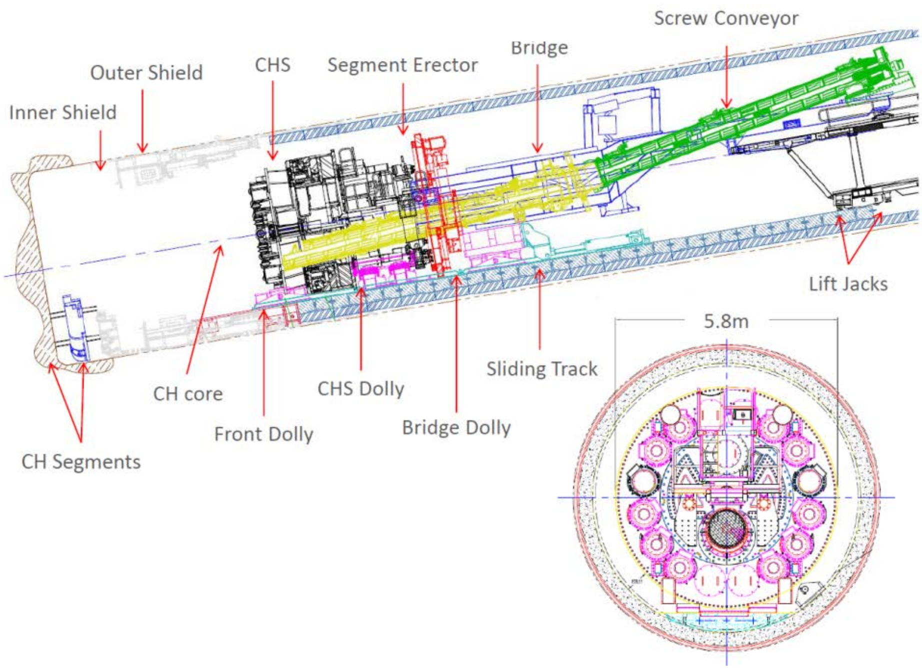


Fig. 10 *TBM core retraction with transport dollies, within the lined tunnel.*

After walking the backup and TBM core out of the drift, to the original assembly pad, the unit was jacked up and loaded onto “super-trucks” for transport to the second launch portal. The transport consisted of two super loads:

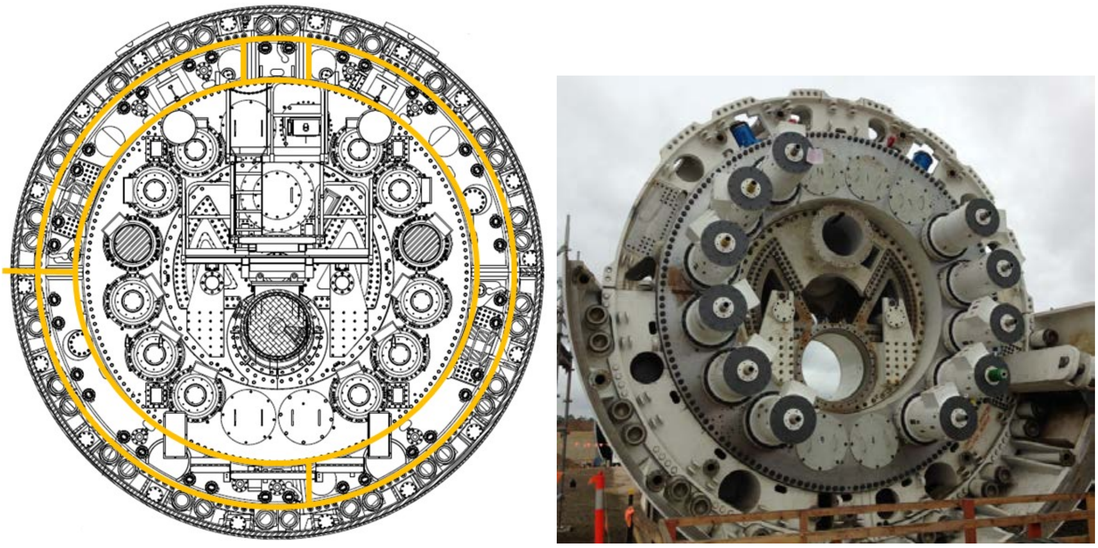
- TBM core, bridge, and Gantries 1-4
- Gantries 5-9

Transport this way allows the majority of the TBM hose and cable connections to be left intact, to minimize the time needed to recover the TBM and to start the second drift.

In parallel with the transport to the next drift, the Grosvenor TBM shield bodies (designed with an inner/outer bolted construction and key segment) were unbolted and recovered from the heading (see figures 11-12). The outer shield bodies were grouted in place and to provide “life of mine” roof support for this final length of the tunnel. For this purpose, they were designed with same ID of the finished tunnel. The forward shield was quickly removed from the tunnel (see Figures 13-15).

Fig. 11. TBM core retraction with transport dollies through the Conveyor Drift launching tunnel (July 2014)

Fig. 12. TBM transport portal-to-portal (Aug 2014)



Figs. 13-14. Forward shield (inner/outer ring construction)

At the second launch portal, a second set of outer shield bodies was ready and waiting for the TBM core and inner shield segments, to be assembled quickly and begin mining of the second drift.

5 TBM Performance on The Conveyor Drift

In order to fit within the tight project schedule, the machine was built using Onsite First Time Assembly (OFTA).

Assembly at the remote jobsite started in July 2013. The machine was ready to be walked down into the first launching tunnel in November. After no-load tests and completion of the compliance dossier, boring operations started on December 20, 2013 (Figure 16-17).

Fig. 16. *Aerial view of the assembly area and decline launching tunnel*

Fig. 17. Robbins Dual Mode for Grosvenor

The first drive (Conveyor Drift) was completed in 20 weeks, on the 13th of May 2014, reaching the coal seam at a depth of approximately 160m. During boring operations, TBM operating parameters were monitored and collected. Using a project-specific visualization software, the contractor monitored the TBM operation and evaluated the operational parameters with regard to the expected geology and presence of gas. Additional documentation and reporting by the Robbins supervisors included shift reports for both production and maintenance.

The total length of the first bored tunnel was 798.41m with an average production of about 40m/wk and an average advance rate of 1.32m/hr. The first 4 weeks of operations were characterized by final load tests, fine tuning of the equipment and interlocking procedures/devices, learning curve of the personnel. Week 6 and 7 were affected by the necessary extraordinary maintenance at the screw conveyor drive, with replacement of the gearbox.

Once a machine availability (production + planned maintenance + contractor delays) consistently above 70% was achieved, the production trend reached about 65m/week (with best day on March 28 - 13.9m), and up to 84m in the last week (no.20) (see Figure 18). The last 6 weeks were characterized by the presence of gas, with routine implementation of the procedures for mitigation and management of the detected gas concentration levels (as per the TARP).

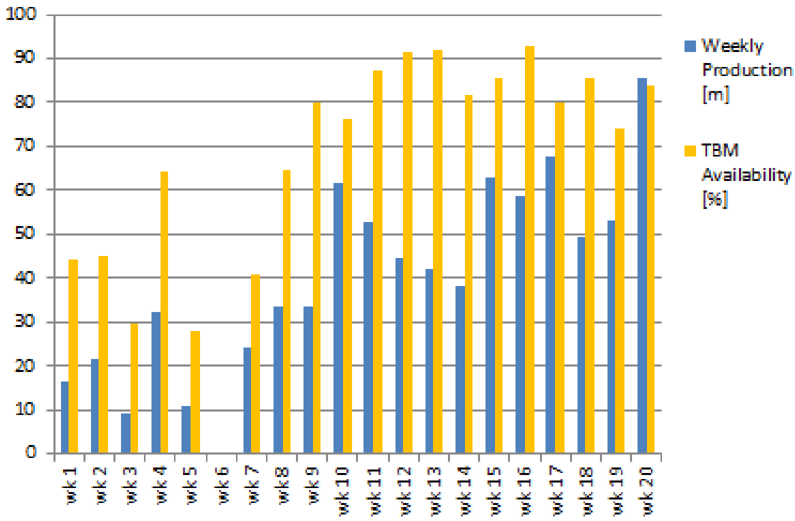


Fig. 18. *Conveyor Drift - Weekly production and TBM Availability.*

Despite the flexibility offered by the dual mode design, for the whole length of the Conveyor Drift the machine was used in mixed ground configuration (disc cutters and scrapers) with consequent lower performances in plain soft ground (with no cobbles) and hard rock (with no fines).

While 7-10 days of suspension of TBM operations for switching from soft ground to hard rock mode were in this way avoided, uneven disc cutter wear was observed in soft ground (with more time and parts spent for maintaining the cutterhead) and muck out difficulties encountered in hard rock (with no bucket lips/loading plates and subsequent lower advance rate).

6 TBM Performance on The Transport Drift

Between July and August the TBM was walked out from the first drive and moved to the Transport Drift portal area for re-assembly. The machines was assembled from September to October and re-launched on November 11, 2014.

Based on the experience gained during the Conveyor Drift construction and the nearly identical geology of the Transport Drift (soft ground with a transition of mixed ground followed by hard rock), the contractor reconsidered the most efficient way to approach the new drive. The goals were to reduce the time for cutter maintenance, take better advantage of the whole timeframe the machine was available, and maximize the production (see Figure 19).

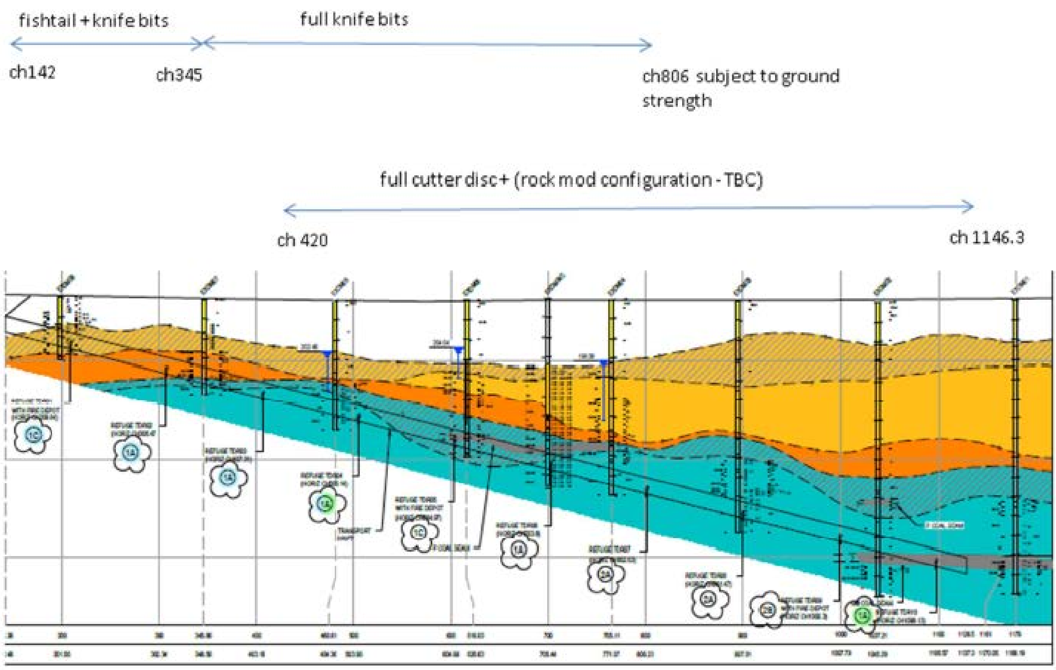


Fig. 19. *Transport Drift - Cutter dressing summary in variable ground conditions*

For the TBM re-launch at the Transport Drift, the cutterhead was completely dressed with soft ground tools (scrapers and knife bits, see Figure 20) as these were more appropriate for the initial soft ground conditions.

After a much smoother TBM re-commissioning/start-up and without any learning period required for the personnel, better production was achieved from the start of the second drift (see Figure 21).

Fig. 20. *Transport Drift - TBM ready for re-launch and soft ground tool dress*

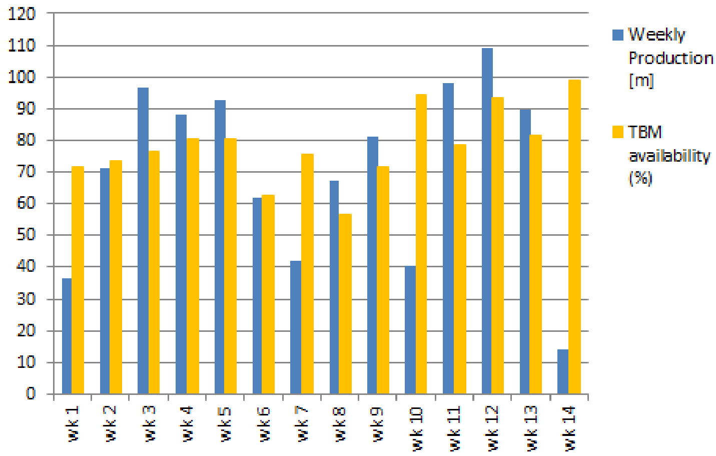


Fig. 21. *Transport Drift - Weekly production and TBM Availability*

Completion of the 988.40m of tunnel was achieved after 13.5 weeks, on February 9, 2015, with an average weekly production of 70.6m, average advance rate of 1.83m/hr and best day of 25.2m. With an average daily production of 10m consistently above the planned 9m/day, the TBM broke through the last diaphragm wall almost 3 weeks earlier than scheduled. The TBM holed into a section of the mine that was already under development from September 2014 using the Conveyor Drift entrance.

After about 540m (between week 9 and 10) the changing geological conditions required 4 days' stoppage to substitute the soft ground tools with disc cutters. Methane gas was encountered with more consistency during this drive and at higher concentration compared to the Conveyor Drift, resulting in over 100hrs total downtime to manage the situation and re-establish the safest working conditions. As an additional preventive measure, during the excavation of the Transfer Drift the dilution of foam with nitrogen instead of oxygen was extensively implemented in the mixing chamber in order to create an inert environment.

At the time of writing in February 2015 the TBM was being walked out from the second decline tunnel to be disassembled and stored on the surface.

7 Advantages and Achievements

The advance rates reached at Grosvenor, especially during the second drive, are remarkable considering that:

- this is the first time TBM technology has been made compliant to an advanced coal mine legislation;
- the expected advance rate through the same ground conditions with a roadheader would have been almost ten times slower (5-6 m/week).

Besides the significantly higher and sustainable progress rates that allowed first development of the mine and coal extraction from the Conveyor Drift well ahead of schedule, the greatest achievement at Grosvenor is the improved health conditions for workers without exposure to un-supported rock or fumes at any stage of the tunnel construction.

The concrete lining built by the TBM makes these drift tunnels two of the highest quality access tunnels to a coal seam worldwide, not only in aesthetic terms, but also for durability over the mine life with very low maintenance requirements: bolts and mesh systems have a lifespan of 10-15 years and need to be monitored and rehabilitated regularly; a segmental lining is stable and long-term especially where the ground conditions are extremely poor and subject to collapse, as in the first 50 meters vertically at Grosvenor.

8 Conclusions and Perspectives

After the earliest applications and attempts of TBMs in mining operations (often with machines not originally or specifically designed for mining projects), in recent years the mining industry has witnessed more successful application of TBMs.The experience gained over the last three decades, the increased willingness of the manufacturers to design machines specifically suited for mining operations, and the constant and growing demand in the mining industry for rapid excavation to develop new ore bodies have all driven investments in TBMs such as the one at Grosvenor.

The Grosvenor project proves that TBMs are well-suited in mining for main access and conveyor haulage tunnels as well as exploratory bores or ventilation tunnels, offering numerous advantages compared to drill and blast or roadheader excavation:

- improved personnel safety
- faster advance
- better precision and control
- better ventilation
- smoother tunnel profile
- less ground disturbance and ground support
- uniform muck for processing

To realize these advantages mines need to invest not only in purchasing the machine, but also in training the crew and hiring skilled workers to run the machines.If the capital cost to purchase a TBM is higher and the mobilization time longer than for other methods, the overall cost during the project can be much lower (cheaper cost per meter of tunnel once the mine is familiar with the method) and the overall time to reach the ore body much shorter (especially if mineral deposits are deeper).

The experience of Grosvenor, with a complex Dual Mode EPB machine designed to operate in the hazardous coal mine environment, represents a great step forward in terms of health and safety (providing a better and more modern work environment), and has a positive impact on the overall mine value and future development. Ambitious applications such as those at Grosvenor are driving technology innovation and encouraging interest from the mining industry, with growing demand from Australia, Chile, USA, Canada, Russia, South Africa and (more recently) China.

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10 References

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