



**International Materials Handling Conference**

**BELTCON 9**

**22-24 October 1997**

**Gallagher Estate, Midrand, RSA**

Under the office of:

**The SA Institute of Materials Handling**

**The SA Institution of Mechanical Engineering**

**Conveyor Manufacturers Association of SA Limited**

**DRIVE TECHNOLOGY UPGRADE FOR  
REGENERATIVE CONTROL OF A  
LONGWALL MAINGATE CONVEYOR SYSTEM**

**Author : M A Patterson**

Nepean Mining Pty Ltd  
15 Bridge Street  
PICTON, NSW  
Australia

Telephone : +6146 771911  
Facsimile : +6146 771669



The S.A. Institution of  
Mechanical Engineering



Conveyor Manufacturers  
Association of SA Limited



SA Institute of  
Materials Handling

## **1. Introduction**

Southern Colliery is amongst the most productive longwall coal producers in Australia. Located in Central Queensland, it forms part of the German Creek operation managed by Capricorn Coal Management Ltd, a wholly owned subsidiary of Shell Australia.

Having exhausted previous longwall panels, lease boundary restrictions required that Southern Colliery relocate their longwall operations to the southern area of the mining lease. To utilise existing trunk conveyors, the new longwall panels retreat to the Northeast at an average decline of 1 in 30. The existing development drives installed on the maingate conveyors now became obsolete, as conveyor demand at production capacity became regenerative.

Nepean Mining Pty Ltd were contracted to design, manufacture, supply and commission a maingate conveyor drive capable of controllably handling both conventional and regenerative demands. An innovative approach to drive design allowed maximum utilisation of existing drive equipment, and kept installation time to an absolute minimum.

Drive philosophy and design was completed within 12 weeks. All equipment was delivered to site for installation by week 18 of the project. No load commissioning took place in December 1995, however due to geological conditions, full production was not maintained sufficiently for the drives to be fully load commissioned until July 1997.

Having now operated successfully for 20 months, it is expected that the maingate drive will convey over 16 million tonnes of RoM coal.

## **2. Objectives**

The maingate conveyor operates in an underground coal mine environment. Due to the potential for a combustible atmosphere, many restrictions are imposed upon electrical and mechanical devices to reduce the risk of ignition. Key criteria for the maingate conveyor included:

- Capacity to operate at 2500 tonnes per hour, with peak loads of 3000 tonnes per hour.
- Drives to operate under both conventional and regenerative load demands.
- Conveyor stopping time to be limited to 30 seconds, even in the event of loss of power. The return strand tensions are not to exceed the allowable working tension of the belt carcass.
- Conveyor shall be cost effective with regard to capital cost, reliability, ease of maintenance and operational costs. Existing drive equipment to be utilised where possible.
- Drive and braking system to be compatible with existing drivehead starter and conveyor equipment layout.
- All equipment to have protection to IP55, and comply with the Queensland Coal Mines Regulations Act.
- 

## **3. Specification**

Consulting firm CMPS&F as part of the tender document provided a detailed specification. Several proposals were presented in the Scope of Work, outlining required modifications for the take up arrangement. Details on the drive/brake design were to be provided by the tenderer.

Regenerative conveyor drives are typically located at the tail end, but due to the retreating tail end of the longwall maingate conveyor, the drive and brake was to be maintained at the head end. This also avoided additional cost to relocate the drivehead starter and belt storage (take up) unit.

A key consideration in the drive design/layout was to ensure sufficient take up tension to prevent belt slip during braking. Tensions generated in the belt storage unit were also to be considered, so as not to exceed the working tension of the belt storage or constant tension winch.

Equipment specification of existing conveyor:

Belt width	1400mm	Belt type	Type 8 solid woven
Length	2700m	Belt mass	22kg/m
Decline	100m	Rotating mass	68.5kg/m
Belt speed	3.76m/s	Idler roll diameter	152mm + 12mm lag
Gear reducer	David Brown B3-400S	SWL belt storage	130kN
Ratio	21.256:1	Electrical supply	1000V, 50Hz
Drive pulley diameter	1032mm	Starter rating	600kVA
Motor type	250kW, 4 pole, 50Hz	PLC control	Allen Bradley PLC-5/10
Motors per drive	3 max.	Data highway	Allen Bradley
Drive couplings	Voith 562 TUVVS	Surface monitoring	Vector Technology

#### 4. Conveyor Design

##### 4.1 Conveyor drive arrangement

Some 12 months previous to time of tender, Nepean Mining and Southern Colliery engineering staff discussed future conveyor arrangements, having realised the regenerative potential of the new longwall panels. Upon installation of the development conveyor, sufficient space was reserved for a second drive/brake assembly to be located between the take up and drive.

A standard underground drive frame issued by the client was positioned between the existing drive (hereby referred to as drive 1) and take up. The drives installed on this second drive frame (hereby referred to as drive 2) contained the braking and regenerative control modules. Upon exiting the take up, the return strand passes through drive 2, isolating the take up from the high tensions imposed on the return strand during braking. Hence the take up operates to maintain sufficient tension on both the drive and brake pulleys to prevent belt slip. Figure 1 illustrates the drive arrangement employed.

##### 4.2 Analysis Techniques

Whilst the tender document provided a summary of the resulting peak tensions, a more detailed investigation into the behaviour of the conveyor was required prior to adopting a final design. Based upon data obtained from the development installation, the CON90T program was used to determine operating demands for various load conditions. Further complicating the analysis is the effect of the diminishing length of the conveyor as the longwall retreats.

Accounting for the additional drive inertia from drive 2, it was determined that (at full length) the conveyor would impose a regenerative demand on drive 2 once the conveyor capacity reached 1000 tonnes per hour, peaking at maximum capacity of 3000 tonnes per hour. The drive design adopted permits load fluctuations from -260kW to +240kW. It was predicted that all operating conditions fall within this range.

Whilst conveying capacities up to 1000 tonnes per hour, the conveyor draws demand from the outbye drive 1, and operates in the same fashion as a conventional drive. Peak conventional demand occurs when the conveyor is running empty, with no load to assist the conveyor running downhill.

As the overall conveyor length decreases, the capacity at which the conveyor becomes regenerative increases. Eventually the conveyor operates under conventional demand (at around 700m total length) for any capacity, however due to the excessive run on time the braking modules are still required to remain operational.

The CON90T program also provided take up tensions for normal running, acceleration, braking and coasting conditions. Aborted start (or power loss) conditions were modelled to investigate the tensions resulting from the dynamic wave introduced into the belt.

Analysis of the gear reducer was also required. It was proposed that the oil immersed disc brakes be mounted on the intermediate shaft of the reducer, typically used to mount hold-back devices. To ensure the stub shaft was capable of transmitting the required torque and support the overhung load of the brake, the shaft design for an infinite fatigue life was checked. David Brown Gear Industries were invited to offer their professional advice, and provided information critical to obtain an accurate result. Methods outlined by Australian Standard AS1403 [1] were adopted for the analysis.

Having established the external loads imposed on the shaft, a bending moment diagram was produced, and critical points of the shaft were investigated. Stress raising characteristics such as keyways, shrink fits, and radii were all considered. From this it was confirmed that the shaft was suitable for mounting of the disc brakes. An illustration of the bending moment diagram is shown in figure 1.

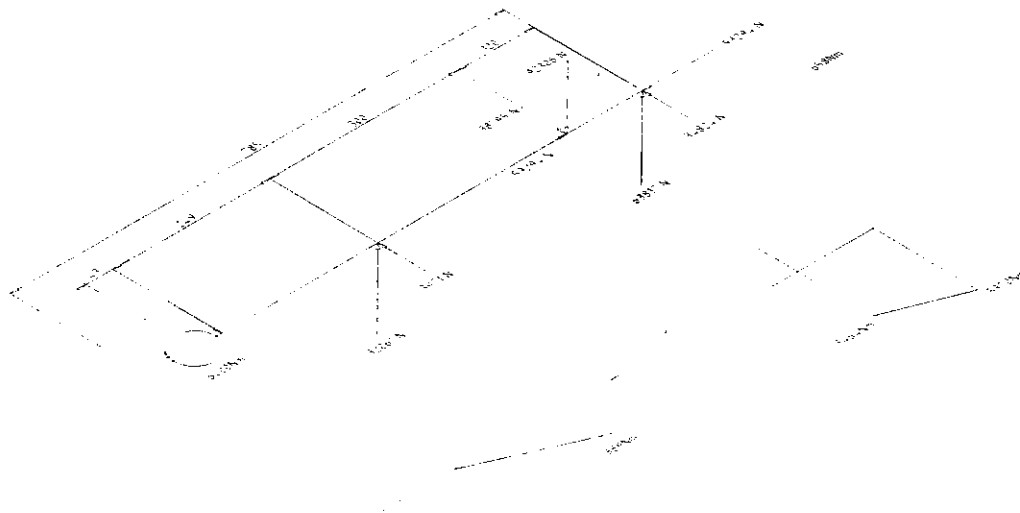


Figure 1. Bending moment diagram - gear reducer shaft analysis

#### 4.3 Scope of Supply

Nepean Mining offered the following as a complete package to upgrade the existing conveyor to controllably handle regenerative and conventional power demands, and to supply fail-to-safe braking during power loss:

- Modify one standard Southern Colliery underground drivehead frame to accept snub pulley assembly
- Modify two x 250kW power modules. Replace existing fluid couplings and retrofit with BOSS 300 Gold transmissions
- Design, manufacture and install two x 6000Nm oil immersed disc brakes. Brakes to be fitted to intermediate shaft of gear reducer.
- Manufacture and supply two x 200 litre/minute hydraulic power packs to provide hydraulic coolant and proportional control for BOSS and brakes.
- Supply IP55 stainless steel starter/controller for winch, BOSS and brake control. Includes Allen Bradley PLC-5 and 540 Panelview.
- Modify existing constant tension winch. Supply larger capacity planetary gear reducer and service brake.

#### 4.3.1 BOSS transmission

The initial drive arrangement proposed by Nepean Mining simplified installation and required minimum additional rotating parts. Drive 2 was to snub the belt coming out of the take up, and provide the necessary wrap for the braking pulley. This arrangement required two power modules to be located on the one pulley. However, after consultation with the client it was agreed to place the drives on the same side, which necessitated the use of a snub arrangement.

To provide a drive capable of controllably handling both conventional and regenerative power demands, a flexible transmission is essential. The existing constant fill couplings are adequate for conventional demand, but during regenerative demand drive 1 would still remain engaged at the synchronous speed of the motor. This would result in the belt storage introducing slack belt into the conveyor as drive 2 is driven past synchronous speed, and attempting to retard the conveyor.

The drive transmission had to satisfy the following criteria:

- Ability to engage/disengage output upon request by PLC
- Provide a controlled start regardless of torque requirements
- Provide fail-to-safe protection of the drives
- Co-exist with installed D.O.L. drivehead starter

Several controlled starts transmissions are available to satisfy the above criteria, most notably scoop controlled couplings, CST's and BOSS transmissions. However, with the client looking to maximise the use of existing drive equipment, the adoption of the BOSS (Belt Optimum Soft start/Slave) transmission proved to be the logical choice. As opposed to providing a new drive base, the BOSS simply became a retrofit to the existing base, requiring minimal structural modification and permitted the power module to be transported as a complete unit. Figure 2 provides an illustration of the 250kW power module.

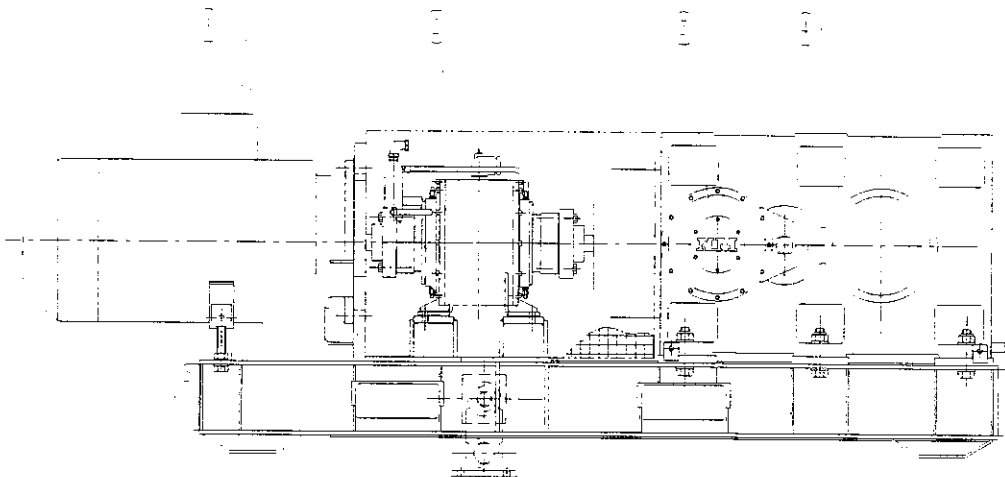


Figure 2. Regenerative power module, 250kW

The drive module consists of a 250kW 4-pole AC motor (1), BOSS 300 Gold transmission (2), 6000Nm oil immersed disc brake (3) and bevel helical gear reducer (4). Typically the drive module on drive 1 consists of items (1), (2) and (4) above.

#### **4.3.2 Oil immersed brakes**

Provision of a fail-to-safe brake suitable for use underground presented several challenges. Conventional disc brakes, whilst commonplace in surface installations, are all but forbidden underground due to excessive surface temperatures generated during braking. An oil immersed disc brake was required, suitable for fitment to the intermediate shaft of the gear reducer.

Nepean Mining designers embarked upon the design of an oil immersed brake to suit such an application. The control concept of the BOSS transmission is carried over into the brake design, only in reverse. Utilising the same friction plate technology, proportional pressure is applied to release the brake, with the braking force supplied by compression springs. A proportional valve block on the hydraulic power pack is used to control the rate of application or release of the brake, as dictated by the PLC.

The oil-to-air coolers on the hydraulic power packs provide sufficient coolant flow to prevent the brakes from overheating, particularly during heavy braking. To prevent the brakes from suddenly applying during a power loss situation, twin accumulators on each power pack allow a gradual reduction of pressure in the brake piston, to gradually apply the brakes. A needle valve allows adjustment of this braking time, which is currently set to apply the brake over a 20 second period.

#### **4.3.3 Hydraulic power packs**

All control pressure and coolant flow is provided by two 11kW hydraulic power packs. Each power pack services one BOSS transmission and one oil immersed brake. A 4litre/minute vane pump, which services both the BOSS and brake control valve manifolds, maintains control pressure. Coolant is provided by a 180 litre/minute pump, and is diverted to both the brake and BOSS by means of a pressure compensated flow divider. This flow divider is adjustable, with final settings tuned during the commissioning of the drives.

The oil cooler is only operated as required. Should coolant temperature in the hydraulic reservoir fall below 50° C, the cooling fan shuts down. As the coolant temperature rises, the fan cuts back in at 60° C. Over temperature cut out occurs at 90° C, to avoid irreparable damage to the surface of the friction plates. Both BOSS and oil immersed brakes have thermal temperature probes to allow exit coolant temperature to be monitored.

#### **4.3.4 Constant tension winch**

Free issued by Southern Colliery, a 55 kW eddy current constant tension winch was overhauled and upgraded to suit the running tensions it would soon be subject to. The original gearbox was replaced with a heavy-duty planetary speed reducer, and the shoe brake replaced with an oil immersed service brake. To maintain an adequate safety factor, the winch cable was also increased from 16 to 20mm. The winch controller was also upgrade, to take advantage of the PLC which was installed in the main starter. This allowed all operational checks and operator commands to be made from the Panelview screen.

### **5. Control Philosophy**

A state diagram as shown by figure 4 provides a graphic illustration of the control sequences.

During motor start up, the BOSS is disengaged, allowing no torque to be transmitted to the pulley, with the brakes engaged. The power packs for the BOSS and winch undergo a series of operational checks, and when complete the winch begins to haul in to obtain the desired start tension in the belt. Once the start tension is achieved, the conveyor is accelerated up to speed in one of two ways:

## **5.1 Last run regenerative**

Due to the load, gravity will naturally accelerate the conveyor up to speed. Pressure is applied to the brake piston, releasing the brakes until motion is detected. Once motion is detected, the rate of acceleration is controlled by gradually releasing the brakes until the conveyor is up to speed. BOSS 1 remains disengaged, whilst BOSS 2 is engaged only when the conveyor reaches run speed. Once BOSS 2 is engaged, the 250kW motor on drive 2 is used to retard the conveyor, as it is driven beyond synchronous speed. A regenerative load of up to 260kW can be retarded in this fashion.

## **5.2 Last run not regenerative**

Power is required to accelerate and run the conveyor. Release the both brakes, and if no motion is detected, apply proportional pressure to BOSS 1 to accelerate the conveyor over an 80 second period using an S-curve acceleration. BOSS 2 remains disengaged throughout the start sequence and whilst the conveyor is drawing demand from motor 1.

Once the conveyor is at speed, full pressure is applied to BOSS 1 and speed sensors mounted on the snub pulley on drive 2 monitor the belt speed. As the belt is loaded with coal, the demand on motor 1 is reduced, and detected by the motor current feedback. Simultaneously, belt speed will increase as the motor is drawn closer to a synchronous speed of 1500rpm. Once no demand is placed on motor 1 (no load motor current achieved), and belt speed indicates motor rpm > 1500, then the load is regenerative. An increase in winch tension will also be noticed.

Should conveyor demand become regenerative, BOSS 2 is engaged. For a brief period drive 1 and drive 2 will be simultaneously engaged. Under normal circumstances this would not be acceptable, as the two drives would attempt to 'load share', resulting in abnormally high loop tension. This would trip the conveyor on an over-tension trip. However, as no demand is being drawn from the motors, no effective load sharing is occurring. Once full BOSS 2 pressure is established, BOSS 1 is disengaged, and the conveyor is now retarded by drive 2. Loop tension should now settle back to normal run tension. If at any stage the belt speed indicates motor rpm > 1515, the brakes are engaged to a light drag to prevent over speed of the belt.

Should motor 2 speed drop below 1500rpm, and motor current increase, the regenerative load no longer exists, and power is required to run the conveyor. BOSS 1 is engaged, and once full pressure is achieved, BOSS 2 is disengaged to allow the conveyor to be powered in a conventional manner.

## **6. Conclusion**

Whilst full load commissioning was not undertaken until July 1997, for a brief period following the installation of the drive upgrade, longwall coal was produced sufficient to bring on full pressure to BOSS 2. The conveyor drive was running at 1500rpm, and had the longwall face continued to load coal onto the maingate conveyor, a regenerative load would have been achieved. Through monitoring of loop tensions and motor rpm, it was possible to determine when coal was being loaded onto the tail end of the conveyor.

All monitoring and sequence functions were tested under no load conditions, and though not available for full load commissioning, several tests were undertaken to simulate the PLC controlling the conveyor under regenerative loads, and switching from conventional to regenerative demand.

In July 1997, a longwall move was completed by Southern Colliery, with mining of the next panel now underway. This new panel requires an empty belt demand in excess of 250kW, with almost no regenerative demand. To accommodate this, BOSS 2 is now utilised on drive 1 to provide 500kW of conventional drive power. The brake remains, to prevent excessive overrun of the conveyor and provide operator safety in the event of loss of power.

## **7. References**

- [1] AS1403-1985 Design of Rotating Steel Shafts  
Standards Association of Australia  
1985

## **8. Curriculum Vitae**

The Author is a Graduate Mechanical Engineer from the University of Wollongong, Australia. Having gained experience in the Southern NSW Coalfields, much time was spent with underground conveyor maintenance crews. Initially employed at Nepean Mining (Picton), the Author held the position of Project Mechanical Engineer. Responsibilities included management and design of several underground and surface conveyor installations. More recently the Author has transferred to Nepean Mining's Queensland operation as Project Mechanical Engineer. In addition to providing a design and auditing service for the mining and minerals development within the region, the Author is also involved with export development to the Indonesian market.