CONVEYOR SYSTEM DESIGN AUDITING, DYNAMIC TESTING AND CONDITION MONITORING OF STEEL CORD BELTS.

Athol Surtees

1. INTRODUCTION.

This paper addresses two important items pertaining to large conveyor installations.

PART 1: CONVEYOR SYSTEM DESIGN AUDITING AND DYNAMIC TESTING.

This topic has relevance in the following applications:

- **Design verification** to allow the designer/contractor to verify his calculations and modelling.
- **Hand-over certification** to give the user and designer mutual assurance of the quality and reliability of the system: a signature or performance blue print.
- **Reducing downtime and preventative maintenance costs** to assist the maintenance personnel with future problem identification.
- **Failure analysis and forensic investigations** to identify and differentiate between cause and effect of electrical, mechanical or belting related failures.
- **Conveyor upgrade feasibilities** for example, extending conveyor length or increasing tonnage handled. The existing performance is quantified and extrapolated.

Examples of application will be presented.

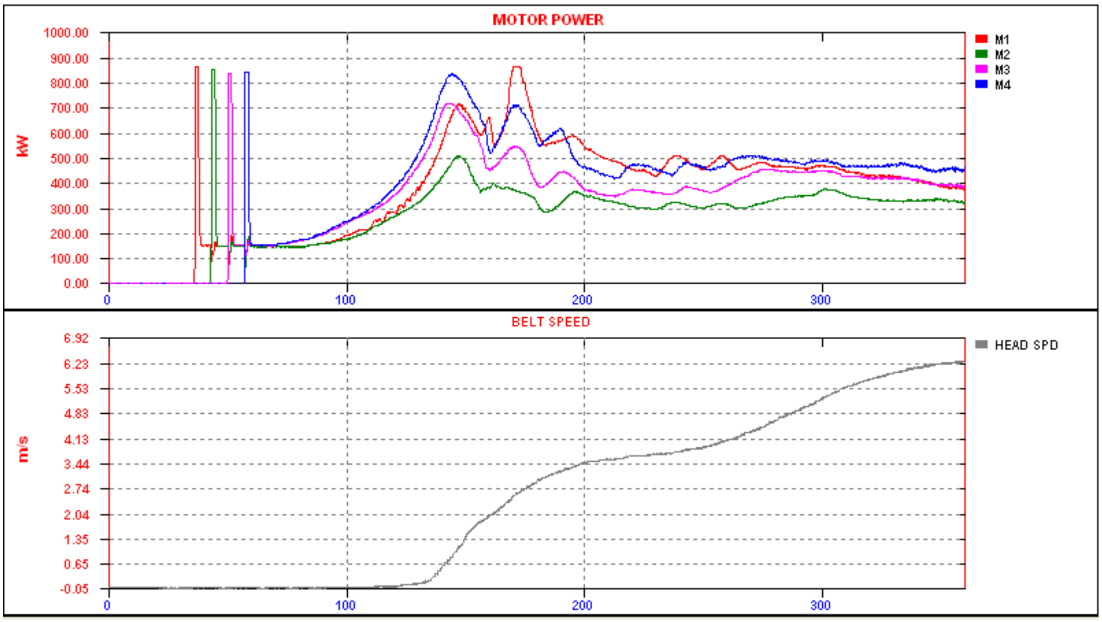
PART 2: CONDITION MONITORING OF STEEL CORD BELTS.

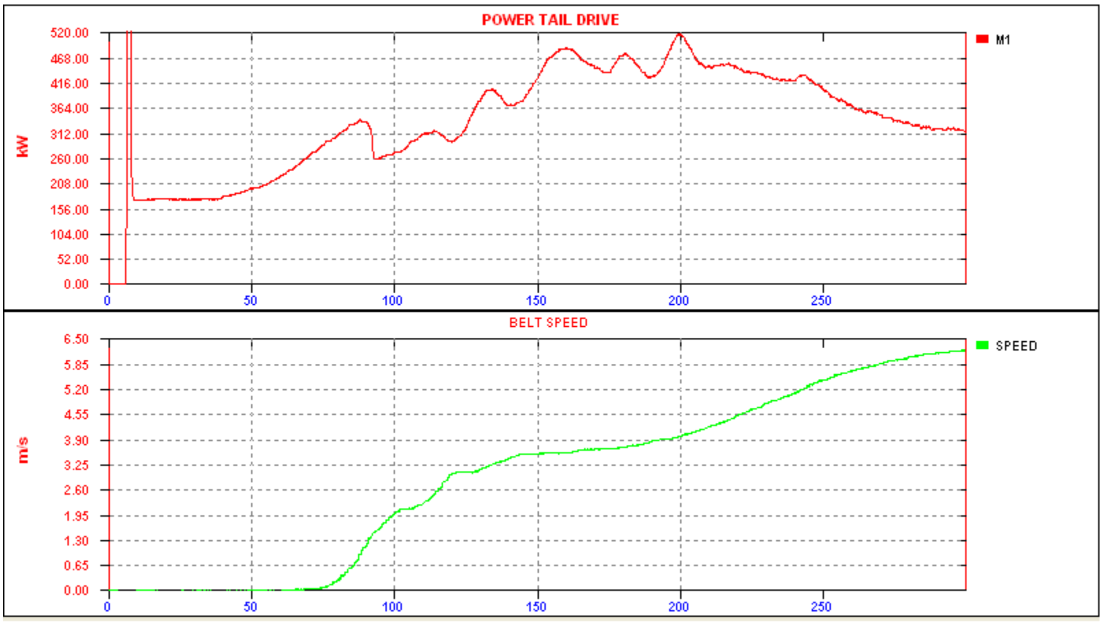
Condition Monitoring is important for preventative maintenance and belt replacement management. There seems to be a lack of awareness about this technology amongst the new generation of engineers / belt users in the conveyor industry.
An overview of available technologies is given. More details and examples of application of the electromagnetic system are presented.

2. PART 1: CONVEYOR SYSTEM DESIGN AUDITING AND DYNAMIC TESTING.

This part of the paper gives 12 interesting examples of various applications / tests.
The examples presented are summarized below:

Example 1: Design Verification.
Example 2: Abnormal Start Attempt.
Example 3: Good Controlled Stop.
Example 4: Bad Controlled Stop.
Example 5: Poor Load Sharing During Starting.
Example 6: Incorrect Drive Starting Sequence.
Example 7: Incorrect Control Starting Sequence.
Example 8: Poor Natural Load Sharing Between Drive Pulleys.
Example 9: Combination of Poor Coupling Characteristics and Voltage Drops.
Example 10: Combination of Different Pulley Lagging Wear and Fluid Coupling Fills.
Example 11: High Belt Transients due to Overfilling of Fluid Couplings.
Example 12: Bad Belt Tracking.

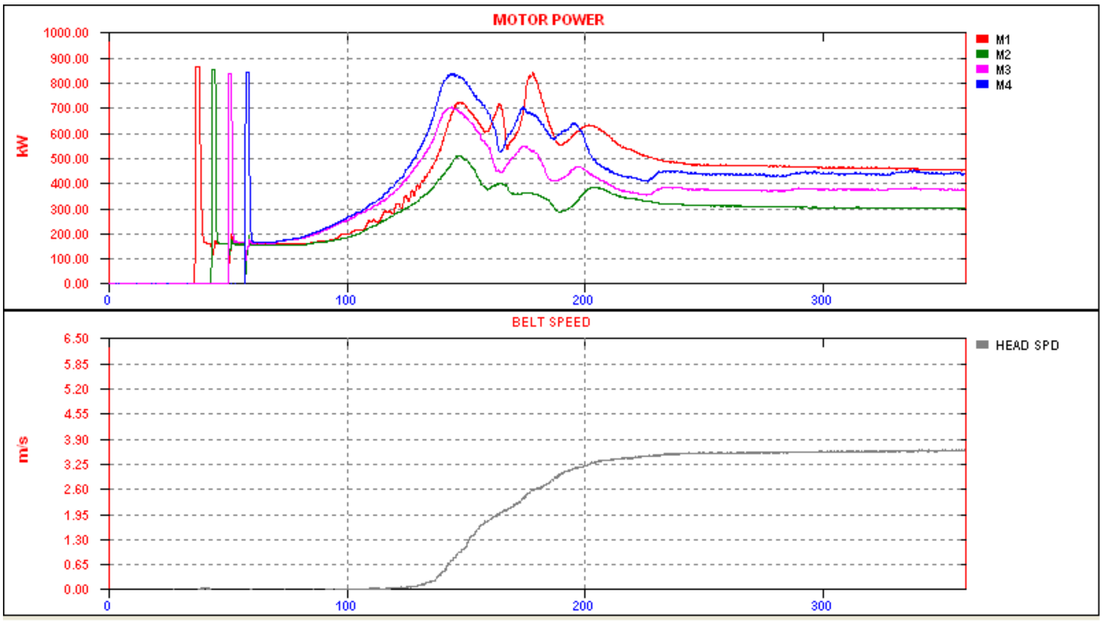


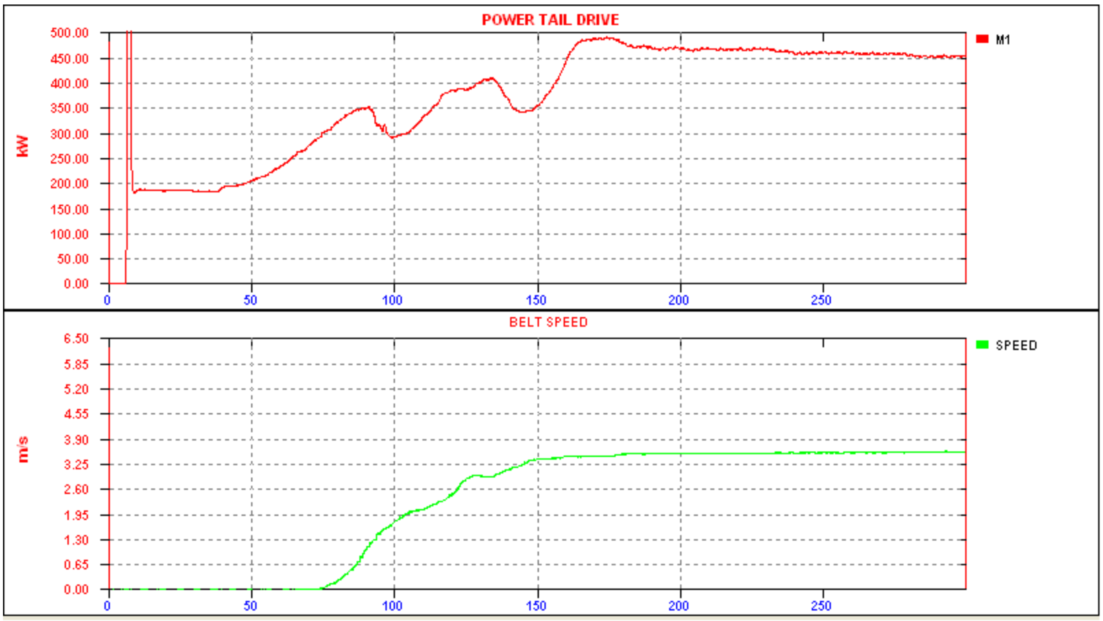


EXAMPLE 1: OVERLAND CONVEYOR - DESIGN VERIFICATION.

Length: 8,8 km Speed: 6,5 m/s Power: 4 X 650 kW at head
1 X 650 kW at tail
Belt Rating: ST 3150, 1200 mm Tonnage: 2850 TPH

Findings: The belt safety factor was 9,1:1. The peak power draw was 67 % of installed. The peak start factor was 124 %. The average start factor was 118%. The starting time of the conveyor was 4 minutes after breakaway.

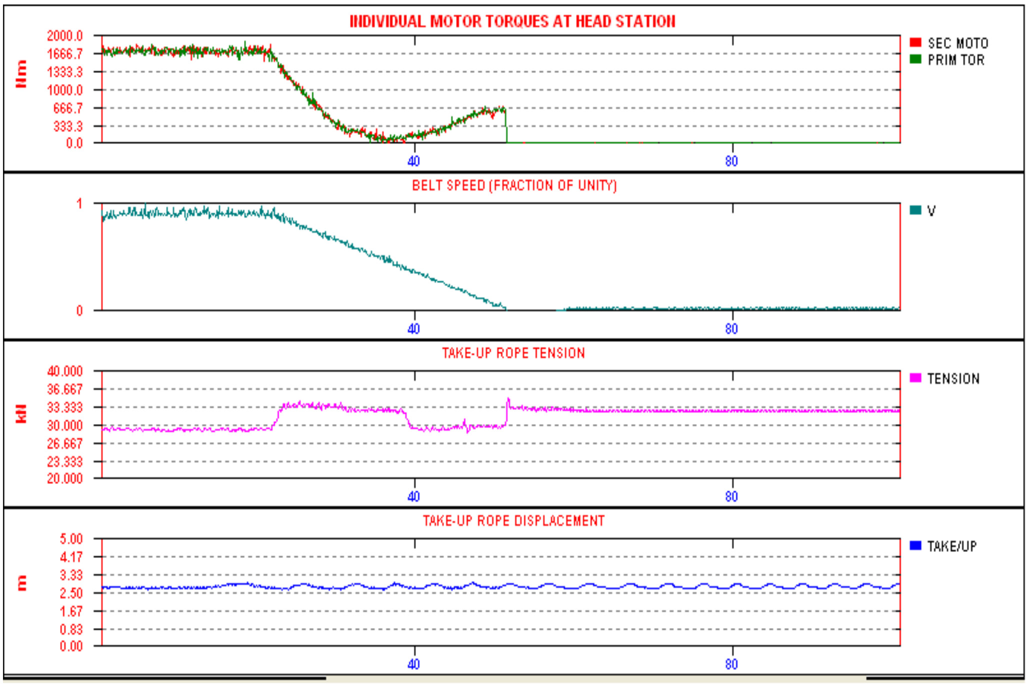




EXAMPLE 2: OVERLAND CONVEYOR – ABORTED START.

Length: 8,8 km Speed: 6,5 m/s Power: 4 X 650 kW at head
1 X 650 kW at tail
Belt Rating: ST 3150, 1200 mm Tonnage: 2850 TPH

This example shows an unsuccessful peak load start attempt – the conveyor only reached 55 % of full rated speed. The reason was insufficient power being transmitted by the drives.



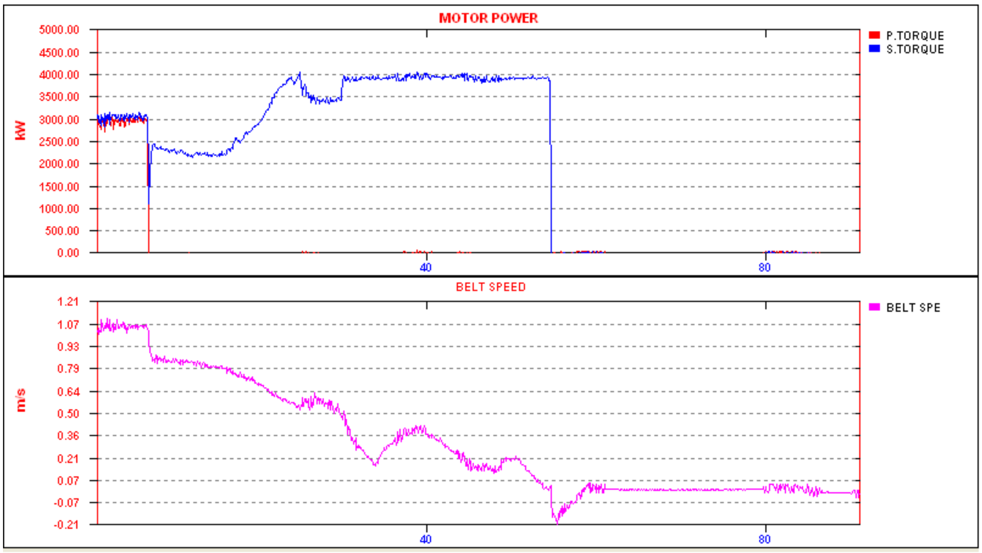
EXAMPLE 3: OVERLAND CONVEYOR – CONTROLLED STOP.
Length: 6,5 km Speed: 4,4 m/s Power: 2 X 630 kW VFD

Belt Rating: ST 1600, 1200 mm Tonnage: 1500 TPH

The variable speed drives are used to power the conveyor down in a linear fashion during a controlled stop, ensuring minimum belt tension transients. The stopping time had been set at 30 seconds.

Subsequent to these tests, the programmed stopping time had been changed to 3 seconds, which resulted in the drives braking the conveyor during the controlled stop, with significant forces evident which resulted in damage to the take-up carriage.

Measurements were subsequently restarted, after changing the stopping time back to 30 seconds.

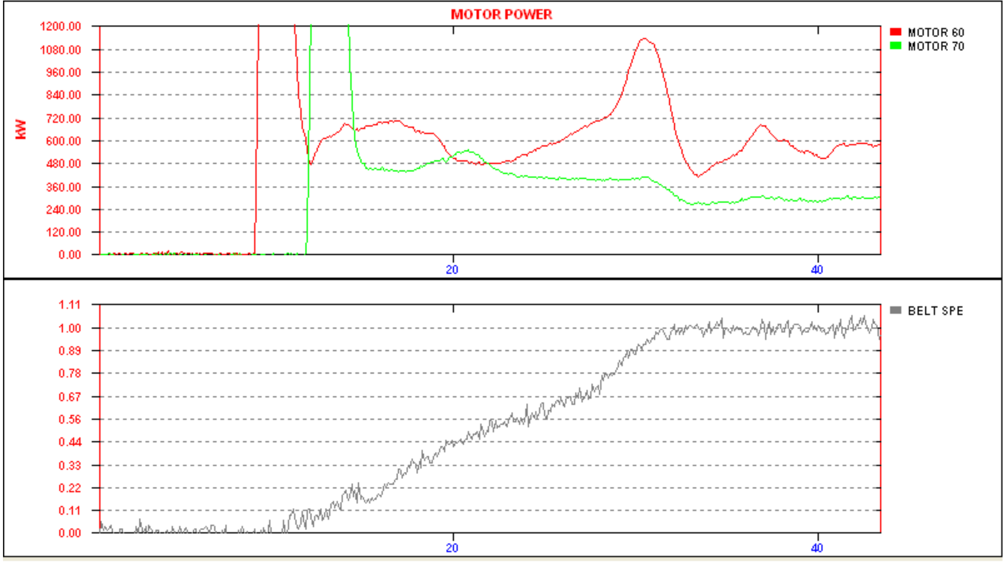


EXAMPLE 4: OVERLAND CONVEYOR – CONTROLLED STOP ATTEMPT.

Length: 6,5 km Speed: 4,4 m/s Power: 2 x 630 kW VFD

Belt Rating: ST 1600, 1200 mm Tonnage: 1500 TPH

The measurements identified that the primary drive was de-energised completely, while the secondary drive increased its power to try to achieve the 30 second stop. The result was a non-linear stop with belt tension transients evident.



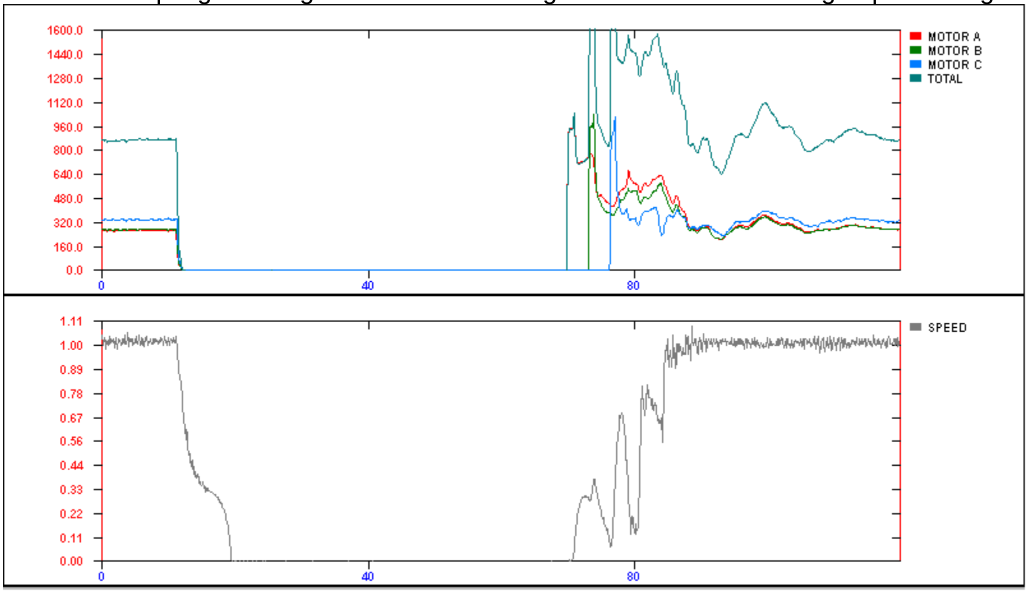
EXAMPLE 5: POOR LOAD SHARING DURING STARTING.

Length: 400 m Speed: 3,5 m/s Power: 2 x 600 kW

Belt Rating: ST 2800, 1500 mm Tonnage: 5000 TPH

Poor load sharing was identified during loaded start conditions. The primary drive transmitted up to 2 times full load motor rated torque while the secondary only transmitted 1 times rated torque. Gearbox failures had been experienced on the primary drive.

The fluid coupling draining nozzles were changed and the load sharing improved significantly.



EXAMPLE 6: INCORRECT DRIVE STARTING SEQUENCE.

Length: 800 m Speed: 3,5 m/s Power: 3 x 470 kW

Belt Rating: 2000, 5 ply, 2100 mm Tonnage: 4000 TPH

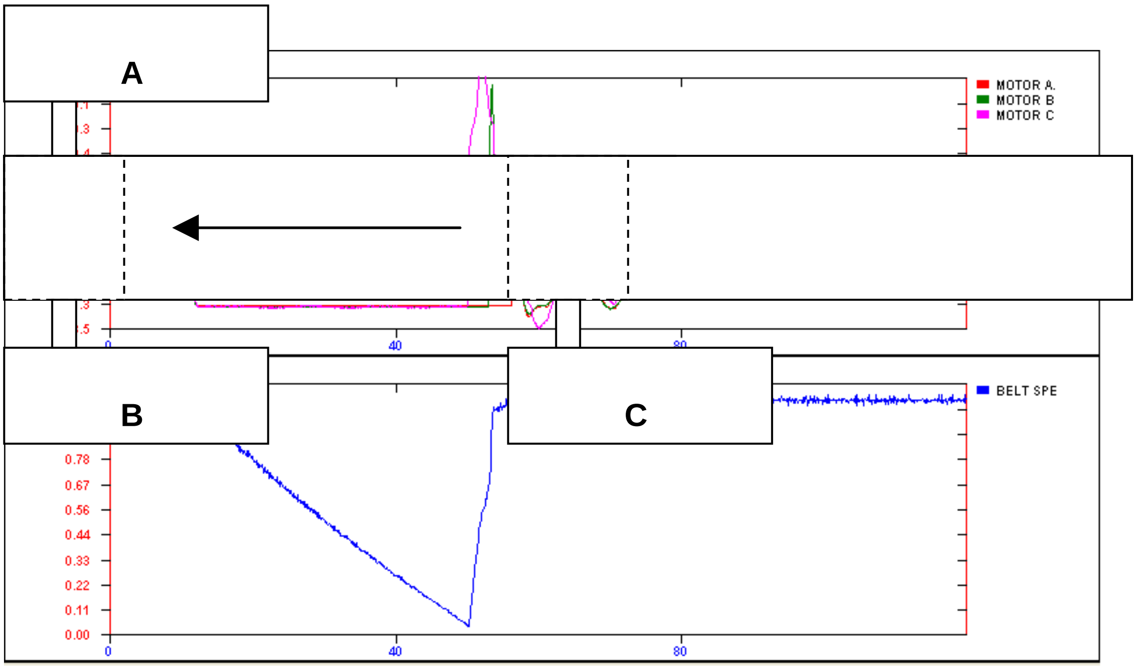
The start-up behaviour is poor:
The starting sequence is wrong; A, B, C (see figure 1).

This implies that the front drive pulley does not have sufficient T2 tension and severe drive slip occurs as evident in the belt speed oscillations.

The peak start-up factor is fair; 157 %. (1590 kW / 1010 kW)

Starting sequence wrong: A, B, C.
Should be C, A, B.

Figure 1.



EXAMPLE 7: INCORRECT CONTROL STARTING SEQUENCE.

Length: 800 m Speed: 3,5 m/s Power: 3 x 470 kW

Belt Rating: 2000, 5 ply, 2100 mm Tonnage: 4000 TPH

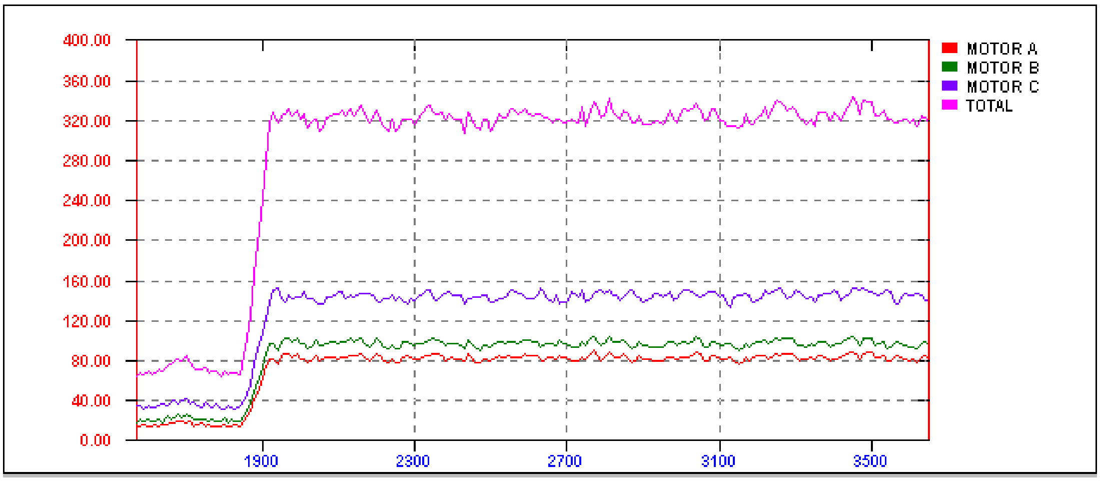
Before the conveyor comes to rest, the drives are re-energising.

The conveyor starts up rapidly in 2 seconds. (Normal start 7 seconds!)

Significant tension transients are evident, with the drives all going into regenerative mode.

The rapid start is due to the fluid couplings not being allowed to drain prior to the next start.

The control software was subsequently changed to prevent this happening again in the future.



EXAMPLE 8: POOR NATURAL LOAD SHARING BETWEEN SINGLE AND DOUBLE DRIVE PULLEYS.

Length: 600 m Speed: 2,8 m/s Power: 3 x 160 kW

Belt Rating: 1600, 4 ply, 1350 mm Tonnage: 1700 TPH

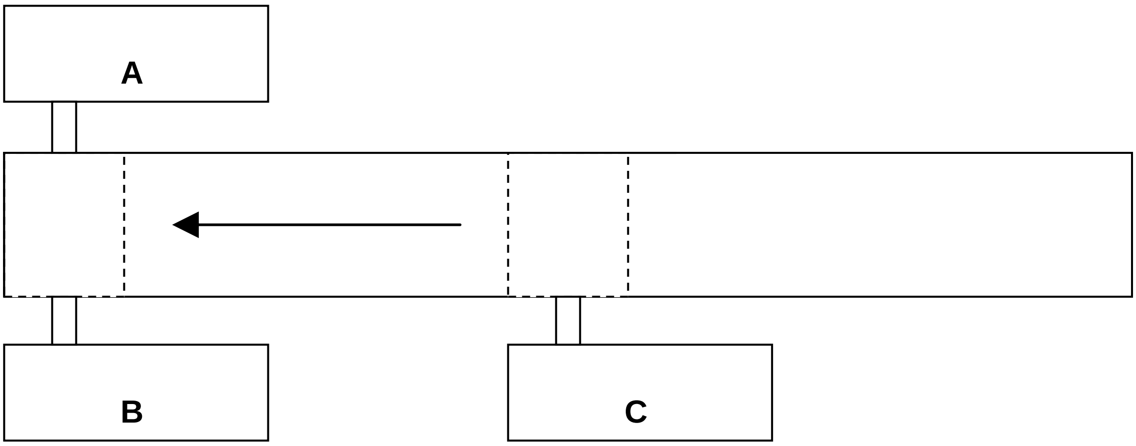
Load sharing between the drives is poor:
Drive C transmits the highest power – 150 kW, 94 % of name-plate rating (see figure 2).

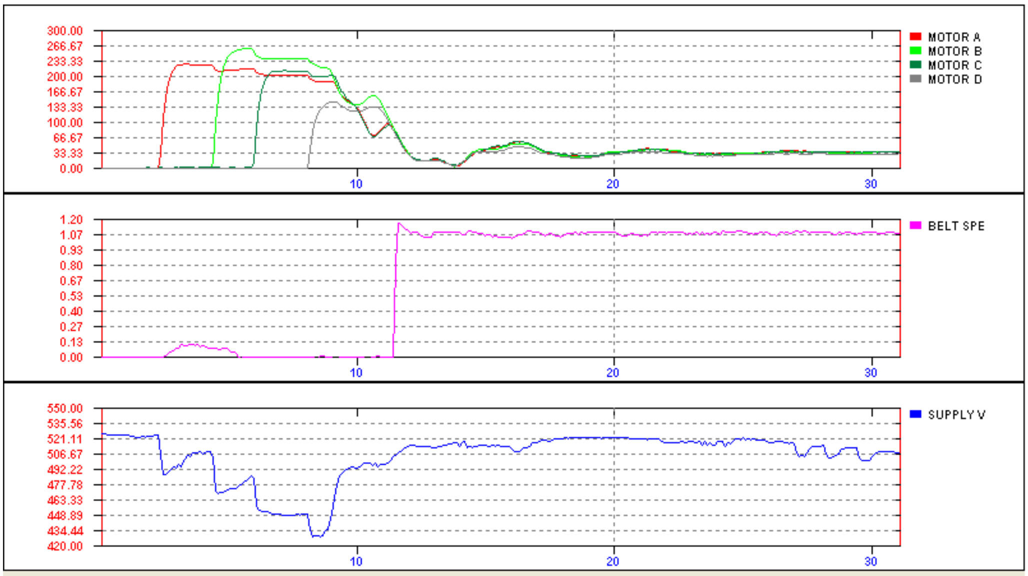
At peak load, the power split is:

Drive C: 150 kW, 44 %.
Drive B: 100 kW, 30 %.
Drive A: 90 kW, 26 %.

This poor load sharing or power split is typical for conveyors having a combination of single and double drive pulleys. The front drive pulley lagging, (in this case with drives A and B) wears down faster than the back drive pulley lagging (with drive C). Because of this, the front drive pulley rotates faster than the back drive pulley and since the belt speed is almost identical at both pulleys, the back drive motor must rotate slower than the front drive motors i.e. it draws more power than the front drives.

Figure 2.





EXAMPLE 9: COMBINATION OF POOR FLUID COUPLING CHARACTERISTICS AND SUPPLY VOLTAGE DROPS.

Length: 2000 m Speed: 5 m/s Power: 4 x 75 kW

The start-up behaviour is poor:

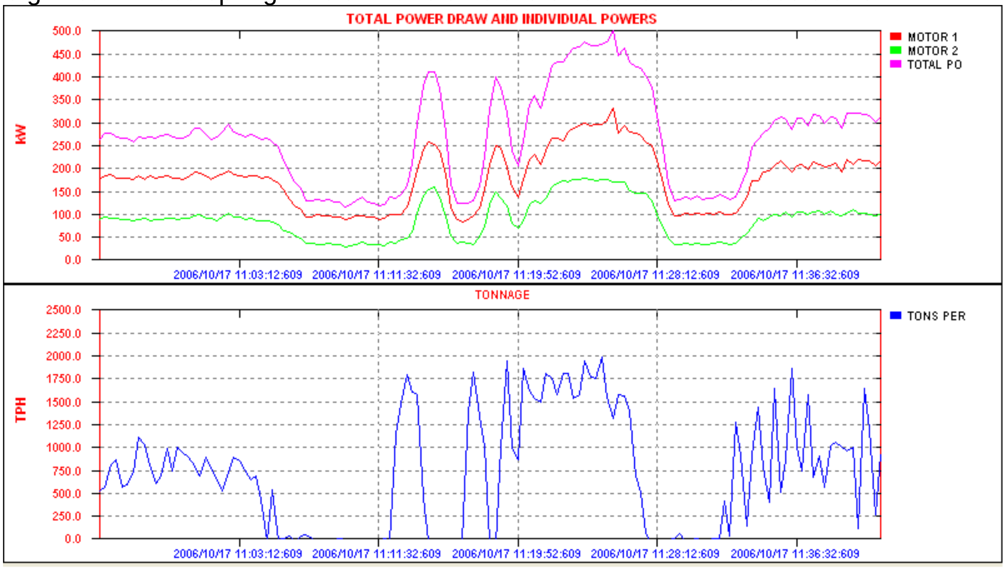
The conveyor reaches 10 % of full speed in 2 seconds, after energising two drives. It then stalls.

There is a total voltage drop of 22 %, with no recovery of voltage between energising drives.

All the drives then slip, and the belt then accelerates rapidly to full speed with severe transients evident.

The fluid coupling run-up curves intersect the motor run-up curves on all drives – This implies that each motor is pulling 5 X full load current during the start; a large load on the transformers.

Significant mass spring tension transients are evident after the acceleration.



EXAMPLE 10: COMBINATION OF DIFFERENT PULLEY LAGGING WEAR AND DIFFERENT FLUID COUPLING OIL FILLS.

Length: 600 m Speed: 3,8 m/s Power: 2 x 250 kW

Belt Rating: St 800, 1350 mm Tonnage: 1800 TPH

The peak total conveyor running power during the 6 days was 500 kW at an average load of approx. 1800 TPH.

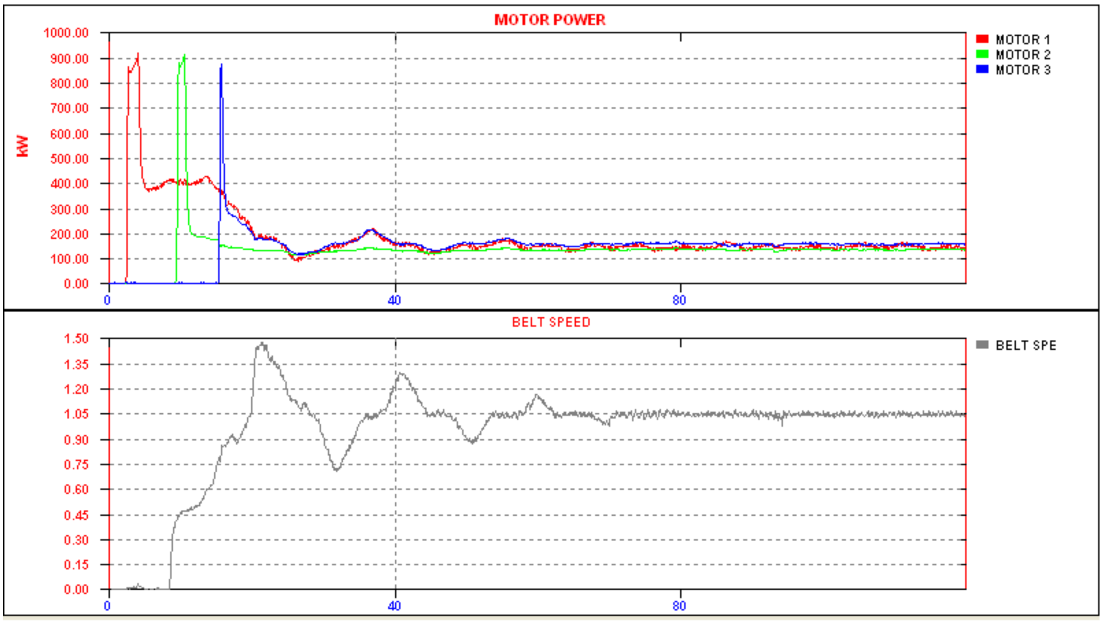
This equates to 98 % of the total installed power.
(1 X 250 kW and 1 X 260 kW)

The empty total conveyor running power was 80 kW.
This equates to 15 % of the total installed power.

The load sharing between the drives is poor:

At peak load the power split is:

M1 Front Drive	330 kW	66%.	127 % of nameplate rating.
M2 Back Drive	170 kW	33%.	68 % of nameplate rating.



EXAMPLE 11: HIGH BELT TRANSIENTS DURING AN EMPTY START DUE TO OVERFILLING OF FLUID COUPLINGS.

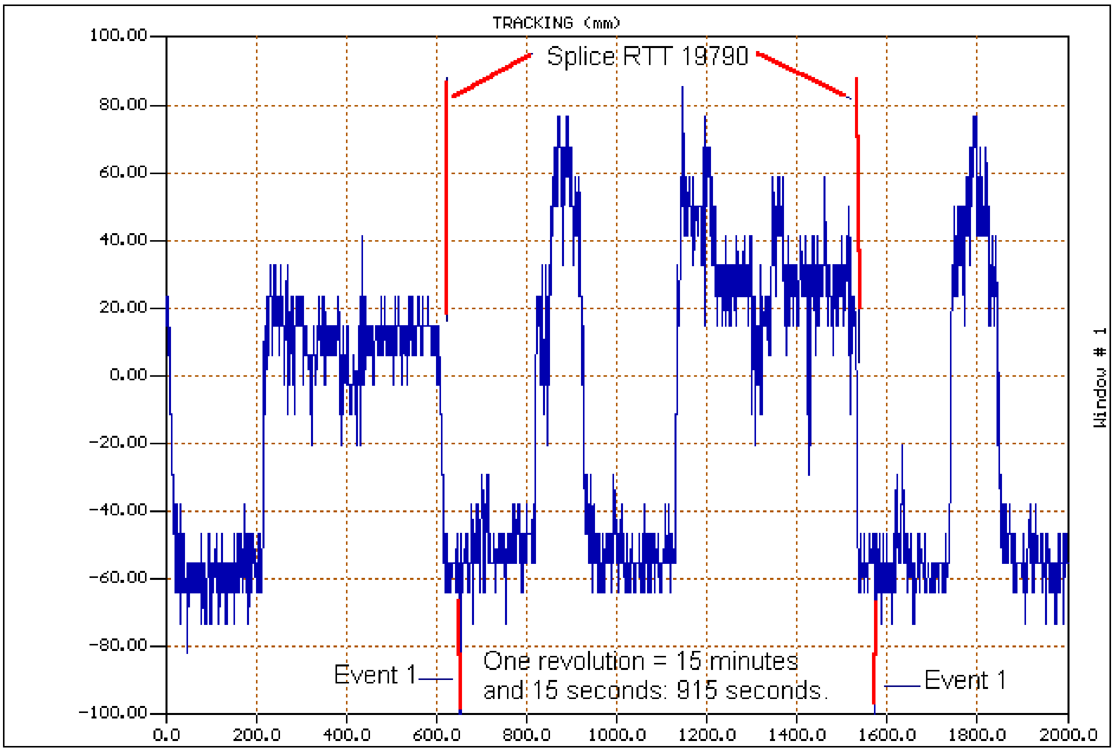
Length: 4000 m Speed: 3,5 m/s Power: 3 x 300 kW

Belt Rating: St1000, 1350 mm

The start-up behaviour is poor.

The conveyor reaches full speed rapidly, in 9 seconds, with significant belt transients evident in the 50 % overspeed in the take-up area.

Like the loaded start, high powers are being transmitted by drive 1, with drives 2 and 3 playing little part in the acceleration:



EXAMPLE 12: BELT MISTRACKING.

Y-axis: Mistracking in mm.

The positive tracking values indicate belt tracking towards the left hand side of the conveyor centre, viewed in direction of product travel, on the carry cover.

The negative tracking values indicate belt tracking towards the right hand side of the conveyor centre, viewed in direction of product travel, on the carry cover.

X-axis: Time in seconds.

The tracking cycle with each revolution of the belt is repeatable.

The maximum amplitude of mistracking measured, from belt tracking right to belt tracking left exceeds 160 mm.

The natural tracking of the belt would even be worse if the self tracking idler sets installed along the entire conveyor length were not installed.
We estimate that the value would exceed 250 mm.

The belt always tracks left when the markings on the carry cover are on the right hand side of the belt.

Inversely, the belt always tracks right when the markings on the carry cover are on the left hand side of the belt. For example:

The tracking swings from one side to the other at those splices where the markings on the belt change from one edge to the other.

From Splice No.	Splice Reference	To Splice No.	Spice Reference	Mistracking	Belt Markings
1	19782	2	19781	Left	Right
2	19781	3	19779	Left	Right
3	19779	4	19794	Left	Right
4	19794	5	19790	Left	Right
5	19790	6	19789	Right	Left
6	19789	7	19785	Right	Left
7	19785	8	19784	Left	Right
8	19784	9	19783	Right	Left
9	19783	1	19782	Right	Left

The tracking is independent of loading on the belt. I.e. even when empty, a similar tracking pattern is observed.

Conclusions

The poor belt tracking is directly related to the occurrence of those splices that have been made between one belt roll end and another belt roll end, or at those splices that have been made between one belt roll beginning and another belt roll beginning.

3. PART 2: CONDITION MONITORING OF STEEL CORD CONVEYOR BELTS:

Scanning or Non-destructive Testing (NDT) is a good preventative maintenance tool for users of steel cord belts.

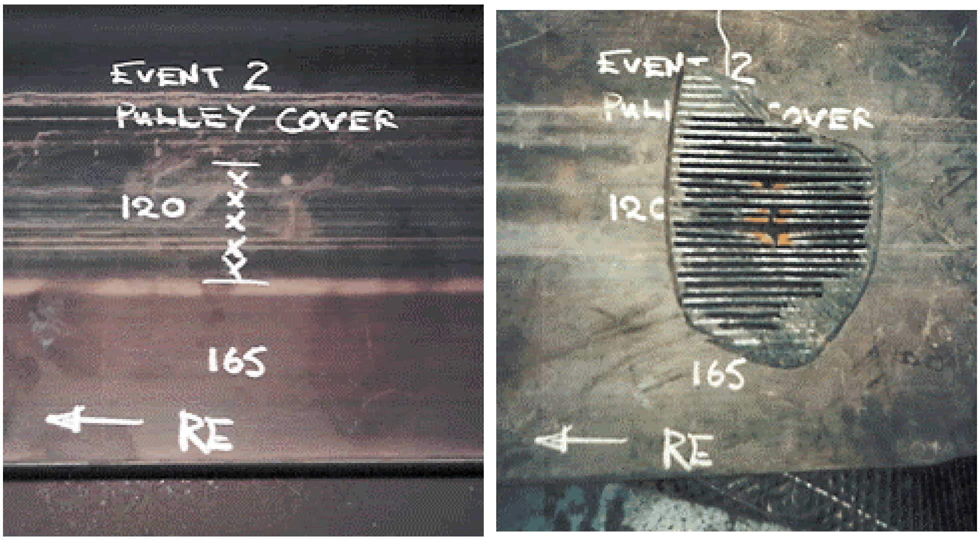
Various methods are used, the most common being electromagnetic inductance and X-rays.

The **X-ray system** shows best the condition of the cords and the lay-up of the cords in the splices. However the X-ray system is bulky and usually needs three or more revolutions of the belt to gather all the data. The scanning area also has to be cordoned off during the process because of radiation hazard.

The **electromagnetic induction system** can also identify the condition of the cords accurately and show the cord lay-up in the splices by analysing the magnetic signatures of the splices.

The aim of the service is to extend the safe working life of the belt by quickly and easily interrogating it at a more affordable price, more frequently.

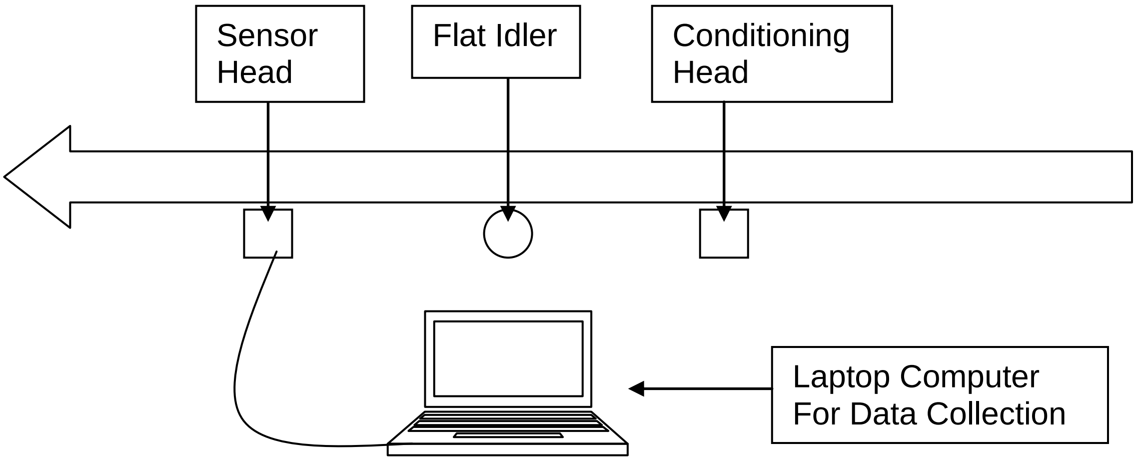
To complement the total system assessment, we use the electromagnetic induction system, which will be elaborated on in the rest of this paper. To date, over 2000 km of steel cord belt has been scanned.



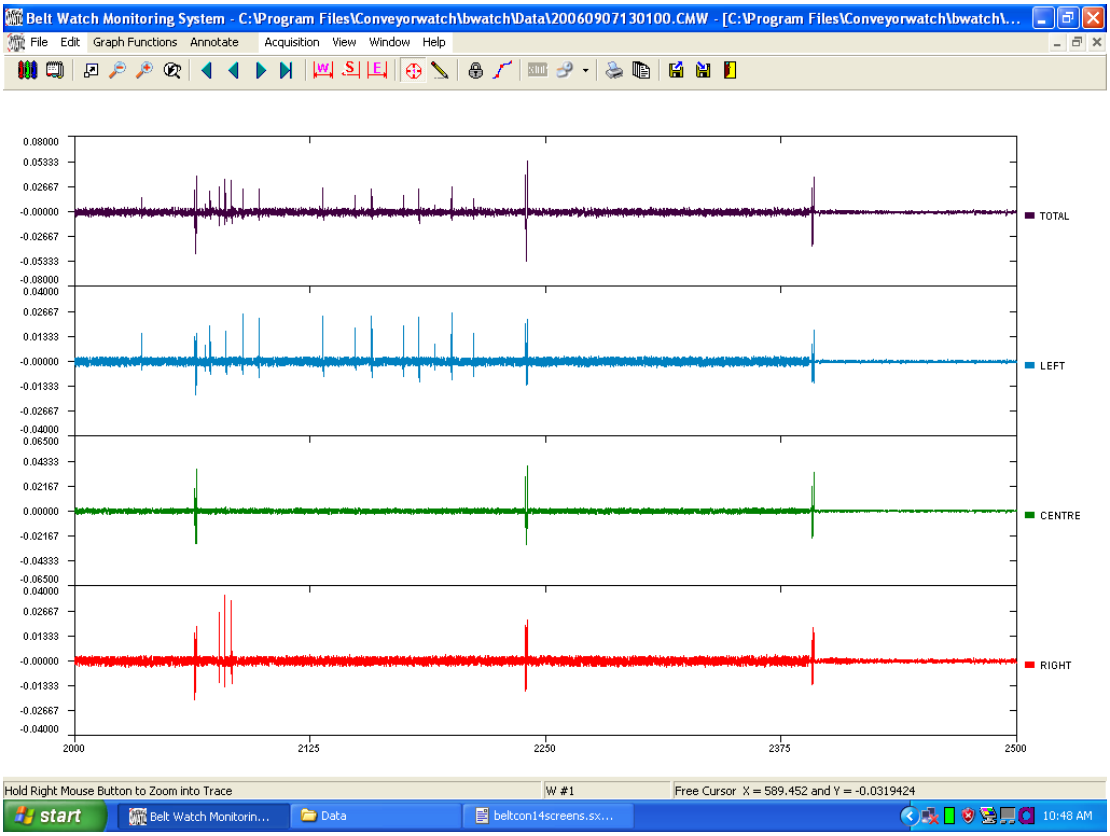
Comparison of electromagnetic system to what the x-ray system would see.

PRINCIPLE OF OPERATION.

All steel cords are magnetised, and any damage is detected by sensing changes in magnetic flux.



The damage, extent and location; both longitudinally and horizontally, are recorded using a laptop computer. The data is then processed / analysed and printed out in a user-friendly manner to enable the operator to prioritise and locate damage in the full belt length.



Belt Watch Monitoring System - C:\Program Files\Conveyorwatch\bwatch\Data\20060907130100.CMW - [C:\Program Files\Conveyorwatch\bwatch\...

Hold Right Mouse Button to Zoom into Trace

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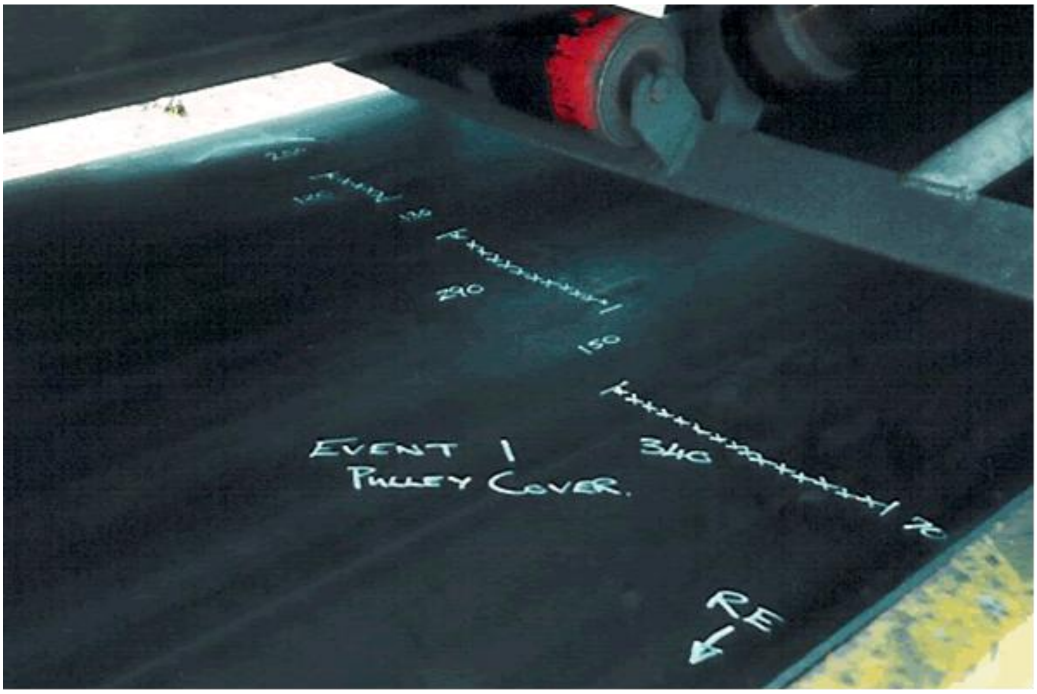
Typical Data Collected showing Splice and Damage Location and Extent.

A physical inspection of the belt is carried out to calibrate the data and thereafter to mark and photograph / identify the largest damage events.



Example of damage identified. 56 % of the belt width has broken cords.

After full visual inspection and analysis, a comprehensive report is presented with the following information:

Prioritised recommendations.

Summary of belt condition.

Location and extent of damage events including;

- Broken or damaged cords.
- Corrosion of steel cords.
- Cover punctures and other cover damage.
- Edge damage.
- Condition of existing repairs.

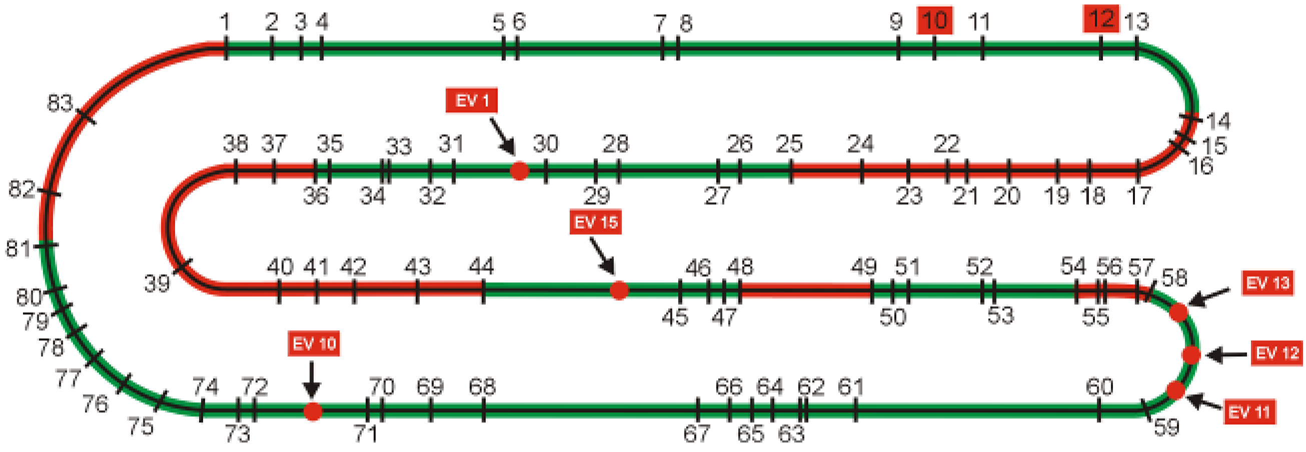
Splice condition via magnetic signature evaluation and visual inspection.

Cover wear and condition.

LEGEND:

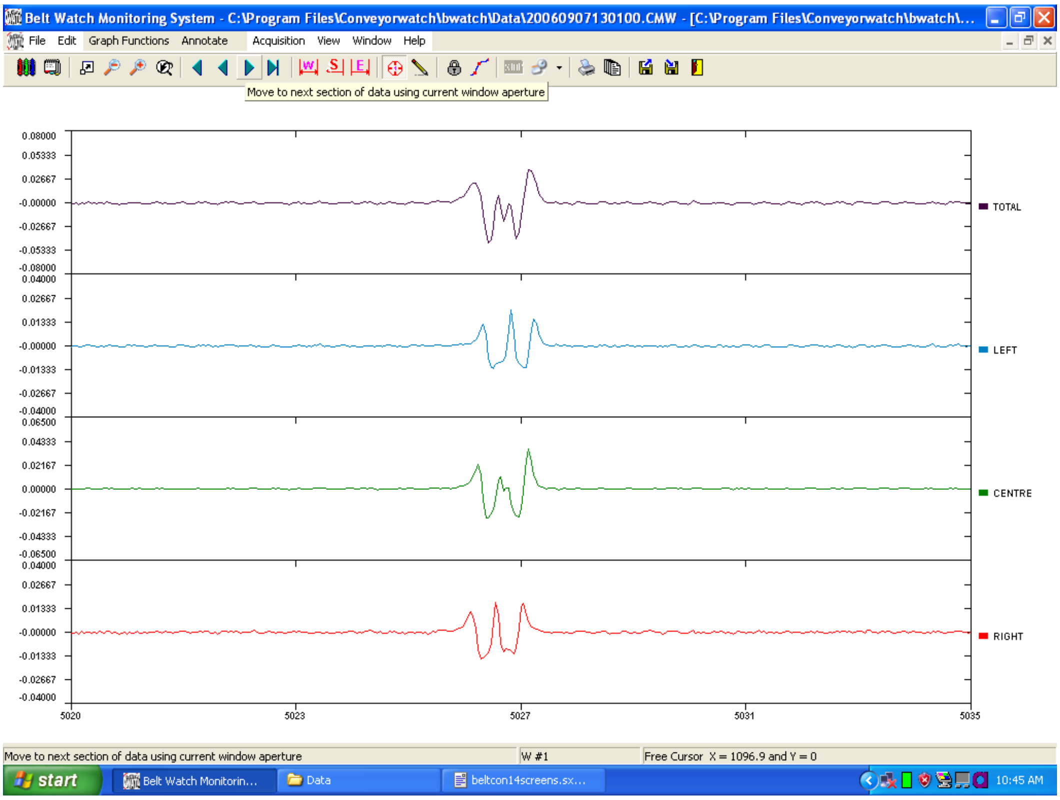
🟩 : **Good belt**

🟥 : **Bad belt**



Example of report output and prioritised repair of damage.

Each splice signature is analysed and any splices with suspect signatures are visually inspected and damage recorded.



Belt Watch Monitoring System - C:\Program Files\Conveyorwatch\bwatch\Data\20060907130100.CMW - [C:\Program Files\Conveyorwatch\bwatch\...

Move to next section of data using current window aperture

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Example of a good electromagnetic splice signature.

Example of visual inspection of damage in splice with suspect magnetic signature.

Permanently installed monitoring systems of various combinations are available depending on clients needs and location.

Example of a permanent installation.

Equipment is installed under the return belt, on either side of a flat idler.
A laptop computer is connected to the terminal box for data collection.
An on-site briefing is given, outlining any major damage needing immediate repair plus a thumbnail condition assessment.

4. REFERENCES.

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Surtees, A.J.: Performance investigation of a longwall panel conveyor incorporating a tripper drive system; Bulk Solids Handling Vol 18 (1998) No. 1, pp 81-85.

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Note: Most of the above papers are available on the web site www.saimh.co.za. Look under the header: Beltcon.

5. AUTHORS CV.

Athol Surtees studied Mechanical Engineering at Wits University in Johannesburg from 1976 to 1979. He registered as a Professional Engineer in 1990.

He has been involved in numerous aspects of Material Handling for the last 25 years. His main interest in is the dynamic behaviour of belt conveyors. This arose during his early years as a conveyor drive designer / supplier, and coincided with the period where dynamic problems started to show up more frequently due to the longer and higher power conveyors being built.

Since 1993 he has been an independent consultant specialising in conveyor dynamic testing and problem solving. Over 400 audits / performance tests have been done to date.

Since 1995 he has also been involved in non-destructive testing of steel cord belts. Over 2 million meters of belting have been scanned to date.

His company, Conveyor Watch, is a member if the Conveyor Manufacturers Association of South Africa Limited and the SA Institute of Materials Handling.

He has worked and presented numerous papers in Europe, USA, India and Australia.

This is his 7th Beltcon paper since his first presentation at Beltcon 3 in 1985.