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CONVEYOR SYSTEM COMMISSIONING, MAINTENANCE AND FAILURE ANALYSIS USING BLACK BOX TECHNIQUES

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SYNOPSIS

This paper discusses the history and developments of sophisticated monitoring equipment used to measure the operating parameters of conveyor systems.

With the radical reduction in price of computer hardware and software during the last decade and an associated increase in memory capacity, the concept of continuous conveyor monitor is now a reality. With this tool, the various problems normally encountered in large conveyor installations can now be avoided at an early stage.

The four main areas of application are:

- Design verification
- Hand-over certification
- Preventative maintenance and increase of system availability
- Failure analysis

The paper introduces the techniques used and gives examples where the service has been used.

CONTENTS

1. INTRODUCTION

Most of the problems encountered in conveying of materials can be overcome by identifying the source of these problems.

Often no one is aware that a problem exists in the system until a failure occurs, or the effect of the failure is mistaken as the cause.

This paper shows ways of identifying problems and their sources before failures occur, so that corrective measures can be taken at an early stage.

The methods used increase conveyor system life, availability and reliability and decrease maintenance costs by quantifying system performance. This results in the right information reaching the right people:

- The right information to the designer/contractor at the commissioning stage to verify his calculations and modelling.

- The right information to the owner/buyer of the system to give him assurance of the quality and reliability of the system, i.e. hand-over certification.

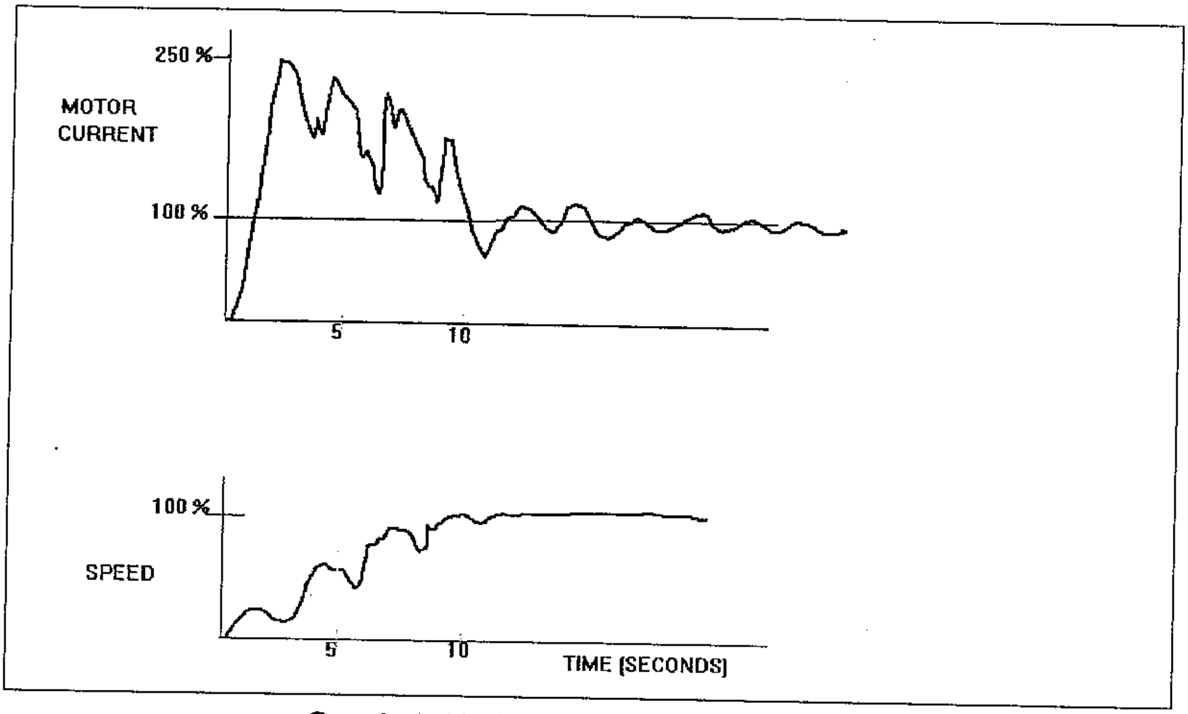
- The right information to the system maintenance personnel to allow ease of future problem identification and implementation of preventative maintenance procedures.

- The right information to all of the above parties to allow ease of failure analysis in the system should it occur.

2. BACKGROUND AND DEVELOPMENT OF MEASUREMENT TECHNOLOGY

Gathering the right information was always difficult in the past. Chart and tape recorders were used, but had the limitations of only being able to record a few parameters and only for short periods of time. In addition, no transducers were available off shelf, they had to be custom-built to suit rigorous mine conditions.

With primitive tools and no experience, initial interpretation of measurements was difficult. The following graph shows an original test done with a current transducer and a hand held tachometer on a conveyor:



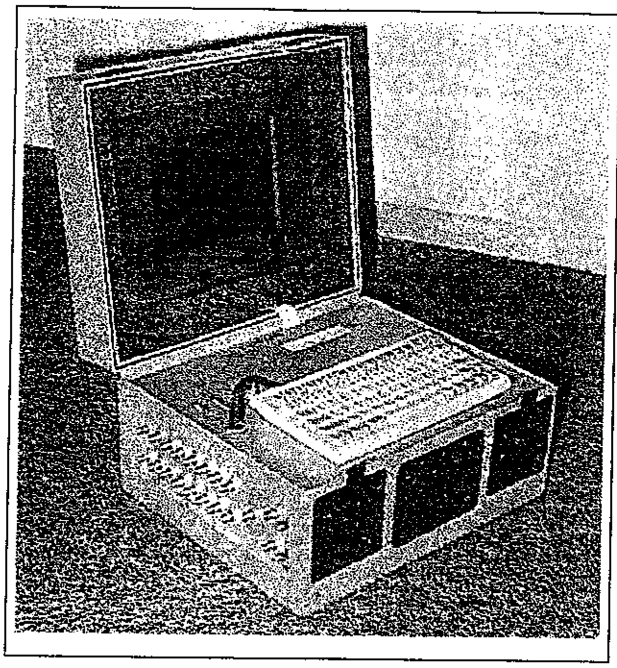
Graph 1: Underground section conveyor

Current and speed measurements did not help quantify what belt tensions were present. Power and take-up performance are necessary to get the whole picture.

With the introduction of cost effective computing, these recorders have been made obsolete. PCs with analogue/digital cards were introduced for easier measurement. Portable PCs with serial links and user-friendly software have now made site measurements easier still.

The only draw back of this system is that an operator is required to run the computer for each and every measurement on site. As a result, the quality of the measurements depend on the time spent on site, availability of the conveyor and load conditions at time of measurement. In addition, mine personnel are understandably against doing tests because of interruption of production.

Custom-built hardware and software has now been developed to overcome the above problems. The new "black box" system allows continuous on-site measurement of long-term operating trends, as well as specific short duration events such as starting and stopping transients, voltage drops and component failures.



16 channels are available for recording conveyor parameters. The channels are usually allocated as follows:

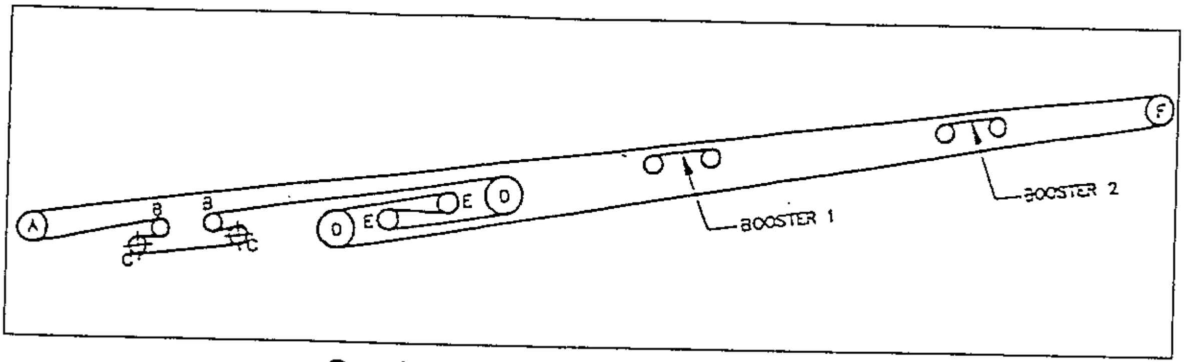
Channels 1 - 6:	Motor powers
Channel 7:	Supply voltage
Channel 8:	Belt speed at head
Channel 9:	Belt speed at take-up
Channel 10:	Belt speed at tail
Channel 11:	Take-up tension
Channel 12:	Take-up displacement
Channel 13:	Tonnage
Channel 14:	Ambient temperature
Channel 15:	Client's request
Channel 16:	Client's request

The black box incorporates further improvements in computer memory capacity and is now capable of collecting almost limitless amounts of information. For example, the computer memory is capable of recording a conveyor's parameters (running starting, stopping, failures, etc.) for more than one year without running out of memory.

The software specification is as follows:

- Continuous monitoring of 16 analogue channels in any combination (10 Hz to one sample per day).
- Real time display of selected channels.
- Intelligent trigger to capture transients. Two triggers can be used simultaneously: trigger on positive slope and trigger on negative slope.
- Powerful graphics software to enable viewing of entire data selection. Selected portions can be loaded for analysis.
- Analysis module which indicates channel manipulation, peak detection, level-crossing and statistical results.
- Output to printer or plotter in high resolution. Supports colour printers.
- Data transfer to ASCII or Lotus/Excel spreadsheets.

Sophisticated yet rugged transducers have also been custom-built and refined to measure all important conveyor parameters. All the transducers are designed to allow their output signals to be transmitted over long distances without losing accuracy. For example, belt speeds and power measurements can be carried via a mine's telephone lines from the tail and intermediate drive stations to the head station several kilometres away where the black box is installed.



Graph 2: 7,1km long booster conveyor

The belt speeds at drive, tail and take-up as well as in-by and out-by of both boosters were recorded. Head and booster drive powers, take-up tension and trolley movement were also recorded.

3. EXAMPLES OF APPLICATIONS

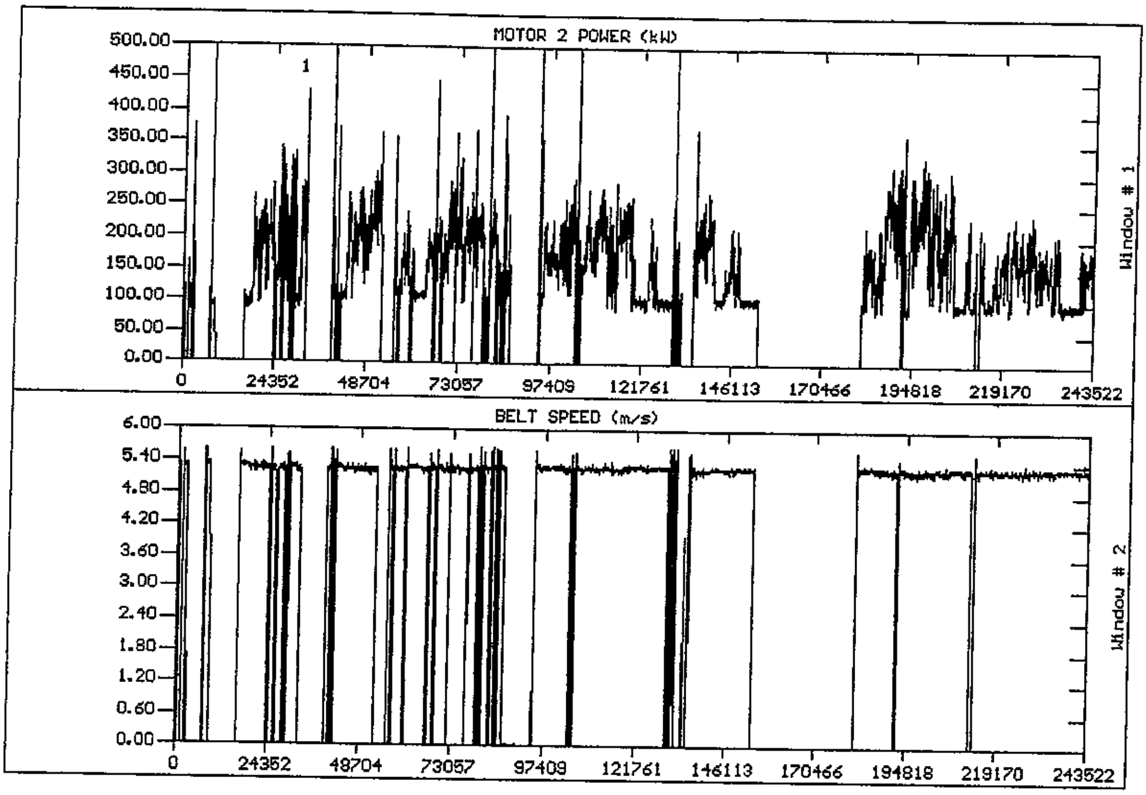
In the following pages, three examples are given for each area of application. (Note: All variables are shown plotted against time in seconds.)

3.1 Design verification: Examples 1, 2 and 3

3.2 Hand-over certification: Examples 4, 5 and 6

3.3 Preventative maintenance: Examples 7, 8 and 9

3.4 Failure analysis: Examples 10, 11 and 12



EXAMPLE NO. 1: Opencast overburden conveyor

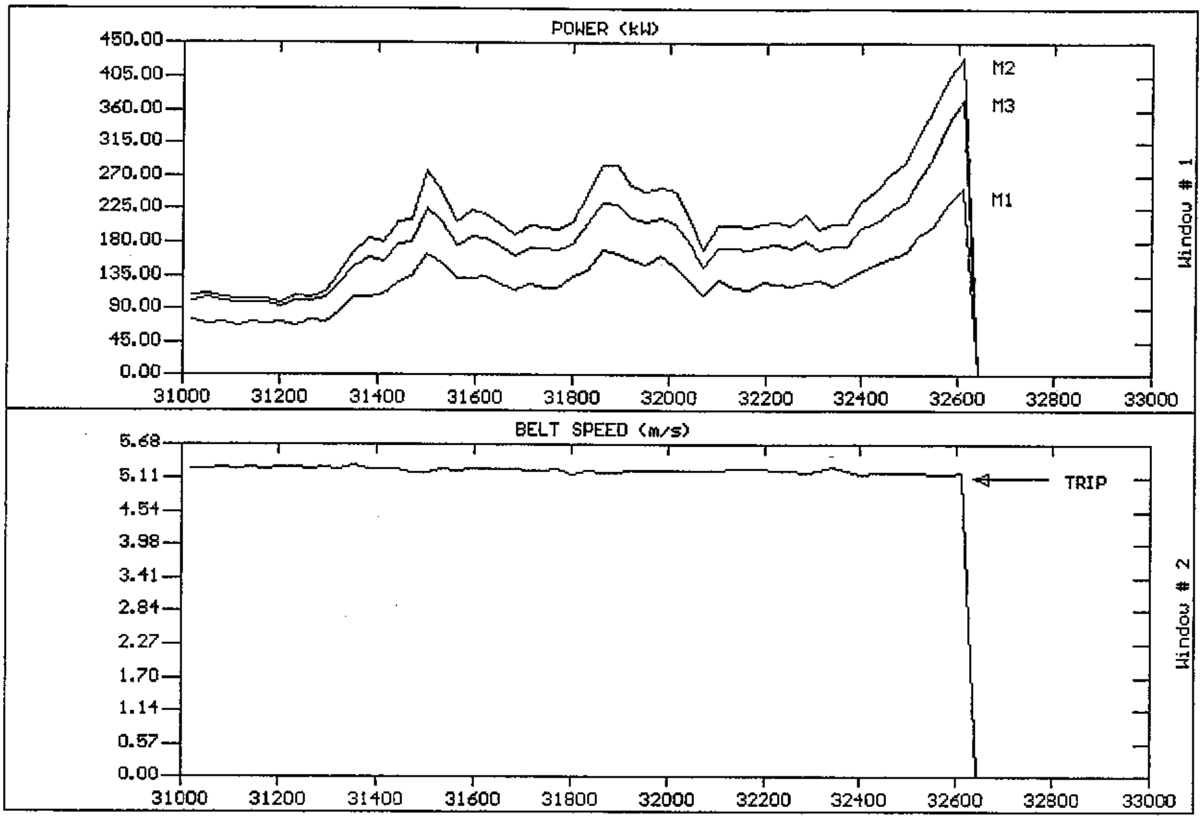
Belt: Steel cord, ST1600
Drives: 3 X 350 kW + FCs
Take-up: Electric winch

Belt centres & lift: 1600 m, 8 m
Belt speed: 5,2 m/s
Tonnage: 3000 TPH

Continuous monitoring of the conveyor was done over a three day period. The graph shows only one of the motor powers and the belt speed.

All stops and starts were recorded. The loading trend and starting peaks are obvious. The highest power drawn by the conveyor was identified as event no. 1, which is analysed on the following graph.

The information obtained is also useful for checking shift performance and conveyor availability over the three days.



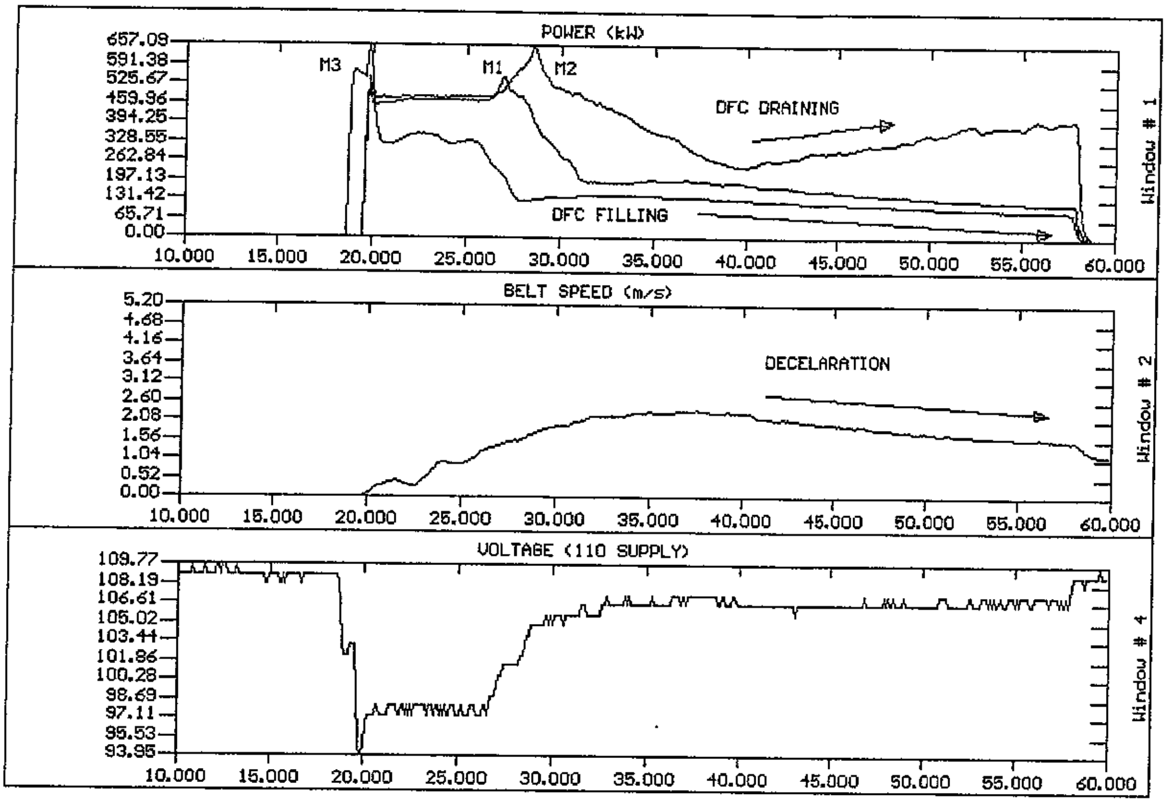
EXAMPLE NO. 2: Overcast overburden conveyor, loaded trip

Belt: Steel cord, ST1600
Drives: 3 X 350 kW + FCs
Take-up: Electric winch

Belt centres & lift: 1600 m, 8 m
Belt speed: 5,2 m/s
Tonnage: 3000 TPH

The graph shows event no. 1 from the previous graph.

The loading trend from running empty on the left to overload trip on the right is evident. The load sharing is poor with motor no. 2 transmitting over 120% of name-plate rating and motor no. 1 transmitting only 70% of name-plate rating.



EXAMPLE NO. 3: Overcast overburden conveyor, aborted start

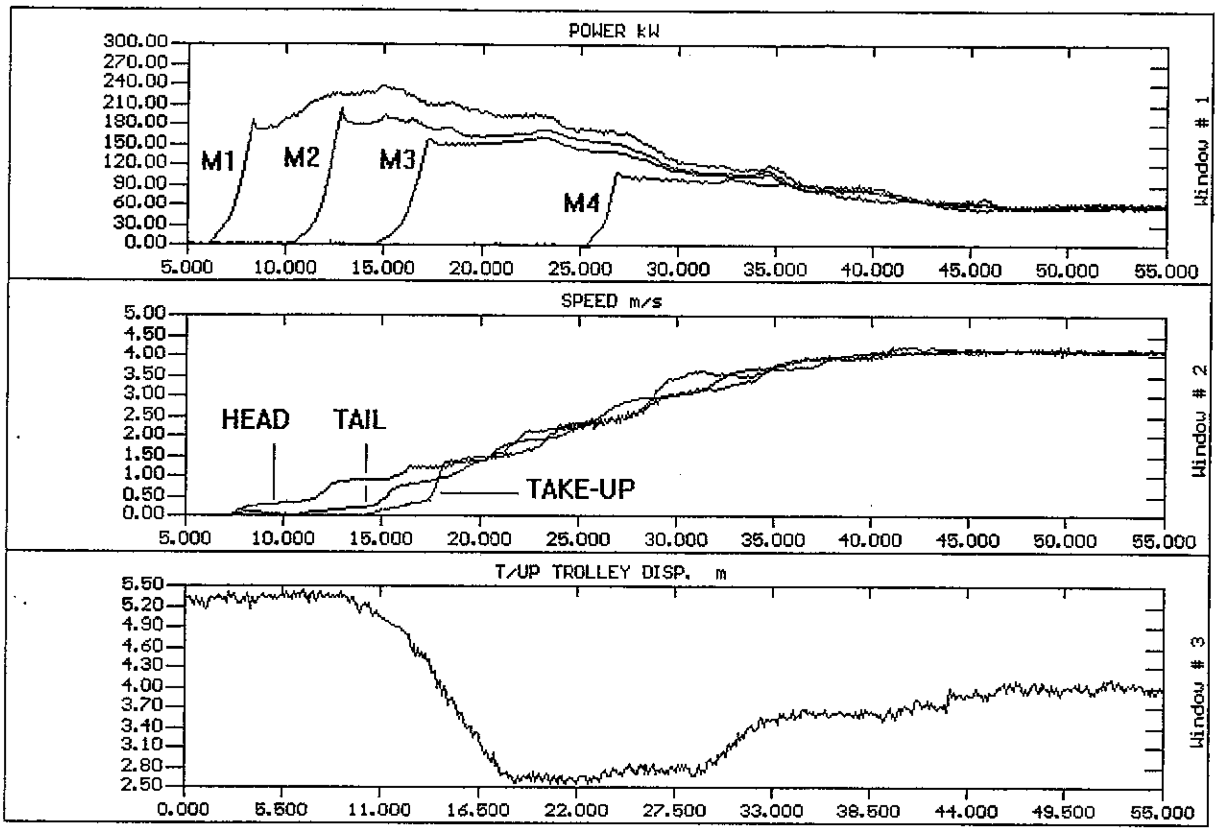
Belt: Steel cord, ST1600
Drives: 3 X 350 kW + FCs
Take-up: Electric winch

Belt centres & lift: 1600 m, 8 m
Belt speed: 5,2 m/s
Tonnage: 3000 TPH

This graph shows the second attempt to re-start the conveyor - the first attempt was unsuccessful due to motor current overload.

Motors 1 and 2 are started simultaneously, one second after motor 3. This induces a 10% voltage drop which, together with the high run-up torque of the fluid couplings, results in motors 1 and 2 taking over 10 seconds to accelerate. (The run-up torque of the coupling intersects the motor torque speed curve prior to the motor reaching full speed.)

Unusual coupling behaviour then occurs - coupling no. 2's delay fill chamber drains while the coupling delay chambers of motors 1 and 3 refill. The net loss of power causes the conveyor to decelerate and the system then trips due to overload of motor no. 2.



EXAMPLE NO. 4: Overland conveyor, empty start

Belt: Steel cord
Drives: 4 X 260 kW + FCs1
Take-up: Gravity

Belt centres & lift: 4730 m, 22 m
Belt speed: 4,1 m/s
Tonnage: 1500 TPH

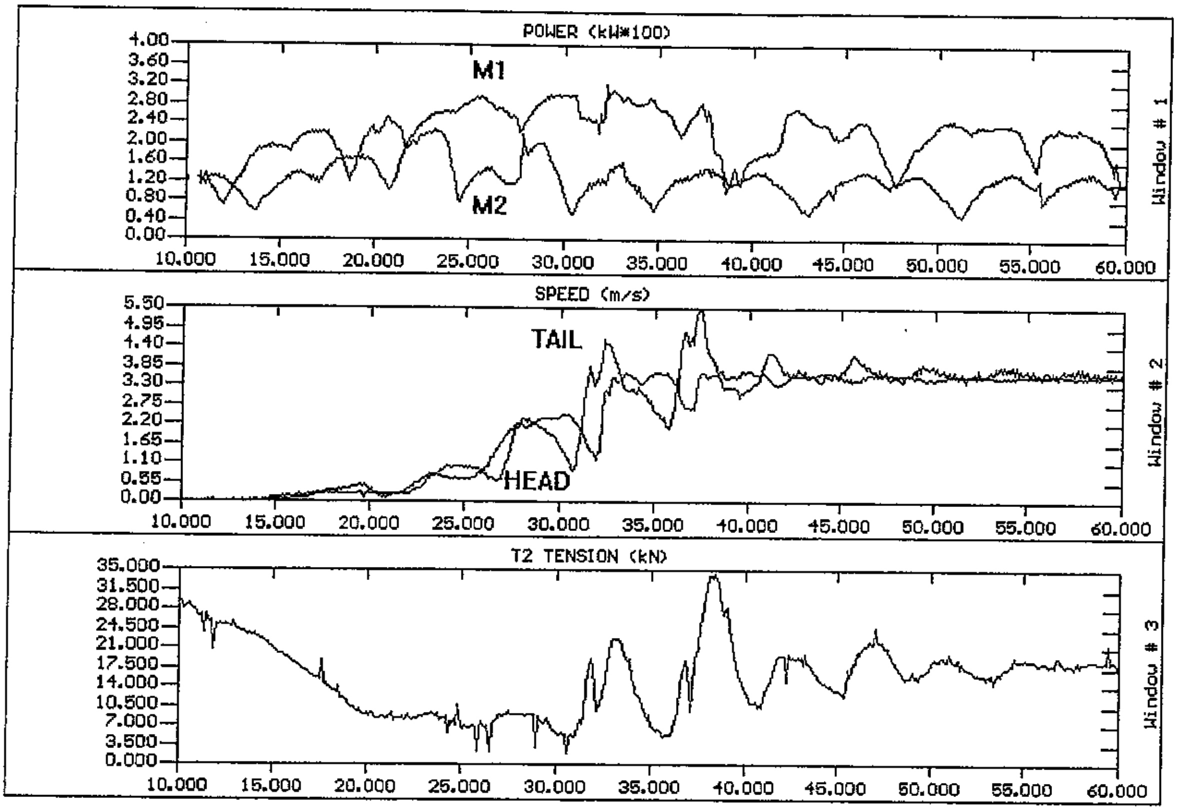
The three head drives are energised with five second time delays. The tail drive (motor 4) is only energised at approximately half speed.

The power build up rate is gradual and longer than that recommended to avoid transients.

The conveyor start up takes 40 seconds with minor transients present.

The take-up movement is slow and a good indication of the excellent starting characteristics.

None of the motors exceed their name-plate rating during the start.



EXAMPLE NO. 5: Underground longwall retreating conveyor, loaded start

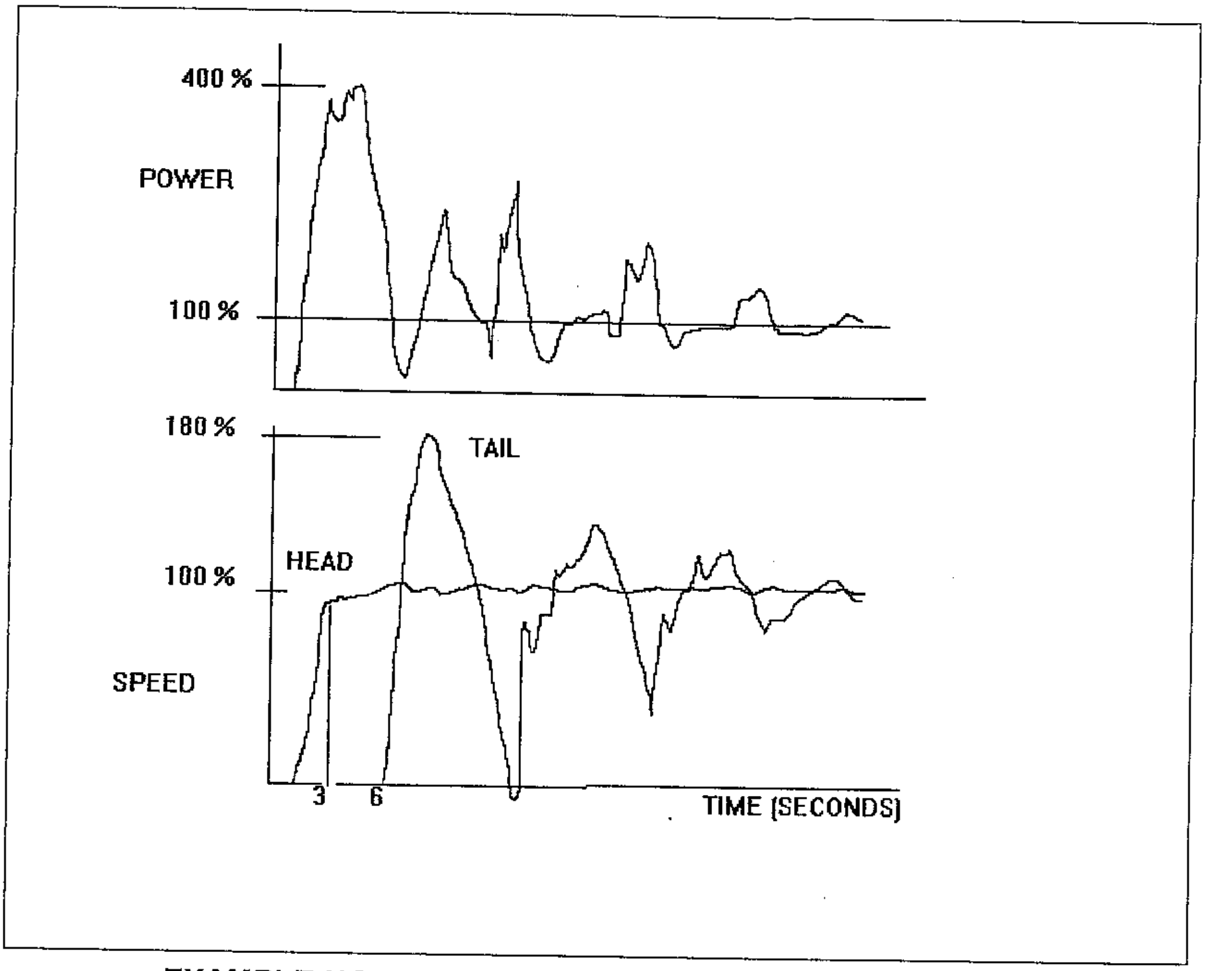
Belt: Solid woven, 1250
Drives: 2 X 240 kW + FCs
Take-up: Electric winch, double trolley and belt storage

Belt centres & lift: 2000 m, 2 m
Belt speed: 3,5 m/s
Tonnage: 1800 TPH

The belt reaches full speed in approximately 40 seconds with significant transients being recorded.

The motors are step started under no load conditions and as the couplings begin to transmit torque, the take-up tension drops in a linear manner until a point where slipping begins to occur between the belt and the drive pulleys. The pulleys slip and grip with a time interval of between five and six seconds, which is evident in the motor power, belt speeds and take-up tension recordings.

From the take-up tension graph, it is obvious that the cause of slip is due to the starting tension being too low. Inspection identified incorrect layout of the winch rope.



EXAMPLE NO. 6: Overland with a concave curve, loaded start

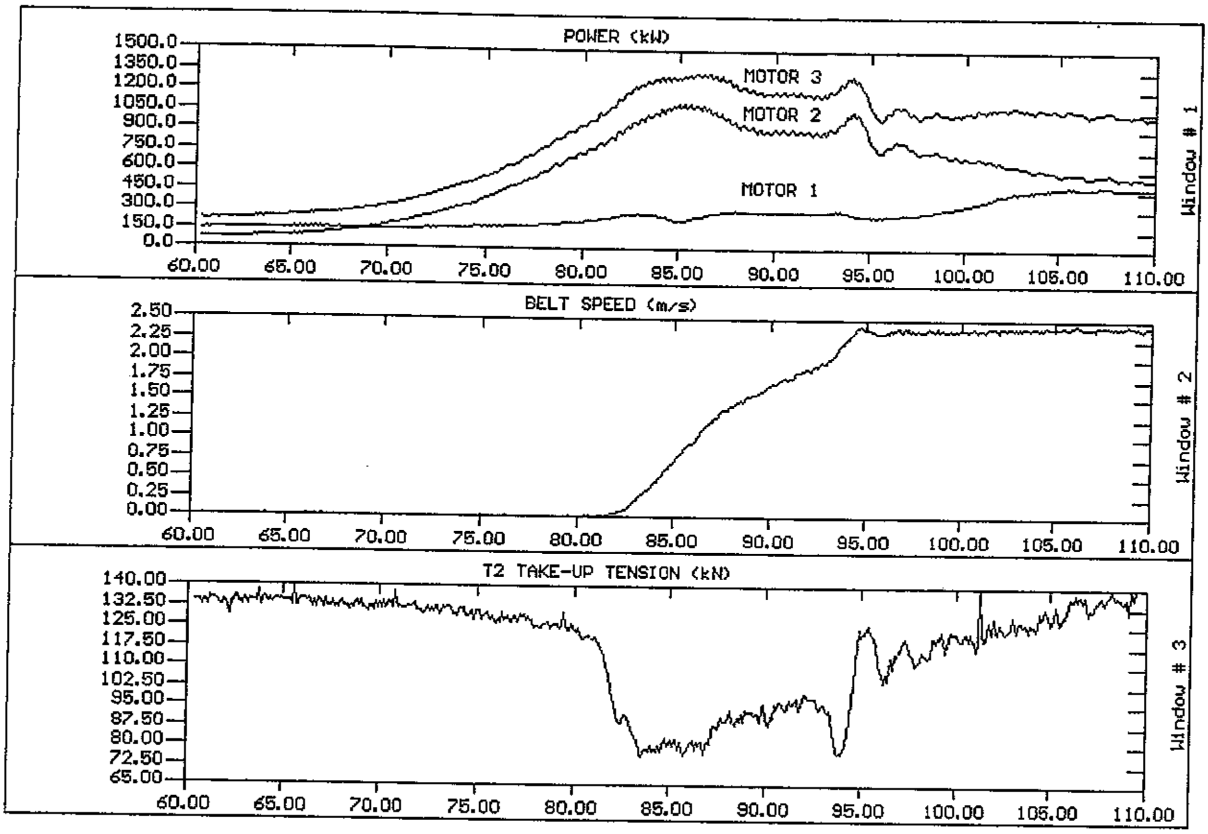
Belt: Ply
Drives: 1 X 132 kW + FC
Take-up: Gravity

Belt centres & lift: 900 m, -5 m
Belt speed: 2,5 m/s
Tonnage: 1000 TPH

The motor and the belt at the head station come up to speed together in three seconds with 400% starting torque. The belt at the tail only starts to accelerate six seconds later and then over speeds up to 180% before being decelerated by the drive to a negative speed - a reversible conveyor!

The acceleration is so rapid that the belt lifts out of the carrying idlers in the concave curve causing severe spillage.

The operators always ensured that the conveyor was only stopped when empty. The empty start was even more dramatic, but the operators preferred to lose the paint on the conveyor roof rather than clear the spillage after every loaded start.



EXAMPLE NO. 7: Plant feed incline conveyor, loaded start

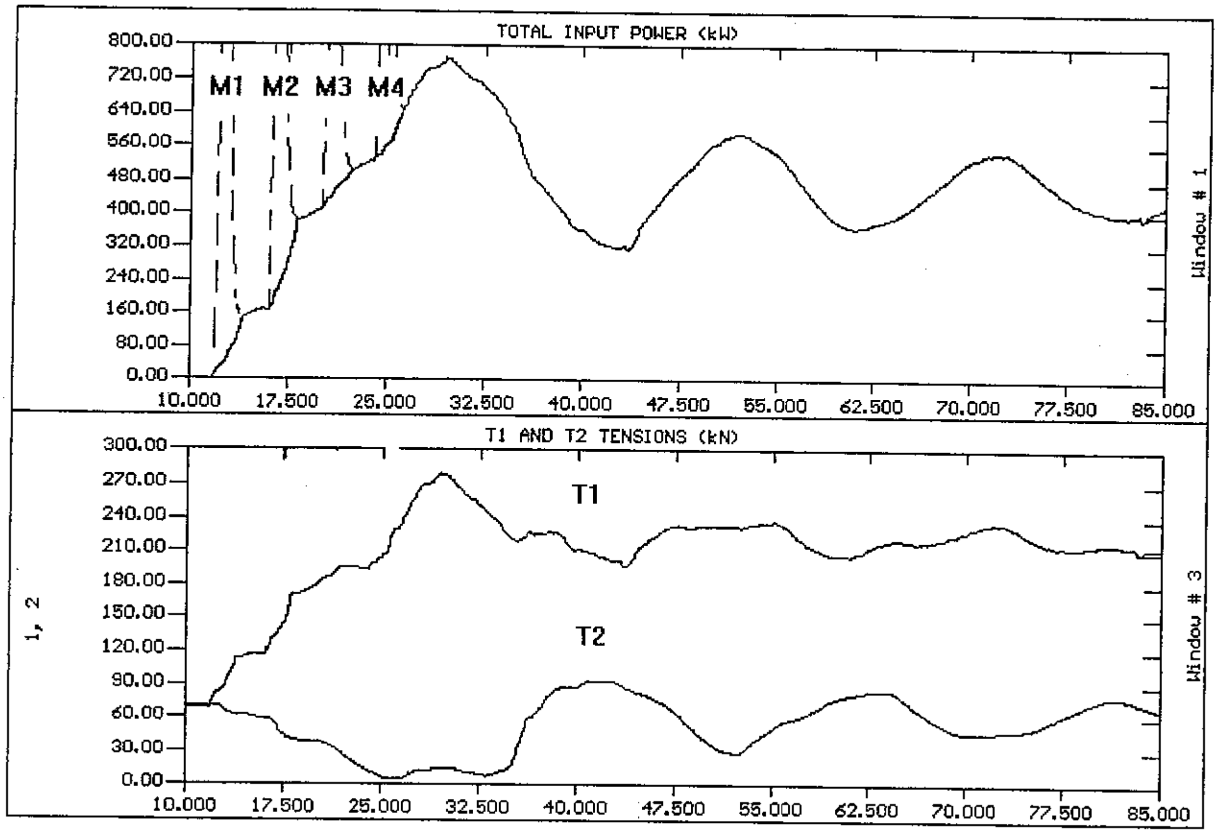
Belt: Steel cord, ST 3150
Drives: 3 X 600 kW + FCs
Take-up: Gravity

Belt centres & lift: 314 m, 75 m
Belt speed: 2,5 m/s
Tonnage: 8000 TPH

Load sharing is poor: Motors 2 and 3 both draw approximately 200% of motor rated power while motor 1 only transmits 50% of its rating.

The gravity take-up is not functioning correctly: it should maintain a constant tension but shows variations of almost 50% during starting.

During running, the tensions were observed to increase with drops in ambient temperature, i.e. the take-up is doing exactly opposite to that which is required.



EXAMPLE NO. 8: Underground trunk conveyor, loaded start

Belt: Solid woven, class 1250
Drives: 4 X 200 kW + FCs
Take-up: Electric winch

Belt centres & lift: 2350 m, 0 m
Belt speed: 2,8 m/s
Tonnage: 2000 TPH

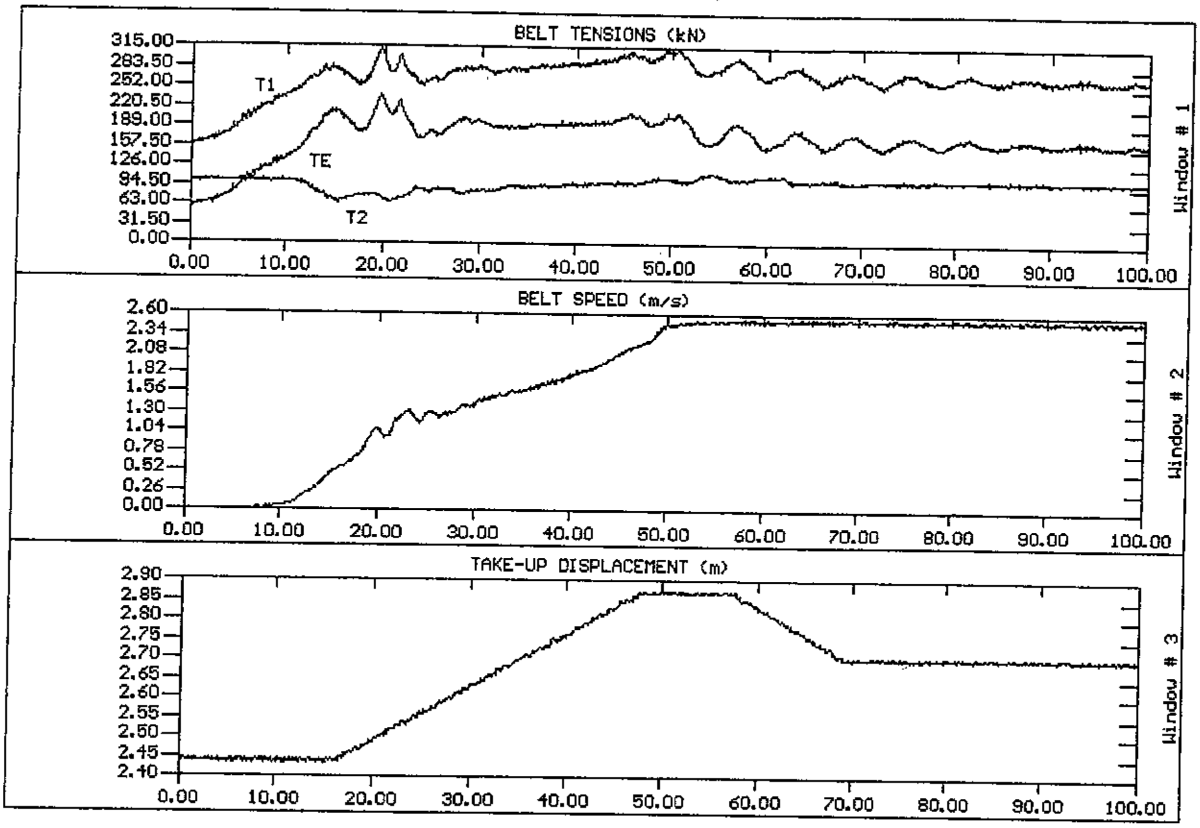
The motors are step started with equal time intervals of four seconds. The power build up is almost linear: 770 kW in a ramping time of 18 seconds, which is well over the recommended minimum time of 13 seconds.

However, the acceleration still results in a 55% over speed of the belt at the tail.

A mass spring oscillation of 20 second period is evident in the power, tension and belt speed measurements.

The T2 tension almost reaches zero at peak power in-put.

An attempt to improve the start is being made by extending the ramping time.



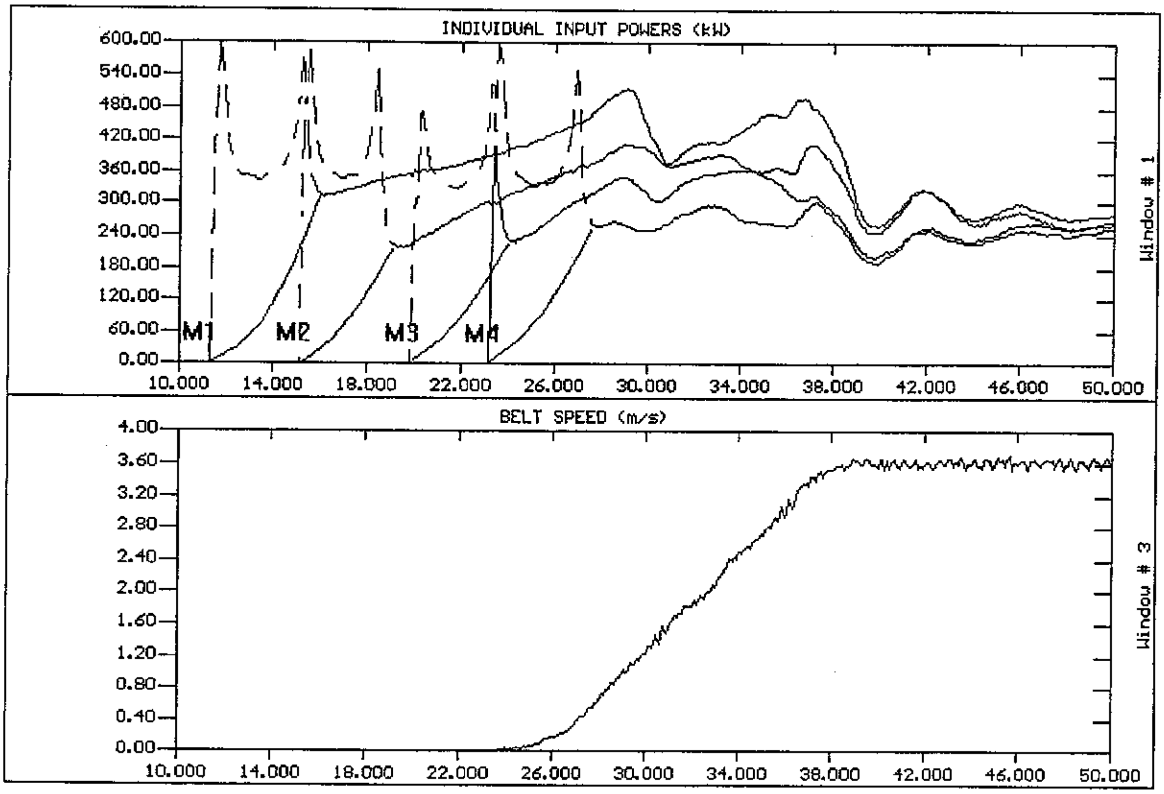
EXAMPLE NO. 9: Incline shaft conveyor, loaded start

Belt: Solid woven, class 3250
Drives: 2 X 450 kW + scoops
Take-up: Electric winch

Belt centres & lift: 1420 m, 200 m
Belt speed: 2,6 m/s
Tonnage: 1000 TPH

The graph shows the starting performance for the conveyor after tuning the system. On initial investigation, one of the drives' scoop coupling control valves had been damaged resulting in the drive transmitting 200% full load torque into the belt. By fitting and adjusting a new control valve, the peak starting tension was reduced from 480 kN to 312 kN - a reduction of 35%.

The winch is functioning well by maintaining an almost constant T2 tension during starting and then releasing to normal running tension once the belt reaches full speed.



EXAMPLE NO. 10: Incline shaft conveyor, loaded start

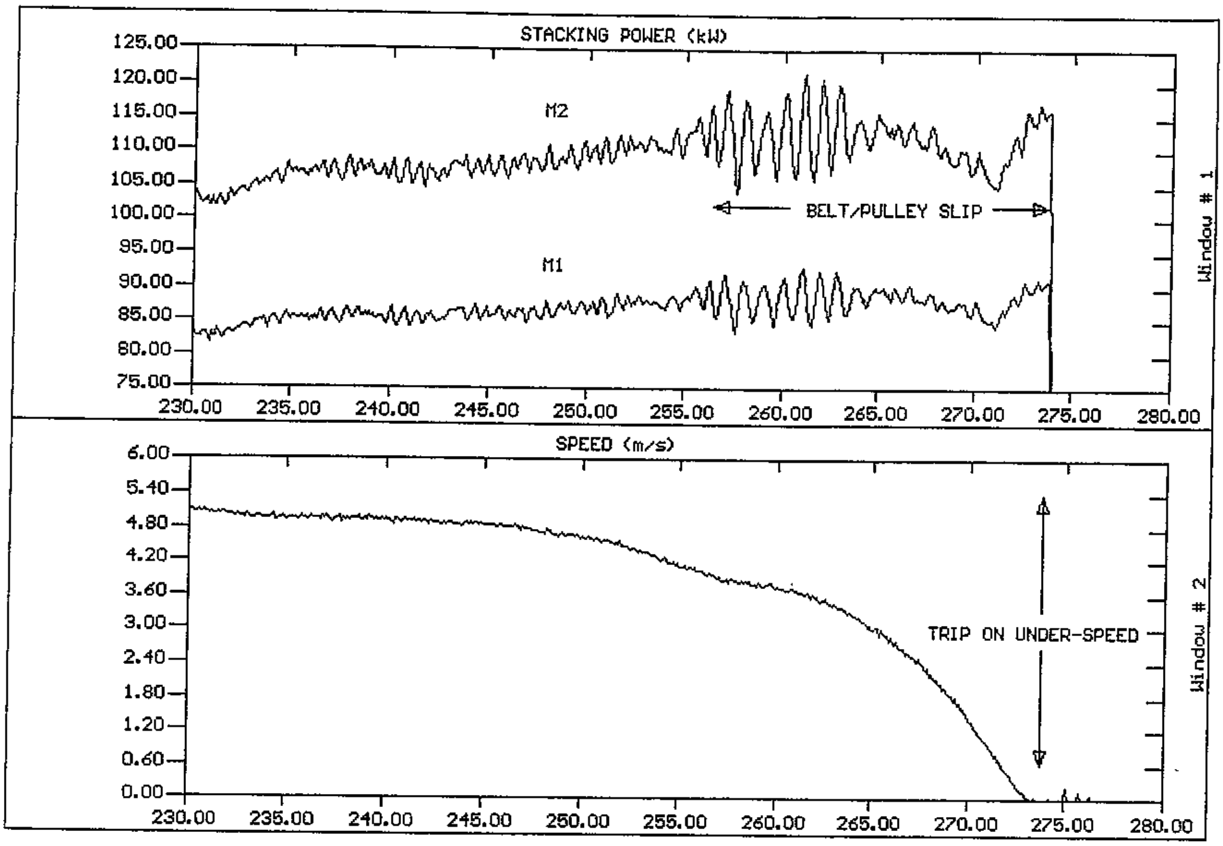
Belt: Steel cord
Drives: 4 X 450 kW + FCs
Take-up: Gravity

Belt centres & lift: 1200 m, 160 m
Belt speed: 3,7 m/s
Tonnage: 2000 TPH

Tests were done on this conveyor specifically to identify the peak power in-puts to the four gearboxes to decide whether gearbox failures being experienced were due to overloading or not.

The continuous monitoring proved that the peak power in-put to each gearbox did not exceed 66% of the motor rating.

In addition, the heaviest load start was identified as shown above - the peak starting factor for each drive did not exceed 115% of name-plate rating.



EXAMPLE NO. 11: Stacker/reclaimer conveyor, under speed trip

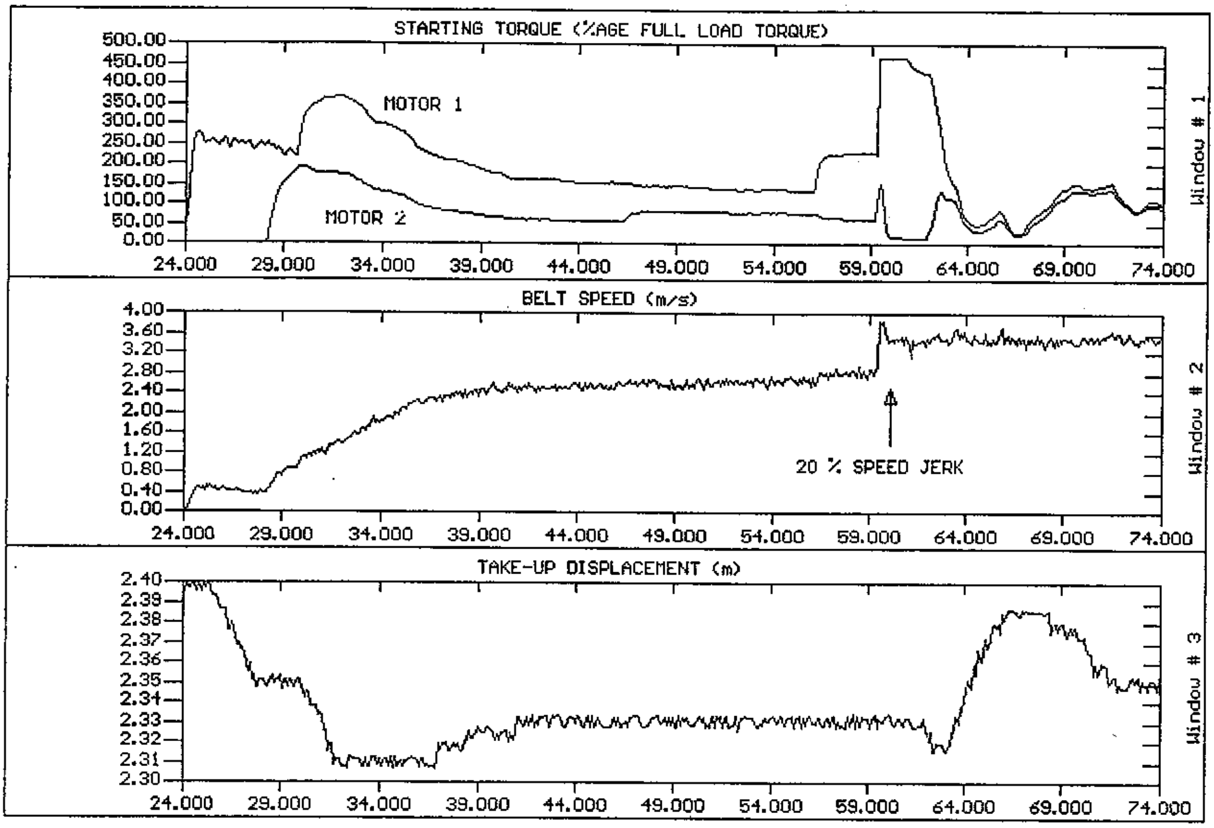
Belt: Ply, class 1000
Drives: 2 X 75 kW + FCs
Take-up: Gravity

Belt centres & lift: 30 m, 7 m
Belt speed: 5,5 m/s
Tonnage: 3300 TPH

Low availability of the conveyor due to under speed trips was reported. The result was always a blocked chute, and thus the chute design was seen as the problem. In reality, it was the result of the conveyor being under powered for the tonnages being handled.

The black box was installed to record one of the trips which is shown above.

Load sharing is poor and, as the load increases beyond the drive rating, the couplings and motor slip increase resulting in a decrease in belt speed. Chute blockage increases the load further and drive pulley/belt slip begins to occur with a one Hz frequency - the conveyor eventually comes to rest and the drives are tripped on under speed.



EXAMPLE NO. 12: Overland conveyor, loaded start

Belt: Steel cord, ST500
Drives: 2 X 200 kW + Slip ring
Take-up: Gravity

Belt centres & lift: 3200 m, 6 m
Belt speed: 3,6 m/s
Tonnage: 1500 TPH

The start up is fair up to 80% full speed when no further acceleration occurs. A switching of resistors induces over 450% of normal rated torque through motor no. 1. The belt accelerates from 80% to full speed almost instantaneously.

This not only induces high tensions in the belt but has resulted in gearbox failures.

4. CONCLUSIONS

Continuous monitoring and simultaneous high speed recording of specific events, such as starting and stopping dynamics, is a useful tool for designers, users and maintenance personnel. It ensures proper performance of the conveyor system, reduces down-time and increases system availability.

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