Verification of Conveyor Designs, Post Installation

Athol Surtees, Conveyor Watch Pty, Ltd.

1. Introduction

During the last 15 years, Conveyor Watch has been involved in over 300 post installation conveyor investigations. These investigations were done either to verify the designs or to check the incorrectness of these conveyor systems. Our task was to try to correct, or by definition, to set right by altering or adjusting the conveyor.

This paper will discuss the source and type of problems encountered in these investigations, with the aim being to assist future designers and users by highlighting areas that need special attention. It will be shown that the problems are mainly not due to poor design, but rather due to poor design specifications, equipment not meeting good design specifications, or incompatibility of equipment used.

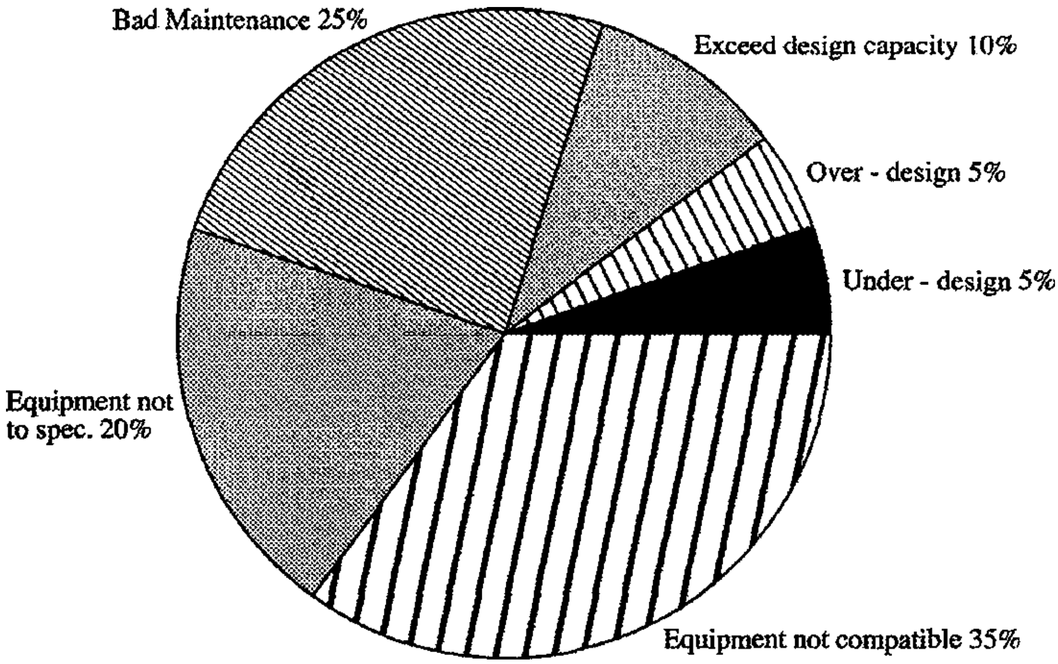
2. Source of problems encountered - refer to graph 1.

2.1 Conveyors Under - designed. 5%

Only a small portion of the investigations identified under - design as the main source. Examples ranged from unintentional errors in design inputs to blatant intent to risk under-design to ensure project profitability.

2.2 Conveyors Over - designed. 5%

Again only a small portion of the investigations identified under - design as the main source. Normal design standards incorporate a 20% over design allowance. However, some investigations have identified excessive over - allowance - up to 100%. Here the designers have been too conservative.
In the past, this has occurred particularly in the case of long overland systems where resistance factors were debatable. One example is a 6 km overland which was designed and buiit with 3 drive units, two at the head and one at the tail. After full load tests, it was found that 2 drives would suffice, and hence the tail drive was subsequently removed. (The belt tensions obviously increased, but were still within rating.) One negative effect of drive over design is excessive forces during starting conditions - high tension transients may occur.



Graph 1: Source of Conveyor Problems

2.3 Conveyors exceeding design capacity. 10%
Numerous investigations identified the source of the problem to be due to tonnage's exceeding the original design specification being transported, or with extendible conveyors - exceeding the original design length. This is a common and understandable effect of a user wanting to increase production to the maximum possible limit.

2.4 Good design, bad maintenance. 25%
Obviously lack of maintenance is a common source of the problem, particularly underground, where working conditions are ever more severe than on surface. This topic is outside the scope of this paper, but would constitute a worthwhile contribution to future conferences - it warrants a paper of its own, possibly compiled by a group of experienced conveyor operators.

2.5 Good design, but equipment not to specification. 20%
Before the advent of good computer based data recorders and associated software, it was difficult to verify, by measurement, the overall performance of a conveyor system once commissioned. It was thus difficult to asses whether the installed equipment met the specifications, and hence the consequential problems went unnoticed until failures began to occur.

Nowadays, it is relatively easy to extract data from continuous monitoring computers, (reference 5), and identify all the operating parameters during normal running and transient conditions; starting and stopping. - e.g. Belt tensions and safety factors, powers, take-up performance etc.

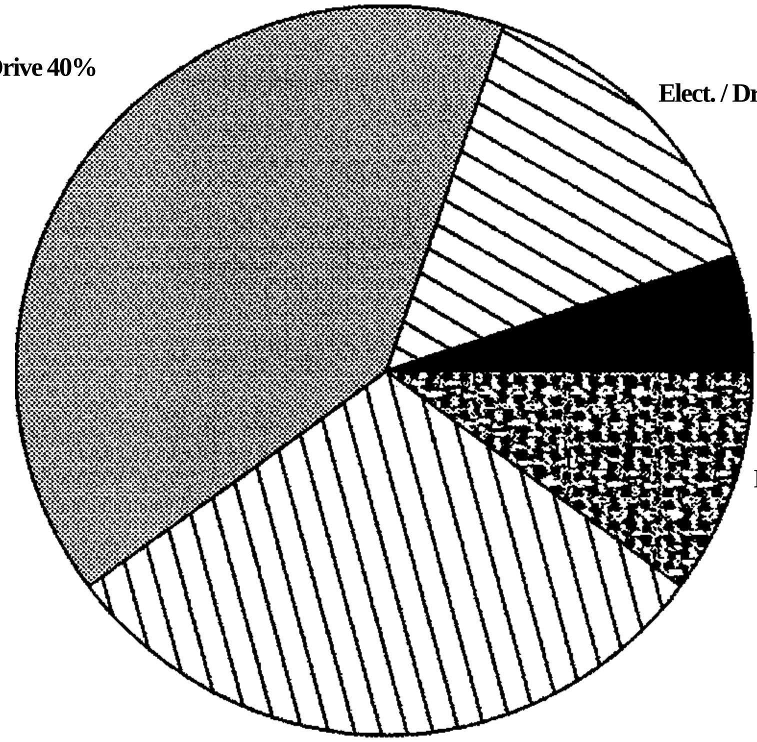
2.6 Good design, equipment to specification but not compatible. 35%
Again, without measurement of the conveyor performance, it was not possible in the past to reach this type of diagnosis. This can also imply that the specifications are not suitable.

From the above, it is thus obvious that **more than half of the problems can be attributed to two sources - either equipment not to specification or not compatible.**

The next part of the paper will look at these type of problems in more detail with examples.

3. Types of problems where equipment is not to specification, or not compatible

The distribution of this type of problem is shown in **Graph 2.**



Graph 2: Type of Conveyor Problems

3.1 Electrical 5%
Electrical equipment normally constitute minor problems. Some examples are as follows:

- Transformer under rated
- Switchgear / Contactors not suitable.
- Excessive voltage drops, e.g. long transmission cables underground.
- Single phasing of motors during normal running.

3.2 Electrical / Drive incompatibly 15%
The main types of problem are :

3.2.1 Current overloads and induced voltage drops due to excessive motor current draw during starting conditions..
Typical examples are :
- Only having one contactor for multiple drives.
- Too short a time delay between energizing multiple drive contactors.

3.2.2 Thermal overloads. Typical examples are :
- Motor and fluid coupling torque speed curves incompatible. This problem is compounded by induced voltage drops as mentioned above.
- Time delays between starts too short to allow fluid coupling to drain completely.
- Under speed switch set too short.

3.3 Drive 40%

3.3.1 Motor

Typical problems are as follows:

- Wiring problems within the motor cause single phasing during normal running.
- Incorrect wiring - Star instead of delta; wrong direction of rotation.
- Different Torque speed characteristics - this is normally the case with different make or series of motors and can lead to load sharing problems on multiple drive conveyors.
- Motor characteristic not to spec.

3.3.2 Starting Device **General Problems**

Irrespective of the type of starting device used, the two main contributing problems are:

Startup factor too high:
According to the various design handbook, the desired starting factor varies from 1,15 to 2 depending on the type and size of conveyor. Specifications applicable to the majority of the conveyors investigated for this paper were between 1,3 and 1,5. <u>These values, verified bv measurement, were rarely achieved in the past.</u>

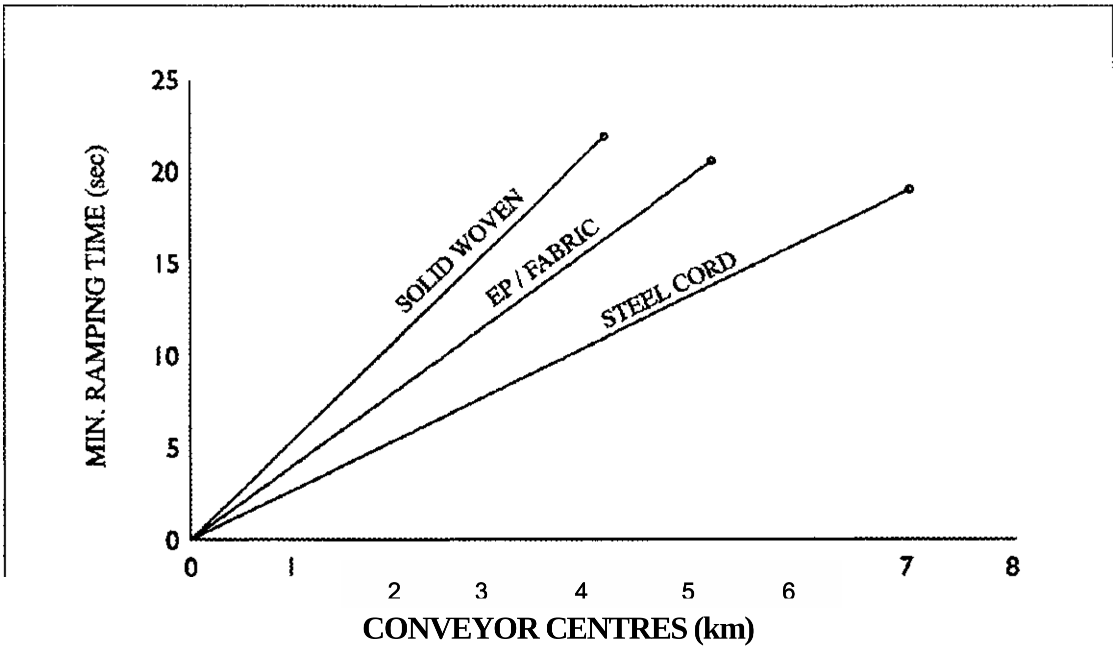
Starting Dynamic Transients : Tension or Torque buildup too fast:
This results in undesirable transients occurring during starting conditions, the magnitude of which may cause severe damage at the weakest link in the system. This issue was not well understood until only recently. During the last 15 years, numerous authorities have published papers on the issue and offer methods to avoid or limit these transients. [ref 1,2,3,4 et al.]

These methods range from sophisticated software modeling programs to simple rule of thumb guidelines.

From experience gained during 15 years of measurements of these transients, [references 1, 2, 3], the simple rule of thumb is suitable for the majority of applications, i.e.:
- For conveyor lengths of up to 6 km centers.
- For belt class's up to 4000 kN/m.
- For relatively flat or inclined conveyors, where any downhill or decline section, (exceeding 10 degrees), does not exceed 20 % of the total length.

The rule defines a minimum ramping time which must be achieved, based oh only two criteria : Conveyor length and belting type. Refer to **Graph 3** Refer to reference [4] for full details on this subject.

Most user design specifications now include some provisor for avoiding the buildup problem.



Graph 3: Min. Ramping Times vs Conv. Length

Specific Starting Device Problems.

Type of starting devices with which measurements have been made:

- D.O.L Direct on line starting
- Star Delta switching
- Voltage Ramp
- Voltage Ramp and Fluid Coupling
- Fluid Coupling
- Slip Ring
- Variable Frequency

Problems experiences with the first 4 devices will not be discussed as they are either unsuitable for conveyor applications, or are only suitable for small conveyor drives, say below 30 kW.

Fluid Couplings

Problem with fluid couplings may be grouped as follows:

- **Weight Problem** : Excessive overhung loads can lead to shaft failures or critical vibration excitement.

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- **Installation Problem** : Alignment and incorrect assembly. Coupling orientation must always be outer wheel drive and not inner wheel drive. This will allow correct functioning, ease of alignment and maximum heat dissipation effect.

- **Starting Problem** : Incorrect interpretation of specifications has occurred where the startup factor or torque limitation has not been clearly defined - It can be exploited to read average or peak value. Ideally, the peak value should be the limiting factor. The coupling characteristics were also always assumed to be flat. This is not the case and needs to be taken into account.

Overfilling can be a problem. Classically, fixed fill traction fluid couplings were always filled to ten to twelve. This is no longer the case with modem couplings which usually require less fill to function correctly. Another common fault encountered is the incorrect logic used that if a conveyor will not start, the oil fill of the coupling should be increased. Exactly the opposite is normally the case.

The thermal capacity of the coupling can be exceeded leading to overheating. This is usually the case for conveyors with large inertias and high belt speeds - I.e. long overlands. The starting time for a conveyor is directly proportional to the sum of the mass of the system and the square of the belt velocity.

Over sizing the coupling to increase the thermal capacity is a trick to overcome thermal limitations, but caution should be taken to prevent overfilling which could impose excessive forces into the system. Excessive stop starts will also result in coupling overheating or motor protection shutdown.

- Running Problems

Load sharing: Due to different oil fills or scoop actuator settings.
Loss of oil: Due to fusible plugs blowing, leaks, or pump failure. It would a good idea to include in the control software of multi motor drives a warning or trip in the event of any drive's power or current varying by more than say 20% from the rest.
Coupling undersized: This was common where a coupling was sized according to the theoretical absorbed power and not the installed power. Most specifications now include a clause that the coupling must be sized according to the motor power rating, and the oil fill according to the absorbed power.
Couplings not identical: This applies to all brands and types, whether they be fixed fill, variable fill, scoop trim or scoop control types.

Slip Ring Starters

Wound rotor motors are not that popular in South Africa and hence few problems have encountered. One important issue is the correct switching of fixed step resistance starters.

Liquid resistance starters also have been known to give problems where the switching set points have been set too high or too low

Variable Frequency Drives

To date, not many measurements have been made by ourselves on these type of drives. In some instances, they have been known to feed undersireable harmonics back into the supply. They can also become unstable.

3.3.3 Brakes

Dynamic Problems are not as prevalent during stopping as they are during starting, mainly because the braking forces, if needed, are usually less than those required during starting. An exception is in the case of down hill conveyors, or conveyors with mayor regenerative sections where controlled braking may be crucial. In South Africa, there are few of these type of conveyors, so generally there have been few investigations necessary.

Incorrect brake layout in drives has resulted in brakes causing other problems.

3.3.4 Speed Reducers I Gearboxes

Problems identified include:
Interpretation of specifications related to ratings.
Using reducers with slightly different ratios, (exceeding 1 %), on multi motor drives causes severely bad load sharing problems.
Ratings are effected by removal of cooling fans.

3.3.5 Drive Pulleys

Problems experienced include:

Drive slip/Worn lagging due to:
- insufficient T2 Tension,

- Excessive start factors
- Spillage entrapment ages lagging

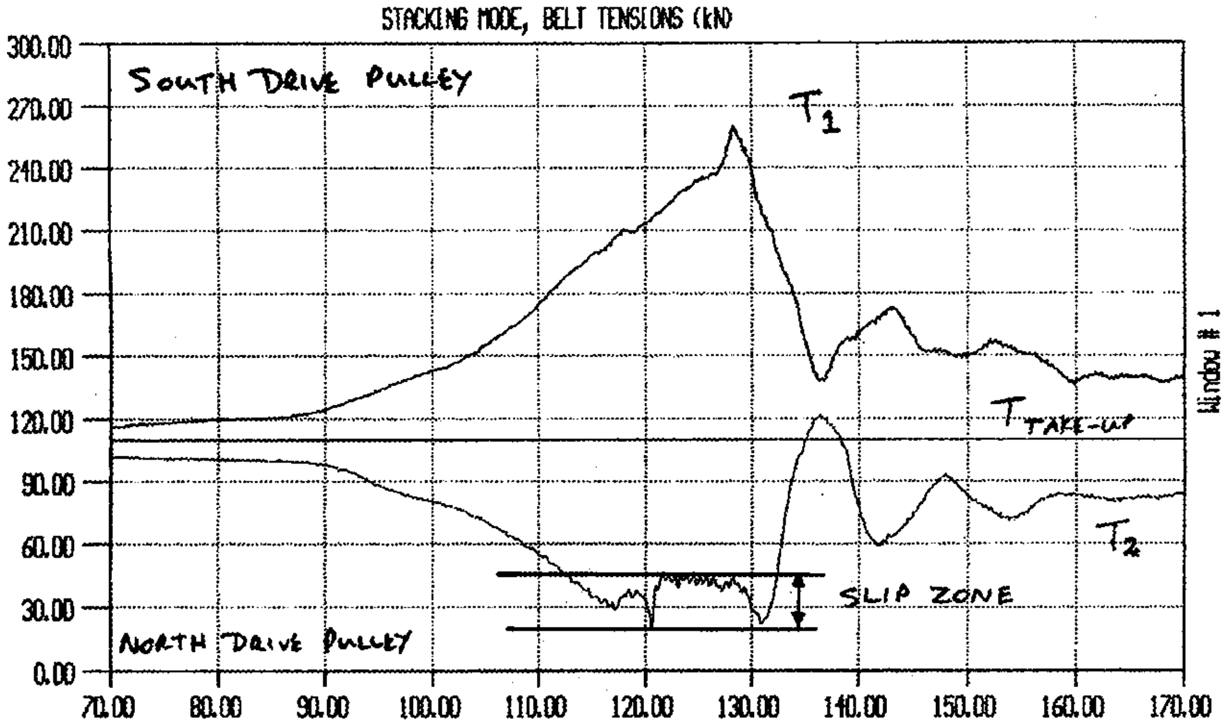
Different pulley diameters or lagging thicknesses on multiple drives results in poor load sharing and rapid lagging wear.
We are not in favour of the use of ceramic lagging as it may damage the belting - rather save the belting and sacrifice the lagging, should drive slip occur. If drive slip is excessive, rather treat the cause and not the symptoms.

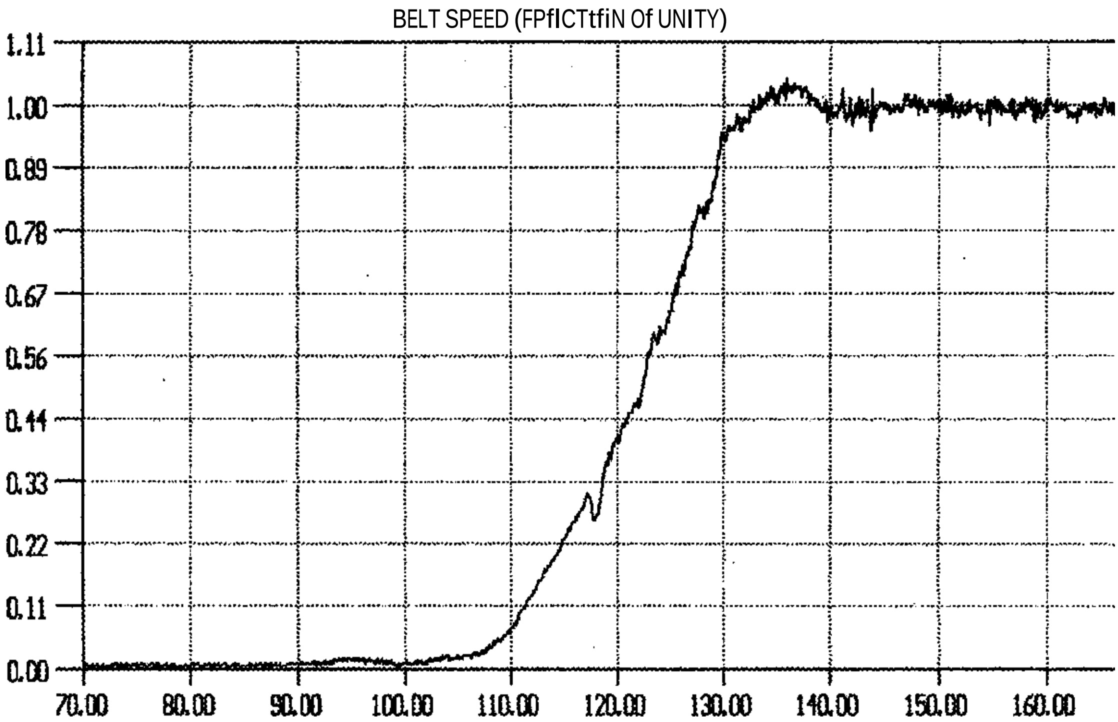
3.4 Drive / Take-up incompatibility 30%
The problems may be grouped according to two areas of application:

Surface Installations
On surface conveyors, gravity type take-ups are generally used - they are simple and relatively cheap to build. (Gravity is for free.) They offer a fast response to any changes in belt stretch or contraction. They cannot easily be adjusted or tampered with, (gravity is constant), and they cannot be switched off. Maintenance is easy - visual. Consequently, not many problems are experienced with them, bar the odd overtensioning or undertension on installation. **Graph 4** shows an example of a stacker / reclaimer where excessive drive slip was found to be mainly due to insufficient take up mass.

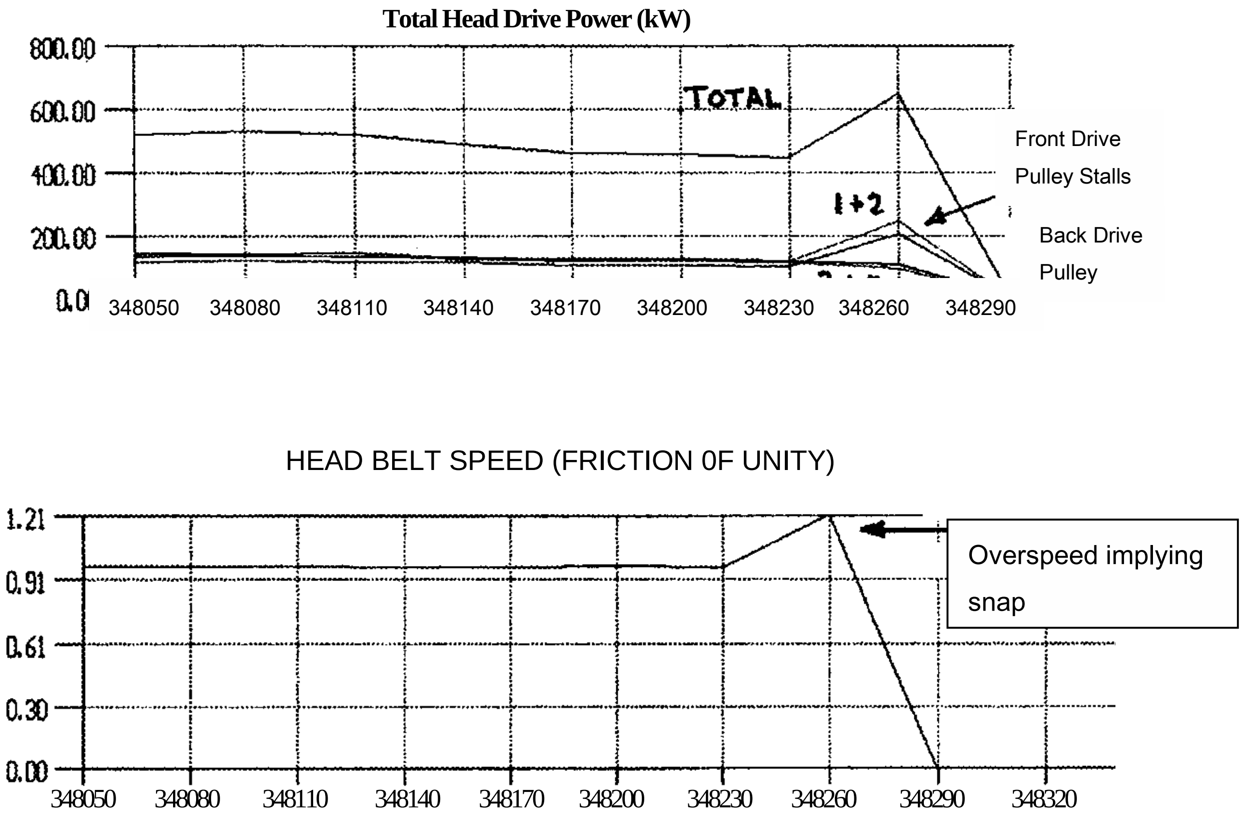
Winch take-ups are occasionally used on long overlands, either because take-up tower heights become prohibitive or because a saving in belt class may be possible. Problems identified with these systems are:

- Winch switched off / brake not releasing during a cold spell - large tensions are induced and eventually something must give.





Graph 4: 12000 TPH STACKER RECLAIMER, DRIVE SLIP DETECTED AFTER 2 WEEKS OF MONITORING.



Graph 5: BELT SNAP ON A 7 KILOMETER OVERLAND DUE TO LOSS OF FEED BACK SIGNAL.

- Loss or incorrect feedback signal from load cell - resulting in incorrect response from the winch. **Graph 5** shows an example where a **7** kilometer overland was reportedly parting its belt during normal running conditions. After logging the system for some weeks, we were able to record what happened at the moment of a failure : The winch lost its feedback signal due to a intermittently loose wire, and detecting zero tension, proceeded to increase the T2 tension, thus increasing the T1 tension enough to cause a belt failure.

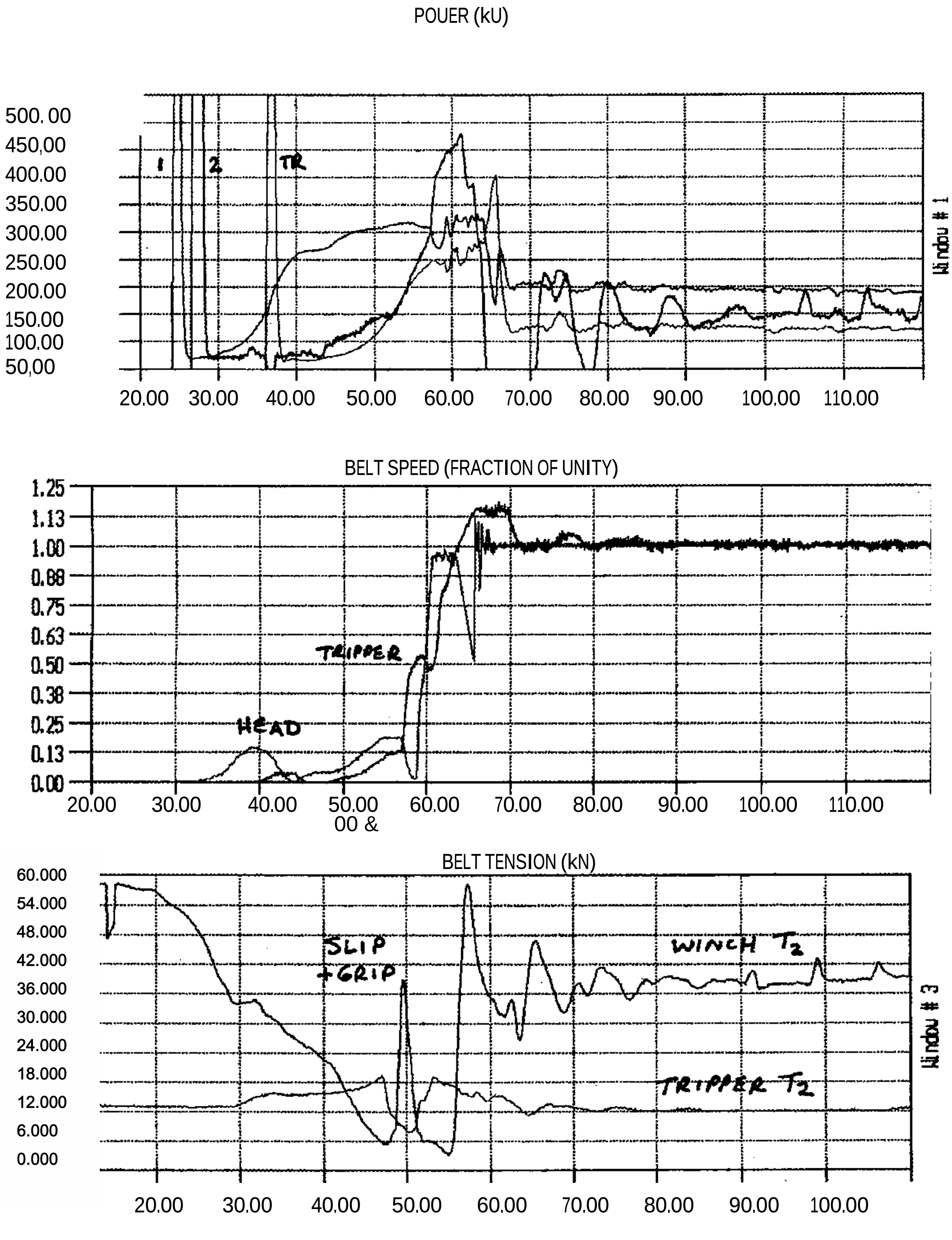
Underground Installations
By far the majority of problems with take-ups occur underground, for three main reasons :

- Height restrictions advocate that gravity take-ups are impractical to install - hence winches must be used which are less responsive than gravity types.

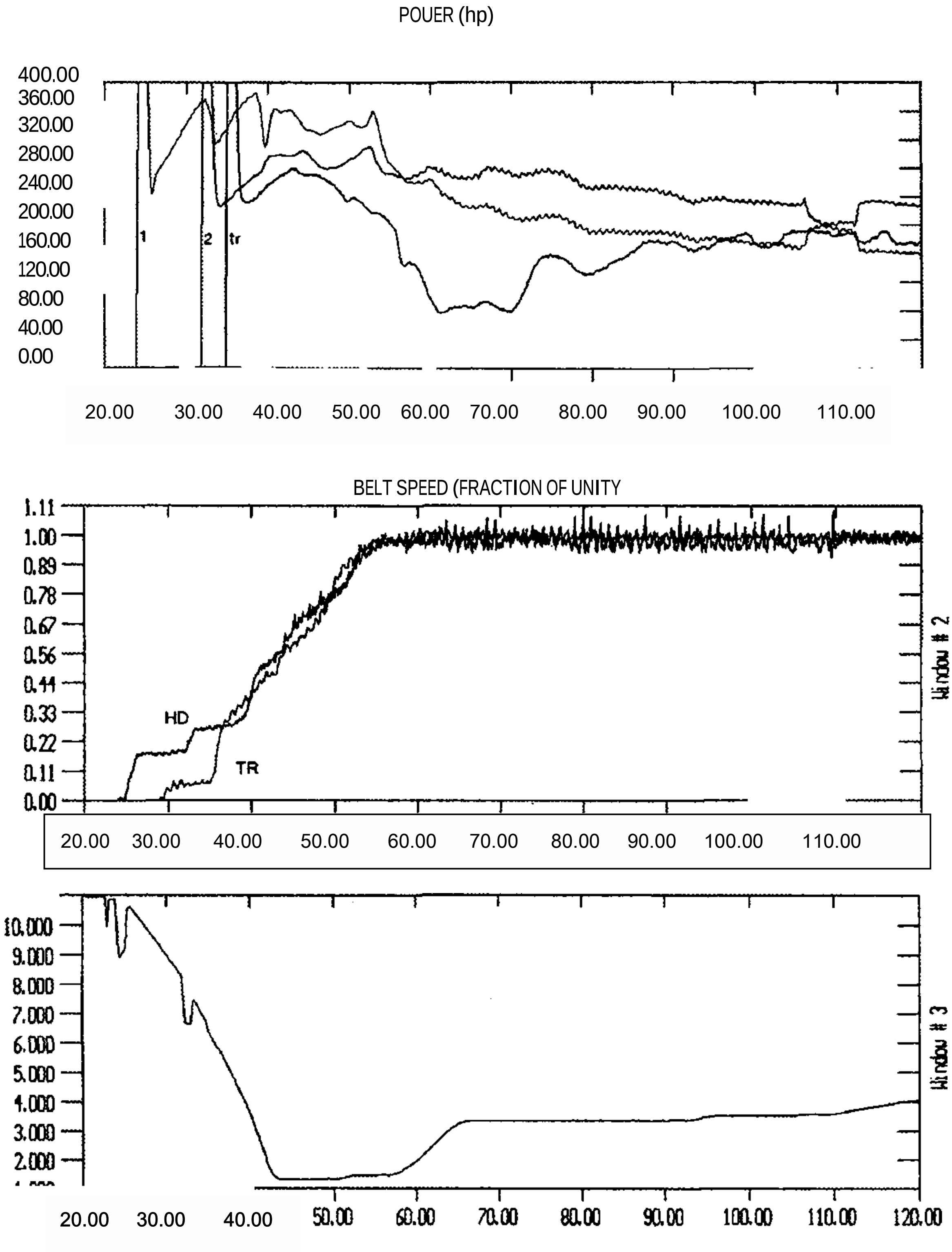
- Belts used underground are generally a solid woven type and are hence far more flexible and thus require faster take-up response times than steel cord surface installations.

- Design specifications do not relate the winch requirements to those of the starting device requirements - obviously the harder the start, the faster the winch reaction needed, and visa versa. The problems resulting are further compounded by the starting device problems mentioned in 3.3.2 - exceeding the specified starting factors and excitation of tension transients.
As an example, consider a typical section conveyor in South Africa - a 3 kilometer tripper type as per **Graph 6.**

Notice the significant transient oscillations, overspeed and drive slip. This is quite typical of the type of behavior we have measured on similar installations in the past, irrespective of which particular mine the measurements were made on, or what type on conveyor; section, trunk, tripper, linear booster, fixed or retreating centers.



Graph 6: 3 KILOMETER LONGWALL SECTION TRIPPER CONVEYOR - BAD START



Graph 7: USA 3 KILOMETER LONGWALL SECTION TRIPPER CONVEYOR - GOOD START.

Compare this type of behavior to the performance of a similar installation measured recently in the USA - refer to **Graph** 7 and reference 6.
There is negligible evidence .of transient oscillations, and no overspeed or drive slip. Note that these tests were done to identify the reason why the conveyor was performing so well in comparison to the conveyors tested here in South Africa.
To try to make some sense out of this, we compared the performance of over 30 conveyors tested in three mines in South Africa with that of the one tested in the USA. For each conveyor, we rated the quality of starting device and winch response speed as follows:

Coupling Rating ranged from 0 for the hardest start to 5 for the best or softest start.

Coupling Rating	Type of coupling installed
0	Fixed fill, traction type
1	Fixed fill, single delay.
2	Fixed fill, double delay.
3	Variable fill, no maximum fill limit.
4	Fixed fill, soft start type.
5	Variable fill, with maximum limit.

Take-up winch rating ranged from 0 for zero response during starting to 5 for the fastest response speed.

Winch Rating	Speed capability of belt retrieval
0	Dead, pretension only
1	0,12 m/s, typical electric winch, 15 kW
2	0,33 m/s, typical two speed electric winch, 55 kW
3	0,4 m/s, eddy current type, 55 kW
4	0,6 m/s, pneumatic type
5	0,91 m/s, hydraulic constant tension type, 100 kW

For each mine, we tabulated all the relevant equipment data, dynamic performance, and allocated coupling ratings.

We then plotted the ratings as per **Graph** 8 for ease of comparing overall system ratings. It is obvious that none of the S. A. conveyors matched the overall rating of the USA conveyor. The historical trend then became clear: Here in South Africa we were trying to solve the starting problems by progressively improving the fluid coupling performance. However, little or no consideration was being given to the winch performance. In fact, in some instances the winch speeds were actually even reduced, as the coupling quality was improved.

It can be concluded from this exercise that we need to increase the reaction times of our winches to enhance the overall starting performance of our conveyors.

One final point to further strengthen this statement or need is to compare the belt types used here and in the USA : The conveyor measured in the USA had ply belting, which appears to be the norm throughout America. Here in S.A., the norm is to use solid woven belts, which can be up to 50 % less stiffer than ply belts. This implies that, by comparison, our winches need to be up to 50 % faster than the USA ones, while in actuality they are generally only half their speed.

In summary, we need to overcome this drive / take-up incompatibility problem by revising the specifications. To date, specifications have been based on historical experience only.

The belt intake speeds required from the winch need to be based on the belt type and length, starting forces and worst starting conditions.

3.5 Belting Problems. 10%
Generally speaking, the quality of new belting supplied in this country is good and hence few problems are encountered during commissioning or the first few years of operation.

The main areas of problems which occur later on are, in order of priority :
- Splice failure. According to one international expert who visits this country regularly, the quality of splices in this country is poor. Apparently, the rate of failures here far exceeds that in other countries. The splice should hold for the entire life of the belt. (Assuming good conveyor maintenance.)

- Carcass damage. Main causes are poor loading/chute design and entrapment of spillage and foreign articles in the drive and snub pulleys.

- Mistracking. Main causes are idlers not in line and skew splices.

- Cover wear. This is particularly relevant in hard rock mining. The main cause is poor loading/chute design.

4 Conclusions

Design specifications should be revised to take into consideration compatibility of individual components, particularly the starting mechanism and the take-up device.

Performance tests should be done on all large conveyor installations, after commissioning but before handover from supplier to user. The tests would verify the design, construction and compatibility of equipment used, and hence help obviate or completely eliminate problems during the life of the conveyor.

5 References

1: Surtees, A.J.: Longitudinal stresses occurring in long conveyor belts during starting and stopping; Beitcon 3,1985.

2: Surtees, A.J.: Further case studies in transient stresses in belt conveyors; Beitcon 4,

1987. 3: Surtees, A. J.: Conveyor Dynamics; Beitcon 6,1991.
4: Curry, S and Surtees, A.J.: Refining conveyor drive specifications and operating procedures to cut running costs and down-time; Beitcon 7,1993.

5: Surtees, A.J.: Conveyor system commissioning, maintenance and failure analysis using black box techniques; Beitcon 8,1995.

6: Surtees, A.J.: Performance Investigation of a Longwall Panel Conveyor, Incorperating a Tripper Drive System; Bulk Solids Handling Vol 18 (1998) No. 1, pp 81-85.