



## **BELTCON 4**

Further Case Studies in Transient Stresses in Belt  
Conveyors

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## S U M M A R Y

High oscillating tensions may be excited in conveyor belts due to unsatisfactory starting and stopping methods. These transient tensions may be of such large magnitudes that severe damage may be incurred by the belting and conveyor system.

In this paper some tests, performed on various conveyors in the South African coal handling industry, are discussed to highlight typical problems encountered.

Ways of reducing the magnitudes of these transient tensions and preventing their occurrence at the design stage are suggested, to improve the life and availability of the conveyor.

This paper may be considered as a continuation of the paper presented at Beltcon III (Ref 1). That paper should be referred to for a more practical introduction to the topic of belt oscillations.

1. INTRODUCTION

The belt selection is undoubtedly the most crucial part of a conveyor design. The belt selection is based on the maximum tension experienced in the belt multiplied by some factor of safety.

In most cases, maximum tensions occur during starting and stopping of the conveyor.

It is thus obvious that the performance of a selected belt depends largely on the performance of the starting and stopping devices used.

Most conveyor design systems or manuals assume the conveyor belt to be a rigid body. They also assume that the starting device limits the accelerating tensions to some fixed percentage of the normal running tension. This allows simple calculations of starting times, since the acceleration is then constant.

Stopping calculations are done in a similar way.

Figure 1 shows such a constant acceleration velocity profile. In comparison, a cosine type velocity profile (shown by the broken line) offers the optimum starting behaviour: Zero acceleration at zero and full speed, and maximum acceleration at half speed (Ref 2)

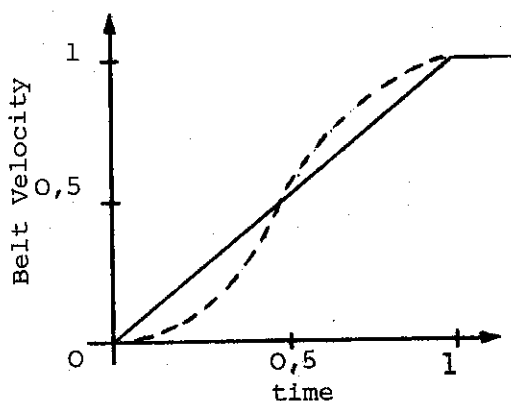


Fig 1 : Ideal Velocity Profiles

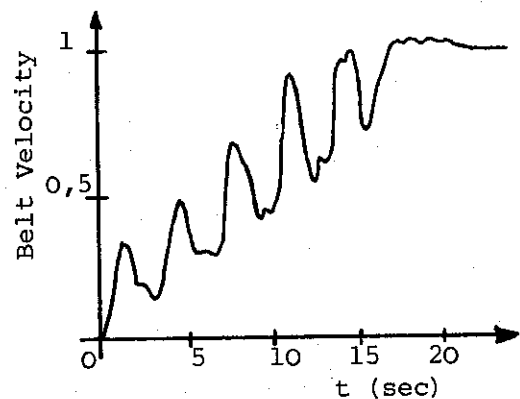


Fig 2 : Conveyor A

2. DISCUSSION

A typical problem experienced in assuming a constant acceleration velocity profile is evident by considering the first case study.

2.1 CONVEYOR A : LOADED START (FIGURE 2)

Relevant parameters : Fabric belt, 940m centres, 180 kW installed power, winch take up.

The operator complains to the conveyor designer about continual belt failures. The conveyor designer checks his belt selection when given the actual starting time of the conveyor : approx 15 seconds. Knowing the full belt speed he calculates the acceleration to be  $0,2 \text{ m/s}^2$  ( $3 \text{ m/s} \div 15\text{s}$ ). This is close to the value he used for determining the peak starting tensions and selection of belt class required.

So why the failures?

A closer inspection of the belt velocity profile confirms a startup time of about 15 seconds, indicating the average acceleration of  $0,2 \text{ m/s}^2$ . However, because of the oscillating changes in velocity, the accelerations, at times are greater than the average acceleration.

The actual peak acceleration may be estimated to be  $1 \text{ m/s}^2$ . ( $3 \text{ m/s} \div 3 \text{ s}$ ). Thus the peak tension is actually 5 times higher than those used in the belt class selection calculations!

2.2 CONVEYOR B : EMPTY START (FIGURE 3)

Relevant parameters : Fabric belt, 1500m centres, 270 kW installed power, winch take up.

In this case the belt velocities were measured at the head and tail stations of the conveyor. The belt at the tail only begins to move 3 seconds after the belt at the head begins its acceleration.

Once the belt at the head reaches full speed, it holds that speed by nature of the drives. The tail pulley, however, has no speed constraint, and the belting at the tail overspeeds by more than 50% of the design speed. The belting is then decelerated by the braking effect of the return belt, it underspeeds, and is then again accelerated by the top belt. This oscillation continues in a dampened manner until steady state conditions are reached - this may be referred to as the mass spring effect.

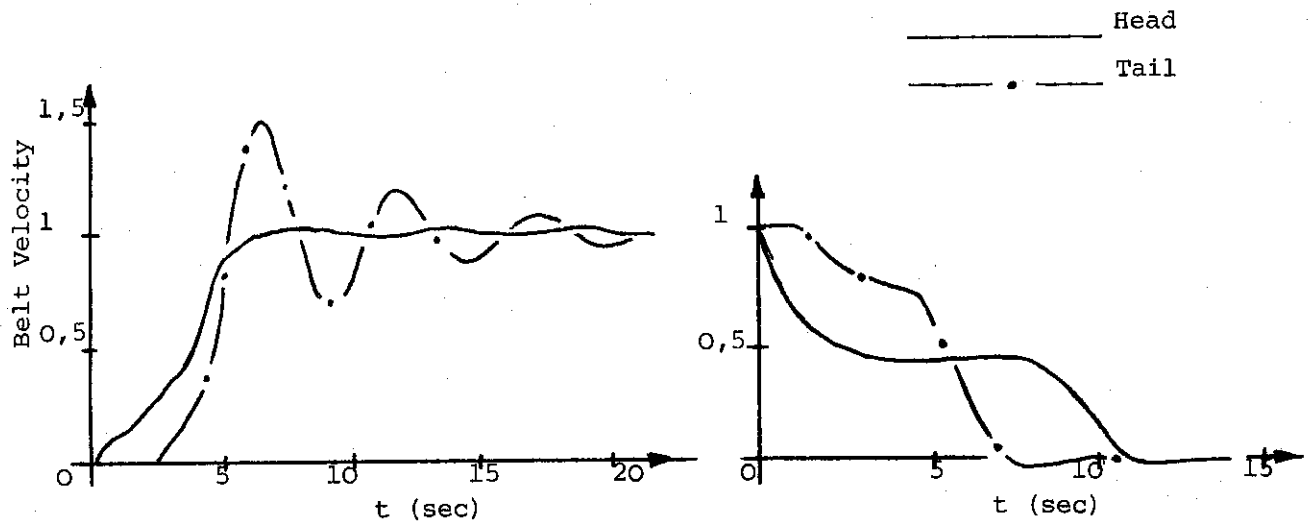


Fig 3 : Conveyor B

Fig 4 : Conveyor C

2.3 CONVEYOR C : LOADED STOP (FIGURE 4)

Relevant parameters : Fabric belt, 1500 m centres, 360 kW installed power, winch take up.

The velocity profiles at the head and tail are shown. The average natural deceleration of any belt is usually quite constant, although the velocity profiles vary considerably between head and tail stations.

Only one cycle of the oscillation occurs during the rundown. (In comparison, with a steel cord belt up to 7 cycles have been recorded).

#### 2.4 CONVEYOR D : EMPTY START (FIGURE 5)

Relevant parameters : steel cord belt (ST 1173), 3320m centres, 900 kW installed power, gravity take up.

In this case, the belt velocities were measured at the head, tail and take up stations.

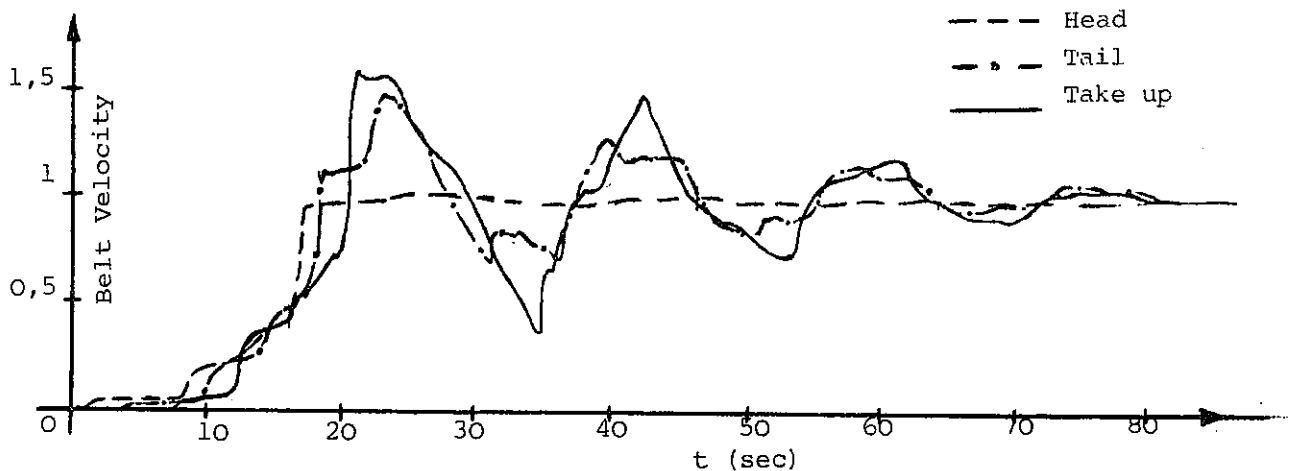


Fig 5 : Conveyor D

The dominant oscillation pattern is one of a damped sinusoidal decay, similar to that in Figure 3. However, the maximum velocity over and underspeeds occur at the take up station.

The tail and take up velocities, at any time during the acceleration cycle, are dependent on the combined effects of;

1. The acceleration of the belt at the head
2. The ability of the drives to brake the return belt
3. The inertia of the take up.

The tension oscillations in a conveyor belt are easily related to the velocity profiles. i.e. Take up displacement. (Note for winch type take-ups, the tension oscillations are not easily evident).

The sinusoidal decay pattern in this case is not as smooth as that in Figure 3. This indicates a more complex oscillation than the simple mass spring effect.

Severe damage to the take-up tower, in this case study, may be attributed to the poor drive characteristics combined with an unsatisfactory step starting sequence of the multiple drives.

## 2.5 CONVEYOR E : LOADED START (FIGURE 6)

Relevant details : Steelcord belt ST850, 3510m centres, 440 kW installed power, electric winch take-up. (Load sensing).

This series of tests was performed on a conveyor to illuminate severe belt slip on the drive pulleys during the starting cycle.

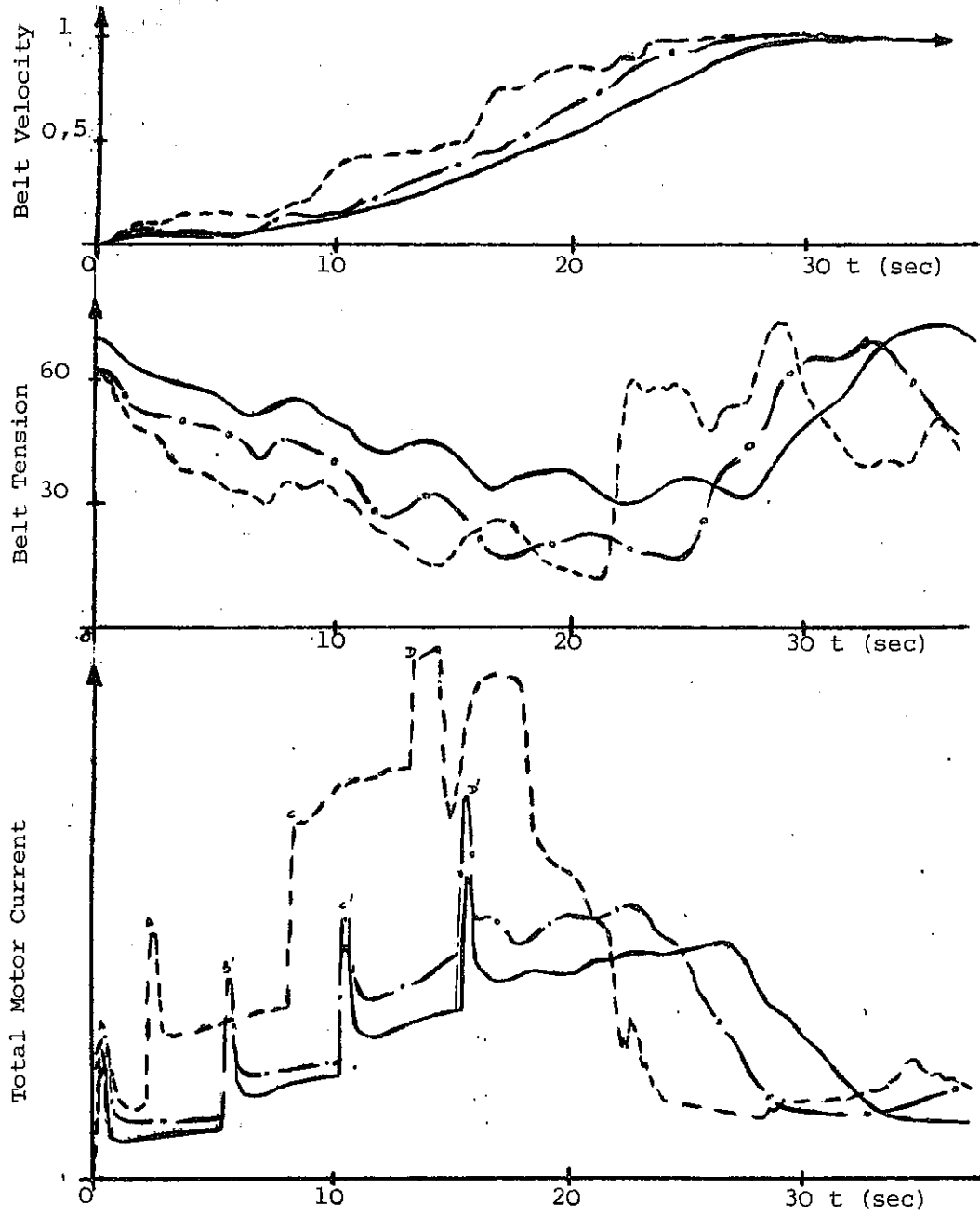
The belt velocity at the head and tail stations, take-up tension, combined motor current, and winch displacement were measured.

With the original installation, oscillations are evident in both velocity and tension. Dramatic changes in tension and motor current indicate the regions of belt slippage.

By correcting the starting sequence (ensuring a more evenly distributed torque build up), the velocity oscillations are eliminated and the severity of the tension variations is reduced. The minimum take up tension does not fall as low as before, and the belt slip is almost completely eliminated.

Fig 6 : Conveyor E, Comparison of different starting methods.

- : Original Couplings, oil fills and time delays
- : Original Couplings, modified oil fills and time delays
- : Modified couplings, oil fills and time delays.





The overall starting performance of the belt was then further improved by using a different fluid coupling type. The magnitude of the accelerating tension is reduced, the start is smoother and longer, and the take up tension does not fall below the critical point at which belt slip occurs. The peak current is almost half of that originally measured. (note the effect of over-filling the fluid coupling).

2.6 CONVEYOR F : EMPTY STARTS AND STOP (FIGURE 7 & 8)

Relevant details : Fabric belt, class 1200, 2000m centres, 480 kW installed power, electric winch take-up (Load sensing).

Figures 7 and 8 show three consecutive starts and a stop of one conveyor under the same operating conditions. However, the starts show no consistency in behaviour.

Consider the different behaviours recorded:

Test No 1 (Figure 7)

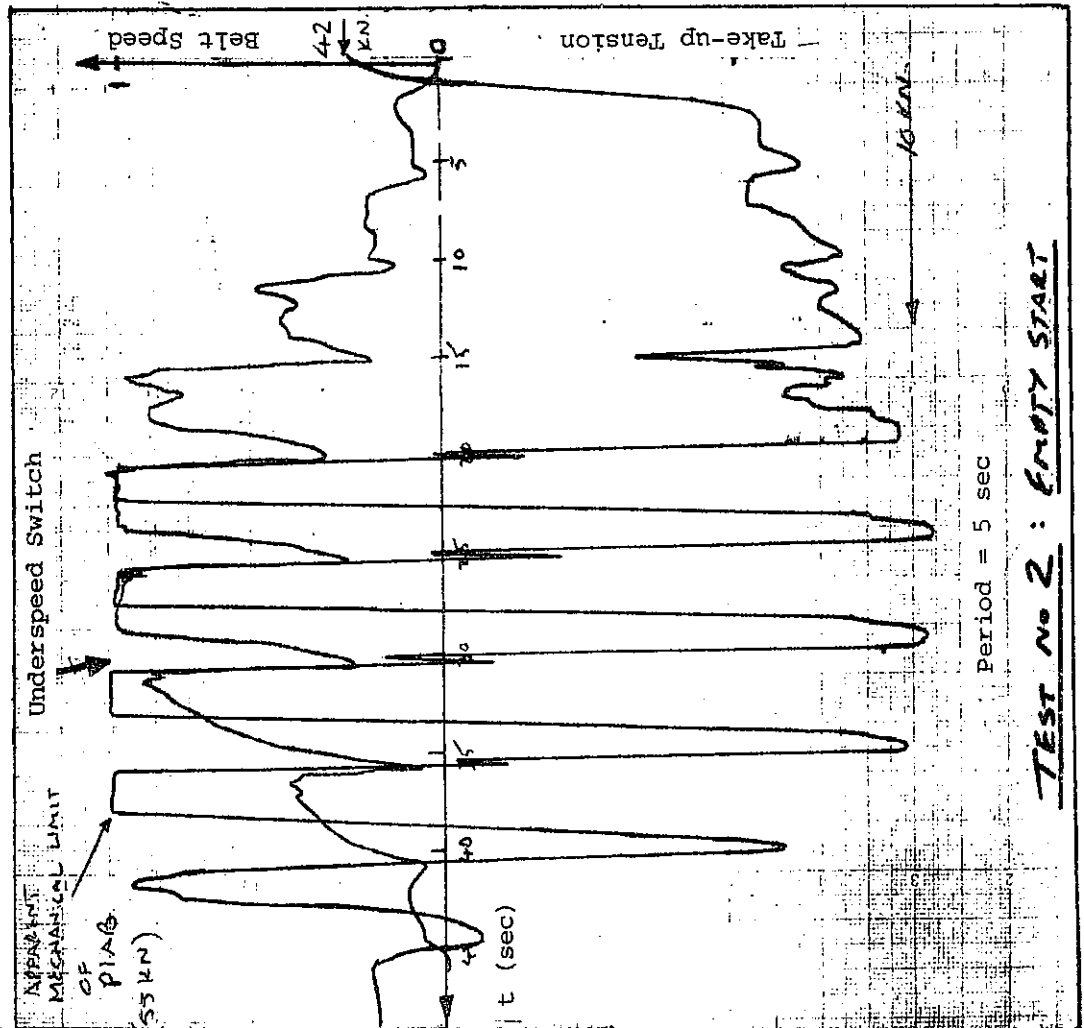
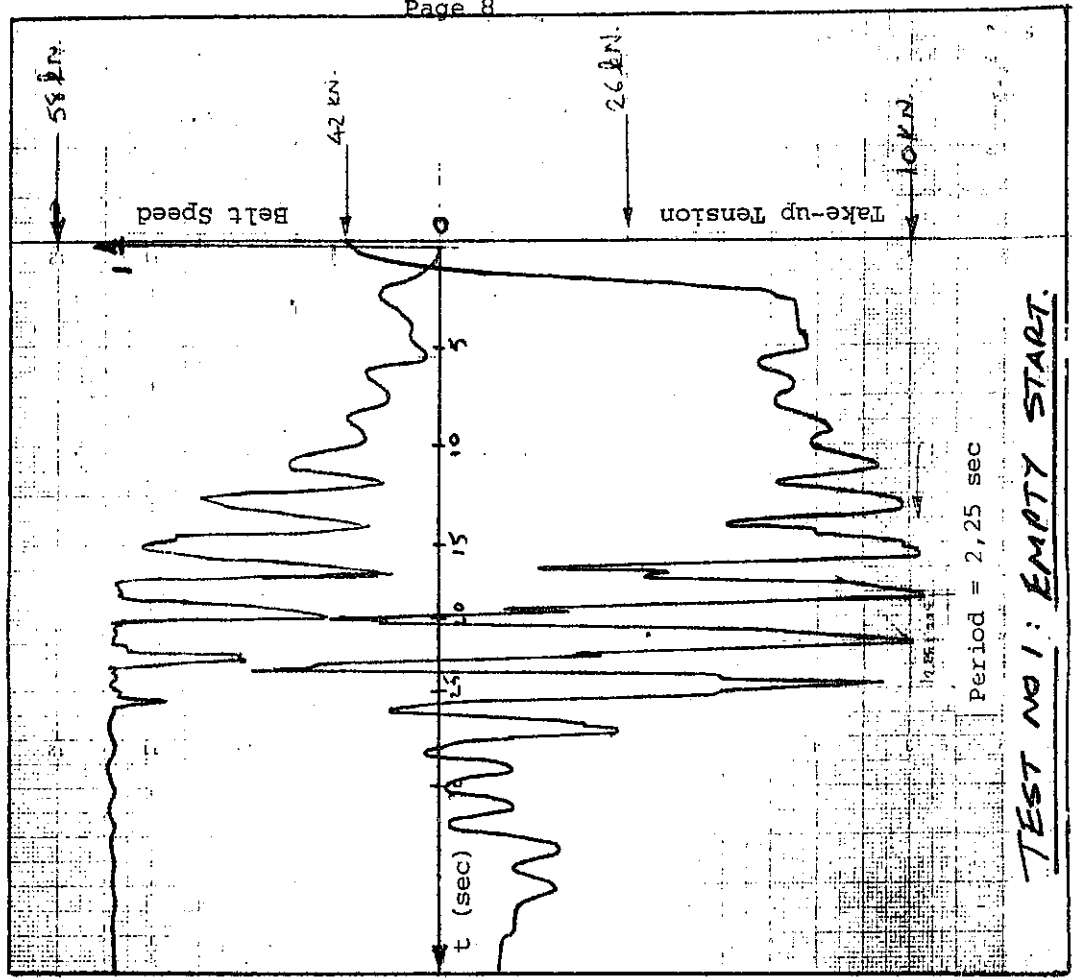
The first start shows severe high frequency oscillations in belt velocity and take-up tension, with a period of 2,25 seconds.

Test No 2 (Figure 7)

The second start shows severe oscillations in velocity and tension, but with a longer period of approximately 5 seconds.

Note how the peak tension oscillations exceed the load cell limit in the winch system. Hence the peak tensions exceed those in test no 1 considerably.

Fig 7 : Conveyor F, First two consecutive starts



After the start is aborted by the underspeed switch, the belt decelerates with a sinusoidal decay in take-up tension.

The small, sudden changes in tension at about 35 kN could suggest the reinforcement of two separate waves travelling in the belt.

Note how the oscillations pass by the drive pulleys during the acceleration.

#### Test No 3 (Figure 8)

In the third start, no regular oscillating patterns are detected and the start is satisfactory. The normal long period sinusoidal decay in tension (with a period of approximately 8 seconds) is evident. This must obviously be related to the changes in belt velocity at the tail pulley.

#### Test No 4 (Figure 8)

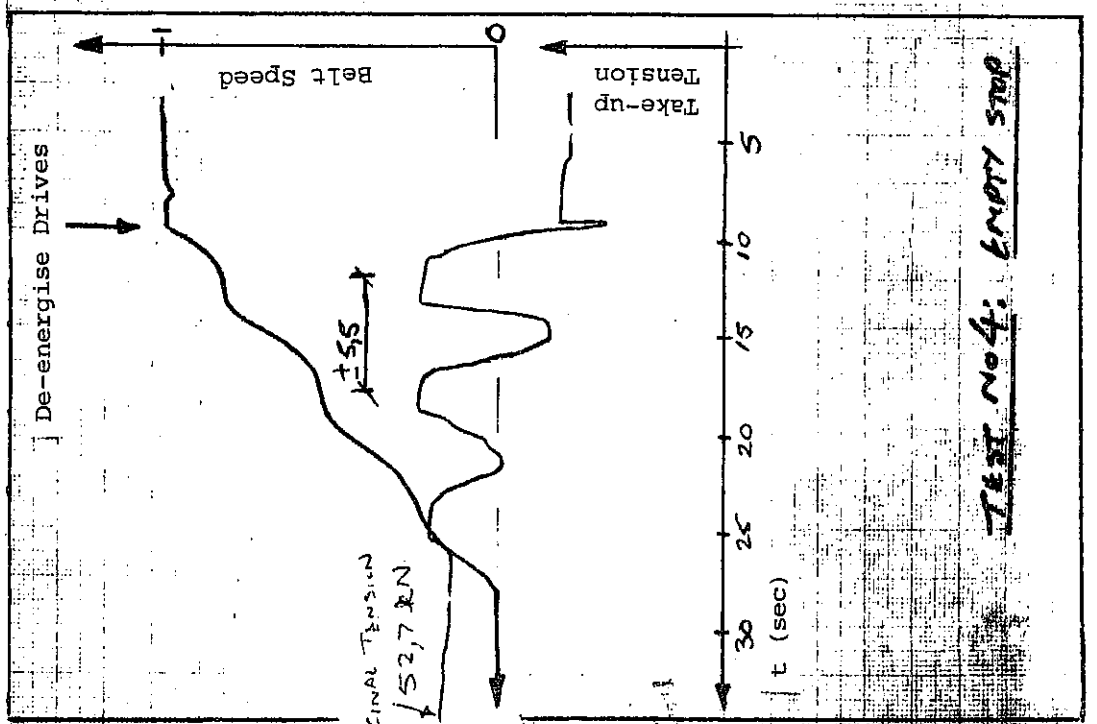
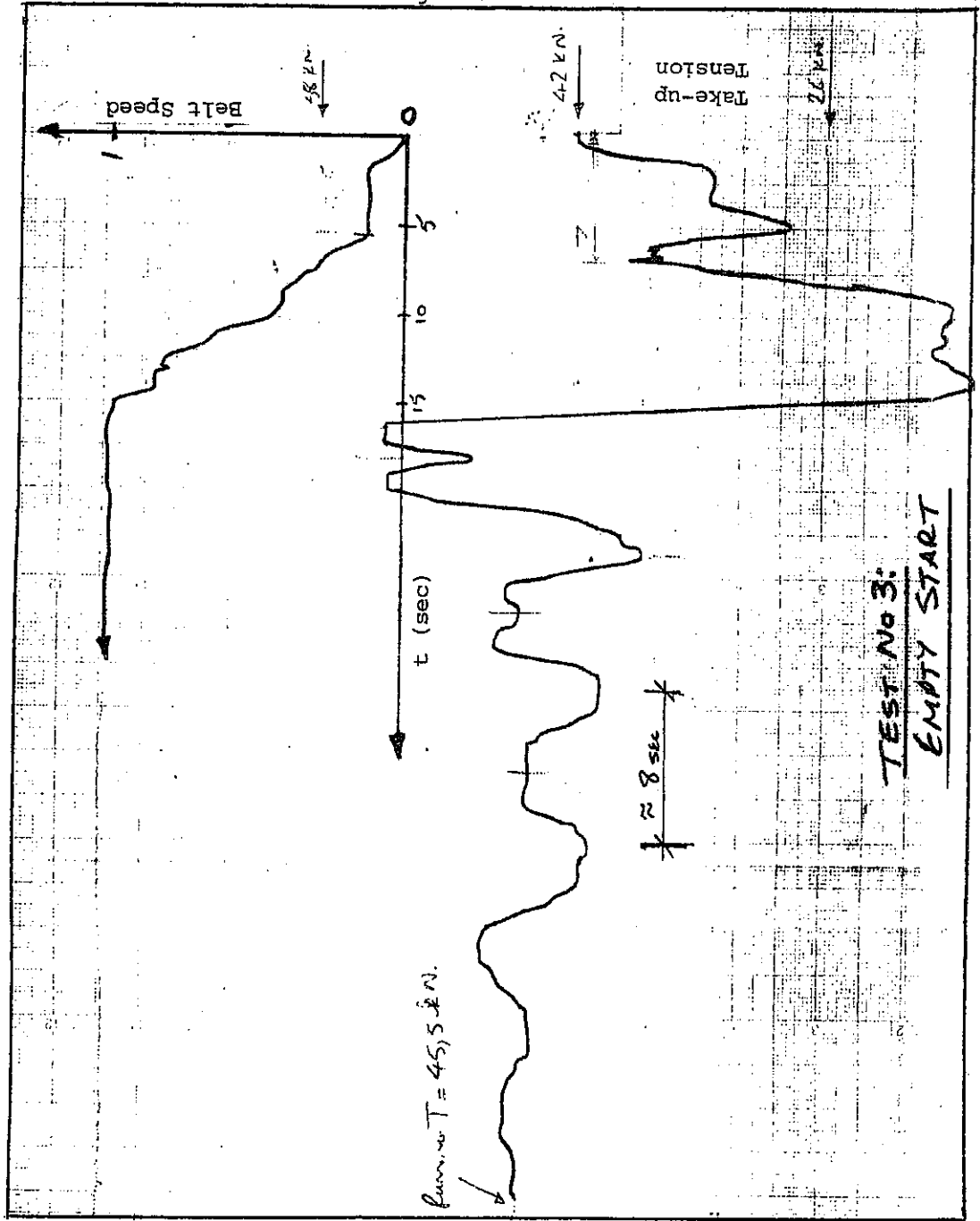
This test shows the stop after the three consecutive starts. It is a typical stopping profile for the belt, with oscillations in velocity and tension (with a period of approximately 5,5 seconds)

In summary, three totally different oscillations were detected in the belt, with no conclusive explanation for their occurrence or relationship.

Unfortunately, as with many underground conveyors, it is not possible to record belt velocities at the tail, because of the strict restrictions on electrical equipment at the coal face. These recordings would possibly help in identifying the cause of the various oscillations.

The problem has been solved temporarily by replacing one of the constant fill fluid couplings (secondary drive) with a scoop trim coupling.

Fig 8 : Conveyor F, third consecutive start, and stop



A new type of hydrodynamic soft start device (not as yet installed) should prove to be a final solution to the problem.

2.7 CONVEYOR G : EMPTY AND LOADED STARTS (FIGURE 9)

Relevant parameters : Fabric belt, extendable conveyor (800m at present) 440 kW installed power, solid winch take-up, new type hydrodynamic soft start.

This conveyor has an excellent starting characteristic, both in the loaded and unloaded condition. The velocity profiles are similar to the cosine profile for minimum belt stresses. (Ref Figure 1 - The conveyor reaches half speed after approximately half the starting time).

The accelerating torque introduction is gradually increased and no oscillations are evident.

3. WAYS TO PREVENT THE OCCURRENCE OF TRANSIENT TENSIONS

3.1 AT THE DESIGN STAGE

More attention should be devoted to the selection and interaction of the drive and take-up devices.

Based on a recent survey of conveyors commissioned in 1986, the most commonly used starting devices used for conveyors were constant fill fluid couplings - approximately 90% by numbers installed or 75% by total installed power. (excluding drives under 15 kW, where direct on line starting is usually used)

So, for a typical conveyor using squirrel cage motor, constant fill fluid coupling and reducer, the starting device (fluid coupling in this case) constitutes approximately 3% of the total capital outlay, (excluding civils) while the belting constitutes approximately 45%.

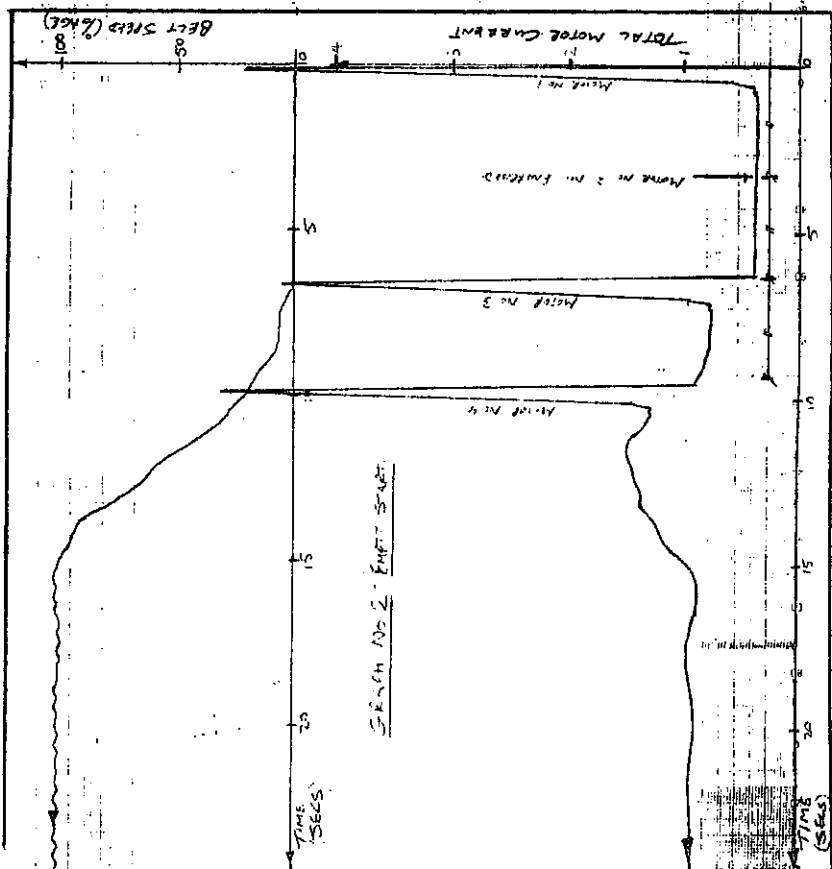
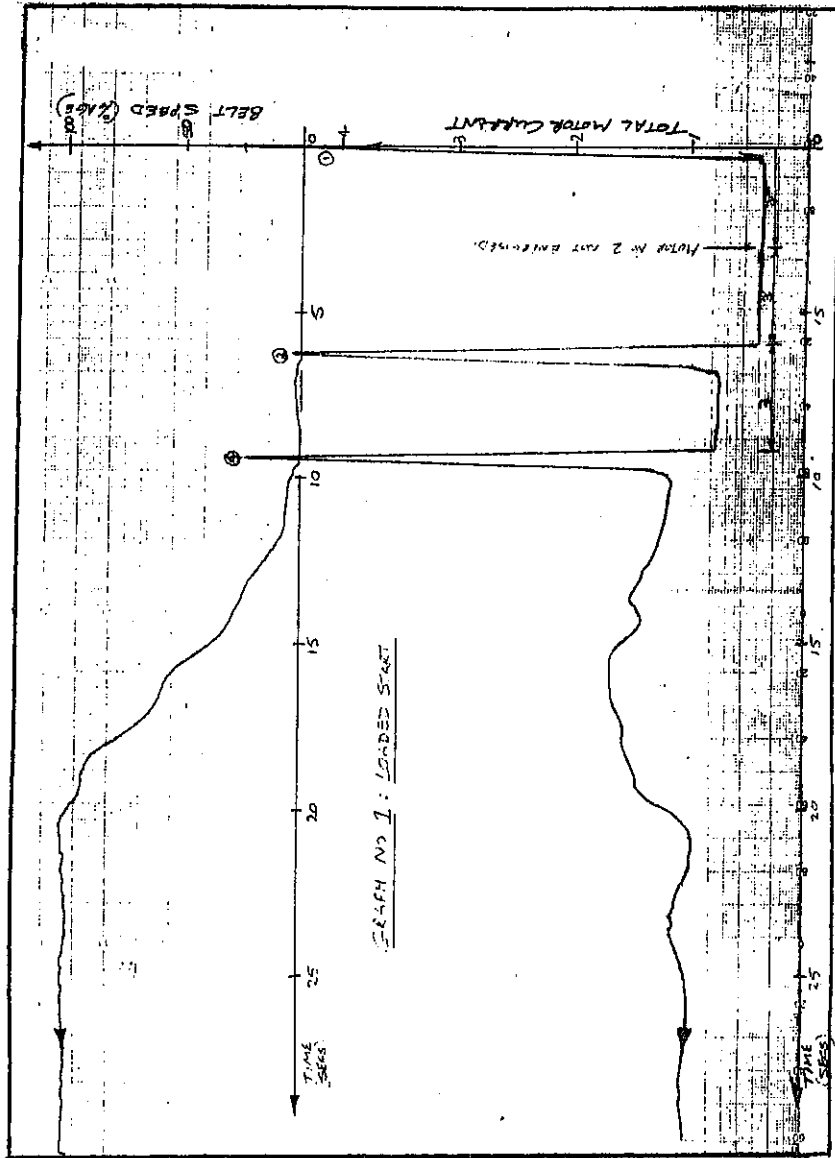


Fig 9 : Conveyor G, loaded and empty starts

By laying out as little as 1/2% extra of the total capital, on the starting device, the belt life and overall performance of the conveyor can be improved substantially.

3.2 ON SITE

- 3.2.1 Ensure correct functioning of starting device (rating, sizes, performance etc)
- 3.2.2 Ensure correct functioning of prime mover (motor etc)
- 3.2.3 Ensure compatability of starting device and prime mover.
- 3.2.4 Ensure correct functioning of take-up device
- 3.2.5 Ensure correct sequencing of motor energising and take-up device, taking into account empty and loaded belt conditions. (Varying oscillating periods must not coincide with motor energising time delays).

4, CONCLUSIONS

From the various case studies discussed, it is obvious that problems related to transient belt stresses are being experienced in industries using belt conveyors.

The problems have been compounded by considerable advancements made in conveyor belt technology in this country.

The problems can be overcome at the design stage by paying more attention to equipment selection and compatability, and on site by better education and training of the personnel responsible for the correct functioning of the conveyors.

5. REFERENCES

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