# Wire Rope Sheave Friction Effects
# on the
# Takeup Carriage Belt Tension

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## ABSTRACT

*When a takeup weight is offset to the side of a conveyor, a wire rope is commonly routed from the take-up weight through a series of sheaves to the take-up carriage. The friction developed from a series of wire rope sheaves can effect the actual belt tension at the take-up carriage. Through real-time testing the actual tension on a takeup carriage was recorded with data acquisition using an internally strain-gauged turnbuckle. The wire rope used to transfer the take-up weight to the take-up carriage was routed through a series of lubricated bronzed bushed sheaves. The tension on the takeup carriage was found to be as much as 26 % higher than the weight of the take-up due to the friction in the sheaves. A detailed discussion of the testing and results will be made.*

## INTRODUCTION

A mobile takeup carriage is designed to provide a constant running tension in a conveyor belt. Consequently, a specific wrap factor can be maintained for the drive pulley, thus preventing belt slip during startup, normal operation, and shutdown. There is a variety of mobile takeup designs available. These designs may include a gravity type design, hydraulic assisted design, or an electric winch design.

The gravity design consists of a takeup pulley that hangs vertically below the conveyor belt with a specific weight attached. This setup allows the takeup pulley to move freely in a vertical direction while adjusting to the belt stretch. Occasionally, the designer encounters a situation where the conveyor's incline is not sufficient, with respect to its length, to allow for the required vertical movement of the takeup carriage. In a case such as this, the takeup weight is most commonly offset to the side of the conveyor. The weight may then be attached to a horizontal takeup carriage by a wire rope routed through a series of deflection sheaves to the takeup carriage. The takeup carriage is able to move horizontally below the conveyor. Gravity take-ups of this type are typically used in above ground cases with clearance problems below the conveyor.

The hydraulic assisted design is most commonly used on underground conveyors where sufficient vertical height is unattainable for normal operation of a gravity takeup. This type of setup typically has a hydraulic cylinder where the end of the rod is attached to a steel cable that is routed through a series of sheaves to the takeup carriage. The takeup pulley is able to move horizontally while adjusting to the belt stretch.

The electric winch design is also common on underground conveyors. Increasingly popular belt storage units provide the constant tension required, while storing belt for future expansions of the conveyor. This type of setup requires an electric winch where the wire rope is routed through a series of sheaves to the takeup carriage. Some of the single takeup designs have eliminated the use of the sheaves.

The gravity takeup design requiring the takeup weight to be offset will be the focus of this paper. However, the theory of wire rope sheave friction applies to all takeup carriage designs where sheaves are being used. The goal is to illustrate the effects of sheave friction on the

takeup carriage belt tension and compare the results with actual test data.

## DESCRIPTION OF TAKEUP SYSTEM

The takeup carriage tested consisted of six deflector sheaves that direct the wire rope from the carriage to the takeup weight. Each sheave consisted of a greased brass sleeve and the wire rope cable diameter was ¾ inches.  Starting from the takeup carriage, the wire rope was directed through three horizontal deflector sheaves, then through three vertical deflector sheaves (See Figure 1). The counter weight was measured to be 7,300 lbs. by cable tension sensors in a crane that was used to elevate the weight.
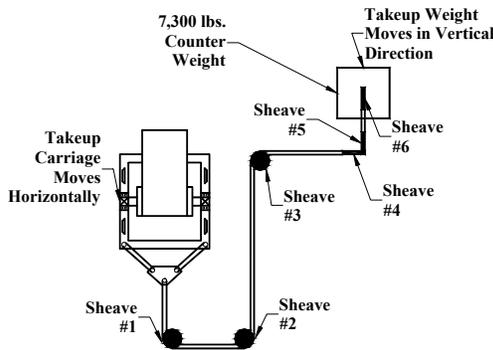


**Figure 1 Takeup Sheave Arrangement.**

The wire rope was attached to the takeup carriage by two turnbuckles at equal angles from the carriage as shown in Figure 2.  The takeup carriage frame rested on four steel wheels that moved freely in a horizontal direction. The takeup carriage was observed closely before testing to ensure smooth operation for a clean test of the takeup carriage tension.



**Figure 2 Wire rope attached to the takeup carriage.**

## PREDICTED TENSION ON THE TAKEUP CARRIAGE

When a single takeup pulley supports a takeup weight, the predicted tension in the belt is simply the takeup weight divided by two, assuming 180 degrees of belt wrap. But, when a takeup weight is supported by a number of deflection sheaves between it and the takeup pulley and the takeup weight is raised, the stress in the wire rope increases progressively from the dead end attached to the weight to the lead end attached to the takeup carriage. This increased stress is due to the cumulative effect of friction in the sheave bearings and the force required when bending the rope around the sheaves. (Macwhyte, 1998)

Because of this and in order to have equilibrium, the lead end nearest the takeup carriage will have slightly more than its proportionate load, while the dead end will have slightly less, and the sum of the stresses in all parts supporting the load will be equal to the load. The forces of acceleration and braking are not included in this discussion.

To predict the increased tension on the takeup carriage due to the friction in the sheaves, the following equation is used:

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$$P = L / (N * E)$$

**Equation 1 (Macwhyte, 1998)**

Where,
P = Maximum rope stress lbs. (occurs on rope part going to the takeup carriage, i.e., on the lead line)
L = Load lifted, lbs.
N = Number of rope parts supporting load.
E = Efficiency of the system. (Note: For cases using more than one deflector sheave, the efficiency factor should be reduced by 8 % for each additional plain bearing deflector sheave.)

The load to be lifted is 7,300 lbs. The efficiency of the system is 0.917 * 0.92^5 for loads supported by a singe wire rope with five additional deflector sheaves. (Macwhyte, 1998)

Therefore,

P = 7,300 lbs. / (1 * 0.6044)
P = 12,078 lbs.

In this case, the predicted increase in tension on the takeup carriage can be as much as 4,778 lbs. It is important to remember that Macwhyte derived the above equation for Tackles, Cranes, Derricks, Booms, Etc and it is being applied to a conveyor takeup sheave arrangement. However, due to the similarities of operation between a takeup sheave arrangement and a crane, for example, the above criteria can be applied to get a close approximation of increased tension on the takeup carriage.

## TEST SETUP

In order to validate the predicted tension on the existing takeup carriage, a load sensing transducer was required. Consequently, an internally gauged turnbuckle was used to read the load on the takeup carriage. The internally gauged turnbuckle was connected to the takeup carriage and the wire rope was then connected to the turnbuckle (See Figure 3). In addition, the signal from the turnbuckle was connected to a Strainsert signal conditioner, Model SCD1/G15,

which in turn was connected to a Control Dynamics data acquisition system. A laptop computer operated the data acquisition system. Both the internally gauged turnbuckle and the signal condition were calibrated by Strainsert to be within 100 lbs. of the actual applied load.
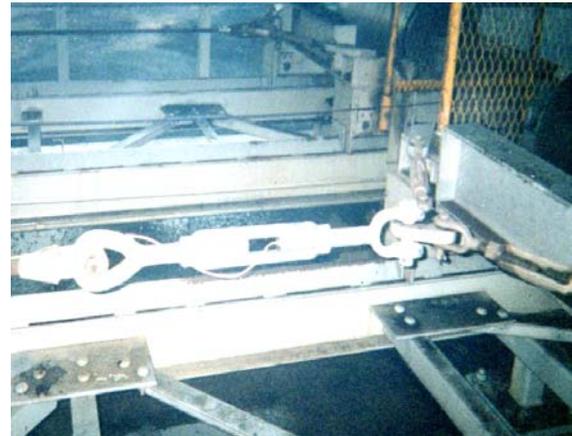


**Figure 3 Internally gauged turnbuckle attached to the takeup carriage.**

## RESULTS

Four 15-minute tests were recorded using a sample rate of 10 samples per second. The first test began just after the internally gauged turnbuckle was put into place. This test shows the line pull tension on the takeup carriage during the initial startup of the conveyor, and how the tension decreases as a full load of coal is transferred to the belt. The initial startup begins approximately 90 seconds into the test. The tension on the carriage stabilizes at approximately 7,000 lbs. (See Figure 4). Furthermore, approximately 630 seconds into the test, as a load is applied to the belt, the tension on the takeup carriage decreases as the belt stretches. The belt is fully loaded at approximately 730 seconds into the test (See Figure 5). Consequently, as the belt stretches under loading conditions, the frictional losses in the sheaves actually decrease the tension at the takeup carriage. This has been a common understanding in the industry; however, the

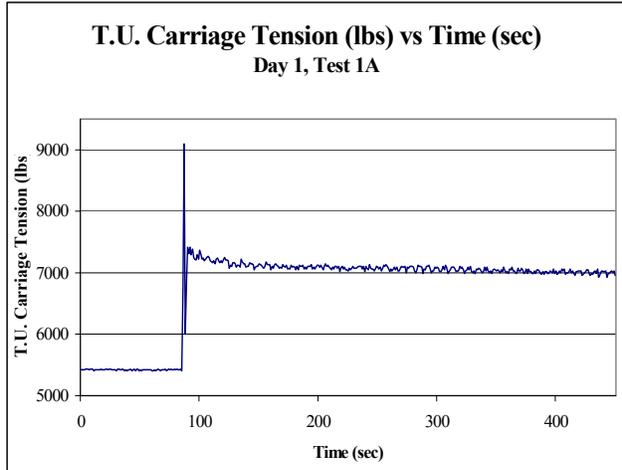friction in sheaves can also increase the tension in a system.

**T.U. Carriage Tension (lbs) vs Time (sec)**
**Day 1, Test 1A**



**Figure 4 Day 1, Test 1A, The tension on the takeup carriage stabilizes at approximately 7,000 lbs.**

**T.U. Carriage Tension (lbs) vs Time (sec)**
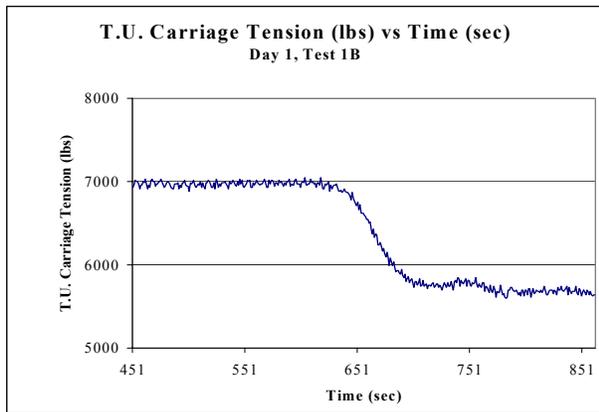**Day 1, Test 1B**



**Figure 5 Day 1, Test 1B, The tension on the carriage decreases as material is loaded on the belt.**

In much the same manner that tension is decreased when the belt is stretching, the tension in a system will increase as the belt is returning to its normal length. For example, during the second test, the material load on the conveyor belt was removed and the tension on the takeup carriage increased to approximately 9,500 lbs. The conveyor operated without load for a short period and was shut down for the day.

The increased tension is a result of the belt returning to its normal length after it has been stretched. In this case, when the belt tries to return to its normal length, the takeup weight must be lifted to allow that belt stretch to return into the system. Due to the friction in the sheaves, more force is required to lift the takeup weight. Consequently, line pull on the takeup carriage is increased; therefore, the belt tensions are increased.

The tension on the carriage at the beginning of test three was approximately 9,000 lbs., which is about the same tension recorded at the end of test two. Similarly, the belt was fully loaded with coal, approximately 840 seconds into the test (See Figure 6). Appropriately, the tension on the carriage began to decrease as the belt began to stretch. Test 3 proved that for at least a 16-hour period, the increased tension on the takeup carriage remained in the system.

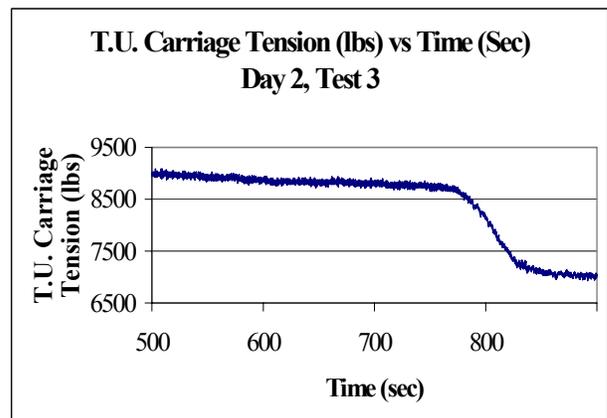**T.U. Carriage Tension (lbs) vs Time (Sec)**
**Day 2, Test 3**



**Figure 6 The running tension of the conveyor has now increased to approximately 9,000 lbs. without load. Similarly, the tension begins to decrease as load is transferred onto the conveyor.**

The conveyor continued to operate between test 3 and 4. Approximately one minute into test four, the conveyor was shut down. Material would no longer be transferred to the belt. The conveyor was restarted just over two minutes into the test. Soon after the conveyor was restarted, the coal being conveyed was removed from the belt. The time required for the

conveyor to remove the material was approximately 1-½ minutes. In that time the tension on the takeup carriage increased from approximately 7,700 lbs. to 9,700 lbs. (See Figure 7). The conveyor was in operation for 10 additional minutes after the load was removed to observe the tension on the takeup carriage. The tension had decreased slightly to approximately 9,200 lbs. by the end of the 15-minute test.

**T.U Carriage Tension (lbs) vs Time (sec)**
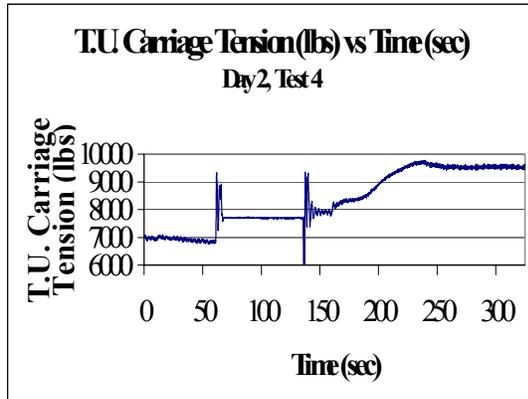**Day 2, Test 4**



**Figure 7 The conveyor is moving coal at 600 tons/hour and is shut down under load approximately one minute into the test. The material load is removed from the belt directly after the conveyor is restarted. The tension on the takeup carriage increases to approximately 9,700 lbs.**

## CONCLUSION

The effects of sheave friction in a conveyor takeup arrangement have been studied and considered in design for some time. Most designers have considered the fact that when the belt stretches, the tension on the takeup carriage can be less than the takeup weight due to system friction. However, designers today need to consider the friction in a takeup sheave arrangement when the takeup pulley is required to pull the takeup weight up as when the belt returns to its normal length after being stretched.

The predicted tension on the takeup carriage was calculated to be 12,078 lbs. by Mcwhyte's equation. The actual tension on the takeup

carriage recorded by data acquisition was approximately 9,200 lbs. after the conveyor operated without any material load for a period of 10 minutes. The actual tension is within the range predicted by Mcwhyte and reflects a 26 % increase in tension on the conveyor takeup carriage. This amount of increased tension is substantial, for example, when applied to project designs that have to be competitive. Furthermore, this increase in tension not only effects the takeup carriage, but also the other components on the conveyor such as the belt pulleys and structure. Therefore, it is recommended that these effects be considered at the design stage of similar systems.

## REFERENCES

_____. 1998. Multiple-Part Wire Rope Reevings, *MacWhyte Wire Rope*

## ACKNOWLEDGMENTS