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BENEFITS OF REMOTE TENSION MONITORING

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ABSTRACT

A remote tension monitor (RTM) system was installed on several haulers in New Zealand to evaluate potential safety and production benefits. Use of the RTM significantly reduced occurrences of overloads in skylines and guylines, and improved the balance in tensions between guylines. A system with load cells for guylines as well as for the skyline appears advisable. There was no significant increase in drag volume, but experience showed that the RTM might improve productivity in some situations.

INTRODUCTION

Safety problems with cable haulers - broken skylines and guylines, pulled anchors and overturned towers - prompted LIRO to pursue the development of remote tension monitors (RTM). Actronic New Zealand Limited built a prototype RTM for LIRO in 1991, which consisted of load cells/radio transmitters to be mounted on one or more lines (for example, skyline and guylines), a radio receiver and a display to be placed in the hauler cab (Smith, 1992a). Although other tension sensors such as in-line load cells are available, the LIRO load cells are unique in that they can be quickly clamped on to a line at any convenient point, even when the line is fully tensioned.

Figure 1 - Remote tension monitor load cells mounted on Bellis hauler

Several potential applications for, and benefits of, tension monitoring have been suggested (Smith, 1992b). This study was aimed at verifying some of the potential benefits to the logger. Targeted applications were production and safety

Table 1 - Haulers involved in the study

Hauler	Configuration	Skyline Brake Control
First Phase:		
Bellis 70	North Bend	Variable and Fixed
Bellis 70	North Bend	Variable and Fixed
Dispatch	Highlead	(not applicable)
Dispatch	North Bend	Fixed
Gantner HSW 80	Standing Skyline Cable Crane	Clamped
Gantner HSW 80	Standing Skyline Cable Crane	Clamped
Madill 071	North Bend	Variable and Fixed
Madill 071	North Bend, Highlead	Variable and Fixed
Skagit BU88	North Bend	Variable and Fixed
Thunderbird TMY 45	Scab Skyline	(not applicable)
Thunderbird TMY 50	North Bend	Variable and Fixed
Thunderbird TMY 70	North Bend, Highlead	Variable and Fixed
Thunderbird TTY 70	North Bend	Variable and Fixed
Wilson	Highlead	(not applicable)
Second Phase:		
Bellis Hauler	North Bend	Variable and Fixed
Madill 071	Downhill North Bend	Variable and Fixed
Madill 171	North Bend	Variable and Fixed
Madill 171	North Bend	Variable and Fixed
Madill 171	North Bend, Shotgun, Slackline	Variable and Fixed
Rosedale Ecologger	Shotgun	Fixed

improvement giving increased wire rope life. Limited use of the RTM as a training tool for new hauler operators was also investigated.

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METHODS

The study had two phases. Between November, 1992 and early 1993, the monitor was demonstrated on 14 haulers to get feedback from the contractors and hauler operators (Table 1). Limited tension data were collected on many of these haulers to help document the existing situation. Data on up to four lines were collected simultaneously at one second intervals, using the download feature of the RTM when connected to a Husky Hunter computer.

A second phase to investigate safety and productivity improvements was conducted on six haulers between February and April, 1993. Assuming that broken skylines, failed guylines and pulled stumps are eventual consequences of high line tensions, use of the RTM was tested to see if it reduced the tension levels and instances of over-tensioning. The Safety Code for Bush Undertakings (Occupational Safety & Health, 1989) specifies that tensions in a cable shall not exceed Safe Working Load (SWL), defined as one-third of the breaking strength of the cable. Although higher or lower levels of SWL have been suggested, based on economic considerations (Sessions et al, 1985), the one-third of breaking strength was used as the standard in this study.

"Control" data were collected before the RTM display was shown to the operator. Then the display was placed in the cab and the tension information and ways of using it were explained to the operator. Most hauler operators became familiar with the RTM display within a few drags, so after a short learning period, the test data were collected. When possible, the learning period was used to check the approximate brake pressure which allowed the skyline to slip at SWL. This gave the driver an idea of what pressure setting would prevent overloads. In order to minimise differences in uncontrolled variables, such as deflection and average log size, the control and test sets of data were collected on adjacent corridors, approximately 30 drags on each.

Load cells were installed on the skyline and on the two or three back guylines which most directly opposed the skyline. Tensions were recorded at one second intervals. Three values were derived from the tension data on each drag:

(1) the peak tension for the skyline, as a percentage of SWL

(2) the peak tension for the most-stressed guyline, as a percentage of SWL

(3) the ratio of peak tension in the most-stressed guy (G1) to that in the second-most-stressed guy (G2). The ratio is a measure of the load sharing balance for the guylines. Ideally, the two guys should have equal tensions, giving a ratio factor of 1.0. There is no standard safe upper limit for G1/G2. For the study, values of greater than 1.5 were arbitrarily defined as unacceptable. (Where three guylines were monitored, the ratio of tension in the most-stressed guy to the average of the other two guy tensions was calculated. These results were similar to those for G1/G2 but less data were available so the results are not reported here.)

Productivity improvement was expected to come primarily in situations where tensions were below SWL. In these cases, drag volumes could be increased to utilise fully the lift capacity of the skyline. This was studied on five of the second phase operations. Hauler operators were asked to use two-way radios to give the necessary feedback on tensions to the breaker-outs. All control and test drags were scaled to evaluate any differences in average volumes.

RESULTS

Reaction to the RTM System

Subjective comments from contractors and hauler drivers during the first phase were overwhelmingly positive. More than 90% thought the RTM would reduce

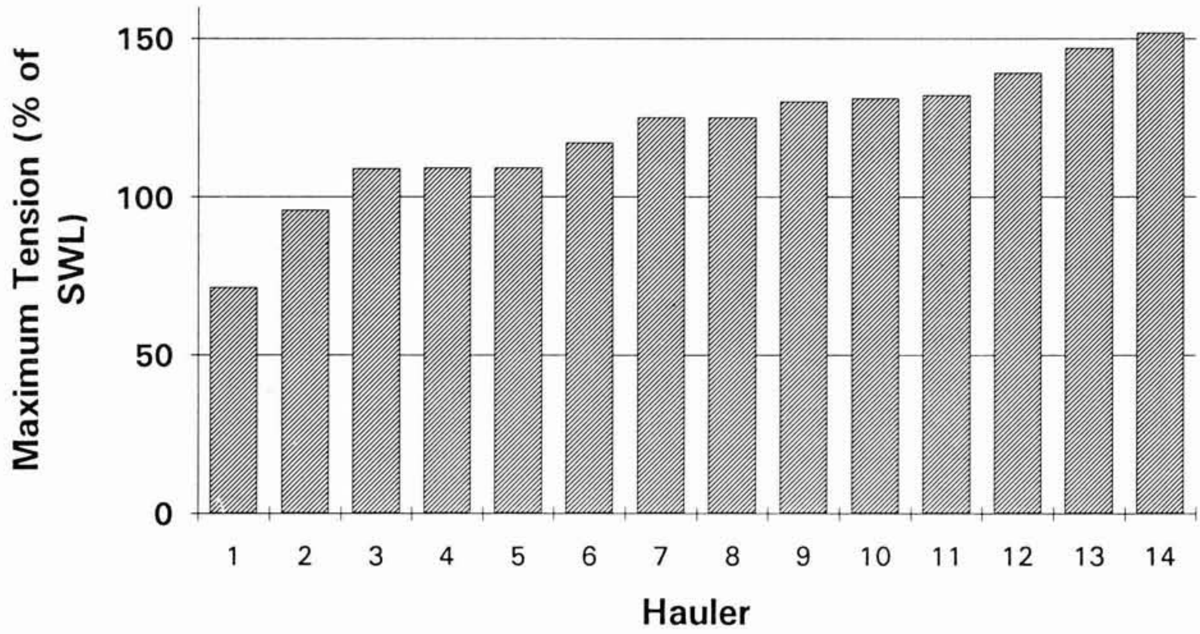

Figure 2 - Worst-case skyline tensions on each hauler, arranged from lowest to highest observed

overloading of skylines, guylines and anchors, and help in training new operators. Two-thirds thought that it could help improve hauler productivity.

Many contractors indicated they would prefer to use only one load cell, mainly on the skyline, to reduce the cost of the RTM. Others, especially those who have experienced tower tipovers due to unequal guyline loadings, were interested in a multiple load cell system.

No formal evaluation was made of the RTM as a training tool. However, the monitor was installed on two haulers owned by contractors who were new to cable operations. In one case the operator found the RTM to be very useful. The other did not; he was heavily over-tensioning lines but was not unduly concerned. This points out that the RTM will only have benefits if the hauler driver understands the basic principles of wire rope, the mechanics of working a skyline and is committed to safe operation.

The analysis of the formal results has been divided into two areas, safety and productivity.

Safety - Operation without RTM

Skyline Tensions

Observations from the first phase, and control data from the second phase, were combined to give an estimate of the existing situation without tension monitoring. Worst-case skyline tensions on 12 of 14 machines exceeded SWL, by up to 50% (Figure 2).

It has been suggested that a tension monitor could be used to calibrate the skyline brake on a hauler and that this would eliminate any further need for the monitor. In theory, it seems reasonable to

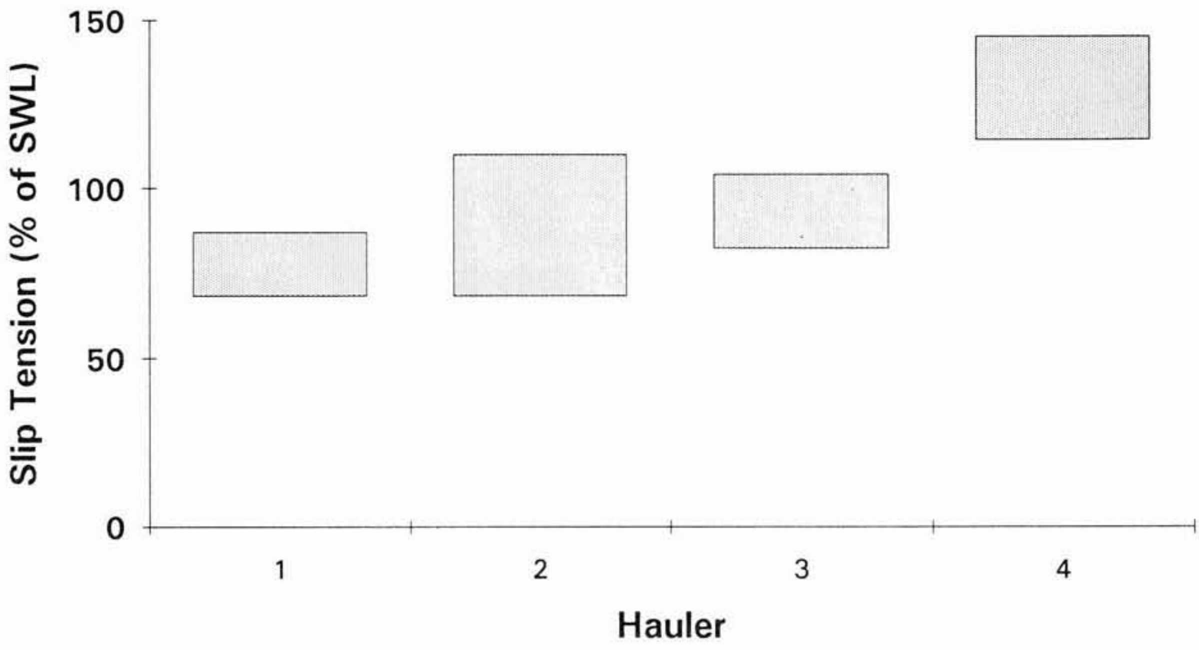

Figure 3 - Ranges (indicated by the shaded regions) in observed slip tensions on four haulers. Control pressures and amounts of line on the drums were constant for each hauler.

pre-tension the skyline, then set the brake so it will slip if tension reaches SWL. However, this is not so easy in practice. As indicated in Table 1, the amount of brake control depended on the machine. The standing skylines had no brake, therefore they were machine-pre-tensioned to two-thirds to three-quarters of SWL and then clamped. On other haulers, the drivers generally pre-tensioned their skylines by lifting them to a height indicated by the breaker-outs, while ensuring that the engine rpm did not exceed a specified limit. Many drivers used a fixed limit, others used a table of rpm versus amount of line on the drum. Observed pre-tensions were in the range of 30% to 70% of SWL, although higher values could have been obtained on some machines, especially when little line was left on the skyline drum.

The fixed brakes could not be adjusted by the driver. Therefore, the tensioning capability varied with the number of wraps on the drum and sometimes exceeded SWL. On some machines with variable-pressure brakes, pressure was set to maximum and the parking brake was also set. This essentially defeated the relief valve purpose of the variable-pressure brake. Other drivers used the foot pedal-controlled variable-pressure brake, but operated it by feel, having no gauge to indicate the pressure when using the foot pedal. Peak tensions on these machines were as high as 150% of SWL.

On the majority of haulers where brake pressure could be varied, the drivers set the pressure at the manufacturer's recommended level for the amount of line on the drum. Unfortunately, the tension at which the brake slipped was not constant, even at a fixed pressure (Figure 3). This indicated that the brakes' coefficients of

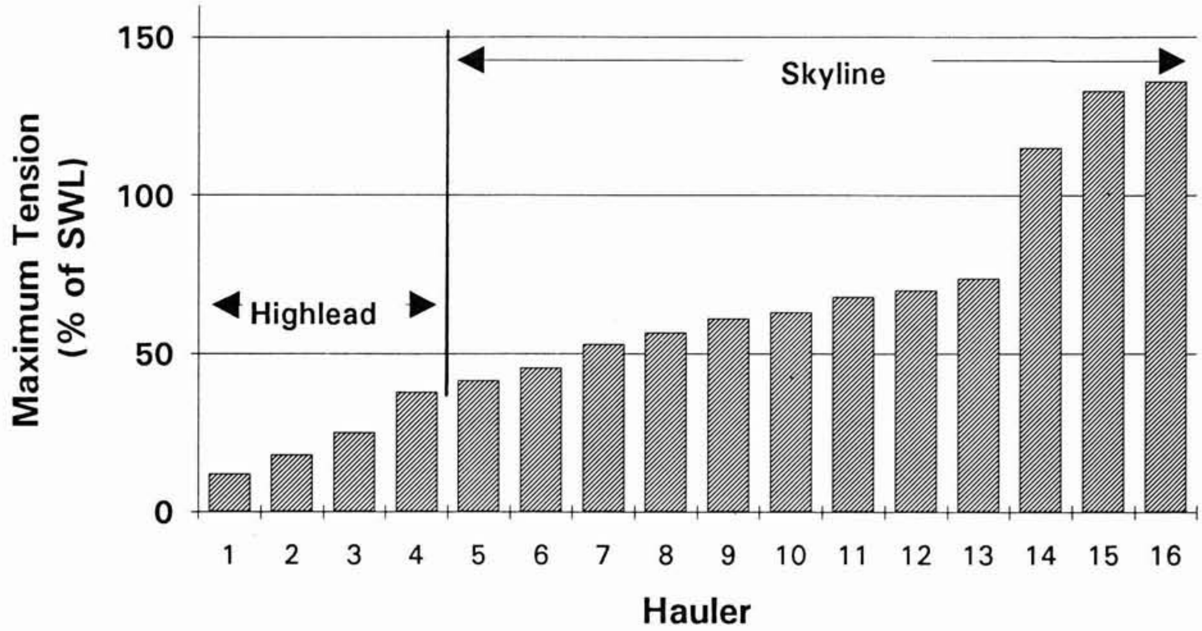

Figure 4 - Worst-case guyline tensions for highlead and skyline machines

friction changed over time in response to temperature, moisture or other conditions. For example, the slip tension for the fixed band brake of one hauler climbed from 15 tonnes to 24 tonnes as the day progressed. Three operators of other machines had found large changes in braking capabilities after replacing brake linings. One had broken a skyline even though the pressure was set at the recommended value. Another was developing tensions near SWL at only half the manufacturer's specified pressure. The limitations of some haulers (standing skylines or those with fixed brakes) and the variability in friction coefficients show that tensions will need to be monitored continuously to keep near SWL.

Guyline Tensions

Guylines were not overloaded as frequently as skylines. Tensions on the four machines rigged in highlead configuration were all less than 40% of SWL (Figure 4). Two of these haulers were monitored while rigged in highlead and North Bend skyline modes. Guyline tensions were two to three times higher when operating with the skyline system.

Over-tensioning was observed on only three of 12 skyline machines. The guy placements on these haulers were mostly favourable. Back guys generally had low vertical angles, equal lengths and good horizontal spacing. Other situations could create much higher tensions in one or more guys. These include skids where the slope drops off steeply behind the hauler and stump anchor locations which result in one guyline being much shorter or longer than another or guylines being spread at unequal angles. Therefore, it is not correct to conclude that guy tensions are of little concern.

Many operators said they used a sequence to pre-tension guys so that tensions under load would be equal. However, in many cases guyline tensions were not well-balanced. On a third of the skyline

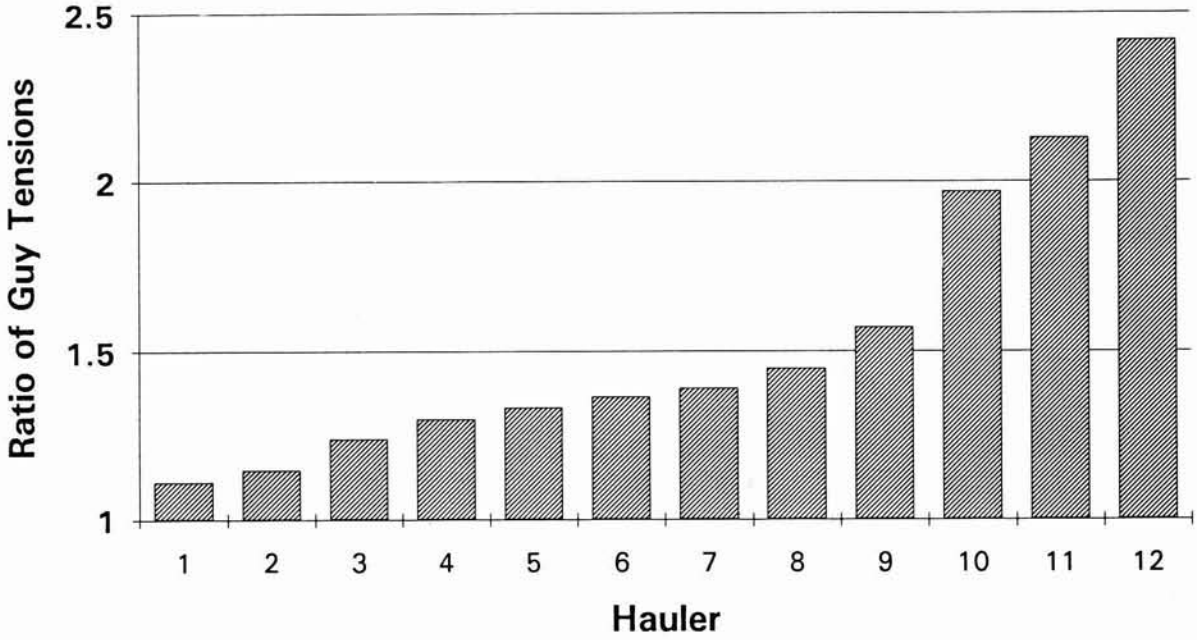

Figure 5 - Guyline tension ratio G1/G2 for skyline machines

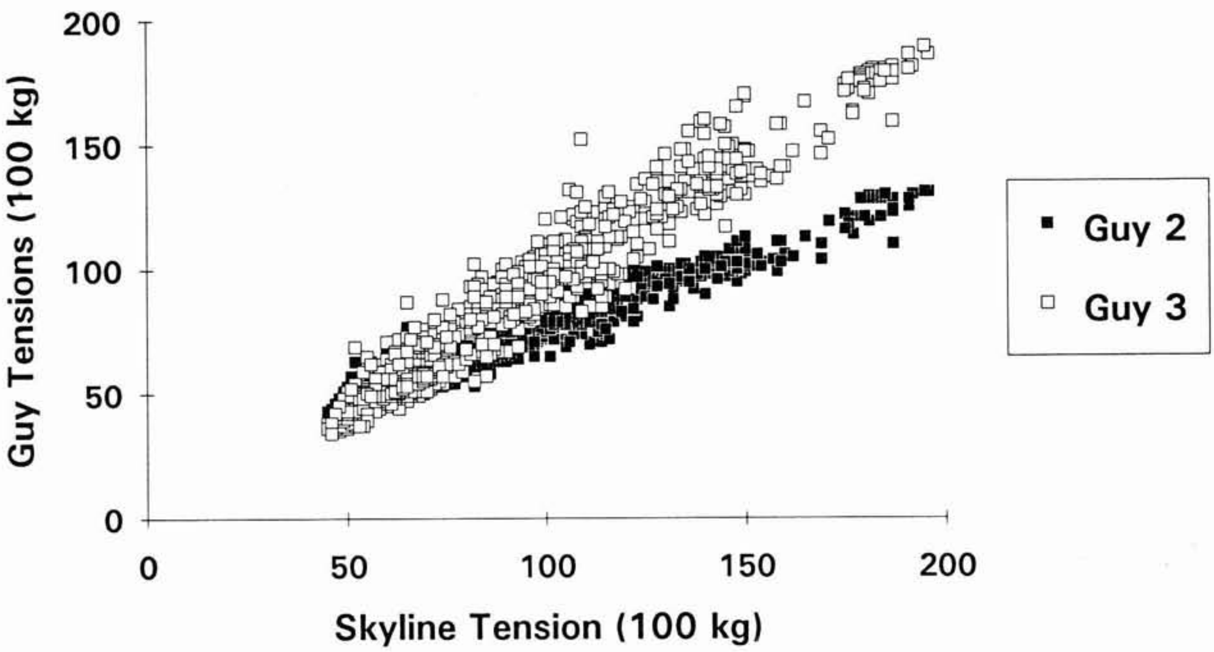

Figure 6 - Change in guyline tension balance with increased loading on a skyline hauler

machines the ratio G1/G2 exceeded the acceptable level of 1.5 (Figure 5). Most hauler operators pre-tensioned their guylines until the guy winches stalled. Pre-tensions, with the skyline slack, were generally low, for example, 10% of SWL. While this usually resulted in fairly even pre-tensions, imbalances showed up under

Table 2 - Number of drags with overload peak tensions and safe peak tensions for the control and test cases

Condition	Skyline		Guylines	
	Control	Test	Control	Test
Overloaded	36	14	17	10
Safe	81	157	141	191
Chi-square test P-value	0.000		0.039	

Figure 7 - Distribution of peak skyline tensions for the control and test cases

load because of differences in line angles or lengths (Figure 6). One hauler had a combination of winch-tightened and machine-tightened guys, the latter being shorter and therefore stiffer because they were shackled to the top of the tower. Another example was anchored to a stump and three deadmen; the deadmen moved slightly, putting an unequal share of the load on the stump.

Safety - Improvement with the RTM

During the second phase of the study, hauler drivers were able to reduce significantly the occurrences of overloading of both skylines and guylines by using the RTM (Table 2). Skylines

Table 3 - Peak skyline and guyline tensions and guyline tension ratios for control and test cases

Case	Average	T-test P-value	Maximum	Observations
Peak Skyline Tension (% of SWL)				
Control	92	0.000	148	117
Test	83		119	171
Peak Guyline Tension (% of SWL)				
Control	58	0.024	133	158
Test	51		134	201
Guyline Tension Ratio, G1/G2 *				
Control	1.39	0.000	1.97	35
Test	1.22		1.56	82
* for the three haulers where tensions were adjusted when using the RTM				

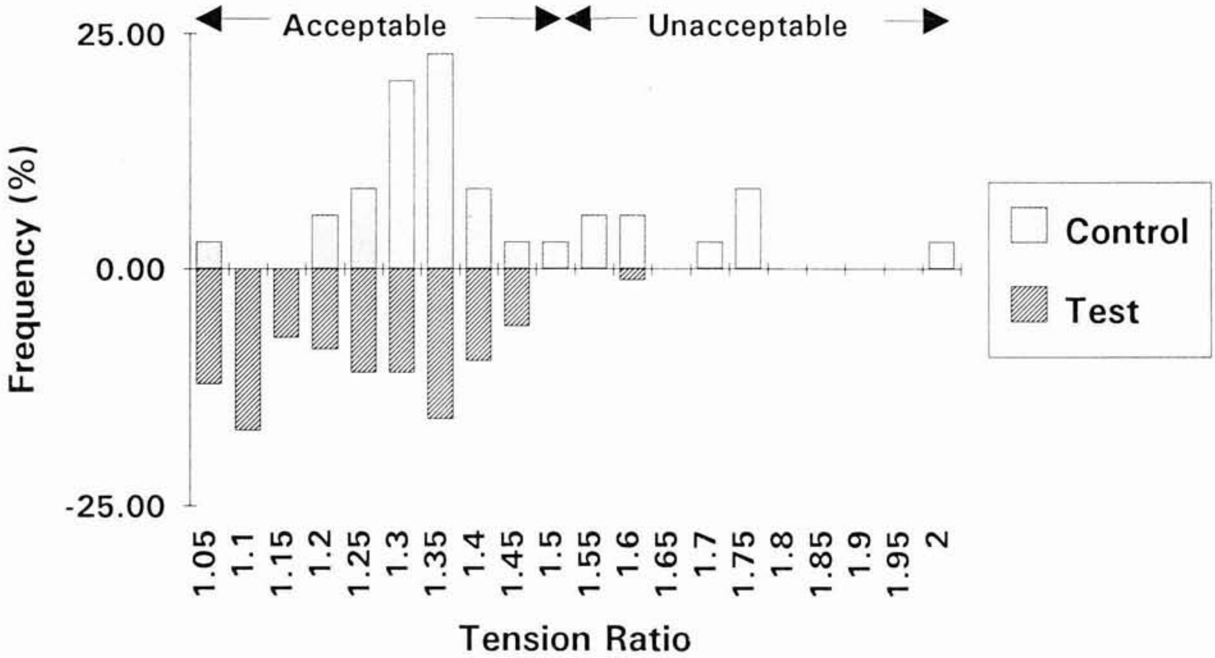

Figure 8 - Distribution of guyline tension ratios G1/G2 for the control and test cases, for the three haulers where adjustments were made

were over-tensioned on only 8% of the test drags versus 31% of the control drags. Although over-tensioning still took place, the most severe skyline overloads were eliminated (Figure 7). Average peak tensions in the skylines and guylines were significantly reduced, by 10% and 12% respectively. Also reduced was the

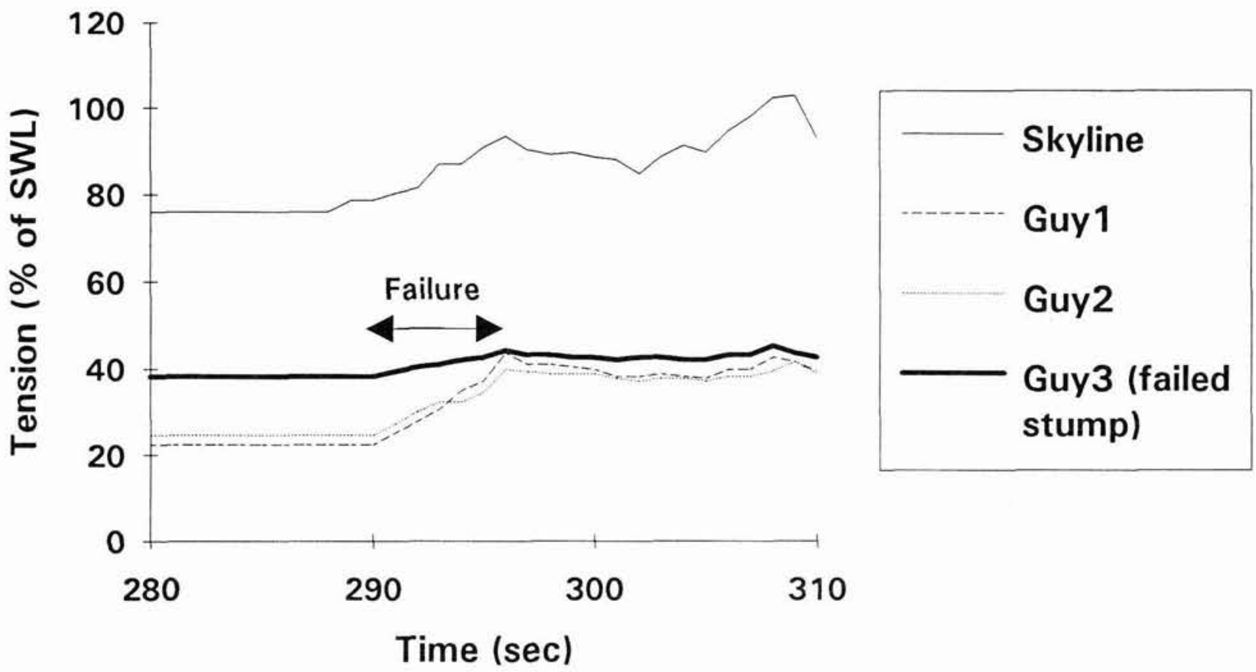

Figure 9 - Change in tension as guylines are loaded and one anchor fails

average ratio of guyline tensions on those haulers where adjustments were made at the start of the test runs in response to readings on the RTM display (Table 3). The unacceptable imbalances between guylines, indicated by values of G1/G2 greater than 1.5, were essentially eliminated by using the RTM (Figure 8).

Skyline overloads were reduced in two ways. Some hauler operators changed the skyline brake pressure so the skyline would slip at or near SWL, as indicated by the RTM. Two others used the two-way radios to ask the breaker-outs to reduce subsequent drag sizes when tensions were too high. It would be logical to use the first method on haulers with variable-pressure brakes and the latter where skyline brake torque could not be modulated or where deflection was limited.

On three of the haulers, guyline pre-tensions were adjusted by the drivers after they saw the imbalances on the RTM display. (In the first phase of the study, guyline adjustments were made on four of the ten haulers equipped with guyline winches.) In these three cases, the hauler drivers were not able to predict which guys were under higher tensions. Minor adjustments (20 cm or so) to guyline length corrected the tension imbalances. These corrections contributed to the decrease in peak guyline tensions. On the other three haulers, the guys were sharing the load equally in the control situations and no adjustments were made. For these machines, any reduction in peak guy tension was a result of lower skyline loading.

The importance of balancing guyline tensions was illustrated during the study when an anchor stump partially failed even though guyline tensions were not high. The guyline on the guilty anchor was the most heavily loaded of the monitored three, yet had been loaded to only about half of the SWL when the stump gave way (Figure 9). The failure occurred during a control sequence so the display was not in the cab. If the operator had seen the display, he may have noticed the change in relative tensions for the three monitored guys and responded by dropping the drag. Future versions of the RTM could be programmed to give a visual or audio warning when the balance of guyline tensions changes drastically. Because of uncertainties in anchor strength, it is important to keep guy loads balanced even when tensions are not near SWL.

Effects on Hauler Productivity

Payload Size

Average drag volume when using the monitor was 2% larger than in the control situation (Figure 10). This difference was not statistically significant. The study had been designed to detect an average difference of 10% or more. On four of the five operations, increases of approximately 8% were observed. In one case, there was a decrease of 23% because drag volumes were reduced to keep skyline tensions within the safe limits.

It was anticipated that any increases in drag volume that are truly related to the use of the RTM would come from the feedback on tensions from the hauler operators to the breaker-outs, allowing the breaker-outs to hook extra logs when possible. Because of pre-tension and rigging weight, a 10% increase in drag volume may change tension by only 3% to 6% so large increases in drag size are physically feasible where tension limits have not yet been reached. A 1% increase in productivity would recover the initial cost of an RTM in about one year, assuming typical New Zealand hauler production and income, and an RTM costing under $10,000 (at $15/m^3 extraction and loading income, 200 m^3/day base production and 200 operating days per year).

Where lines are being overloaded and the skyline is being operated as slack as possible, proper use of the RTM to improve safety will reduce payloads. Safer operations may be more profitable in the long term. In some cases, where the skyline is held too high, it may be possible to increase drag size and still reduce tension by lowering the skyline.

Since cycle times increase with payload size, the largest safe payloads may not be the optimum from a production standpoint. In fact, some contractors limited the number of strops they flew because they felt that the extra time to untangle them in the bush and strop the extra logs more than offset the gains of the larger drag. Another contractor was limited by a production quota.

Faster, More Efficient Operations

As well as increasing drag volumes, monitors might improve productivity by speeding up operations. The study did not formally evaluate production rates, but several time-saving instances were observed. Stuck drags where skyline tension was below SWL, occurred with three different haulers: One drag became stuck just below the skid during a control segment; a skid worker was sent to unhook part of the drag which was then pulled in on a second drag. The two other

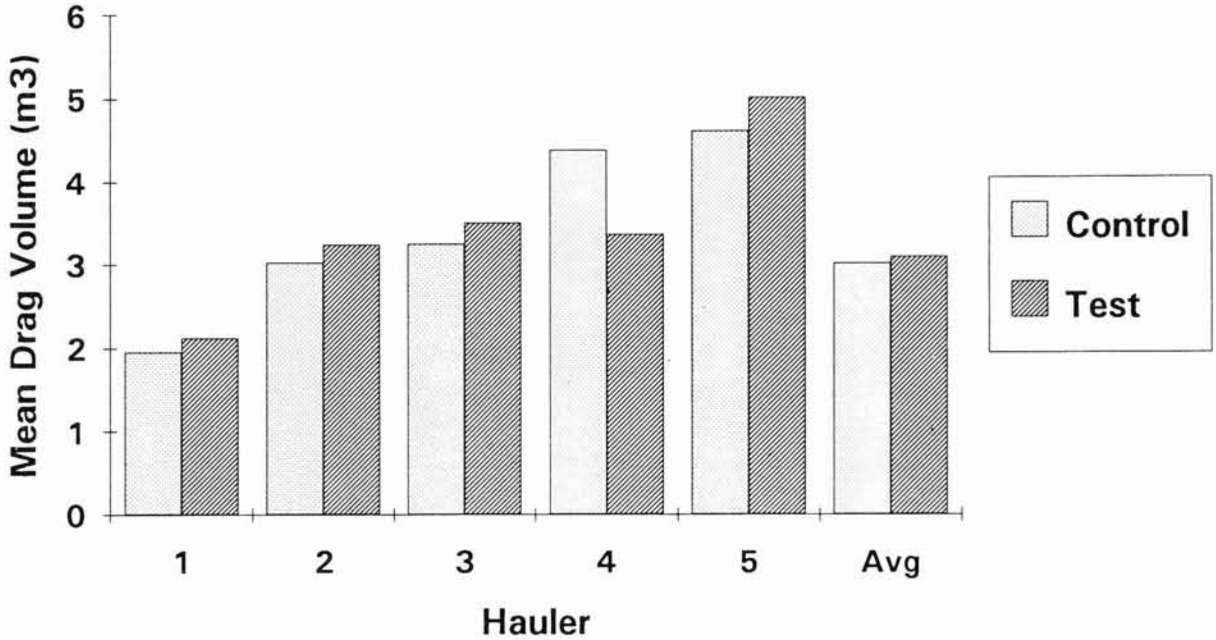

Figure 10 - Mean drag volumes for five haulers for the control and test cases

instances occurred during test sequences. In both cases the operators, by monitoring the skyline tension, were able to raise the skylines (less than a metre of line was winched in in both cases) and lift the drags clear without exceeding SWL. One operator avoided obstacles by lifting the skyline while inhauling at normal speed. He said he would not have done this if he did not have the RTM to check tension, because the drivetrain could easily overstress the skyline at high engine speeds. Another contractor saved preparation time due to the RTM. When shifting the skyline to reach the last part of a block, the monitor showed that guyline tensions were still in reasonable balance and that guy relocation was not necessary.

CONCLUSIONS

The tension results indicated potential for safety improvement in hauler operations. The most critical area was skyline tensioning. The RTM was effective in reducing occurrences and magnitudes of skyline over-tensioning, although it did not eliminate them. Mechanical limitations of some skyline haulers - standing skylines having no brake, some brakes being fixed, and varying coefficients of friction on the controllable ones -point to a need to monitor skyline tensions continuously, rather than using the RTM for a one-off calibration.

The study did not show a significant improvement in drag volume when using the RTM. In some cases, for example where deflection is limited, or the contractor does not want to fly more strops or where there is a production quota, there is no potential for increased volumes. In other situations, for example a setting with good deflection and large average piece size, the RTM might help increase drag size. It appeared that use of an RTM might also save time in some situations by reducing the number of stuck drags, thereby shortening inhaul times, and by decreasing the number of guyline shifts.

While most contractors indicated they would prefer to use a single load cell on the skyline, there appears to be reasonable justification for using load cells on guylines as well. Overloads did not occur as frequently in guylines as in skylines, but they did occur. Anchors may fail at less than the SWL of the guylines, so it is important to keep guy tensions balanced. When multiple guylines are monitored, changes in relative tensions can show that an anchor is failing. When a mix of stumps and deadmen are used, differences in initial movement may also shift the balance, requiring the guys to be readjusted.

Some contractors felt they could check guylines occasionally, for example after each rope shift. However, with only one load cell, there would be no easy means of checking tension balance under load. (The hauler could be stopped on inhaul while the load cell was moved from guyline to guyline.) A set of two load cells, one on the skyline and one on a middle or "suspect" back guy, might be a reasonable compromise, although this would still not indicate shifts in tension balance due to anchor movement or imminent failure.

RTM COMMERCIALISATION

A prototype RTM was used during this study. Actronic New Zealand Limited is currently developing a commercial version which is expected to be available for purchase in 1994. The load cells are expected to weigh 10 kg each and be easier to install than the prototypes, with no loose parts and no tools required. Cost is expected to be under $10,000 for a system which includes one load cell, receiver and display. If desired, the purchaser will be able to add extra load cells to the system at a later date.

REFERENCES

Occupational Safety & Health (1989) : "Safety Code for Bush Undertakings, Part 2 -Cable Logging".

Sessions J., Pyles M.R., Mann J.W. (1985) : "Selection of Design Factors in Cable Logging: An Economic Approach". 8th Annual Council on Forest Engineering Meeting, Tahoe City, California. August 18-22.

Smith M. (1992a) : "Remote Tension Monitor for Cable Haulers". LIRO Technical Note TN-5.

Smith M. (1992b) : "Remote Tension Monitoring for Cable Haulers". LIRO Report Vol 17, No. 23.

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