Field Testing of Synthetic Rope in Logging Applications to Reduce Workloads

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Oregon Occupational Safety and Health Administration
Worksite Redesign Grant Final Report
July 2004

EXECUTIVE SUMMARY

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The purpose of this grant was to put synthetic rope in the hands of actual loggers and truckers so that they can help develop and evaluate the uses of synthetic rope in logging applications.

Prior research and development showed synthetic rope to be suitable as a replacement for wire rope in logging and had potential for ergonomic improvements (Garland, et al, 2001). Additional potential uses for synthetic rope were evaluated by placing synthetic rope with loggers and truckers. These uses were evaluated in a variety of means for the operational efficiency and ergonomic potentials.

The number and types of firms were as listed in the table below:

Logging Application	**Firm/organization**	**Affected Crew**
Static lines in cable operations, winch line on skidder, mainline on yarder	OSU Student Logging Crew	6-9
Skidding line on carriage	Logging contractor	3-4
Static lines on Yarder	Logging contractor	3-4
Static lines - cable yarding	Logging contractor	3-4
Static lines-cable, skyline extension, winch line on skidder	Logging contractor—southern OR	3-4
Static lines-cable, yarder guyline extensions,	Logging contractor—Willamette valley	3
Winch line on crawler	Logging contractor—eastside	1
Winch line on crawler	Logging contractor—westside	1
Winch line on crawler	Logging contractor—Minnesota	1
Winch line on farm tractor, chokers of synthetic rope	Woodland owner—Cascades	1
Log truck wrapper	Woman truck driver-trucking firm	1
Log truck wrapper	Older male driver-logging & trucking firm	1
Log truck wrappers	Longview WA-industry	6
Log truck wrappers	Cosmopolis WA-industry	12
Log truck driver	Willamette Valley-trucking firm	1

Synthetic rope was made available for the operations above with available knowledge of potential uses and the operators and loggers used the ropes to discover new applications, potential improvements, and helped us identify problems.

Overall Results

In general, most loggers and operators see ergonomic and efficiency benefits for the logging applications, but one or two individual loggers and truckers expressed a preference for steel rope in their judgment. By summary of uses, the results show:

- Static lines in cable logging (tree guylines, straps, snap guys, etc,) => efficiency & ergonomic benefits
- Guyline extension => ergonomic benefits but need sizing determinants for yarders
- Skyline extension => ergonomic & efficiency benefits but further study is needed
- Skidding line on carriage => ergonomic benefits but carriage modifications & operations need modifications to use synthetic rope effectively
- Winch lines on crawlers/skidders => ergonomic, efficiency & potential environmental benefits
- Chokers/winch line on farm tractor => ergonomic benefits noted but efficiencies still under evaluation

Because of Oregon laws in effect until later in the study, wrapper use was studied in Washington State where synthetic rope wrappers were allowed (OR law changed on 1-1-04 to allow synthetic rope wrappers). OSU cooperated with Samson Rope Technologies on wrapper trials in WA and found substantial ergonomic benefits with synthetic wrappers. However, tests of residual strengths in wrappers did not meet the manufacturers' expectations and they are currently evaluating how wrappers can be produced. Substantial institutional barriers to using synthetic rope wrappers were identified related to load securement requirements by the federal government. We also discovered that drivers were tensioning wrappers/binders far beyond the recommendations of binder manufacturers and putting themselves at risk for injury in the process. At this time, wrapper trials are suspended until the manufacturer establishes the strength and rope design needed for log truck wrappers. It is expected that a suitable wrapper design will emerge from these trials in the future so log truck drivers can see benefits from synthetic rope wrappers.

Ergonomic benefits of using synthetic rope wrappers were established in the ease of throwing wrappers compared to steel wire rope and in benefits to drivers who already had arm/shoulder complaints. Some drivers indicated their complaints went away completely or were substantially reduced when using synthetic rope wrappers. Only a few drivers expressed preference for steel wrappers.

Several problems or issues were discovered during the research. Synthetic rope is not a direct replacement for wire rope in all applications; it is a "new" product and may require changes in operational procedures to avoid abusing the rope and to realize its potentials. Users need to distinguish between "disposable" uses of rope (chokers, end of winch lines, etc.) and longer term uses (guylines, straps, etc.) similar to the way wire rope currently behaves. Wear and replacement criteria are needed and will not be fully established by this research (more time is needed). The use and field testing of new end connectors (from companion research) is vital for effective use of synthetic rope. Guidance in using synthetic rope is needed in the form of rigging guides and education for loggers to use synthetic rope effectively.

Education and outreach efforts based on this research have stimulated loggers and truckers to purchase synthetic rope for trials on their own. We expect to continue research on synthetic rope in logging and trucking beyond this grant support.

Acknowledgements

The entire team of researchers working on the Synthetic Rope Research Project would like to thank the Cooperators (loggers and truckers) for their field trials and sharing their ideas in an effort to make their jobs easier. We also thank Samson Rope Technologies, Inc. for their support and cooperation on many parts of the projects. Without funding support from the Oregon Occupational Safety and Health Worksite Redesign Grant Program, we could not have undertaken the project. We thank the many people who have expressed interest in the projects and helped us make the potentials known.

TABLE OF CONTENTS

I. Introduction

The overall purpose of the project was to put synthetic rope in the hands of actual loggers and truckers to assess the use of the rope from efficiency and ergonomic perspectives. The range of applications available to researchers is limited while logging and trucking cooperators were able to put the synthetic rope into a wide range of uses for evaluations. The cooperators have put the synthetic rope into use and the researchers have solicited evaluation information.

As part of the project, Graduate Research Assistant, Jared M. Leonard, completed a Master of Forestry (MF) degree on September 8, 2003 with a summary paper titled: Applications for Synthetic Rope in Logging (Leonard 2003). As part of this report, sections from the MF paper will be cited and those sections will be identified with "NB: material from Leonard starts/ends here." Not all of the applications evaluated were included in Leonard's paper and none of the truck wrapper studies were a part of his MF paper. Other inserts from previous publications will be handled similarly.

The report is organized as follows:

I. Introduction
II. Ergonomic Description and Task Assessment
III. Static Line Logging Applications
IV. Running Line Logging Applications
V. Truck Wrapper Applications
VI. Operator Assessments
VII. Continuing Applications and Assessments
VIII. Summary of Applications and Future Research
IX. Technology Transfer Activities
X. Sources
XI. Appendix 1

The difference between ergonomic descriptions, applications and operator assessments are as follows:

- Ergonomic descriptions and task assessments refer to generic jobs/tasks in logging and trucking and the synthetic rope improvements to work practices
- Applications refer to the operations studied in this project for static lines, running lines and truck wrapper uses
- Operator assessments provide key qualitative statements by cooperators.

In addition, three other documents resulted from this research and development effort. A Rigging and Operations Guide for static line applications is from this research effort as a separate document. In addition, photo-based Splicing Guides for the eye splice and long splice were produced in cooperation with Oregon Occupational Safety and Health Administration. Other Guides may follow from these efforts. These documents are available separately.

This report will include figures and tables from other documents which list the figure and table references to match what the included material covers. For figures and tables specifically produced for this report, we use the "R" report designation in front of the figure or table number, e.g., Figure R2 or Table R1, as appropriate.

Mention of trade names in this report is for identification only and does not constitute an endorsement by Oregon State University or the Oregon Occupational Safety and Health Administration. Whenever Amsteel Blue is mentioned we are specifically referring to AmSteel®-Blue synthetic rope by Samson Rope Technologies. We use the shortened version "synrope" to mean "synthetic rope" interchangeably in this paper.

II. Ergonomic Description and Task Assessment

Listed below are the ergonomic assessment and task description for tasks where synthetic rope was used: Hooktender/rigger; skidding machine operator setting chokers; yarding crew pulling skidding line and log truck driver securing loads. The task description is provided first with current practices using steel wire rope and then with synthetic rope. Appendix 1 shows the pre-intervention summary interview used for operators in the assessment of improvements. Additional data of differences from our studies with the Student Logging Crew provide further measures of differences for the tasks. We also show changes in heart rates with steel and synthetic rope on selected tasks.

Hooktender/rigger

While Hooktenders are the onsite supervisors of the cable logging crew, they also have important tasks to "rig up" the next yarding road. They may be assisted by a "rigger" from the crew doing some of the tasks as well. The rig up task involves first getting the steel wire rope guylines, blocks (pulley sheaves), shackles, and miscellaneous tools (tree straps, come-a-long, climbing gear, rigging chains, support jacks, wrenches, rope clips, etc) to the anchor, tailtree or intermediate support tree. The rigging will need to be carried over difficult terrain to the far end of the cable unit or to points about in the middle of the unit-- typically 500 to 3,000 feet from the landing. Most often the direction of yarding is uphill but may also be downhill. While the total weight of the rigging may reach in excess of 350 pounds or more depending on how many guylines are needed. Hooktenders/riggers will carry loads of 60 to 100 pounds or more in coiled steel ropes, individual blocks, shackles tied together, and awkward miscellaneous tools. An example of the heaviest load will likely be in a single steel intermediate support line or a guyline 5/8" in diameter of about 150 feet in length and weighing around 111 pounds.

Often trees must be rigged up to 80 feet or more in height (Figure R1). Blocks, tree straps and lines must be lifted and manipulated by the climber. It can be difficult to bend 7/8" steel rope straps around a tree only 14" in diameter and get the strap to stay in place on the tree. Because the next yarding road will be rigged while active yarding is taking place, two complete sets of the rigging may be needed and carried to the brush. If the terrain requires it, an intermediate support tree and a tailtree may need to be rigged putting 4 sets of rigging to carry and rig up. As yarding roads are completed, the rigging will need to be removed from trees and anchors and moved to the next location involving de-rigging tasks nearly as difficult as the initial rigging of climbing, carrying blocks, pulling lines and so forth. When the entire unit is completed, most of the rigging will need to be carried out. During active operations, yarding road changes typically occur once or twice a day depending distance of the road and timber to yard. Work days are 8-10 hours, but with travel time, the working day often is 12 hours. Five day weeks are normal.

Figure R1. Hooktender rigging tail tree.

Skidding Machine Operator Setting Chokers

A common operation for ground based yarding is to have the operator of a crawler tractor or wheeled skidder drive to a location, position the machine, pull winch line and chokers to logs, set the chokers, clear hang-ups, winch the load to the skidding machine and drive to the landing. The difficulty of the task of pulling the winch line and setting chokers depends on the size of the winch line needed for the weight of the logs skidded. Winch lines from 3/8" to 1" diameter have been used by operators in our study. Typically steel winch lines do not exceed 125 feet in use. The direction of winching can be uphill or downhill but machines typically do not operate on slopes over 40%. One operator reported that it took 5 workers to pull 1" diameter steel winch line down the slope about 75 feet and then up the slope for the final 25 feet to the logs in a special unit he skidded. With the winch line on the ground, operators need to pull the line through obstacles with forces that reach 60 to 80 pounds or more from leg drive and upper arm/body muscles.

The winches on machines may have either "free spooling" or "power out" functions. However, winches are set so that steel wire rope will not "sprong" like a fishing reel backlash and this adds to line pulling efforts. When steel wire rope is winched in, the rope may "dive" into loose wraps requiring the operator to attach the winch line to a stump or other anchor to free it. Chokers are attached to the winch line with sliders or ring/toggles that slide along the line or to a "bull hook" at the end of the line. The end section of the winch line is often damaged and looks like a "pig tail" and will need to be cut off periodically. Jaggers (broken wires that produce lacerations and puncture wounds) are common on the winch line and chokers.

On a daily basis, the skidding cycles average 20 to 40 per day depending on the distance the logs are from the landing and other factors. Working days run 8-10 hours plus travel time for 5 days per week. Ground based skidding may be limited to a dry (or snow) season so pressure to complete the unit in time is often present. See Figures R2 and R3 below.

Figure R2 shows skidding machine operator winching logs to the machine and driving to the landing.

Figure R3 shows skidder operator moving to take the winchline and chokers to the logs.

Yarding Crew Pulling Skidding Line

Another task common to cable operations involves yarding crews pulling line from or through a carriage to reach the logs for choker setting. Some carriages have a winch and motor that both powers out the winch line and pulls the logs to the carriage. In other carriages, the mainline itself is pulled through the carriage either by the crew or with assistance of a “slack puller” arrangement. Once the skidding line is on the ground, pulling the line to the logs is similar to efforts of a skidding machine operator pulling the winch line to logs. Skidding lines typically are 3/8” to 3/4” inches in diameter and are pulled 30 to 100 feet to the logs across the slope or downhill. Forces to pull the skidding line may run 30 to 60 pounds but workers are typically working on steep slopes reaching 100% but typically 50-70% and covered with slash. Crews are usually two people but three to four people are sometimes used.

When the carriage reaches the selected point, line is pulled by workers through the carriage or the motor pulls the line to the workers on the ground 20-100+ feet below. The crew pulls the line to the logs and sets the chokers before moving to a safe position in the clear. The load is winched to the skyline and yarded up/down the slope (terrain dependent). A special circumstance occurs for carriages with manual slackpulling when the mainline develops a sag or belly in the line before the carriage that must be pulled through the carriage. Depending on circumstances, 3 or more workers may be needed to pull the line through the carriage to the logs.

Yarding crews usually work an 8 hour day, five days a week, plus added travel time to the job. Typically 40 to 70+ cycles per day occur for cable yarding depending on distance and circumstances. Some logs are directly under the skyline while others are as far as 150 feet away. See Figure R4 below.

Figure R4 shows Student Logging Crewmember attaching the skidding line to ring chokers for moving logs to the skyline corridor.

Log Truck Driver Securing Loads

Besides driving the truck, log truck drivers need to secure their loads at the landing, tighten wrappers in route if needed, and loosen load binders and wrappers at the unloading point. With steel wrappers, drivers on Oregon highways will throw four wrappers over the load and tighten them with a load binder. The wrapper is typically a 25-30 foot, 3/8" diameter steel wire rope with chain lengths at both ends of the wrapper. Four feet of chain are typical on both ends with the most common overall length of 26 feet. The wrapper end is held in one hand and the wrapper is thrown over the load with the throwing arm by over hand, under hand or some unique throwing motion. Weight thrown varies by technique but approaches the total weight of ~11-14 pounds (the full weight of the wrapper). A flipping technique allows some repositioning of the wrapper on the load but at times the wrapper must be thrown again to get it in the proper position. A binder with chain hooks is attached to the chain ends and closed pulling the wrapper tight on the load (See Figure R5). Using the binder lever unaided produces a 25 to one advantage for force to close the lever on the binder (The Crosby Group, 2002). The force closing the binder is usually increased by using a handle extension, "cheater bar" or pipe on the binder handle. Measures of the tension in the binder/wrapper can reach 3,000 pounds or more from our tests. In special circumstances, loader operators may assist drivers by using the loader to place the wrappers over the load but this is not the typical practice.

If log truck drivers throw 4 wrappers, for about 4 loads per day, and work a full year, the number of wrapper tosses over a 30 year driving career approaches the pitches of the short career of a major league baseball pitcher. Not surprisingly, the injuries to log truck drivers are similar, with rotator cuff and shoulder injuries the most common ailments. One difference is that pitchers get days of rest from pitching duties while drivers throw wrappers everyday and the chronic inflammation is not allowed time to heal. Such injuries cause drivers to seek other types of employment or stop driving log trucks.

Injuries to drivers from load securement include arm and shoulder injuries from over-tightening the binders, slips and falls, and being struck by the binder handle when loosened at the terminal point. The Oregon State Accident Insurance Fund collected statistics from one of its districts for such injuries and found 32 injuries costing $276,000 (SAIF, 2003).

Figure R5 shows driver attaching load binder to steel wrapper on the load. Note use of the binder handle extension or “cheater bar” and tension monitoring device wiring

Ergonomic Improvements With Synthetic Rope

In our project we placed synthetic rope as a substitute for steel wire rope in selected applications for the tasks above to reduce the weight and eliminate the jagger injuries. The ergonomic benefits are discussed here and the specific applications are described individually below .

Hooktender/Rigger Improvements

To varying degrees in our trials, we were able to replace wire rope with synthetic rope for the following lines used by Hooktenders/riggers in cable logging.

- Tree and ground straps
- Guylines for tail trees and intermediate support trees
- Intermediate support lines
- Snap guylines
- Guyline Extensions

By replacing steel lines with synthetic rope lines above we have been able to reduce the weight of the lines to 1/9th. Additionally, synthetic rope will fit on a pack board or within a pack sack and operators report they can take necessary rigging to the anchor or trees in fewer trips in, across, and out of the unit. For a Hooktender who will need to climb and rig the trees after packing the rigging into the site, fewer trips are both labor saving and help reduce fatigue. Pulling lines up into the tree for attachment is much easier with synthetic rope than steel.

Straps that easily bend around the tree and stay in place are also preferred when using synthetic rope. Leonard (2003) measured the effort needed to bend steel rope together around a 13” diameter circular object like a tree and found the differences below in Figure R6.

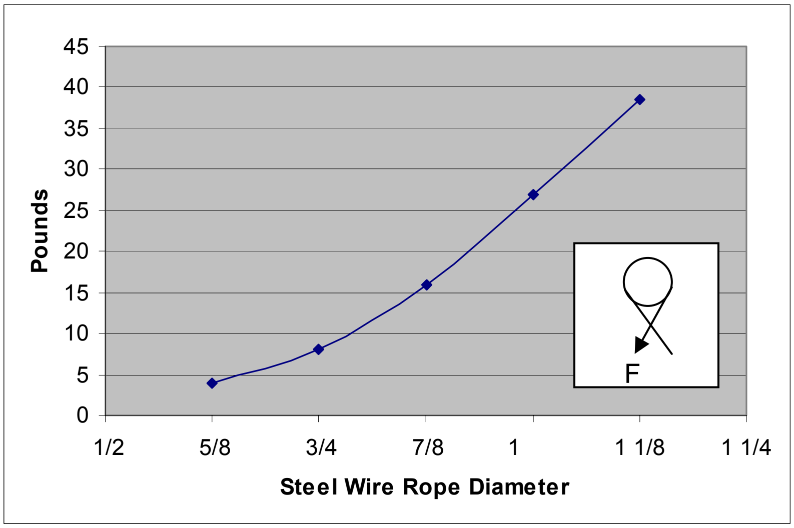

Figure R6. Force needed to bend wire rope around 13” circular object (from Leonard, 2003, p. 19).

The stiffness of a steel wire strap must be handled when the Hooktender is up in the tree balancing and frequently using one hand to hold the strap and the other to attach rigging. In contrast, the use of synthetic rope is much easier to bend as shown in Figure R7 below.

Figure R7. Synthetic rope in an endless loop configuration used as a tree strap.

Wire rope of a similar diameter cannot be used in the same configuration or bent as shown with larger diameter steel straps.

There were other ergonomic improvements with using synthetic rope in rigging application tasks in designed studies of the OSU Student Logging Crew. We had student workers perform the same rigging tasks of carrying and dragging 5/8” diameter lines of steel wire rope (111 pounds) and AmSteel®-Blue (18 pounds) synthetic rope. Various tests on slopes, uphill/downhill, and on the road were done with worker heart rates and subjective evaluations of task difficulty recorded. See Figures R8 and R9.

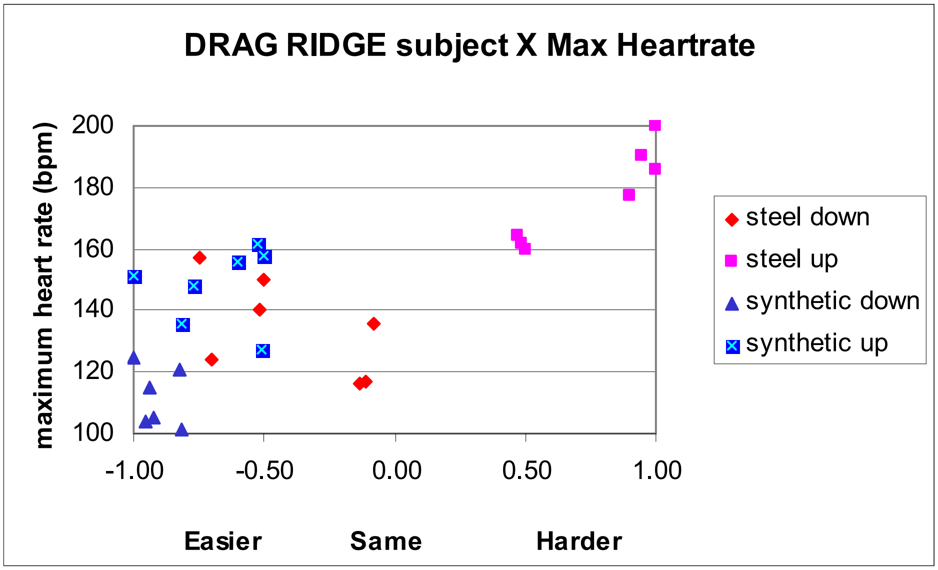

Figure R8. Worker heart rates for steel and synthetic rope dragging on a ridge, 25% slope.

When we tested tasks similar to activities for rigging crews dragging lines on slopes we found time differences for the Student Logging Crew workers in the time to drag the 150-foot line, 150 feet down and up a 25% slope. There were 13 workers participating over the two year period. The group was comprised of 10 males and 3 females. Ages ranged from 20 to 47 years, averaging 29. All participants self rated their physical fitness as “Good” and free of physical limitations.

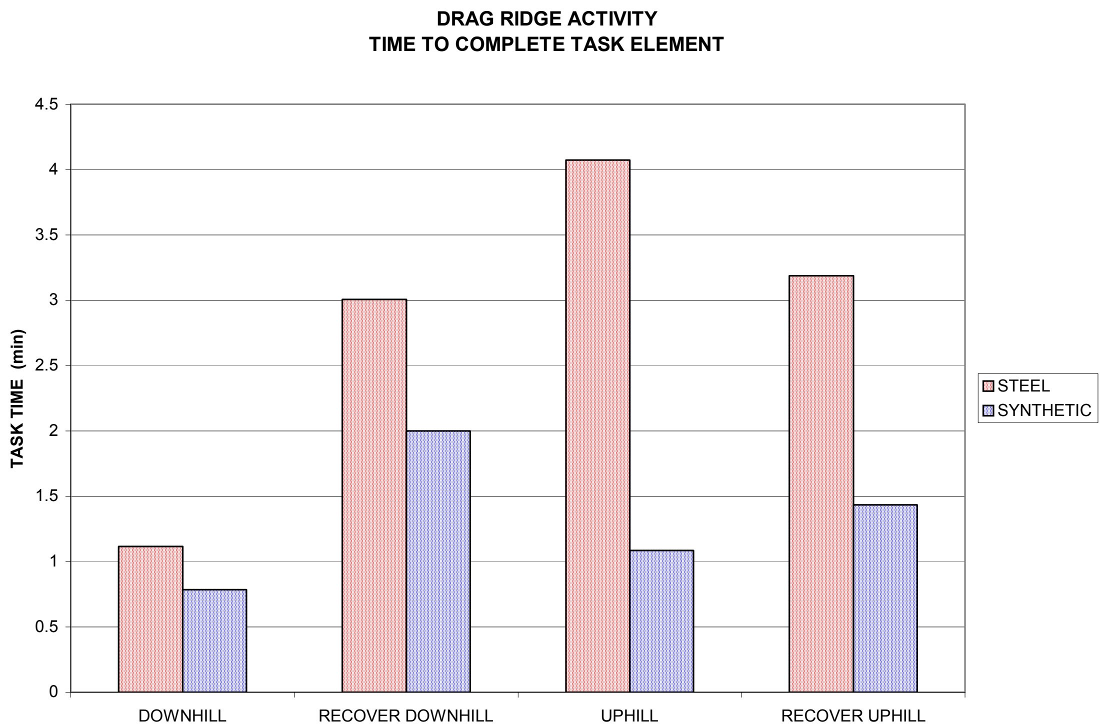

Figure R9. Task time and heart rate recovery (pre-task) time for Drag Ridge activity.

We also noted the time for the worker’s heart rate to recover to the pre-task level for both downhill and uphill was significantly less on average for the group. Recovery times are both a function of task difficulty and worker fitness.

Skidding Machine Operator Improvements

The improvements by using a synthetic rope winch line are both in the weight of line handled and the elimination of jaggers as shown in Figure R10.

Figure R10. Line showing broken wire or “jagger” that will inflict lacerations and puncture wounds during handling of steel wire rope.

As a part of the improvements to using a winch line of synthetic and steel wire rope, we used the Student Logging Crew in a designed experiment to assess the scientific validity of the difference between winch lines. The experiment measured important variables of slope, distance, gender, and rope type for controlled measures of the line pulling times. Our Analysis of Variance results for the experiment showed significance for the rope type: synthetic rope less time consuming than steel. The analysis showed a gender difference as well, indicating females have different (than males) but improved time reductions with synthetic rope winch line pulling over steel. Heart rate measures were also different as were the task times on the line pulling (outhaul) element. The graph below of work intensity for the task shows how difficult logging is for workers. The subjective measures show differences favoring synthetic rope and speak for themselves.

Pilkerton, et al summarized the results in a 2003 paper for winch lines. Note in particular the Rodahl scale for work intensities, as a function of heart rate.

NB: Pilkerton material starts here (Pilkerton, et al, 2003).

Field Trials

Figure 1 shows a sample trend of the heart rate data record for steel and synthetic ropes for 5 turns each. Turn outhaul (pull to log) distance, slope, and uphill/downhill variables are not consistent for steel and synthetic. Peaks generally correspond to end of line pulling element.

Figure 2 shows the heart rate exertion levels for a 24 year old male for pulling a ¾-inch diameter synthetic winch line. Eighty percent of the time the operator's work intensity is in the heavy work or more strenuous categories.

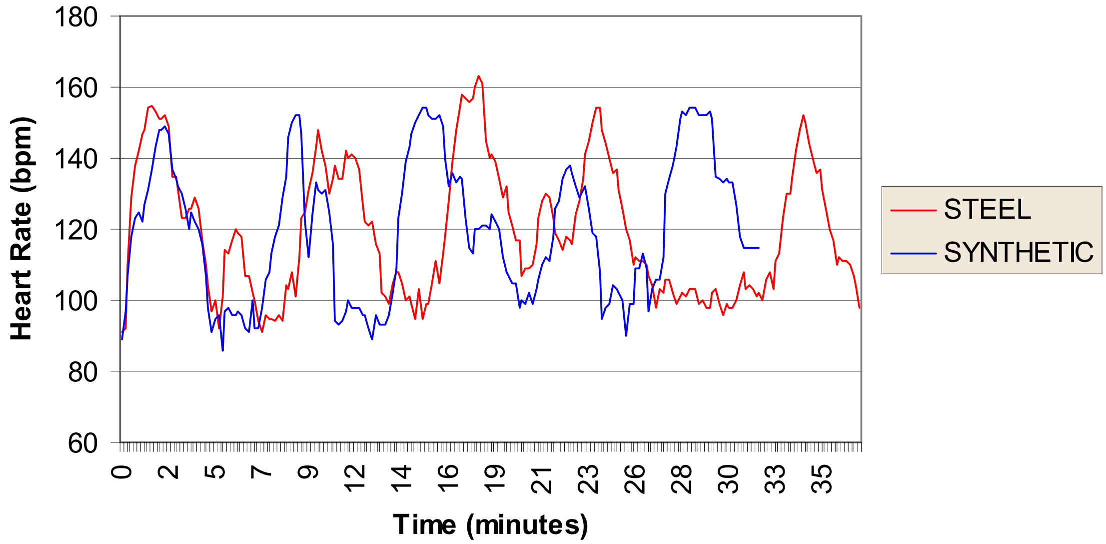

Figure 1. Heart rate traces as a function of time for 5 turn cycles. Elements include lateral out (pull to logs), hook, return to skidder, winch in, and unhook.

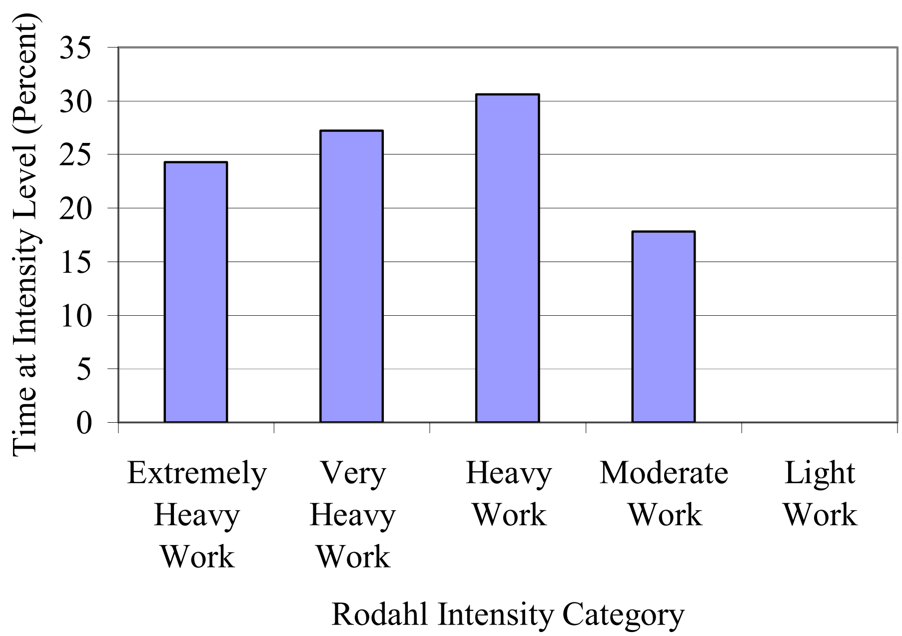

Figure 2. Heart rate exertion intensity, percent time by Rodahl Categories, for a 24 year old male pulling a ¾-inch diameter synthetic winch line.

A standing, at rest, heart rate of 70 bpm was assumed for all individuals. Heart rate exertion intensity zones (average person, 20-30 years of age) can be described as follows (Astrand and Rodahl, 1986):

Heart rate (bpm)	Exertion Level (onset of)
< 90	Light Work
91 - 110	Moderate Work
111 - 130	Heavy Work
131 - 150	Very Heavy Work
151 - 170 +	Extremely Heavy Work

The reader should be cautioned to keep these values in mind when reviewing the results. The initially tendency is to think of a 15 bpm difference as small. However, this represents a 20 percent increase over the standing at rest rate. A 15 bpm increase can move an individual from one exertion level to the next.

The outhaul (pulling line to the logs) element was the focus of the difference in rope type. Heart rates, on average, were statistically similar. However, task time was 0.5 minutes faster with the synthetic rope (Figure 3). Heart rates were lower for all elements when using the synthetic rope. There appears to be an exertion carry-over effect into the next element, ie, when hooking the turn. This activity occurs right after the line pulling element (outhaul).

Still heart rates are 70-85 bpm higher than the initial heart rate of 70 bpm. Heart rates increased 10 – 15 bpm with sustained activity (over the first turn) during the 5 turn sequence. ANOVA analysis showed significant differences in average heart rate for rope types and gender (main effects) and slope gradient, distance pulled, uphill/downhill (covariates).

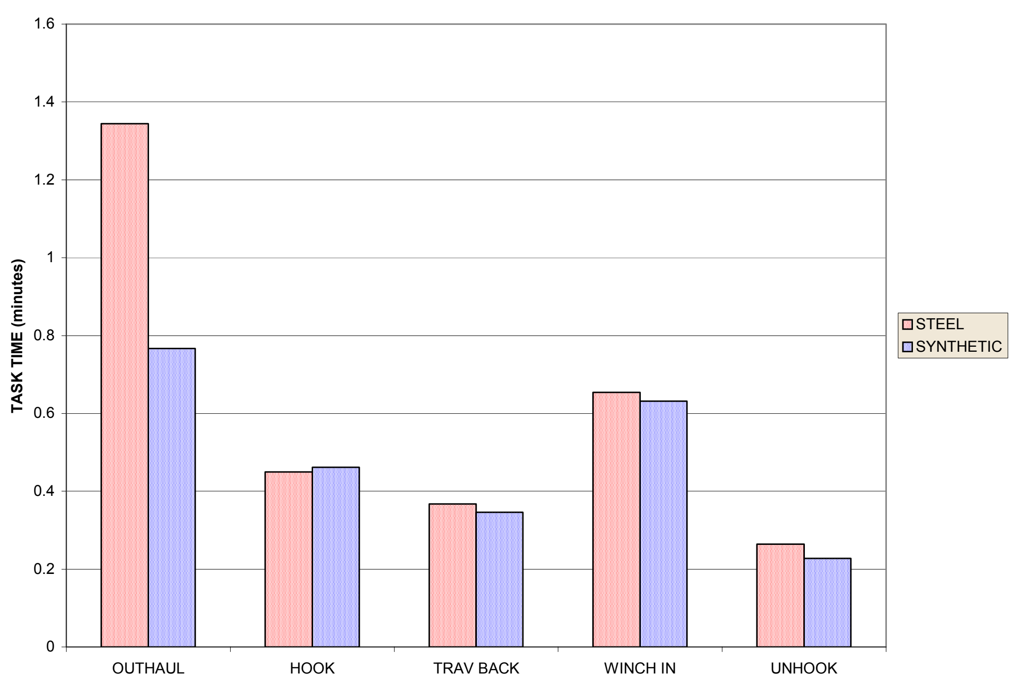

Figure 3. Average skidding task times by activity element for all 7 workers' series of 5 turns for steel and synthetic winch lines.

Subjective Analysis
Evaluated numerically, synthetic rope was subjectively considered 20 percent easier downhill and 15 percent easier uphill when pulled off the skidder bull winch (Figure 4). A t-test on the mean subjective values failed to show a statistical difference in the ratings. Analysis of Variance showed a statistical difference by slope and gender.

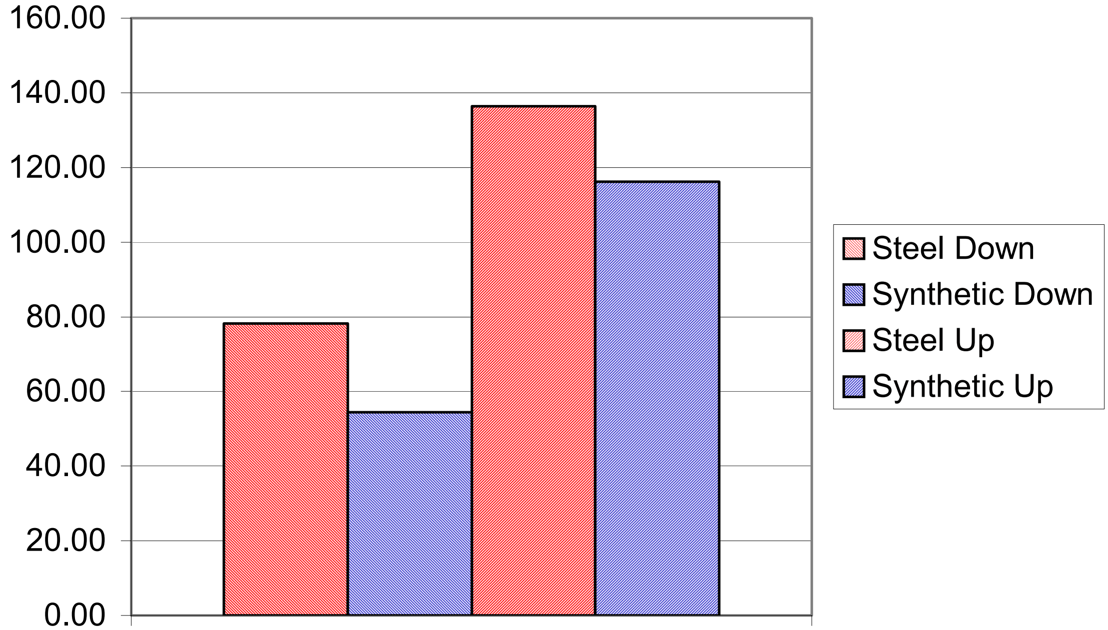

Figure 4. Average (n=7) subjective rating for steel and synthetic skidder winch line pulling. Scale is unitless, relative response to base case task, where zero is considered "extremely easy".

Numeric results of the subjective analysis are informative, but the worker comments are also interesting. Negative comments noted tendency for synthetic rope loops to catch on slash. Overall, synthetic rope was well received, especially by those who have cut their hands on a jaggered steel cable. Not surprisingly, the subjective views of the workers favor synthetic rope over steel wire rope. Recorded observations include:

- "Much easier, almost the same as just walking without anything."
- "Hardly like pulling anything."
- "Felt like leading a good horse."
- "Both directions were easier than dragging cable (steel, sic) on road."

NB: Pilkerton material ends here.

Leonard (2003) made a brief time study of the trial involving the John Deere 650 crawler tractor and found significance for the lateral out element (pulling winch line). Figure R11 shows how the difference increases as the distance of the line pulled increases.

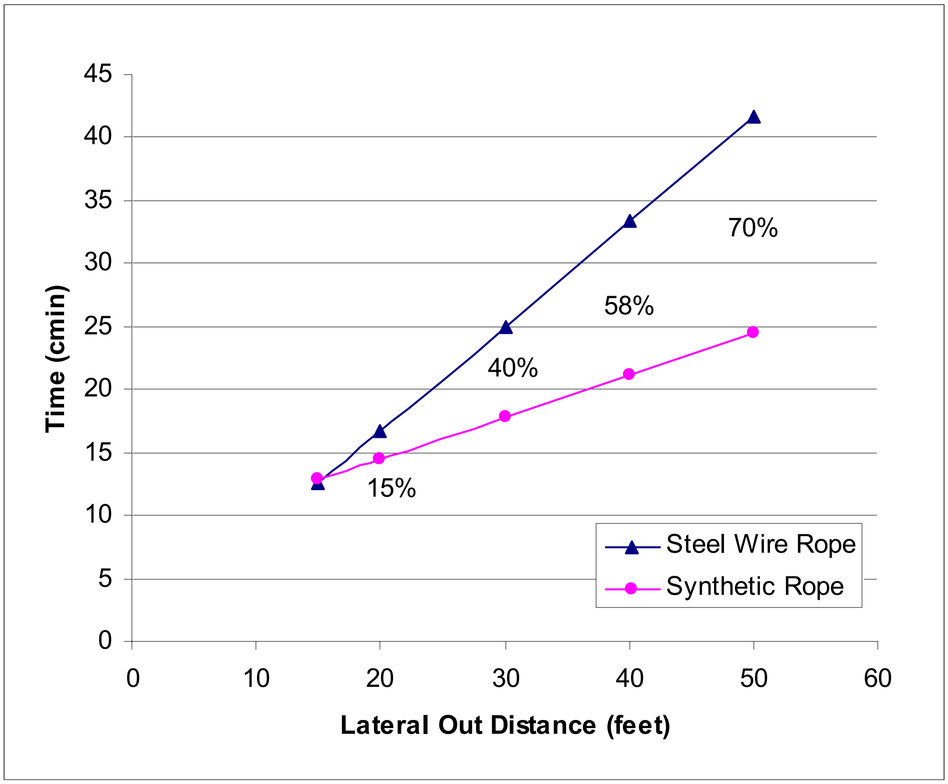

Figure R 11. Differences in time for lateral out as the distance increases from Leonard, 2003, p. 52.

Yarding Crew Improvements With Synthetic Rope

Two efforts were made for yarding crews to make improvements using synthetic rope. One involved using synthetic rope on a Boman carriage trial to replace the wire rope skidding line, and the other replaced the mainline on the Koller K-300 Student Logging Crew yarder.

On the Boman carriage trial, the steel line on the skidding drum was replaced with AmSteel®-Blue line. There were so many operational obstacles in the trial that the ergonomic improvements were only discernable through observations of selected events. With steel line two workers required to haul empty chokers and dropline laterally to hook the pre-set logs. With synthetic, one worker could unhook the empty chokers, assist the other worker by pulling slack from near the carriage, and then move the empty chokers to the next turn and in the clear. The other worker then just walked, pulling the line to the pre-set logs, hooked them, and moved into the clear.

Observations include:

- When the carriage was working properly, it appeared that the yarding crew could more easily pull the synthetic line to the logs compared to the steel line.

- Workers immediately recognized the reduction of physical exertion required to perform the work activities.

- Synthetic, being lighter and more flexible than steel, made it easier to maneuver around obstacles. Also, if a hang up occurred, once past an obstacle, it was usually possible to flip the line clear versus having to walk back to the obstacle and free the hang up.

- Lateral pulling distance increased with synthetic. There was less effort to pull lines and when workers previously reached the point where "that's enough of that, we will get it on the next corridor," they continued lateral pulling. With longer lateral pulls, it is possible to reduce the number of cable roads; and thus, the number of rig-ups the Hooktender makes and the road changes for the entire crew.

In the trial with the mainline on the Koller Yarder, the 3/8" diameter steel mainline is considered to be a "light" line to begin with and the replacement with 3/8" diameter synthetic line did not affect workers as much if a larger line were involved. We were able to use the heart rate monitoring of a chokersetter using the steel mainline and again were surprised at the generally heavy workloads involved. See Figure R12 below where the Rodahl Work Intensity (shown earlier in this section) scale was employed again to characterize the workload.

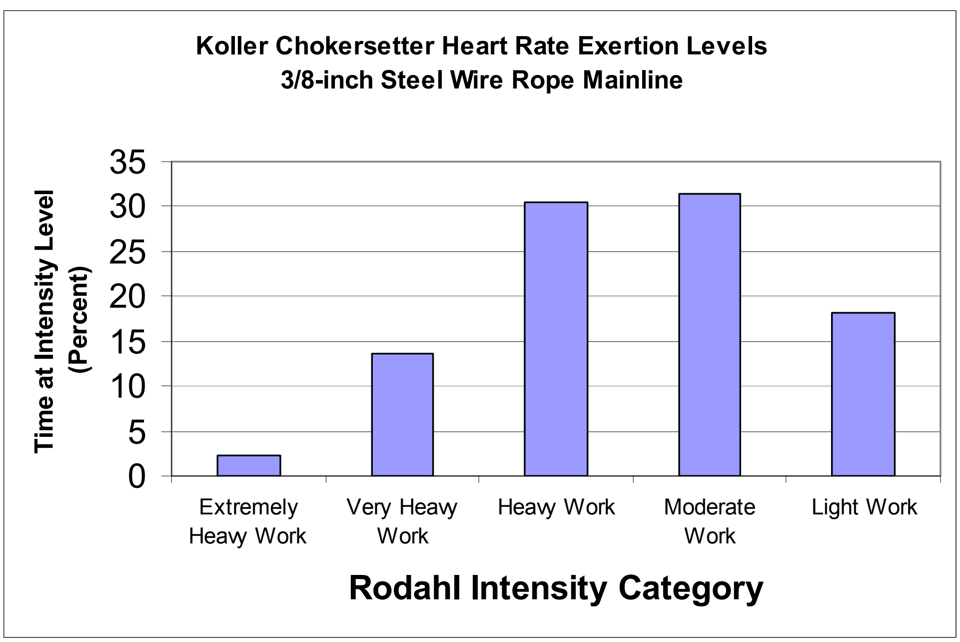

Figure R12. Work intensity for yarding crew member on the K-300 using steel mainline.

Other observations of ergonomic improvements with a synthetic mainline include:

- The ability of a single crew member to pull the “belly” or sag out of the mainline and through the carriage rather than have at least two crew involved was observed during the trials.

- Easier to maintain balance when pulling line laterally to logs.

- Ability to carry the slack and dispense it as compared to always dragging steel wire rope.

- Marked difference in effort (reduction) of pulling mainline here and there (zig-zag) to hook pre-set logs.

- No skin abrasions from the steel or cuts from jaggers.

- Less overall exertion to the body, especially the legs and shoulders, with the more upright pulling versus the “over the shoulder, leaning forward, leg driven pulls” with steel.

Ergonomic Improvements For Log Truck Drivers

At the start of the project, Oregon law did not allow synthetic rope as a log truck wrapper. That law changed on January 1, 2004 when the OR-OSHA Division 7 Forest Activities Code and the Oregon Department of Transportation (ODOT) Load Securement rules were harmonized by ODOT’s adoption of the Federal Highway Safety Standards rules for load securement which allows synthetic rope to be used as a load securement device. Thus, our first efforts before the law change were with two Oregon truckers who were required to throw an additional wrapper of synthetic material besides the steel wrappers. One truck was operated on Oregon highways and four wrappers minimum were required, while the other truck operated off-highway and two wrappers of 7/16” steel diameter wire rope minimum were required. We evaluated the use of comparable synthetic wrappers for one older male driver and one female driver (see Figure R13.) concurrently with steel wrapper use.

In order to better evaluate ergonomic benefits from a larger group of drivers, we cooperated with a Washington firm in Longview to allow us to assess use of synthetic rope wrappers where their use was legal under Washington law. In the Longview trials we had a group of 6 drivers participate in using synthetic rope wrappers for a period and then go back to steel wrappers. In addition, another division of the same firm agreed to participate with drivers from Cosmopolis where two groups of 6 drivers used synthetic rope wrappers and then used the steel ones again. When synthetic wrappers became legal in Oregon, we evaluated another driver with a known injury/complaint from throwing steel wrappers who replaced his wrappers with synthetic wrappers. A pool of 21 drivers were evaluated using synthetic rope wrappers. The weight of the wrapper is the weight of the chain sections at each end (approximately 1 pound/foot) and the weight of the rope (3/8” diameter synthetic= .036 pounds per foot or 3/8” diameter steel= .26 pounds per foot).

Figure R13. A female driver throws an additional synthetic rope wrapper on an off-highway load that requires two 7/16” diameter wrappers.

Ergonomic improvements for log truck drivers came from a variety of sources. These included:

- Lighter weight object to throw over the load
- Adjustable length chain section for each end of the wrapper to allow different chain lengths for wrappers
- Review of the use of the binder handle extension or “cheater bar” to achieve tension in the wrappers on the load

Depending on the throwing action used by the driver, the weight of wrapper section that would need to be thrown over the load could be 2 to 4 pounds for synthetic as opposed to 6 to 12 pounds for a steel wrapper. This reduction in weight alone allows for better throwing and less strain on the arm, shoulder and elbow. All drivers concurred with the ease of throwing synthetic wrappers.

Because synthetic rope wrappers were customized, we tried different lengths of chain sections on the wrappers tested. We offered drivers a total length of synthetic wrapper, say 27 feet with options for chain on one end of 1 foot, 2 feet, 3 feet or the usual 4 feet with the length of chain on the other end variable. For the first time for all drivers, they were able to specify what chain length was most suitable for them as wrappers. In general preferences for the chain length varied among the 2, 3, and 4-foot lengths but nearly all drivers said the one-foot length was too short to keep the wrapper in place on the load while the driver picked up the binder. A major improvement, whether synthetic or steel wire rope wrappers are used, would be to allow the driver a choice in the length of chain to throw over the load. Some wrapper assemblers make the wrapper adjustable by leaving the chain section (usually 8 feet) uncut and allowing the driver to specify the end chain lengths by cutting the chain as desired.

Finally, our wrapper testing revealed an ergonomic issue with the use of the load binder handle extension or “cheater bar” for tightening the wrappers. We found the Crosby Group, a major supplier of load binders for log trucks, specifically states in their product catalog, “The Crosby Group Inc. specifically recommends AGAINST the use of a handle extender (cheater pipe).”…”The increased leverage, by using a cheater pipe, can cause deformation and failure of the chain and load binder.” (The Crosby Group catalog, Load Binder Warnings, p. 207). The same document goes on to warn of hazards from slips, falls, and use of the handle extender. Safety statistics also document these resulting hazards.

We were told that the reason for the high tensions on load wrappers was because log truck drivers did not want to stop often for re-tightening the binders on the load. We measured truck wrapper tensions with steel and synthetic wrappers on a load from the initial tightening until the load reached the mill terminal. Figure R14 shows the trace of the tensions.

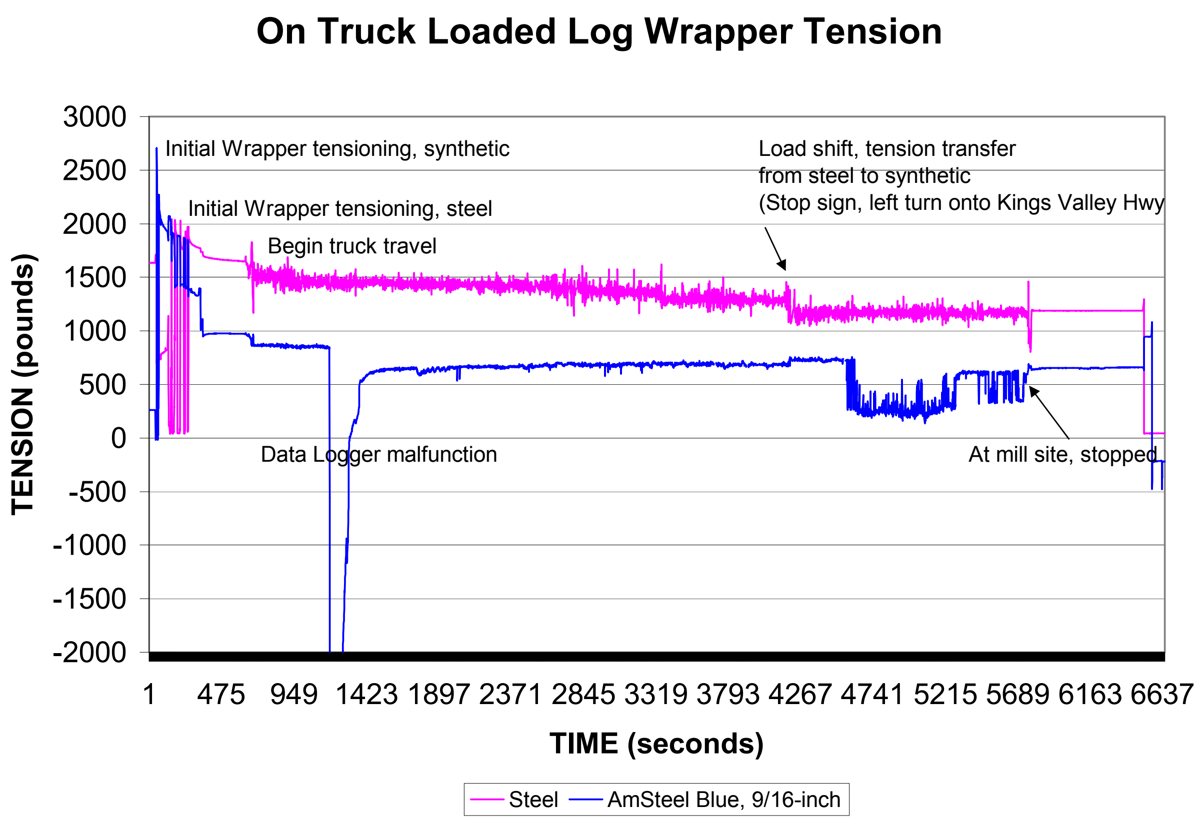

Figure R14. Tension trace of wrappers on log truck driving landing to mill.

We actually observed the driver in Figure R5 put sufficient tension in a wrapper to straighten out a log that had grown with a crook in it. The tension exceeded 3,000 pounds. Our discussions with binder manufacturers revealed that once the eccentric has closed on the binder, the force necessary to open the binder should not be more than about 30 pounds. We measured the force needed to open binders with high tensions in them and found them to exceed more than 90 pounds which explains other driver injuries from being struck by the binder handle during opening (Figure R15).

Figure R15. Tension measurement to open binder

The introduction of synthetic wrappers for log truck drivers should be an opportunity for safety managers to develop a better approach to using binder handle extenders or “cheater bars” on log hauling. It may be that the initial load tightening at the landing may benefit from tighter wrappers – perhaps using the handle extension; however, it is questionable once the load has settled (and re-checked prior to entering public roadways, as is customary) whether additional wrapper tension beyond hand tightening offers greater load securement.

III. Static Line Logging Applications

Based on the results of ergonomic task evaluations of pulling, carrying, and climbing with steel and synthetic ropes (Garland et al, 2002 OROSHA FINAL REPORT), field trials of synthetic ropes as static lines in logging applications were the next logical steps. Applications include rigging straps, lift tree (intermediate and tail tree) guylines, and intermediate jack support / lift lines.

Four cable yarding operations were part of the initial trials. These included the OSU Forest Engineering Student Logging Program and three contract logging companies. The various applications were implemented at all operations. At two of the three contract operations, discussions about the rope properties, study objectives, and splicing demonstrations were conducted with the crews and supervisory personnel. The third contract operation is owned by a former synthetic rope researcher familiar with the study and proficient in splicing.

The operations and findings are described below:

OSU Forest Engineering Student Logging Program

The OSU Forest Engineering department Student Logging Program utilizes a Koller K300 2 drum yarder to conduct standing skyline cable logging operations (Figure R16). Typical conditions are 40-50 year old Douglas-fir stands on slopes up to 60 percent. The tower height of 23 feet typically results in the need for intermediate jack supports and tailtrees to be rigged. This entails hanging rigging straps and blocks in the trees, installing support / lift lines for the skyline jacks, and stabilizing the trees with guylines.

Willamette Valley Contractor

This contractor utilizes a midsize yarder, a Koller K501 3 drum yarder to contract thin and final harvest stands around the lower Willamette valley. Figure R17 shows the yarder as a road change is being performed. Figure R18 shows a tailtree rigged with synthetic guylines and rigging strap (which supports the block and skyline).

Northwest Oregon Contractor

This contractor, who was thinning large timber in the Tillamook State Forest, was provided with a 5/8-inch diameter by 250-foot intermediate jack support / lift line, two 9/16-inch diameter by 150-foot guylines and a couple of 5/8-inch diameter rigging straps. These were used to rig an intermediate jack support tree for a Diamond 210 yarder (Figure R19). The rigged intermediate support tree is shown in Figure R20.

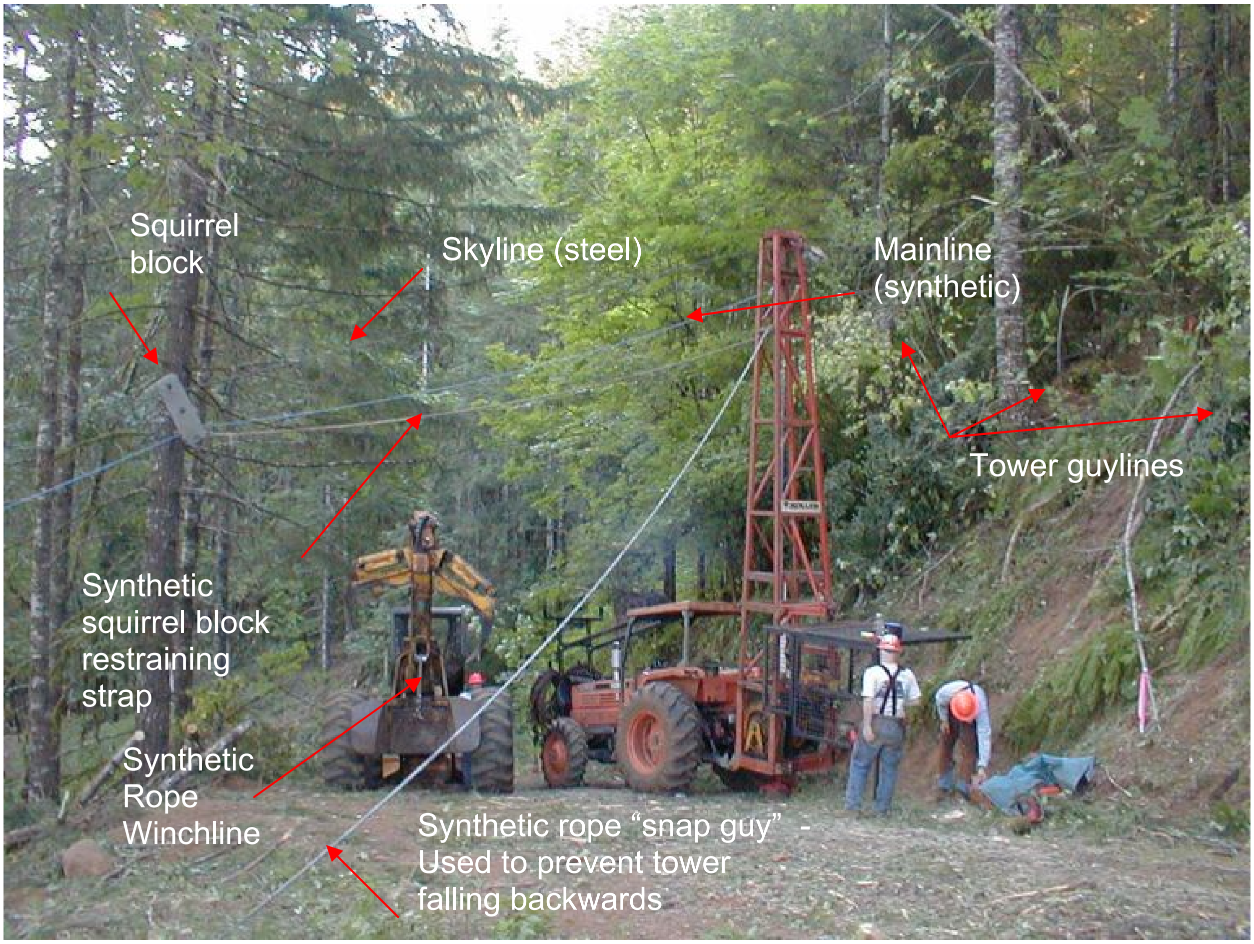

Figure R16. Koller K300 landing configuration with synthetic ropes used where steel wire rope traditionally applied. Tower guylines in this photo are steel. Synthetic rope guyline extensions are now in use with the spooled steel guys.

Figure R17. Koller K501 mid-size yarder in the middle of a road change.

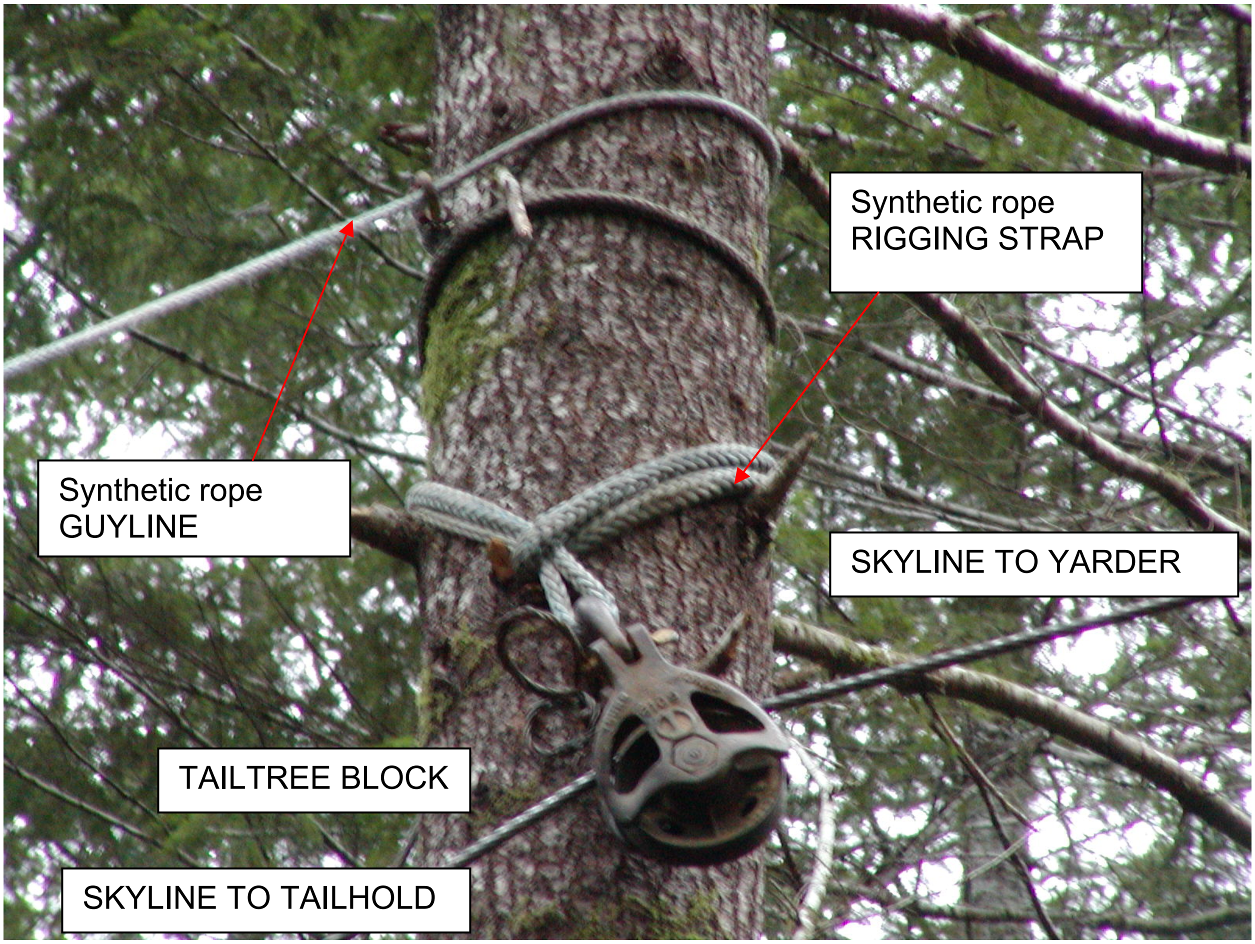

Figure R18. View of tailtree rigged with synthetic rope guylines and rigging strap for the Koller K501 yarder operation.

Figure R19. Diamond 210 yarder operation utilizing synthetic rope for static line applications of rigging straps, intermediate support guylines and jack support line.

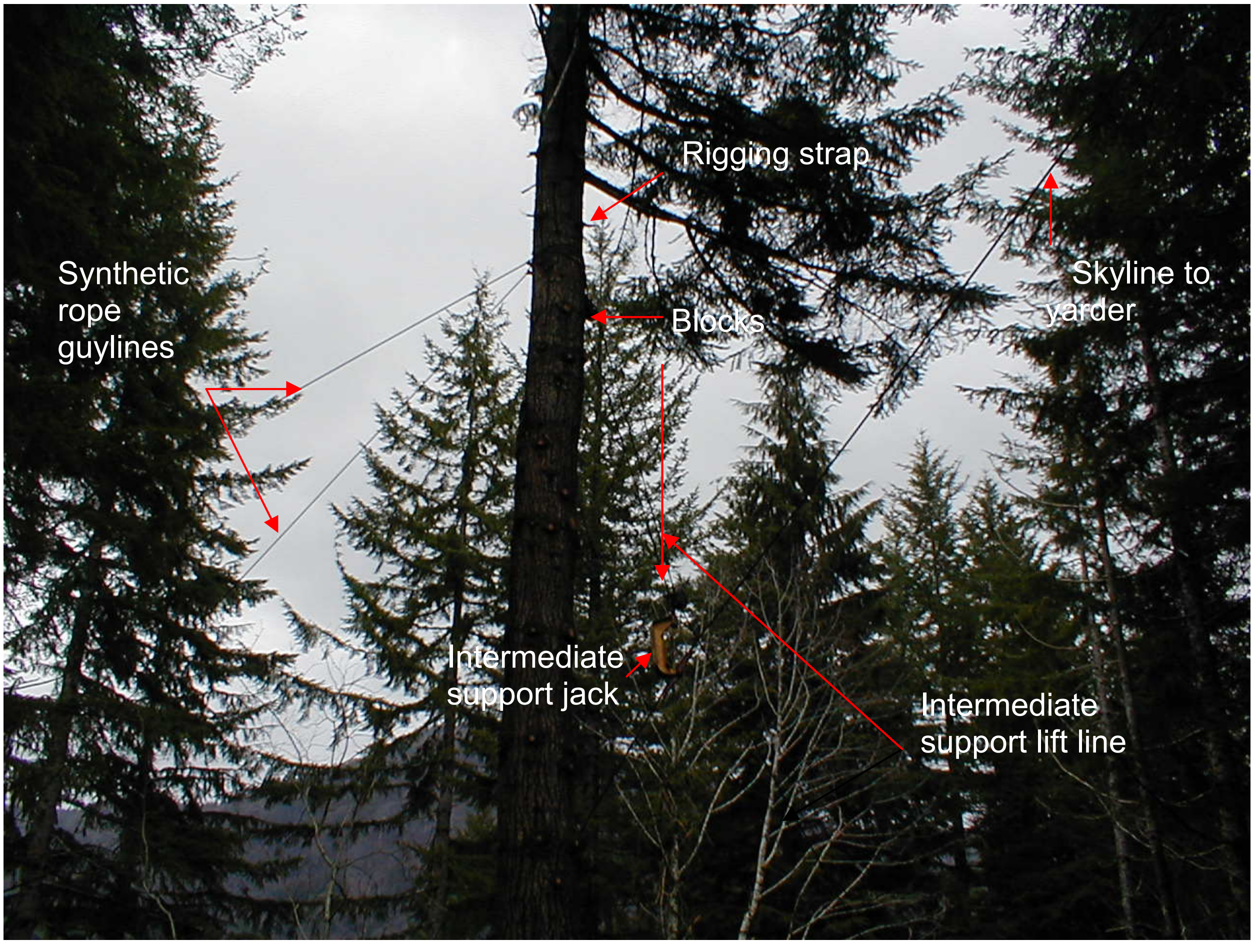

Figure R20. Intermediate support tree rigged with synthetic rope for guylines (2), a rigging strap, and 1 intermediate support lift line. Intermediate support lift line runs from anchor up through block at top of jack (yellow “C”), up to and through block secured in tree with rigging strap, and back down to top of jack.

Southern Willamette Valley Contractor

This contractor had two yarding sides consisting of a Diamond yarder and a John Deere 330 LC “Yoader” conversion yarder (Figure R21). The “yoader” side was selected for the field trial. This side was provided with a 5/8-inch diameter by 250-foot intermediate jack support / lift line, two 9/16-inch diameter by 125-foot guylines and a couple of 5/8-inch diameter rigging straps.

Figure R21. “Yoader” configuration used with one field trial of synthetic lines for rigging straps, guylines, and support jack lift lines.

IV. Running Line Logging Applications

With the success of the synthetic rope in the static line trials, interest in exploring its potential applications as a running line grew. The first trials selected involved the relatively safe operations associated with winching logs with a skidder or carriage. Five skidder winch line trials were conducted. An additional trial as a dropline on a skyline carriage was also conducted. Finally, an initial trial of a yarder running line was conducted. The operations and findings are described below:

Eastern Oregon Crawler Tractor Trial

NB: Material from Pilkerton, et al 2003 begins here

A logging contractor performed sanitation thinnings in mixed ponderosa pine (*Pinus ponderosa*) and western juniper (*Juniperus occidentalis*) stands affected with Black Pineleaf Scale (www.fs.fed.us/r6/nr/fid/fidls/fid191.htm) to remove dead, dying, and severely compromised ponderosa pines. The terrain was broken, and slopes exceeded 30 percent in some areas. The prime mover was a Caterpillar D6C-10K crawler tractor (140 horsepower, 30,600 pounds) outfitted with a Carco F50 integral arch winch. The contractor typically spooled 75 feet of 7/8-inch swaged steel wire rope. For this trial, 120 feet of 7/8-inch AmSteel Blue rope was installed. The operator typically drove to logs, pulled winch line and set pear-ring and toggle chokers to the logs (Figure R22.). Turns were usually of 3-4 logs.

NB: Material from Pilkerton, et al 2003 ends here

Figure R22. Operator setting chokers after pulling synthetic winch line to turn.

Western Oregon Crawler Tractor Trial

Contract operations consisted of clearcut harvest of a 40-year old Douglas-fir (*Pseudotsuga menziesii*) stand. The terrain was uniform, with slopes to 30 percent. The crawler was a John Deere 650G crawler tractor (90 hp, 19,000 pounds) with a JD 4000 series integral arch winch. One hundred twenty feet of 5/8-inch diameter AmSteel®-Blue rope was installed with a pear-ring and toggle choker system. The operator drove to the logs and collected 3-4 logs per turn (Figure R23).

The employee operating the JD 650 crawler tractor had similar positive experiences. The pear ring chokers however occasionally twisted 180 degrees and make a bight on the skidding line winch hindered slackpulling. The operator also encountered two failures due to rope breakage. These failures were not observed by us and we do not know the failure mechanisms. We think the sharp casting edges of the pear-rings may create cutting edges. Subsequent rings were smoothed with a grinder prior to use. The next trial substituted round-ring chokers (with smoothed casting edges) and changed operating procedures. This operation skidded 32 to 40-foot logs from 60-year old timber. The owner reported the line performed well, without any breaks in the line. A 0.010-inch shim was installed on the drum shaft bearing to remove some of the pre-load off drum. This allowed “the line to pull out better than any time previously”. They reported satisfaction with the line with plans to use it on the next job.

Figure R23. Operator pulling synthetic winch line to a log. Note two pear ring sliders staged along winch line for logs to be hooked.

Western Oregon Skidder Trial

The OSU Forest Engineering department Student Logging Program utilized a John Deere 540 B rubber-tired skidder (90 hp, 16,800 pound) to thin 40-50 year old Douglas-fir stands on slopes less than 20 percent. One hundred twenty-five feet of ¾-inch diameter AmSteel®-Blue rope was used with a round-ring and toggle choker system. The skidder operator set his own chokers or had preset turns of 3-4 logs hooked by a choker setter.

The student skidding trials have been more successful in terms of duration. No operational failures were encountered during the first trial. Tufting of the rope due to broken exterior filaments of the strands is the only visible degradation of the rope during use. However, the synthetic rope will not sustain the same abuse as steel wire rope. A student worker wrapped the synthetic skidding line over sharp grab hooks to attempt to pull an artificial earth anchor. The rope was severed and removed from service. This rope had 2.5 years of use prior to this event without failure.

This operation also initially recognized the need for modification of practices for synthetic as opposed to steel. One such modification is the need for adjusting the “free spool tension” on the drum. With the stored torsional energy in steel wire rope, the “free spool” adjustment is set to minimize “spronging” of the wire rope upon drum release. With synthetic rope there is no “spronging” effect, thus the free spool adjustment may be set for minimum resistance and thus easier line pulling. This adjustment has been recommended to all operators installing a synthetic winch line.

Minnesota Skidder Winch Line Trial

The trial involves a mid 1980's model Tree Farmer C-5 rubber-tired cable skidder. The machine is small in comparison to Western skidders, probably 70 horsepower or so. We placed 120' of 9/16" diameter ASB synthetic rope on the machine in August 2003.

We converted four, 6' slider chokers to pear ring chokers. The pear ring chokers lasted 4 months and the design of the pear ring led to the failure of the choker due to continuous bending at the base (wire rope insertion point).

The operator is a one-man operation and harvests 1000-2000 cords annually. He markets many different products and has a small sawmill to create value added products. He performs mainly hardwood thinning and some clearcutting. Long pulls and numerous chokers are often seen in his operation.

After the pears rings chokers broke, the operator put his slider style chokers back on. He says these worked quite well. This was contrary to our experience in the eastern Oregon trial. We believe the smaller rope diameter and wider slider opening diameter allow for less binding, especially near the buried eye splice where the rope diameter may double.

The synthetic rope winch line broke twice as of 2/1/04. Both times the failures occurred in the last six feet of the mainline. It is believed to be due to choker rub during inhaul. The operator also removed the t-bar toggle (for the ring style chokers) and uses one of the pear rings as a terminal connection on the skidding line. He says splicing is easy and the extreme cold did not affect splice times (harvest operations in Minnesota occur primarily in the Fall and Winter months). The accumulated snow wetness may have frozen into the rope, but did not affect splicing in his opinion.

Small Woodland Owner Farm Tractor and Farmi Winch Trial

A small woodland owner performing thinning and small patch clearcut operations in Douglas-fir growing on the western foothills of the Cascades uses a John Deere 5210 Tractor, with front end loader, and a 1998 FARMI JL 351 P three-point hitch winch system (Figure R24.). One hundred and fifty feet of 3/8-inch diameter AmSteel®-Blue rope was installed as a winchline. Initially the operator was using chain chokers secured to keyhole sliders on the mainline. The design of these sliders allowed for the creation of a prototype synthetic choker (Figure R25).

Figure R24. Farmi winch system mounted on farm tractor and powered by power take-off (PTO) drive. Chain chokers shown were initially trialed until replaced with synthetic rope based chokers.

Figure R25. Prototype synthetic choker using Farmi winch line keyhole slider as a choker bell and chain ends for connecting to log and to winch line slider.

We conducted a short duration time study to quantify operational efficiencies with the synthetic winch line. Twenty-five turns were completed for both the steel and synthetic winch line. The outhaul and hook times took about half the time with the synthetic as with the steel winch line (Figure R26).

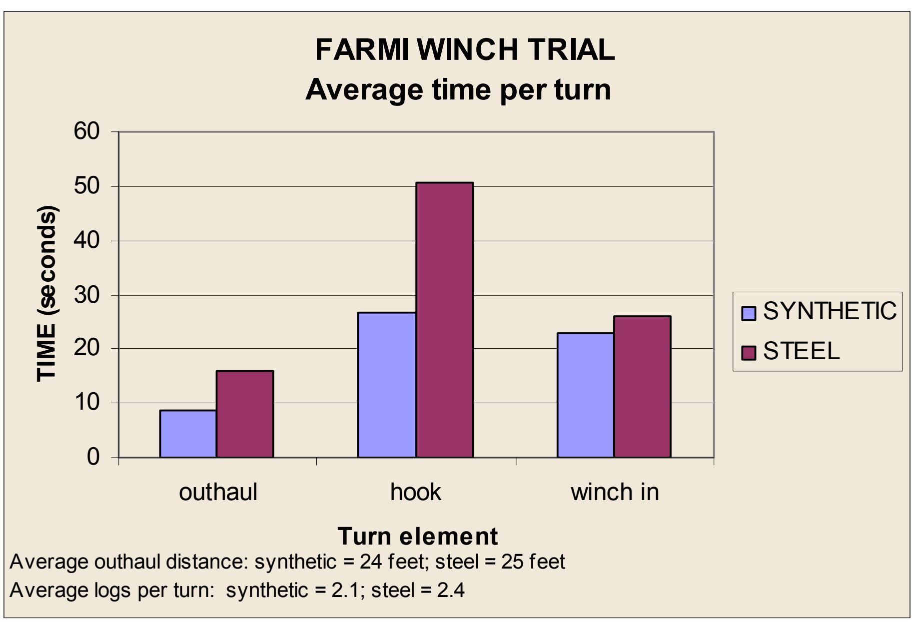

Figure R26. Average outhaul and hook time elements were reduced with the use of synthetic winch line on a Farmi winch system.

Skyline Carriage Dropline Trial

A logging contractor operated a standing skyline system with a Madill 071 yarder and Boman Mark IV carriage (3800 pounds) in a modified seed tree (six trees per acre for wildlife) harvest unit of 100-year old Douglas-fir. Cable corridor slopes ranged from 15 to 60 percent. The carriage used a powered (106 hp) winch for pulling logs into the carriage. The 2-speed winch also powered out (rotationally "pushed") the steel wire rope from the carriage for lateral slackpulling. While the contractor utilized a 5/8-inch diameter swaged steel wire rope dropline, a 5/8-inch diameter AmSteel®-Blue rope was installed for this trial. Chokersetters set 2-4 logs per turn and controlled carriage winching operations by radio signals.

The carriage dropline trial provided information on the failure modes. Sharp edges on the carriage fairlead and housing of the used carriage cut the trial rope (which required re-splicing) on a low deflection corridor with perpendicular lateral pulls. The adage "you can't push a rope" was confirmed in application of this winch design for spooling off the skidding line. The two-speed winch created back-spooling hang-ups on the drum. This carriage design does not incorporate a line pulling device, but rather incorporates the stiffness of steel wire rope to facilitate pushing slack (Figure R27). The lack of stiffness, in the synthetic rope trialed, caused the rope to backspool. When the rigging crew applied minimal, constant pulling tension during lateral slackpulling, the backspooling was eliminated. The rope failed once on the drum as the yarder engineer spooled and unspooled the drum to release the dropline.

Figure R27. Synthetic rope installed on slackpulling carriage. Carriage design does not incorporate a line slackpulling device, but rather depends on the stiffness of steel to "push" the line of the drum. A minimal tension applied to the synthetic rope during the slack phase prevents backspooling of the synthetic rope due to its lack of stiffness.

Cable Yarder Mainline Trial

The OSU Forest Engineering department Student Logging Program utilizes a Koller K300 two-drum yarder and SKA-1 carriage for standing skyline yarding operations (Figure R28). Thinnings on steep slopes (greater than 45 percent) of 40-50 year old Douglas-fir stands are typical; however, our trial included a 1-acre patch clearcut of larger stems. The original 3/8-inch diameter steel mainline was replaced with a 3/8-inch diameter AmSteel®-Blue rope. A round ring and toggle system is utilized to preset 2-4 logs per turn.

The mainline trial has been successful to date. One rope failure occurred early in the trial near the load hook. A “strand interchange” (knotting of old and new spool for a strand) during manufacturing was located near the break and suspected to be the failure mechanism. Subsequently, several more failures have occurred near the end of the buried eye splice (load hook) where the rope bends over two sheaves in the carriage. The frequency of these failures is consistent with normal wear encountered on this operation with steel wire rope. While the steel wire rope typically did not fail completely, it developed jaggers and a pigtail twist in rope which necessitated cutting of 10-15 feet of cable to restore the mainline to service. The Student Logging Program manager noted the synthetic rope recoiled linearly up the corridor, and struck the tower with minimal force, a force that may leave welts, but not inflict serious bodily harm.

While our lateral pulls are not substantially different (due to minor differences in unit line weight with 3/8-inch diameter steel rope), there is a noted difference in the reduced “belly” or sag that develops with the synthetic mainline. With steel, the mainline would sag until it rested on the slope between the carriage and tower. The synthetic mainline would remain in the air. This reduces the human effort required to pull slack for lateral outhaul.

Spooling capacity increased on the drum due to better layering of the synthetic line. The K300 mainline drum capacity is rated at 1150 feet of steel line. We installed approximately 1300 feet of synthetic rope and still have additional drum capacity (Figure R28).

Figure R28. Synthetic mainline on Koller K300 yarder winch set. Drum spooled 1300 feet of 3/8-inch diameter synthetic rope compared to 1150 feet of steel wire rope capacity.

V. Truck Wrapper Applications

We did some initial trials with two Oregon drivers who were required to throw an extra synthetic wrapper in our trial to comply with Oregon rules in place at the time. Subsequently, we had driver trials in Washington State with 3 groups of 6 drivers in two operating locations. Each driver was using steel wrappers at the time of the trial. We started two groups of 6 drivers with synthetic wrappers for a period of several months, then we returned those two groups to steel wrapper use. One group then followed on by starting to use the synthetic wrappers and then were required to go back to steel wrappers again. Summary results of the trials are listed in Table R1 below.

Of the twenty-one truck drivers in our assessment, the drivers either used steel wire rope wrappers concurrently or began using synthetic wrappers after years of experience with steel wrappers. In seventeen cases, we had the drivers return to using steel wrappers after having used synthetic wrappers for a period of several months. The key questions for each driver after using the wrappers were the following

- Years of log truck driving
- Existing physical complaints in arm/shoulders, Y/N
- Ease of throwing synthetic wrappers over steel wrappers, Easier, Neutral or Harder
- Positive or negative reaction to coiling & storing synthetic wrappers, +/-
- Preference as positive or negative for using synthetic wrappers, +/-
- Preference for synthetic wrappers after returning to steel wrappers, +/-

Table R1. Log truck driver response to synthetic rope wrappers. (NA = data not applicable or not available)

Driver	Yrs. Driving	Existing Complaints	Ease of throwing	Reaction to coiling-storing	Preference to use synthetic rope	Preference after using steel again
RWW	8	N	E	+	+	NA
WHW	40	Y	E	-	+	NA
SCA	23	Y	E	+	+	NA
SCB	7	N	E	+	+	+
SCC	3	N	E	+	+	+
SCD	13	Y	E	-	+	-
SCE	24	Y	E	+	+	+
SCF	3	N	E	+	+	+
JCG	15	Y	E	+	+	+
JCC	25	Y	E	+	+	+
JCP	34	N	E	-	-	-
JCF	7	Y	E	+	+	+
JCR	14	Y	E	+	+	+
JCH	17	N	E	-	-	-
JLH	39	Y	E	+	+	+
JLW	31	N	E	-	-	-
JLM	34	N	E	+	+	+
JLB	30	Y	E	+	+	+
JLDH	30	Y	E	-	+	+
JLTB	41	Y	E	+	+	+
JSM	20	Y	E	-	+	NA
N=21	Ave~22	Y=13 of 21	ALL	+=14 of 21	+= 18 of 21	+= 13 of 17

Summary points from the table above show:

- Drivers were experienced, averaging nearly 22 years as log truck drivers
- More than 60% of the drivers experienced complaints in shoulders, elbows, backs or arm from their work at the start of the trial
- All found the synthetic rope wrappers easier to throw
- One third found the synthetic wrappers more difficult to coil and store
- 86% preferred synthetic wrappers over steel wrappers after using them
- 76% preferred synthetic wrappers over steel wrappers after going back to steel wrappers

At the conclusion of the OR-OSHA Worksite Re-design Project, Samson Rope Technologies has pulled in all trial wrappers they can accumulate to test them for residual strength. Drivers in the trials were not happy to give up their synthetic rope wrappers and go back to using steel wire rope wrappers. At the time of this report, Samson Rope Technologies has not released their findings on residual strength of wrappers and are not offering synthetic rope log truck wrappers for sale. From a use standpoint, our project established the initial strength of the synthetic rope wrappers as meeting Oregon, Washington and US Federal Highway Load Securement standards when they were put into use. We have also demonstrated their utility and preference for use by log truck drivers in our study. We await Samson testing results and the availability of synthetic rope log truck wrappers for industry use.

VI. Operator Assessments

In earlier sections, we have provided trial results of the use of synthetic rope in various applications and shown ergonomic improvements. In this section, we provide qualitative feedback by users of the synthetic rope. We first provide them listed by the operator trials. Jared Leonard also asked operators about use of synthetic rope in his Master's paper (Leonard 2003) and those results are listed below as well.

OSU Forest Engineering Student Logging Program

The mainline trial has been successful to date. One rope failure occurred early in the trial near the load hook. A "strand interchange" (knotting of old and new spool for a strand) during manufacturing was located near the break and suspected to be the failure mechanism. Subsequently, several more failures have occurred near the end of the buried eye splice (load hook) where the rope bends over two sheaves in the carriage. The frequency of these failures is consistent with normal wear encountered on this operation with steel wire rope. While the steel wire rope typically did not fail completely, it developed jaggers and a pigtail twist in rope which required cutting 10-15 of cable to restore the mainline to service.

In one failure, the Student Logging Program manager noted the synthetic rope recoiled linearly up the corridor, and struck the tower with minimal force, a force that may have left welts, but not inflicted serious bodily harm.

While our early lateral pulls are not substantially different (due to minor differences in unit line weight with 3/8-inch diameter steel rope), there is a reduction in the "belly" or sag that develops with the synthetic mainline. With steel, the mainline would sag until it rested on the ground between the carriage and tower. The synthetic mainline would remain in the air. This reduces the human effort required to pull slack for lateral outhaul.

Spooling capacity increased on the drum due to better layering of the synthetic line. The K300 mainline drum capacity is rated at 1150 feet of steel line. We installed approximately 1300 feet of synthetic rope and still have additional drum capacity.

The mainline has not been "up-ended" yet on the yarder. Up-ending is performed to extend the life of steel wire rope cable by swapping the working end with the end on the spool. This allows for a more uniform wear over the whole cable. While it is possible to splice new steel wire rope onto the good but used end, this is rarely done as it is time consuming and creates a jaggered rope which is dangerous to handle and spools poorly. Typical practice is to replace the whole line.

With the synthetic, it is not yet clear if the mainline should be "up-ended" or treated like a very long winch line, wearing out the working end and re-splicing the end connection as needed. This ultimately will shorten the length to a point it is not functional for a given cable road. However, the ability to easily and cleanly splice synthetic rope makes it seem reasonable to consider this approach. The deciding factor may be related to where it fails. If the mainline begins to fail at points other than the working end, then up-ending should be investigated. Additional insight may be gained from rope management practices of the marine industry.

Synthetic guyline extensions (5/8-inch diameter by 50 feet) have been added to the Koller K300 yarder's 3 guylines. Recognizing the abrasive nature of the stumps led to the addition of 10 feet of fire hose as sheathing for the stump end of the guyline extension. This should protect the rope fibers in contact with both the stump and the sleeve shackle. While a guyline may initially be thought of as a static line, in practice, they are under constant load fluctuations with accompanying elongation/contraction. Thus, guylines move small amounts at the shackle and initial stump contact points during the outhaul and inhaul activities.

Northwest Oregon Contractor

The Hooktender for this operation first only tried the rigging straps. These were immediately preferred over the steel straps they had been using. With the confidence developed from these straps, the operation then tried a synthetic lift line. As one of the first trials, we did not have experience to guide their operational use. The Hooktender developed rigging techniques by trial and error to develop operational techniques.

Confidence was developed in the strength and suitability of the lift line as a result of a tree that pulled onto the skyline it supported. The falling tree created a serious dynamic load which alarmed the yarder operator. After a visual inspection of the rigged intermediate support line and a couple of trial, the crew decided to continue. The line functioned well for the continued use over the next 18 months.

The line was returned to OSU for inspection and possible residual strength testing. The Hooktender initiated taking the line out of service due to a lack of knowledge on replacement criteria. The Hooktender felt uneasy with the tufting of fibers and loss of the original blue coloring. Upon inspection, the tufting was minimal (less than 5 percent of the 25 percent manufacturer's replacement criteria). Opening of the rope strands showed the blue coating was intact within the rope structure. Based on these observations, this rope is still serviceable. This early replacement highlights the need to educate users in wear and replacement criteria to avoid unnecessarily replacing synthetic rigging.

Willamette Valley Contractor

This operation is fully committed to synthetic rope rigging. They fully utilized, and continue to do so, all the rigging provided to them. In addition, this operator was requested 7/8-inch diameter guyline extensions for his yarder. We provided 3 ropes for 50-foot extensions. The tower requires 4 guylines, however, we only had materials for 3. The operator saw the ergonomic and economic benefit in changing yarding roads and landings. This mid size yarder typically uses manual effort to place the guylines. With steel guylines, 2-3 crew members per guyline maneuvered the guy and secured it. This was especially difficult on settings with a steep slope behind the yarder. The synthetic guylines significantly reduced the effort and time to rig the guylines.

The operator experienced one failed synthetic guyline extension believed to be due to a large dynamic load imparted to the skyline when a turn broke free from a sidehill lay and swung downslope. Other layout and operational factors may have been involved. The guyline appears to have failed near the sleeve shackle at the stump anchor. No one was injured. The operator immediately replaced all of the remaining synthetic guyline extensions with steel wire rope to assure his crew who were nervous about synthetic guyline extensions. Since then, the operator has returned to using the two synthetic extensions.

Southern Willamette Valley Contractor

Like other operations, rigging straps were used first and readily accepted. This operation was performing more final harvest operations than thinning operations. Thus, they used synthetic rope for the guylines on their tailtrees and found these to preferable to the steel in transporting them between tailtrees and rigging the guylines. The Crew noted their ability to pull almost all of the belly from the rigged synthetic guy. As of April 2004, the owner stated the crews were still using the synthetic rigging.

Western Oregon Skidder Trial

The student skidding trials have been more successful in terms of duration. No operational failures were encountered during the first trial. Tufting of the rope due to broken exterior filaments of the strands is the only visible degradation of the rope during use. However, the synthetic rope will not sustain the same abuse as steel wire rope. A student worker wrapped the synthetic skidding line over sharp grab hooks to attempt to pull an artificial earth anchor. The rope was severed and removed from service. This rope had 2.5 years of use prior to this event without failure.

This operation also modified their operational practices for synthetic rope as opposed to steel. They adjusted the “free spool tension” on the drum. With the stored torsional energy in steel wire rope, the “free spool” adjustment of a winch is set to minimize “spronging” of the wire rope upon drum release. With synthetic rope there is no “spronging” effect, thus the free spool adjustment may be set for minimum resistance for easier line pulling. This adjustment has been recommended to all operators installing a synthetic winch line.

Minnesota Skidder Winch Line Trial

The skidder operator is still using the rope and chokers but had to replace some chokers. The operator likes the rope and plans to continue using it.

Small Woodland Owner Farm Tractor and Farmi Winch Trial

The woodland owner/operator has been quite pleased with the performance of the synthetic rope mainline. The jaggers and extreme pig tailing that occurred with the steel wire rope due to small bending radius of the drum and fairlead have been eliminated. The elimination of the pig tailing has made manually pulling the winch line to the logs much easier.

The owner also has been impressed with the synthetic rope choker. He noted once the choker is set, it bites in and the log is not coming off. This eliminated frustration with the chain chokers slipping off the log during winching, requiring the operator to get off the tractor and re-hook the log(s). He noted some trouble with dropping links into the Farmi slider -- cumbersome but feasible. The installation of a short piece of small diameter steel rod to the end of a chain link allowed for pushing the rope choker under the log and dropping the link into the Farmi “choker bell”. This was an adaptation implemented based on the chain chokers.

One choker incurred a couple of cut strands when a high school forestry student set a log larger than the winching capacity of tractor / winch system. The PTO shaft was broken at the same time. The choker was used until it broke about a month later.

The owner presently continues to log with the synthetic winch line and chokers.

Eastern Oregon Skidding Trial

The owner-operator skidding in the ponderosa pine was pleased with the ease of line pulling, especially on difficult uphill pulls. Operational times were decreased, sometimes remarkably. The operator stated that on one difficult uphill pull, a turn would have taken him 30 minutes with steel, but he did it in about 10 minutes with the synthetic line. The operator also had occasional pulls over rimrock outcroppings and around residual juniper stems -- both are abrasive materials. The synthetic skidding line failed (broke) late in the trial period. We did not see this failure and do not know the failure mechanisms. The operator said the turn was normal size. The operator was able to eye splice the line onto the toggle and continue operating. The operator requested a 50 percent longer synthetic line to continue the trial. He now uses a synthetic winch line twice as long as the previous steel line.

In spite of the problems, the owner would like to again try the rope in the near future. This trial again highlighted the need for slight changes or adjustments to operational practices with synthetic rope.

Jared Leonard queried eight cooperating operators about their preferences for synthetic rope use.

NB: Material from Leonard, 2003 starts here (bold added for emphasis):

SURVEY RESULTS

A survey was conducted to assess logging contractor opinions and experiences about synthetic rope use with eight logging contractors. The designed questionnaire collected responses through a phone survey. General information on their uses of synthetic rope, as well as specific questions on rope costs, ergonomic benefits, and rope properties was collected. Loggers also offered anecdotal experiences about using synthetic rope. All of the surveyed logging contractors initially heard about synthetic rope through Oregon State University presentations, logging conferences, or trade magazine articles. …..

The average experience level of surveyed loggers was 24 years. Five of the eight logging contractors classified themselves as owner / operators. Use of synthetic rope ranged from 2 months to 7 years, averaging 24 months for logging applications. The most commonly used applications were guylines, intermediate support lines, and tree straps. However, four logging contractors used synthetic rope winch lines.

When asked the weight of synthetic rope compared with steel wire rope, **all** logging contractors reported a weight of 1/10th the weight of steel wire rope. There were given the choices of ½, ¼, 1/10th, or 1/20th the weight of wire rope.

A **hundred percent of loggers reported they had experienced a jagger** from steel wire rope. Some offered that synthetic rope was more suitable for logging because synthetic rope does not have jaggers.

Loggers reported on coiling and storage of synthetic rope in Figure 14 and ease of use in Figure 15 below.

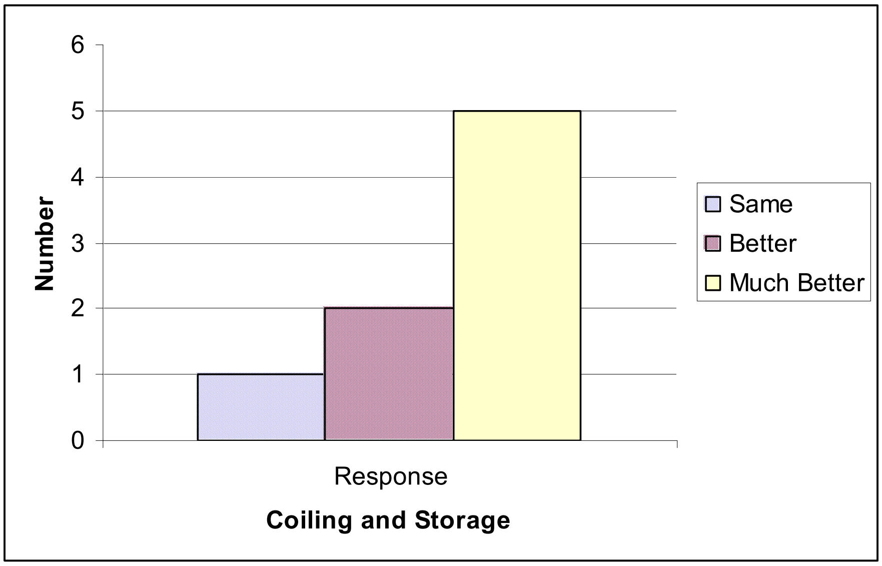

Figure 14. Responses on coiling and storage of synthetic rope compared with steel wire rope

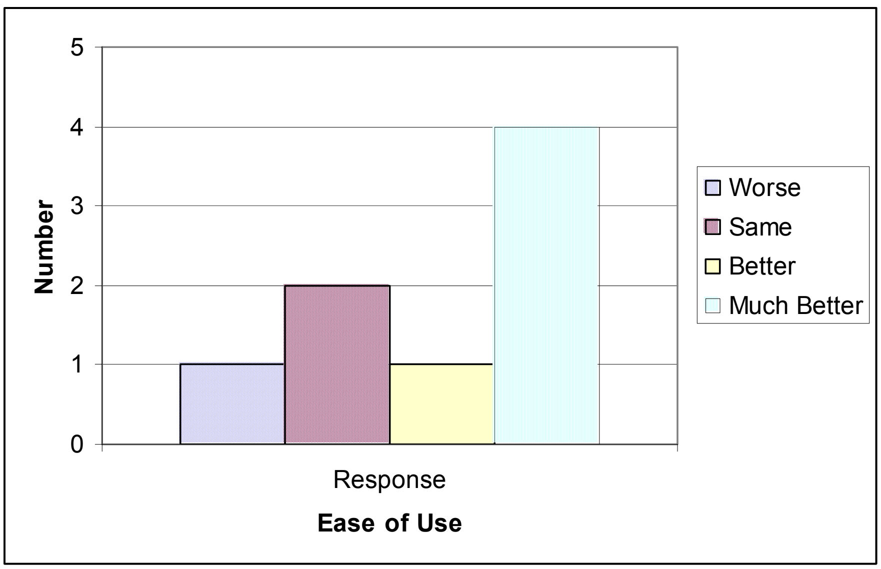

Figure 15. Ease of use of synthetic rope compared to steel wire rope

Seventy-five percent of loggers reported exposure of synthetic rope to hydraulic oil, saw gas, and diesel fuel. Forty-four percent of loggers reported abrasion as the most significant source of damage to synthetic rope during use.

When asked what end connectors they employed, fifty-eight percent of loggers used spliced eyes and shackles to connect synthetic rope. Another sixteen percent of respondents reported temporarily using knots with synthetic rope. Sixteen percent of surveyed loggers also reported using some type of nubbin or ferrule for an end termination of synthetic rope.

Loggers reported general performance of synthetic rope as found in Figure 16.

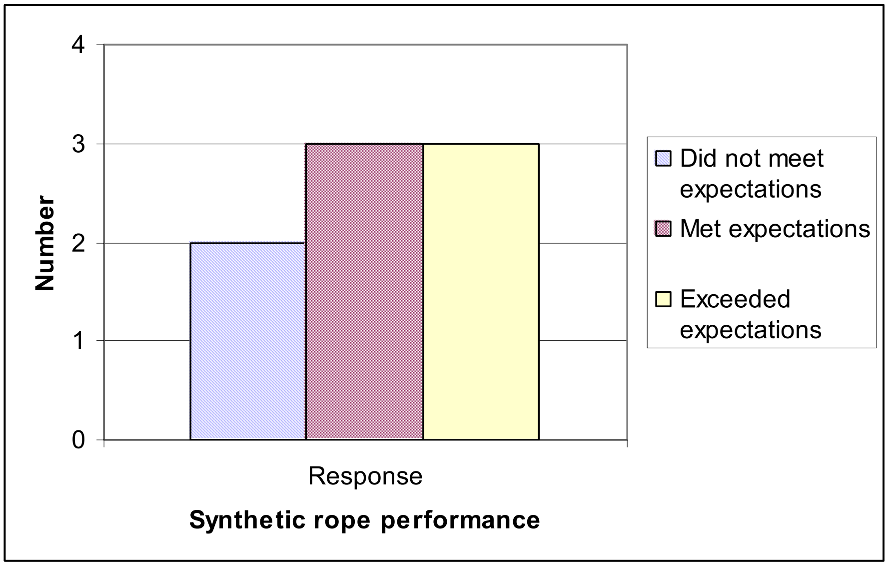

Figure 16. Synthetic rope performance

Sixty-three percent of loggers reported that cost of materials was very important, while thirty-seven percent of loggers reported cost as important (Figure 17). However, one-hundred percent of loggers reported the ergonomic benefits of synthetic rope as very important.

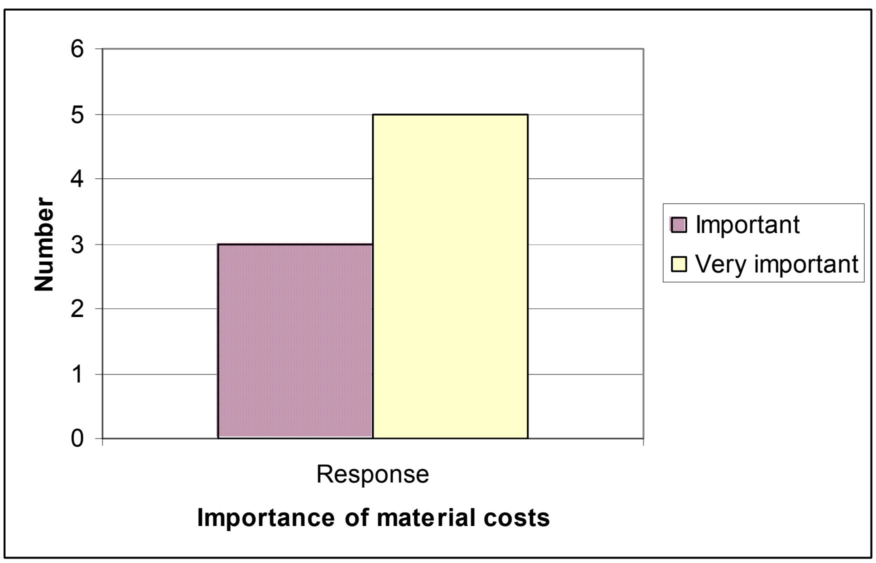

Figure 17. Importance of material costs

Sixty-three percent of loggers reported a willingness to pay twice the current price of steel wire rope for synthetic rope. **One logger reported he would spend five times** that of steel wire rope for synthetic rope (Figure 18).

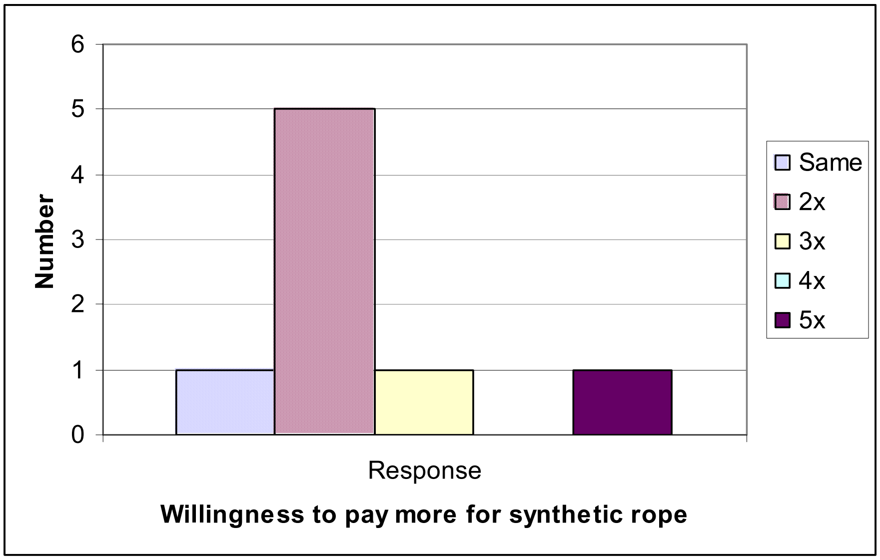

Figure 18. Willingness to pay more for synthetic rope than steel wire rope

Eighty-eight percent of loggers surveyed reported that the ergonomic benefits of synthetic rope outweighed the additional cost of the material; only thirteen percent of surveyed loggers reported the ergonomic benefits of synthetic rope did not outweigh the additional cost of the material.

Overall, synthetic rope was generally accepted by most logging contractors surveyed. Cost was the most significant factor for using synthetic rope. Most loggers reported a willingness to pay twice the cost of steel wire rope. A quarter of the loggers reported that if synthetic rope cost 5 times that of steel wire rope, the ergonomic tradeoff was not worth the additional cost of the material. Synthetic rope is best suited to owner / operators who are aware of the economic tradeoffs and ergonomic benefits of synthetic rope.

NB: Material from Leonard, 2003 ends here

Truck Wrapper Assessments

The log truck drivers were generally positive in their assessments but a couple of drivers preferred steel wrappers and viewed the use of synthetic wrappers as unnecessary and perhaps a bit “un-macho” for the image of the industry. Those who had complaints that were helped by the wrappers were exceedingly positive.

“My elbow quit hurting when I started to use them.”
“Best thing since sliced bread…”
“My shoulder stopped aching when I used them”
“one foot chain too short but two foot is just fine”
“I don’t use the cheater bar on them and they stay tight.”
“I just flick my wrist and they go over”
“Can stand the shoulder pain with these”
Long term damage is done to shoulder. With synthetic, it is easy to maintain shoulder pain, less of a problem at the end of the day”

“Neck and shoulder pain reduced with synthetic. Has not noticed pain in the last 3 weeks”
“Think they are wonderful.” “High opinion.” “Tickled Pink.”
“Shoulders feel a lot better…had shoulder problems…not bothering me now”
“After 35 years of wrapper use, no shoulder problems”

Other comments were not so positive but were useful.

“Bit worried about the fraying and how long they’ll last”
“Won’t last 6 months”
“How much do they cost?”
“Have to learn to throw ‘em, can’t whip ‘em”
“Had to tighten them more often”
“Wet and then freezing made difficult to work with. Eventually worked out”
“Don’t like soaking up water”
“Frozen one stuck to the log”
“Still stretching…(after 3 months)”
“I just use the pipe at the blacktop (cheater bar/pipe)”
“I coil ‘em like a drop cord light”

Truck drivers have continued to show interest in the synthetic rope wrappers and would certainly like to use them once they become available once again.

VII. Continuing Applications And Assessments

While not funded from Oregon Occupational Safety and Health Association grant funds, the project team of OSU Forest Engineering researchers are continuing with monitoring and assessing synthetic rope applications in logging and trucking, and we are still conducting research on the synthetic rope. We continue to follow the applications listed below:

- OSU Student Logging Crew use of synthetic mainline, guylines, lift lines, chokers and line on chainsaw winch
- OSU Student Logging Crew use of synthetic winch line on the skidder
- Small woodland owner using FARMI winch with synthetic rope & chokers
- Southern Oregon Loggers use of synthetic rope straps, guylines, support lines, skyline extensions and winch lines on skidders
- Willamette Valley contractor and former synthetic rope researcher using guylines, straps, support lines and innovative climbing techniques
- Minnesota Skidder Winch Line Trial
- Washington logging division use of synthetic rope as straps, carriage lines, rigging lines, etc.
- Truck wrapper applications in Oregon once wrappers become available once again.

The nature of the continuing assessments will vary but Cooperators' Meetings should still be held annually and a major conference for synthetic rope users would be a good supportable activity in the near future.

VIII. Summary of Applications and Future Research

In summary, synthetic rope is **NOT** the same as wire rope and the differences provide ergonomic benefits. Logging operators will need to change their practices to use the synthetic rope to its fullest benefits. It will not take the same abuse operators give wire rope in logging applications; however, it does stand up comparably when used appropriately. We need to further document the economic gains from using synthetic rope to show benefits against its higher cost.

The use of synthetic lines in static line applications such as rigging straps, lift tree guylines, and intermediate tree jack support / lift lines should be encouraged for both ergonomic and economic efficiency in logging operations. Workers report less effort, less physical strain and fewer loads in transporting and installing synthetic rope rigging. Rigging straps were the first to be readily accepted. With positive experiences in this application, operators expanded applications to other rigging lines--first to lift lines and then to guylines.

With the developed confidence and successes in static lines, trials in the running line applications of skidder and carriage winches were initiated. Operators reported positive experiences with the synthetic winch lines for ergonomic benefits. A synthetic rope was installed as a mainline on a small yarder. Positive experiences were similar to the other winch trials. While rope failures (broken ropes) were observed in most of the winching trials, none of the failures were much different than similar steel wire rope failures and did not cause concern about using synthetic rope. In fact, some synthetic rope failures were similar to "expendable" failures experienced in steel wire rope winch lines.

Our belief that synthetic rope applications would expand greatly, "once in the hands of the practitioners" has proven true. In fact, many operators are taking applications beyond the scope of our research. These applications include chokers, skyline extensions, strawline/haywire for rigging layout, and several others.

Synthetic rope used as static lines such as rigging straps, lift tree guylines, and intermediate jack support lines is safe, ergonomically beneficial, and economically sound application.

Synthetic rope for use as a skidder winch line is beneficial to the ergonomics of the task and to the well-being of the operator. Winch line wear and tear requiring repair and/or replacement is similar to steel wire rope. Synthetic winch line can be spliced, thus a worn/broken section can be replaced, and this is not practical with steel wire rope.

Another important recommendation when converting from steel to synthetic is to smooth all edges, sheaves, fairleads, and other points of rope contact. Poor operating practices with steel edges on machines can create cutting edges abusive to steel and synthetic ropes (Figure R29). Synthetic ropes will not tolerate the same abuse as steel rope. Failures on the operation shown began occurring near the end of the buried eye splice. Initially these were thought to be related to “expendable wear” experienced on other trials. However, observation of the student operators revealed they failed to fully raise the fairlead which caused the loaded synthetic rope to rub on the edges seen in Figure R29.

A failure in proper equipment operation led to the premature shortening of the spooled length. This required splicing the remnant of the first winch line onto the spooled line to extend its operational length back to 115 feet. While the long splice is easy to perform, preventive action is preferable to repair or replacement. Managers must be aware of failures created by improper equipment operation or employee abuse. Owners will not likely continue economic support for an ergonomically beneficial rope if maintenance is a problem.

Figure R29. Gouges cut into ½-inch plate steel by poor operating practices with steel wire rope create cutting edges detrimental to synthetic rope longevity.

Future Research

We are seeking funding to continue synthetic rope research in logging and will continue to research this important area.

We have funding from OSU Sources to conduct assessments and specific measurements below:

1) Durability and wear issues due to line rubbing, steel-synthetic block interactions, sheave travel, carriage clamps, and continuously fluctuating dynamic loads.

2) Payload capacity, as a function of material properties related to stretch and deflection. Current payload equations (LOGGERPC) for steel wire rope require material characteristic values or equivalents, which do not exist for synthetic ropes. Empirical tests are required to quantify deflection for a given load and position.

In addition we expect to evaluate some operating functions of synthetic rope by cooperators and will carry out some trials on the OSU Research Forest.

- Rigging trials involve a cooperating cable logging operator changing from using steel wire rope to synthetic rope for rigging applications. Time and cost savings will be measured for the change along with a sample of ergonomic benefits of using lighter materials. Time and efficiency comparisons on similar operating conditions will provide the basis for the assessment.
- Current designs of end connectors and chokers have been evaluated in the laboratory but lack field trials. Cooperating operators will test our fabricated end-connectors and chokers of synthetic rope in their operations. We will also develop some new end connectors to meet specific needs. The measures of feasibility, time savings and ergonomic benefits will be assessed in a before and after procedure for the operators in this pilot study approach. Patentable new approaches may come out of the trials.
- Harvest of small underutilized materials on OSU Research Forest will be accomplished with a small cable system equipped with synthetic lines and chokers. The Igland double-drum winch system will be used on the back of a rented farm tractor. Such a system is technically feasible with wire ropes but costs and handling difficulties are evident. We will compare time and efficiencies of harvesting small diameter materials and biomass with the modified system to various existing systems. We will also evaluate potentials for smaller scale operations with a winch and farm tractor for use by small landowners doing their own harvest or biomass/fuels reduction harvests.
- If synthetic ropes can be used as skylines, mainlines, and other running lines, we will need to assess wear and damage over current rigging used. We will use the lines on our Koller K-300 Yarder with the student logging crew and monitor results for feasibility and problem development.

- Further, we will set up at the OSU Timber Harvesting Laboratory a skyline and measure tensions and deflection under known loads so as to develop and empirical basis for better planning for synthetic lines in full scale operations. The measurements will be adapted for computer planning models such as the LOGGERPC from the OSU Forest Engineering Department.

Final Thoughts

It has been an interesting and rewarding experience working on synthetic rope research for the past five years for the people involved. We have seen real workload reductions in difficult logging tasks for workers that already face days full of demanding work. We have developed new ideas and approaches and learned much from our cooperators. We hope to continue development of a new approach to logging based on synthetic rope applications!

IX. Technology Transfer Activities

A number of publications from the projects on Synthetic Rope Research are listed above as sources for the reports themselves. In addition, a CD of all publications is provided as a project outcome. Listed below in Table 2 are a summary of technology transfer presentations by OSU Researchers.

Table R2. Technology transfer events for synthetic rope

Date	Event	Presenters	Location	Audience
2004-6-15	Intl. Mtn. Logging Conf. & Sky Symp	Pilkerton, Hartter	Vancouver, BC	96
2004-6-12	Div. 7 Rigging Demonstrations	Garland, Pilkerton, Wimer, Lulay	Astoria, OR	41
2004-6-8	FE Advisory Committee	Hartter	Corvallis, OR	20
2004-5-22	Div. 7 Rigging Demonstrations	Garland, Pilkerton, Wimer, Lulay	Roseburg, OR	45
2004-5-15	Div. 7 Rigging Demonstrations	Garland, Pilkerton, Hartter, Lulay	Springfield, OR	21
2004-5-15	Ferhopper Day for OSU FE Alums	Wimer	Corvallis, OR	43
2004-5-8	Div. 7 Rigging Demonstrations	Garland, Pilkerton, Hartter, Lulay	Corvallis, OR	46
2004-5-7	Cooperators Meeting	Garland, Pilkerton, Hartter, Lulay	Corvallis, OR	24
2004-Spring	OSU Classes on Logging Mgt	Wimer, Pilkerton	Corvallis, OR	39
2004-3-30	Council on Forest Engineering Nat. Mtg	Garland, Pilkerton, Hartter,	Hot Springs, AR	102
2004-3-23	Colorado Timber Industry Assn.	Garland	Grand Junction CO	44
2004-3	OSU Seminar to Faculty & Students	Hartter	Corvallis, OR	40
2004-3-15	Plum Creek Foresters	Garland	Florence, OR	54
2004-2-20	Woodland owners & AOL South Coast chapter	Pilkerton	Coos Bay, OR	60

Date	Event	Presenters	Location	Audience
2004-2-27	Oregon Logging Conference	Garland	Eugene, OR	238
2004-2-26-28	Oregon Logging Conference Booth	Garland, Pilkerton, others	Eugene, OR	122
2004-2-5	Clatsop Safety Council	Garland	Seaside, OR	60
2003-11-8	AOL Safety Conference	Garland	Eugene, OR	226
2003-Fall	OSU Classes on Logging Mgt	Wimer, Pilkerton	Corvallis, OR	41
2003-10-5 to 9	High Tech for Mtn Logging	Garland	Schlaegl, Austria	128
2003-9-7 to 10	Council on Forest Engineering Nat. Mtg	Leonard, Pilkerton, Hartter, Garland	Bar Harbor, ME	98
2003-6-30	Synthetic Rope Cooperators Meeting	Garland, & all	Corvallis, OR	20
2003-Spring	OSU Classes on Logging Mgt	Wimer, Pilkerton	Corvallis, OR	38
2003-5- 12 to 15	2nd Forest Eng Conf.	Garland	Vaxjo, Sweden	286
2003-3-6	Inland Empire For Eng conference	Leonard, Hartter	Moscow, ID	84
2003-1-20	Associated Oregon Loggers Annual Mtg	Garland	Eugene, OR	128
2002-Fall	OSU Classes on Logging Mgt	Pilkerton	Corvallis, OR	39
2002-10-8	AOL Safety Conference	Garland	Bend, OR	260
2002-6- 16 to 20	Council on Forest Eng Annual Meeting	Garland, Hartter	Auburn, AL	138
2002-Spring	OSU Classes on Logging Mgt	Pilkerton	Corvallis, OR	41
2002-3-4	Inland Empire For Eng Conference	Garland	Moscow, ID	78
2002-2-21-23	Oregon Logging Conf. Booth & Mtgs.	Garland, Pilkerton	Eugene, OR	124
2002-Spring	AOL Chapter meeting	Garland	Corvallis, OR	26
2001-12-10 to 12	Int. Log. Conf. & 11th Skyline Symp.	Pilkerton	Seattle, WA	156
2001-7- 15 to 19	Council on For Eng Annual Meeting	Garland, Pilkerton	Snowshoe, WV	112
			Total Contacts	**4008**

The above presentations are supplemented by coverage in various Trade Journals, Magazines, etc. Loggers World has run three major stories on synthetic rope used in logging and they are listed below in the appendices and provided on the Publications CD available as part of this project. There have been other technology transfer publications with the International Labor Office, Pacific Northwest Agricultural Safety Center, and Focus on Forestry (OSU College of Forestry) publications.

In addition, researchers have handled inquiries on synthetic rope research totaling in the hundreds via email, phone, and mail sources.

X. Sources

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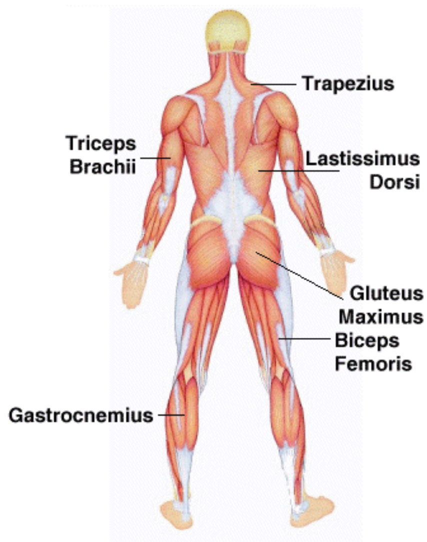
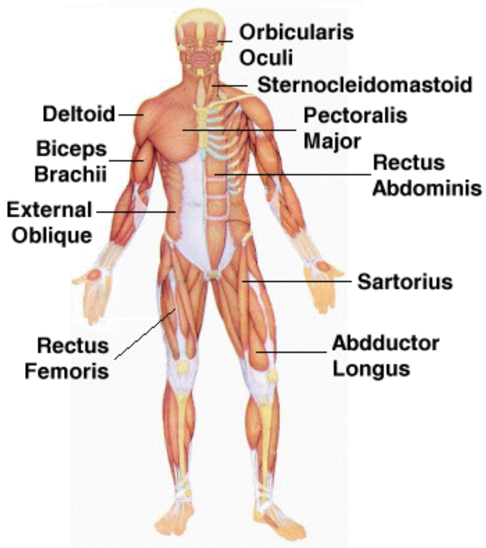
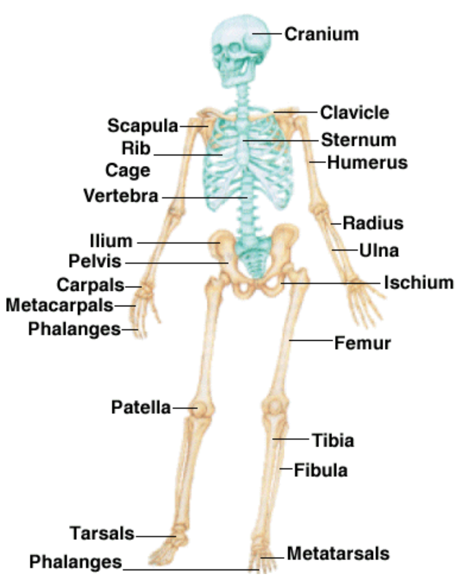
XI. Appendix 1







Ergonomic Checklist for Use of Synthetic Rope: (job/task name)

Task Description:

Task Freq. per shift (shift length):

Major Muscle Groups/Joints/Senses Involved: (circle & describe)

Complaints at end of shift: (circle & describe)

Longer term complaints/disabilities:

Tools/Accessories: (describe, weigh, est. force needed, current & changes)

Photos & videos taken:_________date ______________location __________ss

TSA: (hazards, risks, exposures)

KSA:(knowledge, skills, abilities)

Prepared by:______________date_____