Yarding System and Carriage Development

A Case Study

by

James Zolla Sears

A PROJECT

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Forestry

Completed March 7, 1975

Commencement June 1975

APPROVED:

Associate Professor of Forest Engineering

Head of Department of Forest Engineering

Date project is presented: March 7, 1975

Typed by Linda Sears for James Zolla Sears

TABLE OF CONTENTS

LIST OF FIGURES

Yarding System and Carriage Development

A Case Study

INTRODUCTION

In recent years considerable work has been done in the development of improved logging machinery. The word improvement may bring to mind entirely new or improved systems which offer the logger greater mobility and efficient use of manpower. Logging has generally been labor intensive, however, "The need to achieve greater output to offset ever increasing labor costs prompted continued mechanization of the yarding process." (Hilton Lyson and Roger H. Twito, 1973)

Capital investment as well as labor has been a problem to the logging industry. Large and complex machines represent investments which necessitate continued use on high volume logging areas. The future may see size oriented development of logging machinery. By size oriented, I mean machinery developed so that the machine's size is as small as possible to handle the volumes of logs met on the logging units. To achieve the objective of lower costs through small machinery, the emphasis is on efficient use of gearing and cable alignment to achieve mechanical advantage (increase in power without increases in the forces applied) throughout the machinery system.

The reason for many improvements in machinery or methods is that an industry or individual is confronted with a problem that is not adequately solved by existing methods or machinery. This principle also holds true for logging improvements. Most of the machinery or even the logging methodology improvements require considerable ability in engineering and a knowledge of the problems confronted.

The whole system approach is needed in any machinery development. The system is made up of a number of components with each component relying on or affecting another component's performance. The whole system cannot be any better than the weakest component.

Problem

A logging company is faced with a logging unit that surpasses the capacity of their machine under conventional configurations. The logging unit has been planned for downhill skyline logging for silvicultural reasons. The contractor stated that the log sizes made conventional downhill skyline logging unsafe with the machine they now own, a Schield-Bantam mobile yarder, because of line sizes and braking capability. The contractor realized that the external yarding distances of 1,200 feet exceeded their drum capacities on the yarder (1,000 feet three-fourths inch (19.1 mm) skyline and 900 feet five-eighths inch (15.9 mm) mainline).

The decision was made to adapt a nonconventional system to the Schield-Bantam yarder. The nonconventional system to be used would be the endless line system. By using this system, the logging contractor would hopefully avoid a great financial outlay in a new yarder. A primary part of the nonconventional system was the development of a carriage that could be used with the continuous line method.

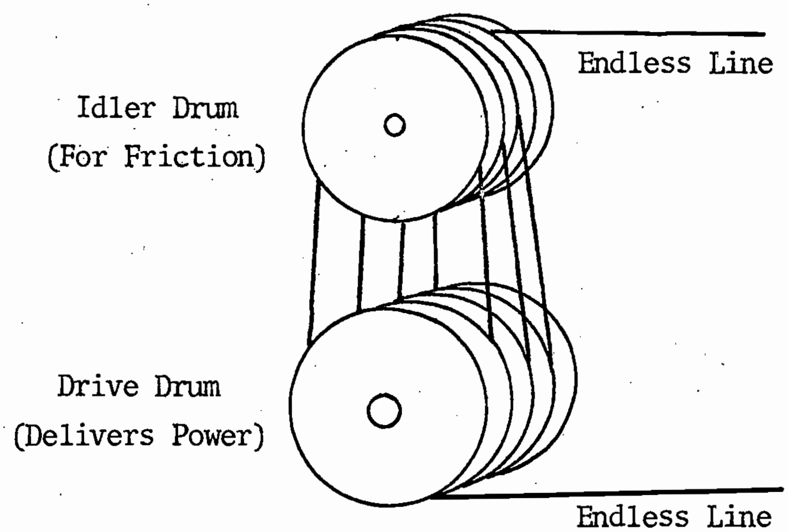
The Continuous Line Principle

The continuous line principle is not a new idea in itself, but it is a relatively new approach to logging. The endless line enters the yarder and makes a number of wraps around a drive drum or a series of drums. The power is delivered to a line by a rotating drum, and the force of friction between the metal line and the metal drums forces the line to drive around the drum. There is no collection of line on the yarder, but the line is passed through the yarder much like a clothes line or ski lift. The ends of the line are joined and the line becomes an endless line, thus the mainline and haulback are the same line.

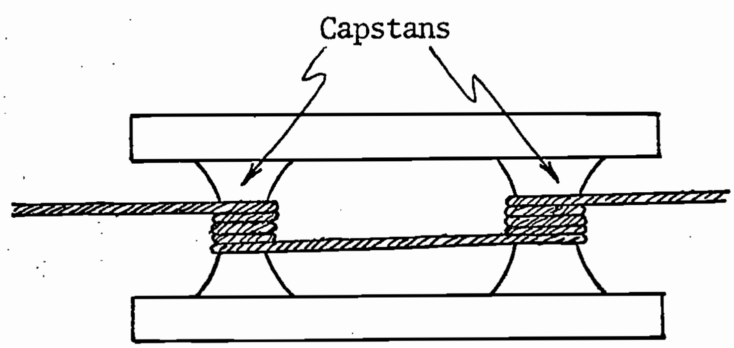
Figures 1A and 1B illustrate two different types of drive mechanisms. In Figure 1A, the idler drum is used to maintain friction in the line and to align wraps so that they may go into the next groove on the drive drum. Figure 1B is an illustration of a capstan drive arrangement. Two capstans are aligned so that the line is wrapped around one capstan several times and then is wrapped around another capstan the same number of times.

Systems in Use

Europeans have introduced such systems as the Vinje, Jobu, Baco and the Wyssen yarding methods. Each system can be used as a continuous line system. (H. H. Lyson and R. H. Twito, 1973) The Vinje system has received some exposure because of the research carried out by the Forest Research Institute Division of Forest Operations and Techniques of Norway. (Oswald, 1971)



1A) Grooved Drum Endless Line



1B) Capstan Drive Endless Line

Figure 1. Drive Mechanisms For Endless Line Systems

For a number of years a private company in Japan, the Nansei Company, has been using a single line called the Mono Cable system. This is a single endless line and the logs are suspended from it. (Kato, 1961) This company has also developed a completely remote control endless line logging system.

The continuous line principle has not yet seen common use in the United States or Canada. The Vinje system has, however, been used in Eastern Canada. (Ross Silversides) In 1973 the continuous line principle was tested in the Appalachian Mountains by Mr. R. H. Perkins who is a member of Purdue University's Agricultural Experiment Station. (Perkins, 1974) This system was called the Purdue Traction Cable System.

Objective of Report

In October of 1974 I learned that a nonconventional type of logging system would be used on Oregon State University's McDonald Forest. I became involved with the nonconventional operation in that I followed the adaptation of the yarder to the system and particularly I became involved with the development of the carriage. This report follows the adaptation of each component of the system and discusses in detail the development of the carriage fabricated to fit the endless line system. My objective regarding the carriage was to report on the carriage development in terms of what the designers considered features necessary to the carriage and to report on foreseen problems and how these problems were solved or the hypothesized reaction of the carriage under the problem situation. The report will then describe the operation of the components that are combined to form the working system. During the development stage the designers tried to form an idea as to how the yarder and carriage should be used. The final sections of this report cover the theories of use developed by the designers and myself.

COMPONENTS OF THE SYSTEM

The system adapted to the Schield-Bantam is made up of three primary components:

Yarder

Carriage

Lines

Each component is a necessary part of the whole system and the lack of any one part will render the other parts inoperable.

The Yarder

The yarder's main purpose is that of a power source. In the endless line system power is delivered to the line as it passes through the yarder. Power and radio control are the yarder's main functions, and the yarder acts as the control center of the carriage in that the radio controls are in the operator's cab.

The yarder is a Schield-Bantam T 350 yarder powered by a 453 horsepower Detroit Diesel engine which has had many changes made to meet the logging requirements of previous logging operations. The installation of a torque converter, three speed transmission, skyline drum and a straight boom are some of the changes. The yarder is mounted on a self-propelled frame and has the capability to rotate 360 degrees. Before this study the yarder was used as a slack skyline machine for logging timber sizes up to approximately 1,200 board feet or 6.2 cubic meters. Two guyline drums are mounted on a stanchion which stands over the mainline and haulback drums. The haulback and mainline drums both have line speeds of 700 feet per minute with the drums empty. The contractor has added a three speed forward and reverse power shift transmission and an Allison torque converter.

To operate the Schield-Bantam yarder in an endless line configuration, both the haulback and mainline drums are used to deliver power to the endless line. As in the conventional slackline configuration, the line enters through a fairlead in the boom and leads onto the mainline drum (front drum). The line then wraps both the mainline and haulback drums simultaneously, and the last wrap passes under the haulback drum and leaves through the haulback fairlead on the stanchion. (Figures 2 and 3)

Very few changes are needed to run the yarder in a continuous line configuration. The drums are not to be changed in the yarder's initial use. The lines wrap the drums with no separation between wraps. The fairleads on the boom and the stanchion tend to lead the line to the center of the drums. The above is true only if the yarder is properly leveled and the line is under proper tension. If the line tends to crawl across the drums (i.e. the line does not maintain a centerline orientation on the drum and the line moves across the drum indiscriminately), the drum diameter would be increased by building up the drum, and grooves might be needed on the drum. The grooves would keep the line in place while on the drum. (Figure 3) Building up the drums would mean some loss of power, but there would also be some increase in speed due to the increase in diameter of the drum.

The haulback fairlead is mounted on the top of the stanchion. (Figure 2) The fairlead is made to fit a five-sixteenths inch (7.9 mm)

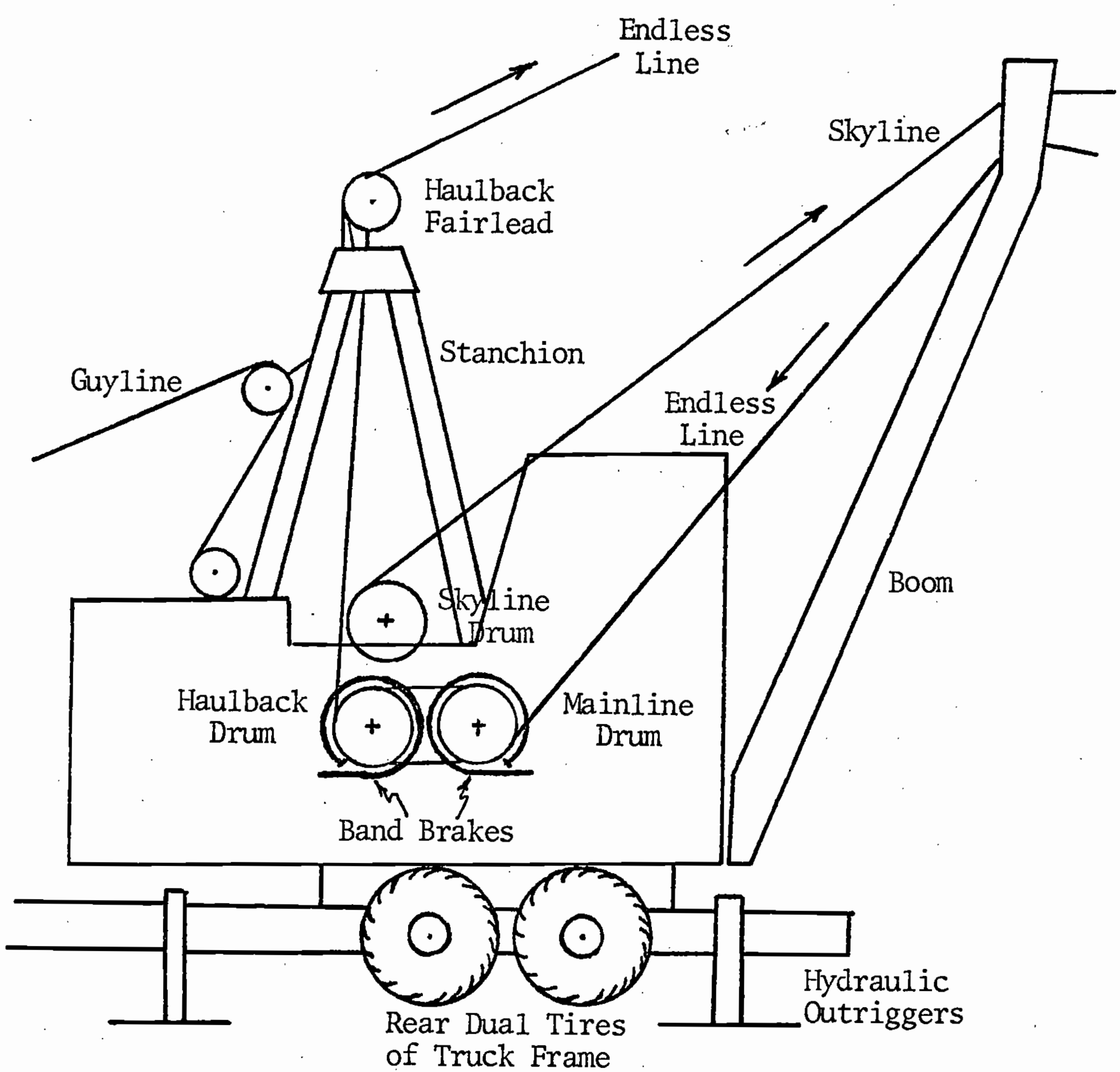


Figure 2. Schematic of Yarder

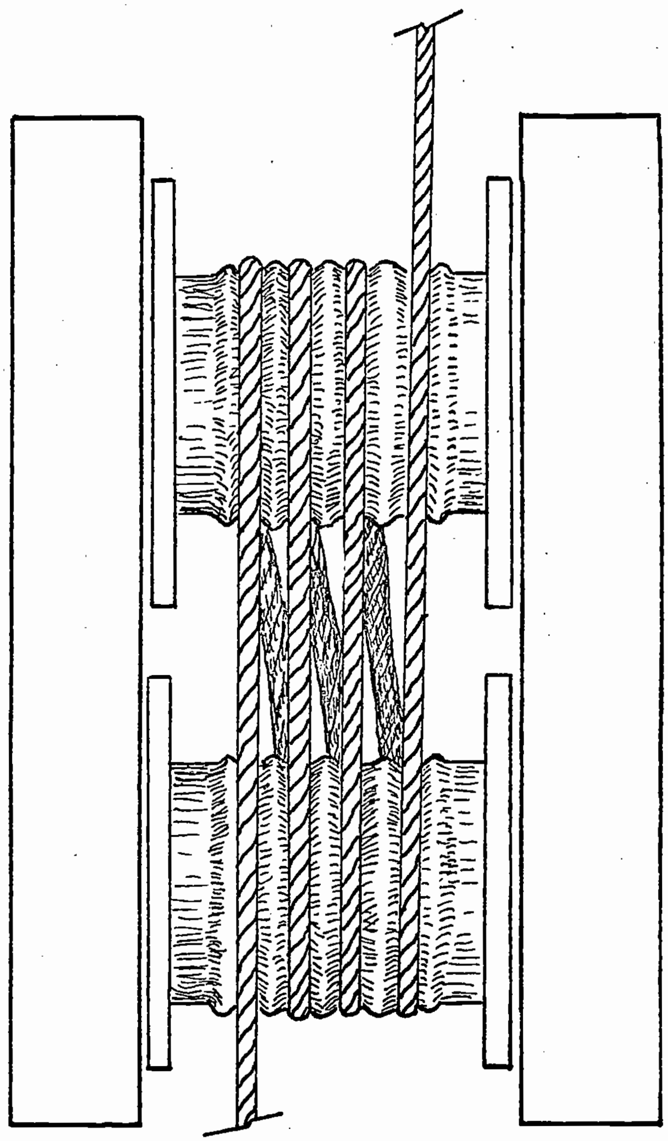


Figure 3. Yarder Drum Configuration

haulback, so it must be increased in size to fit a five-eighths inch (15.9 mm) endless line.

The capability of double brakes and the gearing appear to give the yarder a favorable outlook for downhill yarding. The brakes for the haulback and mainline drums are band type. Band brakes consist of a band wrapped around an extension of the drum. (Figure 2) Friction material is fastened to the inside of this band, and as the band is tightened the friction material comes in contact with the surface of the extension and slows down the turning of the drum. Constant contact of the friction material and the drum will cause heat, and with increased heat the braking ability is decreased and excessive wear of the friction material results.[1] In conventional downhill slack skyline logging, brakes are applied to prevent the turn of logs from running down the hill toward the landing at a dangerously fast speed. Past experience with the Schield-Bantam showed that the constant braking in downhill logging tended to overheat the brakes and the holding ability would decrease. With the endless line wrapping both drums, the two drums are completely interlocked or turn at the same rate. During any running phase (any time the continuous line is moving and the system is in operation), one drum is left in gear to hold back the turn much like a truck gears down when coming down a steep grade. Both the mainline and haulback brakes are available for use if needed. In this way the potential braking capability is increased and overheating of the brake bands is reduced.

---

[1]Information gained from conversation with operator of the Schield-Bantam.

Illustration 1 Schield-Bantam Boom and Fairlead Arrangement
(Top fairlead is the skyline; bottom fairlead is the mainline.)

Illustration 2 Yarder, Stanchion and Boom
(Note guylines coming off stanchion.)

Illustration 3 Mainline and Skyline Drums--Front View

Illustration 4 Mainline Drum

The Carriage

To cable log any partial cut, two choices are immediately evident if the logger is to use a skyline system. The logger has a choice between the added expense of a carriage with lateral yarding capabilities or he may change the line location frequently. Each choice represents a cost to the operator. One choice, lateral yarding, represents a cost in machinery, and the other, changing lines, represents a great expense in time and labor.

Throughout the development of the carriage to be used with the continuous line there were six major features that the designers felt the carriage must have:

1. The carriage must offer lateral yarding capability.
2. There must be some way to hold the turn of logs to the carriage during the inhaul process.
3. The carriage should have some means by which the carriage could be held in place on the skyline during the side haul and the unhooking process.
4. The carriage should use as little space as possible of the critical distance between the skyline and the ground.
5. The carriage should be able to pass over intermediate supports without any interruption of the inhaul process.
6. There must be some way that the logs may be brought up close to the carriage.

1. Lateral Yarding Capability of the Carriage

During a previous study on skyline thinning the lateral yarding function consumed 27 percent of the yarding time. (H. U. Sinner, 1973) During the development of this carriage, powered outhaul was considered necessary because of the following advantages offered by powered lateral yarding:

1) Yarding may operate both uphill and downhill. Manually pulling line from the yarder and through the carriage becomes increasingly difficult as the slope from yarder to carriage approaches zero and becomes positive. Powered lateral yarding would make downhill yarding possible because the tag line could be taken to the side on slopes where manually pulling the tag line might be prohibited.
2) Powered outhaul would result in less fatigue to the crew members because they would not be pulling the tag line from the yarder. This would mean faster turn times.

There are, however, certain disadvantages to powered outhaul. They are:

1) The carriage is typically heavier for powered outhaul than for manual outhaul, unless the power is delivered by the yarder through the lines.
2) The carriage or the yarder is mechanically more complicated if the powered outhaul is part of the system. This complication in equipment increases capital expenses for the system and may increase maintenance costs.

The next step was to decide the method by which the lateral out phase would be powered. Conventional carriages now in use in the United States use such power sources as propane engines.

The propane engine in Skagit's RCC 10 pulls slack in a drop line, and the yarder does the actual pulling of the turn to the carriage. Skagit also manufactures a diesel carriage (RCC 15) that has a diesel engine built into the carriage to execute both the outhaul and inhaul processes of the lateral yarding phase. The diesel carriages are typically heavy and expensive.

Counter-rotating mainlines are normally used with a running skyline or a slack skyline with a haulback. (Studier and Binkley, 1974) The counter-rotating action of the mainlines either turns a drum on which a drop line is wrapped or it simply brings a dropline through the carriage and out to the hooking site. The counter-rotating systems require a three-drum yarder.

The conventional means of powered lateral yarding were discarded for the following reasons:

1) The added weight and expense of a carriage with a separate engine or power source was considered prohibitory.
2) Counter-rotating drums would require at least a three-drum yarder. Even with the three-drum yarder, one drum would have to act as the slack pulling line. This would assume that a running skyline configuration was used. The running skyline approach is not suited to the Schield-Bantam yarder because of its slow speed skyline drum and the lack of any kind of interlocking device.

The designers decided to use the endless line as the power source for both the lateral outhaul and lateral inhaul phases. The force of friction between the metal drums and wire line is used to drive the endless line at the yarder, and it is this same principle that is used to power the lateral yarding sequence.

A carriage design was formulated that used the endless line as power for both the lateral out and the lateral in yarding phase. The endless line wraps two drums inside the carriage, much like the line wraps two drums in the yarder. A shaft is welded to each drum and these shafts are rotated as the endless line rotates the drums. (Figure 4) On the opposite end of each shaft is a sprocket which drives a chain, and this chain drives a 12 inch drum in the middle of the carriage. A line is wrapped around the 12 inch drum, and it is this line that is used in the subyarding or lateral yarding process. Power to the tag line drum was increased by a 3:1 size reduction from the friction drums to the sprockets. The endless line, in conjunction with the braking system, powers the tag line drum in either direction so the tag line may be reeled out or in by switching directions of the endless line. All drums in the carriage are driven by the endless line. Any gearing necessary for directional or speed change is done at the yarder.

2. Means of Holding Logs to the Carriage

Once the turn has been pulled to the carriage, a device is needed to hold it there. Without the device there would be no control over the action of the logs on the tag line, therefore, truck brakes were set into the friction drums on the carriage. When engaged, the brakes

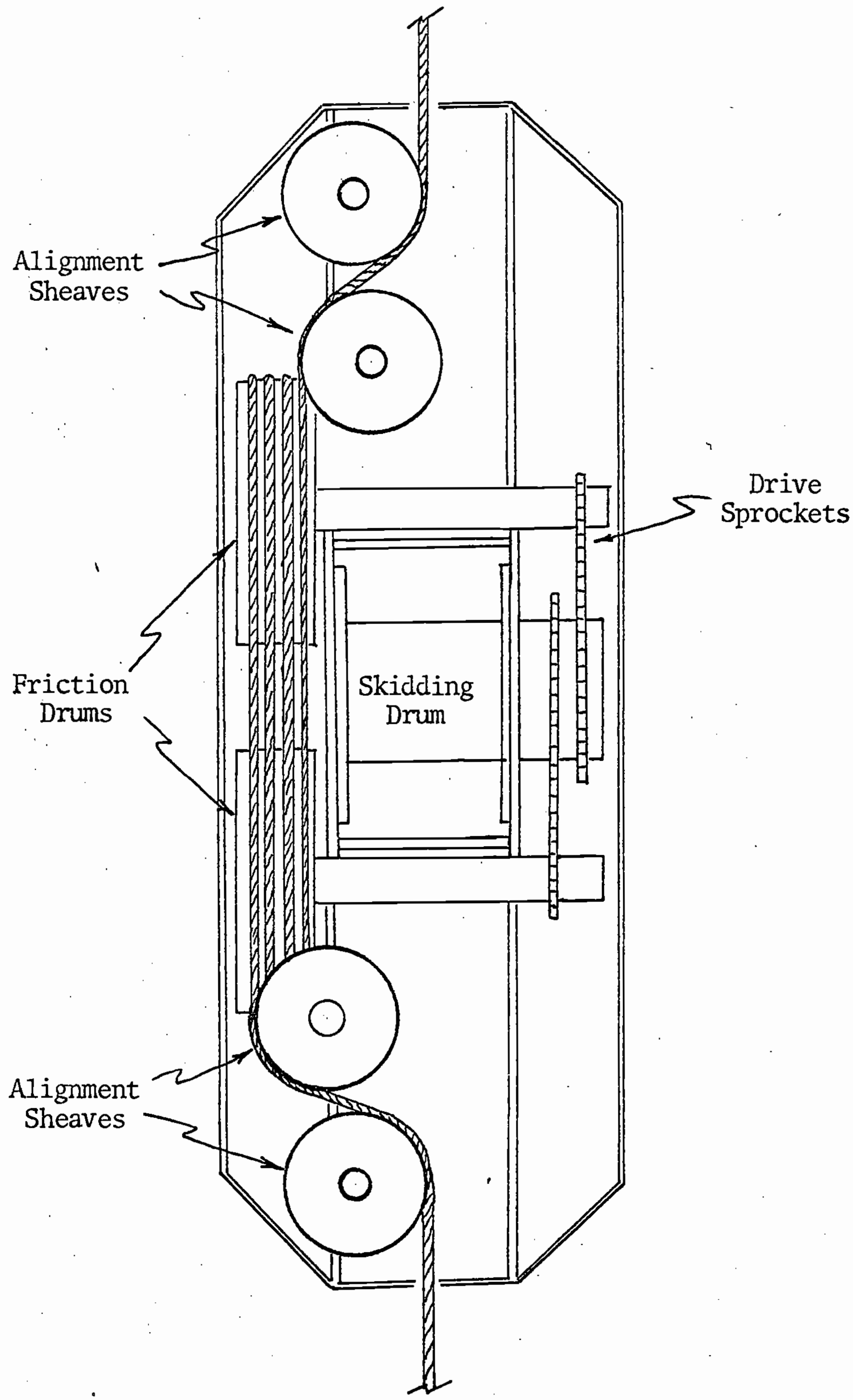


Figure 4. Endless Line Alignment Through the Carriage

prevent the endless line drums from turning and thus keep the skidding drum from rotating. (Figure 5) The brakes hold the turn of logs to the carriage as the carriage moves to the yarder. The brakes are actuated hydraulically when a radio signal is received at the yarder from the rigger and the yarder engineer sends a radio signal to the carriage's receiver. The rigger could also actuate the braking systems if those functions are included on the hand-held signal device that the rigger uses to signal the yarder engineer.

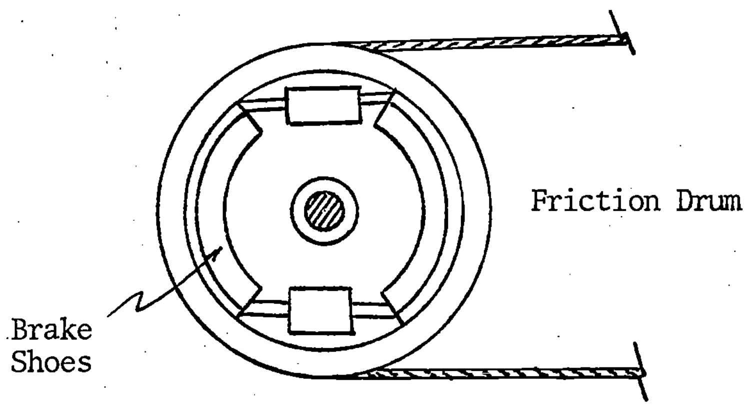


Figure 5. Friction Drum and Brake

3. Means of Holding the Carriage Stationary on the Skyline

The endless line can supply the power to the tag line, but the power is transferred from the endless line to the tag line only if the carriage is locked to the skyline. If the carriage is not locked, it will move along the skyline. Movement of the dropline can only occur as the force needed to turn the friction drums is less than the force needed to move the carriage along the skyline.

The ability to lock the carriage on the skyline was achieved by installing a skyline clamp which clamps the skyline during the subyarding operation and keeps the carriage from moving on the skyline. Two types of locks were designed. The first design worked on the principle of a scissor-like clamp activated by a vertically oriented hydraulic cylinder, while the second design was based on one horizontally oriented cylinder. (Figure 6) The first design consisted of hydraulic clamps which would be mounted in a frame and would act simultaneously to close an iron bar over the skyline. The disadvantage to this method is that it would require three hydraulic cylinders. Also, it would have to be mounted in a frame high enough to enclose the hydraulic cylinders and the clamp and allow for the vertical movement of the hydraulic cylinders. The second and final design utilizes only one cylinder and the size of the frame is considerably less than that of the first design. The reason for the size reduction is that the hydraulic cylinder is mounted horizontally. A wedged bar is pushed by a double acting hydraulic pump (a pump that is powered in both directions, in or out). This bar acts as a wedge to force the scissor-like clamps to tighten on the skyline. (Figure 6) The wedged bar is formed so that the angle of the wedge is extreme at first in order to bring the skyline clamp angle iron to the line quickly. As the angle iron touches the line, the angle of the wedge bar decreases greatly. (Figure 7) The decrease in angle adds force to the squeezing action while the greater angle adds the initial speed needed to get the clamp on the skyline quickly.

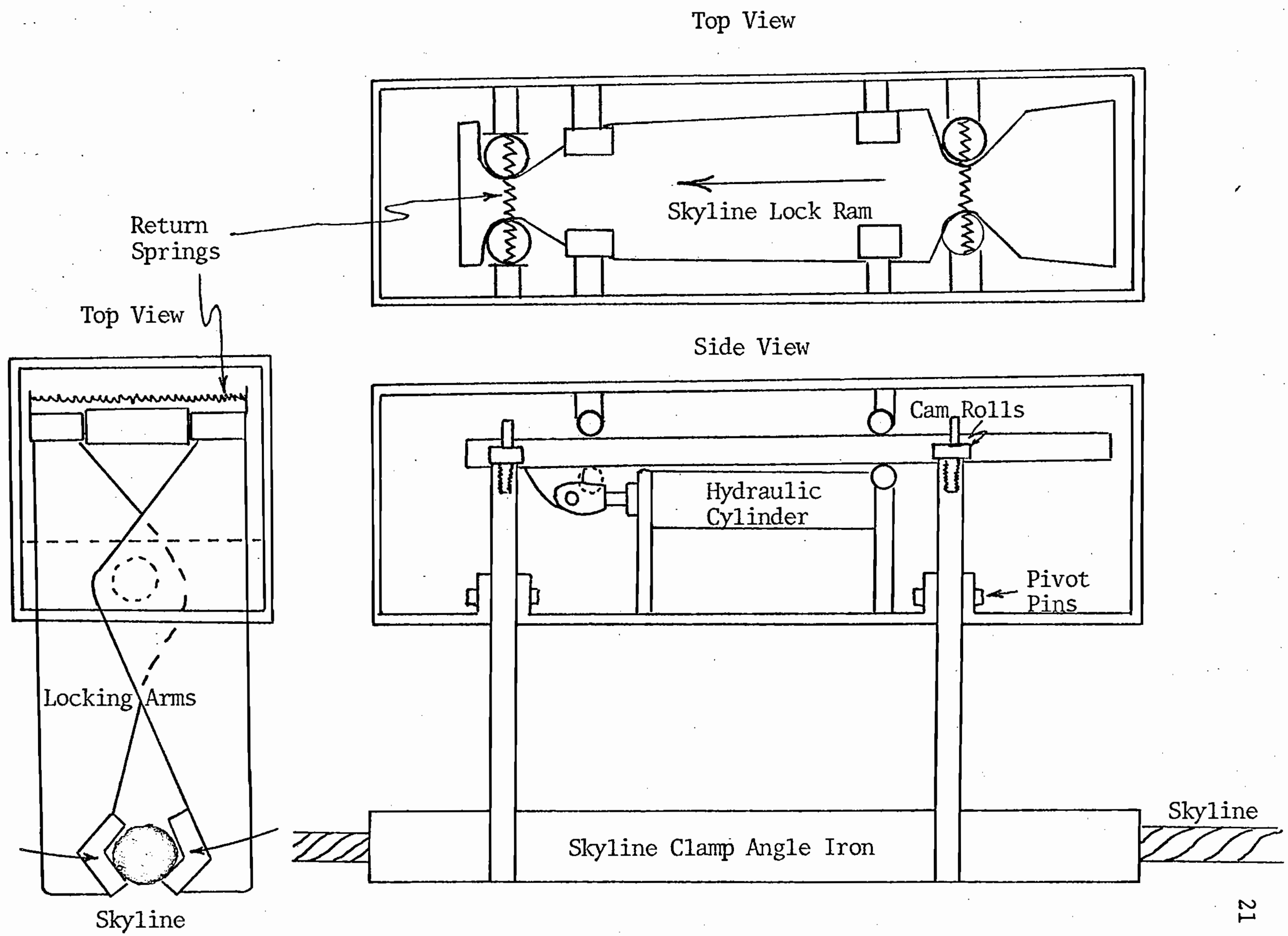


Figure 6. Skyline Lock

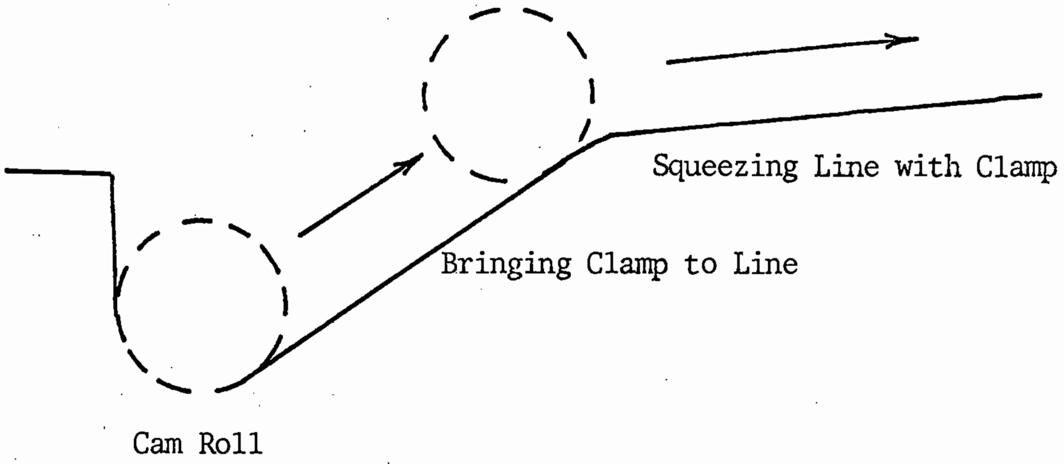


Figure 7. Wedged Bar Angles

4. Holding the Distance from the Skyline to the Bottom of the Carriage to a Minimum

One of the features the designers felt necessary was a low profile for the carriage. This means there should be as little of the carriage hanging below the skyline as possible to maximize that part of the critical distance between the skyline and the ground not taken up by the carriage. This was the prime reason for side-mounted friction drums. The side mounting enabled the tag line drum to be mounted at the same level as the friction drums. The bottom of the carriage was engineered much like a skid so that it could ride over obstacles. The design may help reach farther back on some skyline roads which offer limited clearance between the loaded skyline and the ground. The ends of the carriage are beveled so that it might pass around any obstructions, such as standing trees or tall stumps.

5. Ability of the Carriage to Go Over Intermediate Supports

The skyline clamp, as well as the skyline sheaves, is engineered so that the carriage can go over intermediate supports. This feature was considered desirable because of the limitations in singlespan skyline logging. (Binkley and Studier, 1974) Deflection or clearance of the load above the ground can be a limiting factor in yarding distance. Intermediate supports offer one solution to this problem by allowing the skyline to go over the brow of a hill and still have ample deflection. (Figure 8) Plans for the initial testing of the carriage did not include the use of intermediate supports, but this feature was included in the objectives of the design because we felt that their use would increase in future years.

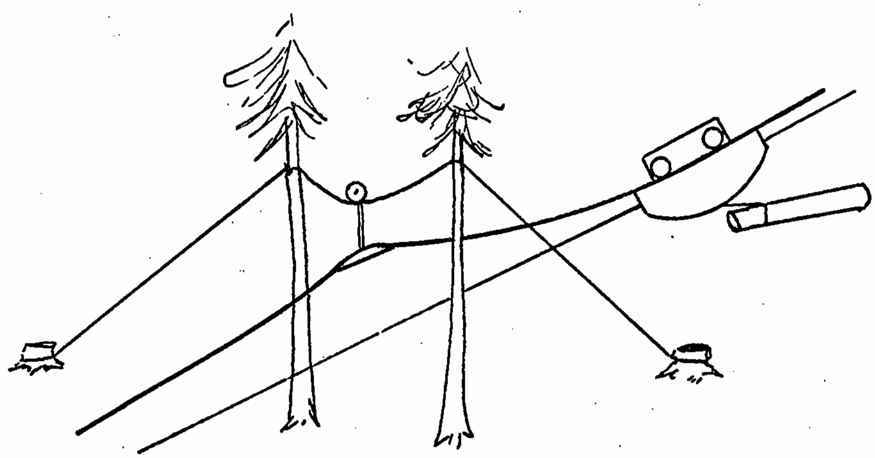


Figure 8. Intermediate Support

Two 12 inch sheaves ride on the skyline. The sheaves are mounted on the side of two supports, and it is this side mounting of the sheaves that allows the carriage to be used with intermediate supports. The carriage passes over the support, but a trip device keeps the carriage from jumping the line during operation between the intermediate supports. The clearance between the skyline and the top deck of the carriage is of primary concern if the carriage is to be used with intermediate supports. The clearance must be enough to allow the intermediate support to pass under the sheaves and not hit the top deck of the carriage. The clearance for the intermediate support was a prime factor when assigning a distance between the top deck and the bottom of the skyline sheave. (Figure 9)

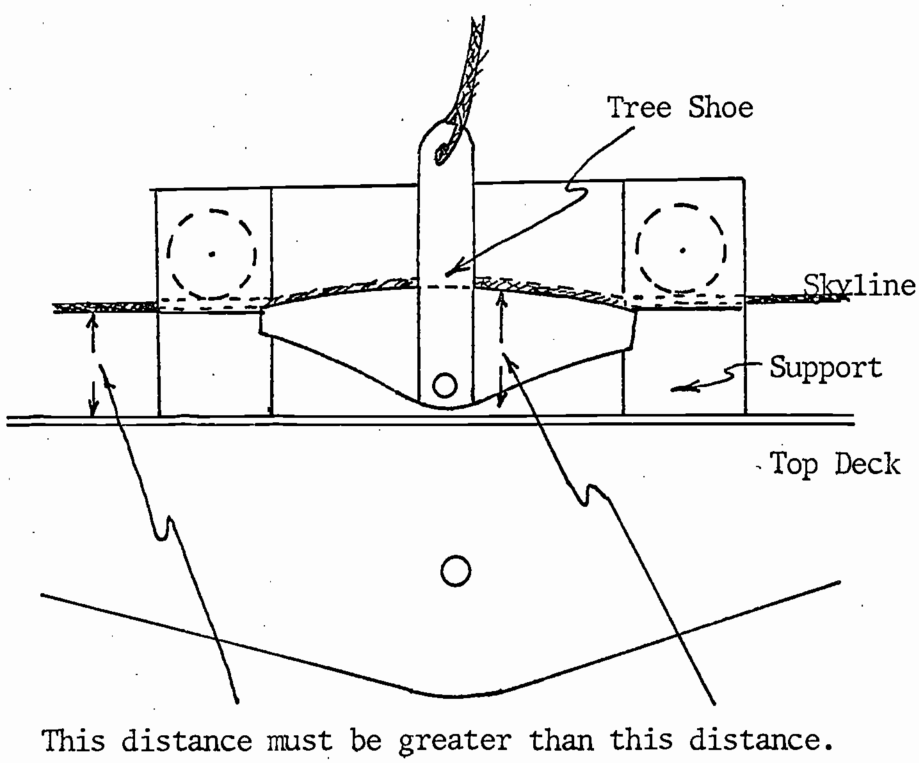


Figure 9. Skyline Support Height and Intermediate Supports

6. Means of Bringing the Turn Right Up to the Carriage

Many conventional carriages allow the logs to be brought up to within choker length of the carriage. The chokers may be anywhere between 12 and 50 feet in length. When there is very little clearance between the carriage and the ground, the length of the choker can be critical. The skyline often leads across a slope and the logs constantly tend to swing downhill. The swinging action is of no consequence in a clearcut area; but on a partial cut, the more the logs swing away from the skyline, the more potential for damage to the remaining trees. (Figure 10)

The tag line drum is in the center of the carriage and it is this drum that holds the tag line. (Figure 4) The outside diameter is 12 inches and flanges are welded to the sides of the drums. The flanges are shaped much like a winch drum on a tractor, with the outside edges rounded. The rounded edges permit the tag line to rub across the edges without cutting the line.

Design of the tag line drum was directed toward decreasing the distance between the log and the carriage. By making the area around the drum as large as possible, the line, hook and chokers can be wound onto the drum. (Figure 11) This feature makes it possible to bring the logs right up to the carriage. The area around the drum is completely enclosed in metal, so the whipping action of the hook, chokers or tangled debris caught in the tag line will at no time come in contact with the inside of the carriage.

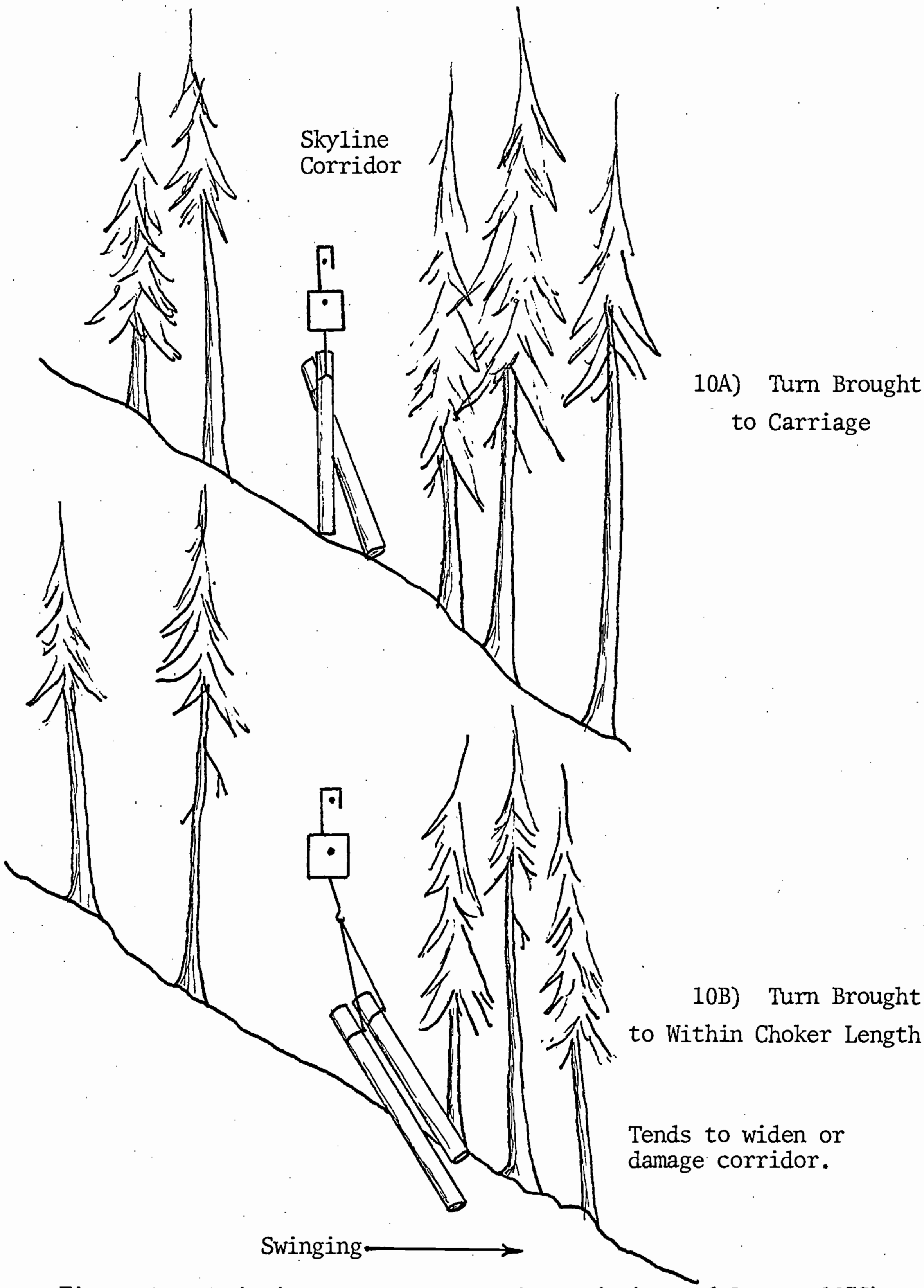


Figure 10. Bringing Logs Up to Carriage (Twito and Lyson, 1973)

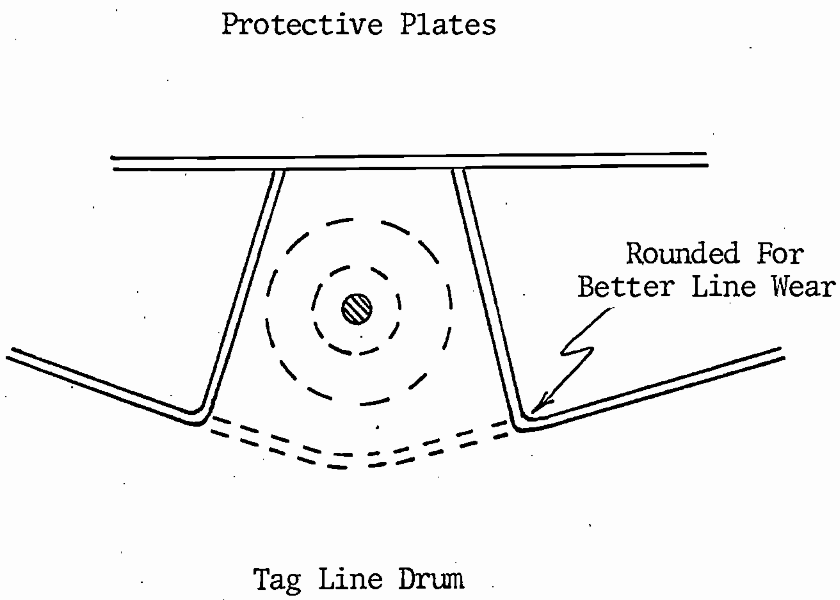


Figure 11. Cross Section of Tag Line Drum and Space Around It For the Hook and Chokers

Control Mechanisms

Hydraulic Controls

The hydraulic system consists of a hydraulic reservoir or storage tank, a hydraulic pump, a one gallon accumulator and control valves. The hydraulic pump is operated by the action of a one inch displacement cam. (Figure 12) The cam is a round metal plate mounted on the shaft one inch off center. The maximum displacement of the cam is one inch and thus gives a one inch drive to the hydraulic pump.

There were two trial designs of the hydraulic cylinder mounting assembly. One design was a stationary hydraulic cylinder paired with an air cylinder used to return the hydraulic ram. (Figure 13) The air cylinder would be charged with air pressure before use; and under proper operation, the air pressure would be maintained with only infrequent recharging needed.

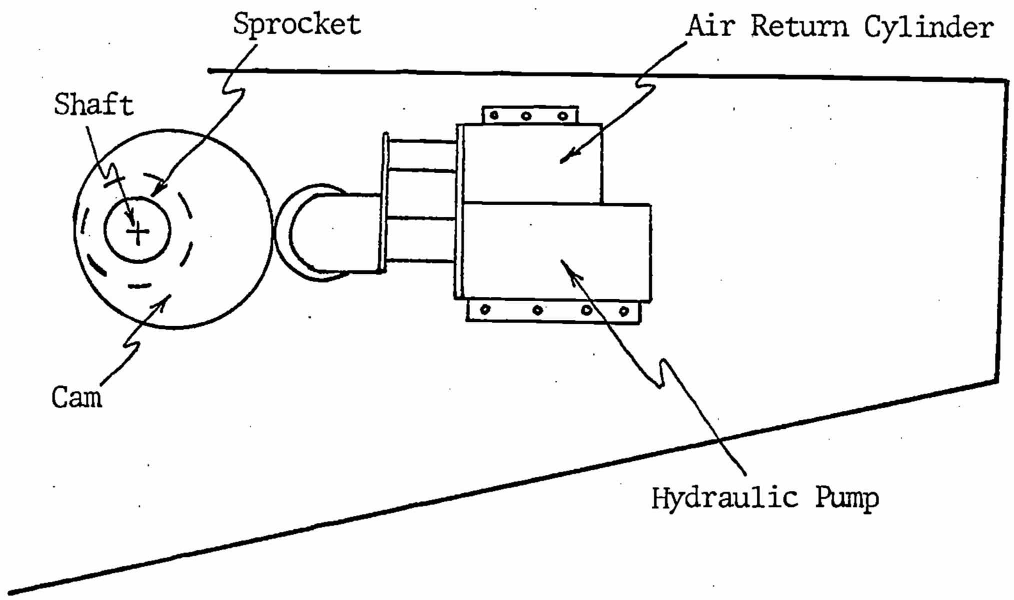


Figure 13. Air Return Cylinder For Return of Hydraulic Cylinder

The hydraulic cylinder assembly to be installed in the carriage is simpler than the air return mechanism and would require less maintenance. The assembly consists of a hydraulic pump mounted at one end and an alignment arm attached to the coupling on the end of the ram. The ram would be pushed in by the action of the cam and a spring would pull the ram back. The spring would be attached to the alignment arm where it connects to the ram and the spring would be anchored to the carriage frame. (Figure 14)

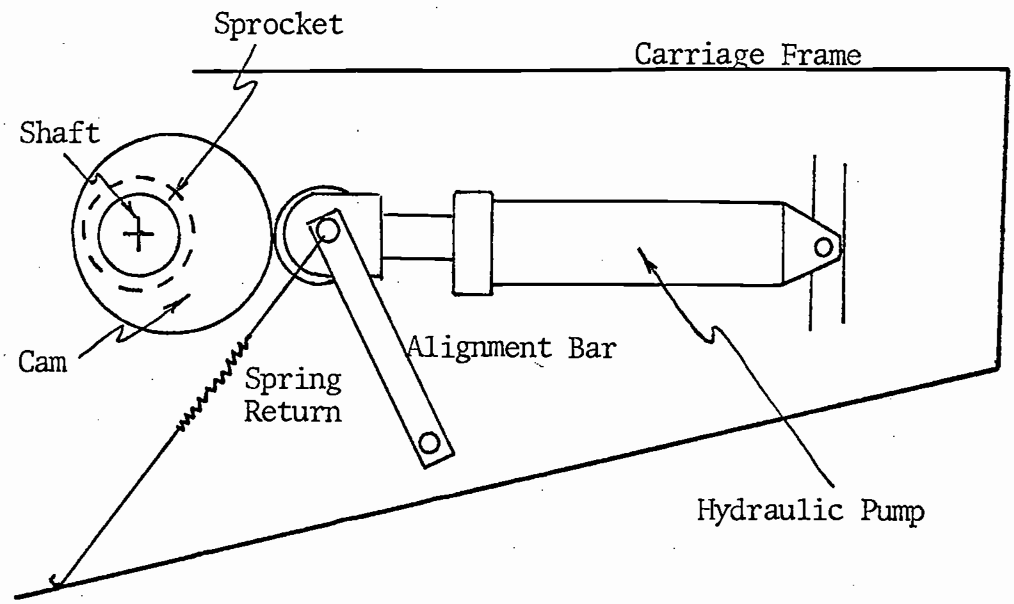


Figure 14. Hydraulic Pump Mechanism

The accumulator accumulates, or stores, hydraulic pressure. (Figure 12) This pressure is in turn used for various functions of locking or unlocking either the skyline clamp or setting the brakes in the friction drums. The accumulator is a necessary piece of equipment because the cam mounted on the shaft rotates only when the friction drums rotate during the lateral out or lateral in phases. The hydraulic pressure is needed to lock the skyline clamp and friction drums before and after the friction drums are rotated. The accumulator stores the hydraulic fluid under pressure to be used at any time, whether or not the hydraulic pump is actually pumping fluid. An unloading valve was installed to prevent overpressurizing the accumulator.

Control valves were installed to regulate the flow of hydraulic fluid to the two braking assemblies. The valve is the link with the electrical system in that the electrical system activates the control valves.

Electrical Controls

The electrical system activates the mechanical movements of the carriage and is the control center of the system. Any malfunction in the radio system will result in either uncontrolled movements or no movement at all.

The radio is a standard package manufactured by Rothenbeuhler Company, the manufacturers of the "Talkie-Tooter" radio system, a system well known in the logging industry. The radio system consists of a transmitter mounted in the control cab of the yarder and a receiver mounted inside the carriage. The yarder engineer receives a radio signal from the rigging crew via an independent radio system. The yarder engineer then transmits a signal to the receiver in the carriage. The radio system completes an electrical circuit to a solonoid which regulates the movements of the control valve on the hydraulic system.

Once the circuit is closed by the radio receiver, electric current flows from a 12 volt DC battery to the solonoid. The battery is the power source for the solonoid, thus the battery is extruding power intermittently. To maintain an electrical charge in the battery, an alternator is mounted in the carriage. (Figure 15) The alternator is rotated by the action of a rubber roller in contact with the upper portion of the skyline sheave. The doughnut-shaped roller rides inside the groove of the sheave and is rotated as the sheave rotates. A drive belt connects the alternator with the roller, thus the rubber roller drives the belt and the belt drives the shaft in the alternator. The battery is charged in both the outhaul and inhaul yarding phases.

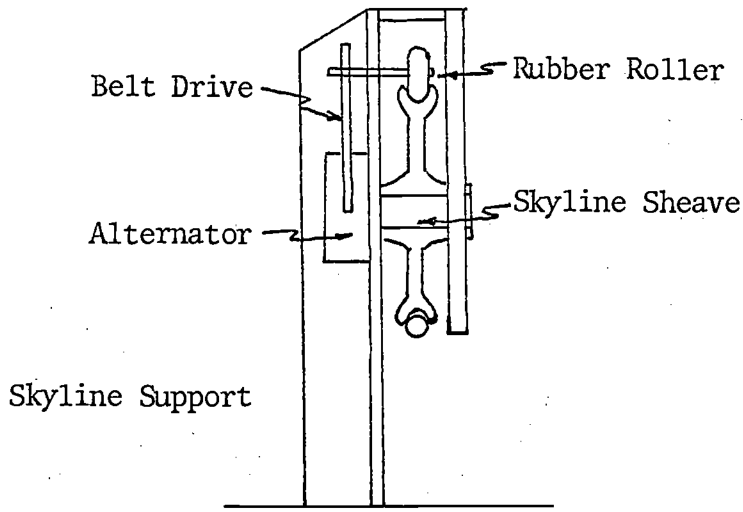


Figure 15. Alternator Drive Assembly

To keep the battery from losing its charge during periods of inactivity, a check switch was installed between the alternator and the battery. During periods when the battery is not charging or discharging, the switch keeps any current from leaving the battery.

The radio receiver and the myriad of hydraulic lines and electrical circuits are fragile, thus necessitating some form of protection. Where possible, parts will be encased in styrofoam to cushion them against such shocks as hitting trees or bumping against logs. All hydraulic lines and wires will be installed inside the frame of the carriage to offer protection against any obstruction that might sever the lines.

Problems Considered Because of Design Configuration

Line Alignment

During the development process a problem arose as to the alignment of all components so that the carriage might be balanced to the centerline of the carriage. To maintain the centerline orientation of the carriage, the running lines (continuous line) must enter and leave the carriage along the centerline of the carriage. If the line did not enter and leave along the centerline, the carriage would tend to twist on the skyline because of the unequal forces acting in opposite directions but with neither force acting along the centerline. Once the lines are within the carriage, the problem becomes one of weight balance.

Two major design types were considered to achieve the alignment of the lines. The first design was one with the friction drums slanted within the frame. The friction drums turned the sprocket on the end of the shaft through a universal joint to the slanted part of the sprocket. (Figure 16) The slanted friction drums kept the width of the carriage narrow. The drawing of this design looked feasible and desirable, but mechanical calculations revealed that the tensions encountered during a logging operation would be more than the universal joints could withstand under constant use. The final design was the vertically oriented side-mounted drums. To align the cable to the center, two sheaves were installed at each end of the carriage. These sheaves direct the cable so that the cable may enter or leave at the centerline and also wrap the internal friction drums, which are not located near the centerline. (Figure 4) The vertical mounting requires no universal joints and would require less maintenance.

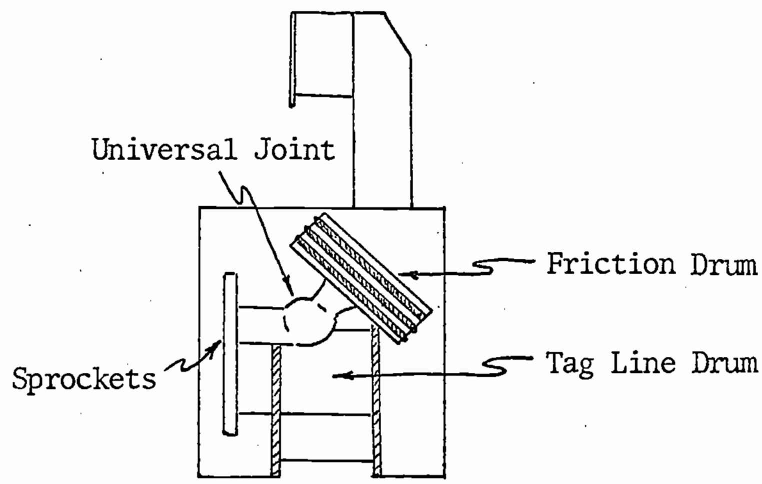


Figure 16. Slanted Friction Drums (End View)

Weight Balance

Weight balance in the carriage was not anticipated to be a major problem. The construction as it appears on the drawings would result in more weight being on one side. (Figure 4) This was partially corrected by using the available space on the chain drive side as the area for the hydraulic pump and accumulator. Considering the overall weight of the carriage (anticipated to be 4,000 pounds), the designers did not think the weight difference would affect the vertical orientation of the carriage on the skyline.

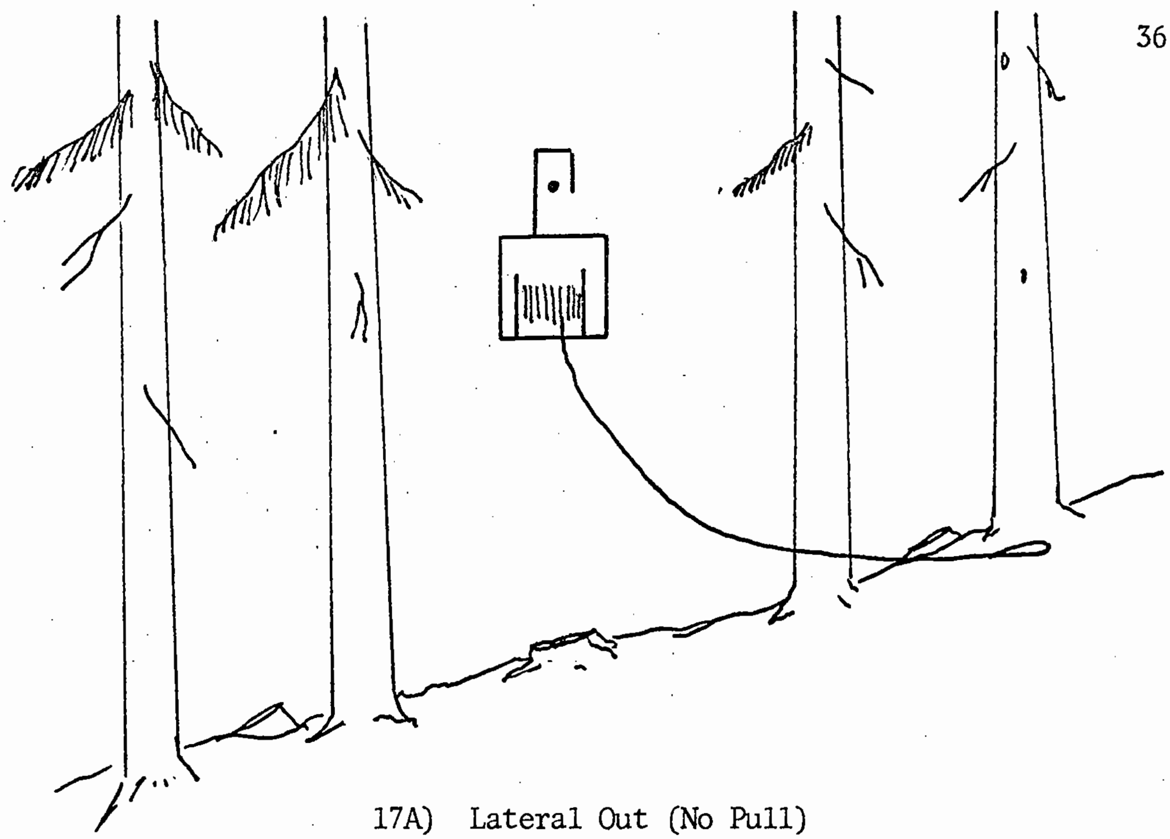
Tag Line Spooling

The tag line drum was built with flanges that would enable the carriage to hold about 300 feet of three-fourths inch (19.1 mm) tag line. This 300 feet gives the operator a wide choice of lateral yarding distance, depending on the difficulty of changing skyline anchors. As skyline changing becomes more difficult, wider lateral yarding may become advantageous.

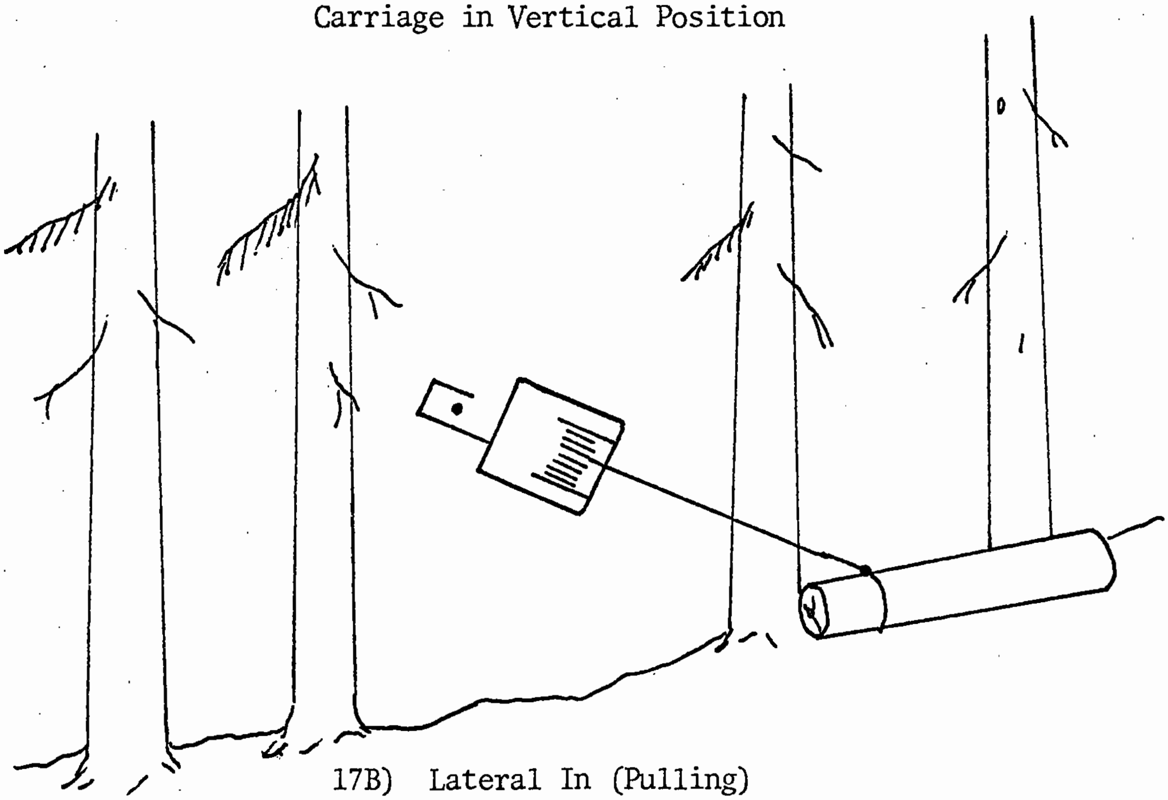
During the designing process some question arose as to whether the line would spool evenly[2] on the drum. We realized we could not expect the line to spool perfectly, as on a yarder drum, without some device to direct the line onto the drum. Our hypothesis was that during the inhaul process the carriage would be free to swing on the skyline and the carriage would orient itself toward the source of the resistance after tension was put on the drum. The orientation of the carriage toward the turn would allow the line to spool on the drum. (Figures 17A and 17B) During the initial logging operation this hypothesis may prove to be wrong. The line may pile up on one side of the drum or be pinched between other wraps of the line which would prevent the line from unspooling. A fairlead (roller guide) may have to be mounted under the tag line drum to direct the line toward the center of the drum and prevent the line from piling onto one side. The fairlead would prevent the hook from being spooled on the tag line drum, thus losing the advantage of bringing the logs up to the carriage.

---

[2]Perfect spooling would be with each wrap of the line falling right next to the last wrap. No line would cross over another wrap. When the line crisscrosses itself, the line tends to break at the crossed point.



17A) Lateral Out (No Pull)
Carriage in Vertical Position



17B) Lateral In (Pulling)
Carriage Oriented Toward the Direction of the Pull

Figure 17. Tag Line Spooling (Twito and Lyson, 1973)

Carriage Fabrication

During the development and design stages, the carriage took form in numerous drawings. The author became involved with the drawing of the various views of the carriage and its components. The sizes were calculated or measured directly from the scaled drawings which were made to a scale of one inch equals three feet (a copy of the drawings accompany this report).

The carriage was built in a welding shop in Corvallis, Oregon. The welding company made some modifications in the structure specified in the plans. These modifications were made to make assembly of the carriage easier or to add strength to the frame.

The welders felt that the bottom plates called for in the design specifications were insufficient with regard to strength and fabrication ease. They welded a one-half inch Ship's Channel to each side of the bottom of the carriage. The Ship's Channel is a channel iron which the welders believed would add stability to the underside of the carriage. The channel iron was of the correct width, so fabrication of the bottom skids was minimal.

The first work done to fabricate the carriage was to build the inside frame. The friction drum shafts were inserted through the frame at the beginning of the construction phase to insure proper alignment of all other components. During the fabrication of the frame the tag line drum was built. The tag line drum was made from pipe stock with the flanges welded onto the drum. The friction drums were also made from the same pipe stock, and the specified inside diameter, outside diameter and grooves were machined into the pipe on a lathe.

The design phase of the carriage development began in February of 1974 and was not completed by August of the same year. All work on the carriage ceased after August to be resumed at a later date. The fabrication phase was delayed because of the difficulty encountered in obtaining the cam rollers for the skyline brake and some parts of the friction drum brakes.

Illustration 5
Framework--End View

Illustration 6
Alignment Sheaves
Mounting Plate

Illustration 7 Tag Line Drum

Illustration 8 Skyline Lock
Clamping Device

Illustration 9
Alignment Sheave,
Skyline Support and
Bottom Skids--End View

Illustration 10
Cam and Sprocket

Illustration 11
Friction Drum

Illustration 12 Friction Drums
and Inner Braking Mechanism--Side View

Illustration 13 Carriage with Cover
over Friction Drum Area--Side View

Lines

The continuous line is the heart of the endless line system in that everything is designed around the endless line. The line literally ties the whole system together. The endless line is five-eighths inch (15.9 mm) 6 by 19 improved plow steel with right regular lay[3] and has a breaking strength of 41,200 pounds (17,946 kilograms) and a weight of .72 pounds per foot (.1 kilograms per meter).

The endless line, as the term implies, is a line which is continuous through the system with no break in the line. The ends are spliced together either by a standard tucking procedure or couplings placed at the ends of the line and the ends coupled together. The couplings must be able to pass through the carriage and the yarder. One idea considered for use of the couplings was to separate the line into sections that could be handled on the logging site by the crewmen. Each section would have a double hook device and an eye at each end. The couplings would quickly join the sections together, but the hooks would also pass through the carriage. The sections would enable the crew to make road changes by stringing the continuous line along the next skyline. The hooks used to fasten the line together would look like the hook in Figure 18.

---

[3]The 6 by 19 means that there are six strands with each strand having approximately nineteen wires. The strands are wound to the right and the wires are wound to the left--this is referred to as right regular lay.

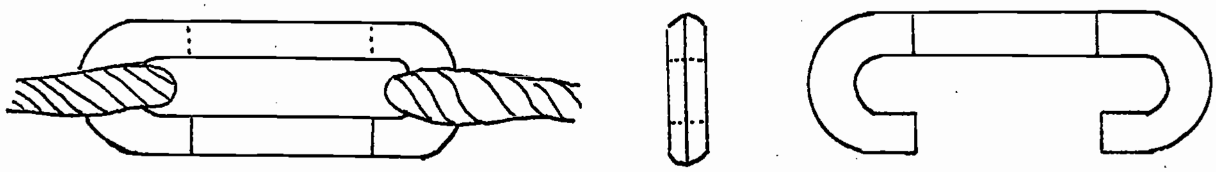


Figure 18. Endless Line Hooks (Couplings)

The tag line is wrapped on the tag line drum. The line is a three-fourths inch (19.1 mm) 6 by 19 right regular lay improved plow steel with a breaking strength of 15,200 pounds (6,894 kilograms) and weight of 1.04 pounds per foot (.14 kilograms per meter). It is approximately 260 feet in length with a ferrule[4] placed on both ends of the line. One end of the line is hooked to the barrel of the drum by passing the ferrule through a machined slot in the barrel. The other end of the line is connected to a hook device on which chokers may be hung.

The skyline is a one and one-eighths inch (28.6 mm) line with right regular lay improved plow steel and a breaking strength of 113,200 pounds (51,348 kilograms) and weight of 2.34 pounds per foot (.32 kilograms per meter). It has an eye spliced into each end so that either end may be used at the tailhold or head stump.

The skyline is a modified tight skyline in that it can be lowered by the yarder for carriage maintenance, but it remains stationary under normal operating conditions by setting the brakes of the skyline drum

[4]Ferrule is a metal enlargement on the end of a line used to fasten the end of the line to a sleeve or choker bell.

on the yarder. The line is lowered for periodic inspection and maintenance of the carriage and when the carriage and turn must be stopped from running back to the head stump because of endless line breakage. The yarder engineer may also tighten the skyline to maintain clearance along the skyline.

The skyline is not directly connected to the yarder. The yarder has a skyline drum mounted above the haulback and mainline drums. The yarder's skyline goes to a block mounted on the head stump and then through a series of blocks with one set of blocks connected to the main skyline. (Figure 19) This gives a four block purchase on the main skyline and offers an increase in power to the yarder's skyline. The pulling power of the skyline is increased by a factor of the number of paired blocks (i.e. the power is multiplied by the number of paired blocks).

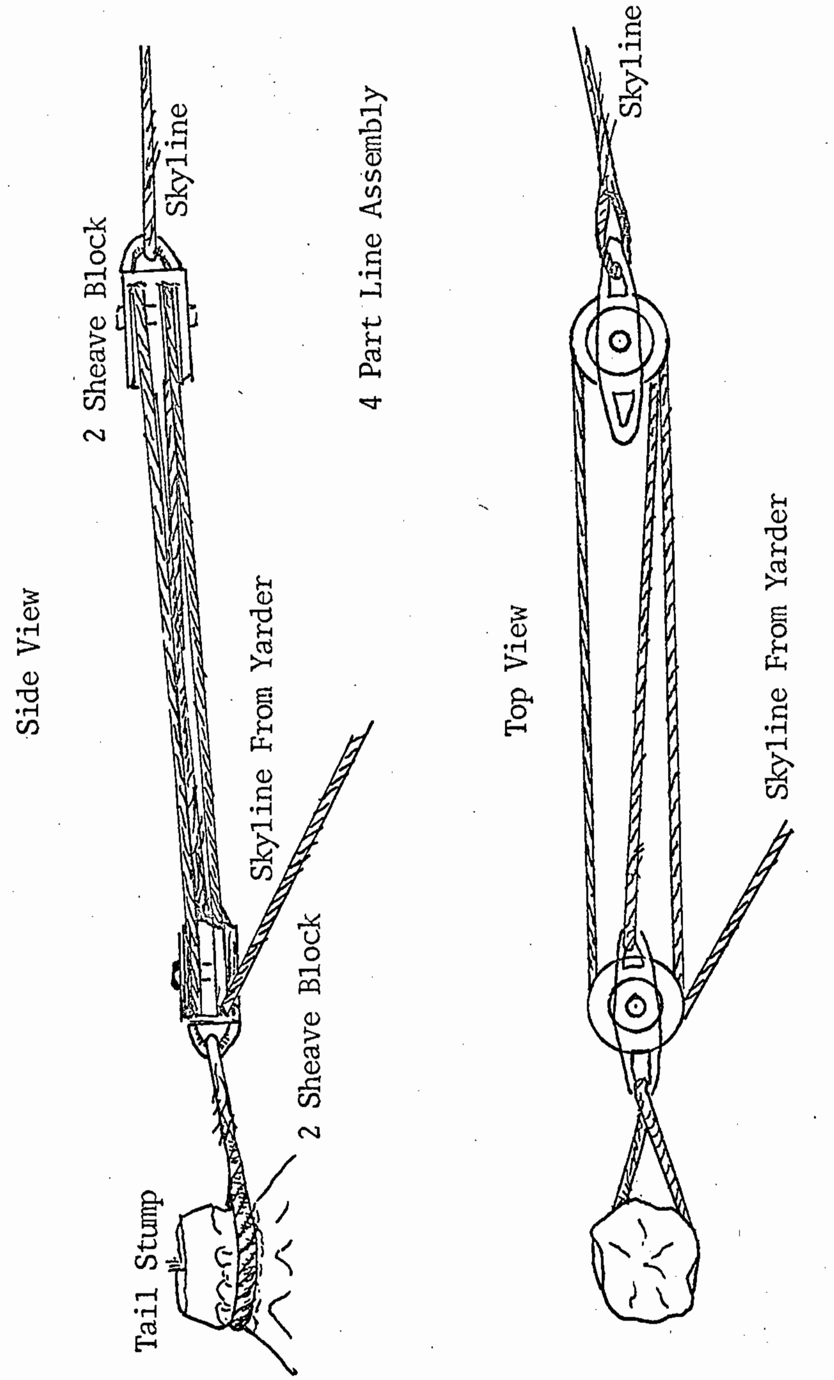


Figure 19. Skyline Head Stump Configuration
(Four Part Line)

OPERATION OF THE SYSTEM

Throughout the development stage of the carriage a theory of the machinery operation was developed. The delay in receiving parts and the extended fabrication stage prevented me from quantifying the performance of the carriage and the system in general. I will describe the operation of the system as the designers and I expect it to operate upon completion of the carriage.

Much of the development of the carriage and the changes anticipated in the yarder were based on the characteristics of the initial logging unit. Long before the design phase of the carriage was finished, the logging unit on which the initial logging test would be made was layed out, the road into the unit planned and built, and the falling of the timber completed. As a result, many of the stress calculations were based on the sizes of the timber already felled.

The initial logging unit is a south facing slope with a species mix of Douglas fir (Pseudotsuga menziesii), grand fir (Abies grandis), big leaf maple (Acer macrophylum) and red alder (Alnus rubra). The cutting types are clearcut and partial cut. Both cutting types are represented on similar slopes and conditions, and it is hoped that the performance of the carriage can be observed under both conditions.

The shaft and line sizes were determined by the largest log on the logging unit (1,700 board feet or 8.8 cubic meters). In this way we could be confident that the carriage designed would handle all the logs found on the logging area. All parts were engineered to reach their optimum point of wear and economy under the conditions of use on the unit. This means that some wear would be evident after a period of time, but there would have to be a balance between the usable life, expense and weight of an oversized part.

Rig-Up Techniques

To adapt the continuous line system to the Schield-Bantam yarder a particular rig-up technique was planned to meet the carriage design and yarder changes.

Skyline Rig-Up

Because the Schield-Bantam yarder is small we felt it undesirable to attach the skyline directly to the yarder. Our first idea was to use stumps for the tailhold and above the landing. The slope of the ground near the landing is such that by tying on a stump in back of the landing, the skyline is clear of the landing. As the stump is chosen further back, more clearance is achieved. With the stump chosen above and behind the landing no spar pole is needed for lift.

The skyline distance will change from skyline to skyline. To allow for the changes in skyline distances there should be enough skyline to reach all the tail stumps selected on the unit or, if the operator desires, enough to reach the tail stumps on any planned unit. The excess could be brought out to the rear stump and the skyline wrapped several times around the tail stump and spiked. The excess in the back of the unit will add to the difficulty of skyline changes; but to use the four-part line from the yarder, an eye is needed to connect with the two-sheave block. Another possibility is that the excess skyline may be dealt with in some manner at the landing and the tail stump wrapped much like a choker. The excess at the landing could be coiled and the skyline hooked to the four part line by making an oversized eye with line clamps. A block could be placed inside the eye and its yolk attached to the four part line assembly.

Rig-Up of the Continuous Line

The endless line will be the first line to be strung on the logging unit. A strawline (small steel cable used to pull the heavier line around the logging area) will be strung first. The strawline will be strung through the corner block and along the back of the unit to the lead block and back to the yarder. (Figure 20) When the end reaches the yarder, a bulldozer with a winch will be used to pull the continuous line around the same path as the strawline. When the continuous line reaches the yarder, after being pulled around the unit and back to the landing, the other end of the line will go through a block mounted in back of the landing. From this block the end will go to the yarder, through it (Figure 2), and back through another block mounted near the previously mounted block in back of the landing. For lack of better terms I will call the first block the haulback block and the last block the bull block. From the bull block the line will be spliced to the end of the continuous line coming from the lead block.

The continuous line will be used to pull the skyline back to its tailhold. A chain and shackle will be used to wrap the continuous line and pull the skyline back to the top of the unit. Depending on the circumstances, the skyline may have to pass through intermediate

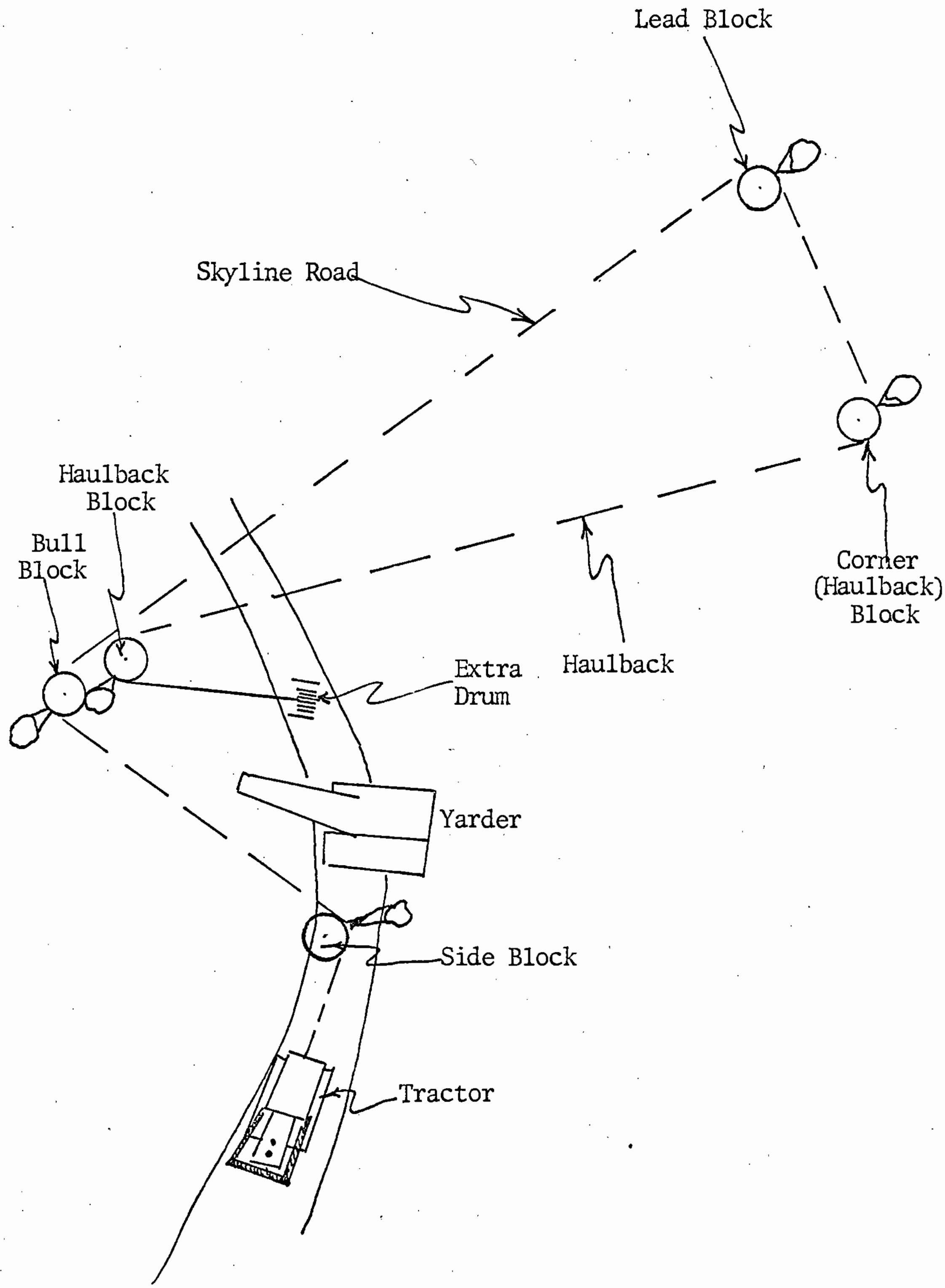


Figure 20. Continuous Line Layout

supports or through a tail tree and will thus need some modification in the hook-up process. When the skyline is strung, the continuous line is put through the carriage and the ends spliced.

To tighten the continuous line the yarder is moved until the proper tension is achieved. The tighter the line, the greater the force of friction; but if the line is tightened too much there will be excessive wear or stretching of the line. The guylines should be used to keep the boom stable and prevent the machine from moving.

System Operation

Once rig-up has been completed, the system will enter a pattern of operation. I have represented this planned pattern by the use of a flow chart. (Figure 21) Note that this is a flow chart for the activities of the yarder and carriage.

Line Changing

Line changing may present the problem of excessive time spent moving the lines. Some ideas have been formulated as to how line changing will be accomplished. We had planned to test these ideas on the logging unit.

The idea of using special hooks to join the ends of the line will doubtlessly prove beneficial in line changing. (Figure 18) The hooks will speed up the separation and joining of the ends to form the endless line. They will also enable the operator to increase or decrease the length of the endless line by adding or subtracting sections of line with hooks at each end. There is a possibility that with 100 foot sections of the five-eighths inch (15.9 mm) line, the next skyline road may be partially layed out before the previous skyline road is finished. One hundred feet of the line would weigh 72 pounds. (H. H. Lyson and C. N. Mann, 1967) This would not be too heavy to handle. A few 100 foot sections of the continuous line could be strung along the top of the back line (between the lead block and the corner block). Haywire could then be brought from the landing to meet the continuous line that was prestrung. When the skyline road is finished, the continuous line would then be broken at the carriage and the end brought around the layout to meet the end of the continuous line that was prestrung. The two ends would be connected and the haywire pulled toward the landing and the continuous line brought around to the landing. (Figure 22) During the line changing phase a means of pulling line toward the landing would be needed. The yarder cannot be used because all drums will be used for some other line. We have considered using a tractor to pull line for the initial test of the system. The tractor would pull the line down the road until the continuous line was brought around the layout and back to the landing.

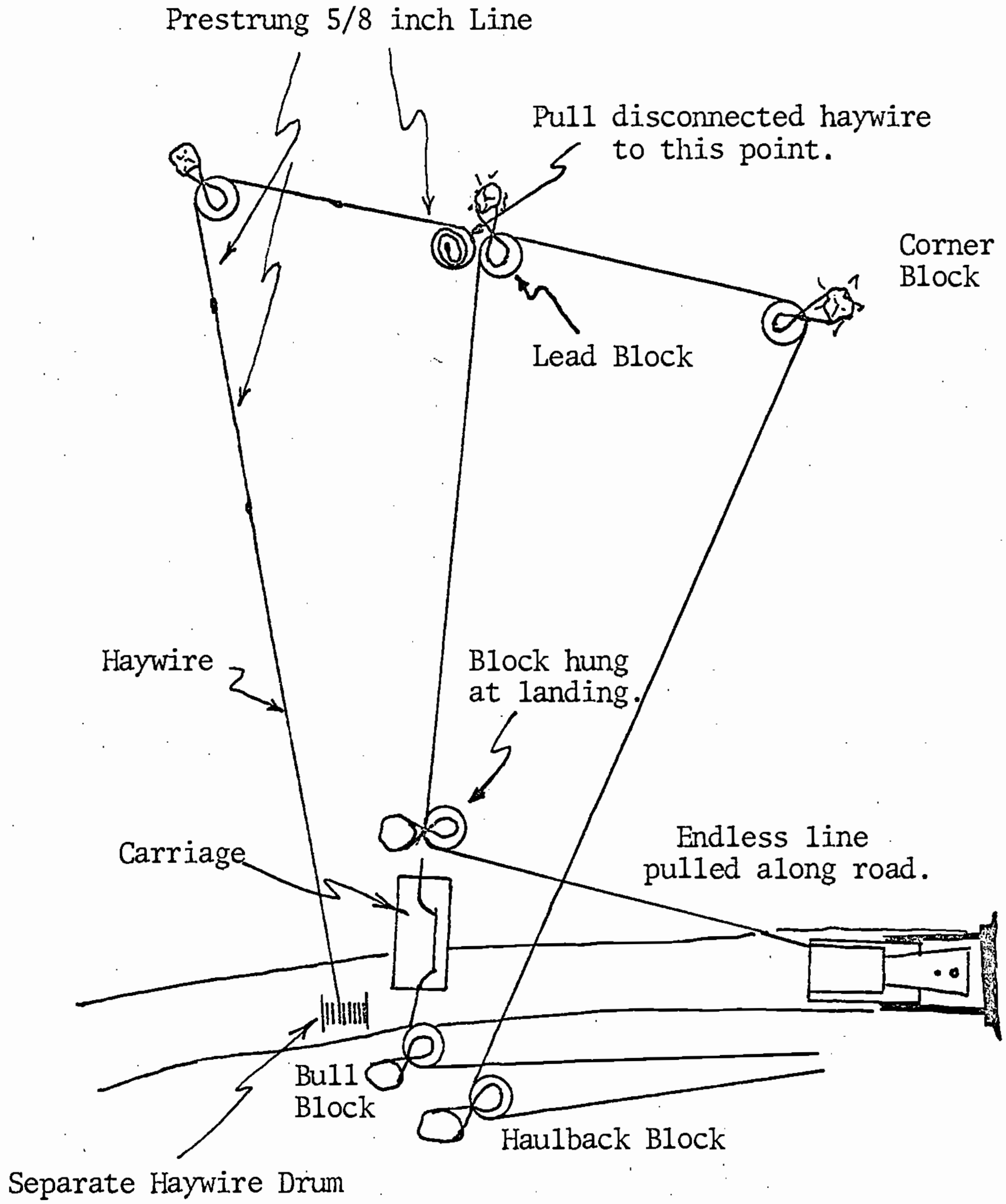


Figure 22. Line Changing (Endless Line)

FUTURE OPERATIONS

If the carriage and yarder system is a success, a smaller version of the carriage will be built and used for small wood harvesting. Drum, shaft, frame and line sizes will be greatly reduced. The first carriage is estimated to weigh 4,000 pounds and it is hoped that a smaller carriage could be designed to weigh 1,500 pounds. The smaller carriage design would emphasize reduction in the size of the carriage to handle only small timber. Smaller line and carriage sizes will make the carriage and lines easier to handle than the first model. Line changes, perhaps, will be done without haywire.

RECOMMENDATIONS

The testing phase had not yet started as of the writing of this report. Any recommendations I may make cannot, therefore, be in regards to the system's successful use. I have made three recommendations from the work that was accomplished in the design stages of the carriage and the accompanying machinery adaptation.

1. I recommend that any further development of the carriage include a critical path analysis. (J. E. Kelly and M. R. Walker, 1959) With the use of critical path, the ordering of parts could be carried out so as to minimize the slack time during the fabrication stage. A critical path analysis would have shown that ordering of parts is on the critical path of the fabrication network. Many times during the carriage fabrication the lack of an ordered part delayed production. At one point a part was delayed so long that it finally had to be made at the welder's own shop. This meant a loss of time and a greater expense, since the cost of making the part was more than the ordered part.
2. The tractor is an inefficient and slow method of pulling line around the layout (yarder to corner block, then to lead block and back to the yarder), so a one drum machine should be considered. The one drum machine would be used to hold and supply power to the haywire. The haywire would not be needed to pull the skyline because the skyline would be taken to the back of the unit with the endless line.

3. The endless line system followed by this report should be monitored for its production rate in an effort to look for ways the carriage design and yarder adaptation can be made more efficient. I recommend that a time study be made on the initial production to see what phases take the bulk of the yarding time. With the time study data, the engineer could work on improving those phases that take the most time. This may mean that line changing will have to be greatly improved or that some of the basic components of the carriage will have to be changed. The time study will not reveal whether the carriage and yarder system is practical or impractical. Only by looking at production costs of the system over varying conditions may we arrive at the system's practicality.

BIBLIOGRAPHY

1. Information in letter from C. R. Silversides, November 21, 1973.

2. Kato, S., "Popular Skyline Cable Systems Used in the Mountain Forests of Japan," 13th IUFRO Congress, Vienna, 1961.

3. Kelly, J. E. and M. R. Walker, "Critical Path Planning and Scheduling," 1959 Proceeding of the Eastern Joint Computer Conference.

4. Lyson, Hilton H., "Understanding Skylines: Are They Problems or Panaceas?" Reprint from Forest Industries, Reprinted by U.S. Forest Service (1966).

5. Lyson, Hilton H. and Charles N. Mann. Skyline Tension and Deflection Handbook. U.S. Forest Service, Research Paper PNW-39, 1967.

6. Lyson, Hilton H. and Roger H. Twito, "Skyline Logging: An Economical Means of Reducing Environmental Impact of Logging," Journal of Forestry, Sept. 1973, p. 581-583.

7. Oswald, Dieter, "The Norwegian Radio-Controlled Cable Crane," SYMPOSIUM ON FOREST OPERATIONS IN MOUNTAINOUS REGIONS, FAO publication # LOG/SYMP.5/38, (1971).

8. Perkins, R. H., "The Purdue Traction-Cable Running Skyline System," Journal Paper Number 5069, Purdue University Agricultural Experiment Station, (1974).

9. Silversides, Ross, "Systems Approach to Logging Machinery Development," (Lecture presented to Forest Engineering class at Oregon State University, Corvallis, Oregon (1974).

10. Sinner, Hans-Ulrich. "Simulating Skyline Yarding in Thinning Young Forests." Unpublished thesis, Oregon State University, 1973.

11. Studier, Donald D. and Virgil W. Binkley, Cable Logging Systems, Pacific Region, U.S. Department of Agriculture--Forest Service, Portland, Oregon (1974).