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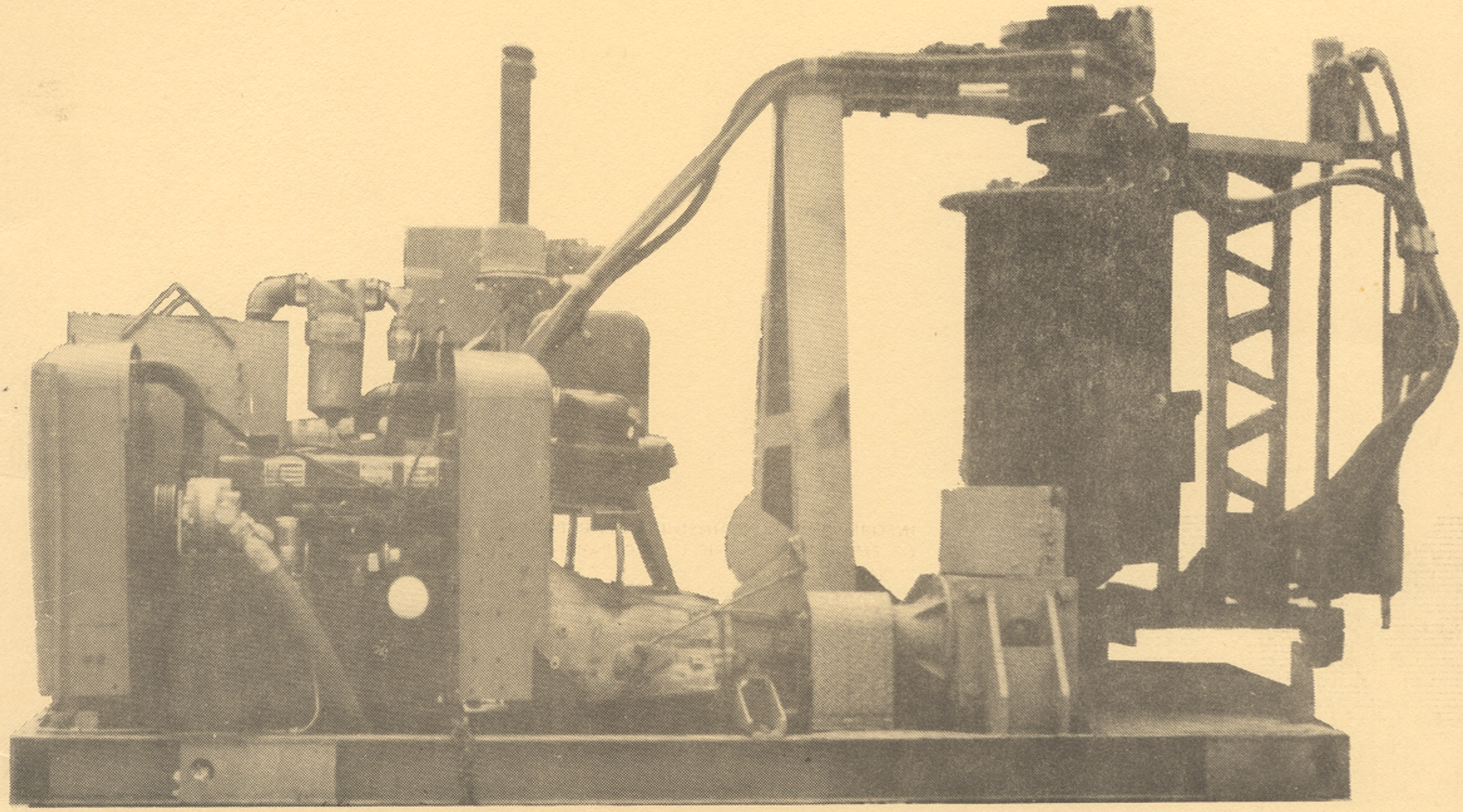
project record

San Dimas Equipment Development Center

UPHILL TREE PULLER



FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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UPHILL TREE PULLER

by

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ED&T Project No. 2694
Steep-slope Slash Equipment

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INTRODUCTION

The practice of felling trees in a particular direction frequently requires the help of mechanical aids to apply a positive force to the tree. Frequently, timber on slopes is felled uphill because that way it does not have so far to fall. Breakage usually is reduced. Two methods of uphill felling are currently being used—jacking and pulling. The Ad Hoc Slash Equipment Group in its December 1976 meeting recommended that the San Dimas Equipment Development Center (SDEDC) investigate uphill pulling. 1/

Two basic questions were to be answered. First, were there features of currently used uphill pulling equipment (figs. 1 and 2) that could be improved? Secondly, was it feasible to develop a remotely operated uphill puller? The puller operator's job is an easy and ostensibly unproductive one. He might pull no more than 20 or 30 trees a day, total pulling time being only 1 or 2 hours in an 8-hour shift. Yet it is necessary that he be at the equipment, at least with current equipment designs.

This *Project Record* presents the results of tests on the SDEDC testbed uphill puller. The answer to the first of these questions is yes and the second, no.

A Skagit model BU50 yarder is mounted on a White cab-over-engine tractor. The yarder is powered by a GMC 305 CID automotive engine and automatic transmission. The entire puller is enclosed in a house for operator comfort.

Figure 1. Rosboro Lumber Co. tree puller.

1/ **See the Glossary for uphill pulling terms.**

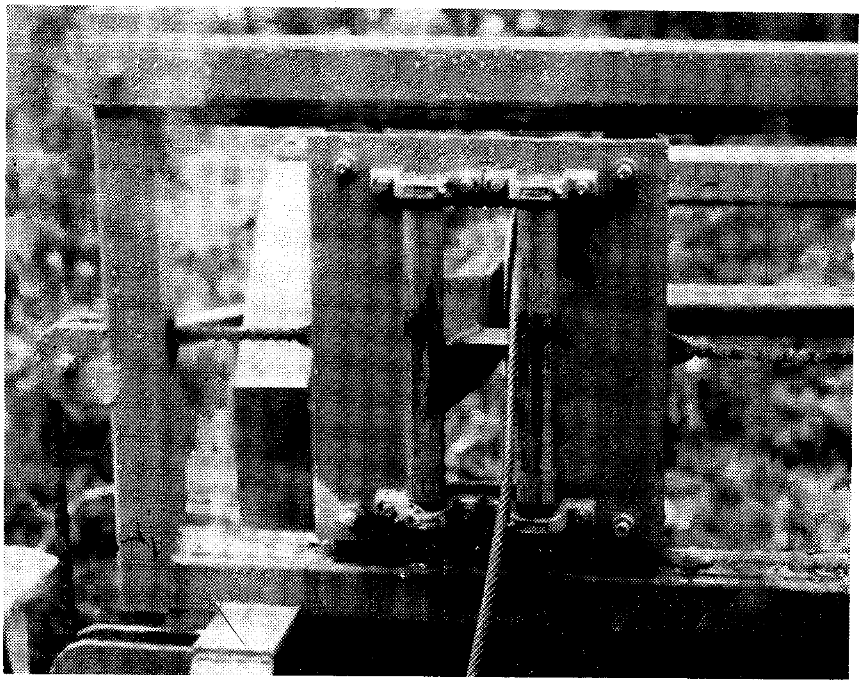


Figure 2. Hydraulic fairlead.

UPHILL PULLING

Pulling is the most readily applicable directional felling method in old growth. The technique involves using a puller, spooled with wire rope, to fell the trees in the desired uphill direction. The puller is located on a landing above the trees to be felled.

Felling Procedure

An uphill pulling-felling crew consists of four members: a crew chief (who is also the faller), a bucker, a climber, and a puller operator. The climber takes a choker up the tree to a height determined by the crew chief. When the choker is in place, the operator is then signaled to apply tension to the tree via the choker. The faller, using his past experience, determines the amount of tension. For smaller trees (from 12 to 16 inches dbh), which do not lean out too far beyond vertical from the hillside, approximately 10,000 pounds of tension is usually adequate. For larger trees, trees with heavy lean, or trees with assymetrical crowns, line tension estimated in excess of 20,000 pounds is often used.

The puller operator is signaled to begin his pull, to slack line, etc., using a talkie-tooter. This is a combination two-way radio and signaling device. Radio signals transmitted from the faller's talkie-tooter activate an air horn at the puller location which is audible both to puller operator and crew in accordance with applicable local safety regulations.

After the first hard pull to insure that the line is clear and to establish that the puller can overcome the weight of the tree, the line is slackened a little to relieve tension. The buck out is then completed. If the saw pinches it may be necessary to pull a little or use a plastic wedge. This procedure not only results in extremely accurate felling between stumps, rocks, etc., it also allows cutting personnel to pull saws and move to a safe area (at least 30 feet) from the stump.

Since Oregon Industrial Accident Examiners figures show that over 90 percent of all felling accidents occur within 15 feet of the stump of the tree being felled and over 99 percent of all felling accidents occur within 25 feet of the stump of the tree being felled, the safety benefits of this practice are obvious. Further, pulling reduces the incidence of "runaways," i.e., trees that scoot downhill just after felling. The pulling line also may be used to hold unstable logs while the bucker completes his task in safety and to hold large root masses of windfalls which could tip onto a bucker.

Uphill Pulling Costs

Breakage is greatly reduced by this method of felling. Less slash is produced. This often makes slash treatment by burning unnecessary for planting objectives, thus gaining a year or more on reforestation. Stream protection is simplified because all slash is up on the slopes instead of in the creek bottom. Less pieces mean cheaper yarding and loading and far less material to pull.

On most old growth, Douglas-fir shows an increase in utilization, the savings in timber being between 10 and 30 percent. Pulling costs range between 2 and 3½ times as much as conventional felling, however. Conventional felling generally costs about $7 per mbf, therefore, the cost of pulling is between $14 and $25 per mbf.

If stumpage costs are $70 per mbf, then a 10 percent reduction in breakage must occur before pulling will pay for itself. However, if stumpage is $280 per mbf (as is the summer 1978 price), then only a 2½ percent increase in utilization will make pulling costs break even.

Currently Used Equipment

Most pullers are obsolete yarding machines mounted on obsolete trucks. The obsolete yarders work well and are inexpensive. However, there are very few obsolete yarders available, as most of these are now being shipped overseas.

Shortcomings

Currently used equipment has other shortcomings. One problem is insufficient drum capacity to carry the required 3,000 to 4,000 feet of 9/16-inch wire rope. The most serious problem is that since most of the spooling the puller actually does is with the cable under no load, it is difficult for the puller operator to achieve a tight lay of cable upon the drum. Then, when pulling force is applied, the running part of the cable will wedge down into a loosely laid course, leading to a terrible mess on the spool. (Observation of existing equipment under actual operating conditions indicate that maximum travel under load is in most cases no more than 5 to 10 feet.)

Another shortcoming is the difficulty in obtaining even lays (see Glossary) from course to course, even with the line under load. This situation is present even though the cable is run through a block attached to a tree a hundred feet or more from the puller in an attempt to keep fleet angle within acceptable limits.

Line pull and line speed are interdependent. The line pull and line speed available from currently used machines vary from puller to puller as well as from working radius to working radius with the same puller. Most experts in uphill pulling hold the opinion that, contrary to normal hoisting practice, a puller should be able to exert enough force to break the line. Almost all currently used pullers can. The reason is that it is safer to break the choker than have the puller dragged down the hill in the event that a tree too large to pull is attempted or one "gets away." For the 9/16-inch improved plow steel wire rope used in current pullers, this equals a line force of roughly 26,000 pounds. Fast line speed is of less importance than sufficient static pull.

Trees should not be pulled in exactly the same direction as they are to be felled, because the falling tree then covers the choker, which becomes very difficult to retrieve. This also introduces a bucking safety hazard because it is impossible to tell which way a bucked log will roll. Therefore, trees should be pulled slightly "sidehill" and angled. Only on severe sidehill pulls does high line speed become important. Maximum line speed available for most current equipment is on the order of 3 or 4 feet per second.

Advantages

Other features of current yarding machines make then good pullers. These are the sensitivity of the "friction" (see Glossary for its use here) and the drum brake and the free spooling capability.

As already mentioned, the required amount of tension is applied to the line during pulling and, then upon the faller's signal, the drum is braked, holding the proper tension. This demands a sensitive friction and brake "feel" so that the puller operator can hold the proper tension without releasing any slack whatever. Figure 3 is a schematic drawing of currently used spools showing the friction and brake arrangements. Both are manually operated and have large surfaces for sensitive control.

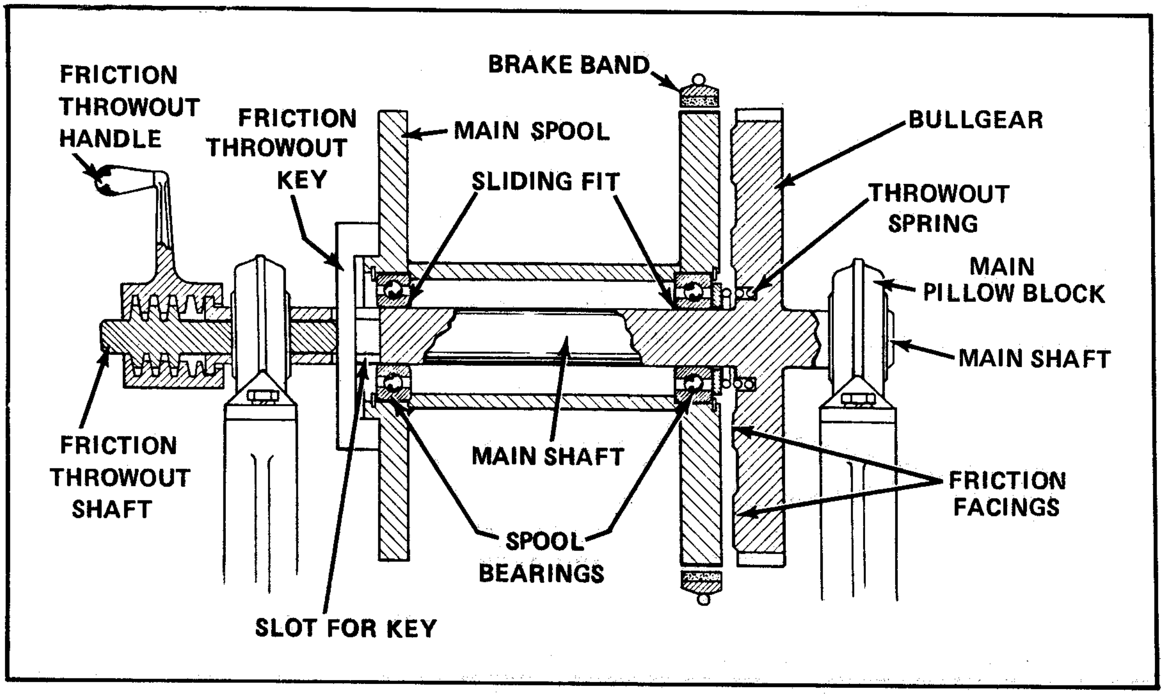


Figure 3. SDEDC tree puller mechanical arrangement.

The drum must free spool to allow the climber to pull out slack as he needs it. In steep terrain, the weight of the cable will assist the climber in pulling out slack, and in very steep cliffy terrain he may actually rappel using the inertia of the reel and the operator's control over the brake to slow his descent. Since the drum is free to rotate on the main shaft when the friction is disengaged (fig. 4), under free-wheeling conditions the only drag in the system which the climber must overcome is between the drum and the main shaft. In current designs, this bearing surface is bronze bushed, while main shafts run in bronze bushings or roller bearings, thus allowing this drum to free wheel.

SDEDC TESTBED UPHILL PULLER

The SDEDC testbed uphill puller is shown in figure 5. Its specifications are:

Weight	8000 lb
Height	76 in
Width	50 in
Length	116 in
Fuel capacity	15 gal
Hydraulic oil capacity	20 gal
Engine—Ford industrial model 300 GFV	124 hp @ 3,600 rpm 241 ft-lb torque @ 2,000 rpm
Transmission, Borg-Warner automatic	Model T-6
Line capacity, 9/16-in line	5000 ft
Maximum pull	
Minimum working radius	15,500 lb
Maximum working radius	6,000 lb

The spooling system is failsafe; i.e., if the engine fails, the line will not unwind. The most interesting feature of the testbed is the arrangement of the levelwind. To make the fairlead self-aligning with the direction of pull, the levelwind is mounted on arms (*A*, figs. 5A and 5B). Cable tension aligns the levelwind. This feature is essential for an unattended (remote radio control) operation, since no operator is on hand to manually insure that drum and levelwind are truly perpendicular to the running part or the line.

A sensing valve (*C*, fig. 5B) is actuated by the running part of the line. This sensing valve directs hydraulic oil, under pressure, to the up-side or down-side of the hydraulic motor, which is attached to the screw jack which operates the fairlead. Thus, as fleet angle increases to an unacceptably large value, the jack screw automatically adjusts the fairlead to reduce the fleet angle.

The spool is fit with a side pinch roller (*B*, fig. 5B), intended to prevent the line from falling down and bunching at the bottom of the drum during no-load spooling.

The line pull developed by the machine is a function of both the speed of the line and the effective working radius. Force developed as a function of line speed for maximum and minimum radius are shown in figure 4.

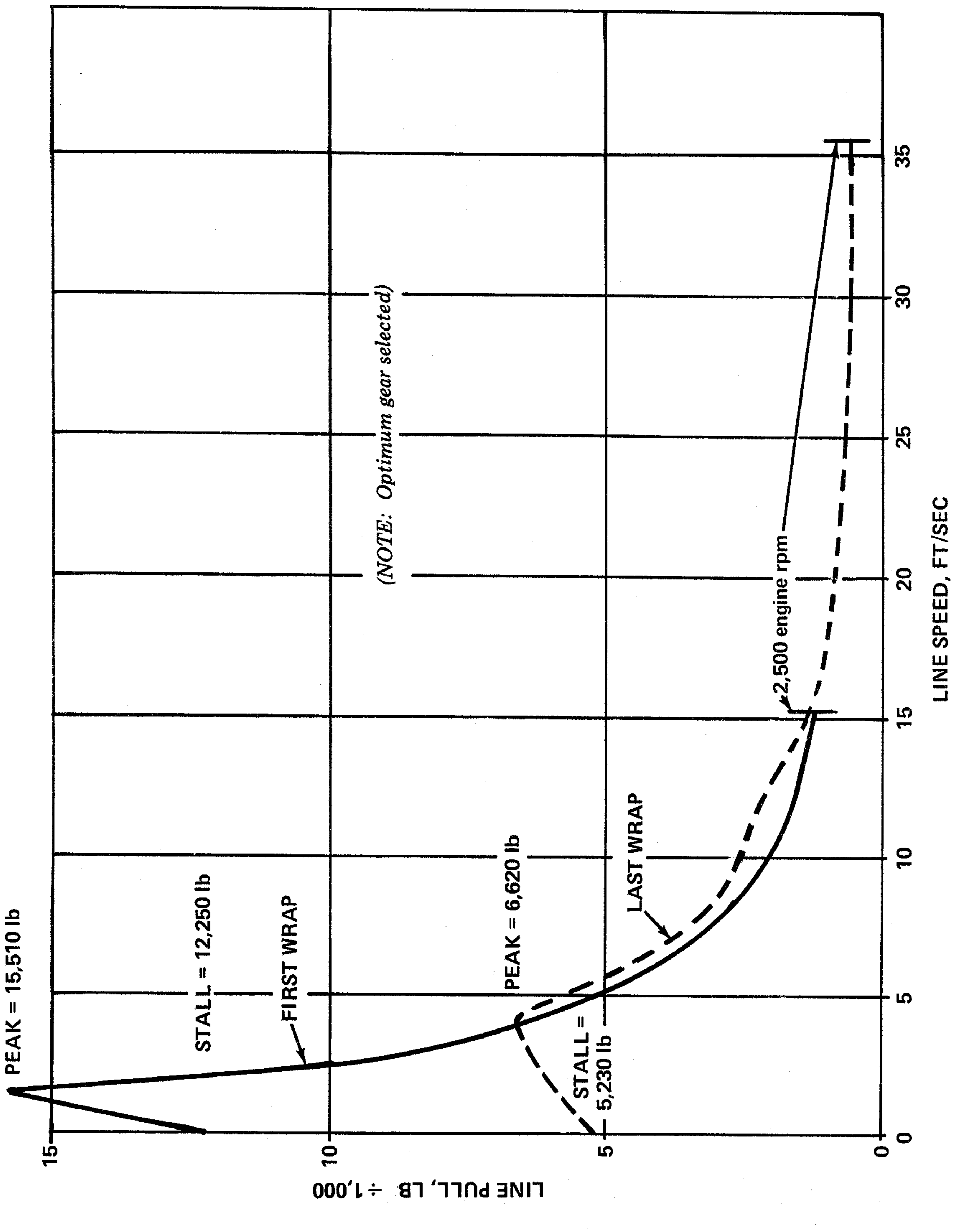
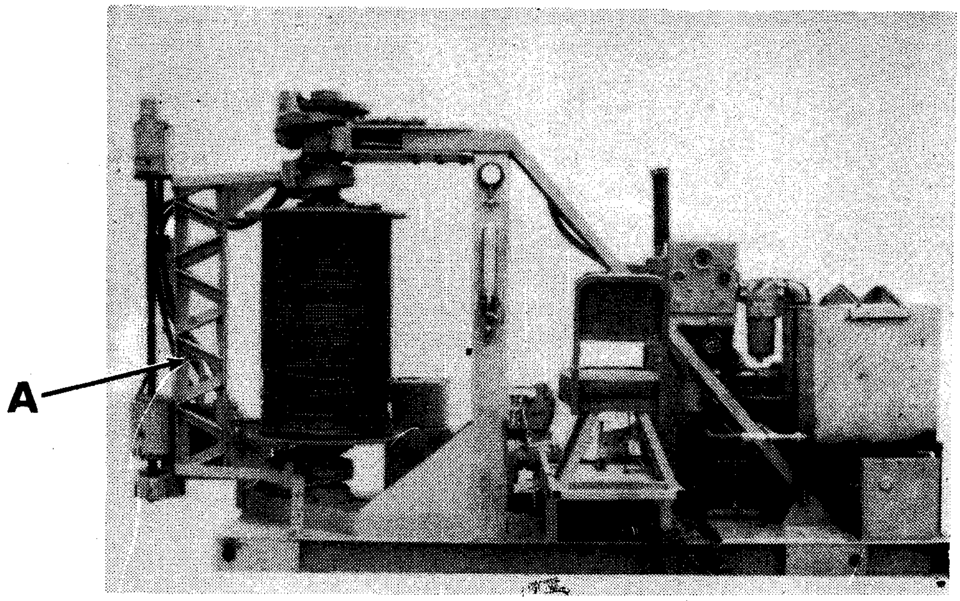
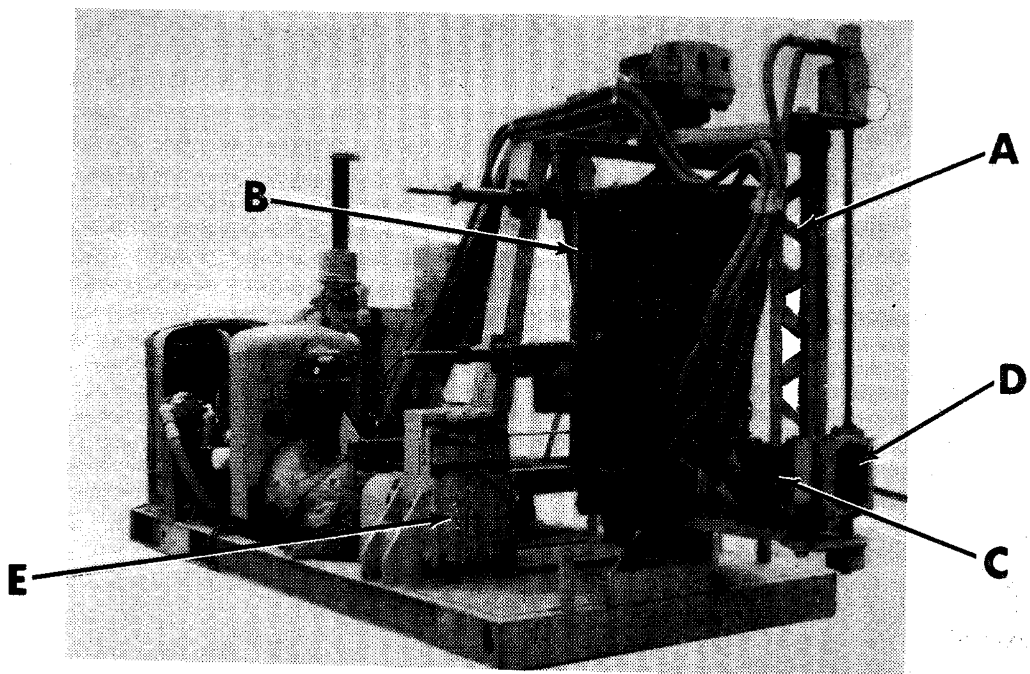


Figure 4. SDEDC tree puller performance.



A. Left side.



B. Rear three-quarter view.

A LEVELWIND ARMS
B SIDE PINCH ROLLER
C SENSING VALVE
D FAIRLEAD
E RIGHT ANGLE DRIVE

Figure 5. SDEDC testbed puller.

TESTS AND RESULTS

Functional Evaluation

A functional evaluation and break-in were performed on the testbed puller in March 1978. The speed-force characteristics, as shown in figure 4, were determined by test. A tensiometer recorded the pull at various speeds. A pickup truck was used as a rolling dynamometer. Peak force at minimum radius is 15,500 pounds. Peak force at maximum working radius is 6,600 pounds. Note that the curves of line pull vs. line speed for minimum and maximum working radius are nearly colinear at operating speeds above the maximum pull. This demonstrates the excellent match between torque converter, transmission, and engine used in this machine.

Levelwind Device

The spring-loaded side pinch roller (*B*, fig. 5B) was adequate at all speeds when the line was under load. The no-load spooling was noted to be somewhat erratic, tending to bunch at the bottom end of the drum. Modifications to the spring rates eliminated this tendency as far as we could tell under all line pull loads in excess of 100 pounds.

Safety Observations

Installed guards were found to be adequate to prevent access to moving parts. A-weighted sound level, as measured by a class 1 sound level meter at the operator's ear, ranged between 85 and 92 dBA during operation. This was low enough so that hearing protection is not required, and no hearing hazard would be expected. The foot brake developed force commensurate with line pull. However, the hand brake design proved inadequate. The master cylinders and the slave cylinder were mismatched, causing inadequate braking force to be developed.

Backlash tendency was observed to be nearly nil in the final configuration at line pulls of about 100 pounds. Under this line pull, the levelwind function was found to function properly at all positions between extreme right and left deflection and at all vertical pull angles of from 0 to 60 degrees.

Cooling

Cooling was found to be adequate under all foreseeable conditions of use and misuse. Hydraulic oil temperatures never exceeded 110° F, engine coolant was maintained near the set point of 180° F, engine oil never exceeded 175° F, and transmission oil never exceeded 155° F during extensive testing.

Field Tests and Observations

After the functional evaluations, the SDEDC testbed puller was loaded on a truck and transported to a logging side on Rosboro Lumber Company land near Finn Rock, Oreg., for a field test. The puller was used in actual operation during several days of tests and observations. Additionally, actual pulls applied to trees to be felled were measured and recorded.

Pull and Line Speed

It was quickly determined that the SDEDC testbed puller did not have sufficient line pull and did have excessive line speed. Thus, it proved impossible to actually pull trees in excess of about 16 inches dBh, even when the trees did not have excessive lean-out from the hill or had assymetrical crowns. At the working radius used, with approximately 3,100 feet of line on the puller, the maximum pull developed was 7,600 pounds. It was estimated by Rosboro experts that pulls in excess of 20,000 pounds are often required on trees of 36 inches diameter and greater.

Since the engine develops torque and horsepower comparable to that developed by engines currently used in successful pulling operations, it appears that a lower overall gear ratio (higher numerically) would remedy this difficulty. Examination of existing machinery reveals that the overall gear ratio of current successful pullers is roughly 3 or 4 times that of the SDEDC testbed.

Levelwind Function and Line Fouling

It became apparent during the test period that most line travel is accomplished under conditions of very light line pull, much less than the 100 pounds used as a minimum during the functional evaluation. During spooling with line loads of less than 100 pounds, there is a marked tendency for the line to fall down and bunch in the lower part of the drum, as shown in figure 6. Also, without at least 100 pounds of line pull, the levelwind sensing device (*C*, fig. 5B) cannot be activated by the running part of the line between the fairlead (*D*, fig. 5B) and the point where the running part begins to wrap around the spool. Once the line falls and bunches, the operation of the fleet angle sensor becomes erratic leading to further unacceptable increases in fleet angle and entangling of the line. Attempts to adjust the pinch roller springs, tension on the springs which regulate the position of the fleet angle sensor, and hydraulic flow rates through the motor, all failed to rectify this problem.

Free Spooling

As mentioned above, the climber must pull off line to reach the tree which is to be uphill pulled. To do this, the drum must free spool. Excessive friction in the drive train prevented manual free spooling with the testbed. Excessive friction was caused by the vertical position of the drum, which caused all of the load to be taken in thrust on the bearings; the additional two bearings upon which the fairlead was mounted; and the fact that the main power flow to the drum is through a two row 1-inch pitch sprocket-chain assembly mounted with the axis of the sprockets vertical. Also, the friction in the right angle drive (*E*, fig. 5B) resists free spooling.

In an attempt to assist the climber in pulling out slack, many trials at placing the transmission of the testbed in reverse and allowing the engine to unspool the drum were made. The climber just could not follow the unspooling of the machine rapidly or consistently enough to prevent serious spool backlash. Since a steady line pull of at least 100 pounds must be applied for the fleet angle sensing device to operate properly, serious tangles resulted.

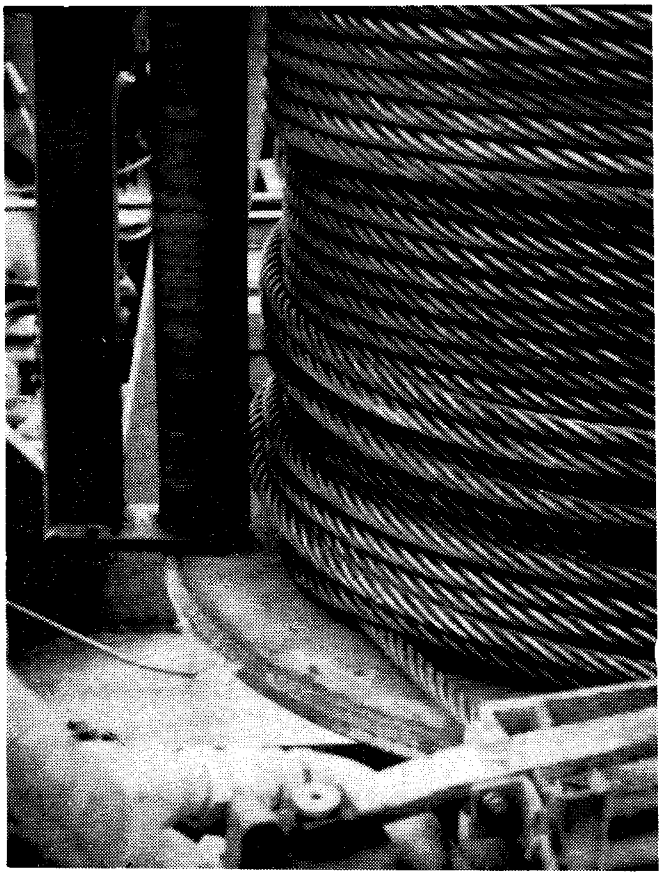


Figure 6. Line bunching at bottom of drum.

Holding Ability

As previously mentioned, a smooth transition from pulling to holding must be made during the uphill pulling operation. Because of slack in the power train, it proved impossible to maintain a steady line pull with the foot brake. This further limited the already insufficient available line pull.

Remote Operation

Interest in remotely operated pullers has waned since SDEDC's initial discussions with logging executives of companies that regularly practice pulling. The continuing escalation of timber prices makes the cost of the puller operator a less significant factor in the overall harvesting cost picture. Further, the added safety of having an experienced operator available at the puller to monitor cable condition on the drum presents significant safety advantages.

Even with the most carefully engineered levelwind and fairlead, the man operating the uphill puller remotely from the stump site could never be absolutely sure of a line hangup or stoppage. If the drum gets pulled even slightly out of lead, the line will pile up next to one flange of the drum. Then during a hard pull, it would fall back down onto the drum leading to excessive slack. An operator at the machine will prevent these failures.

Another consideration is that runaway logs are most effectively played to a stop, in much the same way that a game fish is played to a stop, by the sensitive feel of an operator on the machine. A puller operator remote from the controls would be at a serious disadvantage in attempting to play the log to a stop without the benefit of direct contact with the drum brake.

Finally, the current model SDEDC testbed uphill puller does not solve the main problem faced by loggers currently employing uphill pulling; i.e., difficulty with obtaining a tight spooling during low-load operations. Further work in the area on insuring tight spooling of currently used directional fellers is needed.

CONCLUSIONS

Currently used uphill tree pullers suffer from two major problems: insufficient drum capacity and line tangling under tight load.

The development of a remotely controlled uphill puller based on the SDEDC testbed uphill pulling machinery is not practical at the present time for the following reasons:

1. Difficulties occur with the vertical spool, particularly with regard to free spooling, and with the line bunching under low-load conditions if a puller operator is not present.

2. Safety is increased when an operator is present at the puller at all times.

3. The cost of using a puller operator is no longer a significant expense in a logging operation.

RECOMMENDATIONS

1. A method for insuring tight spooling under low-load conditions should be developed for tree pullers of current design.

2. No further work with the concept of a remotely controlled directional feller should be undertaken at the present time.

If recommendation No. 1 is accepted, it is further recommended that the testbed puller be modified to be similar to the most successful current pullers to test alternative concepts of developing a "tight spooling" device.

GLOSSARY

Brake—The device that slows the rotational speed and absorbs the rotational energy of the drum.

Bucker—A crew member whose job is to cut the felled tree into appropriate length logs.

Climber—The crew member who pulls out the cable, climbs the tree, and attaches it at the appropriate height.

Course—One layer of cable tightly wound upon either the drum core or the layer below it.

Drum—The large spool upon which the pulling cable is wound.

Faller—The crew chief of an uphill pulling crew, who also operates the chain saw used to sever the tree from its stump.

Fleet angle—The angle between the perpendicular to the axis of a drum and the running part of the line being spooled or unspooled.

Friction—The clutch that connects the power from the engine through a gear train to the drum.

Lay—Course (see above). *Tight lay*—The quality of having adjacent wraps of the line immediately next to each other so no space is available for wraps of a course above to wedge between them.

Line—cable; in the case of the SDEDC puller it is 9/16-inch improved plow-steel wire rope.

Logging side—Area where logging is going on.

Running part—The end of the pulling cable which unspools from the drum.

Spool—*n.* drum on which a line or cable is wound.
v. property or action of winding the cable on the spool. Good spooling implies that the line is wound under uniform tension, the lays are even, and no bunching occurs.

Working radius—The distance from the center of the running part of the line where it leaves the drum to the axis of the drum—i.e., the "lever arm distance" for a particular drum configuration.

EQUIPMENT DEVELOPMENT AND TEST

The Forest Service's Equipment Development and Test (ED&T) program, conducted by two Equipment Development Centers (San Dimas, Calif., and Missoula, Mont.), provides systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that meet the objectives of advanced forest management and utilization in the United States. The ED&T effort, featuring Mechanical Engineering activities, encompasses projects in forest engineering, aviation and fire management, recreation, timber, range, wildlife, occupational safety and health, forest insect and disease, and forest residues to enable forest work to be performed more efficiently, at less cost, with minimum hazard.

As needs for field development services are identified and defined, the Centers determine if already available commercial products are suitable as is or if they require modifications necessitated by the forest environment. On the other hand, sometimes needs can only be met by the Centers taking advantage of the latest technology to create new concepts through a step-by-step product development program. These developments are typically achieved by active ED&T involvement with disciplines found throughout the Forest Service. The new equipment is field tested and demonstrated and user feedback is obtained to evaluate results. The role of the Centers is not considered complete until project output is implemented in the field.