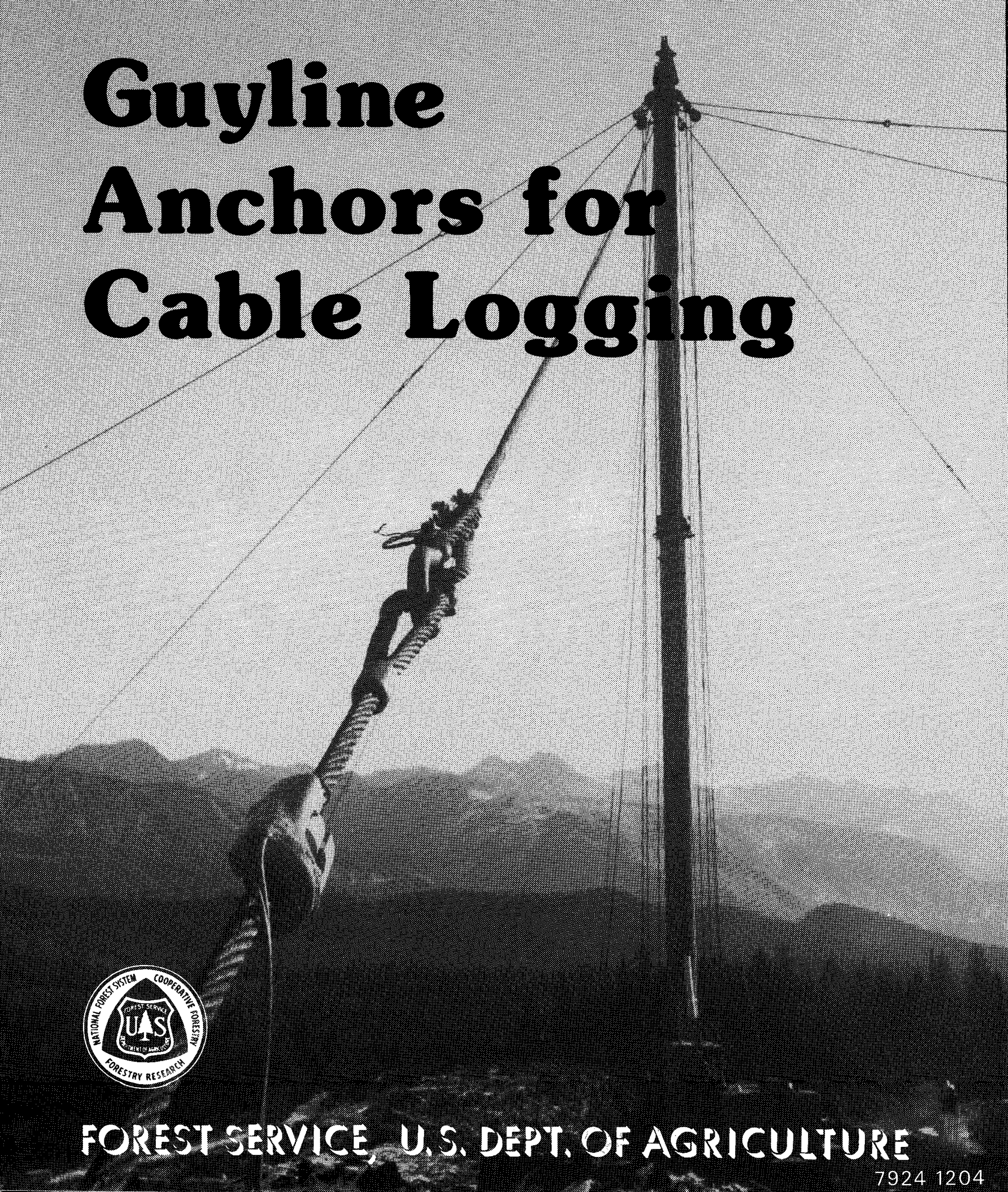
project record
San Dimas Equipment Development Center
JUNE 1979

Guyline Anchors for Cable Logging



FOREST SERVICE, U.S. DEPT. OF AGRICULTURE
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ABSTRACT

Investigations of the static and dynamic behavior of cable logging systems at the anchor, possible substitute anchors, and an early warning anchor failure detection system were conducted. Data were gathered to improve logging site safety and efficiency through man-made substitute anchors and effective anchor failure warning systems.

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GUYLINE ANCHORS FOR CABLE LOGGING

by

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and

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ED&T Project No. 2640
Substitute Anchors for Cable Transport Systems

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INTRODUCTION

Yarding logs with cables began in about the year 1900 and has become a prime method of harvesting timber. Skyline logging was "sold" to the timber industry, governmental agencies, and the general public as a means of timber harvesting that would reduce the adverse impacts often associated with conventional logging systems. Less road construction, soil and watershed disturbance, damage to residual timber, and adverse visual impacts were promoted as beneficial aspects of skyline logging.

To work safely and efficiently, a cable logging system must be anchored. For many years timber harvests were conducted in areas of old growth where large stumps were available; these stumps proved to be satisfactory anchors. Then harvesting progressed into areas where large, undecayed stumps were not always available—such as cutover second-growth plantations and nontimbered ridges. Anchoring in these areas became dependent on something other than stumps.

Extensive study has been conducted during the last 10 years by the forestry industry on substitute anchors. Several systems have been developed and are presently in use. However, with concern growing as a result of Occupational Safety and Health Administration programs, some of the assumptions which have been made as to the reliability of certain of these substitute anchors have to be validated. The San Dimas Equipment Development Center (SDEDC) was given the assignment to come up with alternative anchors to be used to support the skyline system and also to develop an early warning detection system for anchor failures.

Man-made anchors (such as rock bolt, deadman, picket, screw, and plate) have been devised. These are basically designed for static-load conditions, and cable logging by nature introduces dynamic loads. Engineering mechanics and geometry can describe static loads in cables; however, little is known about their dynamic behavior in logging operations. Before attempting to make broad-scale application of substitute anchors, there was a need to determine the magnitude and duration of dynamic loads in the cables and also the static and dynamic behavior of skyline logging guyline cable systems at the anchor.

The information to be gathered would aid in establishing design criteria and construction and installation techniques. To obtain the information, an operational skyline logging system had to be instrumented and tests conducted in conjunction with normal operations. Properly applied, the obtained information will help meet the occupational safety and health requirements of local, State, and Federal regulations.

The final portion of this effort focused on the development of a reliable, inexpensive detection system to provide the yarder operator with a warning of potential failure of an anchor, thus preventing possible injury to personnel or damage to equipment. This, of the tasks undertaken, is by far the most involved. Previous efforts by aerospace firms resulted in the development of hardware for motion detection—including a biaxial tiltmeter that detects tilting in both the X- and Y-planes of the plates that compose the earth's crust.

Using the biaxial tiltmeter as the detection mechanism, with associated signal-conditioning equipment and integrated circuitry to provide a warning (horn, light, etc.) to the operator, SDEDC is developing an anchor failure detection/warning system. The greatest difficulty SDEDC personnel have encountered is filtering out extraneous signals received by the detection system from the yarder, trucks, crawler tractors, and other pieces of equipment.

GUYLINE ANCHOR STATIC AND DYNAMIC BEHAVIOR

SDEDC conducted tests to determine the static and dynamic behavior of skyline logging guyline cable systems at the anchor. The primary objective was to record guyline loads experienced during typical logging operations. Load cells were inserted in the guylines to gather these data (fig. 1 and photograph on cover). A secondary objective was to establish useful information for dynamic behavior analyses that would lead to a better understanding of all cable logging systems. To accomplish this, several tests (discussed in the six subsections that follow) were undertaken to determine anchor reactions under various conditions.

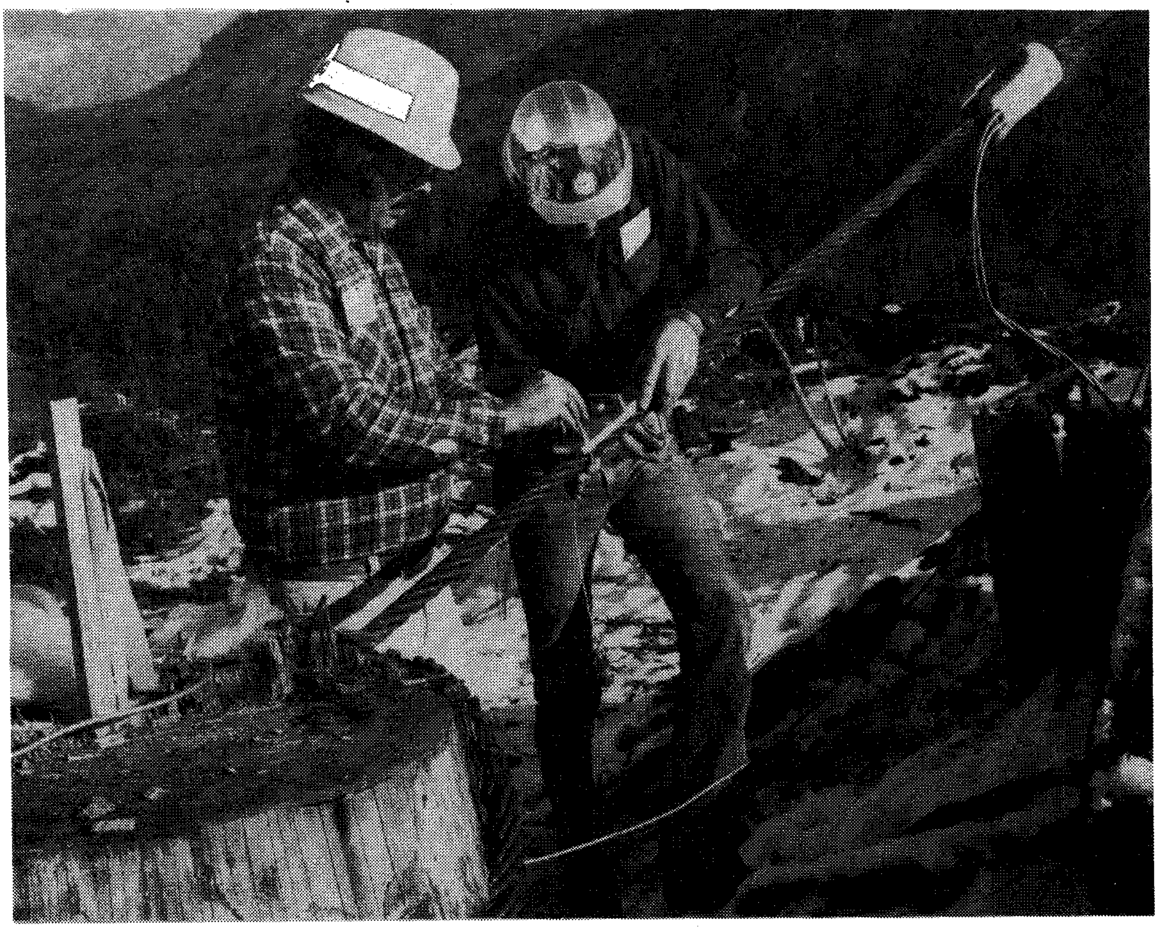

Figure 1. Guyline instrumentation installation.

Guyline Static Tension

This test measured stump movement by adjusting mainline and skyline tensions. The guyline pretensioning was in the usual manner and accelerometers and load cells were attached to two guylines. A log of known weight was picked up and the carriage moved into the test position. The system was then loaded by tensioning the mainline and the skyline to a range of tensions which had been determined through previous testing.

While all this was proceeding, data were being recorded as to guyline tension, stump and tower displacement, and carriage transferral. Maximum stump displacement (0.5 in, 1.27 cm) was recorded at a guyline stress that was in the mid-30,000-lb (13 600-kg) range. Since stump motion was minimal and permanent displacement of the stump was not detected, the effects of static guyline tensioning was well within the range of the cable and guyline absorption characteristics of the stump.

Guyline Vibration Transfer

This test measured dynamic responses at the stump as a result of the guyline being subjected to transverse perturbations. The guyline was pretensioned, then a lateral force was introduced into the guyline. A tethered sideload was attached and the tether was cut, permitting the guyline to swing freely until all the energy introduced had dampened.

This test pointed out an interesting characteristic of transferred energy in a tower guyline system that can occur between guylines. When energy is imparted to one guyline, it is systematically dampened by that guyline, while at the same time it is transmitted onto the next guyline in a clockwise direction. This force is subsequently transmitted throughout all guylines until it is completely dampened.

Stump Impact Test

This test measured the response of a stump subjected to an impact load and determined the dampening characteristics of a stump as an anchor, which is of major importance in anchor dynamics. A known mass adjacent to the stump was suspended and drawn back, allowing it to swing free and impact the stump. The lack of stump motion somewhat detracted from the test; however, the test provided excellent information to check the plastic properties of a guyline.

Sudden Load Response

This test measured the reaction of the guyline system to a sudden load created in the operating lines. A log of known weight was suspended below the carriage and above the ground—then the mainline was released, allowing the log and carriage to accelerate down the skyline. The mainline brake was applied very quickly, bringing the load to a sudden stop. Data on the rebound and subsequent load distribution to the individual guylines were recorded.

This was the most severe of all tests conducted. A rebound of 10 to 30 ft (3.05 to 9.14 m) of the suspended load resulted in tensions ranging from 30 to 110 percent variance applied to the skyline. The resulting forces transmitted to the guylines and stumps were within the ranges of the cable and the absorption characteristics of the stumps.

Yarding Sequence

This test measured responses to a yarding sequence consisting of three phases:

1. Load fully suspended above the ground

2. Load partially suspended, the trailing end of the log contacting the ground

3. Full length of log in ground contact.

The results for phases 1 and 3 ranged near 20,000 lb (9 070 kg) in each of the guylines, with a fluctuation of less than ± 5 percent. In phase 2, the tension reached a level in the mid-40,000-lb (18 150-kg) range as the log bounced along. Stump deflection was in the 0.5- to 0.75-inch (1.27- to 1.91-cm) range. Each time the stump returned to its original position, indicating that the stump was still intact.

Yarding Sequence with Hangups

The objective here was to measure the response to a common operational occurrence—yarding into a hangup, which abruptly stops the load. So as not to damage the yarding system with an actual hangup and cause possible system failure, the log was suspended above the ground by attaching a 5/8-in (1.59-cm) choker cable to the lower end of the suspended log. This choker cable was then attached to a stump in the skyline corridor. As the carriage was moved forward, the choker cable would tighten and the mainline would continue on until the choker cable failed. The dynamic response to the hangup test is very similar to the sudden load test in that both represent the reaction of a fast or "impulsive" tension loading.

Results and Conclusions

The dynamic data collected on both the transverse vibration and on the sudden-load test are an excellent source for determining skyline dynamics. In particular, the transfer of vibration tests provides a means for field checking. The loads transmitted to the stump appear to be within the range of known data on man-made anchors.

SUBSTITUTE ANCHOR DEVELOPMENT

An object placed into the soil or rock becomes an anchor and the quality of that anchor is its difficulty or resistance to removal. Anchors come in two basic types: soil and rock. The state-of-the-art in rock-type anchors is well established and they have been used extensively in Europe; however, in most parts of the United States the availability of ideally located rock masses for rock-bolt anchors is limited, so efforts have been with soil-type anchors.

The strength of different soils and the problems of getting anchors into the different soils result in a variety of anchors. The following synopsizes four existing soil- (or earth-) anchor types.

Deadman

This is a large mass (log, concrete block, or other object) buried within the earth with a tension line attached (figs. 2 and 3). Its holding characteristics depend on the frontal area of the mass and the amount and type of soil above and in front of the anchor. Installation is difficult because of the amount of excavation required; these anchors are not suitable for shallow soils. Retrieval is normally not attempted, since excavation is required and costs are prohibitive.

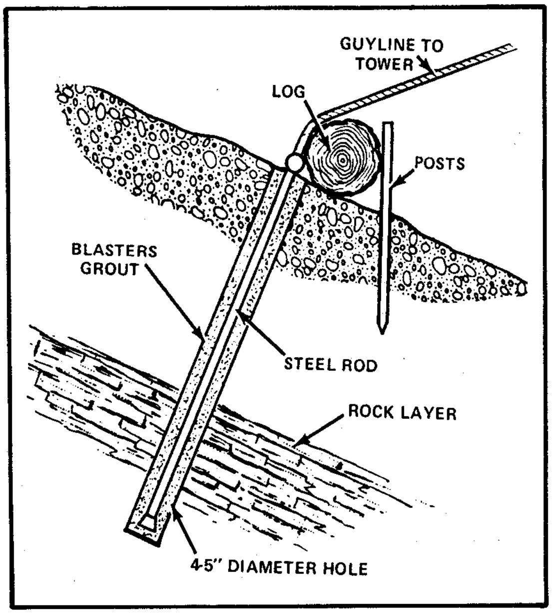

Figure 2. Concrete pile earth anchor.

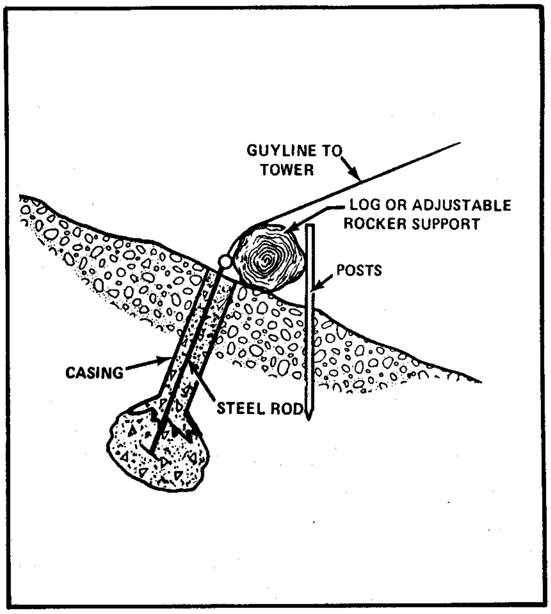

Figure 3. Raymond monotube pile earth anchor.

Pickets

In this approach, stake(s) are driven into the ground and a load line is attached at the ground level (fig. 4). A picket system can be reinforced by installation of additional pickets rearward from the initial picket with tiebacks attached. The method is excellent in firm and stony or shallow soils. Recovery of pickets is possible without elaborate equipment or great cost.

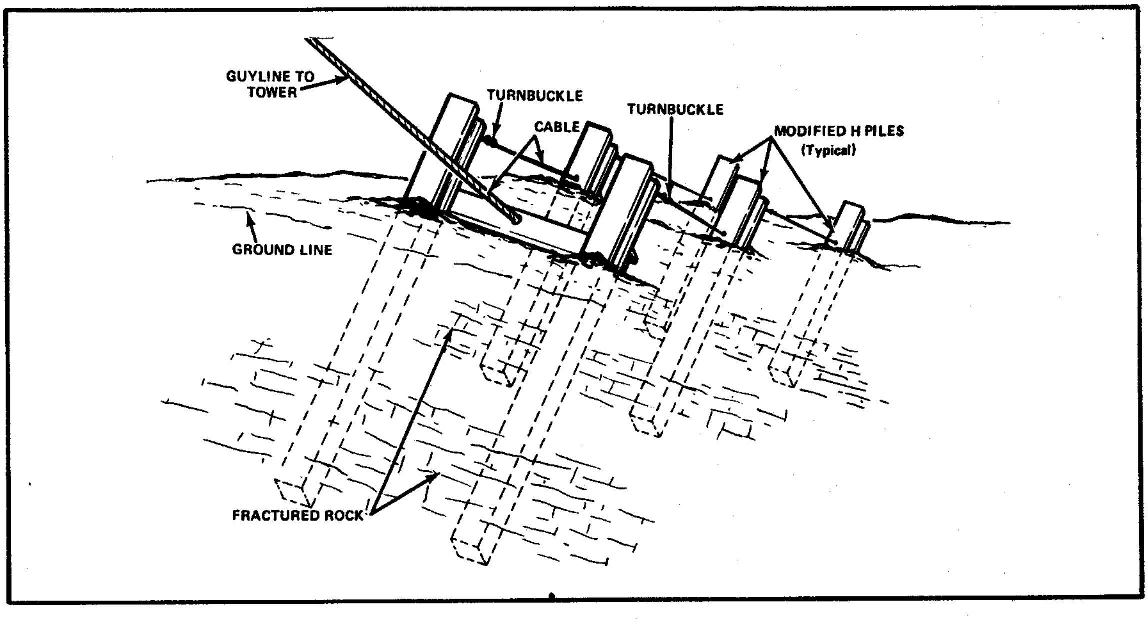

Figure 4. Multipicket anchor system.

Screw Anchors

These are metal rods with an eye at one end and an auger plate (or helix) at the other (fig. 5). They are installed by applying downforce and torque as they embed themselves until the eye is at ground line. They are especially suited for heavy soils. Retrieval is normally not attempted, since excavation is required.

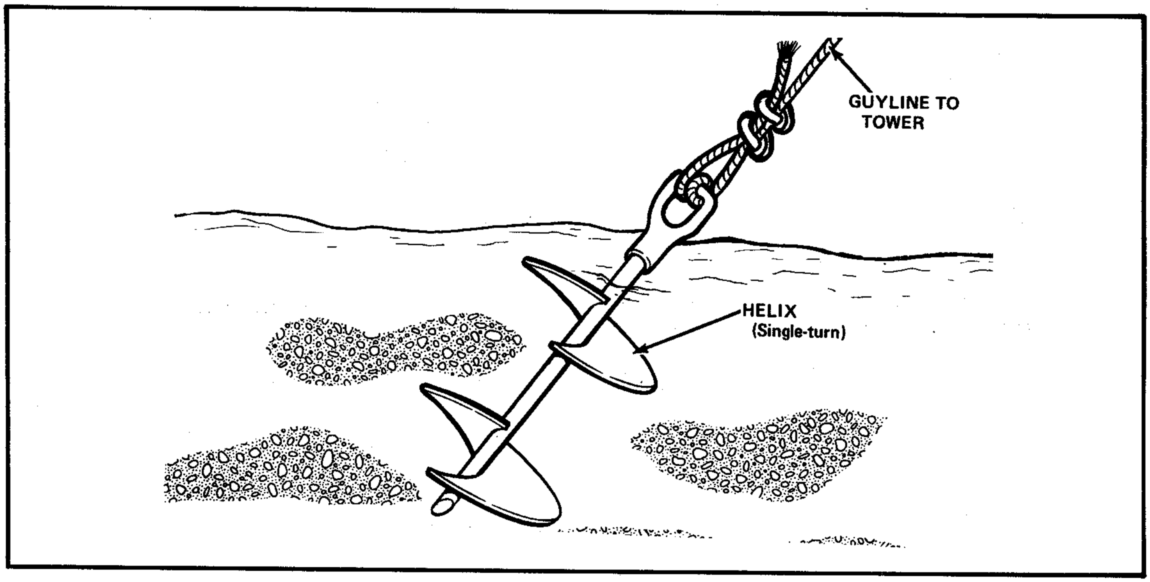

Figure 5. Screw anchor.

Plate Anchors (or Flukes)

These are single or hinged multiplates, driven edgewise into the soil, that turn or open up to present a large resistance area when withdrawal is attempted (figs. 6 and 7). These anchors are especially suited to soil without a large amount of rock. Recovery is normally not attempted, since excavation is required.

Embedment vs. Recovery Force

With the exception of the deadman anchors, all of the earth anchors require a driving or embedment force. The embedment force required is normally a function of the frontal area of the anchor as it relates to the cohesion characteristics of the material into which it is being driven. On the other hand, recovery efforts are related to characteristics of the soil in which the anchor is embedded. The factors affecting the recovery force depend upon the viscous and frictional soil properties–which are related to water content. Short- and long-term static and repeated loads have differing effects on different soils, depending upon the pore pressure generated by fluid escapement. When the soil mass has been determined, weight and shear stress on the exterior of the mass can be calculated and summed to yield the required recovery force.

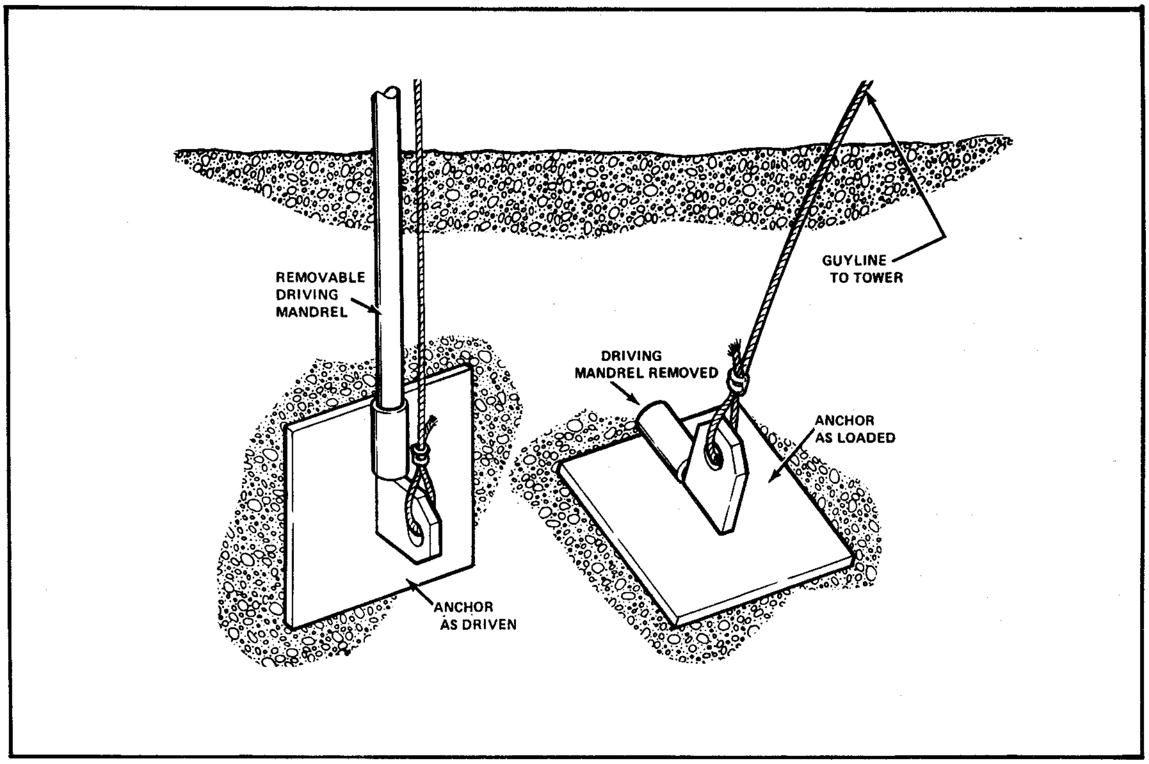

Figure 6. Plate anchor installation.

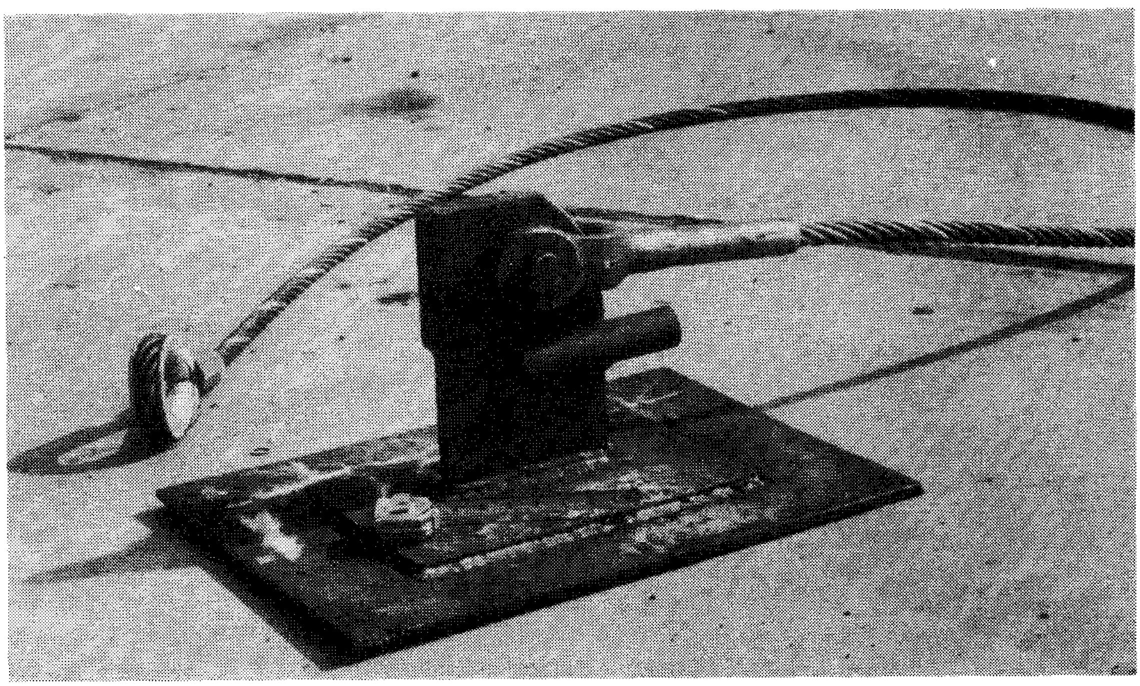

Figure 7. Plate anchor.

Results and Conclusions

Testing has established that the ratio of embedment-to-recovery force ranges up to 1:5. Larger ratios provide a more satisfactory holding power characteristic. For this reason, efforts are being made to work extensively with plate anchors, since they can be installed with a vibratory impact hammer. The size of anchor to be used is affected only by the size of available hammers and soil characteristics.

EARLY WARNING ANCHOR FAILURE DETECTION SYSTEM

An Autonetic electrolytic level detector (biaxial tiltmeter) has been utilized as the primary level reference on inertial navigation systems for ballistic missiles. Its simple construction, reliability, and small size lead to its evaluation as a level detector in other fields–including the geophysical applications related to the need for detection of the movement of anchors in a skyline logging system.

The proposed early warning system consists of sensor(s), power supply, electronic package, and operator warning system. The sensor is approximately 1-in (2.54-cm) in diameter and 0.75-in (1.91-cm) thick, and is mounted in a three-legged tilt table (fig. 8). The tilt table serves to level and zero the sensor during setup and calibration.

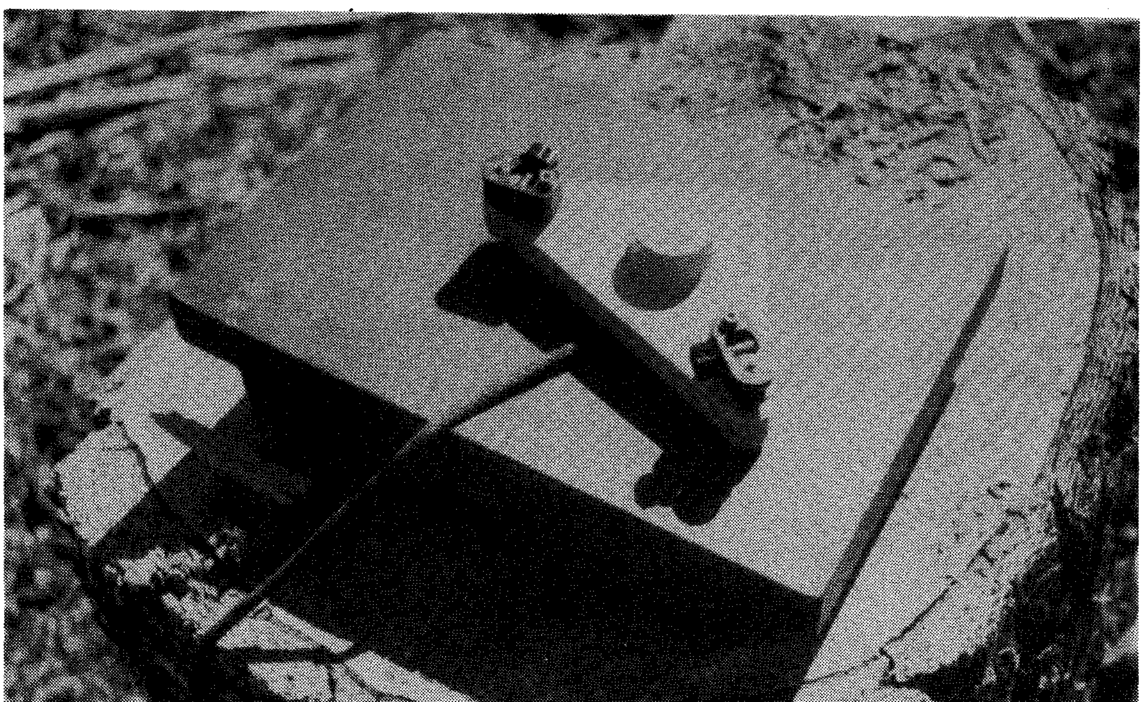

Figure 8. Biaxial tiltmeter sensor.

Instrumentation

The power supply (12-v dc for remote operations or 115-v ac when available) provides energy to operate the sensor(s) and the associated electronic package. The electronic package (fig. 9) was used as data-gathering test instrumentation to condition the signal from the sensor(s) and compare it to preset parameters. If the parameters are exceeded, a warning is automatically relayed to the yarder operator, who discontinues yarding until the suspect anchor(s) can be inspected.

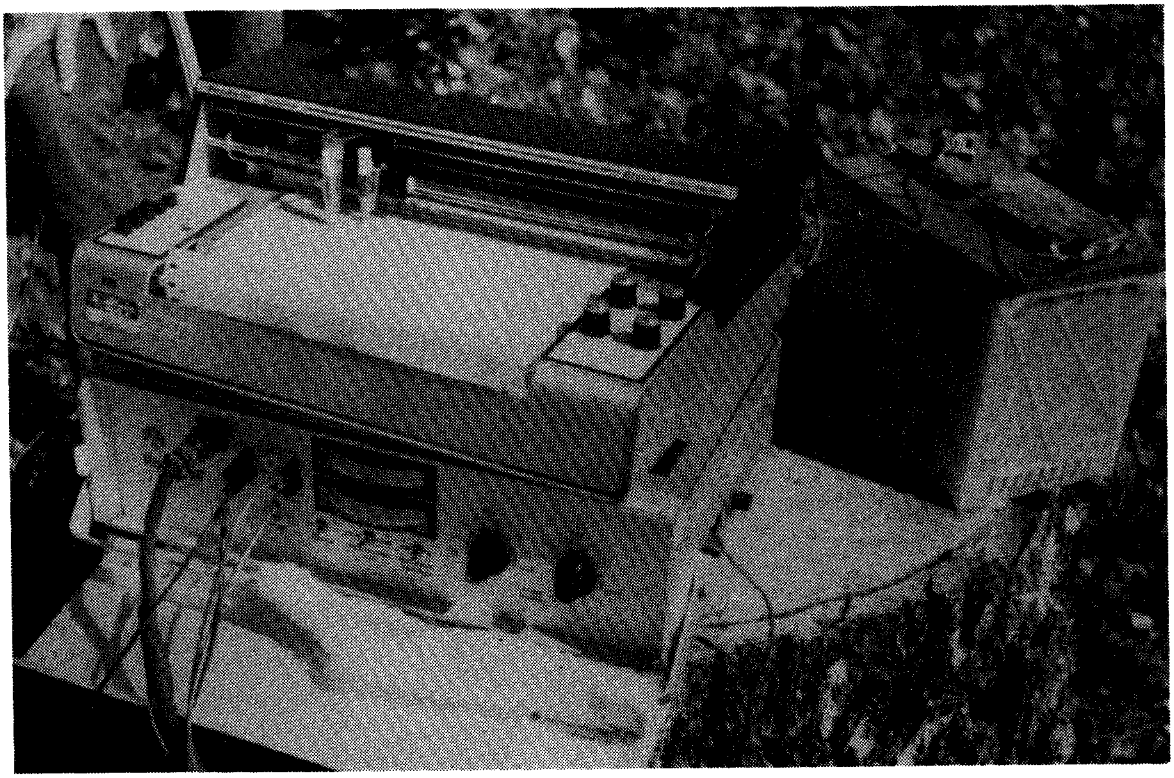

Figure 9. Electronic instrumentation package.

The sensitivity of the system (1/1000 of an arc second) is such that, assuming New York and San Francisco are on the same plane 3,000 mi (4 800 km) apart and a silver dollar is placed on end under New York, a sensor located in San Francisco would register the tilt caused by the 2-in (9.1-cm) lift given to New York. With this high level of sensitivity, anchor motion will be detectable.

Results and Conclusions

The preliminary evaluation of the sensor(s) at logging sites indicate concept feasibility. The electronic package for signal conditioning and filtering is nearly perfected and will undergo field testing during 1979. Efforts are underway to simplify the system even further, thus reducing its cost.

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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.