a TREETOP TRAMWAY SYSTEM for meteorological studies

by Raymond E. Leonard
and Arthur R. Eschner

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TREETOP TRAMWAY SYSTEM

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The Authors

RAYMOND E. LEONARD, meteorologist, received his Bachelor's degree from the University of Vermont, Master's degrees from both the University of Helsinki and Yale University, and his Ph.D. degree from Syracuse University. After employment with the Vermont Forest Service and the University of Vermont, he joined the U. S. Forest Service's Northeastern Forest Experiment Station in 1957 at the Hubbard Brook watershed unit in New Hampshire. He is now project leader of the Station's cooperative watershed management research unit at the New York State College of Forestry at Syracuse University, Syracuse, N. Y.

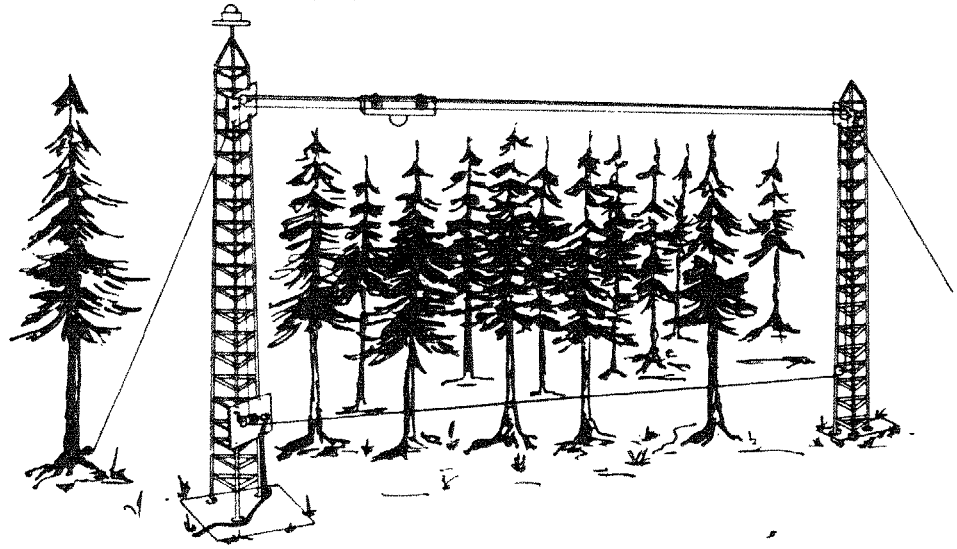
ARTHUR R. ESCHNER, associate professor of forest influences at the New York State College of Forestry at Syracuse University, received his Bachelor's and Ph.D. degrees from the New York State College of Forestry and his Master's degree from Iowa State College. He worked for the U. S. Forest Service from 1953 to 1964 in the Northeastern Forest Experiment Station at Kingston, Pa., Parsons, W. Va., and Syracuse, N. Y.

TO GET ABOVE THE TREETOPS

IN A RECENT STUDY of the solar radiation reflected by a red pine canopy, one of the first problems we had to solve was how to position measuring devices above the tree canopy. We considered two alternatives. Should we erect a number of towers or masts at various locations to hold radiation-measuring devices above the stand? Or should we erect a few towers and run a system of tramways among them so that the instruments could be moved around to different positions above the tree canopy?

The tramway system appeared to be less expensive; so we devised a system consisting of three 70-foot towers and two 100-foot tramways. This system, constructed at a cost of about $1,000 for materials, has been operated successfully for more than a year (fig. 1). Because of the ease of construction and the relatively low cost, other research workers might be interested in such a system.

Figure 1.—The tramway system consists of two towers with tramway cables between them. Instruments may be moved across the tramway to sample spatial variation in radiation, temperature, or other meteorological variables.



CONSTRUCTION

Towers

The towers we used to support the ends of the aerial tramway were of the type commonly used to hold television antennae. These are available through the major TV supply stores. Each section of the triangular steel tower is about 12 inches on a side and 10 feet long, and weighs around 35 pounds. A section can be handled easily by one man.

The base of the tower may be embedded in a section of concrete (3x3x3 feet) for permanent installation. For temporary installation the base section may be placed in a hole 2 or 3 feet deep, the bottom of which has a firm base of rock or concrete blocks. It is advisable to coat about 3 feet of the bottom section of the tower with tar or similar material before setting it in place. The hole is then refilled and tamped well. We used a carpenter's level to insure that the first section was plumb.

After the bottom section is firmly in place, the other sections are hoisted up; the three legs are slipped over the top of the previous section, and the two sections are bolted in place. We found that two men using standard lineman's safety belts could slip the two sections together without difficulty. However, an erection boom is commercially available to facilitate the hoisting and placement of the sections.

Steel guy cables should be attached at about 20-foot intervals on the tower. We found that 1/8-inch fiber-core steel cable was adequate for our purpose. Anchors for the cables should be placed at a considerable distance out from the base of the tower so the angle of the guy cable is a minimum of 60 degrees from vertical. A variety of anchoring systems may be used, including a concrete slab, commercial pole anchors, or tree stumps. We have found that a ½-inch diameter screw eye embedded in a sound tree stump as low as possible is satisfactory for our purposes.

Attachment of the guy cables to the tower and ground anchor follow standard procedures. Wire-rope thimbles should be used on all cable eyes. Two cable clamps, spaced 3 to 4 inches apart, were used to secure the cable eyes. Turnbuckles may be used to tighten the guy cables; however, we found it a simple task to take up the slack in the cable with a light block and tackle.

We used slightly slack guys. Our experience has been that at least 6 to 8 inches of slack per 100 feet of guy cable is preferred. Tree limbs and small trees may push against the guy cables during periods of high wind and cause considerable damage to the tower if the guy cables are stretched too taut.

One of the more frustrating problems in tower construction in the forest is to pass guy wires from the tower through the tree crowns at an angle to the ground. We tried several methods. We found that attaching a light line to a 6- or 8-foot pole and throwing it like a javelin down through the canopy worked fairly well. The light line was then used to pull the guy cable up to the tower. A bow and arrow equipped with a fishing reel might also work well. Guy cables were first attached to the tower and then were secured at the ground anchor and tightened. Three cables were used at each 20-foot guying level.

Tramway

To sample variation in reflected solar radiation above the canopy, an instrument must be placed in a stable level position above the canopy. Therefore the prerequisite of a good tramway system is to allow the instrument to move and yet hold the instrument in a level position.

To fasten the tramways to the towers, backing boards of ¾-inch exterior-grade plywood were attached to the towers at the desired height (fig. 2). Four U-bolts (¼ x 2 x 3½ inches) were used to secure each backing board to the inside legs of the tower.

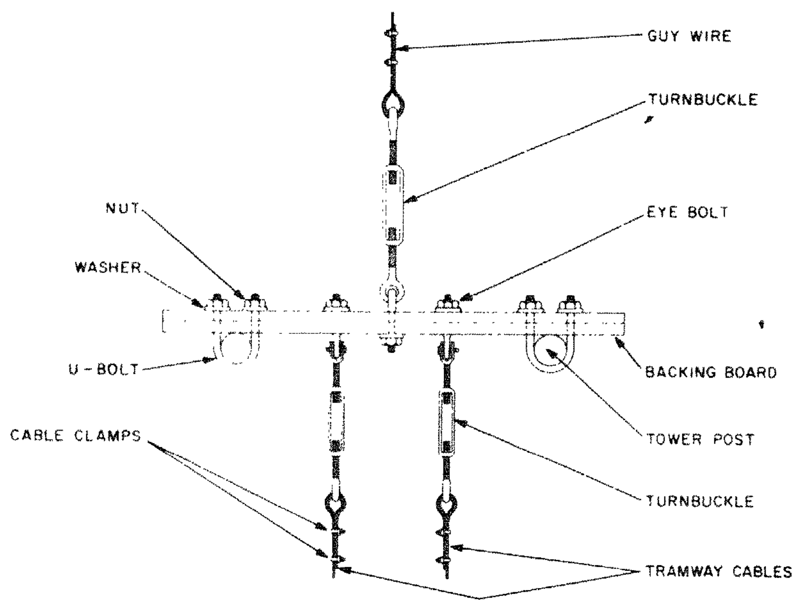


Figure 2.—Tramway cables were attached to the tower at a special backing board as shown in this construction drawing.

To secure the tramway cables to the backing board, two eyebolts (3/8 x 3 inches, drop-forged galvanized steel) were fastened to the face of each backing board, 6 inches apart in a horizontal line. A third eyebolt of the same size was set through the other side of the backing board, midway between the other two, for a guy line. The guy lines were needed here to take up the added strain that the tramways put on the tower.

For the tramway cables we used aircraft-grade steel cable (1/8-inch). To rig the cables to the backing board, we passed the cable end through the eye bolt, with a steel rope thimble, formed an eye in the cable around the thimble, and secured the free end of the cable to the standing end with two cable clamps spaced about 2 inches apart.

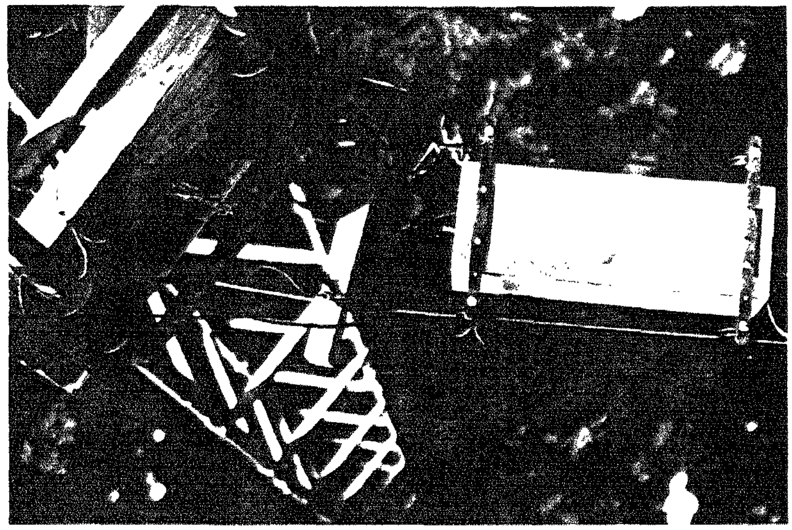
The guy cables to the backing board were rigged the same way. The other end of the guy cable was led to the ground at an angle of about 45 degrees and was secured to a convenient tree stump or was anchored to a deadman in the ground.

After the tramway cables were attached to one tower, they were led over to the other tower and were pulled taut with block and tackle. The cables were then secured to the other tower, to 6-inch turnbuckles (backed off 80 percent) secured to the eyebolts. The cables were then adjusted with the turnbuckles.

This was done by sighting along the tramway with a level and tightening the turnbuckles until the cable sag was less than 2 inches in the middle of the tramway. As the tramway cables were tightened, guy-cable turnbuckles were also adjusted to keep the tower plumb. Tower position was checked with a carpenter's level on the backing board. Final adjustment was made by placing an instrument equipped with a level bubble in the middle of the tramway and sighting on the bubble with binoculars.

A small tramway cart was built to hold the Kipp-Zonen solarimeter used in our studies. The cart consisted of a light-weight housing mounted on four flanged wheels that rode the tramway cables (fig. 3). The sensing unit of the solarimeter faced the tree canopy to measure reflected radiation.

Figure 3.—Looking down on the instrument housing and end of the tramway from the upper portion of the tower.



OPERATION

Hand Winch

With the towers up and the tramway in place, some method was needed to move the instrument car along the tramway. Several systems were tried, and we finally settled on a system involving an endless cable and winch. A simple crank-operated drum winch with a cylinder 8 inches in diameter was constructed of scrap materials. The crank was fabricated with 1-inch diameter copper pipe and elbows. Flat copper flanges were bolted on each end of the drum, and the copper pipe was soldered in place. The entire winch must be securely located, either bolted to a bench or to a post driven in the ground. We located the winch on a bench in a field laboratory a short distance from the base of one of the towers.

A light steel cable, 1/16 inch in diameter, was passed around the drum and then fed through pulleys attached to each tower so that the haulback cable traversed from the instrument bench over to the base of the more distant tower, up the outside of the tower, then along between the tramway cables to the opposite tower, down the tower leg, and finally back to the instrument bench. A minimum of six pulleys was used; more might be required to position the cable correctly on the drum. All pulleys, like those used on motorboat steering mechanisms, were plastic, 3 inches in diameter.

The haulback cable had to be kept taut at all times to avoid slippage on the drum. This was accomplished by placing a heavy-duty door spring, 12 inches long, between the pulleys at the base of the towers and the point of attachment on the tower. The cable was pulled taut with block and tackle and secured with two cable clips.

To put the system in operation, we placed the instrument at one end of the tramway and turned the drum so that the haulback cable was attached to the instrument at the cable clip splice. When the instrument was attached to the cable at this point, turning the winch crank moved the instrument to any desired location on the tramway (fig. 4).

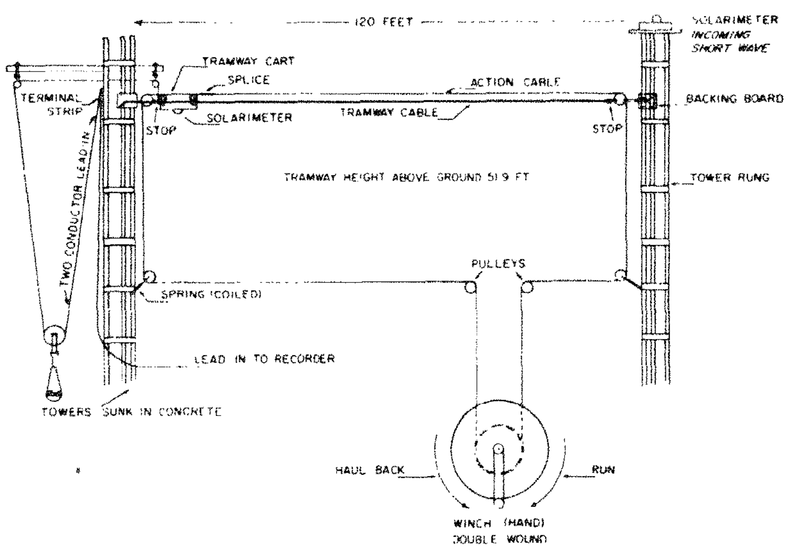


Figure 4.—A crank-operated drum winch may be used to move the instruments along the tramway.

Power Winch

To eliminate the inconsistent speed of hand-operated winches, we built a power winch from a ½-inch electric drill and a light boat winch. The lower of two gear ratios (4.1:1) was used. The handle was removed from the boat winch and a ½-inch hardened steel rod about 3 inches long was inserted into the drill chuck. A ½-inch flexible coupling was used to connect the drill and winch.

This power winch was then firmly attached to a double thickness of ¾-inch plywood mounted on a tower (fig. 5).

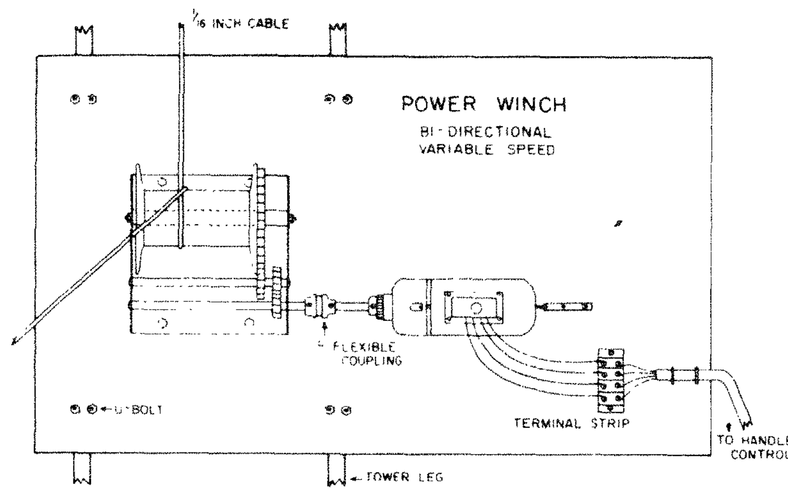


Figure 5.—A power winch built from a 1/2-inch electric drill and a light boat winch was used to move the instruments along the tramway.

A 20-foot extension wire was inserted between the drill motor and handle. This made it possible to keep the drill handle at the workbench while the winch was attached to the tower. The forward and reverse switch on the handle allowed the necessary directional run of the tramway.

The original diameter of the winch drum — about 1 inch — was too small to give the necessary speed. So we wound the winch drum with wire, and about four layers of electrical tape over the wire, to build up the circumference to 12 inches. This gave the desired speed range.

A variac (variable auto transformer) was used between the 115-volt power line and the drill handle. This allowed the operator to vary the line voltage to the drill from about 20 volts to 120 volts and in turn vary the rate of speed of the cart as desired. With the 12-inch drum circumference, 4.1:1 gear ratio, and the variable voltage to the drill, we could run the tramway cart from tower to tower at rates of less than 1 minute to more than 10 minutes.

The electrical tape wrapping, coupled with a one and one-half lap of the tramway cable on the winch drum, permitted the cable to slip if the cart was accidentally run up against the stop at either end of the tramway. This protected the cart and solarimeter from damage. The tension of the tramway cable and the friction of the electrical tape prevented slippage under normal operating conditions.

When first put into operation, the power winch interfered with the accuracy of the millivolt recorder. This effect was more prominent when the drill was first started for a run. The large number of instruments being powered by the single line electrical line to the workbench caused a drop in voltage to the recorder. In addition, the highly sensitive millivolt recorder, when recording on 1 mv full scale, may have picked up radio waves produced by the armature and brushes of the drill.

The problem was partially solved when a second electrical line was brought to the workbench, with only the variac connected to it. This situation can also be relieved by the use of copper screen encasing the d.c. motor. This will filter out most of the d.c. interference. The radio waves apparently decreased sufficiently after more use of the drill so as not to affect the recorder.

A second power winch was built for the other tramway. The bearings of the boat winches were not designed for the frequent use at the relatively high speeds to which we subjected them. However, we believe that they will last for more than 1 year with frequent lubrication.

Recorder Hook-up

To read the output of the instrument on the tramway, we set up a system for running a two-conductor electric cable from the instrument bench to the tramway. The cable ended at a terminal strip located at the end of the tramway. A light two-conductor cable was run from the terminal strip to the instrument on the tramway. The wire was long enough to cover the entire distance between the two towers.

One end of this lead wire was attached to the terminal strip on the tower and clamped securely to the tower leg. The lead-in wire was then passed through a 6-inch-diameter weighted pulley that was free to move up and down the tower, keeping the lead wire taut. The wire then passed through a 3-inch-diameter pulley, attached between the tramway cable at a distance 1 foot out from the tower, and terminated at the instrument on the tramway (fig. 4). As the instrument moved out along the tramway the weighted pulley moved up the tower, keeping the lead wire at sufficient tension to eliminate disturbance of the field of measurement.

DISCUSSION

Although this system was designed primarily for sampling spatial variation in reflected shortwave radiation, it should be suitable for measuring several other meteorological variables such as net radiation or surface temperature.

Our experience with this system of cable tramways has been good. Two tramways have been in operation for over a year under all weather conditions without major problems.

The cost of this system is relatively low: metal tower sections were purchased at about $2.00 per lineal foot, and cable and wire are widely available and cost between 4 and 60 cents per foot. Construction costs were also favorable. Two men can erect two towers to a height of 70 or 80 feet and string the tramway in about 2 days without any outside equipment.

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