NORTH CENTRAL FOREST EXPERIMENT STATION 1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.
Research Note NC-304
1983

AN ELECTRONIC TIMER FOR MEASURING SPREAD RATES OF WILDLAND FIRES

Richard W. Blank, *Biological Laboratory Technician*
and **Albert J. Simard**, *Principal Research Forester*
East Lansing, Michigan

ABSTRACT.—There are many disadvantages to current techniques for measuring the spread rate of wildland fires. This paper describes the design and use of an electronic timer that resolves most of the problems. The unit is small, lightweight, inexpensive, easy-to-assemble, self-contained, and long-running.

KEY WORDS: Sampling, prescribed burning, small, inexpensive, self-contained.

Knowing the rate of spread of wildland fires is fundamental to planning and conducting a broad spectrum of fire management activities. Rate and direction of fire spread are highly variable, however, both temporally and spatially. Measurements are further complicated by the smoke and heat of a fire environment.

Current techniques for measuring rate of spread can be grouped into three classes: visual, mechanical, and electrical. Visual observations (including photographs) are constrained by two needs: to see what is happening and to observe from a safe position. As a result, sample plots cannot be randomly located throughout a burn area except for low intensity fires or on small areas. Mechanical observations can be obtained by attaching one end of a wire to a stake with string (inside the fire area) and the other end to a weight (draped over a horizontal support outside the fire area).[1] This method has three disadvantages: a long set-up time is needed, equipment and personnel have difficulty traversing the burned area, and the method is logistically impractical for large fires. Conventional electronic techniques use thermocouples and a data recorder to measure the time that the thermal pulse reaches each thermocouple location. In addition to the previous disadvantages, however, this method also requires expensive equipment. Aerial infrared imagery is often used on large wildfires, but it is too expensive for routine prescribed fires.

Solving the preceding problems would greatly facilitate obtaining rate-of-spread data in the field. In this paper, we describe a small, inexpensive, self-contained, electronic timer that solves these problems.

DEVELOPMENT AND DESIGN

Our original timer was an insulated unit that could be laid on top of the litter layer. The insulation eliminated the need for burial to protect the unit from the heat of the fire. Initial tests exposed some problems with this design, however. Because of the timer's weight (4 pounds) and size (4 inches x 12 inches) it was difficult to carry more than a few units at one time. The combined cost of the insulation (silicon cloth) and the container (thin-walled conduit) was twice that of the timer itself. Finally, when tested in a high intensity fire, more than half of the 13 units malfunctioned. Three clocks were irreparably damaged (internal temperatures in excess of 180°F) and four clock displays turned black and lost data (internal temperatures of 150° to 180°F). We concluded that, although there may be a limited role for surface units where burying is not possible, the problems outweigh the benefits in most cases.

[1]*Stocks, Brian J. Canadian Forestry Service, Great Lakes Forest Research Centre, personal communication.*

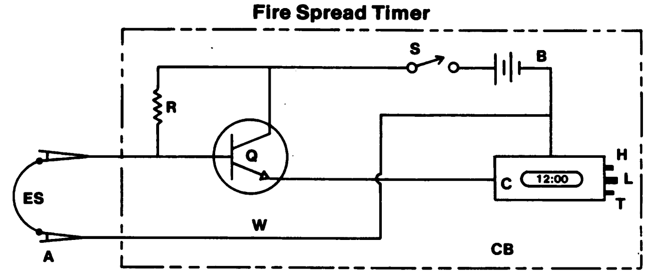
N. C. ARCHIVES

Based on our experience with the first timer, we modified the design so that burial is now required for protection. The key element of the current design is a narrow pendant watch with a digital liquid crystal display (LCD) and built-in reset buttons (C, fig. 1).[2] (The original design used a clock without built-in reset buttons, which proved more costly for parts, more time consuming for assembly, and less reliable.) We glued the night light (L, fig. 1) and time-set buttons (T, fig. 1) in place to prevent accidental triggering (they are not needed). Only the hour-minute-second button (H, fig. 1) remains functional. Pushing this button twice displays seconds and pushing it once returns to hours-minutes. In practice, the data are recorded in such a way that the second display is not needed, nor do the clocks have to be synchronized before use. We removed the original battery from the watch to gain access to the internal power connection and inserted two hearing aid batteries (B, fig. 1), in series, to provide additional voltage needed for circuit operation. Both batteries were attached to the circuit board for ease of maintenance.

The external trigger (ES, fig. 1) is the only sensing element and therefore is critical to reliable operation. We chose to break rather than make a circuit because the latter is less reliable in a hot, smoky, soot-filled environment. We also avoided spring devices because they lose their tension after repeated heating. After testing numerous alternatives, we selected a 2-inch length of 0.04 diameter high-temperature solder attached to two alligator clips to make an inexpensive, yet reliable, trigger. The alligator clips (A, fig. 1) are for making the final connection in the field as the unit is deployed (this allows last-minute checking of proper operation). Although the clips could be cleaned and reused, it is easier to replace them each time (they cost only 5 cents each). Clips with teeth should be used for a more positive and reliable electrical connection.

To test the trigger mechanism, we set out 10 pairs of units in a grassy area and ran a fire through the test area. We bent the lead-in wire so that the solder trigger for each unit was vertical and so that the paired triggers were no more than 1 to 2 inches apart. Seventeen units performed satisfactorily, yielding seven pairs of observations (each malfunction eliminated one pair). The average time difference between pairs was 2.5 seconds, with a range of 0 to 7 seconds.

[2] *Most miniature LCD clocks may be used. We used the pendant watch because it was the least expensive locally available clock.*



A	Alligator Clips
ES	External Solder Switch
R	22K 1/4 Watt Resistor
W	High Temperature Wire
Q	Transistor NPN 2N2222
S	SPST Micro Miniature Toggle Switch
B	Batteries, 1.4 Volt Mercury Hearing Aid (2)
C	Clock Timer
CB	Circuit Board, 3-3/4" x 5/8"
H	Hour-Minute-Second Button
L	Night Light Button
T	Time Set Button

Figure 1.—*Schematic circuit diagram for the electronic timer.*

Because the lead-in wire from the trigger (W, fig. 1) must withstand repeated burning, we used iron-constantan thermocouple wire with high-temperature insulation. This poses two problems, however. Because the glass insulation is not resistant to abrasion, the wire must be replaced periodically, and the constantan wire is difficult to solder. The lead-in wire may be of any length. The 2 to 3 inches of wire closest to the timer should be waterproofed (we used a silicone coating) to prevent soil moisture from shorting the circuit. The trigger contact points on the lead-in wire should be far enough apart so that the clips cannot touch if they are loosened.

The case consists of ¾-inch, thin-walled, copper pipe, 3-¾ inches long; it is capped at both ends. This makes a rugged case that can withstand rough handling in the field. The base cap is soldered in place; the top cap is removable. (The cost of the unit might be reduced by 50 cents and the weight by an ounce by substituting a less rugged but possibly adequate plastic case.)

An assembled unit is illustrated in fig. 2. The lever on switch S (fig. 1) must be trimmed to fit inside the case. The circuit board must be thoroughly cleaned with a solvent after assembly, because even minute residues of conductive material will result in erratic functioning. After cleaning, exposed connections were coated with a silicone insulation. We used vinyl electrical tape to attach the timer to the circuit board and to insulate exposed connections from the container. We attached the circuit board to the top cap with a separate wire to relieve the strain from the lead-in wire when the cap is removed.

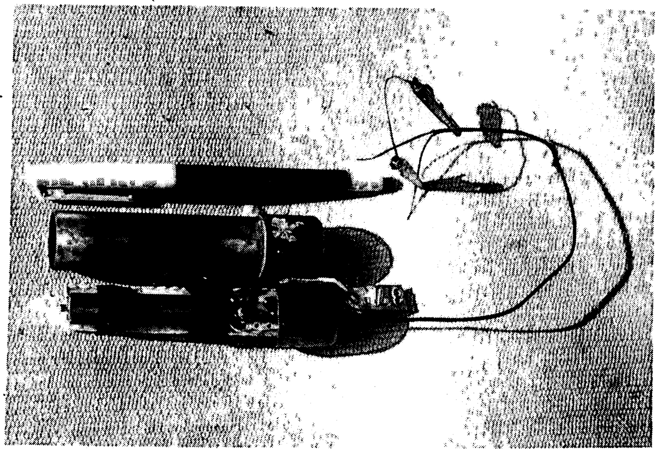


Figure 2.—*Assembled timer.*

Operation of the circuit, diagramed in fig. 1, is relatively simple. With switch S closed and the external solder trigger (ES) intact, the current passes through resistor R and bypasses clock C. When the solder melts, transistor (Q) acts as a switch, transferring the flow of current through the clock and starting timing at 1:00:00. The clock continues to run until switch S is opened or a connection is made across the external trigger or ends of the lead-in wire (if, for example, an enthusiastic mop-up crew sprays water on the mechanism). Current requirements are so low that the clock can hold (with the solder intact) or run (after being triggered) for months. The timer should be buried only as long as necessary, however, because internal moisture condensation may cause erratic behavior. If the timer will be in the ground for several days, we suggest inserting a small amount of desiccant in the base of the case.

APPLICATION

We recommend a minimum timer spacing so that a fire takes at least one minute to spread from one timer to the next.[3] Based on an average 2.5 second error from our trigger test, this spacing will yield an average 4-percent measurement error—not ideal but normally acceptable. Relative measurement error can be reduced by wider timer spacing (e.g., 2 to 3 minutes apart). Variability in spread rate and direction measurement could become excessive, however, if the timers are spread too far apart. Placing the timers near barriers to fire spread (logs, rocks, etc.) or in areas with insufficient fuel to carry a fire could also result in measurement error.

A systematic procedure for sequentially deploying and retrieving the timers minimizes errors and malfunctions. We recommend a two-person crew—one to perform mechanical tasks and one to help carry equipment and record data. To deploy the units, we first make a 6-inch deep, 1-inch diameter hole in the soil. A tree-planting dibble (for container stock) works well for this purpose. We remove each timer from its case, turn it on, and verify that the clock is working. We clip the solder trigger in place and verify that the clock has stopped (the LCD face fades within a few seconds). We recommend having one or two extra units on hand in case of last-minute malfunctions. We then replace the timer in the case, place it in the hole, and cover it with 1 to 2 inches of soil (with the trigger exposed). Finally, we verify that the clips have not loosened in handling; if they have, they must be reclipped. We bend the lead-in wire so that the trigger is 2 to 4 inches above the ground, with the solder vertically aligned. The latter eliminates possible variability due to differences between trigger alignment and spread direction. We use a 2-foot-long steel rod to mark the timer location. The number and location of each timer are recorded. It takes about 5 minutes to set each unit in place, including pacing between points.

A master stopwatch is started or wristwatch time is recorded (to the nearest second) at the time of ignition. We recommend a second watch to provide a backup and to serve as a further check against errors. As each timer is retrieved after the fire, we record its time in hours and minutes (rounded to the next minute) next to the timer number. A mark is given by one person when the timer minute advances and a second person records the hours, minutes, and seconds from the master watch. Subtracting each unit's time from the corresponding watch time gives the elapsed time (stopwatch) or clock time (wristwatch) that the fire arrived at each unit[4]. Allow 5 minutes for retrieving each timer and recording data.

In an early field trial, on an operational prescribed fire, 70 percent of the timers performed satisfactorily. Additional design and procedural improvements increased satisfactory performance to 85 percent. The timer and procedures described in this paper should yield good data 90 percent of the time. Because little things always go wrong, we doubt that 100 percent satisfactory operation can be achieved. We therefore recommend that some redundancy be built into sampling procedures, particularly at important points. As an additional precaution, these timers should supplement rather than replace conventional measuring techniques until the user becomes familiar with their operation.

[3]*This requires that an estimated rate of spread be determined before the timers are deployed.*

[4]*Because our clock starts with 1:00:00, 1 hour is subtracted from the unit time.*

SUMMARY

The electronic timer described in this paper resolves most problems associated with conventional techniques for measuring the rate of spread of a wildland fire. When a fire arrives at the timer location, an external trigger starts a miniature electronic clock, which runs until data are retrieved, after the fire has passed. The timers eliminate the need for visual observations, thereby permitting random plot locations on any fire. Due to the low cost ($9.50 for materials) and ease of assembly (3 hours each, in small quantities), many units can be used on an individual fire, permitting extensive sampling. Due to its small size (1 x 4 inches) and light weight (4 ounces), many units can be carried at one time and quickly deployed with minimal effort. Because the timers are self-contained, they do not impede access to the burned area. Because the units are long-running (they can hold or run for several months), delays between deployment, fire ignition, and retrieval will not result in loss of data. Use of the timer will greatly facilitate obtaining rate-of-spread data in the field.

ACKNOWLEDGMENTS

The authors thank Doug Blue, Michigan Department of Natural Resources, who helped design the electrical circuit and Roy Milnes, Michigan Department of Natural Resources, who helped field test the units. We also appreciate the assistance of Brian Stocks, Great Lakes Forest Research Centre, and Jerry Drysdale, Ontario Ministry of Natural Resources, in testing the timers on a prescribed crown fire.

U.S. GOVERNMENT PRINTING OFFICE:1983-765-018/5091