U. S. Geological Survey
National Wetlands Research Center
Fire Science Team

Firelogger User's Manual

(Version III: July 2005)

By: Jim Grace[1], Alaina Owens[2], and Larry Allain[1]

Open-File Report 2005-1212

[1] U. S. Geological Survey, [2] Johnson Controls World Service

TABLE OF CONTENTS

INTRODUCTION

Although scientists and fire monitors are currently equipped with a variety of methods for measuring fire characteristics, many of these tools are expensive, cumbersome, or simply fail to provide detailed information. In an effort to both simplify and standardize fire-monitoring practices, researchers at the U. S. Geological Survey (USGS) have developed an inexpensive and compact temperature-logging device called the “Firelogger”. It provides critical data regarding many components of fire dynamics, and it is simple to carry, deploy, and retrieve.

The waterproof Firelogger has been constructed for easy burial while allowing the heat resistant thermocouple cable and temperature sensor to extend out along the ground surface. In situations where burial of the Firelogger is not possible (e.g., rocky ground), the body of the logger must otherwise be protected from the heat of the fire. Once deployed, the Firelogger records one temperature reading each second, securing valuable information that the user can download from the logger. Data are easily downloaded and when transferred to a computer where they can be manipulated and graphed.

This manual provides detailed instructions regarding logger configuration and field deployment, as well as data retrieval and manipulation. For a more detailed scientific background and justification, see Appendix A, and for a Firelogger supply list, see Appendix B.

FIRELOGGER OVERVIEW

Firelogger Construction

The Firelogger consists of a data logger (HOBO Type K "thermocouple") connected to a temperature sensor (insulated thermocouple cable, Type K style II) via a waterproof electrical junction. The data logger is housed in a 2" O.D. waterproof***** PVC container, fig. 1).

*******Note: waterproofing maintenance includes lubricating the o-ring by using silicon lubricant and maintaining the silicon sealant around the electrical junction.*

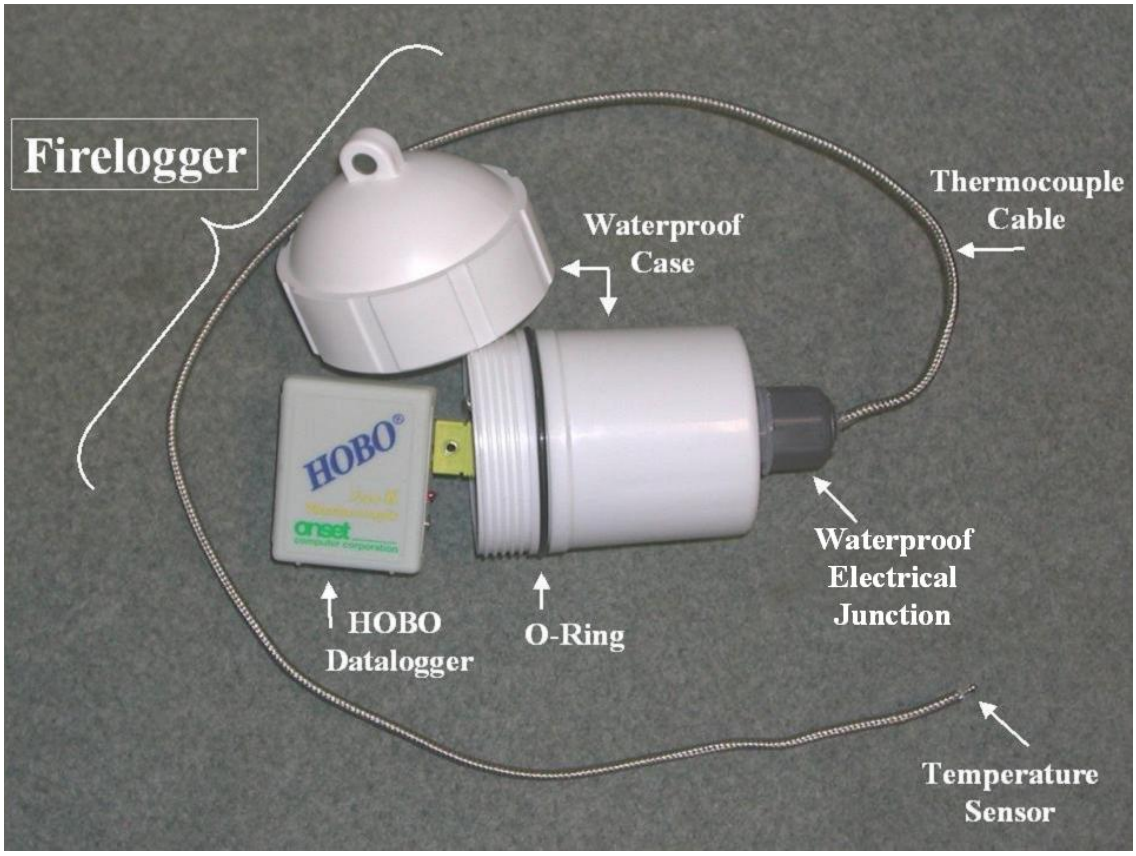


Figure 1. Firelogger components.

Firelogger Software
For data retrieval from the firelogger we used BoxCar software. Two versions of this software are currently available, BoxCar and BoxCar Pro. For most applications, BoxCar is what we used.

Connecting to the HOBO Data Logger
Communication with the HOBO data logger can be achieved by using either a laptop or desktop computer and the BoxCar software. Through this interface, it is possible to set logger options, initiate logging ("launching"), download data, and terminate logging. HOBO sells a device called the “Shuttle” that can also be used easily for launching and downloading data.

Firelogger Options
The HOBO data logger component of the Firelogger has a number of options that can be set via the laptop or desktop interface. These options relate to (1) data acquisition interval and duration, (2) temperature range, (3) data wraparound, and (4) delayed starting time for data acquisition.

(1) Data Acquisition Interval and Duration - For most of our applications we use a one-second logging interval. This frequency of data collection provides a clear picture of the rapid changes in heat flux that take place during the short period when the thermocouple is exposed to the fire. At this frequency, current models of the HOBO logger component can record continuously for 9 hours.

(2) Temperature Range - The Type K HOBO data logger, which we use for measuring surface temperatures, has three channels. Channel 1 has a range of 0-500°C (32-932°F) and a resolution of 1-2°C (1.8-3.6°F). Channel 2 has a range of 0-1250°C (32-2282°F) with a resolution of 5-10°C (9-18°F). Channel 3 is used for recording internal temperatures in the logger itself and has a range of 0-50°C (32-122°F) with a resolution of 0.4-21°C (0.7-70°F). It is suggested that the logger be configured such that Channel 2 is the only channel enabled. If Channels 2 and 3 are both selected, data recording duration is cut in half.

(3) Data Wraparound - The HOBO data logger’s default setting is to stop logging when the memory is full; however, users may select the “wrap around when full” option in BoxCar. This option will program the logger to write over previously recorded data once the memory is full. We typically use the default setting for our applications, which alleviates the necessity to access the loggers immediately following the fire.

(4) Delayed Starting Time for Data Acquisition - Logging can be programmed for delayed starting times. This feature is useful as the user can launch the logger from an office setting (using a laptop, etc.) at any time prior to field deployment. This alleviates the need to bring delicate, and often very sensitive, electronic equipment into the field for launching purposes.

Procedures for Launching Loggers and Downloading Data

The basic procedure for using loggers involves plugging the HOBO data logger into a computer using the cable that comes with the BoxCar software. This connection can be used to begin data acquisition at some convenient time prior to deployment, such as the morning of the fire. If there is a possibility that fire will not reach the logger well before the 9-hour maximum recording time, a delayed start should be used. Once loggers are retrieved following a fire, they will continue to acquire data until the memory is full or until data are downloaded and loggers are turned off using BoxCar.

HOBO shuttles are waterproof, handheld devices that can be plugged directly into data loggers and are capable of launching loggers, checking their batteries, and downloading data easily in the field. Shuttles are not capable of turning loggers off. However, the loggers can initially be set to terminate logging when full. A single shuttle can hold the maximum contents of 13 loggers (such as the HOBO 32K, K-type logger). Data can be retrieved from a shuttle by using a computer with BoxCar software.

Sample Graph

Data from Fireloggers allow the user to derive the following types of information: peak temperature, duration of heating, and total heating (degree minutes above 60^{o}C). When multiple loggers are deployed, one can obtain rate of spread (ROS) by calculating the time it took for fire to move from one logger to another.

Figure 2 is a graph created from fire temperature data recorded from six Fireloggers deployed in an experimental plot. As can be seen in this example, the head of the fire first reached Logger #1, which experienced a maximum temperature of 413°C. Some time later, the fire reached Logger #6, which experienced a maximum temperature of 513°C. With the known distance (and time between peak temperatures) between #1 and #6, the user can calculate the rate of spread (ROS, meters/second). Temperatures declined gradually for all sensors and the time when values were in excess of 60^{o}C can be used to estimate the duration of heating.

The number of loggers deployed and the spacing between each sensor are based upon the user's study objectives. Fireloggers may be deployed in a number of configurations to estimate ground surface fire intensity (GSFI) as the fire passes. Figure 3 shows how the distances between loggers can be used to estimate rates of spread in a 4-logger deployment.

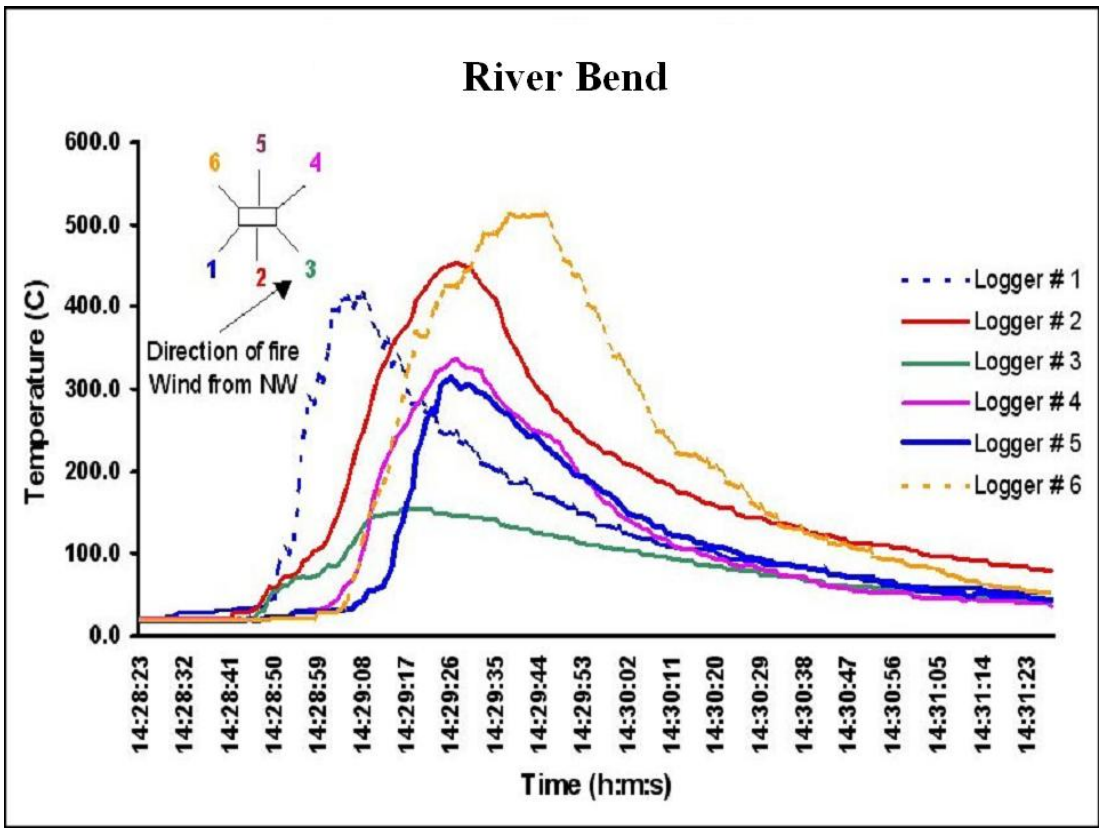


Figure 2. Temperature profile of a prescribed burn in a Texas coastal prairie. Six Fireloggers were buried with their sensors arrayed as shown above in the insert figure (which has the numbers 1 - 6 representing locations of loggers).

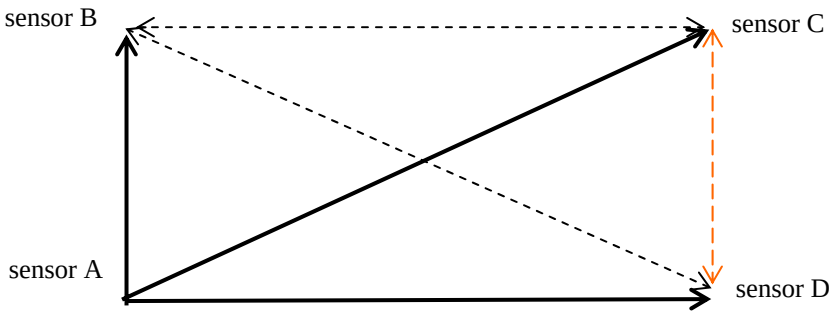


Figure 3. Example of aerial view of four buried Fireloggers. The distance between temperature sensors must be measured in order to determine rate of spread.

HOW TO:

Configure the Logger

HOBO data loggers, as received from the factory, are assigned the default name "TEST,"and are programmed to record two temperature readings each second. If the user is working with a logger that has not been previously configured, it is suggested that the user change both the name and the internal logging configuration of the logger prior to field deployment.

Note: loggers obtained from the USGS should already be preconfigured to the specifications stated in this document.

1. Connect the data logger to the laptop via the PC interface cable.
2. If handheld computer software called HotSync (or any other similar software, such as ActiveSync) is active on the desktop tool bar, deactivate it now, as the logger software BoxCar and HotSync are unable to run simultaneously, Fig. 4.

Figure 4. HotSync and BoxCar Pro desktop icons.

3. Open the software titled BoxCar.
4. Click on "Logger," then select "Launch."
   a) Name the logger (only if not preconfigured).
      i. find the "Description" box; delete the word "TEST."
      ii. type a new name (i.e., K1, K2, etc.) into the cell;
      NOTE: this new name should also be handwritten on the external surface of the logger allowing the user to later document which data set has been recorded by which logger.
   b) Program the internal logging specifications (only if not preconfigured).
      i. find the "Interval(Duration)" box; select "1 second for 9 hours."
      ii. go to the bottom of the BoxCar dialog box; verify that Channel #2 is the only enabled channel.
5. Click "Start" and then click "Yes."
6. Unplug the logger from the PC interface cable and then click "OK."
7. The logger has now been launched (the small red light on the top of the logger is blinking, indicating that the logger is recording data).
   a) If your interest is in configuring the logger but not launching it at this time, you will need to deactivate the logger.
   b) Deactivate the logger.
      i. reconnect the logger to the PC interface cable.
      ii. click on "Logger," then select "Readout."

iii. the data just recorded by the logger will be downloaded. You are not interested in saving these data; therefore, click "Cancel" when the "Save As" box appears.
iv. click "Yes."

Launch the Logger

Loggers may be launched (activated) during any length of time prior to field deployment and subsequent ignition. It is possible to launch just prior to deployment, or by using BoxCar's delayed activation feature; users may prelaunch days/hours prior to actual deployment/ignition. The user has the option of launching the Firelogger by using a laptop, handheld computer (Palm), or HOBO shuttle. The interface with handheld computer technology is no longer being supported by the makers of the HOBO loggers and so we do not use it.

1. Launch logger via a laptop, Fig. 5.

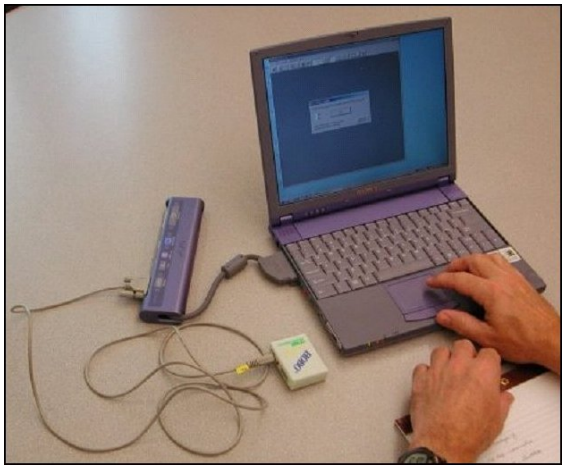


Figure 5. The logger may be launched through a laptop or by using a desktop computer.

a) Connect logger to laptop via the PC interface cable.
b) Deactivate HotSync, ActiveSync, etc. if its icon is present in the desktop tool bar.
c) Open the software titled BoxCar.
d) Click on "Logger," then select "Launch."
   i. verify that the logger's date/time are correct.
   ii. verify that the logger is displaying a reasonable temperature, helping to ensure that it is functioning properly.
   iii. check the logger's battery status.
   iv. do not select "Wrap around when full," as doing so will result in logged data being written over once the logger's memory is full.

v. depending on your needs, you may choose to select “Delayed Start” which programs the logger to launch automatically later.
vi. click “start” and then click “yes.”

e) Unplug the logger from the PC interface cable and then click “OK.”
f) The logger is launched when the small red light on the top of the logger begins blinking, indicating that the logger is recording data.

Note: If a message stating, “invalid byte returned, logger stopped communicating with program" appears following a launch, simply relaunch the logger.

2. Launch logger via a HOBO Shuttle, Fig. 6.

Figure 6. The logger may be launched using a HOBO Shuttle.

a) Attach logger to shuttle via the shuttle-logger interface cable.
b) Press the black button located on the top of the shuttle.
i. the shuttle’s “Offloading” LED will begin blinking (~10 seconds).
ii. the shuttle’s “Relaunching” LED will blink very briefly.
iii. the shuttle’s “Successful” LED will begin blinking.
iv. turn the shuttle off by pressing the black button located on top of the shuttle.
c) Unplug the logger.
d) The logger is launched when the small red light on the top of the logger begins blinking.

Note: In the event that a Firelogger provided by the USGS malfunctions, please contact the USGS – National Wetlands Research Center: Fire Science Team (Dr. Jim Grace, James_Grace@usgs.gov, 337-266-8632).

Deployment in the Field

With the HOBO data logger secure in its waterproof case, it is safe to deploy it even into moist environments. However, to ensure protection of the PVC case and data logger from fire damage, the entire PVC case should be buried on its side (covered by at least 4" of soil), allowing only the heat resistant thermocouple cable and temperature sensor to extend out above and along the ground. The temperature sensor (i.e., tip of the thermocouple) should be placed on the surface of the ground by using a metal staple as an anchoring device, fig. 7. Care should be given to ensure that the staple is placed 2-6 inches away from the tip. Users may also find it useful to attach a small chain to the top of the PVC cover to aid in the removal of buried Fireloggers.

Note: the thermocouple may not give accurate readings if it is in substantial contact with water, especially at the junction tip where readings are taken.

Figure 7. Fireloggers should be buried prior to ignition of fire, allowing the heat resistant thermocouple cable and temperature sensor to extend out above and along the ground.

Retrieve the Data

Each time a logger is launched, all data currently stored in the logger are erased. It is therefore very important to download the data from the logger following each deployment.

1. Connect logger to laptop via the PC interface cable.

2. Deactivate HotSync, ActiveSync, etc., if their icon is present in the desktop tool bar.
3. Open the software titled BoxCar.
4. Click on “Logger” and select “Readout.”
    a) The PC will connect to the logger and offload the data; for a full logger (9 hours of recorded data), offloading will take 10-15 minutes.
5. Unplug logger from the PC interface cable when prompted and click “OK.”
6. The “Save As” option automatically appears.
    a) Select the destination folder and filename (the filename should automatically be the name that was given to the logger); leave the file extension as “.dtf” and click “Save.”
    b) A graph of the fire temperature/duration automatically appears, fig. 8.
    c) By clicking on the “Toggle View Details” button in the upper right corner, the user can view the actual temperature data points.

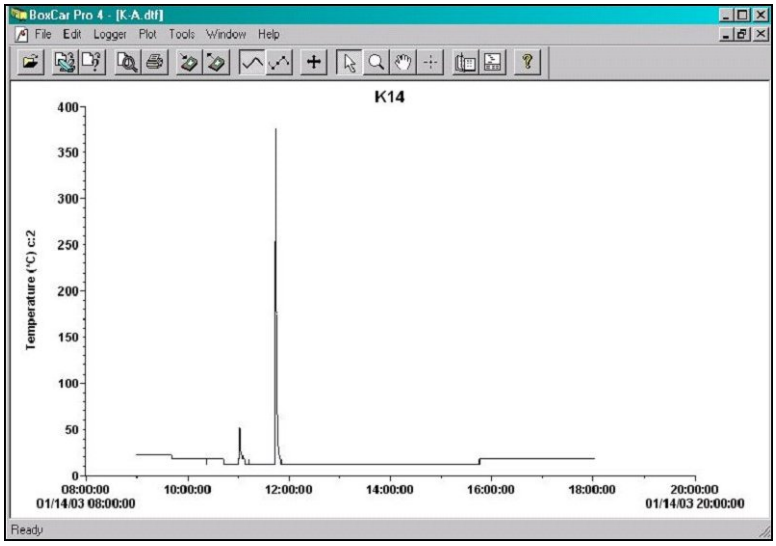


Figure 8. Sample BoxCar graph showing temperature data during entire recording interval.

Export Data to Microsoft Excel

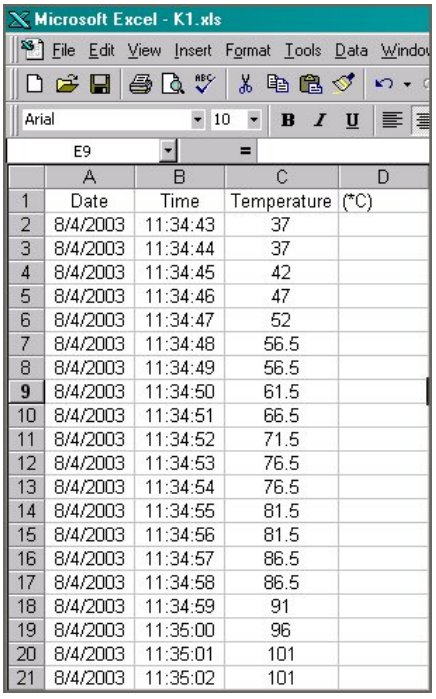
A wide range of information can be derived from temperature data collected during a prescribed burn or wildfire. While BoxCar is the software package necessary to download data from the Fireloggers, Microsoft Excel provides many options for data manipulation and graphing, as well as the incorporation of mathematical formulas that can be used for calculating important fire parameters.

1. Open the BoxCar “.dtf” file of interest.
    a) First opening BoxCar software.
        i. click on “File” then select “Open.”
        ii. select the folder where the BoxCar “.dtf” file of interest is located.

iii. select the BoxCar ".dtf" file of interest and click "OK."

b) When the "Select Series To Show In View" dialog box appears, select either "Temperature ^{o}F" or "Temperature ^{o}C" and then click "OK."

2. Click "file" and select "export" to Microsoft Excel.
   a) Ensure that the "All Series" option is selected.
   b) Click on "Export."
      i. the "Save As" option automatically appears.
      ii. select the destination folder, etc., leave the file extension as ".txt" and click "Save."
3. Open a new Microsoft Excel spreadsheet.
   a) Open the ".txt" file that was just created by clicking "File" and selecting "Open."
   b) Select the folder where the ".txt" file is located and then select "All Files" in the "Files or Type" box .
   c) Select the ".txt" file of interest and click "Open;" the "Text Import Wizard" dialog box will appear.
      i. select "Delimited" (do not select "Fixed Width").
      ii. click "Next."
      iii. select both "Tab" and "Space" as the delimiters.
      iv. ensure that the "Treat Consecutive Delimiters as One" option is selected.
      v. a single quotation mark (") should be the "Text Qualifier."
      vi. click "Next."
      vii. Ensure that the "Column Data Format" is "General."
      viii. click "Finish."
4. The data should appear in three columns, titled "Date," "Time," and "Temperature" (fig. 9).



	A	B	C	D
1	Date	Time	Temperature	(°C)
2	8/4/2003	11:34:43	37	
3	8/4/2003	11:34:44	37	
4	8/4/2003	11:34:45	42	
5	8/4/2003	11:34:46	47	
6	8/4/2003	11:34:47	52	
7	8/4/2003	11:34:48	56.5	
8	8/4/2003	11:34:49	56.5	
9	8/4/2003	11:34:50	61.5	
10	8/4/2003	11:34:51	66.5	
11	8/4/2003	11:34:52	71.5	
12	8/4/2003	11:34:53	76.5	
13	8/4/2003	11:34:54	76.5	
14	8/4/2003	11:34:55	81.5	
15	8/4/2003	11:34:56	81.5	
16	8/4/2003	11:34:57	86.5	
17	8/4/2003	11:34:58	86.5	
18	8/4/2003	11:34:59	91	
19	8/4/2003	11:35:00	96	
20	8/4/2003	11:35:01	101	
21	8/4/2003	11:35:02	101	

Figure 9. A sample Excel spreadsheet containing date, time and temperature data from a single logger named “K1.”

5. The “Time” column should be formatted at this time.
    i. select the entire “Time” column by clicking on the gray tab above that column; it should be the column labeled “A.”
    ii. select “Format” and then click on “Cells.”
    iii. select “Number” and then click on “Time.”
    iv. select the time option hh:mm:ss / 13:30:55, which is the third option in the “Type” box.
    v. click “OK.”
6. To save these data as an Excel file, select “File” and then click on “Save As.”
    a) Select the destination folder, etc.
    b) Select Microsoft Excel Workbook (“.xls”) in the “Save as type” menu; the file will be saved in Excel format.
    c) Click “Save.”

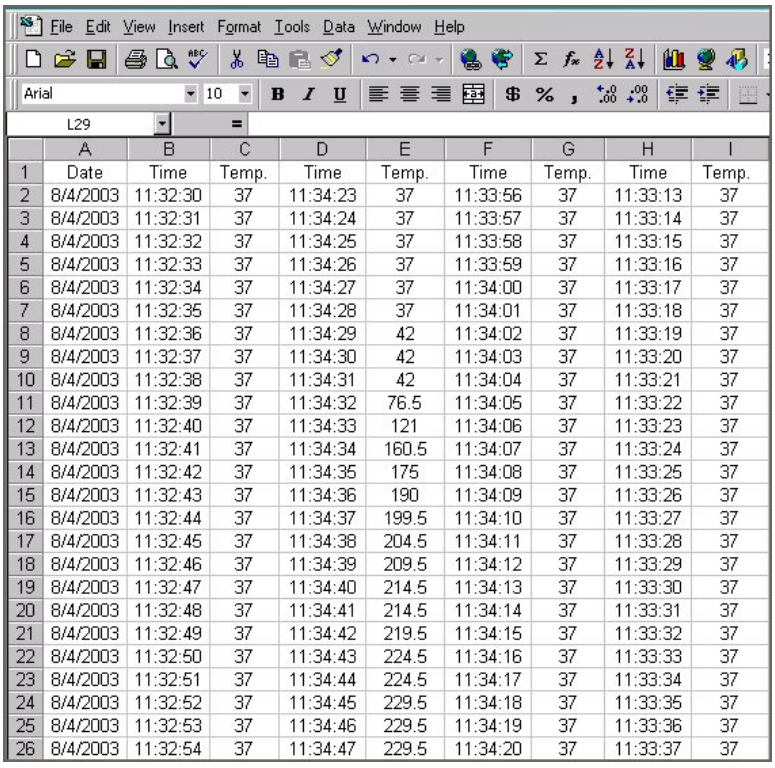
Note: steps 1-6 must be repeated for each BoxCar “.dtf” file from any given burn; therefore, three files in total (BoxCar = .dft, Text = .txt, and Excel = .xls) are created for each logger from which you’ve downloaded data, Fig. 10.

Figure 10. Representative icons of the three file types created from one data logger named “K1.”

Manipulate Temperature Data in Excel

Once your data are in Excel, the data sets from a given burn should be combined into a single file, simplifying graphing and calculations.

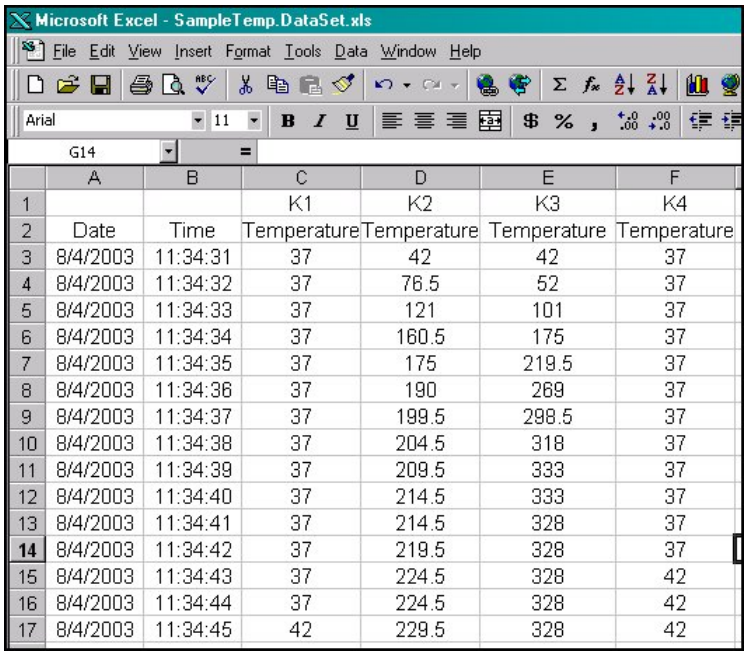
1. To create this composite file, open one of the Excel files, click “File” then select “Save As.”
    a) Give this file a new name, such as “all data_9_15_03.xls.”
2. Copy the time and temperature columns from the other Excel files that were created from a particular burn, and paste the data from each separate file into this new Excel spreadsheet.
3. This new Excel spreadsheet should contain one date column and the same number of time and temperature columns as the number of loggers used for a particular burn (i.e., if four loggers were deployed, this new Excel spreadsheet should contain one date column and four sets of time and temperature, one set for each logger), fig. 11.



	A	B	C	D	E	F	G	H	I
1	Date	Time	Temp.	Time	Temp.	Time	Temp.	Time	Temp.
2	8/4/2003	11:32:30	37	11:34:23	37	11:33:56	37	11:33:13	37
3	8/4/2003	11:32:31	37	11:34:24	37	11:33:57	37	11:33:14	37
4	8/4/2003	11:32:32	37	11:34:25	37	11:33:58	37	11:33:15	37
5	8/4/2003	11:32:33	37	11:34:26	37	11:33:59	37	11:33:16	37
6	8/4/2003	11:32:34	37	11:34:27	37	11:34:00	37	11:33:17	37
7	8/4/2003	11:32:35	37	11:34:28	37	11:34:01	37	11:33:18	37
8	8/4/2003	11:32:36	37	11:34:29	42	11:34:02	37	11:33:19	37
9	8/4/2003	11:32:37	37	11:34:30	42	11:34:03	37	11:33:20	37
10	8/4/2003	11:32:38	37	11:34:31	42	11:34:04	37	11:33:21	37
11	8/4/2003	11:32:39	37	11:34:32	76.5	11:34:05	37	11:33:22	37
12	8/4/2003	11:32:40	37	11:34:33	121	11:34:06	37	11:33:23	37
13	8/4/2003	11:32:41	37	11:34:34	160.5	11:34:07	37	11:33:24	37
14	8/4/2003	11:32:42	37	11:34:35	175	11:34:08	37	11:33:25	37
15	8/4/2003	11:32:43	37	11:34:36	190	11:34:09	37	11:33:26	37
16	8/4/2003	11:32:44	37	11:34:37	199.5	11:34:10	37	11:33:27	37
17	8/4/2003	11:32:45	37	11:34:38	204.5	11:34:11	37	11:33:28	37
18	8/4/2003	11:32:46	37	11:34:39	209.5	11:34:12	37	11:33:29	37
19	8/4/2003	11:32:47	37	11:34:40	214.5	11:34:13	37	11:33:30	37
20	8/4/2003	11:32:48	37	11:34:41	214.5	11:34:14	37	11:33:31	37
21	8/4/2003	11:32:49	37	11:34:42	219.5	11:34:15	37	11:33:32	37
22	8/4/2003	11:32:50	37	11:34:43	224.5	11:34:16	37	11:33:33	37
23	8/4/2003	11:32:51	37	11:34:44	224.5	11:34:17	37	11:33:34	37
24	8/4/2003	11:32:52	37	11:34:45	229.5	11:34:18	37	11:33:35	37
25	8/4/2003	11:32:53	37	11:34:46	229.5	11:34:19	37	11:33:36	37
26	8/4/2003	11:32:54	37	11:34:47	229.5	11:34:20	37	11:33:37	37

Figure 11. Sample Excel spreadsheet containing date, time, and temperature data from four loggers. Note that each data logger was launched at a slightly different time.

4. Insert a row at the top of the spreadsheet.
   a) Put the cursor over the gray tab left of the first row labeled number "1."
   b) Select "Insert" on the toolbar and click on "row."
   c) Type the logger name in the blank cell above each temperature column.
5. Time and temperature data for each logger should be arranged such that each logger begins with a common starting time (hh:mm:ss).
   a) Highlight the time and temperature data for the three earliest launched loggers, until the start time of the latest launched logger is reached.
   b) Select "Edit" and click on "Delete."
      i. Select "Shift cells up" in the "Delete" dialog box.
      ii. Click "OK."
6. Delete all time columns, leaving only one which is to be used for reference.
7. Finally, the Excel spreadsheet should contain one date column, one time column and several temperature columns (the name of the logger appearing in the first cell of each temperature column) arranged side by side, fig. 12.



	A	B	C	D	E	F
1			K1	K2	K3	K4
2	Date	Time	Temperature	Temperature	Temperature	Temperature
3	8/4/2003	11:34:31	37	42	42	37
4	8/4/2003	11:34:32	37	76.5	52	37
5	8/4/2003	11:34:33	37	121	101	37
6	8/4/2003	11:34:34	37	160.5	175	37
7	8/4/2003	11:34:35	37	175	219.5	37
8	8/4/2003	11:34:36	37	190	269	37
9	8/4/2003	11:34:37	37	199.5	298.5	37
10	8/4/2003	11:34:38	37	204.5	318	37
11	8/4/2003	11:34:39	37	209.5	333	37
12	8/4/2003	11:34:40	37	214.5	333	37
13	8/4/2003	11:34:41	37	214.5	328	37
14	8/4/2003	11:34:42	37	219.5	328	37
15	8/4/2003	11:34:43	37	224.5	328	42
16	8/4/2003	11:34:44	37	224.5	328	42
17	8/4/2003	11:34:45	42	229.5	328	42

Figure 12. Example of an edited Excel spreadsheet containing temperature data from four loggers.

8. As you scroll down the Excel worksheet, you will notice that the temperature readings eventually rise, peak, and then decline to prefire ambient temperature.
9. This worksheet may be edited by removing those rows located beyond the time when the temperature readings returned to ambient temperature following the fire.

Note: the loggers will record more data than you will need, for example, once the loggers have been launched, they record one temperature every second for 9 hours; if ignition occurred only 3 hours past the launch time, there will be many hours (i.e., several thousand rows) of data un related to the fire.

Graph in Excel

Once multiple data sets have been compiled into a single Excel spreadsheet, a single temperature/duration graph may be created for all of the loggers deployed for a particular burn (fig. 13).

1. Simultaneously highlight the time column and all of the temperature columns (this is done by clicking on the gray lettered tab above each column while holding the “Control” key on the keyboard).
2. Click on the “Chart Wizard” button in the Excel toolbar.
   a) Select “Line graph.”
   b) Select the smooth-line sample graph in the upper left corner of the “Chart Sub-Type” dialog box.

c) Click “Next.”
d) The data series should be in “Columns.”
e) Click “Next.”
   i. under the Title tab, type a chart title, label the X-axis “Time, hh:mm:ss,” and label the Y-axis “Temperature, ^{O}C.”
   ii. under the Axes tab, ensure that the “Category (X) Axis,” “Automatic,” and “Value (Y) Axis” options are selected.
   iii. under the Gridlines tab, deselect the “Value (Y) Axis” major gridlines by clicking (removing the “x”) on the box next to this option.
   iv. under the Legend tab, ensure that the “Show legend” option is selected.
   v. under the Data Label tab, ensure that “None” is selected.
   vi. under the Data Table tab, ensure that the “Show data table” option is NOT selected.
f) Click “Next.”
g) Select “As a new sheet,” and give the graph a name by deleting “Chart1” and typing in a new name.
h) Click “Finish.”
i) Each logger should be represented by a different colored line in the graph.

3. By inspecting the graph carefully and comparing the data lines, the user can assess whether any of the loggers may have malfunctioned while logging data.

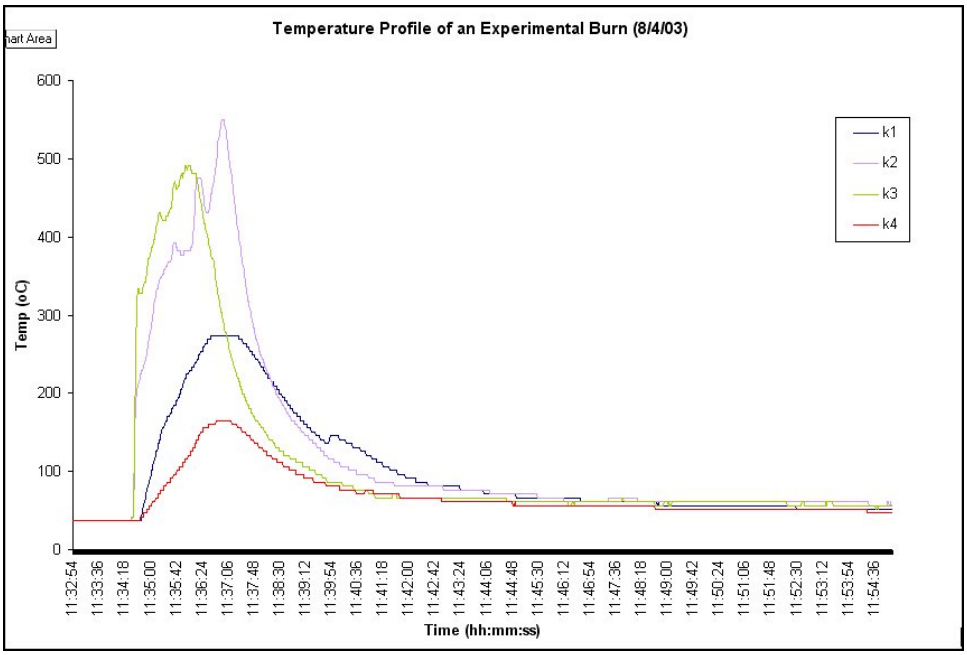


Figure 13. Sample Excel graph created from temperature data from four loggers.

Calculate Fire Parameters in Excel

Using the compiled Excel spreadsheet, the user may determine important fire parameters such as peak temperature, duration of heating (above 60°C), total heating (degree minutes above 60°C), and rate of spread, Fig. 14.

1. Begin scrolling down the worksheet and write down the cell number (E39, C87, etc.) in which the temperature first equals or exceeds 60°C. Do this for each column of temperature data. If six loggers were used, there should be six "starting points."
2. Continue to scroll down the data set until the temperatures peak and begin to decline.
3. Write down the cell number in which the temperature first drops below 60°C. If six loggers were used, there should be six "end points."
4. Calculate the length of time in seconds that the temperature was above 60°C for each of the columns of temperature data by entering the following equation: **=Count(F28:F515)** into the cell following the last row of data. Note: this equation is appropriate if these cell numbers represent the aforementioned starting point and end point, respectively. The title "Time (sec) > 60°C" may be entered in the cell to the left of this equation.
5. You may calculate the total heating (degree minutes above 60°C) by entering the following equation into the next row: **=Sum(F28:F515)-(60*F758),** assuming that cell number "F758" represents the cell containing the previous calculation (time in seconds that the temperature was above 60°C). The title "Total Heat Index > 60°C" may be entered in the cell to the left of this equation.
6. The peak temperature is calculated by entering the following equation into the next row **=Max(F28:F515)**. The title "Peak Temperature" may be entered in the cell to the left of this equation.
7. Both the distance between loggers as well as the length of time it took for a fire to move from one logger to the other must be known in order to calculate the rate of spread. The former is measured in the field, while the latter is calculated based on the amount of time between the temperature peak at each logger.
   a) For example, two loggers are placed at a known distance of 10 m, and upon inspection of post-fire temperature data, it is clear that the temperature peaked at logger "A" at 11:44:42 (hh:mm:ss) and at logger "B" at 11:48:08 (hh:mm:ss).
   b) Calculate the time (in total seconds) between peak temperatures: (44 * 60) + (42) = 2682 seconds, and (48 * 60) + (8) = 2888 seconds. The difference between the two total seconds values is 206 seconds.
   c) It is now known that the fire has moved a distance of 10 m in 206 seconds. To convert meters to feet, multiply 10 meters by 3.3 feet (10 meters * 3.3 feet = 33 feet), and finally, to determine how many feet the fire traveled per second, divide the number of feet by the total number of seconds (33 feet / 206 seconds = 0.16 feet per second).

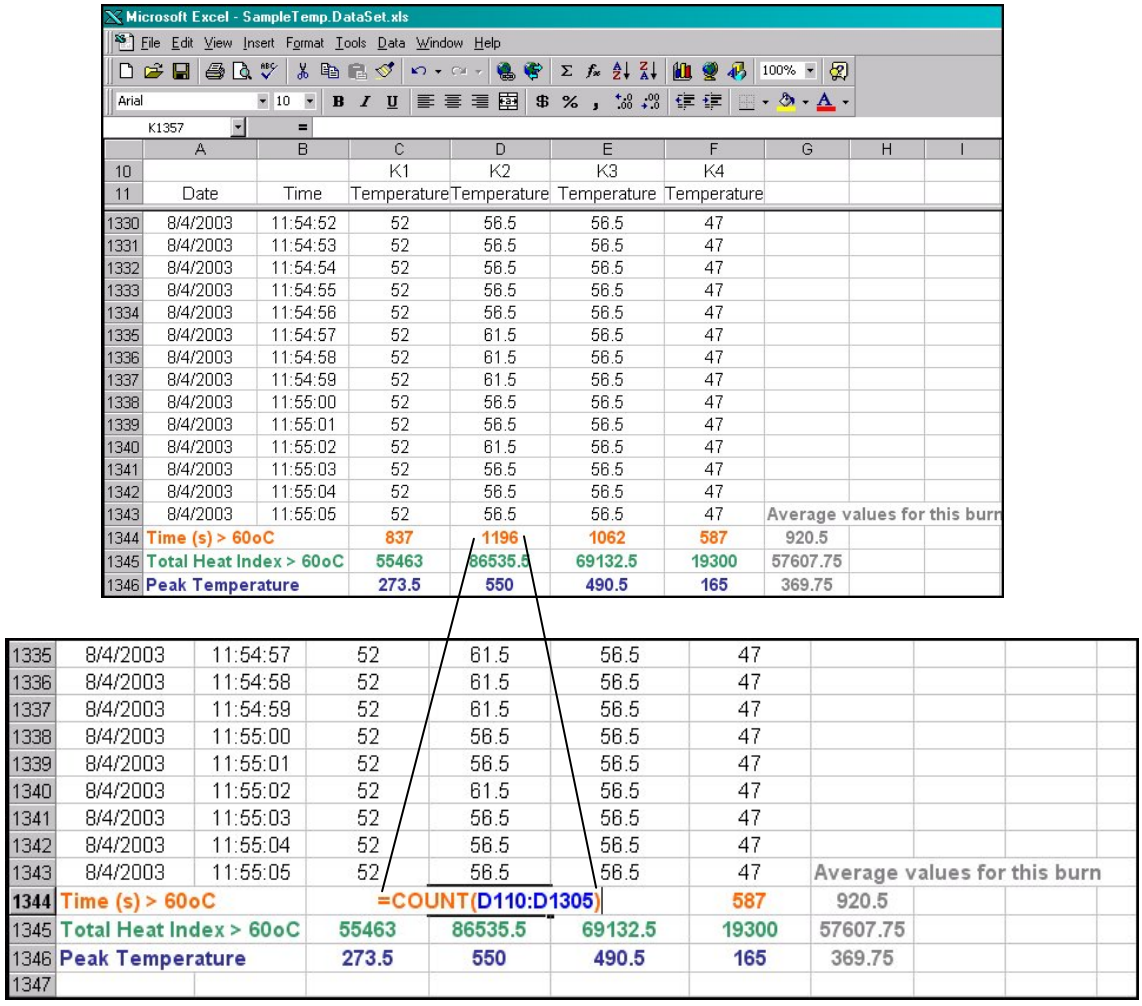


Figure 14. Equation to calculate the length of time that the temperature recorded by logger "K2" remained greater than 60°C.

Troubleshooting

Questions regarding Firelogger configuration, deployment, and troubleshooting/repair should be directed to Dr. Jim Grace (James_Grace@usgs.gov; 337-266-8632).

ACKNOWLEDGEMENTS

We wish to thank the U. S. Fish and Wildlife Service, Region 2 Office for funding and support in the development and refinement of Fireloggers and this document. We are particularly appreciative of the involvement and support by Mark Kaib, project manager, as well as Jeff Whitney in Albuquerque, New Mexico. Field support by Mike Hayes and the staff at the Midcoast National Wildlife Refuge Complex in Texas has been instrumental in our efforts. A number of fire personnel have worked with us to use these loggers in the field conditions, and that work is ongoing. We especially appreciate the involvement of Miranda Miller and Matt Whitbeck. A special thanks to Arlene Billock for early work with the use of Fireloggers in the field. Any use of trade, product, or firm names is for descriptive purposes only and does not constitute endorsement by the U.S. Government.

APPENDIX A

BACKGROUND AND JUSTIFICATION

Researchers have long used electronic data loggers and thermocouples to characterize temperature dynamics during fires (e.g., Stinson and Wright, 1969; Wright, 1970). Knowledge of the temperature dynamics during a fire, either at ground level, critical soil depths, or at various heights above the ground, has been shown to be helpful in quantifying fire characteristics and understanding ecological fire effects (Wells and others, 1979; Whelan, 1995; Molina and Llinares, 2001). Up to the present, measurement of fire temperatures under field conditions has been somewhat limited by the expense, size, and complexity of available measurement instruments (e.g., Bradstock and others, 1992; Jacoby and others, 1992; Sackett and Haase, 1992). Because of these limitations, characterizations of fires are either not measuring fire temperatures at all or have relied on less comprehensive approaches, such as the use of temperature-sensitive paints or tablets (e.g., Drewa and others, 2002).

Typically, routine fire operations have characterized fires based solely on visual estimates of parameters such as flame length, rate of spread, and completeness of combustion. Such measures are often inadequate when the goal is to understand ecological fire effects. It has been our experience that habitat responses to burning can be quite variable and unrelated to general characterizations of fuel, weather, flame lengths, and rates of spread. In order to understand things such as woody plant mortality, fuel recovery, or impacts on herbaceous vegetation, there is a need to measure the temperatures that plants are exposed to during fire, including both the magnitude and duration of heating.

For many plant responses, the temperature dynamics at or near the soil surface are most critical. For example, while shrubs can often be easily damaged or top killed by prescribed burning, their ability to resprout and recover may be strongly influenced by the exposure of plant bases to prolonged heating. Similarly, the recovery rate of native grasses following a fire may relate to the depth of heating, which is related to heat flux as the soil surface. Soil sterilization and mortality of seeds and other propagules can also be impacted directly by the exposure of the ground surface to heating.

In this manual we describe methods for characterizing temperature dynamics at the soil surface. Our rationale is that if we are to choose a single location for characterizing fire characteristics, the surface of the soil is the most logical for several reasons. There are many instances when one may wish to also measure heating at various depths in the soil or at particular heights above the ground. The equipment described here can be adapted to include such measures as well.

REFERENCES

Bradstock, R.A., Auld, T.D., Ellis, M.E., and Cohn, J.S., 1992, Soil temperatures during bushfires in semi-arid, mallee shrublands: Australian Journal of Ecology, v.#17, p.#433-440.

Drewa, P.B., Platt, W.J., and Moser, E.B., 2002, Fire effects on resprouting of shrubs in southeastern longleaf pine savannas: Ecology, v.#83, p.#755-767.

Jacoby, P.W., Ansley, R.J., and Trevino, B.A., 1992, Technical note: an improved method for measuring temperatures during range fires: Journal of Range Management, v.#45, p.#216-220.

Molina, M.J., and Llinares, J.V., 2001, Temperature-time curves at the soil surface in Maquis summer fires: International Journal of Wildland Fire, v.#10, p.#45-52.

Sacket, S.S., and Haase, S.M., 1992, Measuring soil and tree temperatures during prescribed fires with thermocouple probes: U.S. Department of Agriculture, Forest Service, General Technical Report PSW-GTR-131.

Stinson, K.J., and Wright, H.A., 1969, Temperature of headfires in the southern mixed prairie of Texas. Journal of Range Management, v.#22, p.#169-174.

Wells, C.G., Campbell, R.E., DeBano, L.F., Lewis, C.E., Fredriksen, R.L., Franklin, E.C., Froelich, R.C., and Dunn, P.H., 1979, Effects of fire on soil, a state-of-knowledge review. USDA Forest Service, Washington Office, General Technical Report WO-7. 34 p

Whelan, R.J., 1995, The ecology of fire: Cambridge University Press, Cambridge, UK., 346 p.

Wright, H.A., 1970, A method to determine heat-caused mortality in bunchgrasses: Ecology, v.#51, p.#582-587.

APPENDIX B

How to Build a Firelogger

1. Determine whether your measurements will be at or above the soil surface. If so, you need Type K HOBO loggers, which have a range of 0 – 1250^{0}C (32 – 2282^{0}F) and a resolution of 5 – 10^{0}C. If you intend to take readings in the soil or under tree bark where temperatures are generally lower, you will need Type J HOBO loggers (same cost, different part number).

2. Determine whether you want to use individual loggers (each logger is in a separate container and individually deployed, which is our usual configuration) or grouped loggers (4 – 6 loggers are put into one case). There is some degree of personal preference involved in this choice; however, two particulars can help make the decision for you. If you want to be able to deploy the thermocouples more than 4 m apart, you will need individual loggers. If you only want to dig one large hole for the case instead of individual small holes, you will want the group configuration. If you don't mind digging individual holes for each logger, we recommend the individual loggers. We should add, however, that more assembly is required for the individual loggers.

3. Decide whether 3 ft. – long thermocouple cables will serve your needs or whether you need 10 ft. cables. We find that 3-foot cables are suitable for most applications in grasslands with individual loggers. With group loggers, we use the 10-foot cables. If you intend to measure temperatures very far off the ground (e.g., fire effects on trees), you will probably want 10-foot cables. Some users buy both types of cables for each logger, though you will probably end up making a separate logger case for each cable. Our standard configuration for individual loggers in grassland studies is the 3-foot cable.

4. Now you are ready to order the parts. For loggers, you will need the following:

Go to:
http://www.onsetcomp.com/Products/Product_Pages/Other_HOBOs/thermocouple_data_loggers.html

A. Select the Type K logger (H12-002) or Type J logger (H12-001).

B. Order subminiature connectors for Type K wire (# SMC-K), or for Type J (# SMC-J). These will be used to attach the thermocouple (obtained from Omega Co.) to the HOBO logger. These can be found at the same URL listed above.

C. Select the PVC water proof case for single data loggers. This part can be found at http://www.onsetcomp.com/Products/Product_Pages/temperature_pages/Subcase.html. We used part SUBC2-WH for individual loggers.

D. For the thermocouples, go to http://www.omega.com/pptst/XCIB.html.

For the 3 ft cable for a K logger, we order part XCIB-K-2-3-3. Options are clearly marked on the order form.

E. Now, you need a waterproof electrical junction for entering electrical wires into circuit boxes. This inexpensive part is found at any electrical supply house.

5. Having all the parts you need for your loggers, you will need one copy of data retrieval software (e.g., BoxCar) and perhaps a shuttle (HOBO).

A. Software: (Boxcar or Boxcar Pro)
http://www.onsetcomp.com/Products/Product_Pages/BoxCar_Pro_pages/4263_BC36.html

B. Data shuttle:
http://www.onsetcomp.com/Products/Product_Pages/temperature_pages/HOBO_shuttle.html

Now, you have all the materials you need. Refer to the Firelogger User's Manual (USGS) for assembly, configuration, and use.