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Test of a new heat flux sensor in an experimental burn

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Background

A heat flux sensor is an important tool for studying the effects of wildfire on the urban interface. It provides a measurable reading of the radiant energy applied to surfaces that are exposed to wildfire.

A new heat flux sensor prototype (Figure 1) was developed by Mark Ackerman, an engineering consultant based in Alberta, in 2016. The old style of heat flux sensor (Figure 2) was designed to simulate human skin conditions in order to conduct research on firefighter safety. This sensor became saturated by high heat in a very short time, usually before the passage of the fire front. It would be physically destroyed if the heat flux was high or the duration of exposure was long. The new sensor can record heat flux data during the passage of a crown fire's front due to changing the calorimeter material on the sensor.

The new heat flux sensor has one 68-g block of aluminum which is the calorimeter and it is painted with a black surface. M-board insulation surrounds the aluminum block. Stainless steel shells the outside of the M-board insulation to protect it and to keep it from breaking apart. A stainless steel over braiding and fibreglass-insulated Type K thermocouple is inserted into the aluminum block to measure temperature changes. Heat flux is determined by measuring the rate of change of temperature in the aluminum block. The sensor is capable of collecting data in a high-intensity crown fire, and the size was selected (5 cm in diameter and 4 cm in thickness) to ensure the calorimeter (sensor) temperature did not exceed 300^{o}C during a 2-min exposure. For lower-intensity short-duration fires, the mass of the calorimeter can be changed to increase the thermal response.

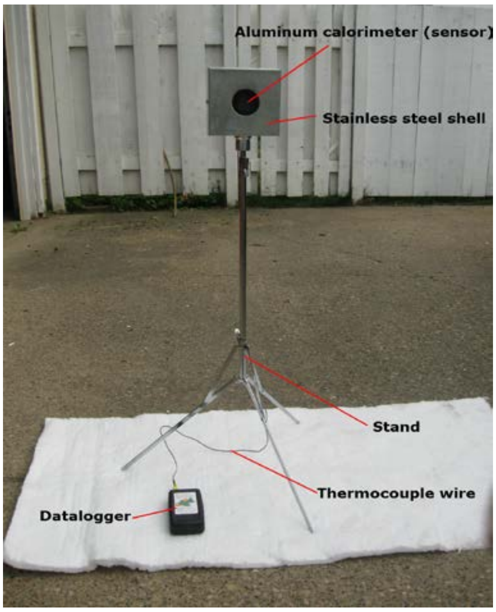

Figure 1. The new heat flux sensor.

Figure 2. The old style of heat flux sensor.

Site of the prescribed burn

The new heat flux sensors were tested during an experimental burn at the Pelican Mountain FireSmart Research Area in central Alberta on May 31, 2017. The burn occurred on a flat surface comprised of a layer of mulched fuels. The burn plot was 80x40 m in size. Flame heights averaged 1 m and the burn moved at an average rate of 0.8 m/min.

Field setup

Twelve heat flux sensors were deployed for testing at the burn site. Each sensor was placed on a support stand that was either a 120 cm stainless steel pole (Figure 3) or an off-the-shelf music tripod (Hamilton KB400N folding sheet-music stand) (Figure 4). All sensors were positioned 1 m above ground level. Data were recorded by Alberta Agriculture and Forestry rate-of-spread dataloggers. To limit the amount of heat affecting the dataloggers, they were buried in a hole adjacent to the stand. Dataloggers with the music tripod were in holes that were 15x15 cm wide and 15 cm deep, and those by the steel pole were buried in holes 15x15 cm wide and 20 cm deep. The stainless steel pole required a deeper hole to stabilize the pole.

Results

Nine sets of temperature data were collected for the embedded thermocouple were downloaded successfully. A program was required to convert the temperature data (^{o}C) to heat flux (kW/m^2). Following validation of the data, only six data sets were usable (Table 1).

Table 1. Peak heat flux recorded during the experimental burn

Data logger no.	Peak heat flux (kW/m^2)
E1	67
E2	49
E3	37
E4	Sensor had no direct contact with fire
C1	Could not download data
C2	Could not download data
C3	123
C4	Data error caused by data logger
W1	Data error caused by thermocouple
W2	86
W3	80
W4	Data error caused by thermocouple

Observations

The rate-of-spread dataloggers were set to the default mode, which meant one temperature reading was recorded every 30 seconds when temperatures were <50^{o}C. The peak heat flux occurs during the rapid temperature increase which may happen below 50^{o}C. Thirty seconds per recording is not sufficient to convert temperature to heat flux. In future trials, the dataloggers will be configured to record once per second from the time they are deployed. The datalogger download program was also modified to take advantage of the higher resolution temperature measurements the dataloggers are capable of.

It was suggested that the outer steel cases of the heat flux sensors be painted in a highly visible colour rather than the original stainless steel colour to aid in locating them after each fire. This will depend on the availability of a high-visibility paint that is capable of withstanding high heat exposure.

The music tripod was preferred over the single stainless pole. The single stainless pole required a bigger and deeper hole to hold it solidly in the ground. The music tripod was preferred because it was simple and quick to set up.

During the experiment, the dataloggers were buried underground. However, the groundwater table was high and some thermocouple wires which were not waterproof were submerged. We suspect water caused the errors in multiple data sets due to the thermocouple shorting.

Based on these findings, all new heat flux sensors will be modified so they can be mounted on the music tripods.

A simple user guide will also be developed to assist users in using the sensors. A short instruction manual on downloading the data and then converting it to heat flux should make it easy for anyone to use these sensors.

Figure 3. The new heat flux sensor positioned 1 m above the ground on a stainless steel pole.

Figure 4. The new heat flux sensor positioned 1 m above the ground on a basic metal sheet-music tripod.