ERROR REDUCTION IN HEAT FLUX SENSOR USED IN FOREST FIRES

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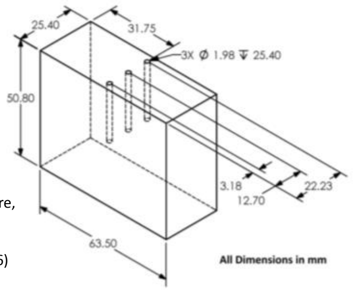
INTRODUCTION

Forest fires have been increasing in frequency due to various factors such as increased temperature, variability in moisture conditions and communities expanding into wild land urban interface environments. Quantifying the energy being released by the forest fires to its surroundings is crucial to fire fighting safety as well as in the effort to suppress wildfires. Thus a low cost heat flux sensor was built based on a one dimensional heat transfer model to measure the energy emitted by forest fires. The purpose of this research was to reduce the errors in the readings obtained from this sensor.



(E. Sullivan, A. McDonald, Int. J. Wildland Fire, in press, DOI: 10.1071/WF14016)

Figure 1: Dimensions of the Heat Flux Sensor

ESTIMATION OF ERROR

The equation used to calculate the heat flux from the sensors is shown below:

$$q''_{\text{incident}}(t)=\frac{1}{\varepsilon}\left(\frac{k\left[T(d,t)-T_1(t)\right]}{(L-d)}+\sigma\varepsilon\left[T(d,t)^4+T_1(t)^4-2T_\infty^4\right]\right).$$

(E. Sullivan, A. McDonald, Int. J. Wildland Fire, in press, DOI: 10.1071/WF14016)

There are several assumptions that could affect the accuracy of the heat flux estimate:

- The errors in emissivity and thermal conductivity were assumed to be zero even though in practice there would be some error.
- The error in the Stefan Boltzmann constant is taken as zero as the value is well documented.
- The error in the value of ambient temperature was assumed to be zero.
- The positioning of the thermocouples (*L* and *d*) was done with a tape measure, with an accuracy of 1 mm.
- As for the two temperature measurements, the values were taken using two J-type thermocouples, each of which had an error of 1.1°C, which was provided by the manufacturer.

METHOD

A significant amount of the error in the heat flux sensor was due to the error associated with measuring the temperature. Therefore, the thermocouple circuit was wired such that it gave the difference between the two temperature readings rather than the individual temperature readings, which would help reduce the error.

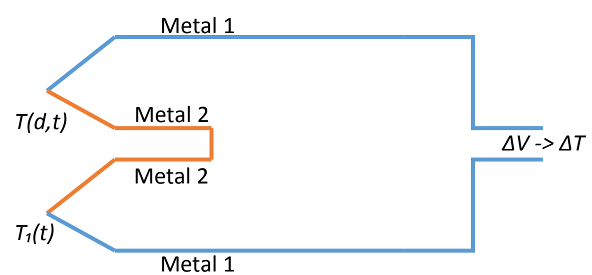


Fig 2: Thermocouple Circuit to obtain ΔT

The circuit is set up such that it requires the cold junction compensation present in most data acquisition systems to be removed. This is done by setting the cold junction compensation value to zero.

PROPAGATION OF UNCERTAINTIES

The propagated uncertainty in the estimated heat flux was calculated using the following equation:

$$\left(\frac{\omega_{q''_{net}}}{q''_{net}}\right)^2=\left(\frac{\left[(\omega_{T_1(t)})^2+(\omega_{T(d,t)})^2\right]^{1/2}}{T_1(t)-T(d,t)}\right)^2+\left(\frac{\left[(\omega_L)^2+(\omega_d)^2\right]^{1/2}}{(L-d)}\right)^2+8\left(\frac{\omega_{T_1(t)}}{T_1(t)}\right)^2+8\left(\frac{\omega_{T(d,t)}}{T(d,t)}\right)^2$$

The error values obtained upon using the original sensor designed by Sullivan and McDonald (2014) was 142% for low heat flux (12.7 kW/m2) and 33% for high heat flux (64.2 kW/m2).

On implementing the new circuit and using differential temperature, instead of the individual temperatures, the error for low heat flux (12.7 kW/m2) was reduced to 101% and the error for the high heat flux (64.2 kW/m2) was reduced to 22%.

CONCLUSION

- By using the new circuit to determine the differential temperature, the error in the heat flux sensor was reduced significantly.
- The error can further be reduced by using a material that has lower thermal conductivity to increase the temperature difference.