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# Interactions of separated lines of fire in a ‘V’ formation

The behaviour of two intersecting lines of fires in a ‘V’ shape burning in the Pyrotron was previously reported in *PyroPage #26*. Interactions between these firelines were most evident with wind and typically doubled the expected rate of spread of the point of intersection. A subsequent extension of this study investigated non-intersecting (i.e., separated) lines of fire under similar conditions with fundamentally different fire behaviour to that of intersecting firelines. Many fires maintained the initial separation for some distance downwind before merging, suggesting that the behaviour of such separated fires is driven by both radiative and convective interactions acting in concert.

## Fireline interactions and merging fires

Understanding the potential for adjacent fires to interact and merge to form larger propagating fronts is critical to many aspects of fire behaviour and fire management, including the behaviour spotfires, with implications for the prediction of fire spread in the landscape and firefighter safety, and the lighting of multiple simultaneous ignitions for prescribed burning.

Previously, small intersecting lines of fire in a ‘V’ shape were studied under the controlled conditions of the CSIRO Pyrotron combustion wind tunnel both in the presence and absence of wind (Sullivan *et al.* 2019). Fuel beds of 1.2 kg/m$^2$ of dry eucalypt litter were conditioned to 3-6% oven-dry weight moisture content and pairs of fire lines of ignition line lengths 800 and 1500 mm were studied at four incident intersection angles, 15, 30, 45 and 60°.

In the absence of wind, no effect beyond that of the geometry was observed in the progression of the vertex point (the junction or join of the arms of the ‘V’) between the firelines. With a wind (~1 m/s), however, a strong interaction between firelines was observed, resulting in rates of vertex spread almost twice that expected if there were no interactions. It was concluded that convective and radiative thermal interactions between the individual firelines acted to enhance the spread of the fire but generally only between the arms of the ‘V’.

## Non-interacting fireline experiments

A complimentary set of experiments exploring the effect of a 150 mm separation of the firelines was undertaken utilising the same experimental conditions, with and without wind. In this case only ignition lines at 30 and 45° were studied with four replicates of each arrangement and a control consisting of one half of each fireline pair.

## Results

In the no wind experiments (i.e., calm conditions), the pairs of separated fires quickly merged at the closest point and subsequently behaved very similarly to the previous non-separated experiments. However, the separated experimental fires burning with wind behaved very differently to these and also the controls (Fig. 1), requiring a different method of analysis.

Separated fires in the presence of wind often sustained the initial separation for some time without developing a vertex. When the fires did finally merge, it often did so first at a location some distance downwind from the point at which the ignition lines were closest.

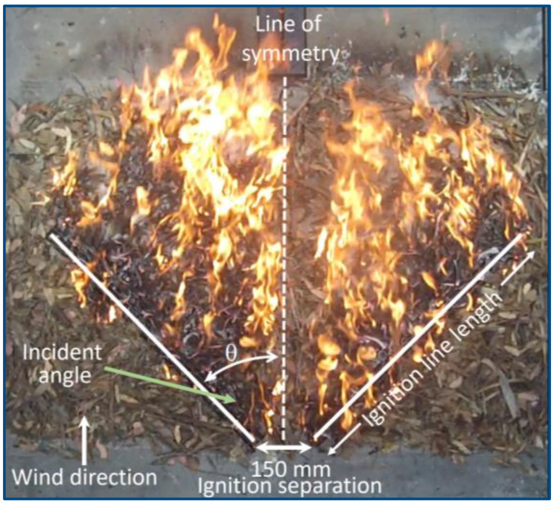


**Figure 1. Annotated frame from rectified video of experimental fire #5, 800 mm ignition length, 45° incident angle(θ), 40 s after ignition. The effect of the 150 mm separation is evident.**

Figure 2 summarises the spread of experimental fire #5 as an example, based on analysis of the propagation of the fire perimeters every 10 seconds from imagery obtained from rectified planar video. The fires maintained the initial separation for more than 50 s after ignition before the inner flanks finally merged. The trajectories of the heads of each fire (marked by 'H') showed a tendency to burn in the direction of the wind up to 30 s after ignition before they finally were drawn toward each other.

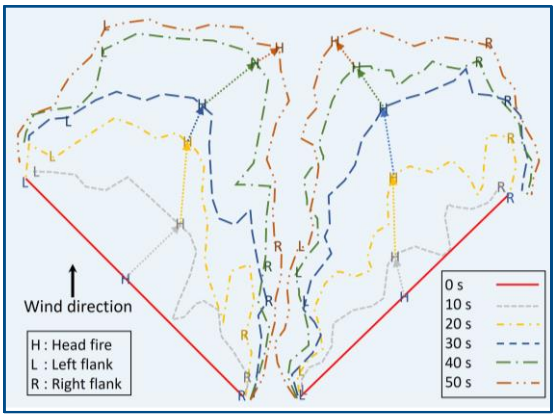


**Figure 2. Summary map of the progression of the fire perimeters in experimental fire #5 at 10 s intervals showing the sustained separation of the fires until it merged after 50 s. The position of each part of the perimeter is marked by H, L or R. Dashed lines show the head fire trajectories.**

All head fires eventually drew toward each other reducing the head fire separation before merging, but often took some time (Fig. 3a). No significant difference was observed between the 800 mm long 30° and 45° treatments but there was between the 800- and 1500-mm treatments, with the latter exhibiting a much faster rate of merging. Conversely, there was a significant difference in the merge location between the 800 mm 30° and 45° treatments but not between the 30° treatments (Fig. 3b).

## Implications and conclusions

The behaviour of these experimental fires, with and without wind, was intriguing. The sustained separation of fires burning with wind could be because the wind was strong enough to dominate the heat transfer mechanisms (i.e., the convection driven by buoyancy of the flames in the direction of the wind and radiation from the flames in all directions) and their interactions. Yet, ultimately, the fires *did* merge, suggesting that some interaction of the radiation and buoyancy-driven convection from the flames (for which we coined the phrase *convecto-radiative* interactions), affected by the wind, was driving these fires, over and above the normal lateral spread of the fire edge.

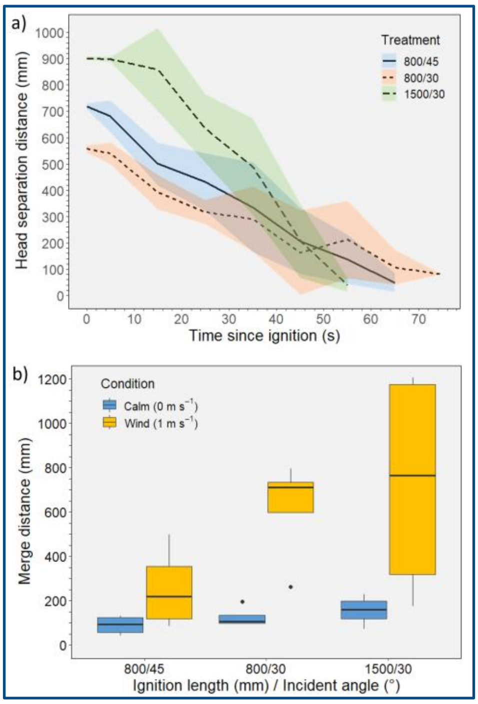


**Figure 3. a) Summary plot of the distance between the wind-blown head fires with time since ignition showing range of values (shaded areas) across all replicates and treatments. b) Summary box plot of merge distance across all replicates and treatments.**

This joint consideration of both convective and radiative heat transfer is more intuitive than trying to account for convection and radiation separately, and better captures the nature of wind-affected flames. Understanding the complex interactions of these mechanisms with burning conditions is critical to improving our ability to predict the behaviour and spread of multiple simultaneous ignitions and nascent fires. Future research will aim to quantify contributions of aspects such as fuel combustibility (e.g., fuel moisture) and fuel structure (e.g., bulk density) to the convecto-radiative interactions of fires so such behaviour can be predicted.

### Further reading


Sullivan AL, Swedosh W (2023) Interactions of non-intersecting oblique lines of fire burning in surface fuels in a combustion wind tunnel with and without wind. *International Journal of Wildland Fire* 32, 1741–1757. doi:10.1071/WF23075.


### References


Sullivan AL, Swedosh W, et al. (2019) Investigation of the effects of interactions of intersecting oblique fire lines with and without wind in a combustion wind tunnel. *International Journal of Wildland Fire* 28, 704–719. doi:10.1071/WF18217.





FOR FURTHER INFORMATION

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