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### Title

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### Authors

Weise, D.R.  
Cobian-Iñiguez, J.  
Princevac, M.

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## Surface to Crown Transition



David R. Weise<sup>1</sup>, Jeanette Cobian-Iñiguez<sup>2</sup>, and Marko Princevac<sup>2</sup>

<sup>1</sup>PSW Research Station, USDA Forest Service, Riverside, CA, USA

<sup>2</sup>Department of Mechanical Engineering, University of California, Riverside, Riverside, CA, USA

### Synonyms

Intermittent crown fire, blowup fire

### Definition

Process in which a fire spreading horizontally in surface fuels moves vertically by igniting vegetative fuels located above the fire.

### Introduction

Wildland fires are generally classified into three categories: ground fires, surface fires, and crown fires (Fig. 1). Soils are described worldwide by the various layers that have formed or been deposited on top of bedrock or other parent material. In wildland areas, the layer closest to the surface is composed of organic

material deposited by plants (Foth 1978). The organic layer is divided into two parts – the O<sub>1</sub> layer at the surface and the O<sub>2</sub> layer which forms under the O<sub>1</sub> layer. Ground fires burn the matted and decomposed organic material that forms the O<sub>2</sub> layer. Surface fires burn the surface litter (O<sub>1</sub> layer), other loose debris, and small vegetation. Crown fires burn through the living foliage and branches of trees and shrubs independently or coupled to a surface fire. Because the fire environment consisting of vegetative fuels, weather, and topography is complex and dynamic, these fire types often occur simultaneously within a wildland fire, and transitions between the fire types occur as fuels, weather, and topography change.

### Current Understanding

Crown fires are dual layer fires which usually involve both the surface fuel layer and the crown fuel layer. Most, although not all, crown fires depend on the surface fire for the supply of energy. In general, a crown fire will be initiated by the transition of a surface fire to the crown fuel layer when crown fuels reach the critical temperature required for ignition after being heated by the energy flux from the surface fire. Even though the transition of a surface fire to a crown fire is essentially a gas-phase reaction between gases produced by the heating (pyrolysis) of the solid crown fuel and oxygen which occurs at the



**Surface to Crown Transition, Fig. 1** Wildland fire can spread as a ground fire in peat in Tablas de Daimiel, Spain (left), a surface fire in 3-year-old rough under longleaf pine near Tifton, Georgia, USA (middle), or a crown fire on the Okanogan-Wenatchee National Forest, Washing-

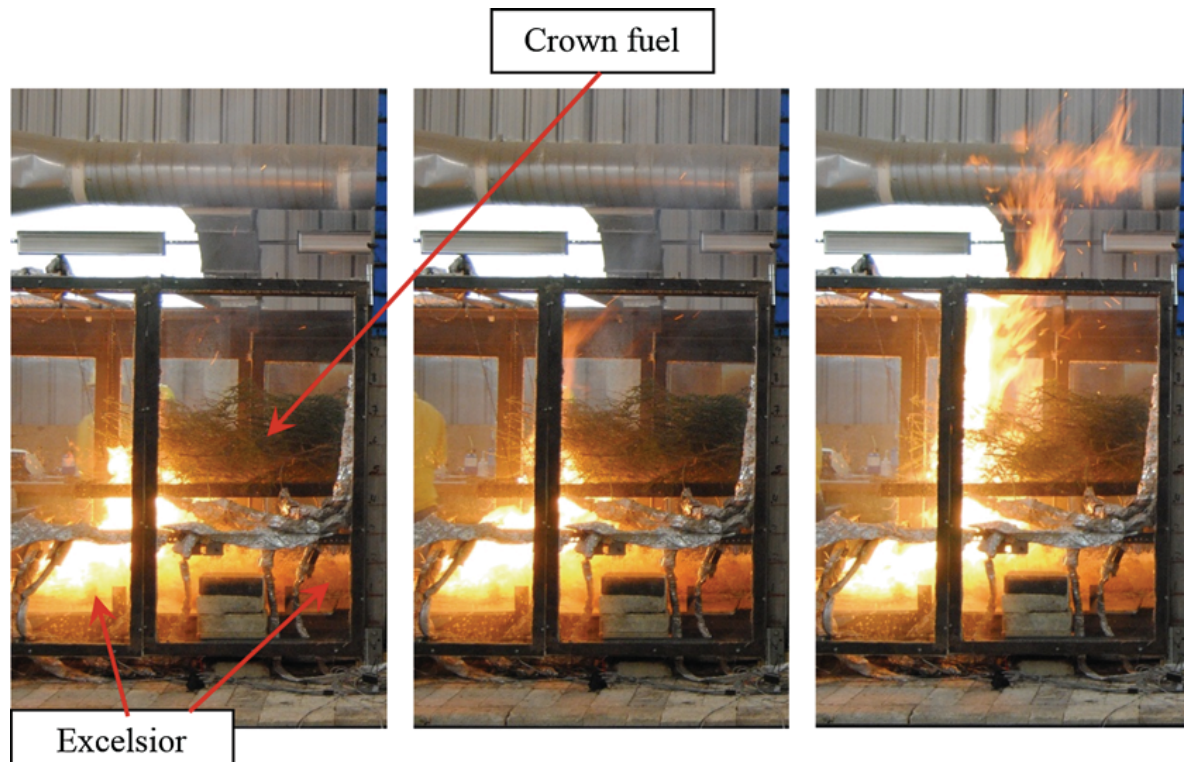
ton, USA (right). (Photographic credits: Guillermo Rein, 2010 CC BY (right); David J. Moorhead, University of Georgia, [Bugwood.org](http://Bugwood.org) (middle); Kari Greer, USDA Forest Service (right))

molecular level (Drysdale 2011) (also see entries for [Combustion](#), [Ignition](#), and [Pyrolysis](#)), more readily observable fuel and fire characteristics have been used. A surface fire will transition to a tree crown if the surface fire intensity (energy release rate) surpasses a critical value which is governed by the crown fuel bed properties. Surface fire intensity ( $I = hwr$ ) is the product of the surface fuel's energy content ( $h$ ), the mass of fuel that is being burned ( $w$ ), and the rate of spread of the surface fire ( $r$ ) (Byram 1959) and is equivalent to  $\dot{Q}_l$  (Yuan and Cox 1996). The critical value that surface fire intensity must exceed is a function of the distance between the ground and the bottom of a tree's crown and the energy required to ignite the crown foliage. This ignition energy is influenced by the amount of water in the foliage. The amount of foliage (crown bulk density) is also an important factor governing the successful spread of a crown fire. Since the initial work focused on conifers in Canada, this basic understanding has been examined, refined, and developed to include other coniferous forest types throughout the world (Werth et al. 2011, 2016).

In shrub and woodland types, fires have often been described and modeled as surface fires in deep fuel beds of living vegetation; however, in

many shrub types, there is often little fuel in contact with the ground, and the fire spreads through the elevated shrub crowns independently of any surface fire. Crown fires occur in shrub and woodland vegetation types in Mediterranean climate regions of the world as well as the eucalyptus forests of Australia. In eucalyptus forests, the transition from surface to crown fire is strongly influenced by profuse spotting (ember production and transport) and multilayered fuel beds. The profuse spotting results in localized areas of increased fire intensity, and the multilayered fuel beds provide a "ladder" or vertical continuity enabling a surface fire to "climb" into the upper forest canopy.

The fuel parameters and physical processes that have been identified for crown fires in coniferous forests also govern the transition of a surface fire to a crown fire in shrub fuels (Fig. 2). These include wind speed, surface fuel loading (if present), the distance between the shrub crown and the flame, the foliage moisture content, and the shrub crown bulk density. Increasing bulk density in the shrub crowns results in slower passage of the hot flame gases through the crowns resulting in increased heating due to increased convection and in increased likelihood of successful foliage ignition.



**Surface to Crown Transition, Fig. 2** Sequence of photos showing transition from a surface fire in quaking aspen (*Populus tremuloides* Michx.) excelsior (shredded wood) to a crown fuel made of chamise (*Adenostoma fasciculatum* Hook. and Arn.) branches and foliage. Elapsed time is approximately 1 minute. In the left panel, the surface

fire is heating the crown fuel. In the middle panel, a portion of the crown fuel has ignited as indicated by the small flame. In the right panel, the crown fuel is fully ignited and spreading with the surface fire. Photographic credit: Jeanette Cobian-Iñiguez, University of California – Riverside

## Ecological Aspects

Fire is a significant evolutionary force on terrestrial vegetation, and many species are reliant on fire in order to successfully reproduce (Barbour et al. 1980). Following a fire, plants will regenerate from viable seeds or by sprouting from buds protected from the damaging heat of a fire. The seeds are either stored in the soil or released by the plant fruits after a fire's passage. Many plants exhibit serotiny which means that seeds are retained in the fruit on the plant for a long time and the seeds are gradually released. Heat from a fire can cause the fruit (often a cone) to open releasing the seed. For those plants which use sprouting following fire as a reproductive strategy, fire transition from the surface into the plant's crown is necessary in order for the living foliage and woody branches to be consumed. Removal of the aboveground plant material stimulates the protected buds to

grow. Transition to a crown fire may also be necessary in order to provide enough heat to open the cones and fruit. These ecological adaptations have been studied extensively in the conifers as well as shrub species in Mediterranean regions of the world. Lack of fire transition resulting in reproductive delay or failure could have significant consequences on the survival of these species. Species not adapted to crown fire can be adversely affected if fuel and weather conditions are favorable resulting in the transition of a low-intensity surface fire to a higher-intensity crown fire.

As described elsewhere (see [Emissions](#) entry), heat, water vapor, CO<sub>2</sub>, particulate matter, and a myriad of trace gases result from the combustion of vegetation (Ward 2001). The composition, quantity, and release rates of these combustion products change with fire type and burning conditions. The transition of a surface fire into a crown



fire changes the type of fuel being burned, increases the rate at which energy is released, alters the completeness of the combustion and the composition of the smoke, increases the height into the atmosphere at which the combustion products are mixed, and typically increases the size of the area which is burned. All of these changes in fire character as a result of the transition have different ecological effects when compared to surface and ground fires.

### Human Safety Aspects

Prediction of when and how a transition from a surface fire to a crown fire will occur is of keen importance when human safety is considered. The safety risk is immediate for people in close proximity to the transition. As a crown fire is more energetic, the risk to people and resources removed some distance from the actual transition location is quantifiable. Tools predicting the transition from a surface fire to a crown fire (Werth et al. 2011, 2016) can be used for risk analysis by estimating when a transition may occur. Risk reduction as a result of fuel modification can be estimated with these tools as well. The risk of transition can be reduced by (1) increasing the distance between the surface fire and the crown fuel and/or (2) decreasing the heat release rate of the surface fire. In forests and woodlands, various silvicultural practices such as mechanical thinning, herbicide use, and prescribed burning are used to reduce the risk of fire transition. Grazing by various domestic animals is an effective vegetation management technique applied worldwide in many shrub and woodland systems. Similarly pruning and fuel wood gathering interrupt vertical fuel continuity reducing transition risk. Conversely, the abandonment or reduction in these various vegetation management techniques through fire suppression and rural to urban population shifts has increased the risk of surface fire and transition from surface to crown fire in many places in the world (Pyne and Goldammer 1997).

In the wildland-urban interface, the transition of a surface fire in vegetation to a fire spreading from structure to structure has some similarities

to the transition of a surface fire to a crown fire in vegetation. In order for a structure to ignite from a surface fire, the heat flux from the surface fire needs to be sufficient to ignite the structural fuels adjacent and above the surface fire. A surface fire can also produce firebrands which may cause structure ignition. Successful structure to structure fire spread is influenced by many variables including structure density which is similar to crown bulk density. To our knowledge, the surface to crown fire transition models developed for wildland settings have not been evaluated for use in the wildland-urban interface. Guidelines exist in many jurisdictions worldwide governing the proximity of surface vegetative fuels to structures and the composition of the exterior of structures as a means to reduce the risk of transition of a surface fire to the structure.

### Cross-References

- ▶ [Combustion](#)
- ▶ [Convection](#)
- ▶ [Crown Bulk Density](#)
- ▶ [Crown Fire](#)
- ▶ [Crown Fuel](#)
- ▶ [Direct Flame Contact](#)
- ▶ [Ember](#)
- ▶ [Emissions](#)
- ▶ [Fire Intensity](#)
- ▶ [Firebrand](#)
- ▶ [Fireline Intensity](#)
- ▶ [Ground Fire](#)
- ▶ [Ground Fuel](#)
- ▶ [Heat Release Rate](#)
- ▶ [Ignition](#)
- ▶ [Ladder Fuels](#)
- ▶ [Plant Adaptations to Fire](#)
- ▶ [Pyrolysis](#)
- ▶ [Rate of Spread](#)
- ▶ [Spotting](#)
- ▶ [Structure Firebrand Attack](#)
- ▶ [Surface Fire](#)
- ▶ [Surface Fuel](#)
- ▶ [Vegetative Firebrand Attack](#)
- ▶ [Wildland Fuel Treatments](#)
- ▶ [Wildland-Urban Interface](#)

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