

THE GENERAL NATURE OF CROWN FIRES



Martin E. Alexander and Miguel G. Cruz

In conifer forests, three broad types of fire are commonly recognized on the basis of the fuel stratum or strata controlling their propagation:

- Ground or subsurface fire,
- Surface fire, and
- Crown fire.

Ground or subsurface fires burn very slowly in the duff layer with no visible flame and sometimes with only the occasional wisp of smoke. Surface fires spread in the litter and dead-down woody fuel layer of a stand in either the heading direction with the wind and/or upslope, or as backing fires advancing into the wind and/or downslope.

Crown fires are dependent on a surface fire and, in some instances, ladder or bridge fuels for both its initial onset and capacity for maintaining flames in the crown space of a conifer forest stand. Thus, a crown fire advances through both the surface and tree canopy fuel layers with the surface and crown fire phases more or less linked together as a single unit. Thus, the term “crowning” refers to both the fire’s ascension into the crowns of trees and the spread from tree to tree.

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According to Davis, “In actual fire situations, these three kinds of fire may occur simultaneously and in all kinds of combinations. Surface fires are by far the most common, and nearly all fires start as such. A surface fire may spread into the crowns and develop into a sweeping crown fire. A crown fire may drop to the ground and become a surface fire. Similarly, a surface fire may develop into a stubborn ground fire that may plague control forces for days or weeks. On a hot, dry, and windy afternoon, a rather innocuous-looking ground fire may be fanned into surface or crown fire” (1959).

The Power and Significance of Crown Fires

Crown fires in conifer forests constitute one of nature’s most spectacular phenomena. The power exhibited by crown fires, including the spawning of tornadic-like activity, can leave one awestruck—as it did pioneer forest fire researcher Harry T. Gisborne (see the sidebar). Crown fires can, for a number of reasons, be dangerous for firefighters to attempt to control by direct attack. They also pose a safety threat to members of the general public that live, work, and recreate in crown fire-prone environments.



Active crowning associated with the Jackpine Fire in the Willmore Wilderness Park, Alberta, Canada, at 4:29 p.m. MDT on July 4, 2006. Photo taken by Emile Desnoyers, Alberta Environment and Sustainable Resource Development.

Until there is a major, favorable change in the prevailing environmental conditions (fuels, weather, and/or topography), there is little that can be done to contain the headlong rush of a high-intensity crown fire—at least by conventional means of suppression, including attack by aircraft. This is due to the crown fire’s rate of spread, the fierce thermal radiation emitted by the “wall of flame” front, and the spotting activity downwind of the main advancing front. Crown fires are thus capable of burning large tracts of forested landscape, seriously impacting environmental and ecosystem resources, damaging and destroying values at risk in the wildland-urban interface zone, and increasing fire suppression expenditures.

Types of Crown Fires

The term “crown fire” has appeared in the forestry and ecological literature since at least the 1880s. Eventually, two broad types or classes of crown fire—“dependent crown fire” and “running crown fire”—became recognized by the late 1930s to distinguish the degree of dependence upon the supporting surface fire. A dependent crown fire depends upon the heat generated by the surface fire for its spread whereas a running crown fire is one that generates enough heat for crown-to-crown spread.

Other terms have come to describe crown fires: “fully developed” crown fire (Luke and McArthur 1978), “wind-driven” and “plume-dominated” crown fires (Rothermel 1991), and “intermittent” and “continuous” crown fires (Forestry Canada Fire Danger Group 1992). Van Wagner’s (1977) crown fire classifi-



Post-burn mosaic pattern in the Bunsen Peak area of Yellowstone National Park associated with the occurrence of the North Fork Fire during the 1988 fire season, illustrating various types of fire activity. This includes: (i) no fire, ground fire, and low-intensity surface fire (green crowns); (ii) high-intensity surface fire and passive crown fire (red, scorched crowns); and active crown fire (black, flame defoliated crowns). Photo by Jim Peaco, National Park Service, courtesy of the Yellowstone Digital Slide File.

cation is the most widely accepted. He proposed that three kinds or classes of crown fire could be described according to their degree of dependence on the surface phase of fire spread using several semi-mathematical statements:

- Passive crown fire,
- Active crown fire, and
- Independent crown fire.

The third kind or class was regarded as a rare and short-lived occurrence (Van Wagner 1993).

Generally, all fires classed as crown fires contain areas of ground fire and low- to high-intensity surface fires as well. In dense, conifer-dominated forested landscapes, this complex mosaic pattern is the result of short-term variations in wind speed and direction interacting with stand structure, surface fuel characteristics, and topography (Alvarez and others 2013). Van Wagner (1977) regarded this type of crown fire behavior as “intermittent active crowning.”

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Harry T. Gisborne's Account of the 1929 Half-Moon Fire "Explosion"[†]

Newspaper accounts of large forest fires in the northern Rocky Mountain region frequently refer to "runs," "blow-ups," and occasionally to "explosions" of the fire.

"When Montana's largest human-caused fire, the 90,000-acre [36,425 ha] Half-Moon conflagration, ran this summer [1929] from Teakettle Mountain to Belton and Glacier Park Headquarters in 1 afternoon it left a trail of desolation which ruined that 12-mile [19 km] auto drive for many, many years.

"At the Desert Mountain forest-fire lookout station, 4 miles [6.5 km] south of Belton and 5,000 feet [1,525 m] above it, the man on duty made fast time down the 9-mile [14.5 km] trail to Coram Ranger Station when the head of this fire came roaring toward his mountain. But the natural wind channel, formed by the gorge of the Middle Fork of the Flathead River, drew the center of devastation past him temporarily. Two days later, on August 23, 1929, we went back to the top of Desert to obtain measurements of atmospheric temperature, humidity, and wind, and to note for comparison the behavior of the fire in different timber types on different slopes and exposures according to the prevailing weather.

"We arrived in the lookout station about noon and after making a first series of weather measurements. I went north the half mile along the ridge top to Belton

Point, a secondary observation station.

"At the time the southern flank of the fire was still over a mile [1.6 km] from the base of the steep north end of the mountain. Perhaps 6 miles [10 km] of front were visible, the rest hidden by soft swirls of big columns of smoke. Although the front below me was beginning to boil actively in the green timber, as a result of rising temperature and wind and decreasing afternoon humidity, it was not yet crowning extensively. And with the light wind coming from the southwest, diagonally opposite the advance toward the south, I thought it was safe to go down to the spring, some 800 feet [245 m] in elevation and 13 switchbacks by trail, below Belton Point and on its eastern slope."

"The trip to the spring and back to the lookout station, with a 5-gallon [19 l] back-pack, was completed just in time for the 4 o'clock weather measurements. It seemed preferable, however, to make these on Belton Point closer to the fire and where the front, which was now very active, could be seen more extensively than from the main station. This was a sad decision, because it resulted in no measurements whatever.

"The lookout, Mr. Tunnell, who had been cleaning up the cabin while I went for water, decided to go with me to Belton Point. As we walked toward it, smoke was boiling up from the north end of the mountain in a tremendous pillar towering ... above our 7,400-foot [2,255 m] station. Just as when one

looks up from sidewalk at the base of a sky-scraper the top is out of view, so the top of this column of smoke was hidden by its sides, even though we were over half a mile [0.8 km] from its base. For some unknown reason, the customary roar of such rapidly rising masses of smoke, gas, and flame was not present in this case, nor did I notice it later when the mile [1.6 km] wide whirling "explosion" developed and swept in under us. It was obvious, nevertheless, that the fire front that had been over a mile from the base of the mountain an hour ago was now going to reach Belton Point before we could, or at least before we would.

"Like all truly massive movements the great pillar of smoke belching from the north face of the mountain seemed to move slowly. Black bodies of unburned gases would push their fungoid heads to the surface of the column, change to the orange of flame as they reached oxygen, and then to the dusty gray of smoke. Huge bulges would grow slowly on the side of the column obliterating other protuberances and being in turn engulfed. We could see beautifully, as the atmosphere between the fire and us was kept clear by the light southwesterly wind. There seemed to be no danger as the mountain of smoke leaned appreciably with this breeze, and leaned away from us. We went forward about 200 yards [180 m].

"Such a spectacle, even as it enlarged one's heart enough to interfere with normal breathing, made us wish for the presence of others to enjoy the thrill. We

[†]Adapted from Gisborne (1929)

stopped to take two pictures, one of the soft and apparently slowly boiling smoke column to the north, and one to the northeast out across the 2-mile [3.2 km]-wide canyon. Down there lay the valley in the shadow of death, but although even the poor photograph portrays it, we did not realize what was to happen in the next few minutes.

“Even as I snapped these two photographs, we noticed that the wind velocity was increasing. One glance at the boiling inferno north of us, and we saw the reason. The southwest wind, sweeping gently as it was around northwest shoulder of Desert Mountain, was striking the periphery of a rising mass of

hot gas and smoke. The result was the being of a whirling, clockwise motion, with the deep canyon east of us acting to draw the center of suction into it.

“Suddenly, yet it seemed slowly—the movement was so massive, the curtain of smoke across the mouth of the canyon bulged at about our level. The bulge moved south, up the canyon, turned toward the southwest and up the slope towards us.

“Most of this we saw over our shoulders as we sprinted south along the open ridge-top trail to the lookout cabin. As we dashed in the door to snatch our packsacks, we saw a sec-

ond whirl developing. As we came out the door, hurriedly adjusting our shoulder snaps, the new revolution swept majestically up the creek, up the slope under the lookout cabin—but a full quarter mile [0.5 km] below us, turned west, northwest, and north, and obliterated the spot from which we had taken our pictures.

“Then came the finale, the explosion, the display that should terminate any really spectacular show. The suction of this rising mass of heat drew the air across our ridge with a velocity that bounced me up against the lookout house as I stood there gaping. About 2 square miles [5.2 km²] of surface area, over 1,300 acres [525 ha], were devastated by these two whirls in a period of possibly 1 or 2 minutes.

“Ordinarily, the front of a forest fire advances like troops in skirmish formation, pushing ahead faster here, slower there, according to the timber type and fuels, but maintaining a practically unbroken front. Even when topography, fuels, and weather result in a crown fire, the sheet of flames leaps from tree crown to the next, changing green forest to black ruins at a relatively slow rate, from one-half to 1 mile an hour [0.8 to 1.6 km/h], according to two measured runs on the Sullivan creek fire. “Blow-ups” begin when such “runs” commence to throw spots of fire ahead of the advancing front, the spots burning back to swell the main front and thereby adding appreciably to the momentum of the rising mass of heat. Men have been able to race out to safety from in front of many ordinary runs and crown fires. Some men have escaped and some have been trapped by blow-ups.”



The first of two photographs taken of the Half-Moon Fire by H.T. Gisborne from between Belton Point and Desert Mountain Lookout during the late afternoon of August 23, 1929. From the Harry Thomas Gisborne Papers, Archives & Special Collections, Mansfield Library, University of Montana, Missoula, MT.

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On the Cover:



Crowning associated with the major run of the Cottonville Fire in central Wisconsin at 5:11 p.m. CDT on May 5, 2005, in a red pine plantation. Photo taken by Mike Lehman, Wisconsin Department of Natural Resources.

The USDA Forest Service's Fire and Aviation Management Staff has adopted a logo reflecting three central principles of wildland fire management:

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