Introduction to Wildland Fire Management

Fireline Safety 101: Know what your fire is doing at all times

REM 244: Introduction to Wildland Fire Management

5. Introduction to Fire Behavior
   • The Fire Environment
   • Fire Behavior Terminology
   • Fire Intensity and Rate of Spread
   • Extreme Fire Behavior

FOR 450: Fire Behavior

REM 244: The Fire Environment

Definition: The fire environment includes the weather, fuels, and topography factors that affect the ignition, sustainability, and spread of fires.

Most important factors are:

Weather: wind, temperature, and relative humidity >> rate of spread, direction of spread, and intensity
Topography: slope and aspect >> direction and rate of spread
Fuels: fuel moisture and fuel temperature >> fire intensity

Source: Firefighters Handbook of Wildland Firefighting, TIES (2005)
There are several terms used to describe different forms of fire behavior:

<table>
<thead>
<tr>
<th>Term</th>
<th>Flames / Direction</th>
<th>Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoldering</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>Creeping</td>
<td>Small</td>
<td>Low</td>
</tr>
<tr>
<td>Running</td>
<td>Well-defined head</td>
<td>High</td>
</tr>
<tr>
<td>Backing</td>
<td>Moving against wind, downhill, away from head</td>
<td>Low</td>
</tr>
<tr>
<td>Tending</td>
<td>Surface fire igniting occasional crowns or shrubs</td>
<td>n/a</td>
</tr>
<tr>
<td>Spotting</td>
<td>Firebrands and embers are carried by convection and ignite outside the fire perimeter</td>
<td>n/a</td>
</tr>
<tr>
<td>Crowning</td>
<td>Trees and crowns ignite and travels independent of surface fire</td>
<td>High</td>
</tr>
<tr>
<td>Blowup</td>
<td>Sudden increase in fire intensity or rate of spread</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Source: Firefighters Handbook of Wildland Firefighting, TEIE (2005)

212°F (100°C): Fuels heated and moisture is driven off the surface as steam
~620°F (327°C): Vapors and O₂ mix: ignite (combustion)

From Hardy et al 2001: Smoke Management Guide
**Lets Consider Flaming Combustion:**

900-2500°F (480-1400°C): Fuel temperature rapidly rises increasing pyrolysis and combustion
High Combustion Efficiency while vapors persist: Low emissions per fuel combusted
What Emissions are Mostly Produced at this Stage?

From Hardy et al 2001: Smoke Management Guide

---

**Lets Consider Smoldering Combustion:**

572-1100°F (300-600°C): Insufficient vapors to sustain flaming combustion to stop – drop in rate of spread
What Emissions are Mostly Produced at this Stage?
Low Combustion Efficiency: High emissions per fuel combusted

From Hardy et al 2001: Smoke Management Guide

---

**REM 244: Fire Intensity and Rate of Spread**

Definition: Fire intensity is the rate of energy release during combustion.

- **Fire Line Intensity:** Quantity of heat released per meter per second of the fire front
- **Heat per Unit Area:** Often used for smoke calculations

Fire intensity is dependent on fuels (loading, arrangement, and moisture), slope, and wind speed

Rate of Spread and Burn Patterns are dependent on wind speed, fire intensity, slope, fuels, spotting, and man-made barriers.

Wind Speed and Direction

---

---
The Process: Surface Fire Spread

Assumptions of Rothermel's Surface Fire Spread Model:
- Uniform and Continuous Fuels
- Subsequent ignitions not affected by source of 1st ignition
- No extreme wildfire behavior
- Describes fire behavior at flaming front of fire
- Weather and Slope are constant over fire affected area

REM 244: Extreme Fire Behavior

Definition: Extreme fire behavior are cases where direct attack is not possible and fires behave erratically, sometimes dangerously.

Fuel Loading Warning Signs:
- Large buildup of continuous fine fuels can lead to high spread rates
- Accumulation of dwindled wood can lead to long duration, high intensity fires
- Ladder fuels can facilitate crown fires
- If crown spacing is less that 20' => active crown fires are possible
**REM 244: Extreme Fire Behavior**

**Definition:** Extreme fire behavior are cases where direct attack is not possible and fires behave erratically, sometimes dangerously.

**Fuel Moisture Warning Signs:**
- RH dropping below 25%
- Large downed logs below 20% moisture content

The Zaca fire burned more than ¼ million acres and was the 2nd largest wildland fire in California's history. The Zaca fire was the 1st major incident to use WFDSS successfully.

*Source: Wildlandbehaviors.net; Firefighters Handbook of Wildland Firefighting, TEIE (2005)*

**Terrain Warning Signs:**
- Steep slopes can allow fires to rapidly spread uphill
- Box canyons and chutes can act like a chimney causing rapid rates of spread
- Fires on one side of a narrow canyons can causes fuels to pre-heat the other side >> increased ignition chance via spot fire.

*Source: Firefighters Handbook of Wildland Firefighting, TEIE (2005); Jenkins, Utah State University*

**Wind Warning Signs:**
- Look for swaying branches in trees
- Look to the clouds! Lenticular clouds indicate strong winds at high elevations
- Look for signs of thunderstorms and other signs of atmospheric instability
- Know weather forecast – look out for approach of cold fronts
- Foehn (“fane”) winds like the Santa Ana
- Understand the Beaufort Scale

*Source: Firefighters Handbook of Wildland Firefighting, TEIE (2005); Jenkins, Utah State University*
REM 244: Extreme Fire Behavior

Definition: Extreme fire behavior are cases where direct attack is not possible and fires behave erratically, sometimes dangerously.

Fire Behavior Warning Signs:
- Leaning smoke columns indicate wind driven fires with high rates of spread.
- Sheared smoke columns rise and then flatten off due to either inversions or upper-level winds >> potential for long range spotting
- Changes in color or shape of the smoke column
- Collapsing smoke columns are a warning of sudden wind gusts and erratic fire behavior

Sources: Firefighters Handbook of Wildland Firefighting, TEIE (2005); Jenkins, Utah State University
REM 244: Extreme Fire Behavior: Crown Fires

Passive Crown Fire: single or group of trees torch – spread of crown fire dependent on surface fire conditions

Active Crown Fire: direct heat transfer from one crown to another – still affected by surface fire spread. Fire often “pulses” from canopy to surface to canopy. Very Dangerous – Be Careful!

Independent Crown Fire: spread is not dependent on the surface fire. Get out of its way!

Los Alamos Fire 2011

Sources: Firefighters Handbook of Wildland Firefighting, TEIE (2005); Jenkins, Utah State University

The Process: Crown Fire Initiation

Van Wagner (1977) canopy fuels ignition model:
Surface Fires that reach an ‘Initiation’ Intensity or Rate of Spread exhibit sufficient HEAT to drive off canopy moisture and raise the canopy to the ignition temperature:

\[ I_{\text{Initiation}} = \left( \frac{CBH(460 + 25.9FMC)}{100} \right)^{1.5/2}, \quad R_{\text{Initiation}} = \frac{60I_{\text{Initiation}}}{HPA} \]

From Scott & Reinhardt (2001): Assessing crown fire potential by linking models of surface and crown fire behavior

The Process: Crown Fire Spread

Van Wagner (1977) stated that for crown fires to spread a critical amount of surface fuels need to combusted per/sq m/second:

0.05 kg/sq m/sec = Rate of Spread * Canopy Bulk Density

Rate of Spread per minute:

\[ R_{\text{Active}} = \frac{3.0}{CBD} \]

From Scott & Reinhardt (2001): Assessing crown fire potential by linking models of surface and crown fire behavior
The behavior of wind-driven fires are dominated by the prevailing wind.
- Crown fires are likely
- Rates of spread are rapid
- Long range spotting
- Direction of spread is predictable
- Flank attacks may be possible
- Shifts in wind should be monitored

Wildland fires with extreme fire behavior can generally be classified as either wind-driven or plume-driven fires.

The behavior of plume fires are less predictable
- Sudden increases in fire intensity are possible
- Spotting can occur in all directions
- Spread direction is difficult to predict

Wildland fires with extreme fire behavior can generally be classified as either wind-driven or plume-driven fires.

Fire Driven Weather
- Indrafts: winds replace where heated air has risen
- Downdrafts: convection columns collapses spreading wind and fire in all directions

!!! Warning Signs !!!
Light rain & Virga