

EFFORTS TO UPDATE FIREFIGHTER SAFETY ZONE GUIDELINES



Bret Butler

One of the most critical decisions made on wildland fires is the identification of suitable safety zones for firefighters during daily fire management operations. To be effective (timely, repeatable, and accurate), these decisions rely on good training and judgment, but also on clear, concise guidelines. This article is a summary of safety zone guidelines and the current research efforts focused on improving firefighter safety zones, and a request for input from firefighters and fire managers.

How Far Should We Be From the Flames?

Guidelines for the minimum distance a firefighter should be from a flame are discussed in training curricula and published in the Incident Response Pocket Guide (IRPG) and Fireline Handbook (fig. 1). The current safety zone guidelines are based on the distance at which exposed human skin will develop a second-degree burn in less than 90 seconds (the distance corresponding to a radiant incident energy flux level of $7.0 \text{ kW}\cdot\text{m}^{-2}$). An approximation of this model used in the field indicates that a firefighter should keep a minimum distance of four times the flame height. For a circular safety zone, this would be the safety zone radius.

Current safety zone guidelines were developed based on fires located on flat terrain. When fires burn

When fires are located on slopes or ridges, convective energy transfer may reach distances equal to several flame lengths ahead of the fire front. This implies that the current safety zone guidelines may be inadequate in situations where the safety zone and/or fire are on slopes.

on flat terrain, convective energy transfer is primarily upward in the plume and radiant energy transfer is directed in all directions, including out ahead of the fire front. Therefore, firefighter safety guidelines are based on the assumption

that radiant energy transfer is the dominant energy transfer mode. Experimental measurements verify the accuracy of this assumption, but also indicate that when fires are burning on slopes, convective energy transfer can be significant.

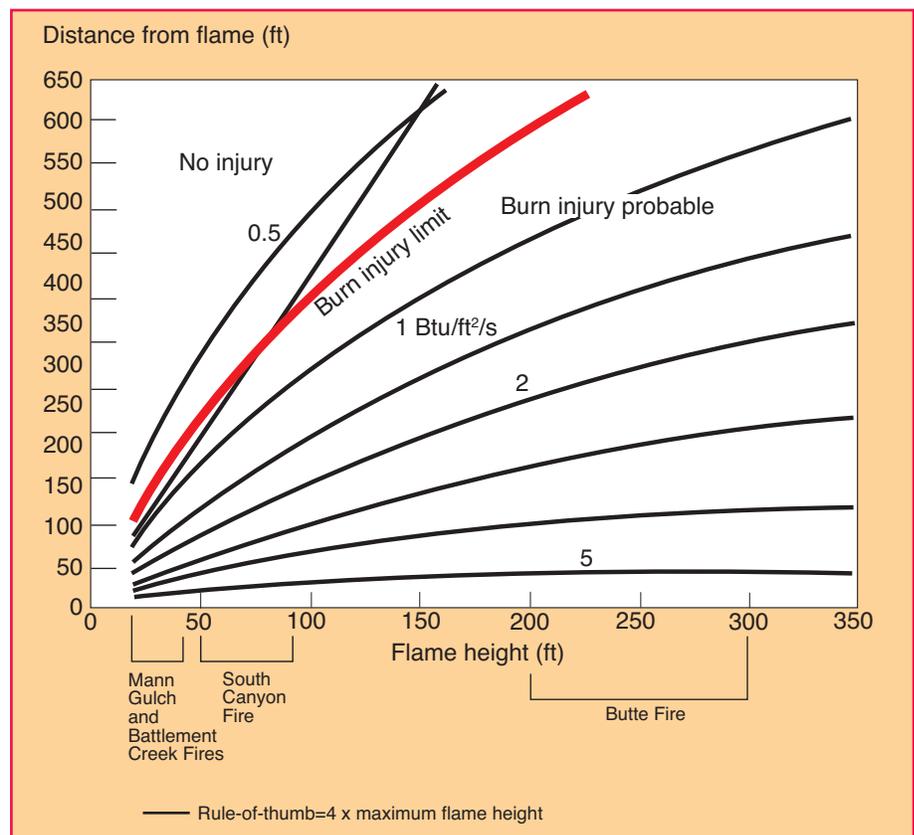


Figure 1—Results from original safety zone analysis. Model results were verified by comparison against past fires.

Bret Butler is a research mechanical engineer for the fire, fuel, and smoke science program at the Forest Service Missoula Fire Sciences Laboratory in Missoula, MT.

Intuition, professional observations, and the few experimental measurements that have been reported indicate that, when fires are located on slopes or ridges, convective energy transfer may reach distances equal to several flame lengths ahead of the fire front. This implies that the current safety zone guidelines may be inadequate in situations where the safety zone and/or fire are on slopes. It is also clear from visits to designated safety zones on numerous wildland fire incidents that considerable ambiguity exists regarding identification or creation of true “safety zones,” versus “deployment zones.”

New Research for Variable Terrain

The Joint Fire Science Program is supporting a new research project to measure convective energy transport and use those measurements to develop safety zone guidelines for slopes. We expect the guidelines will depend on multiple variables, including fire characteristics (flame length or height), site characteristics (e.g., slope), and relative location (i.e., chimney, ridge, midslope, ridgetop). We place special emphasis on the effect of “chimneys” and other terrain features that produce dangerous levels of convective heating ahead of the fire front. The approach for this study has several phases:

1. Measure convective and radiant energy transport in fires across a range of slopes and fuel types. An experienced team has started gathering measurements at various sites over a range of slopes and fire intensities using two types of instrument packages: the Fire Behavior Package and the Video Acquisition Box.

The Fire Behavior Package (FBP) measures 11 inches (27



Fire researchers installing a video acquisition box. Photo by Bret Butler, Forest Service.

A new research project supported by the Joint Fire Science Program is underway to measure convective energy transport and use those measurements to develop safety zone guidelines for slopes.

cm) by 5.9 inches (15 cm) by 7.1 inches (18 cm) and provides an insulated protective enclosure for a datalogger, sensors, and other electronics. The standard instruments consist of radiometers that measure total and radiant energy fluxes; small-gauge thermocouples—36 gauge (0.13 mm diameter) wires—that sense flame and air temperature; and pitot-static type velocity probes that sense the magnitude and direction of airflow before, during, and after the fire passes.

The Video Acquisition Box provides digital video imagery, an integral component of our field campaigns. Collecting video imagery not only allows us to observe actual footage of the

fire behavior but also provides insight into our data analysis. Camera(s) are housed within 3.9-inch (10 cm) by 7.1-inch (18 cm) by 7.5-inch (19 cm) fireproof enclosures. The boxes have a double-lens configuration: one lens of high temperature Pyrex glass and a second lens of hot mirror coated glass that reflects infrared radiation (heat) while allowing visible light to pass through. The cameras can be turned on manually or set to trigger and record through a wireless link to the FBP sensor packs.

2. Use measurements to “tune” and validate theoretical heat transfer models. Tools include software that simulates heating rates due to conduction; radiation; convection (steady-

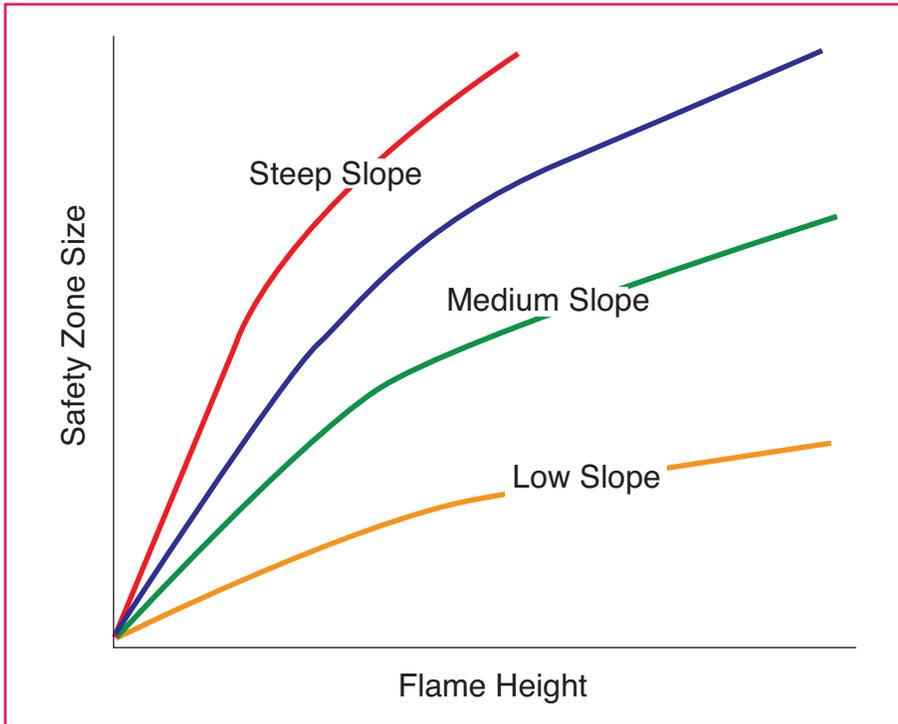


Figure 2—A possible format for Safety Zone guidelines on slopes.

state or transient); and the flow field that develops ahead of a fire over the expected range of flame sizes, fire front location relative to slope, slope steepness, and slope shape (i.e., concavity). Fire growth is being explored using existing spatial fire models like FARSITE and the new Wildland Fire Dynamics Simulator developed at the National Institute for Standards and Technology. The measurements collected in the field efforts are being used to “tune” and validate theoretical heat transfer models. Measured and modeled convective and

radiant energy distributions around the fires are being compared to human burn injury limits to determine appropriate separation distances and associated safety zone sizes.

3. Consult with incident management teams (IMT), fire crews, and others from the wildland fire community to determine the best methods for delivering new slope/safety zone guidelines. We expect that the results will indicate that slope steepness and concavity may be nearly as critical to safety zone characteristics as fire intensity. Consequently, the

attributes of an effective safety zone may depend on more than one variable. Some potential tools for presenting and using multidimensional information are pocket cards, nomograms (graphic representations), and computer models. Figure 2 presents one possible method for presenting the results—here, slope steepness and fire intensity dictate the minimum safe separation distance from the flames. Interviews and consultations with IMTs and fire crews during the field deployment phase of the study will guide the selection and development of one or more products for delivering the new safety zone guidelines.

How Firefighters Can Help

This effort depends heavily on participation from the wildland firefighting community. The research team requires assistance during all phases, and particularly in identifying potential measurement sites and developing the best format for presenting new guidelines. If you have suggestions for potential opportunities to measure convective flow, either on prescribed burns or ongoing wildland fires, or how best to convey the new guidelines (pocket card, nomograms, and/or computer models, etc.), please contact the author. Your input will be greatly appreciated. ■