

UNIT IX--EXTREME FIRE BEHAVIOR

This unit is on erratic or extreme fire behavior. After you have read the instructions to students on page 1 of your workbook, carefully read the unit objectives on page 2. When you have finished, return to this text.

We will start out this unit by reviewing some terminology relating to what is frequently called "extreme" fire behavior. On page 3, a definition is given: "It implies a level of wildfire behavior that ordinarily precludes methods of direct attack. Predictability is difficult because such fires often exercise some degree of influence on their environment, behaving erratically, sometimes dangerously."

The terms erratic or severe fire behavior might be preferred by some to describe the levels of fire activity that will be discussed in this unit. To others, the terms are somewhat interchangeable. In any case, we are concerned with levels of fire activity that present serious control problems and can threaten lives and property. Such levels of fire activity usually have one or more of the following involved: very high to extreme rates of spread; prolific crowning and/or spotting; presence of fire whirls; and a tall, well-developed convection column.

The most extreme fire situations are usually described as being one of the following: Under item A, first note blowup. This is defined as a sudden increase in fire intensity or rate of spread sufficient to preclude direct control or to upset existing control plans. It's often accompanied by violent convection and many other characteristics of a fire storm.

The second term is fire storm. This is violent convection caused by a large, continuous area of intense heat. It is often characterized by destructive, violent surface indrafts near and beyond the perimeter and sometimes by tornado-like whirls.

The third is conflagration. It is a large, raging, destructive fire, and the term is often used to denote such a fire with a moving front as distinguished from a fire storm.

The term blowup is most used by firefighters to describe extreme fire conditions on any size wildfire. Even relatively small fires can reach the blowup stage when they suddenly reach intensity levels that defy all control actions and pose a threat to life and property.

Fire storms and conflagration fires are usually associated with mass fire, which connotes both large size and high rates of energy release. Fire storms have occurred during wartime when many ignitions over a wide area quickly coalesce into a single fire. Fire storms can develop under light wind conditions but produce strong indrafts as the many fires burn together.

Conflagration fires have definite moving "heads" or fronts. They are strongly affected by wind and topography; thus the depth of the intense burning area is usually relatively narrow.

The high intensity levels in blowups, fire storms, and conflagration fires usually involve several of the processes in exercise 1 on page 4. As a review of each of these processes, complete this matching exercise; then check your answers and return to the text.

Wildfires can be disastrous, all too frequently claiming the lives of firefighters or others who were unfortunate enough to be caught in their paths. We have divided this unit into three major parts: first, analyzing why such tragedies have occurred; second, giving guidelines or tools to predict where and when hazardous conditions can develop; and third, emphasizing safety precautions that should be taken on wildfires to help prevent tragedies in the future.

On page 5, we start our discussion of tragedy fires. Through analysis, we can learn from mistakes made in the past. You will see that not all of the tragedies occurred on large fires, or on fires that exhibited extreme fire behavior. In most cases, the victims were surprised by a change in weather and an increase in fire intensity and rate of spread.

A study made in the late 1970's by Carl C. Wilson, U.S. Forest Service, retired, on fatal and near-fatal forest fires showed that 222 people died from fire-induced injuries on 67 fires between 1926 and 1976. These fatalities occurred on fires of various sizes on Federal, state, county, and local ownership lands. Many more have died from other causes while fighting fires, such as vehicle and aircraft accidents, falls, falling snags, rocks, etc.

In addition to the average of four or more people per year who died from fire-induced injuries, many more have barely escaped close calls with or without burns. Many of these near-miss fires have been described by Mr. Wilson in publications.

See item B. Wilson's studies indicate that most fatalities occurred on fires under these conditions:

1. Relatively small fires or quiet sectors of large fires;
2. Relatively light fuels, such as grass and light brush;
3. Unexpected wind shifts or increase in windspeed; and
4. Fire responded to terrain and ran uphill.

These seem to be the common denominators of fire behavior on tragedy fires.

Now we want to illustrate further how some of the fatalities occurred. We have selected seven tragedy fires from which to discuss the circumstances involving the fatalities. On each of these, from 2 to 13 persons lost their lives.

The first is the Mann Gulch Fire, which took place in the Helena National Forest, Montana in 1949. Here 13 men, mostly U.S. Forest Service smoke-jumpers, were overcome by a running surface fire in open timber. See figure 1.

The Mann Gulch Fire started on August 5. There had been an extended period without rainfall, thus making forest fuels very dry. A planeload of smoke-jumpers arrived over the fire that afternoon, sized it up, and jumped nearby. While hiking down the ridge to the small timber fire

in the base of Mann Gulch, they reported that they could easily handle the situation. Sometime after 1700 hours that day a thunderstorm cell passed through the area, and strong, gusty winds from the cell spread fire up the ridge and over the other side. Only a portion of the men were able to reach safety.

On page 6, figure 2 illustrates the Inaja Fire disaster. This occurred in the Cleveland National Forest in California in 1956. Here, 11 men were lost in San Diego Canyon when fire suddenly made an uphill run and overran them.

During that day, a flow of air from a Santa Ana across the top of a large canyon had created a stable air situation that served to hold down fire combustion. Warm temperatures and heating by the fire preheated and dried the light fuels. Volatile substances in brush probably produced gases which accumulated in less ventilated areas of the canyon. Crews in the canyon were attempting to secure firelines but were having difficulties with rolling firebrands on the steep slopes. About midafternoon, firebrands rolled into a draw above which firefighters were working. Shortly after, the Santa Ana lifted temporarily, removing the stable air "lid" from the canyon. Fire in the canyon quickly came alive and made an uphill run through the draw. Although fuels were somewhat sparse, the steep, rocky slopes made escape difficult for the firefighters working above.

Figure 3 illustrates the Decker Fire disaster that took place in August, 1959 near the town of Elsinore, California. Here a total of six men died of burns when fire whirls came upslope and crossed the highway that was being used as a burnout and control line on the upper edge of the fire.

The fire was located on a 3,000-foot high, east facing front, above a large dry lake bed, called Lake Elsinore. Afternoon winds on the fire were-downslope, which is unique to this area. During the heat of the day, the large lake bed acted as a giant heat pump with heated air rising above the lake and air being drawn in from surrounding areas. At sundown, the heat pump stopped, and the downslope winds over the fire diminished. Heated air from the valley and very dry brush fuels provided the energy to generate the fire whirls.

In figure 4, we have the Loop Fire disaster. This occurred in November, 1966, on the Angeles National Forest, when a Forest Service inter-regional fire crew was caught in the path of a sudden upcanyon run in a chimney canyon situation. The crew had been ordered to complete 200 feet of fire-line through the head of a steep- box canyon to tie off and gain control of the 2,000-acre Loop Fire. They were working the fire's edge, cold trailing, which is considered the safest method in California brush fields. Santa Ana wind conditions had been prevalent for several days and caused the fire to spread mostly downslope throughout that day. At approximately 1535, the Santa Ana slackened, and fire burning in the base of the chimney began its death run. Ten fire crew members were immediately trapped and overcome by fire, while 12 others escaped with critical to minor injuries. Two of these died later.

During the summer of 1967, the Sundance Fire in Northern Idaho stood out as a giant among several major fires in the Northwest that year. See figure 5. It made its major run within a 9-hour period, during which it traveled 16 miles, mostly by spotting, which occurred up to 12 miles

ahead of the fire front. It engulfed more than 50,000 acres of timberlands and burned two men to death.

On August 23, that year, a weak cold front triggered dry lightning storms which started five fires in the vicinity of Sundance Mountain. Following this, a stable high-pressure zone settled over the area causing large-scale subsidence. As a result, a period of hot, dry weather followed. The last of the fires to be mopped up jumped firelines and began its major run at approximately 1400 on September 1. By 2300 that day, it had traveled 16 miles to the northeast.

Intermittent areas of timber and logging slash several years old were responsible for heavy volumes of available fuels. Strong winds that pushed the 4-mile wide front were caused by a rapidly approaching cold front. The Forest Service employee and dozer operator who died of burns were working in an area far ahead of the fire front and considered to be safe. However, long-range spotting in advance of the fire front quickly put them in the direct path of this conflagration.

On page 8, figure 6 illustrates the 1979 Romero Fire in the Los Padres National Forest which claimed four victims. Extreme fire whirls were observed that evening as a cat operator, spotter, and two firemen attempted to retreat through heavy brush on the slopes below the fire. The Santa Ana was again a factor. Extended periods of hot dry Santa Ana winds dried the already cured light fuels in brush fields.

During the day of October 10, a coastal sea breeze had been meeting and lifting the Santa Anas. Shortly after dark the Santa Ana overpowered the sea breeze and caused the fire to run downhill. Fire whirls developed from the intense heat generated in the heavy fuels, and escape was cut off for the four firefighters.

One of the more recent disaster fires was the Bureau of Land Management Battlement Creek Fire in Colorado in July, 1976. Here, three firefighters were killed and a fourth severely burned when their primary escape route was cut off by a fire run from below. See figure 7.

The incident occurred during a burnout operation to secure firelines near the top of a ridge above the fire in a steep drainage. Normal fair weather patterns existed over the area. However, fuels and topography played a critical role in this incident. A late, hard, spring frost was responsible for a heavy kill of Gambels oak leaves and small branches in the fire area. Relatively warm, dry weather following the frost provided tall stands of dead, dry, light and brushy fuels. A southwest exposure with slopes up to 75 percent in the chutes below the ridge line was a significant factor.

Shortly after noon on July 17, burnout crews from below fired out fuels in the lower portion of the drainage with the intention of eliminating fuels inside the control lines. The burnout fire from below moved with moderate rates of spread upslope until it reached the steep chutes. At approximately 1430, this fire exhibited extreme rates of spread and cut off escape for firefighters above. Investigations later indicated that it was as much a communication problem as it was a fire behavior problem.

Hindsight allows us to analyze and determine the factors of fire behavior that caused these fatalities. However, this is too late for those who lost their lives trying to protect our natural resources. Let's try to summarize the principal factors contributing to the fatalities. On page 9, exercise 2 is intended for that purpose. Please do the exercise and check your answers; then return to the text.

It's not enough to know what's causing such tragedies, but we must be able to do something to prevent them in the future. The first step is to recognize when fire conditions can and may change for the worse and threaten lives and property. On page 10, we began our discussion on predicting severe or extreme fire behavior. We have already identified the fire processes that contribute most to fatalities--crowning, spotting, fire whirls, and blowups. This section will present guidelines to predicting whether any of these might occur on your fire.

First, let's look at crown fires. Under item C, please list these factors affecting crown fire development: Dead and live fuel moisture contents, volatility of foliage, crown closure, intensity of surface fire, vertical continuity or ladder fuels, winds at upper crown level, and steepness of slope. Steepness can give the same effect as wind. These are all factors that have been discussed in past units, and you will be required to know them.

Figure 8 illustrates most factors affecting crown fires. At the surface, we see rather low flames that are not reaching into the foliage. The convective heat above the fire is certainly drying and scorching the foliage, perhaps to the point of killing it. Until the flames actually reach the foliage, torching and crowning probably will not occur.

The wind near the surface has considerable effect on scorch height. Under very light wind conditions, the convected heat goes straight up into the canopy, thus producing a higher scorch height effect. When surface winds are somewhat stronger, the flames and convected heat are angled; thus scorch height can be effectively lowered.

See page 11. In order to have a sustained crowning fire; that is, running for considerable distances, there usually must be strong winds and/or steep slopes to angle the flames and carry convected heat to the next crown. There must be a relatively closed canopy or crown cover to make the process of heat transfer easier. And there normally must be spotting ahead in discontinuous aerial fuels. When you have all of these conditions existing on a fire, crown fire is a strong probability.

Our next topic is spotting. Spotting normally results from firebrands being lifted by convected heat and then carried downwind into new fuels. See figure 9. Windspeed has a direct effect on the distance that spotting might occur. In the illustration, we have chosen a burning spruce tree, approximately 50 feet high, as the firebrand source. Under average burning conditions, firebrands produced might be lifted to about 450 feet. Five windspeeds are illustrated with respective distances that spotting could occur given receptive fuels. With 40 miles-per-hour winds in the lower atmosphere, spotting over 1 mile is possible.

In predicting spotting potential, we must be concerned with three aspects--the production of firebrands, the transporting distance, and the receptiveness of new fuels to ignite and sustain fire.

As the intensity of a fire increases, so does the production of firebrands. By considering such factors as fuel moisture, fuel temperatures, and windspeed, we can have a good indication of whether firebrands will ignite new fuels. These factors will be discussed in more detail in Unit 11.

Long-range spotting can occur when large glowing firebrands are carried high into convection columns and then fall out downwind from the main fire.

The height of the convection column is a factor in spotting distance. Figure 10 illustrates two columns. The one on the left has developed under moderate wind conditions to an altitude of well over 10,000 feet. Fire-brands lifted to that altitude can travel downwind several miles.

The column on the right is rising in moderate winds at lower altitudes to about 5,000 feet, where it encounters high speed winds aloft, perhaps 40 to 60 miles-per-hour. The column is sheared at that point, breaking up the convective cell, and causing firebrands to fall out. In comparing the two situations, the longer range spotting will be with the taller convection column.

Now do question 1 on page 12; mark your choice or choices.

For question 1, you should have marked statements 2 and 3 as being true. In number 1, strong surface winds certainly will aid spotting, but for relatively shorter distances. Strong winds discourage the development of strong convection cells; thus the lifting altitude of firebrands is much less. Statement number 4 is not correct because of statement number 3. Some fuel types do not produce firebrands large enough to survive long distances.

The next fire phenomenon for discussion is the fire whirl. There are four principal factors that cause firewhirl development. Under item D, list the following: Surface heating, light but gusty winds, atmospheric instability, and intense heat from fire. Usually all four of these must be present to cause firewhirls.

We'll go back and discuss each of these four factors. Surface heating occurs with direct exposure to the sun, thus causing a superheated layer of very unstable air at the surface. Indicators of surface heating are mostly clear, sunny skies, a favorable exposure or angle to the sun, and exposed soil or a burned over area.

Second, fire whirls develop in light but gusty winds or winds converging, shifting, or eddying. Whirls usually get their start from two winds coming from different directions and occur more frequently when winds are light to moderate. They can result from any disturbance in the air flow. Favorable locations are the lee side of ridges or in canyon topography where local winds intersect.

The third factor, atmospheric instability, encourages strong convective air columns which create indrafts at the base of the columns. The fresh air indrafted at the base can feed fire whirls as well. Indicators of instability are cumulus cloud development; smoke rising to great heights; and rough, bumpy air encountered by aircraft.

The last factor, intense heat from a fire, produces extreme instability, strong convection, and indrafts at the base of the flames. High energy outputs come from heavy, dry fuel concentrations, or from very dry, light fuels when the relative humidity is very low. Although fire whirls are most common in heavy slash concentrations, they occasionally occur on desert range lands. Flame lengths-over 11 feet and rolling convection columns with strong indrafts are other indicators of possible fire whirls.

Figure 11 on page 13 illustrates one firewhirl development situation. Here a fire is burning on the lee side of a ridge from the general winds. Solar heating has created thermals in the basin below the fire, and warm upslope drafts are feeding the fire. Wind eddies on the lee side of the ridge can offer the triggering mechanism to start the whirls. Fire whirls might remain mostly stationary for several minutes. They frequently might move upslope until they reach the top where stronger winds break up the whirls, or they can move downslope in the direction of the prevailing wind.

We should mention here that dust devils or the smaller whirl winds develop under very similar conditions. The last factor, intense heat from a fire, is not always a requirement, as dust devils develop easily over desert lands, plowed fields, and other heat absorbing surfaces.

The effects of dust devils and fire whirls on wildfires should be obvious. Think about it, and please do question 2. Mark your choice or choices.

For question 2, you should have marked choices 1, 3, and 4. Choice number 2 is not correct, as dust devils and fire whirls usually move relatively short distances, less than 100 yards. Only a few have been known to travel over a half mile.

While discussing spotting potential and fire whirl development, we brought in their relationships to the fire convection column. Now we'll cover that aspect in more detail. We've described the convection column as a thermally produced ascending column of gases, smoke, and debris produced by a fire. How high will a column rise? Well, on the Sundance Fire, convection columns rose to over 30,000 feet. The height a fire convection column will rise into the atmosphere is dependent upon three factors. These are the degree of instability in the atmosphere; the heat energy output of the fire; and the speed of winds aloft. In the case of the Sundance Fire, the tremendous heat energy release from the fire was the dominating factor and winds aloft had little effect on the column.

Please turn to page 14. When we talk about convection columns of great heights, we usually associate them with blowup fire situations. As fire combustion processes increase, so do the rates of heat energy output and the magnitude of the smoke convection columns. Our concern, then, is, "When are blowup conditions likely to develop?" Under item E, please list the factors that contribute most to blowup fires: Unstable atmosphere; very dry, heavy fuels; strong winds with spotting; and steep terrain; i.e., narrow canyons and box canyons. Please come back to these factors later, as you will be required to know them.

Now see question 3; mark your choice or choices.

In question 3, you should have marked statements 2, 3, and 4. In number 1, we find that blowup conditions frequently develop in grassland fuels, with rates of spread very high to extreme.

On page 15, figure 12 gives fire severity or fire activity levels based on relative humidity and fuel moistures for 1 hour and 10-hour time lag fuels. This table gives six levels. Take some time to study this table and see how it could be used as a guide to predicting fire behavior; then return to the text.

On pages 16 and 17, exercise 3 will require that you use the fire severity table and other materials presented to predict fire behavior on five different fire situations. Please do this exercise; then return to the text.

The last portion of this unit is on fire safety precautions. Once we can realize that certain hazardous conditions can develop on a fire, what do we do about it? First of all, we must recognize our obligation of fighting fires in a safe and effective manner. On page 18, we have stated a fire safety policy common to most fire control agencies is: To prevent accidents, thereby protecting the lives and well-being of firefighters while accomplishing fire control at least costs.

Still we have accidents on fires, some of which are fatal. A question that might be asked is, "Are these due to acts of God, or to carelessness or lack of knowledge on the part of people?" Certainly many of the fatalities could have been prevented if the proper precautions had been taken.

Let's review again the major common denominators of fire behavior on tragedy and near-miss fires. Most of them occurred on relatively small fires or deceptively quiet sectors of large fires, and in relatively light fuels such as grass, herbs, and light brush. In most cases, there was an unexpected shift in wind direction or in windspeed, and/or fires responded to topographic conditions and ran uphill.

Now do question 4; mark your choice or choices.

All of the choices in question 4 should be marked. They are all factors which have influenced the safety and survival of many firefighters on wildfires. In this course, we prefer to stress the last three choices as the best options for survival.

On page 19 are listed eight cautions for firefighters. They are--be alert and be informed: In light fuels where high rates of spread are possible, such as grass and/or brush; in steep terrain where fire can make an uphill run, such as in narrow canyons and box canyons; to wind shifts and other weather changes--get the latest forecasts, take observations, and watch the sky for indicators; to traveling in unfamiliar country, hazardous terrain, and/or heavy fuels: to what the fire is doing--host lookouts and keep in communication with others on the fire; to means of escape, such as escape routes, safety islands, and fire shelters; to prop wash and turbulence from low flying aircraft, such as helicopters and air tankers; and to supervisor's orders and instructions, and be sure you understand them.

Compare these cautions to the four common denominators of fire behavior on tragedy fires. How many accidents could have been prevented had fire-fighters taken these as warnings?

Figure 14 illustrates a fire situation where several firefighters are working a spot fire in a canyon. How many hazardous conditions can you identify in this figure? Probably all of the cautions above could apply to the overall situation.

On page 20, we have listed the 13 situations that should "watch out". These have been around for a long time but certainly deserve to be repeated in this unit. Read through the 13 situations. Take time to think a bit about each one. When you have finished, go on to exercise 4 on page 21. This exercise is intended to make you more familiar with safety precautions to be taken on wildfires and to help you in the unit test. When you have finished the exercise, check your answers; then go back and review the objectives for this unit. We hope that this course will make you a safer firefighter and reduce the number of fire-induced injuries and fatalities on future wildfires. You will conclude the unit by taking the unit test.