Module 1: Basic Concepts of Wildland Fire

Topic 1: Course Introduction

Wildland fire behavior course introduction

During the heat of summer, avoiding news reports of a *wildland fire* **raging somewhere across the country is nearly impossible. Wildland fire is often thought of as something that happens deep in national forests, out in rangelands, or perhaps in crop fields. Unfortunately, the truth is that wildland fires also occur in areas adjacent to residential and commercial development, such as:**

- **Vacant lots**
- **Parks**
- **Golf courses**
- **Highway medians**

When this happens, you are facing an increasingly common scenario—a *wildland/urban interface* **fire.**

In either case, you need to understand the basics behind *fire behavior* **in order to begin to anticipate how tactics and safety procedures change according to the conditions at hand.**

Narration Script: Welcome to the Introduction to Wildland Fire Behavior Course—S-190. You're probably here to acquire skills to move toward your goal of becoming a certified wildland firefighter. This will take dedication, knowledge, and skill on your part, and this course will be part of your preparation.

Every fire season seems to set yet another record for number of acres burned and the amount of money spent to fight wildland fires. A recent fire season was double the 10-year average of prior fire seasons—and with temperatures trending upward, there's sure to be more wildland fires in our future.

As you'll soon discover, mental preparation is as much a part of wildland fire fighting as your physical conditioning—so let's get started.

Course objectives

The course objectives are simple enough to describe—however, attaining these goals will require the professionalism and determination required of all wildland firefighters.

By the end of this course, you should be able to:

- **Identify and discuss the three sides of the fire triangle**
- **Identify the environmental factors of** *fuels***, weather, and** *topography* **affecting the start and spread of wildland fire**

- **Describe the contributing factors indicating potential for increased fire behavior that might compromise your safety**

This course provides the foundation to understanding the characteristics and interactions of the wildland fire environment and how those factors influence a fire's behavior. Ultimately, your safety is the top priority.

Narration Script: On the fireline, you'll need your powers of observation to maintain your safety and that of your fellow crew members. This course is designed to give you the foundational knowledge you'll need to follow one of the golden rules of wildland fire fighting: look up, look down, and look around. Experienced firefighters know that observation, evaluation, and anticipation are your friends when managing a fire—make sure to study up and make them yours as well.

Course overview

There's a good chance this is your first formal wildland fire behavior training—so we'll give you the basics.

The modules you will be working through are:

- **Basic Concepts of Wildland Fire—introducing wildland fire terminology, the fire triangle, and heat transfer methods**
- **Principles of Wildland Fire Behavior—describing fuels and their relation to the** *rate of spread* **(ROS) as well as weather and topography impacts**
- **Wildland Fire Behavior and Safety—discussing the differences between problem and extreme fire behavior and emphasizing the must-follow rules described in the Incident Response Pocket Guide (IRPG)**

After each module, there will be a Challenge Review where you'll show you've picked up the required knowledge, so be sure to take your time and feel free to review the material as much as you'd like.

Narration Script: The purpose of this course is to help novice firefighters—or anyone tasked with wildland fire fighting duties—safely perform fire suppression and management duties in a wildland environment and obtain their Firefighter Type 2 certification.

If you're under the impression that fire fighting is a literal "walk in the park" or a nice job to perform in the great outdoors—realize now that you'll need to spend as much time training your mind as you will your body. If you're new to Type 2 skill sets and responsibilities or if you come from a structural fire fighting background and tend to fall back on that mind-set, you're going to need to rethink a few things and maybe learn from scratch about wildland fire behavior terminology, fuels, weather and topography, safety, observation, and following the by-the-book procedures designed to maintain your safety.

Course prerequisites

There are no prerequisites to the S-190 Introduction to Wildland Fire Behavior course—but completing the course won't necessarily ensure you are ready to hit the *fireline* **immediately. Your local agency determines the requirements for each fire fighting position. These are all established by your local authority having jurisdiction and may include:**

- **Minimum educational requirements**
- **Minimum age requirements**
- **Local medical requirements**
- **Local physical requirements**

So, be sure to get the basics here and then consult with your local agency. Good luck and good learning!

Narration Script: Completing the S-190 Introduction to Wildland Fire Behavior course is one step toward getting your Firefighter Type 2 certification, but it doesn't necessarily ensure you'll be able to fight fires. For instance, some local agencies are concerned that you've got the educational background, the stamina to pass some physical challenges, and that you're at least 18. Like structural fire fighting, wildland fire fighting is a hazardous, physically demanding activity that requires good decision-making skills. So, be sure to consult with your local agency and make sure you have all your "t's crossed" and the "i's" dotted before applying for a position.

Topic conclusion

That concludes the *Course Introduction* Topic. You should now have a good idea of:

- **Why you are here**
- **What we expect you to get out of the course**
- **How the course is organized**

Narration Script: You should now have a good idea of where we're going with this course.

Topic 2: Fire Behavior

Topic introduction

Welcome to the world of wildland fire fighting. You're probably anxious to get started fighting ***wildland fires*****, but before you do, you need to have a firm grasp of many key concepts.**

As the saying goes, Rome wasn't built in a day—and you won't be prepared to fight wildland fires in a day either. So let us help you build a strong foundation of knowledge to stand on before you head out to the heat of the ***fireline*****.**

This first topic covers these basics of wildland fire fighting:

- **Wildland fire fighting terminology**
- **Fire triangle**
- **Heat transfer**
- **Breaking the fire triangle**

Narration Script: Before you head for the field, you need to know the basics. Even the most experienced of wildland firefighters will turn to their trusty Incident Response Pocket Guides (IRPGs) and Fireline Handbooks to refresh themselves on the all-so-important basics. In this topic, we'll help you begin building the knowledge base you'll need to fight wildland fires safely and effectively.

Parts of a wildland fire

Part of "talking the talk" is having a diverse wildland fire fighting vocabulary. All firefighters working on wildland fires will use certain terms, and you need to be "in the know." In this section, you'll learn about the parts of a wildland fire. These parts are named for their unique characteristics and locations.

Some of the most common names you'll hear associated with the main fire are:

- **Origin**
- **Head**
- **Fingers**
- **Pocket**
- **Perimeter**
- **Rear**
- **Flanks**
- **Islands**

Read about each term to learn the lingo.

Origin

The *origin* is the area where the fire started. It is also the point from which the fire spreads, depending on the fuels present and the effects of wind and slope.

When the fire is human caused, you often find the origin next to a trail, road, or highway, but a lightning strike or campfire can result in a very inaccessible point of origin. Protect the area of origin for subsequent investigation of fire cause whenever possible.

Head

The *head* is the part of a wildland fire with the greatest forward rate of spread (ROS). Because wind and slope affect the rate and direction of spread, the head is normally either on the edge of a fire opposite to the direction from which the wind is blowing or it is toward the upper part of a slope.

The head of a fire often burns intensely and may move with alarming speed. Some large fires may have multiple heads. Ultimately, you have to control the head(s) and prevent the formation of new heads to suppress a wildland fire.

Fingers

***Fingers* are typically long, narrow strips of fire that extend from the main body of a fire. They form:**

- **When a fire burns into mixed fuels; slowing in heavy fuel, but spreading quickly in light fuels**
- **Due to variations in terrain or wind direction**
- **When the head is split by natural features such as fields, water, or rock outcroppings**

Caution—uncontrolled fingers may form new heads. If possible, contain the fingers when they're small and manageable.

Pocket

A *pocket* is the unburned area between the main fire and any fingers.

Perimeter

The *perimeter* is the outer boundary—or the distance around the outside edge—of the burning or burned area. Also commonly called the *fire edge*, don't confuse the perimeter with the *control line* (an inclusive term for all constructed or natural barriers and treated fire edges used to control a fire) or *fireline* (the part of the control line that is constructed by firefighters). Obviously, the fire's perimeter continues to grow until you get it controlled and extinguished.

Rear

The *rear* or *heel* of a wildland fire is the end opposite the head—that is, relatively closer to the point of origin than to the head. Be aware that a wind shift can quickly change the relative calm of the rear to a new blazing fire front.

Because fire at the heel usually burns *into* any prevailing wind, it generally:
- **Burns with low intensity**
- **Has a low ROS**
- **Is generally easier to control than the head**

Flanks

The *flanks* are the sides of a wildland fire, roughly parallel to the main direction of fire spread. Flanks are identified as either left or right as you are looking from the heel of a fire toward the head.

Control flanks as soon as possible, because:
- **A shift in wind direction may quickly change a flank into a head.**
- **Fingers often extend from flanks.**

Islands

***Islands* are unburned areas inside the fire perimeter. Because they are unburned potential fuels, patrol them frequently and check for spot fires.**

Islands close to a control line *may* flare up later and start spot fires across the control line. You may want to burn out islands, consuming fuels between the perimeter (fire edge) and the control line.

Narration Script: Every profession has its jargon. You need to learn and use the correct wildfire terminology the same way a doctor or paramedic uses special terms to describe the human body. Of course, there are a few other terms that we'll get to in a moment, but these are the main ones you'll use to describe a fire.

Additional wildland fire terms

A few other common terms relate to the *perimeter* and what's inside and outside the fire edge. A few more terms are:
- **Spot fire**
- **Slopover**
- **Green**
- **Black**

You will investigate each term in this order so you can complete your vocabulary lesson.

Narration Script: One of the most common bits of advice you'll hear on the fireline is to "get in the black." If you don't know what that means, you're putting yourself and others in unnecessary danger. So get in the black and learn a few more common wildland fire terms.

Spot fires

Spot fires are small fires burning beyond the main fire boundary. As gases rise from a fire into the *convection column***, sparks, embers, and burning twigs are carried aloft. Spot fires result as these hot and burning items fall back to the ground or are blown across a fireline by** *winds***. Spot fires can also result when embers or burning** *fuels* **roll downhill across the fireline into unburned fuels beyond the main fire.**

If spot fires burn unchecked, they may form a new head or another major fire. If this happens, firefighters could be trapped between two fires, or the fire may move in an unanticipated direction.

Narration Script: Depending on the size of a wildland fire—as well as weather conditions and the type of fuels involved—spot fires can ignite miles from the main fire. That would make your job a little harder, wouldn't it? And there's not much you can do about it. On a smaller scale, you can help control spot fires by being vigilant and building appropriate control lines, which you'll learn about in just a bit.

Slopover

Also known as *breakover, slopover* occurs when fire crosses a control line or *natural barrier* **intended to** *contain* **the fire. Slopover and spot fires differ mainly in their location relative to the control line:**

- **Slopover occurs immediately across and adjacent to the control line.**
- **Spot fires occur some distance from the control line.**

The green

Any area that's not burnt—but is adjacent to an involved area—is called the green. Fuels in the green may be:

- *Live fuels***, including:**
  - **Vegetation with a high** *moisture* **content that is relatively slow to ignite**
  - **Vegetation with lower moisture content and that is highly flammable**
  - **Dense, golden-yellow annual grasses and other similar fuels with low moisture content that may burn vigorously**
- *Dead fuels***—dried vegetation that is highly flammable and will go up like kindling**

The term *green* certainly does *not* define a safe area. It is simply the opposite of the black, or burned, area. The edge of the green is usually where you construct a control line.

Narration Script: Don't get hung up on colors here. While the term "green" may refer to the color of some fuels in an area, the "green" may not be green at all. If you're in a stand of dead, leafless

oak trees with lots of forest debris, you better realize you're in the green. And if you're looking at an active fire, you better realize you are not safe—it's as if you are standing in a pile of kindling!

The black

The opposite of the green—the *black* or the *burn*—is the area (including both *surface* **and** *aerial fuels***) in which the fire has consumed, or "blackened," the fuels.**

Whether the black is safe or not depends on a few factors. If it is completely burned over and little, if any, unburned fuel remains, the black is a relatively safe area during a fire. However, the black is not always safe.

Hazards of the Black

The black or burn area may not be safe for a few reasons:

- **In steep terrain, exposure from adjacent unburned fuels can cause reburn**
- **Residual heat and smoke**
- **Hot spots and smoldering snags (standing dead trees), stumps, and downed trees**
- **Falling snags**

Warning! Reburns

If a surface fire leaves aerial fuels more or less intact in the black, or vice versa, a reburn can occur when burning conditions are more favorable—for example, if the winds shift or humidity drops. This often occurs when fire moving quickly through an area fails to consume all fuels.

Narration Script: In many cases, getting into the black is a good safety move. But you've got to be smart about it. The black has its own hazards that can get you even if the main fire front doesn't.

Fire spread

The terms you'll learn about in these next few sections refer mostly to how the fire *behaves* **and *spreads*. Fire spread is simply the movement of the fire, classified as** *rate of spread* **(ROS) and given in *chains per hour*. A *chain* is a surveying term and equals 66 ft. (20 m).**

A good rule of thumb is to watch the fire spread for a minute. Since there are 60 minutes in an hour and just over 60 ft. (18 m) in a chain, using the rule of thumb will give you a reasonably accurate measurement of the fire's forward progress. For example:
1 ft. (0.3 m)/minute = 1 chain/hour
10 ft. (3 m)/minute = 10 chains/hour

A fire that burns an area 10 chains by 10 chains is a 1-acre fire.

Narration Script: “Fire Behaving Badly” is not a TV series, but it is something you may be forced to watch on the fireline. Now that you know how to describe the parts of the fire, you also need to master some terms about the behavior of the fire itself and how it spreads.

Chains per hour is a term often used for reporting fire spread, fire perimeters, and other fireline distances. The term is popular in fire management because it is easy to use “chain” to convert to “acres.” Since 10 square chains is equal to 1 acre, you can easily calculate the acreage covered by a fire. Also, since there are 60 minutes in an hour and just over 60 feet in a “chain,” if you watch the fire for a minute you can estimate the number of “chains per hour” it is spreading. For example, if the fire moves 1 foot per minute, then it is moving at a rate of 1 chain per hour. And if the fire moves at 10 feet per minute, then the ROS is 10 chains per hour.

Fire behavior terms

So, what are the terms you need to know about that deal with fire spread? We’ll take a look at these terms in order in the next few sections:

- **Flaming front**
- **Smoldering**
- **Creeping**
- **Running**
- **Backing**
- **Spotting**
- **Torching**
- **Crowning**
- **Blowup**
- **Flare-up**
- **Firewhirl**

Narration Script: From smoldering fires to crowning fires and everything in between, you need to be familiar with the terms that describe how a fire is spreading.

Flaming front

The *flaming front,* also known as the *fire front,* is the part of a fire within which continuous flaming *combustion* **is taking place. Most of the time, the flaming front is the leading edge of the fire perimeter. However, in surface fires, the flaming front may be mainly** *smoldering* **combustion.**

Behind this flaming zone, combustion is primarily glowing or involves the *burning out* **of larger fuels (fuels greater than about 3 in. [8 cm] in diameter).** *Light fuels* **typically have a shallow flaming front, whereas** *heavy fuels* **have a deeper front.**

Narration Script: The flaming front is often the “leader of the pack.” Many of the terms we explain on the next few pages refer to various behaviors of the flaming front.

Smoldering and creeping fires

Two terms refer to fires that are spreading very slowly:

- **A *smoldering* fire is one that burns without a flame and is barely spreading.**
- **A *creeping* fire burns with a low flame and spreads slowly.**

Running and backing fires

A *running* fire is one that spreads rapidly with a well-defined head. Compare and contrast this to a *backing* fire, where the fire moves *away* from the head, downhill, or against the wind. A backing fire, also called a *heel* fire, is usually a portion of the fire with slower ROS and lower intensity.

Narration Script: A running fire is one that spreads rapidly with a well-defined head. This type of fire can overrun anything in its way in a few seconds.

Spotting

A fire is *spotting* when winds or a convection column carries sparks or embers produced by the main fire. Obviously, spotting causes spot fires in advance of the fire's head.

Narration Script: Sometimes fires have winds and convection columns that carry sparks and embers ahead of the fire, starting spot fires in advance of the fire head.

Crowning and torching

A fire is *crowning* when it advances across the tops of trees or shrubs more or less independent of the *surface fire***. Crown fires are sometimes classed as *running* or *dependent* to distinguish the degree of independence from the surface fire. Use the terms *crown fire* and *crowning* carefully because they describe a very serious fire situation.**

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A term commonly confused with a crowning fire is a *torching* fire. Unlike a crowning fire, a torching fire periodically ignites the crown of a single or small group of trees or shrubs before returning to the surface. A torching fire is not as serious as a crown fire.

Narration Script: Crowning fires burn largely at the tops of the trees rather than on the surface. This is a very serious fire condition.

Blowup and flare-up

A *blowup* occurs when there's a sudden increase in ROS sufficient to prevent or rule out direct *control* **of the fire. Blowups are often accompanied by violent convection, can behave like fire storms, and will most likely set back existing** *suppression* **plans. A *flare-up* is any sudden acceleration in the ROS or intensification of the fire. Unlike blowup, a flare-up is of relativity short duration and does not radically change existing control plans.**

Stay alert because:

- **Blowups and flare-ups can occur on smaller fires or on isolated portions of large fires.**
- **Most fires are innocent in appearance before blowups or flare-ups occur, such as fires in the** *mop-up* **stage.**
- **Flare-ups generally occur in deceptively light fuels.**
- **Blasts of air from low-flying helicopters and** *air tankers* **have been known to cause flare-ups.**

Narration Script: You would expect blowup on fires that are spotting, torching, and crowning. But as you will learn later in the course, watch out because blowups and flare-ups can be sneaky. They don't always do what you think they'll do, and they don't always do it where you think they'll do it.

Firewhirl

The last fire behavior term we will look up is *firewhirl*. Firewhirls are spinning, moving columns of rising air and fire gases that carry smoke, debris, and flames aloft. They're usually formed on the leeward side (protected from wind) of elevated terrain features and can cause spotting.

Firewhirls range in size from less than 1 ft. (30 cm) to over 500 ft. (150 m) in diameter. Large fire whirls have the size and intensity of a small tornado!

Narration Script: Firewhirls can be a spectacular sight, but these "dust devils on steroids" are also a force to be reckoned with.

Knowledge Check 1

Matching—select the match you choose from the pull down list.

The list of terms continues. This time, we'll see how well you remember the definitions of the different terms pertaining to fire spread.

Match each wildland fire-spread term to the appropriate description.

Backing	Fire intensity increases suddenly, posing a setback to suppression plans
Running	Fire intensity increases suddenly, posing a setback to suppression plans
Torching	Fire intensity increases suddenly, posing a setback to suppression plans
Crowning	Fire intensity increases suddenly, posing a setback to suppression plans
Blowup	Fire intensity increases suddenly, posing a setback to suppression plans
Flare-up	Fire intensity increases suddenly, posing a setback to suppression plans

The correct matches are as follows:
Backing: Fire moves *away* from the head
Running: Fire spreads rapidly with a well-defined head
Torching: Fire ignites the crown of trees, then returns to the surface
Crowning: Fire advances across the tops of trees, independent of surface fires
Blowup: Fire intensity increases suddenly, posing a setback to suppression plans
Flare-up: Fire intensity increases suddenly but doesn't pose a setback to suppression plans

Additional wildland fire terms

Just a few more terms to know and you're on your way to bigger and better training concepts. Here are a few other common terms related to wildland fire fighting:

- **Control line**
- **Fireline**
- **Anchor point**
- **Containment and control**
- **Mop-up**

We'll cover each of these terms in sequence.

Narration Script: The terms you just looked at deal mostly with the fire itself. Now we'll look at some terms mostly describing your fire fighting efforts.

Control line, fireline, and anchor point

The terms control line, fireline and anchor point are closely related.

- ***Control line* refers to all constructed or natural fire** *barriers***. It's also used to describe the treated fire edges used to contain the fire.**
- **A *fireline* is any cleared strip or portion of a control line where flammable material has been removed by scraping or digging down to** *mineral soil***.**

- **The *anchor point* is any good place where you can start constructing a fireline. Generally, a fire barrier is a safe anchor point. Using an anchor point minimizes the chance of being outflanked by the fire while the line is being constructed.**

Narration Script: The terms control line, fireline, and anchor point are closely related, so let's examine them together. The terms control line and fireline are basic to any discussion of attack methods, and they are often confused with the term "fire edge."

While "control line" refers to all constructed or natural barriers, "fireline" applies only when you are dealing with a portion of a control line where flammable material has been removed by scraping or digging down to mineral soil. There are a number of other terms used in various regions to describe different types of lines. Among these terms are *wet lines, retardant lines, scratch lines, hand lines, dozer or Cat lines, hot lines, undercut* or *underslung* lines, *cold lines*, and *open lines*. As you can imagine, some of these terms actually describe a "control line" instead of a "fireline" and indicate both the line's method of construction and its width.

When you start building a fireline, however, it must always be started from an "anchor point," such as a road, lake, pond, stream, earlier burn, rock slide, or cliff. This type of barrier provides a safety point for you that will keep you from getting outflanked by the fire.

Containment and control

***Containment* is the status of a wildfire suppression action that can reasonably be expected to stop the fire spread under prevailing and predicted conditions. *Control* is the point in time when the perimeter spread of a wildland fire has been halted and can reasonably be expected to hold under foreseeable conditions.**

To *control a fire* means that all of these actions have been taken:

- **Complete the control line around a fire, any spot fire from the fire, and any interior island to be saved**
- **Burn out any unburned area adjacent to the fire side of the control lines**
- **Cool down all hot spots that are immediate threats to the control line until the lines can reasonably be expected to hold under foreseeable conditions**

Narration Script: Wildland fires can grow very rapidly, especially if they go undetected in their early stages. Timely containment and control can significantly reduce the loss of life and property.

Mop-up

If you hear the term *mop-up*, it's a good thing. The mop-up phase marks the final extinguishing of a fire after it has been completely surrounded by control lines. It is a strategy to make a fire safe or to reduce residual smoke. But always be at the ready—blowups and tragedies have occurred in the mop-up stage.

During mop-up, you will extinguish or remove all burning or *smoldering* material within a specified distance of the control line. A general guideline is to mop up within 100 ft. (30 m) of the control line—but follow the control objectives set for the *incident*. Mop-up involves felling snags and trenching logs to prevent rolling after an area has burned.

Mop-up must be thorough because a small spark or flame left along the line could rekindle hours or days later, starting another and perhaps larger fire.

Knowledge Check 2

Matching—select the match you choose from the pull down list.

You are called to work on a wildland fire and need to know your stuff.

Match each term with the MOST appropriate description.

Control line	Refers to an area that is not burnt
Fireline	Refers to an area that is not burnt
Anchor point	Refers to an area that is not burnt
Mop-up	Refers to an area that is not burnt
Green	Refers to an area that is not burnt
Black	Refers to an area that is not burnt

The correct matches are as follows:
Control line: Refers to all constructed or natural fire barriers
Fireline: Involves removing flammable material down to mineral soil
Anchor point: Minimizes the chance of being outflanked by the fire
Mop-up: Begins after a fire has been completely lined
Green: Refers to an area that is not burnt
Black: Contains hot spots, smoldering snags, stumps, and downed trees

Combustion process

The remainder of this topic will introduce you to the combustion process in the wildland environment from three perspectives:

- **Fire triangle**
- **Heat transfer**
- **Breaking the fire triangle**

You will learn even more about fire behavior in the wildland environment—specifically the impact of differing fuels, *topography*, and weather a little later in this course.

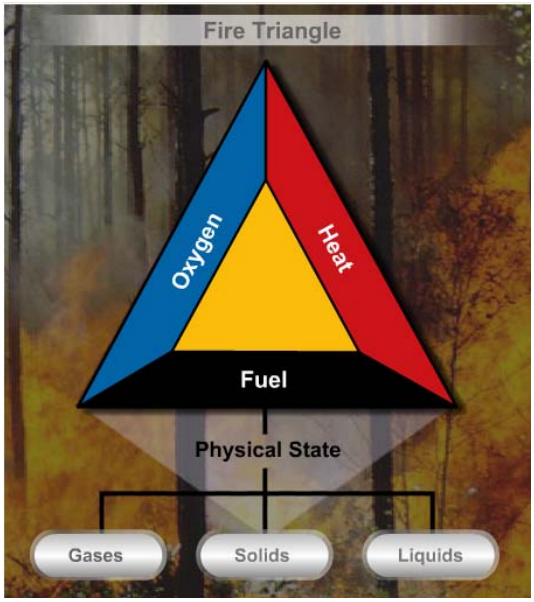
Narration Script: Now that you know the core terminology to use when fighting wildland fires, it's time to crank up the heat a little bit. Consider the rest of this topic as "Fire Triangle 101."

The fire triangle

Fire **is actually a by-product of a larger process called combustion. Wildland fuels have an abundant supply of oxygen available in the air. Rapid oxidation occurs in two forms:**

- **Smoldering fires**
- **Steady-state fires (unchecked rapid burning)—steady-state fires are sometimes called free-burning fires**

The three sides of the triangle consist of oxygen sources, heat sources, and fuel. Read the following for the details.



Caption: The fire triangle's sides represent the three components required for combustion—oxygen, heat, and a fuel source. These components can occur in three states including as a gas, a solid, or a liquid.

Oxygen Sources

A concentration of approximately 16 percent oxygen is required for combustion, but normal air contains 21 percent—more than enough for combustion to occur. However, some fuel materials contain sufficient oxygen within their makeup to support burning.

Heat Sources

Heat sources sufficient to reach ignition temperature may come from:

- **Open flame**
- **Sun**
- **Lightning**
- **Hot surfaces**
- **Sparks and arcs**
- **Friction**
- **Chemical action**

- **Electric energy**
- **Compression of gases**

Fuel

Fuel may exist in any of the three states of matter—solid, liquid, and gas. However, only gases burn. The initiation of combustion of a solid or a liquid fuel requires its conversion into a gaseous state by heating. During combustion, heat and chemical changes in the fuel cause fuel gases to evolve from the fuel. So, even though fuel and oxygen are present in the wildland, heat must be added to liberate the fuel gases and initiate the combustion process.

Fuels in Gas Form

Gas fuels can include:
- **Natural gas**
- **Propane**
- **Butane**
- **Hydrogen**
- **Acetylene**
- **Carbon monoxide**

Fuels in Liquid Form

Liquid fuels can include:
- **Gasoline**
- **Kerosene**
- **Turpentine**
- **Alcohol**
- **Cod liver oil**
- **Paint**
- **Varnish**
- **Lacquer**
- **Olive oil**

Fuels in Solid Form

Solid fuels can include:
- **Dust**
- **Coal**
- **Wood**
- **Paper**
- **Cloth**
- **Leather**
- **Plastic**
- **Sugar**

- **Grain**
- **Hay**
- **Cork**

Narration Script: Let's start with a basic concept—the fire triangle. There are lots of fuels, such as trees, branches, and brush, in wildland areas, so fuel is the foundation of the triangle. Fuel may exist in any of the three states of matter, but only gases burn. This means heat is required for fuel gases to evolve from wood and the other solid fuels you might find in the wildland. So, even though fuel and oxygen may be present, heat must be added to liberate the fuel gases and initiate the combustion process.

Heat energy

As heat energy is released, further chemical changes occur, adding more fuel and possibly producing a self-sustaining process. Heat activates and sustains the chemical reactions needed for continued combustion.

Heat generated by a fire evaporates the moisture in the fuel and heats the fuel to its ignition temperature. The amount of heat required to reduce the moisture content of the fuel depends upon the physical and chemical makeup of the fuel and the percentage of *atmospheric moisture***.**

If the supply of oxygen available to the combustion process increases, then combustion intensifies. While the percentage of oxygen in the atmosphere does not vary appreciably from place to place, wind can effectively increase the amount of oxygen available to a fire and thereby increase the rate of combustion.

Narration Script: Once the chemical reaction, or combustion, has begun, some of the energy is released as heat and light. Heat may then activate and sustain the chemical reactions needed for continued combustion. It does this by evaporating the moisture in the fuel and heating the fuel to its ignition temperature. And in the wildland, if wind is present, it serves to increase the amount of oxygen available to the combustion process.

Knowledge Check 3

Matching—select the match you choose from the pull down list

Are you ready to spontaneously combust?

Try your hand at matching each term related to the fire triangle with the correct description.

Combustion	May exist in any of the three states of matter
Fuel	May exist in any of the three states of matter
Oxygen	May exist in any of the three states of matter
Heat	May exist in any of the three states of matter
Fire	May exist in any of the three states of matter

The correct answers are as follows:
Combustion: Self-sustaining process of rapid oxidation
Fuel: May exist in any of the three states of matter
Oxygen: Supply can be increased by wind
Heat: Causes fuels to reach ignition temperature
Fire: By-product of combustion

Heat transfer

For sustained combustion, heat must *transfer* from involved fuels to those that are not involved. Three primary methods for heat transfer are:

- **Conduction**
- **Convection**
- **Radiation**

You will investigate each of these methods in turn.

Narration Script: You have already seen how heat is involved in producing a self-sustaining reaction. But for that to occur, heat has to transfer from the things that are hot to the things that are not. Investigate the ways this happens.

Conduction

When two objects of different temperatures contact each other directly or through a medium, heat *conducts* from the warmer object to the cooler one until their temperatures equalize.

Metals such as aluminum, copper, and iron conduct heat readily and can play a significant role in fire spread within structures. However, fibrous materials such as plants and wood are poor conductors of heat. Therefore, heat transfer by conduction has a limited effect on the spread of wildland fires.

Narration Script: While conduction is a significant player in structure fires, it is less significant in wildland fires. Of course, there are exceptions, as this vehicle illustrates. In this case, the vehicle equipped with a catalytic converter—or with a faulty or overheated exhaust system—stopped in an area of tall dry grass. The heat from the exhaust system conducted to the grass to cause a fire.

Caption: A severely fire-damaged truck from conducted heat from the exhaust system.

Convection

During *convection***, gases heated in a fire expand, become lighter, and rise. In a wildland fire, fire gases rise in a convection column, and cooler air flows in to replace the rising gases. In some cases, this inflow is sufficiently strong to affect** *local winds***.**

As these gases rise up into the column, sparks, embers, and burning twigs are carried aloft. These burning materials fall back to earth up to several miles downwind and can start spot fires well ahead of the main fire.

Hot convected gases moving up a slope can dry out fuels, lowering their ignition temperature. These fuels also become preheated by the convected heat, thus increasing their susceptibility to ignition and more rapid fire spread.

Narration Script: Spot fires resulting from convection are characteristic of very large fires. But convection can also come into play on a smaller scale when, for example, the heat from a fire preheats fuels that are upslope or downwind.

Radiation

Heat transfer by *radiation* **is one of the major sources of fire spread in wildland fires. It's as simple as 1, 2, and 3:**

1. **Heat waves, sometimes called** *infrared rays***, radiate in all directions from the heat source.**

2. **Heat waves travel through air until they are totally or partially absorbed by an opaque object.**
3. **The opaque object gains heat and in turn radiates heat from its surface.**

One of the most common examples of radiant heat in a wildland context is fire burning in a narrow canyon. Radiating heat preheats and dehydrates exposed fuels immediately adjacent to the fire and initiates combustion. Another common example is the heat firefighters feel on the fireline—radiant heat is also responsible for many burn injuries to those working near wildland fires.

Narration Script: Radiation is as serious a factor in wildland fire spread as it is for structures. You may have seen the building across the street from a fully involved structure begin to steam and smoke even though there is no direct fire impingement. Consider a narrow canyon—if one side is burning, it's a good bet that the other side will go up as well through radiant heating. And of course, you probably already know that radiation is a common cause of firefighter burn injuries.

Knowledge Check 4

Matching—select the match you choose from the pull down list

You've got an active wildfire on your hands with multiple exposures.

Match each heat transfer method to the appropriate exposure situation.

Conduction	Wind is blowing heat from a grass fire into tree branches
Convection	Wind is blowing heat from a grass fire into tree branches
Radiation	Wind is blowing heat from a grass fire into tree branches

The correct matches are as follows:
Conduction: A burning log is sitting on a bed of dried leaves
Convection: Wind is blowing heat from a grass fire into tree branches
Radiation: Fire is burning down one side of a steep, forested canyon

Breaking the fire triangle

You interrupt the combustion process (and extinguish the fire) by disrupting one or more of the three required elements as shown earlier in the fire triangle. In other words:

- **Removing fuel**
- **Removing oxygen**
- **Removing the heat energy that sustains the chemical reactions**

Read below for more information.

Removing Fuel

Clearing a space of all surface fuels down to mineral soil (dirt containing little or no organic material) is a common way of controlling and extinguishing wildland fires. This is the basic idea behind the creation of any fireline.

Removing Oxygen

Wildland fires burn in the open air; therefore, attempting to restrict the oxygen supply to a fire (removing oxygen) is usually limited to smothering relatively small fires with dirt. Of course, make sure the dirt you use doesn't have a lot of flammable organic material in it, such as pine needles and dead leaves.

Removing the Heat Energy

Cooling the fire with water or Class A foam is one of the most common and effective fire extinguishing methods.

Narration Script: Remember our discussion earlier about the fire triangle? You figure it out—if combustion requires fuel, oxygen, and heat, how would you go about controlling combustion…?

Topic summary

An observer of life once noted that before you can walk, you have to learn how to crawl. We hope this topic did, indeed, help you learn how to crawl—with respect to becoming a wildland firefighter, that is.

In this topic, we covered:

- **Wildland fire fighting terminology**
- **Fire triangle**
- **Heat transfer**
- **Breaking the fire triangle**

Narration Script: The information we covered in this topic should have helped you begin building the knowledge base you'll need to fight wildland fires safely and effectively.