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Guide to Wildland Fire Origin and Cause Determination

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The *Guide to Wildland Fire Origin and Cause Determination* provides recommended procedures, practices, techniques, and methods designed to encourage the use of a systematic approach during the investigation of a wildfire. This includes the application of the scientific method, which includes but is not limited to, collection of factual data pertinent to the investigation, an analysis of pertinent data, formulation of a hypothesis(es), testing of the hypotheses, and selection of a final hypothesis.

While this guide is not intended to be all-inclusive, the guidelines and recommendations were developed to follow a science-based, systematic methodology, incorporating the scientific method, that has been published, peer-reviewed, and is generally recognized by the wildfire investigation discipline. The guidelines assist in identifying evidence and forming conclusions to be used for legal proceedings that serve as the basis for administrative decisions and policy development. Although similarities exist between structural fire investigations and wildfire investigations, the differences require specialized training and experience.

Early investigator response, coupled with timely protection of the ignition area, may increase investigation success. The protective measures described in the guide should result in the preservation of evidence to ensure effective and fair administrative, civil, or criminal proceedings.

The investigation should start at the time a fire is reported or discovered. First responders play an important role in protecting evidence and should be trained to identify and protect the general origin area of the fire. Wildfire investigators (hereinafter referred to as investigators) should impress upon firefighters, law enforcement, and other first responders that the preliminary protection of the general origin area and any associated evidence on any wildfire is the responsibility of first responders, and emphasize that first responders are the most important link in the subsequent origin and cause determination. It is important that other actors understand how their actions, both during and following suppression, can enable a wildfire investigator to accurately determine the origin and cause.

This document does not cite or reference the specific Federal, State, Tribal, and local laws and regulations that give direction with respect to wildfire investigations and the legislative authority to investigate wildfires.

NWCG provides national leadership to enable interoperable wildfire operations among Federal, State, Tribal, territorial, and local partners. NWCG operations standards are interagency by design; they are developed with the intent of universal adoption by the member agencies. However, the decision to adopt and utilize them is made independently by the individual member agencies and communicated through their respective directives systems.

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PMS 412—A Guide Through the Complexities of Wildfire Investigations

In the United States, the National Interagency Fire Center found in 2023 that, over a 10-year average, human-caused fires accounted for 88 percent of all wildfires. Most of these human-caused fires could have been prevented through mitigation and ignition risk reduction. Importantly, preventing these unplanned ignitions helps protect lives, property, and the environment. Relying solely on suppression without investing in ignition risk reduction can lead to a cycle of reactive firefighting.

Determining the cause of wildfires is a critical part of wildfire prevention. Firstly, by finding the origin and cause, agencies can develop more effective fire prevention programs, including advice to community groups and landowners. Secondly, if a wildfire is proven to be intentionally, maliciously, or negligently caused, then criminal or civil prosecution (to enable cost recovery associated with suppression and damages) can be pursued.

The application of a thorough and proven investigative process has been the cornerstone of successful wildfire investigation for decades across the globe. This has been achieved after the collective experience of wildfire behavior experts, forensic scientists, and investigators led to the development of consistent methodology in PMS 412. This latest edition refines the document by including updated knowledge, providing consistency of cause classifications, removing redundancy, and enhancing key references.

Nevertheless, the wildfire investigation community continually evaluates and refines this methodology based on cases, peer review, court determinations, and evolving research. Importantly, this document is a testament to this collective expertise and its strength lies in its empirical approach and observational data collection. For decades, investigators have applied these processes across an international landscape, resulting in accurate determinations and the locating of ignition evidence. However, continued review is recognized as being essential to ensure these methods remain valid and based on experience, new data, and research.

NWCG's Wildland Fire Investigation Subcommittee (WFISC) provides international leadership in wildfire investigation through: (1) developing and promoting wildland fire investigation standards, qualifications, training, certification, and practices; (2) supporting fire prevention efforts as well as criminal, civil, and administrative actions related to wildfires; (3) establishing and maintaining a nationally recognized certification program for wildfire investigators (in the United States); (4) promoting systematic and science-based methodologies for conducting wildfire investigations; (5) developing and maintaining training courses, handbooks, and guides; and (6) coordinating with stakeholders to provide expertise in wildfire investigation.

Through this leadership, the WFISC goal is to include additional material, studies, and research to incorporate into its publications. As this field of work evolves, the WFISC intends to incorporate these findings in the future.

Introduction

Purpose of Wildfire Investigation

The purpose of a wildfire investigation is to determine the ignition area (origin), cause, ignition sequence, ignition source, and responsible party.

The results of an investigation can take four basic directions:

- Administrative actions, remedies, or penalties to recover suppression costs and damages
- Court proceedings under civil law to recover costs for suppression and/or property loss
- Court proceedings for criminal violations of Federal, State, Tribal, or local laws or regulations
- Assisting in policy development, implementation of fire prevention programs, and presuppression planning

General

Every wildfire investigation is unique. Portions of this document may not apply to every wildfire investigation. The recommendations presented here should be followed to the greatest extent possible but other specific practices may apply to unique fire scene conditions. Policy, time, assignment, and resources may dictate the scope and extent to which these guidelines may be applied to a certain investigation. If an investigation deviates from the recommended systematic approach, the investigator should be prepared to explain the reasons for this.

The NWCG training course, FI-210, Wildfire Origin and Cause Investigations, is the primary method by which the principles, procedures, practices, and techniques provided in this guide are transmitted to investigators. The course is based on the procedures established in this document.

Safety

Wildfire scenes may be dangerous, and safety is the highest priority on wildfires. Investigators have a duty to exercise due caution during their investigations and should abide by safety-related policies and procedures established by their agency, Federal, State, Provincial, and local governments, or industry.

Communication

Whenever possible, fire scene investigations should be conducted with two or more investigators. The investigator(s) should be able to communicate with suppression resources on the incident. Cellular phones are **not** an adequate substitute for emergency radio communications, but they may be useful for investigative communications to help ensure confidentiality.

Hazards

In addition to the usual physical hazards of outdoor work, such as extreme heat or cold, adverse weather, and sun exposure, investigating wildfires involves specific hazards that should be considered while on the fire scene. The investigator should be aware of areas where the fire remains active. The investigator must always identify an escape route and continually reevaluate their surroundings as fire conditions change.

- Ground fire in a smoldering stage can erupt into flaming combustion if the fire burns to the surface or if the top layer of soil is disturbed, exposing the heated fuel to air. This can happen if the investigator steps into an area burned out from below, such as in peat or a stump hole.
- Environmental hazards include venomous snakes, spiders, stinging insects, poisonous plants, dangerous wild or domesticated animals, falling trees and other debris, fire-weakened limbs, and logs and rocks that become unstable and roll down a slope. When fire destroys a root structure, soil may begin to lose its stability, which in turn can cause slides that may injure the investigator or destroy evidence.
- Working around the human-created infrastructure—such as energy generation, distribution, and transmission, roads, and railroads—requires appropriate precautions.
- Wildfire suppression operations present safety hazards relating to aircraft, heavy equipment operation and other suppression tactics, even loud noises. Investigative personnel should contact and coordinate with suppression personnel.
- Investigators should always be alert to the possibility that hazardous materials (hazmat) in forms such as illicit and/or infectious substances, flammable liquids and gases, and explosive materials may be found in or near the origin of wildfires, and call in hazmat resources as appropriate.
- The people investigators encounter can present as much of a hazard as the surroundings. Investigators should be alert to the possibility of encountering angry, upset, or altered-state (i.e., under the influence of alcohol or drugs, mental health, etc.) landowners or members of the public, or encountering individuals engaged in illicit activities. If safe to do so, attempts should be made to de-escalate conflict. If safety is compromised, investigators should leave the area until additional resources arrive.

Personal Protective Equipment

Investigators should comply with agency or industry requirements regarding personal protective equipment (PPE) such as protective clothing, safety equipment, and law enforcement defensive equipment. These will vary depending on the circumstances.

Wildfire ash and smoke present health hazards. The investigator may consider using an N95 mask along with agency-approved long sleeves, pants, socks, boots, and gloves. The investigator should change clothes and wash as soon as possible. Launder clothing before wearing it again. Minimize the transfer of ash or smoke to the workplace or home.

Investigation Team

The investigation team should include a qualified and trained wildfire investigator. Some wildfire investigations may require additional resources to support the team. Additional investigators may be required to conduct interviews, collect evidence, take photos, or map and sketch the site. Initial investigations may be handled by local law enforcement or fire management officials. Additional expertise may be requested and staffed as needed.

A second opinion from another qualified investigator can add weight to the conclusions in subsequent proceedings if the second opinion corroborates that of the original investigator.

Complex Investigations

A fire investigation may involve a number of interested parties. The investigator should follow agency policy when dealing with these parties, which may include multiple agencies, representatives of State or local governments, private landowners, public land users, and news media. A protocol should be developed to meet agency objectives.

The primary goals in these situations are to:

- Preserve the scene
- Locate the ignition area
- Determine the cause
- Identify potential responsible parties
- Protect evidence
- Preserve the interests of all parties

Thorough investigations result from appropriate planning, adequate resources, documentation, and the ability to anticipate problems before they arise.

Confidentiality

All evidence and information obtained during an investigation is confidential in nature. The premature release of information before any adjudicative action may jeopardize the outcome. Local laws and policies may require documents to be retained. These retention requirements vary among jurisdictions.

- Investigators should only disclose information to authorized personnel.
- First responders should be aware of the responsibility to maintain confidentiality of any information they may have received relating to the origin and cause of the fire.
- Investigative reports are often developed in anticipation of legal proceedings. Under no circumstances should copies be released without prior agency and/or prosecutorial approval.
- The Privacy Act, Freedom of Information Act, and similar privacy requirements apply to all investigative work products.

Chapter 1. Fire Behavior

Introduction

Fires burn according to scientific principles, and the evidence of a fire's progress takes the form of fire pattern indicators. A fire pattern indicator is a physical object that displays changes (fire effects) from exposure to heat, flame, and combustion byproducts. An accurate analysis of an individual fire pattern indicator can reveal fire progression at that precise location. Analyzing the individual fire pattern indicators reveals the overall fire progression.

For a wildfire to occur, an ignition source must contact the host fuel (material first ignited) and have sufficient heat over a sufficient duration to raise it to its ignition temperature. The smallest area that the investigator can define, within the specific origin area using the available fire pattern indicators, is referred to as the ignition area. The ignition area may include indications of smoldering or flaming combustion, and evidence of each should be noted as it pertains to the ignition sequence. Physical remains of the ignition source may be located within this area if they have not been removed, completely consumed, or destroyed by suppression activities.

Fire Behavior Factors

An investigator needs to understand the basic principles of wildfire behavior, and this guide cannot provide a comprehensive explanation of all related principles. Texts such as *Wildland Fire Behaviour: Dynamics, Principles and Processes* (Finney et al. 2021) and fire behavior courses offered by NWCG to explore the subject in greater depth. The ability to re-create fire progression, based on knowledge of these principles, will assist the investigator in identifying and correctly interpreting fire pattern indicators and overall burn patterns. Additional training on wildfire behavior will assist the investigator in identifying and correctly interpreting fire pattern indicators and overall burn patterns.

Three main elements influence a wildfire: weather, fuels, and topography. Each of these elements has multiple sub-elements. The combination of these elements forms the fire behavior context. Understanding how these elements interact and affect the formation of fire pattern indicators is crucial to properly interpreting a wildfire's burn pattern.

Weather

The three components that compose the weather element of fire behavior are wind, relative humidity, and temperature.

Wind normally has the greatest effect on fire spread and intensity. Wind speed and direction are important in determining both the ignition area and the potential ignition sources. Wind speed and direction can vary dramatically at ridge levels and above the vegetation canopy as compared to below the canopy.

Wind data from most automated weather stations is taken at the 20-ft (6.01-m) level and in areas cleared of vegetation, thus having no canopy to affect the speed and direction of the wind. Below the 20-ft level, friction loss by the canopy and other obstructions can reduce wind speed. Surface wind direction can differ dramatically from that indicated by the smoke column after the fire is established. On-site data should be taken as soon as possible and compared to wind information taken at the 20-ft level. Air movement at the surface level is important when evaluating the potential for a smoldering ignition and transition to flaming combustion.

Fire advancing with the wind generally progresses faster than a fire backing into the wind. This will be evident by the difference in the fire patterns and the amount of fuel consumed. As a wildfire grows, it can create its own weather.

A change in wind direction can substantially affect fire patterns. General winds (ridgetop not influenced by terrain) usually remain steady at higher windspeeds, but may become less steady in their direction at 5–7 mph. Many variables influence wind direction at the surface, including terrain, cloud cover, temperature, and fuels. Surface winds across the landscape are rarely steady out of one direction due to many complex factors.

Relative humidity directly affects ignition probability, fire intensity, and fine dead fuel moisture. It is important to understand the lag time and the relationship between fuel moisture content and changes in the relative humidity. Fine fuels of less than 0.25 in (0.61 cm) in diameter respond quickly to changes in the relative humidity, while larger diameter fuels take longer to gain and lose fuel moisture content. The investigator should obtain and consider the changes in relative humidity before and after the ignition of a fire when determining the availability of certain fuels.

Temperature influences fire behavior by the drying and preheating effect it has on fuels. Areas exposed to or shaded from the direct rays of the sun can produce different fuel temperatures and moisture content. Therefore, slope, aspect, and canopy cover should be noted during the investigation of a fire.

Temperatures and relative humidities at ground level can differ from those readings taken from remote automated weather stations (RAWS) or by handheld instruments.

Fuels

Fuels are characterized by a variety of factors. These include vertical and horizontal arrangement, type, species, size and fuel moisture, live and dead fuels, surface area to volume ratio, and fuel bed depth. Fires tend to ignite more easily and spread more rapidly in fine dead fuels with low moisture content. Fuels most commonly associated with ignition areas are those characterized as having a high surface-area-to-volume ratio. These typically include dead grass, conifer needles, small twigs, duff, punky material, and other similar fuels.

Topography

Topography consists of slope, aspect, and terrain. Following wind, and assuming similar fuels, slope is the next greatest potential influence on the rate and direction of fire spread. Fires progress faster uphill than downhill due to the preheating of uphill fuels and the influence of daytime upslope and up-canyon winds. Slope may also contribute to the propensity for hot debris to roll or slide downhill, creating spot fires that may burn back uphill to the main fire.

The aspect of the slope also plays a role. In the northern hemisphere, south-facing slopes generally exhibit higher intensity and more rapid rates of spread because of greater exposure to the sun and the subsequent solar heating. The converse is true for fires in the southern hemisphere. Terrain may affect both intensity and rate of spread when either barriers or natural chimneys are present. Barriers, such as logs, bare dirt, or rocks, can cause a fire to slow down or extinguish. Almost any barrier will at least lessen the intensity of the fire as it passes. Larger terrain features often cause wind eddies, which can change the fire’s direction for short distances. Natural chimneys can increase wind velocity caused by the channeling effect and accelerate fire spread and increase intensity substantially.

Wildfire Terminology

The following discussion defines terms used in wildfire investigation.

- Fire behavior context
- Fire pattern indicator
- Fire effects
- Fire pattern
- Fire progression
- Fire pattern indicator vectors
- Advancing fire
- Backing fire
- Lateral fire
- Transition zone
- Spot fire and rolling material effects
- Fire pattern indicator categories
- Macroscale fire pattern indicator
- Microscale fire pattern indicator
- Fire pattern indicator cluster
- Damage differential

Fire behavior context. The specific fuel, weather, and topographic conditions that were present at or near the time of fire passage for a specific location.

Fire pattern indicator. A physical object that displays changes (fire effects) from exposure to heat, flame, and combustion byproducts. Accurate analysis can reveal fire progression at that precise location. A fire pattern indicator is a single component of the overall fire pattern.

Individual or small clusters of fire pattern indicators that conflict with the majority of indicators in an area may represent fire progression at that point. These should be interpreted within the overall fire progression and fire behavior context.

Fire effects. Observable changes to a material as the result of a fire. The term has a similar but broader meaning in the context of prescribed fire (the physical, biological, and ecological impacts of fire on the environment). In fire investigation, "fire effects" refers to the specific changes caused to a combustible or noncombustible object when it is exposed to heat, flame, and/or the byproducts of combustion. Fire effects that do not reliably reflect the direction of the fire's passage in a particular context are not considered to be fire pattern indicators.

Fire pattern. The observable physical changes formed by a fire effect on a single object or group of fire effects on multiple objects. Analyzing the relationship of the majority of individual fire pattern indicators reveals the overall fire pattern. This, in turn, may reveal overall fire progression.

Fire progression. The spread of a wildfire from one location to another. Most fires start small and, under the right conditions, burn in all directions until influenced by weather, topography, fuel, suppression activity, or a combination of these factors. Once influenced, the fire will progress outward (advancing, lateral, and backing) in a direction influenced by these factors, with the most dominant factor(s) establishing the primary advancing direction.

Fire pattern indicator vectors. One or more fire pattern indicators which reflect the fire spread direction within that area. The three vector areas, based on the direction of the fire's progression, are: head or advancing; flanks or lateral; and heel or backing.

Advancing fire vector is characterized by:

- Rapid fire spread
- Forward spread
- Higher intensity
- Increased flame length
- Macroscale fire pattern indicators
- More damage when compared with backing and lateral areas

Figure 1.1. Example of advancing fire vector.

Figure 1.2. Example of advancing fire vector.

Figure 1.3 shows a backing fire within a stand of young pine trees. The line of fire is burning the ground fuels, such as pine needles and cones, with spots where dead or downed trees and branches are burning more intensely. The flame length is low to the ground. The smoke is blowing back into the burn, indicating that the low flame length is consistent with a backing fire.

Backing fire vector is characterized by:

- Slower rate of spread—against wind, downslope
- Lower intensity
- Lower flame length
- Less damage when compared with advancing and lateral areas
- Microscale fire pattern indicators

Figure 1.1. Example of backing fire.

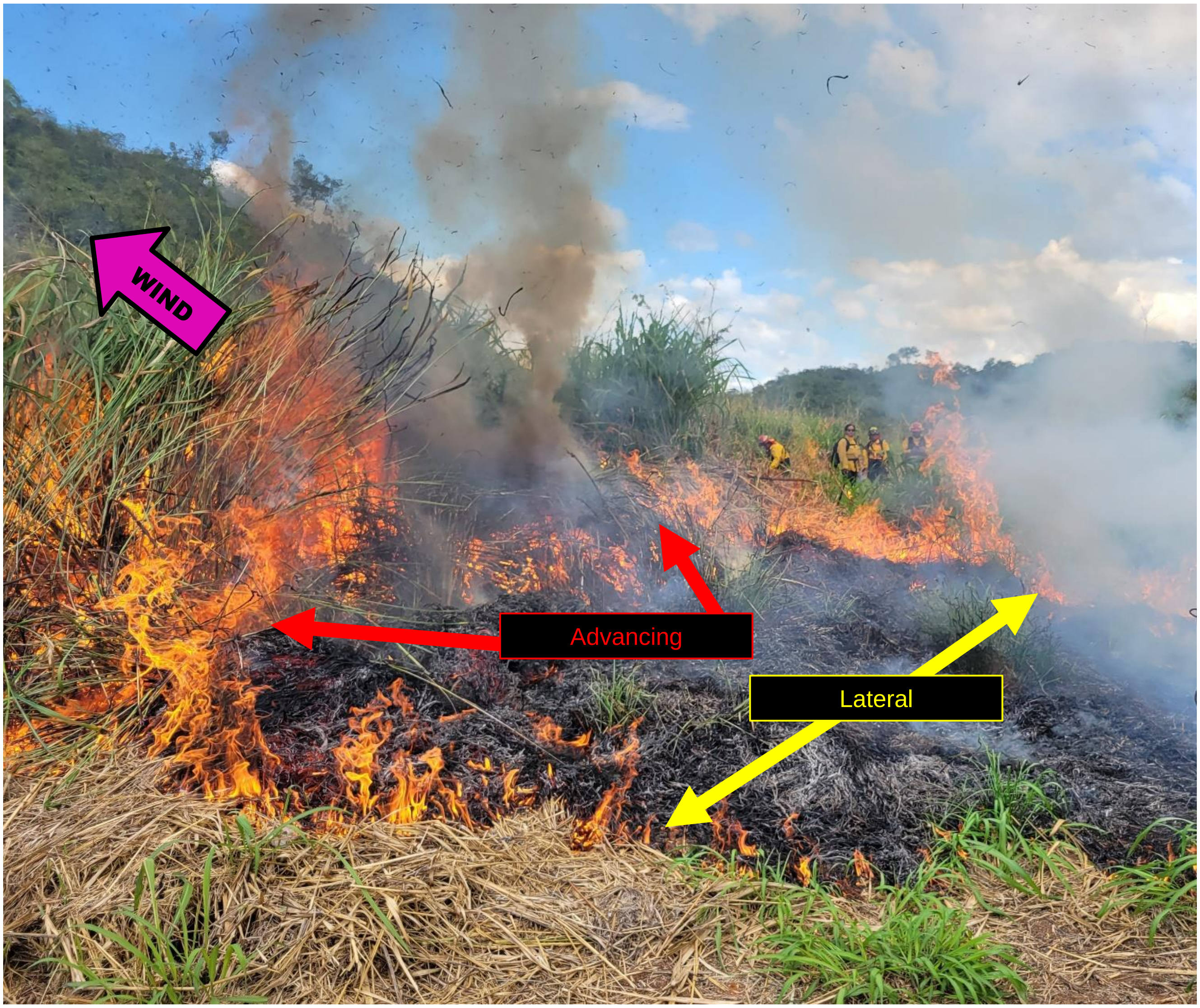
Figure 1.2. Example of backing fire.

Lateral fire vector is characterized by:

- Rate of spread and intensity between advancing and backing—flank fire, spread generally lateral to advancing fire.
- Indicators can have characteristics of backing or advancing, depending on fire behavior.
- A higher intensity flank may leave indicators consistent with advancing fire spread—exhibiting a more defined and narrower transition zone.
- A lower intensity flank may leave backing-type indicators—exhibiting a more subtle and wider transition zone.
- Intensity on flanks may change with wind, slope, and fuels.

Along the flanks, lateral fire spread tends to be at a 90-degree angle to the advancing fire, but as the flanks transition to the head of the fire, lateral fire progression may be more consistent with a 45-degree angle or something between 90 and 45 degrees.

Figure 1.3. Example of lateral fire.



Transition zone is characterized by:

Area of directional change, which may be subtle, based on variations in intensity—advancing to lateral, advancing to backing, backing to lateral

- Change in appearance and characteristics of indicators
- May define the flanks of the specific origin area

Identifying transition zones is a key to accurately interpreting fire patterns.

Advancing fire will spread at different rates depending on the type and availability of the fuels. A fire may spread very quickly under the influence of moderate wind in dry grassy fuels. The same fire burning into a stand of timber may slow its rate of spread while the fire in the grassy area continues to spread.

These changes in the composition of the fuels are part of the fire behavior context that the investigator should observe and understand. Very few wildfires burn in the same fuel conditions through their entire duration.

Changes in wind direction and/or speed create changes of the transition zones.

Spot fire and/or rolling material effect. Firebrands can carry downwind, causing spot fires ahead of the main fire. This may result in the formation of new ignitions. Each spot fire behaves as a separate fire until they burn together, or the main flaming front overtakes the spot fires.

Likewise, rolling material can cause new fires to start downslope of the main fire. Each fire from rolling material behaves as a separate fire until they join with the main fire.

Fire pattern indicator categories. Fire pattern indicators discussed in this guide are based on wildfire behavior principles and the materials the fire affects. Each category can exhibit any of the three vectors: advancing, lateral, or backing. The physical appearance may differ depending on the vector (direction of fire progression). The fire pattern indicators are also divided into two general classifications, macroscale and microscale.

Macroscale fire pattern indicators. Usually associated with larger objects or areas and are easily visible from a distance. These are typically found in areas of higher fire intensity. Macroscale fire pattern indicators commonly define areas of advancing fire and are key clues to identifying the general origin area of a wildfire.

Microscale fire pattern indicators. Associated with smaller objects or areas and may not be as easily observed from a distance. Their importance increases with proximity to the ignition area. Microscale fire pattern indicators are typically more subtle than macroscale indicators, and these indicators generally need to be observed from a closeup position (kneeling, squatting, or on hands and knees).

Fire pattern indicator clusters. A group of indicators in proximity to each other that contain fire effects portraying a consistent vector among them. Clusters are most reliable when a variety of fire pattern indicator categories are represented within the group or cluster.

Damage differential. One of the underlying principles governing the interpretation of most fire pattern indicators. The damage differential on individual fire pattern indicators is the change that occurs to combustible and noncombustible objects after interaction with fire. The principle of damage differential on individual fire pattern indicators is a matter of comparing and contrasting the damage to determine which side was exposed to the oncoming fire. In this respect, damage differential underlies the processes that form protection fire pattern indicators and others.

In viewing larger areas (V and U patterns), the principle of damage differential is used to compare and contrast areas of higher intensity burning, indicating advancing fire, to areas of moderate (lateral fire) or low (backing fire) intensity. Identifying a large-scale damage differential is part of the process of identifying the general origin area. A large-scale damage differential should be confirmed through the observation of individual fire pattern indicators. The amount of change will be based on the relative fire intensities and exposure to the oncoming fire.

Possible characteristics to compare and contrast:

- Amount of charring
- Amount of white ash
- Degree of loss of material
- Amount of sooting or staining
- Height and type of foliage freezing
- Degree and location of spalling
- Height and type of angle of char
- Location and extent of cupping
- Location and relative extent of general fire damage over larger area

Principles of Fire Pattern Interpretation

The interpretation of fire pattern indicators is governed by general principles that have been found to be reliable and which the investigator needs to apply while conducting their origin investigation. These principles have been around for many years. The first known documentation was by Bob Bourhill of the Oregon Department of Forestry (Bourhill 1982). They have been further refined by subsequent testing and experience.

Base your interpretation on the majority of the fire pattern indicators within an indicator category. Single fire pattern indicators reflect the fire direction at a precise point and may be unreliable in the context of overall fire progression.

Base your interpretation on the fire pattern indicators within a variety of categories. Using as many of the 11 categories of fire pattern indicators as possible provides for greater reliability. Fire does not burn in perfectly straight lines. Radical but brief directional changes may occur. The actual progression of the fire is based primarily on the wind, fuels, and slope. Fire pattern indicators will align with the progression at the point of each indicator and reflect the direction of the fire at the time it passed that specific location.

Interpret fire pattern indicators within the context of fire behavior principles. Determine the fire behavior context through weather observations, topography, reliable witness information, and reconstruction of probable fuel conditions. This should include consideration of both unburned fuels and burned remains. Check the observations through interviews with first responders and civilian witnesses.

Fire pattern indicators will usually become less pronounced as you approach the ignition area. Most fires start small and with lower intensity. Following ignition, the fire will progress outward from the ignition area. The initial spread of the fire will be generally circular until the fire falls under the influence of wind, slope, and fuels. Intensity usually increases as the fire progresses outward from the ignition area. In this initial area of combustion, due to the lower intensity, most of the fire pattern indicators will be microscale and subtle.

This area immediately surrounding the ignition area is called the specific origin area. Because of the lower intensity associated with this area, it is often characterized by the presence of more unburned material, unlike a structure fire, where the origin is often the location of greatest damage. As the fire comes under the influence of the varying fire behavior factors, it will begin to spread with uneven intensities and rates. This area is referred to as the general origin area. The fire will now exhibit different areas of progression but is often influenced by localized barriers and smaller changes in fuel availability.

Document the fire pattern indicators during the investigation. Use directional flags, fire spread sketches, diagrams, and photos to document the fire progression. Directional flags (discussed in chapter 6, Documentation) help the investigator keep track of fire progression and provide a visual representation of that progression.

Work from the area of more-intense burning to the area of less-intense burning, following the fire's progression back to the ignition area(s). As the fire spreads, it will create transition zones—areas of directional change based on variations in intensity—between the areas of progression. Transition zones may outline the specific origin area and can be identified by the appearance, often subtle, of the fire pattern indicators.

The initial transition zone may be hard to define. By starting the search for the ignition area where clear advancing fire pattern indicators are present in the form of more intense burning, the investigator reduces the risk of prematurely entering the ignition area and damaging it. Macroscale indicators, witness statements, and the fire behavior context form the basis for establishing the initial search for the general origin area. Care should be taken to start far enough out in the higher intensity advancing fire area to account for the possibility of multiple ignitions and ignition areas.

Avoid attempts to prematurely locate the ignition area. Indicators become increasingly subtle the closer you get to the ignition area. Investigators will need to pay closer attention to detail, take their time, and avoid the pressure to rush. Working the specific origin area to locate the ignition area is typically the most time-consuming portion of the search. Investigators should be especially disciplined in their work within these areas. Patience is the key.

Direction of fire travel will be influenced by obstacles. The movement of fire is like the fluid movement of water around obstacles. Physical objects in the path of the fire's spread will cause the fire to go around, through, or over them and may result in loss of intensity and speed. Temporary direction change should be expected.

View and document fire pattern indicators from all sides, as appropriate. Some fire pattern indicators cannot be contrasted unless viewed from various angles. Documenting from only one side may give a one-sided viewpoint. Angle of char, protection, white ash, sooting, and staining may not be evident unless looked at from various angles. Photo-document contrasting views where appropriate.

Chapter 2. Fire Patterns Indicators

As a fire progresses, it will produce visible changes to combustible and noncombustible objects in its path. These changes are called fire effects. Consistent fire effects indicate the direction of fire progression at that location. These are then referred to as fire pattern indicators.

These can point to advancing, backing, or lateral directions of fire progression. When analyzed within the fire behavior context, they form distinct overall fire patterns. These fire patterns identify areas of fire progression and the accompanying transition zones that can then be traced back to the fire's ignition area.

General Reliability and Possible Variances

Fire pattern indicators accurately reflect fire behavior at a particular location at the time the fire passed. However, the individual direction displayed may not be consistent with general fire progression. Investigators should be familiar with the fire behavior conditions (fire behavior context) that may cause one fire pattern indicator to be inconsistent with another.

Fire pattern indicators may be misleading. if not correctly interpreted. Their general reliability and possible variances may be influenced by these factors:

- Variations in fuel loading
- Long-term fire residence
- Wind speed or direction change
- Fire progression downslope against the wind
- Fuel moisture content and composition
- Scene disturbances from previous fires (reburns)
- Convection-caused indrafts

Validate or evaluate fire pattern indicators for reliability by considering:

- Fire behavior context
- Other indicators within a nearby pattern cluster
- General known fire progression
- Witness observations
- Video or photo evidence
- Circumstances that can create variances

Fire Pattern Indicator Categories

The NWCG methodology organizes fire pattern indicators into categories based on how the fire pattern indicator is formed and the materials upon which it is found. A category can exhibit any one of the three fire vectors. Many of these fire pattern indicators will be apparent on both large and small objects and fuels.

The NWCG fire pattern indicator categories are:

- Protection
- Grass stem
- Freezing
- Angle of char
- Spalling
- Curling
- Sooting
- Staining
- White ash deposit and exposure
- Cupping
- V / U shape

Protection Fire Pattern Indicators

An object may shield the unexposed or protected side of a fuel from heat damage, ignition, or deposits of products of incomplete combustion such as soot, ash, and oils. Fuels will be unburned or exhibit less damage, including less staining, sooting, and/or white ash, on the unexposed, protected side (figs. 2.1 and 2.2). Compare and contrast the degree of damage on all sides of objects.

Photograph objects in place before moving them to compare the damage and protection. Objects resting on top of the ground and surface fuels will protect the fuels on the side opposite the fire's approach. Surface fuels on the exposed side will exhibit a clean burn line and surface fuels on the protected side will appear ragged and uneven (figs. 2.3 through 2.6).

Figure 2.1. Protection on a log.

Figure 2.2. Protection on a pinecone.

Figure 2.3. A noncombustible object shielding fuel from heat damage.

Figure 2.4. Clean and protected burn lines after the noncombustible object has been removed.

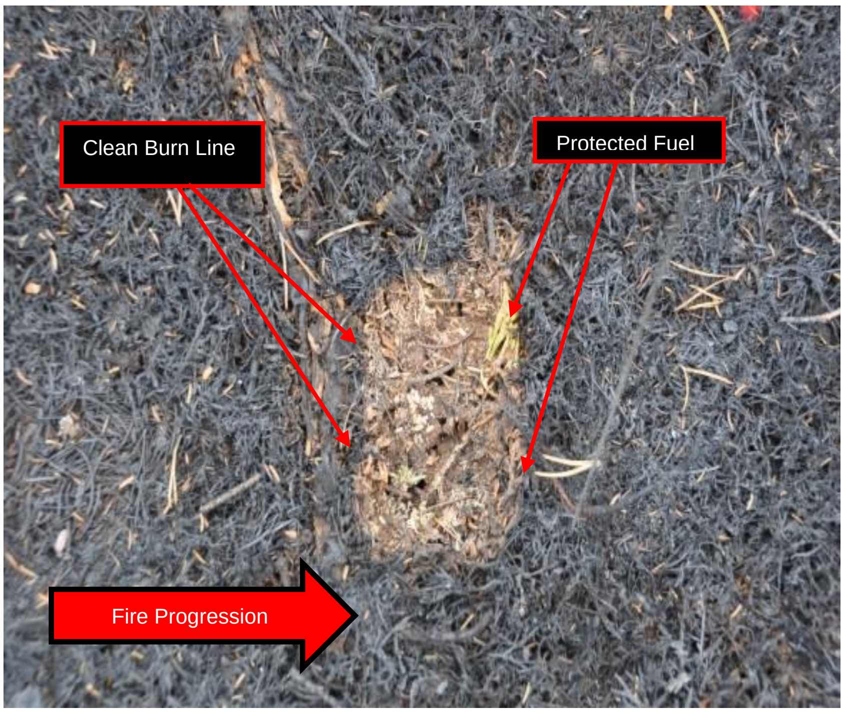


Figure 2.5. Closeup of the clean and protected burn lines. Clean burn line on one side (the left) and partially burned protected fuel on the opposite side indicates the direction the fire came from.

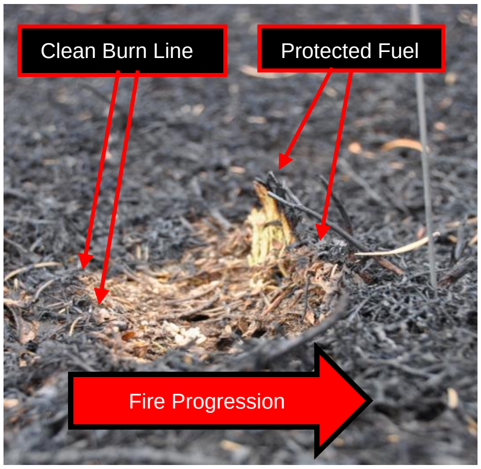


Figure 2.6. Closeup of burned grass with protected burn lines. The clump of grass is burned on the side facing the camera, indicating where the fire came from, with unburned and partially burned grass stems on the protected side away from the camera, indicating the direction the fire moved toward.

Both combustible and noncombustible objects can shield fuels from heat and flame. The same object may shield itself on its unexposed side.

General reliability: Protection accurately shows fire direction and is most reliable in low- to moderate-intensity fires.

Possible variances:

- Pithy stalks—a vascular plant with a continuous central internal strand of soft, spongy tissue in the stem with a thin outer sheathing. Pithy stalks may not be reliable as a fire pattern indicator due to the small diameter and soft, porous tissue.
- Suspended fuels—Limbs and tree trunks may be suspended off the ground by other fuels or objects. Gaps between the fuel and the ground allow for horizontal wind vortex flame wrap that may increase the damage on the protected side of the object. If the suspended fuel falls to the ground after the fire has passed, with damage on the opposing side or equally distributed on both sides, it may appear that the fire came from the opposite direction.

Figure 2.7. Cross-section of pithy grass stem.

Figure 2.8. An example of wind flame wrap on the exposed and unexposed side of suspended fuels.

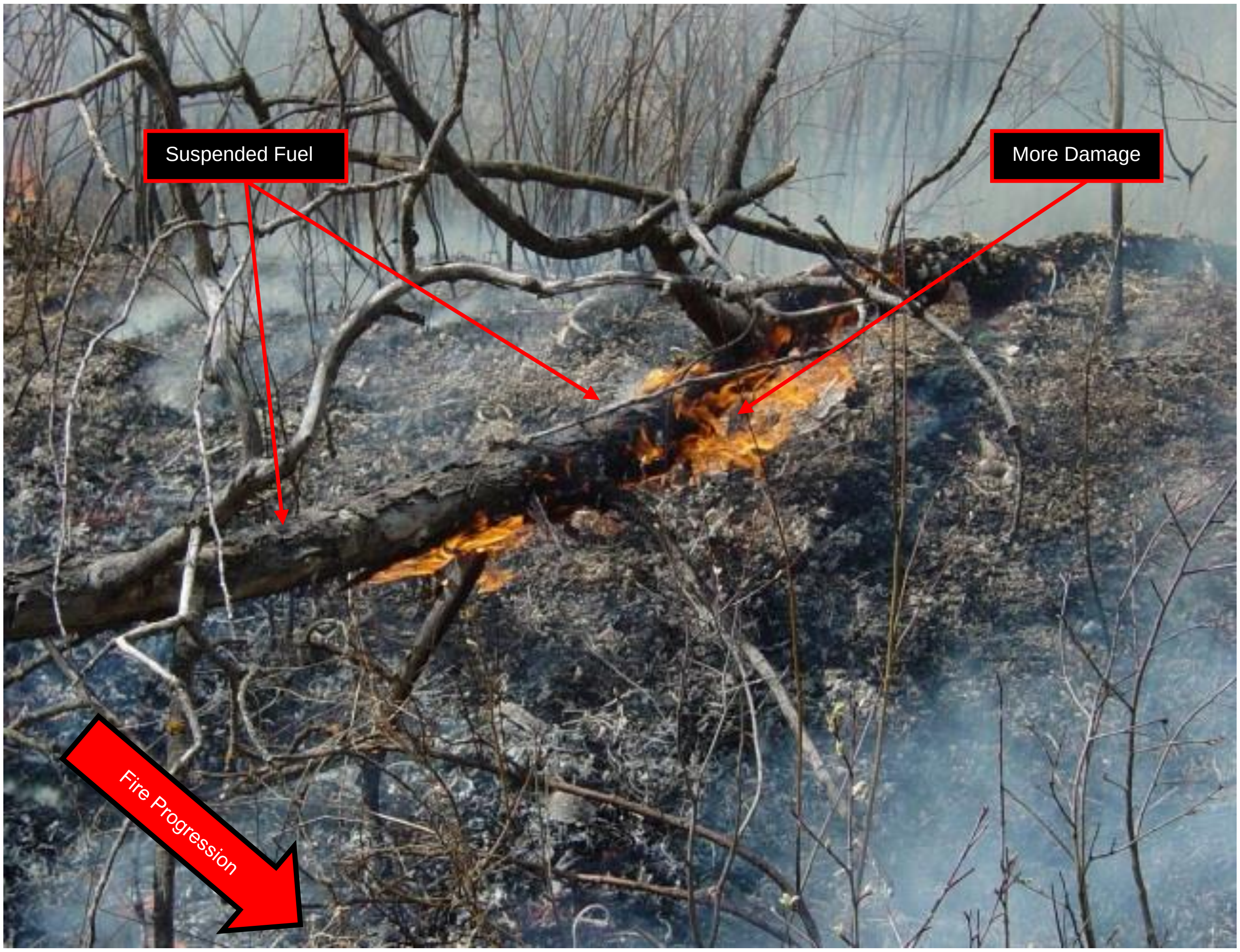


Figure 2.9. Transition area of suspended fuel and fuel in contact with the ground and the differences in damage.

Protection – Macroscale, Advancing Fire

These fire pattern indicators are more apparent on larger objects and may be difficult to differentiate on smaller objects due to the entire object being charred. The difference from exposed side to unexposed side can still be determined (compare and contrast).

Protection – Microscale, Advancing Fire

These fire pattern indicators may be used to validate macroscale fire patterns and indicators and can be used when macroscale fire patterns do not exist. These may be found in pattern clusters and include fuels shielded from damage on the unexposed side including:

- Downed logs and tree limbs
- Pinecones
- Grass clumps
- Small stumps
- Brush
- Deer or rabbit pellets
- Rocks and other noncombustibles

Figure 2.10. An example of microscale protection.

Protection – Microscale, Backing Fire

These fire pattern indicators are generally found on smaller protected fuels and objects due to the generally lower intensity of fire in backing areas. The indicators typically form on the side of the object exposed to the flame and heat. The indicator may initially form on the side first exposed to the flame and heat. However, as the fire moves past the object, if the flame tilts back over the burned area, the indicator may form on the side facing away from the origin.

Protection – Macroscale, Lateral Fire

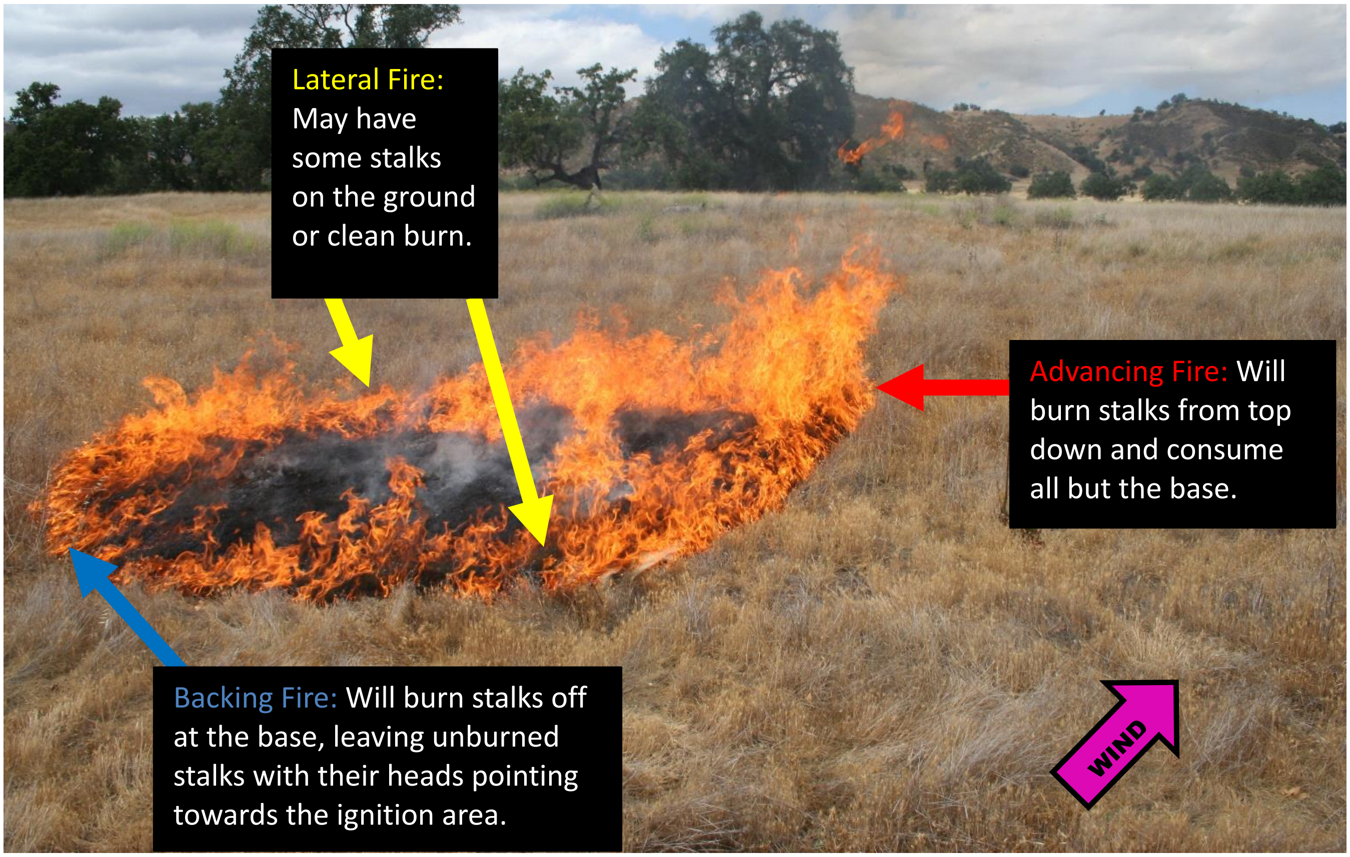
These fire pattern indicators generally exhibit more damage on the side closest to the advancing fire front. Protection is more noticeable when contrasted with advancing fire area.

Grass Stem Fire Pattern Indicators

The charred remains of grass stems left in the fire's wake will have different appearances depending on the direction of the fire's travel and intensity. In advancing fire areas, the flames will burn the stem from the top to ground level, consuming all but the very base of the stem. The base of the stem may show cupping.

Look for transition zones between backing and lateral progression. Heads or stalks may outline lateral transition areas from the advancing fire area.

Figure 2.11. Advancing, lateral, and backing fire progression.



Grass Stem – Macroscale, Advancing Fire

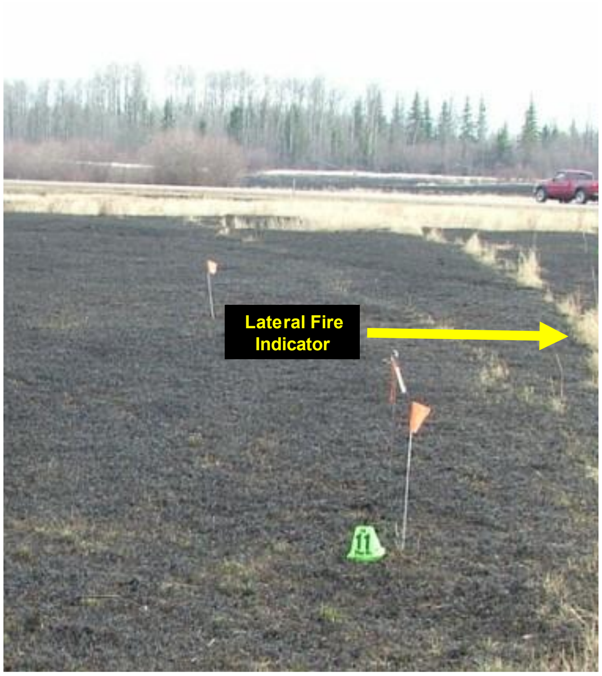
Grass stem remains found in the advancing area will typically consist of only a small part of the stem base and may show cupping fire effects. The advancing grass stem area is found by looking for the transition zones between the backing and lateral areas.

Figure 2.12. Advancing fire direction in grass.

Grass Stem – Backing and Lateral Fire

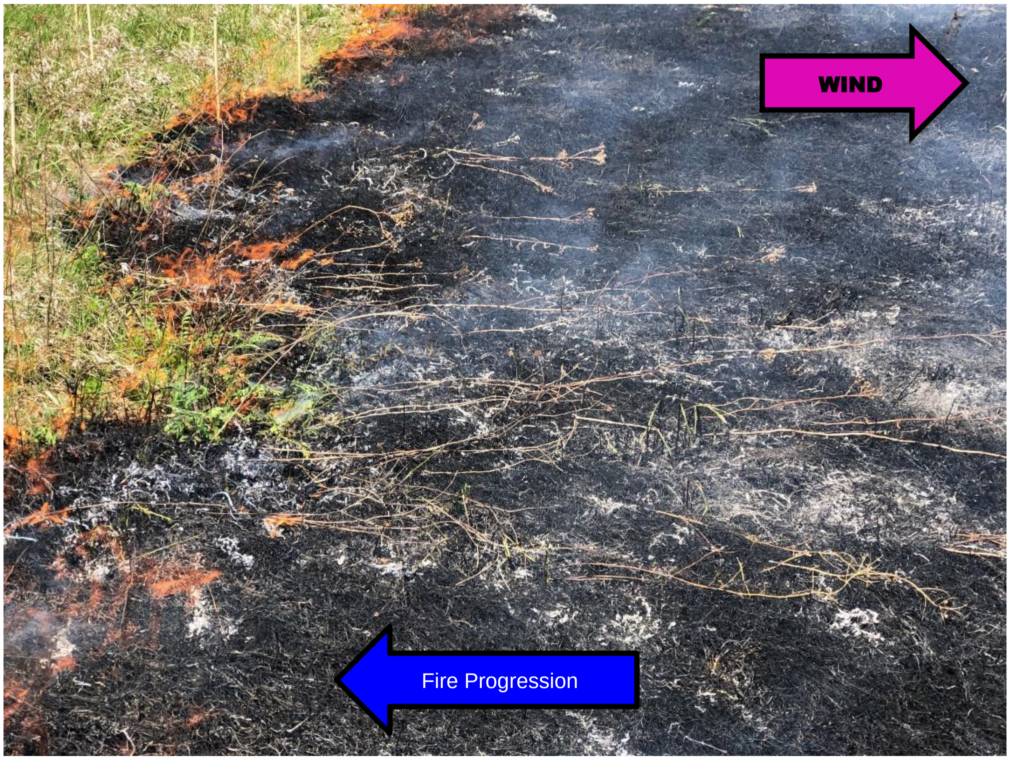
In backing and lateral fires, wind indrafts, the natural lean of the stems, and the fire itself may influence the direction the stems fall. Fire weakens the side of the grass exposed to the oncoming fire, which may cause the stem to fall in the direction the fire came from. Indrafts of wind may pull stems toward the direction the indraft came from. Parts of the stems that fall into the burned-out area behind the flaming front survive and point back toward the direction the fire came from. Stems that fall into the flame zone are typically consumed by the flames.

Figure 2.13. Before and after photos of lateral fire in grass.



Backing and lateral fire pattern indicators are more reliable on lower intensity fires. The grass stem heads may point toward the direction the fire came from, primarily in backing areas but may occur in lateral transition zones.

Figure 2.14. Example of a low-intensity backing fire traveling from right to left with grass stem heads pointed in the direction the fire came from.



Grass Stem – Transition Zones, Ignition Area

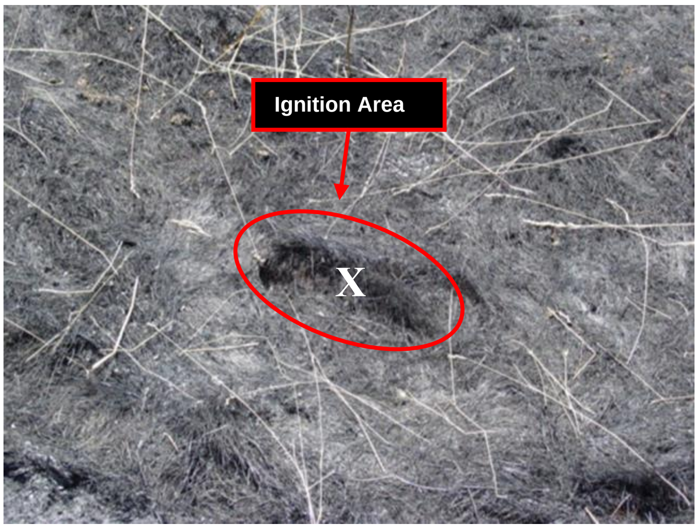
Grass stems leaning into the burned area may fall with grass heads pointing the direction the fire traveled from. Grass leaning in direction of fire travel may be fully or partially consumed as the fire progresses. Remaining grass stems may form recognizable patterns within the specific origin area:

- Backing to advancing transition zone.
- Lateral transition areas may be outlined with downed stems.

Circle fire pattern:

- Fire burns away from the ignition area equally in all directions until influenced by fuel, wind, and or topography.
- Grass stems fall inward toward the ignition area and remain relatively intact, forming a circle.

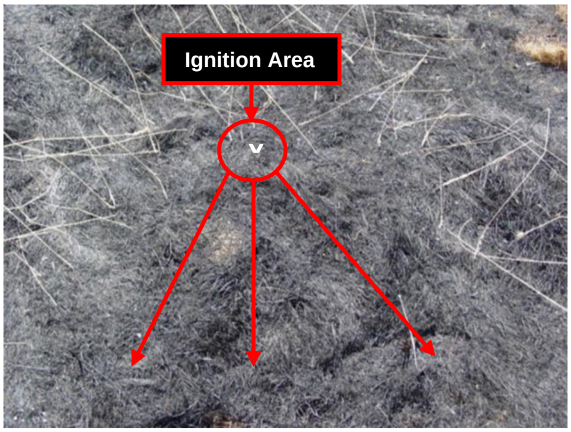
Figure 2.15. Demonstration of a grass stem circle fire pattern.



V or U microscale fire pattern:

- Takes place near or in the specific origin area when the fire is gathering its initial advancing direction.
- Fire under the influence of wind or slope advances in an initial direction.
- Backing, lateral, and advancing transition zones first form, creating a V or U pattern.

Figure 2.16. Demonstration of V- or U-shaped fire patterns.



General reliability: Grass stem indicators are usually very reliable. They segregate backing from advancing areas very well and define lateral areas.

Possible variances:

- Matted grass may leave stalks in all areas and inconsistent direction of fire spread.
- Wind disturbance may leave stalks in all areas and inconsistent direction. Reliability increases with the number of consistent grass stems.
- Uncured grass may leave stalks in all areas and inconsistent direction.
- Suppression activity, such as hose stream application.

Always examine the unburned fuel areas to determine if these conditions existed before the fire.

Grass stems that have fallen due to high winds may not be reliable as a directional indicator, but the amount of grass stem remains can be used to help determine transition areas and fire intensity.

Grass Stem – Macroscale, Advancing Fire

Advancing macroscale grass stem fire pattern indicators are generally represented by a clean burn and the transition to backing and lateral may form a V- or U-shaped fire pattern.

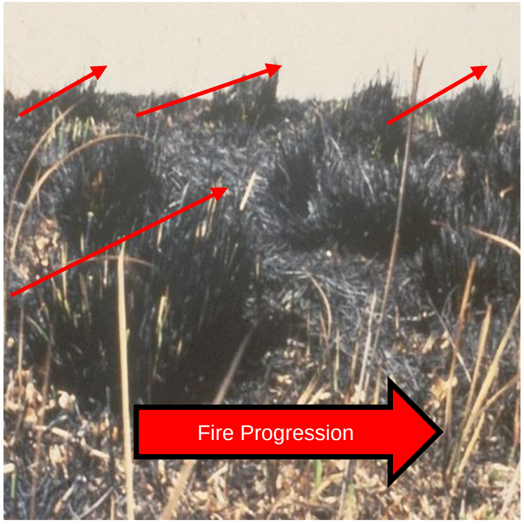
Figure 2.17. Photo shows a clean burn showing no grass stems in advancing area with grass stems outlining the lateral and backing areas.

Grass Stem – Microscale, Advancing Fire

- Lack of residual stems
- Stems burned off at or near the base

These fire pattern indicators will generally have less grass stem remains than the lateral and backing transition zones.

Figure 2.18. An example of microscale fire patterns in grass.



Grass Stem – Macroscale, Backing Fire

Backing macroscale grass stem fire pattern indicators will show a littering of unburned or partially burned grass stems and heads.

Figure 2.19. Backing area showing most stems and heads that have fallen point in the direction the fire came from. Multiple stems increase reliability.

Grass Stem – Microscale, Backing Fire

Grass stem microscale fire pattern indicators in the backing fire area will be viewed by the individual heads and stems, which generally point toward the oncoming fire.

Figure 2.20. Backing fire and grass stem fall.

Figure 2.21. Backing fire and grass stem fall.

Backing microscale grass stem fire pattern indicators in higher intensity fires will sometimes result in the stalk being completely consumed. The grass seed head itself, while completely blackened, may remain intact and indicate the fire's progression. Without close examination, it may appear to be an advancing area. Compare and contrast with seed heads in the advancing area.

Figure 2.22. The drawing illustrates the effects of a backing fire on grass stems.

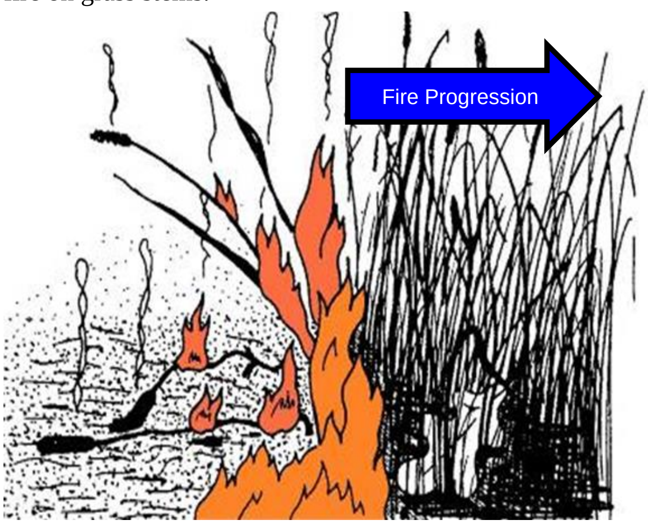


Figure 2.23. Backing fire moving right to left with grass stems falling back toward the burn.

Foliage Freeze Fire Pattern Indicators

Foliage freeze in the advancing and lateral areas takes place when needles, leaves, and small stems are heated, become soft and pliable, and bend in the direction of the prevailing wind or drafts created by the fire. They often remain pointed in this direction (i.e., freeze) as they cool and stiffen following the passage of the flame front.

Figure 2.24. Foliage freeze in the needles of a pine tree.

Backing fire foliage freeze is less common than in the lateral and advancing areas of the fire and usually presents in the form of drooped foliage that is still somewhat brittle and dry.

Lateral fire foliage freeze is most likely to indicate the wind direction rather than the lateral fire spread direction and should not be relied on to determine lateral spread direction.

Figure 2.25. Foliage freeze.

General reliability: As a fire direction indicator, foliage freeze is most reliable within the advancing fire area when wind is the dominant factor influencing advancing fire progression.

Foliage freeze is a wind direction indicator that also corresponds with the direction of fire spread in an area of advancing fire progression. Foliage freeze in lateral areas of fire progression will continue to indicate the wind direction, which typically remains in the direction of the advancing fire. To establish the direction of lateral fire progression, this indicator should be applied in conjunction with the fire behavior context and other types of fire pattern indicators.

Possible variances: Locations with a natural prevailing wind where the foliage is already fixed in a position and locations with preexisting drought conditions.

Foliage Freeze – Macroscale, Advancing Fire

Foliage freeze is a good indicator of wind direction and may reflect the direction of the fire's advance.

Foliage freeze fire pattern indicators being used to determine the fire direction should be compared and contrasted to other fire pattern indicator categories in the same area to check for consistency.

Foliage Freeze – Macroscale, Backing Fire

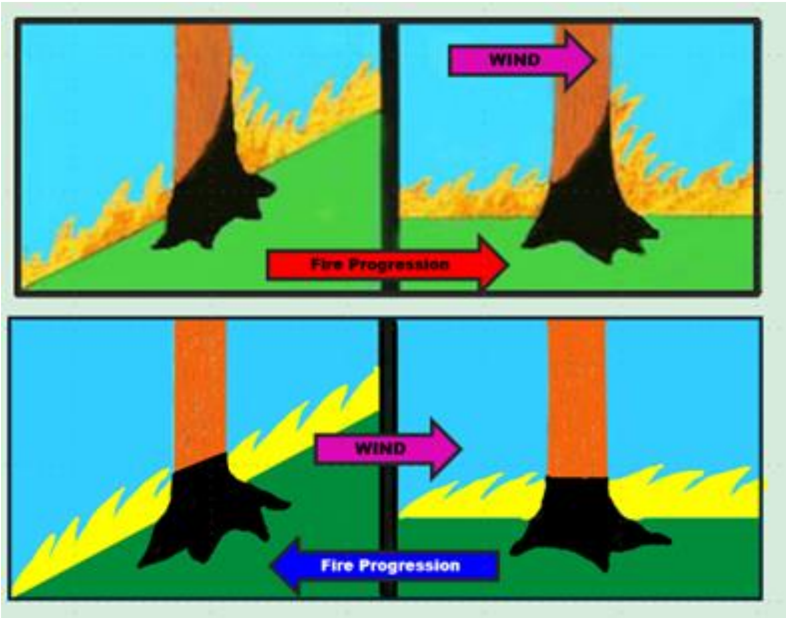
In backing fire areas, foliage freeze is more likely to be on the foliage of low brush and the lower level of tree crowns near the ground. It may be observed when fire backs into strong wind in heavy fuels and the foliage may appear drooped rather than windswept. The foliage in the backing area may still be somewhat brittle and dried out. Foliage freeze is predominantly an indication of wind direction.

Figure 2.26. Macroscale foliage freeze with drooping and brittle appearance in the backing area of a low-intensity ground fire.

Angle of Char Fire Pattern Indicators

The angle of char fire pattern indicator is formed when fire burns up to and beyond standing fuels, such as a tree, utility pole, grass clumps, or a bush. Flame height and angle corresponding to advancing, lateral, and backing fire directions and intensities char the fuel at an angle compared to both the unburned portion of the object and the slope.

Figure 2.27. Illustration shows examples of char angles on level ground and on slopes and different fire direction. The drawings on the left illustrate a slope-influenced fire; those on the right show a wind-influenced fire.



Scorch vs. Char

Angle of scorch is a subset of the angle of char and is formed by the similar processes—fire and/or heat moving to, past, and beyond a standing fuel.

The difference between the two indicators is a matter of heat duration or fire intensity (or both).

Scorch typically appears on remaining foliage of trees or brush where the foliage was not consumed but simply heated and dried.

Char results from the burning away of portions of the actual foliage or the charring of the bark or wood of a standing fuel.

The angle of char is exhibited as a line of diagonal charring in the canopy or cylindrical object.

Figure 2.28. Example of angle of scorch and char.

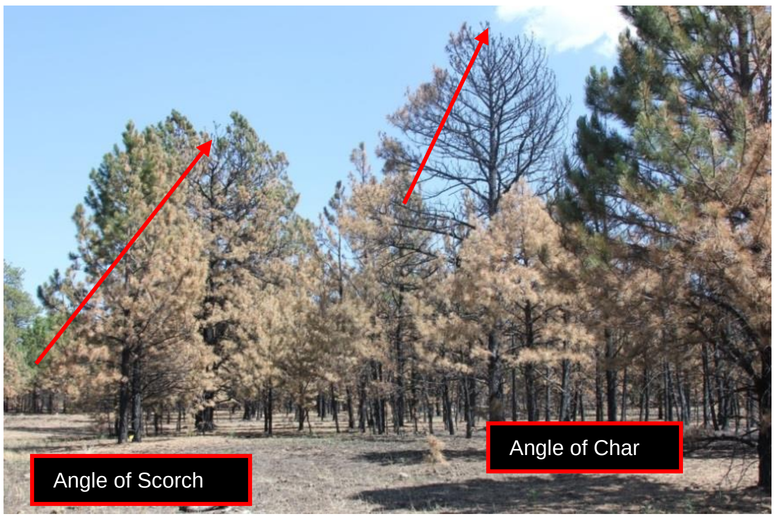


Figure 2.29. Angle of char on a tree trunk.

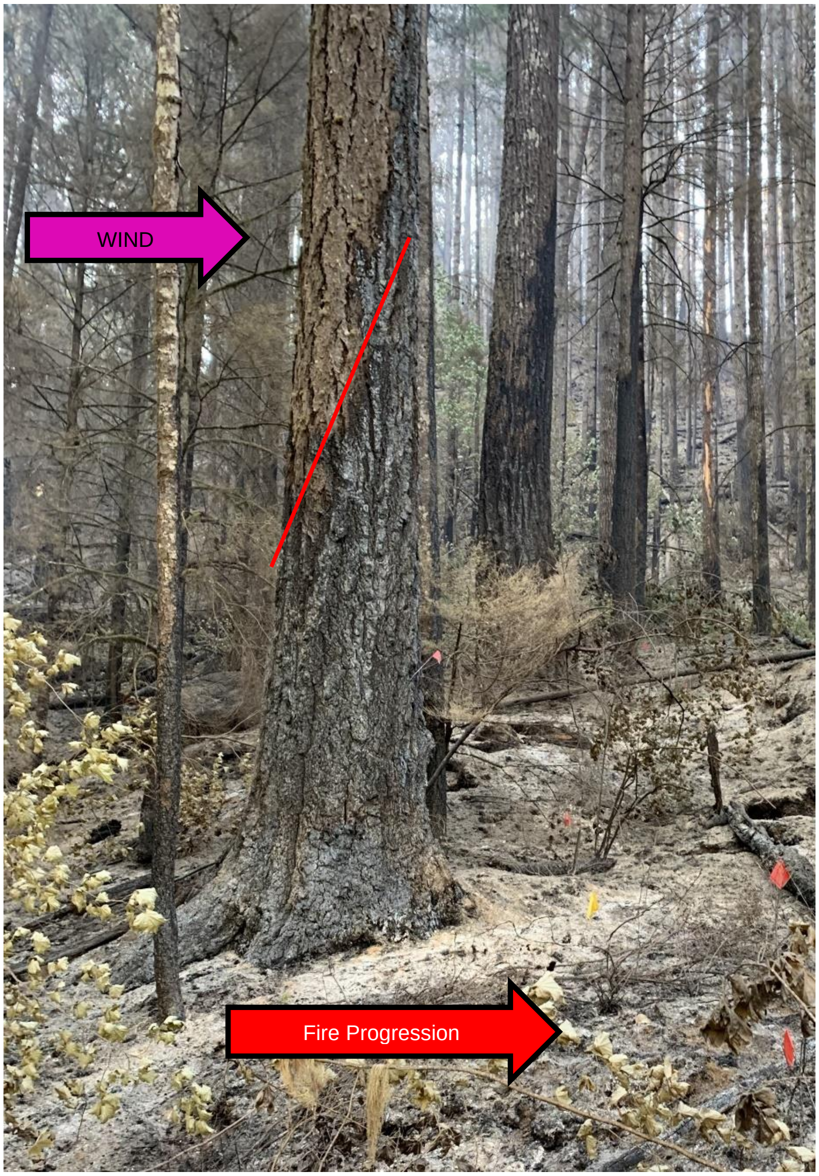


Figure 2.30. Angle of char and scorch on a tree crown.

General reliability: Reliable for assessing advancing fire areas.

Possible variances:

- Small-diameter stems—less than 3 in (7.6 cm) in diameter—or short heights
- Fuel accumulations at base of trunk on uphill side when fire is backing downhill
- Preexisting char patterns from old burns
- Thin-barked—evenly blackened on all sides
- Areas where fire did not burn entirely past the fuel (near fire control lines, etc.)

Angle of Char – Microscale, Advancing Fire

Grass that grows in clumps (bunchgrass/tufted grass) may not be entirely consumed, showing protection on the unexposed side. When this occurs in advancing areas, the residual basal stalks will normally show an angle of char that is steeper than the slope and may exhibit cupping on the tips, with the low side of the cup on the exposed side. Examples of these include:

- Lack of residual stems
- Stems and clumps burned off at or near the base
- Angle steeper than slope on clumps
- Individual stems sharp or pointed on the unexposed side

Figure 2.31. Example of microscale angle of char fire patterns in grass clump.

Angle of Char – Macroscale, Advancing Fire

Angle of char and scorch form consistent patterns in advancing fire areas. The angle of char or scorch in the advancing area is steeper than the slope. The low side of the char or scorch fire effect is located on the side facing the advancing fire.

Advancing fire normally enters standing fuels low and exits high due to flame angle and wind influences, creating the typical angle of char fire effect. Angle of char and scorch are often found in clusters in the advancing area of the fire. Compare and contrast the angle and height of the char or scorch to backing and lateral fire areas.

Figure 2.32. Photo shows advancing angle of char fire pattern indicators in a cluster that are consistent with each other. Angle of char is steeper than the slope and indicates the fire direction.

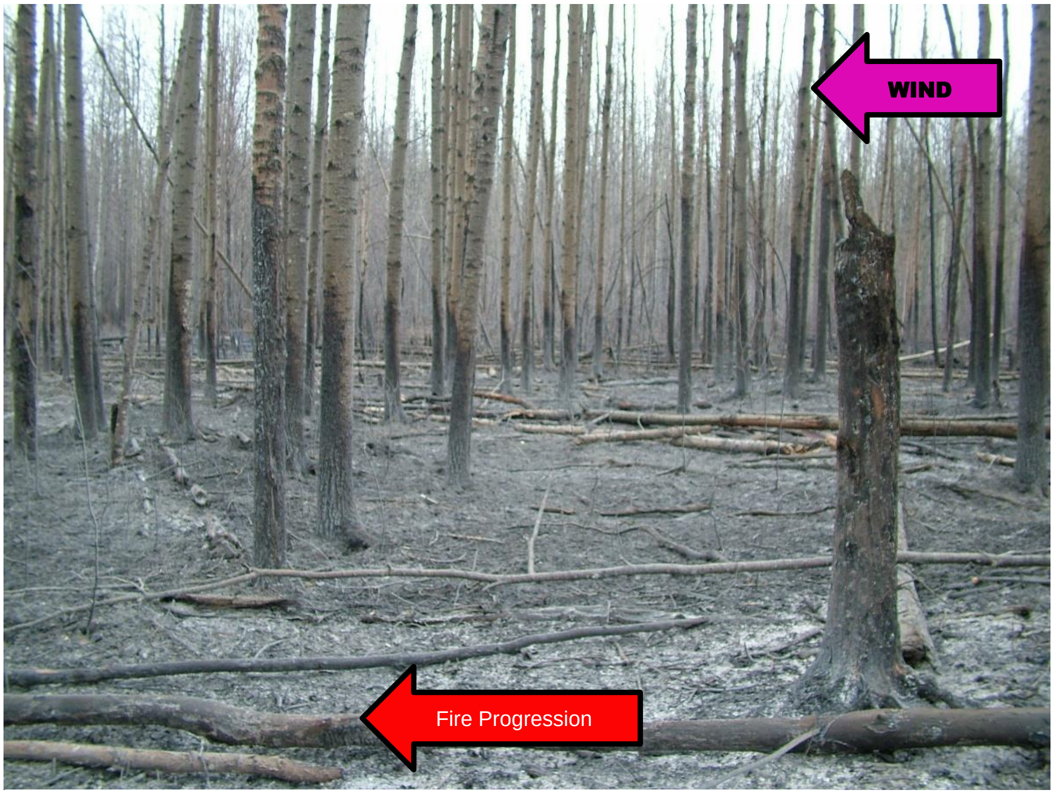


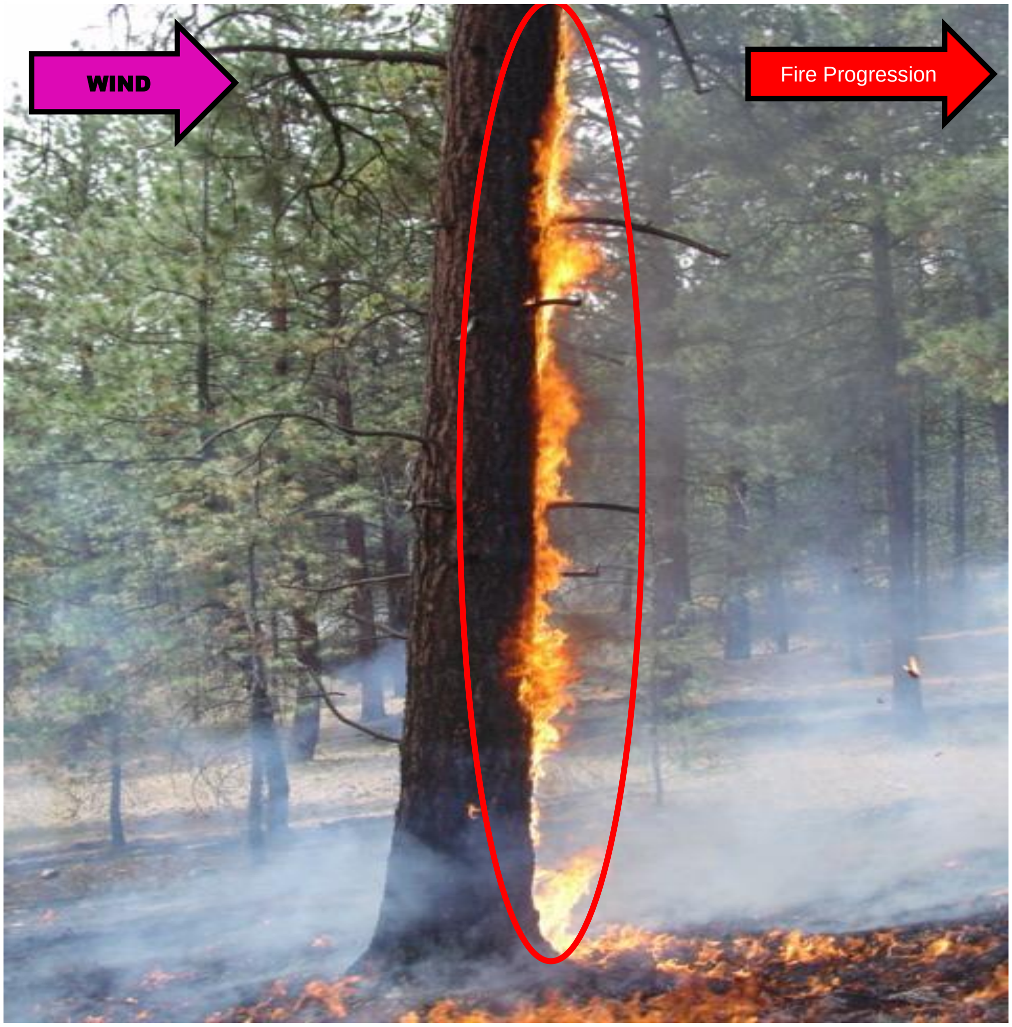
Figure 2.33. Advancing angle of char fire pattern. Angle of char is steeper than the slope and angle indicates the fire direction.

Figure 2.34. Advancing angle of char fire pattern. Angle of char is steeper than the slope and angle indicates the fire direction.

In the advancing fire area, the wind causes the flame to draw up the lee side of pole-like objects. Under high wind conditions, this char pattern can extend further up the pole. This is referred to as wind vortex flame wrap. The base of the char fire pattern will typically remain at an angle greater than the slope.

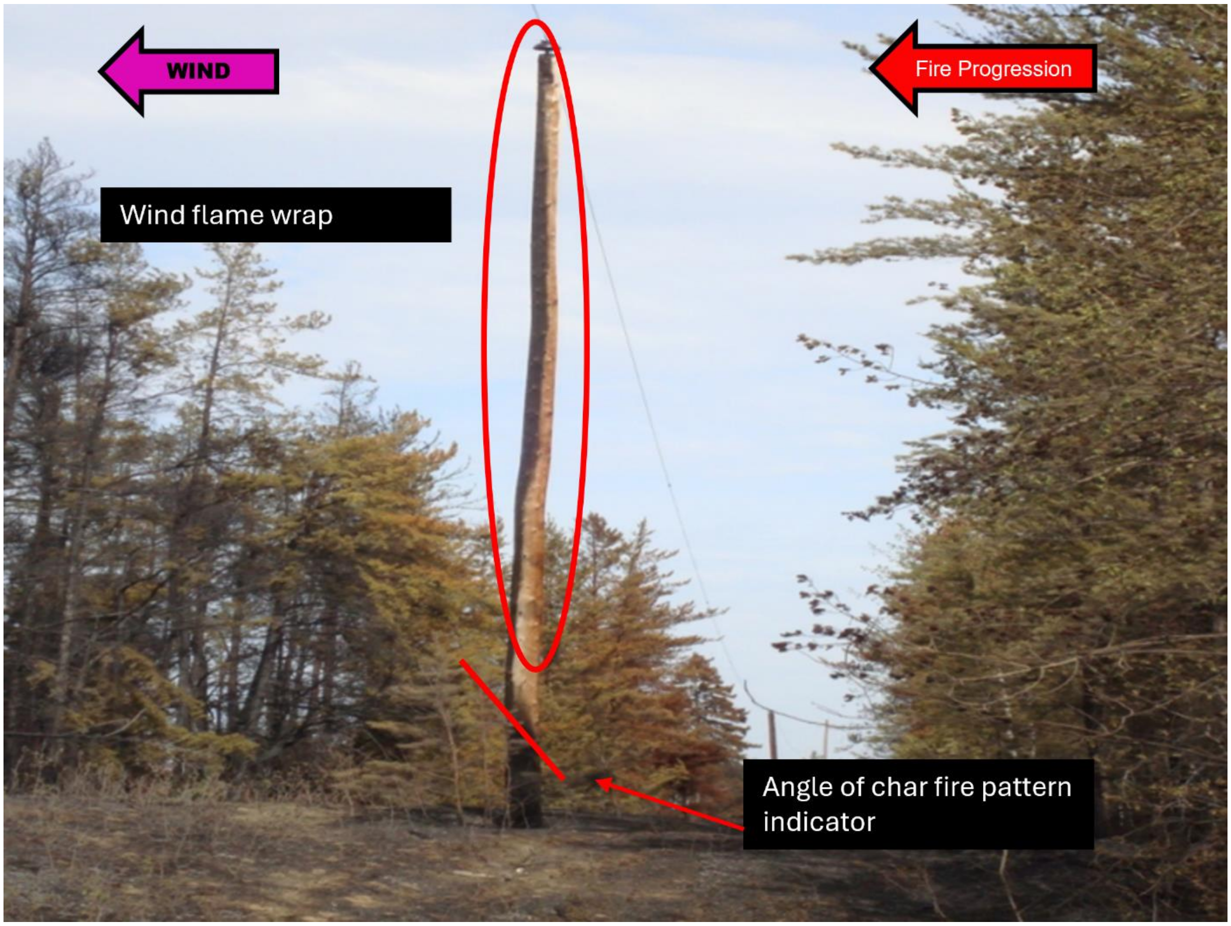
Figure 2.35. Photo shows wind vortex flame wrap on the downwind side of the trees.

Figure 2.36. Photo shows wind vortex flame wrap on the leeside of a tree.



In figure 2.37, the lower text box and arrow show the angle of char fire pattern indicator that should be considered. The upper oval demonstrates the effects of wind vortex flame wrap and is an indicator of wind direction with the char caused by the vortex on the leeside of the object. It is the lower fire effect—angle of char—that is used. The upper wind vortex flame wrap pattern can be used to assist in establishing the wind direction at the scene. Generally, the stronger the wind, the higher on the object the wind vortex flame wrap will be.

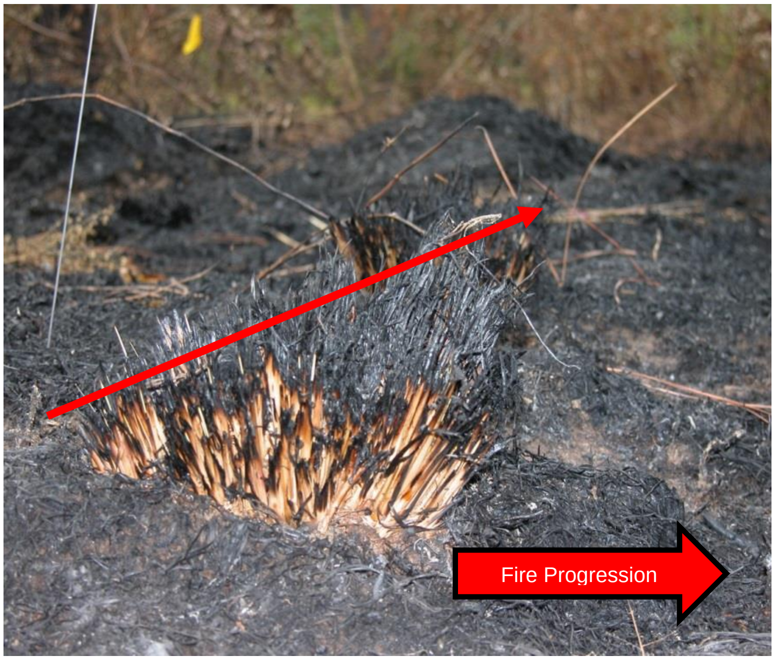
Figure 2.37. Photo shows wind vortex flame wrap and angle of char on a pole.



Angle of Char – Microscale, Advancing Fire

Microscale angle of char fire pattern indicators have many of the same fire effects as macroscale angle of char fire pattern indicators. Microscale indicators are generally found on smaller objects, such as small shrubs, seedlings, and grass clumps. In the advancing area, the angle will remain steeper than the slope and the low end will be toward the exposed side. Figure 2.38 shows an example. The advancing fire is moving from left to right, with an angle of char greater than the slope.

Figure 2.38. Example of grass clump microscale fire pattern.



Angle of Char – Macroscale, Backing Fire

With fires backing against the wind or downslope, the char angle will be parallel to the slope angle (fig. 2.39) and low to the ground unless affected by increased fuel loading.

Accumulation of debris on the uphill side may cause char up the side of the tree above the debris, but it will have little effect on the char pattern around the rest of the tree.

Figure 2.39. An example of macroscale fire pattern angle of char for a backing fire.

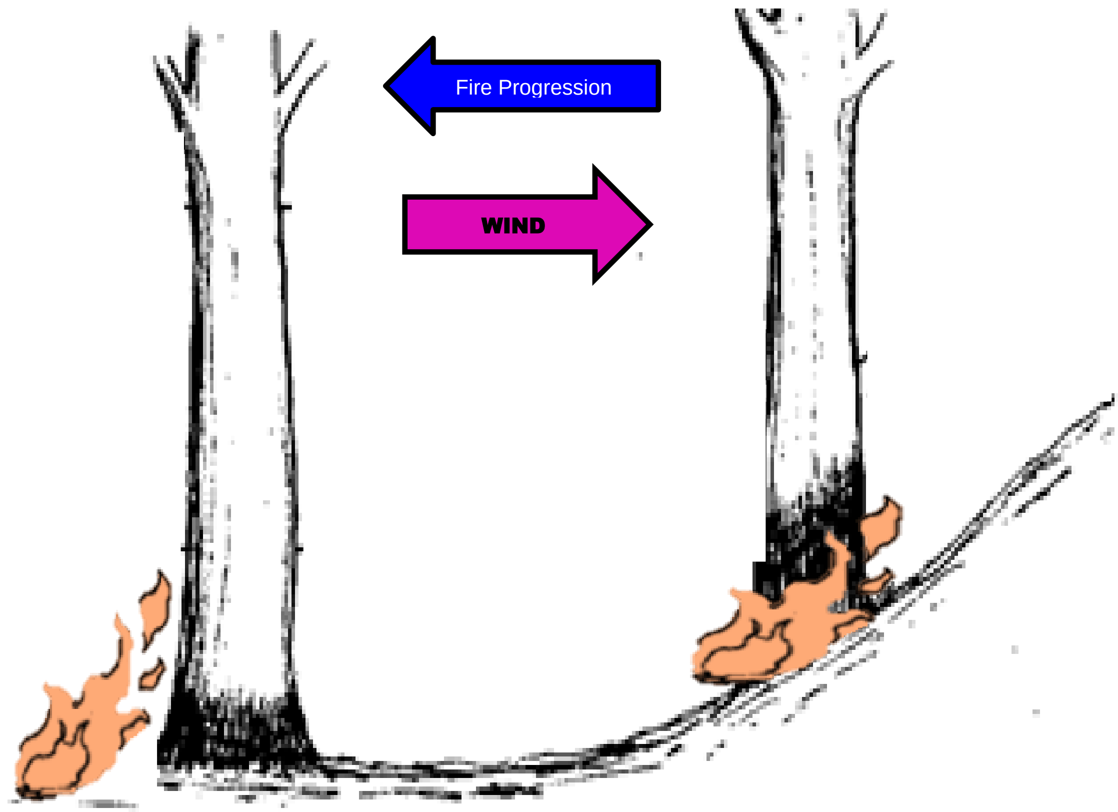


Figure 2.40. Example of macroscale fire pattern angle of char for a backing fire.

In figure 2.41, the angle of char fire pattern indicator is level with the ground, consistent with a backing angle of char fire direction. The height of the char pattern above the ground is a clue as to fire intensity.

Figure 2.41. Macroscale char pattern on level surface.

Char may sometimes form an “L” or “barber-chair” burn pattern. The overall pattern remains parallel to the slope. Fuel accumulation, preexisting stem/pole damage, exposure to other nearby fuels, or backing into high wind can create this char pattern.

Figure 2.42 shows two separate char patterns. The char level to the ground indicates backing fire progression; the vertical char is a wind vortex flame wrap wind direction indicator. These two separate char patterns form an L shape when viewed from the side.

Figure 2.42. Example of an L-shaped char pattern on a tree trunk.

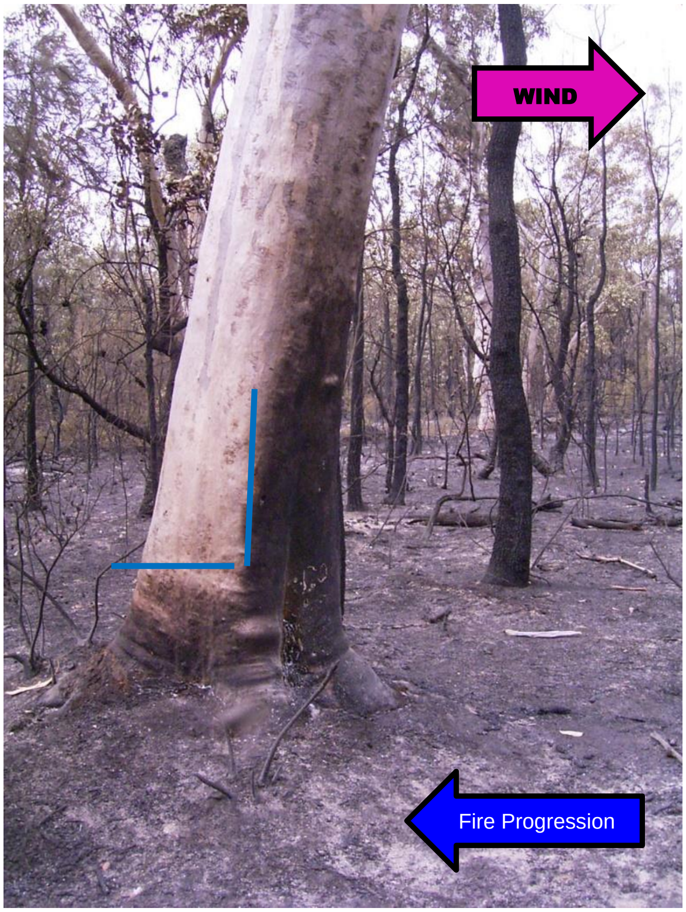
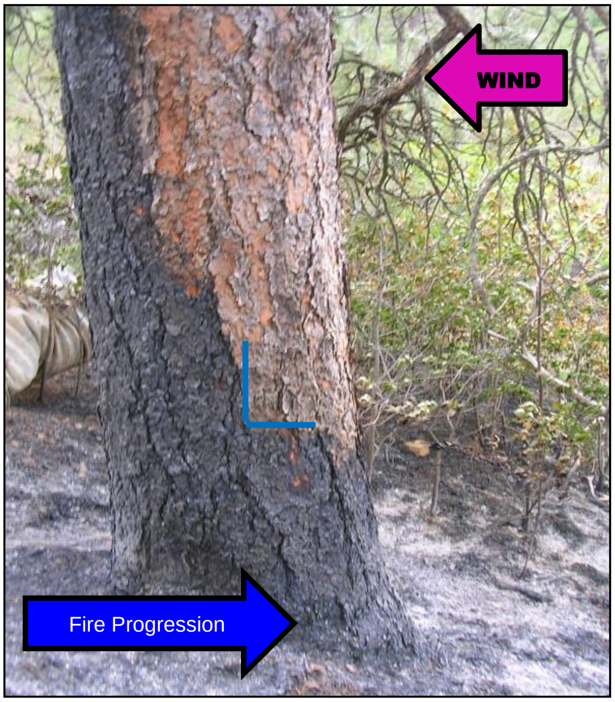


Figure 2.43 shows the char higher up the left side of the tree and steeper than the slope, which is consistent with a wind from right to left. The angle of char on the tree trunk is lower and level with the ground on the right side of the tree, consistent with a backing fire from left to right. The two char patterns form an L shape when viewed from the side. The vertical char on the left side of the tree is an artifact of wind vortex flame wrap and indicates the wind direction from right to left. The investigator is interested in the lower char line when interpreting this pattern as backing.

Figure 2.43. Example of L-shaped char pattern on a tree trunk.



Angle of Char – Microscale, Backing Fire

As with advancing microscale angle of char indicators, backing microscale fire patterns will be on smaller bushes and saplings. The angle of char fire pattern in backing direction areas will be parallel to slope, whether backing downslope or against the wind on flat ground.

Figure 2.44. The microscale backing fire pattern on a small shrub the fire is backing from left to right.

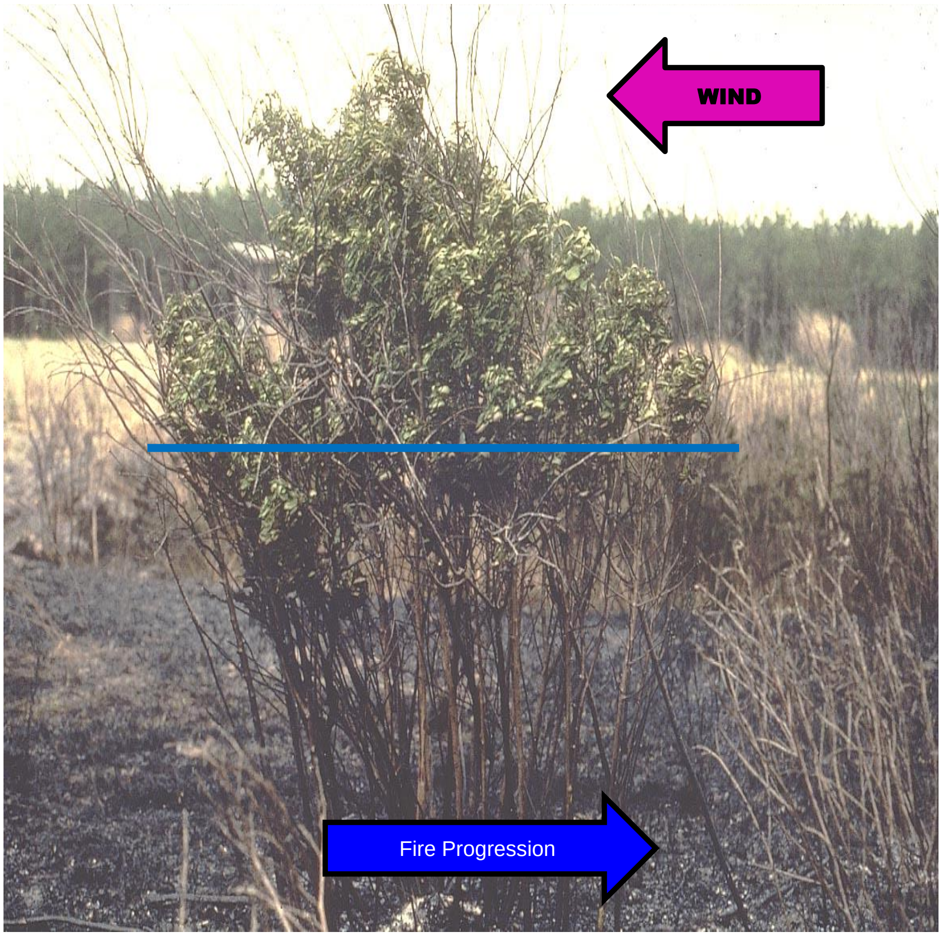
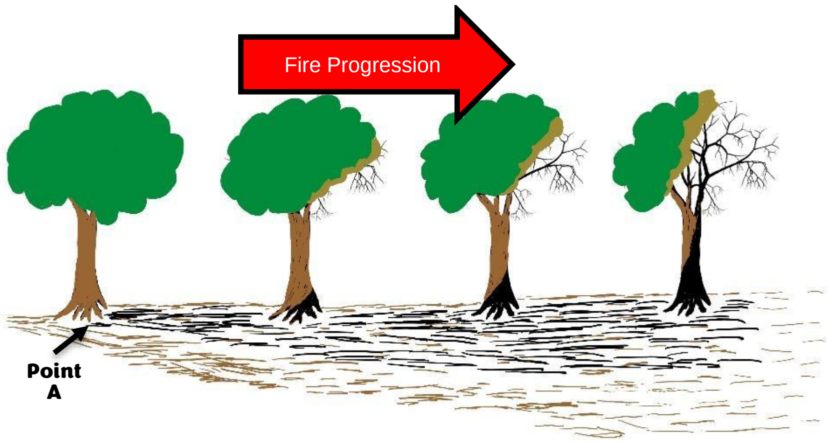


Figure 2.45 shows the typical effect on the crown of trees or brush as a fire starts at point A and moves out, slowly building up heat and intensity. In the ignition area, the fire is less intense, so the tree's crown is left mostly intact.

Farther from the ignition area, the fire has spread out and gained intensity, which results in a higher heat release and more of the crown is consumed.

Figure 2.45. An illustration of the angle of char effect on tree crowns as the fire moves away from the ignition area, left to right.



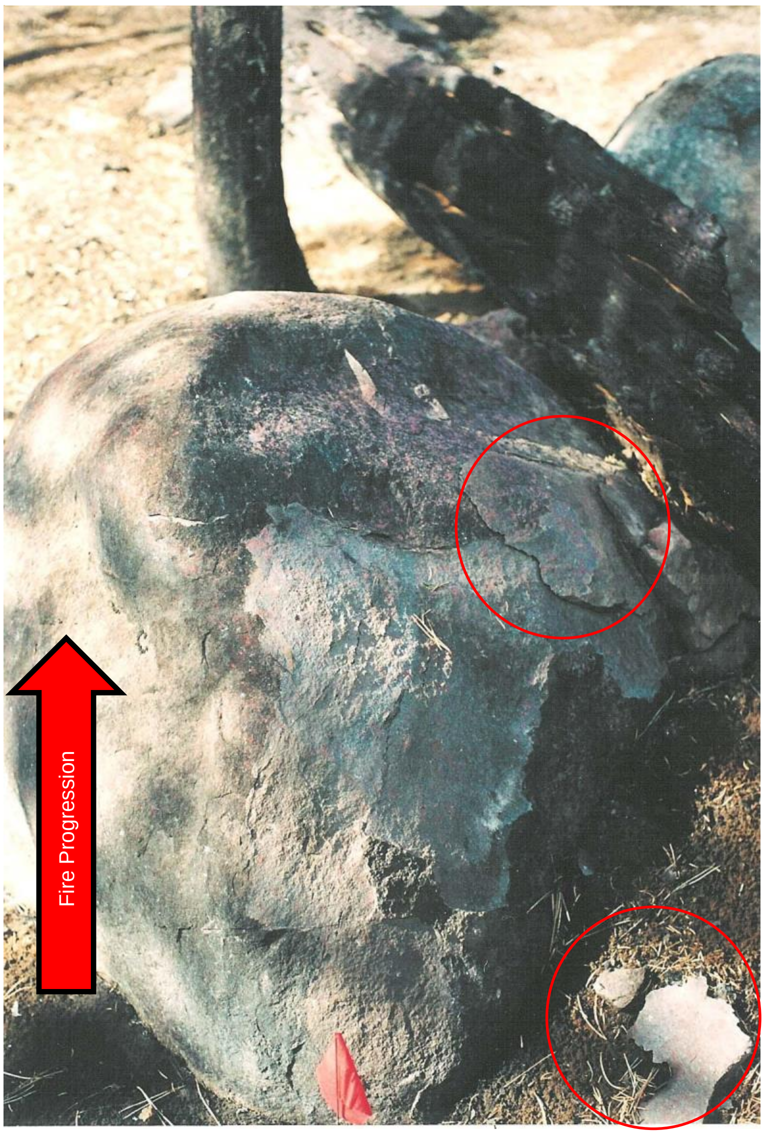
Spalling Fire Pattern Indicators

Spalling is caused by a breakdown in the tensile strength of the rock's surface that has been exposed to heat. The area surrounding craters will usually be sooted or stained (or both).

Spalling fire patterns will appear as shallow, often light-colored craters or chips in the surface of rocks (fig. 2.46). They will usually be accompanied by slabs or flakes exfoliated from the surface of the rock.

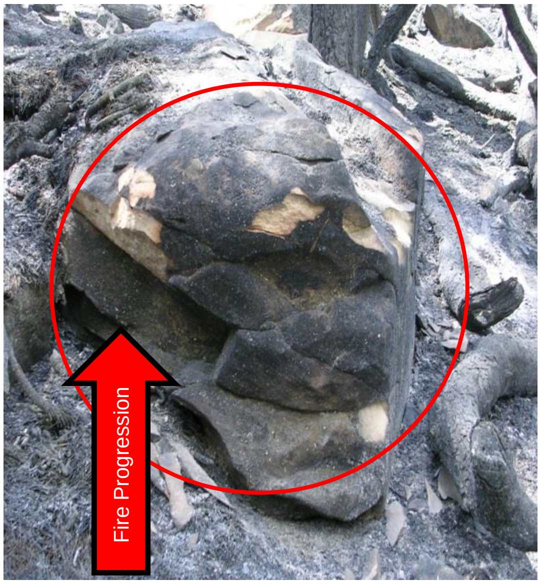
In figure 2.46, notice the light color of the area where the rock has been chipped. Comparing this to the sooting around the cratered area indicates that the chips fell off after the heat of the advancing fire passed by. Taking note of this contrast can help to exclude mechanically caused chipping, either before or after the fire passage.

Figure 2.46. Example of spalling.



Also known as micro-fracturing, spalling is caused by exposure to heat or flame. Rocks are not efficient conductors of heat energy, and when subjected to the oncoming fire, the outermost layer becomes hotter than the rock underneath it. Differential expansion causes sub-surface shear stress and thin layers of rock to break off, usually after the fire front has passed. Spalling can also occur during rapid cooling of the surface from a water hose stream.

Figure 2.47. Combination of spalling and the surrounding area of sooting.



General reliability:

- Usually reliable for advancing fire areas.
- Not common in backing areas, as heat may not be sufficient to cause the rock to exfoliate.
- Compare and contrast the opposite sides of the rock to determine where the most spalling has occurred, indicating the exposed side of the rock.

Possible variances:

- In areas of high fire intensity or long-term fire residency, spalling may be present on multiple sides.
- Preexisting stress cracks may provide unreliable spalling fire pattern indicators. Compare the rock structure with nearby rocks to determine if stress cracks are common within that area and type of rock.
- Mechanical damage caused by heavy equipment either before or after the fire passes can be mistaken for spalling. Close examination will normally show that the dirt around the rock and the rock itself have been disturbed by the equipment and thus the mechanical damage caused the appearance of spalling.
- Spalling that has sooting within the face of the crater may indicate damage took place before the fire.

Spalling – Macroscale, Advancing Fire

Advancing macroscale spalling indicators will display on numerous large rocks within the advancing fire. Spalling evidence will be concentrated on the exposed side of the rock and absent or less evident on the protected side of the rock.

Spalling – Microscale, Advancing Fire

Microscale spalling fire pattern indicators will be visible on smaller rocks and will be concentrated on the exposed side and absent or less evident on the protected side.

Figure 2.48. Example of spalling on a small rock.

Spalling – Microscale, Backing Fire

Microscale spalling fire pattern indicators are not usually associated with backing areas, and spalling in these areas may result from fuel accumulations. Compare with spalling on the same type of rocks in the advancing area.

Curling Fire Pattern Indicators

Curling is a natural reaction of the leaves to become more aerodynamic in an effort to stay cool (Vogel 2009). In some species, curling can occur when green leaves curl inward toward a heat source. This is not normally a macroscale indicator. The leaves may also exhibit wind-influenced foliage freezing.

Figure 2.49. Example of leaf curling.

The process that creates curling is like that which forms foliage freezing. Heat exposure causes a leaf to dry out and shrink on the surface exposed to heat. Shrinkage causes edges to curl in toward the source of heat.

Curling of broadleaf plants may be observed because of a low-intensity fire moving through an area. It is a reliable indicator of fire intensity but the reliability of curling as a directional indicator is limited, as shown in figure 2.49.

Heat exposure causes a broadleaf to dry out and curl. Leaves may move and freeze with the wind. This usually occurs with slower moving, lighter burns associated with backing and lateral fire movement. Protection fire patterns may also be present on the individual leaves, which can form a cluster of indicators with the curling fire pattern indicators.

General reliability: Most reliable in low-intensity, backing areas of the fire.

Possible variances:

- Long-term drought may cause leaves to be curled already.
- Direct flame impingement may create false indicators.
- Curling could be in combination with foliage freeze.
- Fire may impact leaves from a variety of different directions.
- Thick leaves with a strong central vein may not curl at all or may curl in toward the vein.
- Leaves may curl toward an approaching heat source, but then move and freeze with the wind.

Curling – Microscale, Advancing Fire

Curling is not commonly associated with advancing fire. If curling does form in a low-intensity advancing fire, it will typically be found on the exposed side of the vegetation.

Curling – Microscale, Backing Fire

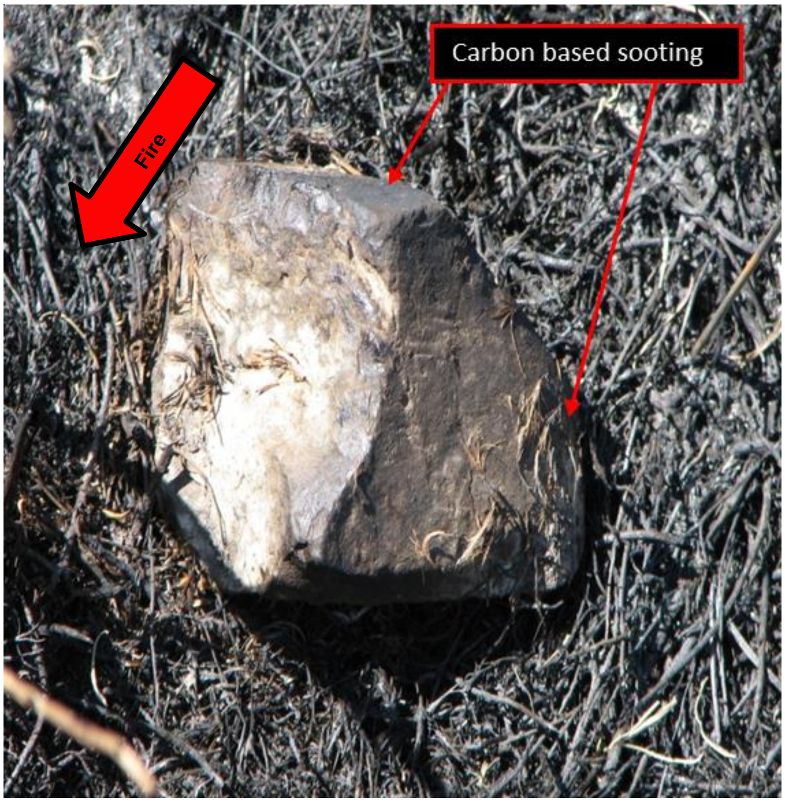
Low-intensity backing fire microscale curling fire patterns may form on small vegetation close to the ground and the leaves may curl toward the exposed side.

Figure 2.50. Example of leaf curl on small vegetation.

Sooting Fire Pattern Indicators

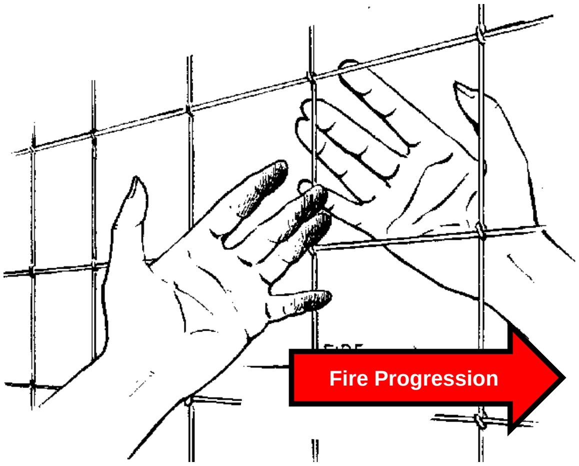
Sooting is a black, carbon-based deposit caused by incomplete combustion. Carbon is typically more heavily deposited on the side facing the approaching fire.

Figure 2.51. Example of sooting on a rock.



Soot will be deposited on the side of fence wires facing the direction the fire came from and can be detected by rubbing fingers along the wire. On larger objects, soot deposits can also be noticed by rubbing a hand across the surface. In many cases there will be other indicators, such as protected fuel or staining. When checking a wire fence for soot, compare and contrast multiple levels of the fence.

Figure 2.52. Example of sooting on fence wires.



Run a finger and thumb along a wire on the fence. The finger or thumb with the heavier sooting on it will likely be the direction the fire traveled from.

The process that creates sooting fire pattern indicators includes airborne particulates resulting from incomplete combustion. These particles adhere to rocks, cans, fence wire, metal posts, and some vegetation.

General reliability: Reliable

Possible variance: Nearby accumulations of debris that generate large volumes of smoke

Sooting – Macroscale, Advancing Fire

Advancing fire macroscale sooting fire pattern indicators may be present on large individual rocks and rock outcroppings or similar objects. Look for consistency within the run.

Figure 2.53. Example of sooting on multiple rocks.

Sooting – Microscale, Advancing Fire

Advancing fire microscale sooting fire pattern indicators are more subtle, as the smaller objects may have soot on all sides. The degree of sooting may be the only difference between the protected and unprotected sides.

Figure 2.54. Example of sooting on a rock.

Figure 2.55. Photo shows a burned can of WD-40 with soot on the left side, with more soot on the side facing the direction the fire came from.

Sooting – Microscale, Backing Fire

Backing fire microscale sooting fire pattern indicators are generally not as predominant. The predominant sooting will be on the side of the object exposed to the wind.

Staining Fire Pattern Indicators

Staining is caused by the products of incomplete combustion condensing on cooler surfaces of objects. Staining may appear glossy and light yellow, orange, to dark brown in color and occurs most commonly with noncombustible objects such as metal cans or rocks. Stains will appear more on the side of the object exposed to the oncoming flames in an advancing area. These stains may feel tacky and may be covered with a thin layer or specks of white ash and other lightweight fire debris.

Figure 2.56. Staining on a metal can.

Staining is commonly a subtle microscale indicator that is more pronounced in advancing fire areas. Smaller objects may have staining on all sides but may display more of a glossy look on the exposed side than on the unexposed side. The color of the staining is generally darker on the exposed side of small objects than on the unexposed side.

Figure 2.57. Photo showing staining on a rock. Note the thicker layer on the near end of rock due to its exposure to the oncoming fire, and a thinner layer of stain on the protected end.

General reliability: Reliable.

Possible variances:

- Repositioning of lightweight objects by wind or suppression activities.
- Accumulation of debris.

Staining – Microscale, Advancing Fire

Advancing area microscale staining may be darker and cover a larger area of an object when compared to backing area staining.

Figure 2.58. Example of advancing fire with staining and white ash deposit on a can.

Staining – Microscale, Backing Fire

Staining on small objects is less noticeable in the backing areas and may be very subtle. Examine small pebbles, rocks, and similar items.

Figure 2.59. Photo shows staining on small objects in a backing fire. Staining is on the right side of the rock but not the left, indicating fire moving from right to left. After photographing in place to show the rock in its original state, the rock was lifted to reveal protected fuels on the lee (left) side of the rock.

Differences between staining and sooting:

Staining	**Sooting**
Glossy pale yellow to dark brown in color.	Dull black in color.
Cannot be rubbed off and may be tacky to the touch.	Can be rubbed off with fingers.
White ash may adhere to it.	White ash will generally not adhere to it.

White Ash Fire Pattern Indicators

There are two subsets of the white ash fire pattern indicator: white ash exposure and white ash deposits.

White ash exposure takes place when the side of a combustible object facing the oncoming fire is exposed to higher intensity fire than the protected side, leading to more complete combustion on the exposed side and more white ash remains attached to the object. White ash exposure is directly related to fire intensity and fuel loading.

White ash deposits occur when white ash is blown downwind from its source until it contacts another object. This other object may be either combustible or noncombustible. Rocks are the most common objects to display white ash deposits.

White ash can be dispersed downwind and deposited on the windward sides of objects. These deposits can be a reliable indicator of wind direction and fire direction in advancing fire areas, when observed at or near the time the fire was burning in that area. White ash deposits become less reliable as time passes as wind changes over hours and days and deposits ash on multiple sides of the objects.

Figure 2.60 shows white ash on the tree bole (left photo) on the side facing the oncoming advancing fire and the back, or protected side, of the same tree (right photo). Comparing the two sides shows that the side facing the oncoming fire has more white ash present. The arrows correspond with the direction of the advancing fire progression.

Figure 2.60. Example of white ash on tree trunk facing the fire and the backside (shielded side) of the same tree.

In grass fuels, white ash may be more noticeable when looking in the direction the fire traveled. The exposed side of the grass stems will be subjected to higher fire intensity, resulting in more complete combustion and white ash production. Looking back toward the direction the fire came from (protected side), the grass stem may appear darker or may have more of its unburned grass color due to protection on the unexposed side.

Figure 2.61. The photos show a comparison of white ash in burned grass looking toward where the fire went, and where the fire came from.

General reliability: Reliable—wind and rain affect this.

Possible variances:

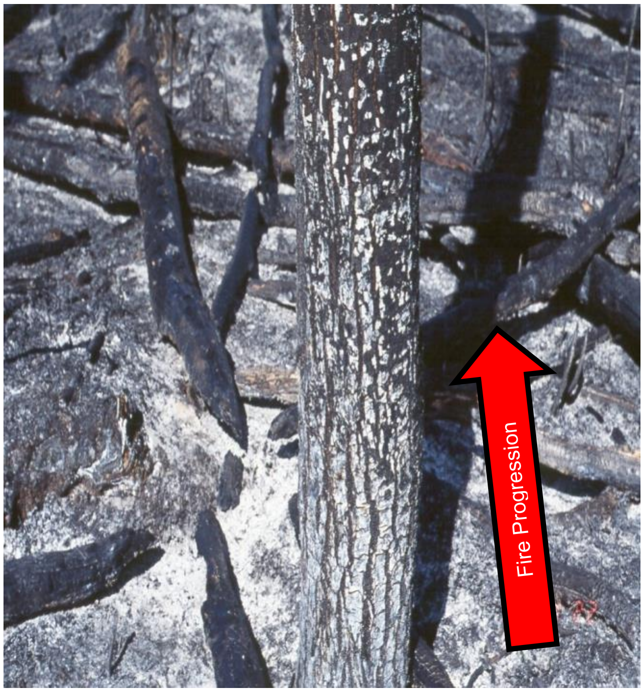
- Thin-barked trees may show more white ash on the protected side, particularly during strong winds.
- Long-term fire residency.

White Ash Exposure – Macroscale, Advancing Fire

Compare and contrast damage on opposing sides. Look for consistency on similar objects and with the fire intensity of the area.

In figure 2.62, the white ash on the exposed side of the tree and the intensity of the burn around the tree are consistent with an advancing fire vector.

Figure 2.62. Example of advancing fire vector with white ash exposure.



White Ash Exposure – Microscale, Advancing Fire

Advancing microscale white ash fire pattern indicators may appear on relatively small objects. These fire effects may be closer to ground level than macroscale fire patterns. Microscale white ash fire pattern indicators created by exposure to heat and flame are typically found on small trees, twigs, and branches on low-lying brush and trees.

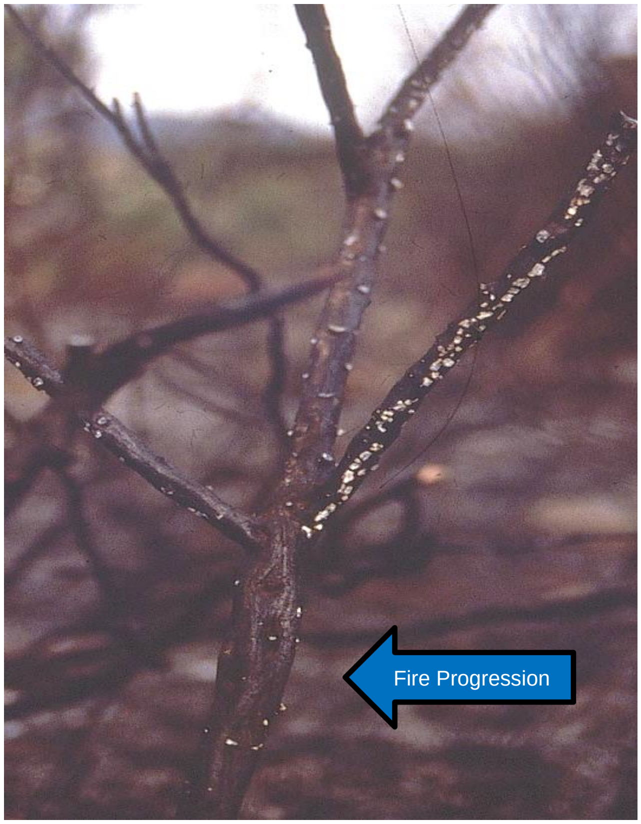
Figure 2.63. Photo shows a small tree trunk with char and white ash on one side. The other side, the protected side of the tree trunk, is not charred and has no white ash.

White Ash Exposure – Backing Fire

In backing areas, there will generally be less white ash overall, compared to advancing areas. These backing areas may have a darker appearance of burned materials or an appearance of its unburned fuel color when compared to advancing areas due to unburned fuels. White ash (exposure) will be found on very fine fuels, and at levels that are generally closer to the ground on the exposed side in the backing area.

Figure 2.65. Backing area with very little white ash in the burned vegetation.

Figure 2.64. White ash (exposure) on a twig from a backing fire.



White Ash Deposits

White ash, dispersed downwind in fine particles, can be deposited on fuels and noncombustible objects.

Figure 2.66. Example of white ash deposits on a stem.

General reliability: Reliable in advancing and lateral fire areas.

Possible variances:

- Reliability or presence decreases with time.
- White ash is deposited on the upwind side and may be unreliable in the backing area.

White Ash Deposit – Advancing Fire

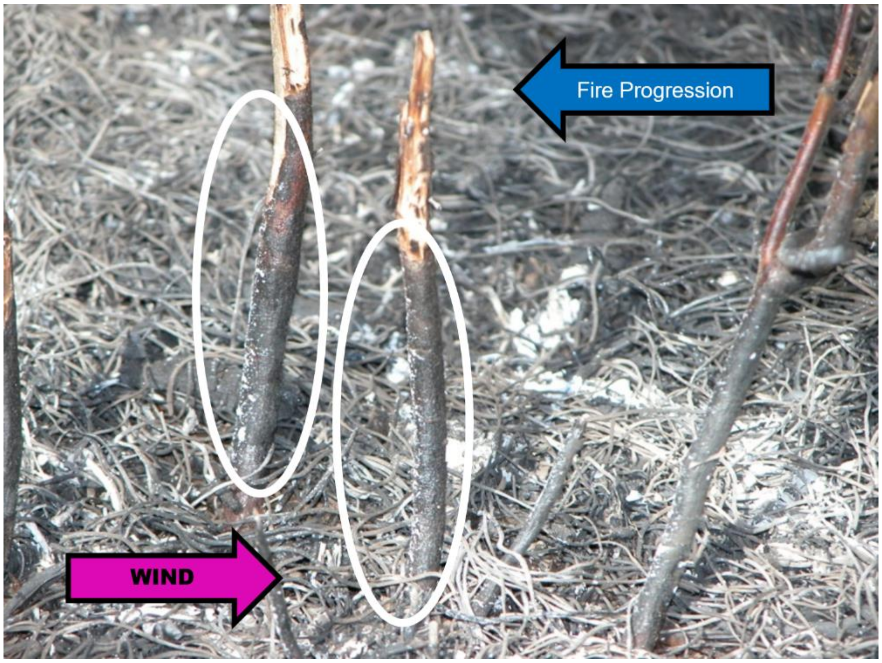
In the advancing area, wind may place white ash deposits on objects over wide areas. Look for consistency within an area and identify clusters of white ash deposit fire pattern indicators.

Concentrated areas of white ash on the ground are a result of more complete combustion of fuels. Large woody debris or debris piles where little or no remains of the nearby fuels are present, the depth and amount of white ash deposits will provide information concerning fuel loading in that area and fire intensity, helping to establish the direction.

White Ash Deposit – Microscale, Backing Fire

White ash deposits can be created in backing areas but transported downwind and deposited on the side opposite the direction of travel. It is important to determine if white ash is due to more complete combustion at its location or if it has been blown by the wind and deposited. As in figure 2.67, windblown white ash deposits in a backing area will be on the upwind side of the object.

Figure 2.67. Example of white ash deposit on vegetation in a backing fire.



Cupping Fire Pattern Indicators

Cupping is a concave or cup-shaped char pattern on grass stem ends, small stumps, and the terminal ends of brush and tree limbs. Cupping may be found on horizontal or vertical fuel. Vertical cupping tends to represent a chair-like shape. Horizontal cupping represents pointed and blunted ends of opposing sides of vegetation.

In horizontal cupping, limbs and twigs on the exposed side will have their tips burned off by the approaching flames, leaving a rounded or blunted end. On the protected side, twigs and limbs will be subjected to flames from underneath, along the base to the terminal end, creating a tapered point.

Vertical cupping is a concave char pattern that results in a cup or chair shape, with its lower portion facing the direction the fire came from.

Figure 2.68. Example of cupping on limbs of a bush and on a stump.

General reliability: Most reliable in advancing areas of the fire. Cupping is usually not associated with backing areas.

Possible variances:

- On large-diameter fuels, the cup direction may be inconsistent with spread direction because of long-term fire residency and possible change of wind direction.
- Small-diameter fuels may not be reliable when wind is gusty and erratic.

Cupping – Microscale, Advancing Fire

Microscale cupping is generally very similar to macroscale cupping. The difference will be found on the fuel for each.

- Low end of the cup: exposed side
- Pointed on the protected side
- Blunted, rounded, exposed side on terminal twig ends

Figure 2.69. Example of pointed (left side) and blunted (right side) twig ends.

Cupping – Microscale, Backing Fire

Cupping is not normally associated with backing fire areas.

V and U Fire Pattern Indicators

This is the overall V or U shape associated with typical wildfire progression. The left and right flanks of the fire form the shape of the V or U with advancing fire in between. The flanks typically get further apart as the advancing fire continues unless barriers, fuel changes, or suppression action affects the fire's ability to spread.

The ignition area is generally located in an area of less-intense burning near the apex of the V. View and document this pattern from an aerial perspective, where possible.

Figure 2.70. Example of a V-shaped burn pattern.

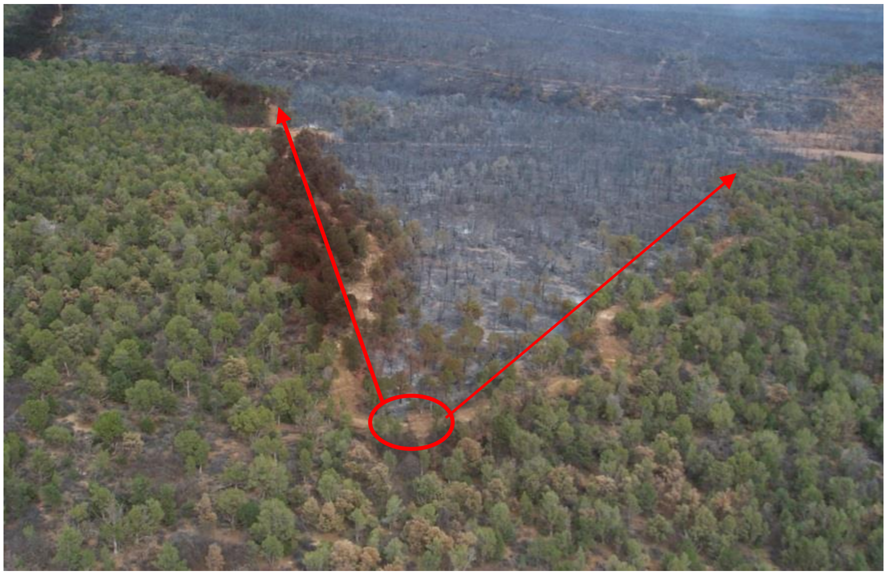
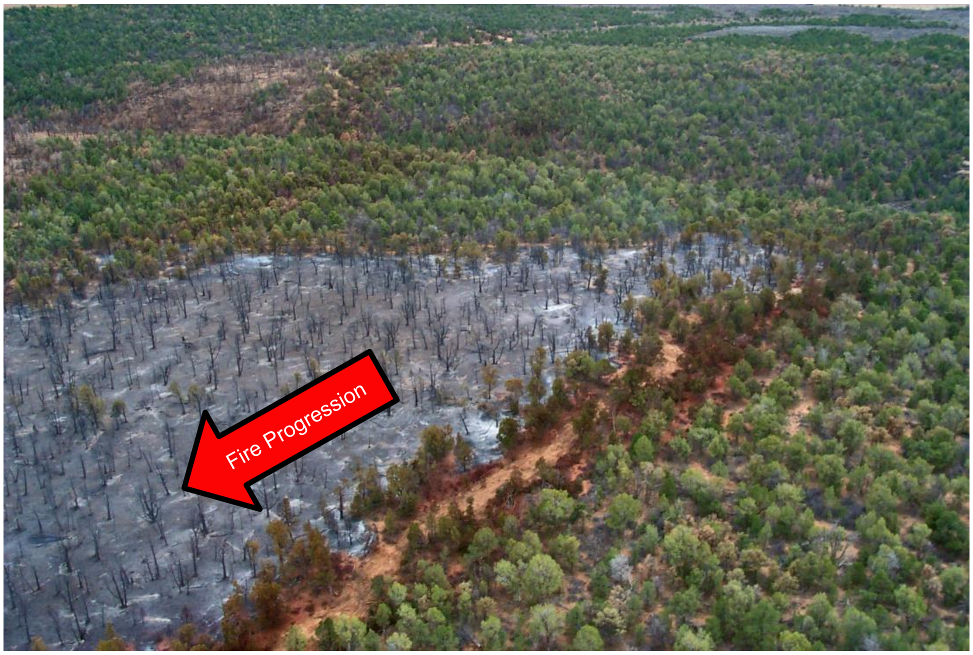


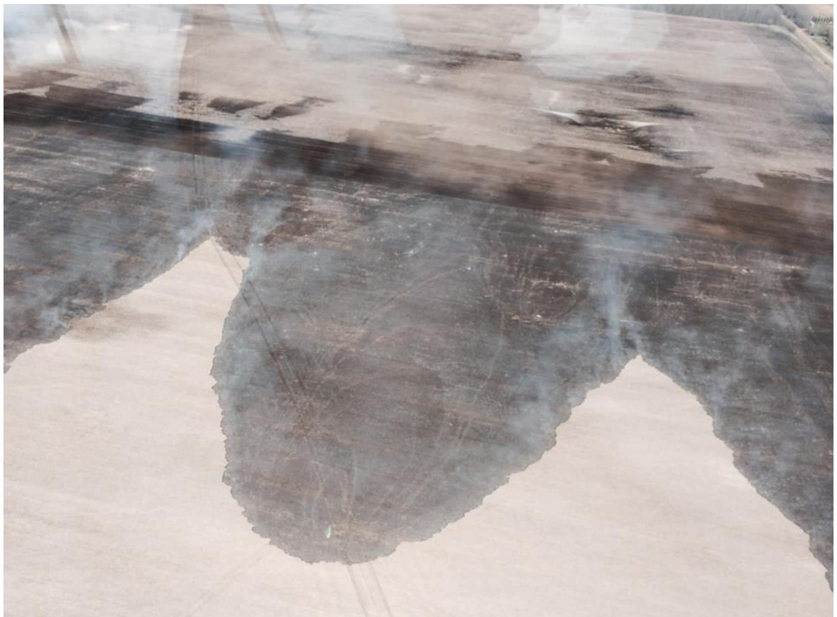
Figure 2.71. Example of a V-shaped burn pattern.



Investigators should recognize that the two patterns, V and U, are formed by different conditions that may provide further clues to the location of the ignition area. U-shaped patterns tend to form on flat ground under light wind conditions or on moderate slopes. The ignition area is often located near the base of the U. A U-shaped pattern can indicate a combined slope and wind influence on the fire.

V fire patterns are primarily influenced by strong winds or steep slopes (or both). The ignition area is often located near the apex of the V pattern, including microscale V fire patterns.

Figure 2.72. Example of a U-shaped burn pattern.



When determining the boundaries of the V or U pattern, consider the conditions of the fuels. View these indicators from a combination of aerial and ground perspectives.

Pattern boundaries may not be confined to fully consumed canopy. Look below the canopy to identify the actual pattern boundary. On a smaller scale, the pattern may not show up in the canopy but may be visible below.

V and U indicators can be both macroscale and microscale. These patterns can be formed over shorter and longer periods of time, and multiple V or U patterns may be formed due to wind speed and direction changes.

Changes in slope may also affect the formation of V and U patterns.

Figure 2.74. Example of an irregular V-shaped fire pattern.

Figure 2.73. Example of a V fire pattern indicator formed by a strong wind on nearly flat topography. Note the long and narrow nature of the pattern.

Figure 2.75 shows an example of a U fire pattern created when the lower initial run reached a bench on the hillside and thunderstorm winds momentarily changed direction, spreading the fire to the sides before resuming an advancing direction to the ridgeline.

Figure 2.75. Example of a U fire pattern.

Always consider the effects of suppression actions, wind, and slope changes along with artificial and natural barriers such as roads and lakes.

Figure 2.76. Example of wind direction and a road on the fire pattern.

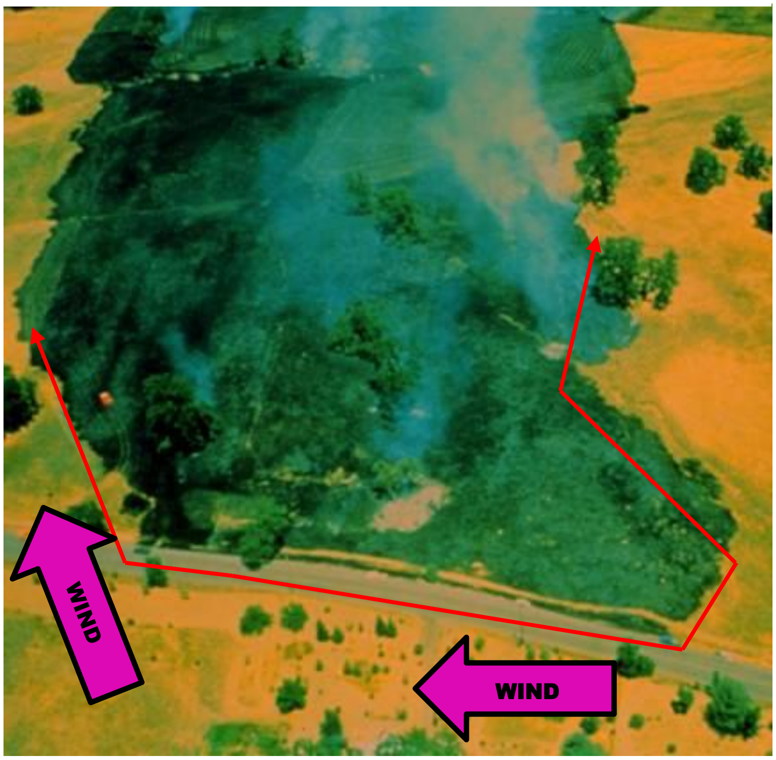
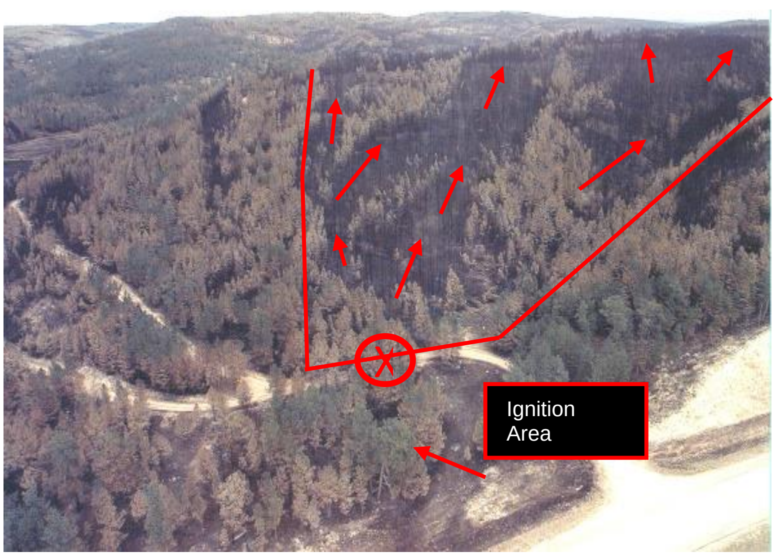


Figure 2.77 is an example of larger scale U pattern made up of multiple V patterns created by changes in the terrain, fuels, and wind conditions.

Figure 2.77. Example of multiple V patterns.



General reliability: Can be very reliable.

Possible variances:

- Fire suppression tactics
- Rolling material
- Wind shifts
- Fuel type changes
- Spot fires
- Artificial or natural barriers

V or U patterns will often die out due to:

- Slope reversals
- Changes in aspects
- Fuel bed changes

Fires may develop multiple V or U patterns within the overall fire area. As the slope, wind, or vegetation changes, a fire may develop V or U fire patterns that may present as separate advancing fires.

V and U Patterns – Macroscale, Advancing Fire

Advancing V fire patterns are most likely to take place and indicate a wind- or slope-influenced advancing fire direction.

Advancing U fire patterns are more likely to be created on flat or gentle slopes or on steeper slopes where the wind direction is not in alignment with the slope. Each shape can be a clue as to the forces that influenced the initial macroscale spread of the fire.

V and U Patterns – Microscale, Advancing Fire

The microscale patterns tend to be in areas of lower intensity, which often still retain a canopy. These microscale V and U areas are defined by locating the lateral transition zones near the ignition area using individual fire pattern indicators.

A fire burning away from the ignition area may establish a microscale V or U fire pattern, which will transition to a macroscale V or U fire pattern as the intensity of the fire increases. This increase in intensity and transition from microscale to a macroscale fire pattern may be due to a change in fuels, weather (wind), or topography (slope).

Chapter 3. Methodology

Methodology: A body of methods, rules, and postulates employed by a discipline: a particular procedure or set of procedures.

Systematic: Relating to or consisting of a system; presented or formulated as a coherent body of ideas or principles; methodical in procedure or plan; marked by thoroughness and regularity. (https://www.merriam-webster.com/dictionary/)

In the context of this guide, the methodology consists of practices and methods common and accepted in the discipline of wildfire investigation.

Using the accepted methodology presented here gives the investigator the best tools for accurately determining the origin and cause of fires, as well as having their opinions accepted as valid by others.

A systematic approach includes the orderly and thorough application of practices, procedures, and techniques specific to the investigation of a wildfire.

The framework for problem solving used to complete a thorough wildfire investigation is the scientific method.

The scientific method does not provide or specify the techniques that should be applied in solving each problem. It is up to the investigator(s) to select the best techniques to apply to the specific scene or circumstance. This guide includes recommended techniques that have been vetted by subject matter experts, peer reviewed, and accepted by the discipline as suitable for application to most wildfire investigations.

Consistent application of recognized methods during wildfire investigations leads to the development of good investigative habits, methods, and skills, which adds to the credibility of the wildfire investigation.

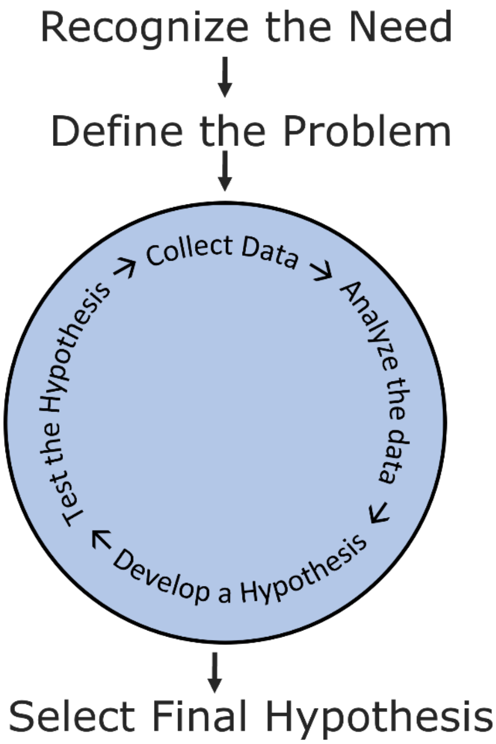
Methods not included in this document are not excluded from use but should be explained in the documentation along with the reasons for their application.

The scientific method was not designed specifically for the investigation of wildfires, or the investigation of any crime or violation, but it provides a framework for problem solving to which appropriate techniques can be applied. The scientific method does not exclude the use of methods regularly used and accepted in law enforcement investigations.

The scientific method is also recommended for use in fire investigations by the *Guide for Fire and Explosion Investigations* (NFPA 2024).

The scientific method is a form of inquiry that is applied using the processes shown in figure 3.1.

Figure 3.1. Diagram of the scientific method.



The need to do something is recognized, the problem is defined, and the investigation begins. Data is collected and analyzed as the investigation continues. Hypotheses are developed and tested. The goal is to arrive at one hypothesis that is supported by the data.

While some outlines of the scientific method may show a step-by-step process, it should not be thought of as a linear process with no opportunity to go back to earlier steps. "The process of science is iterative. Science circles back on itself so that useful ideas are built upon and used to learn even more about the natural world. This often means that successive investigations of a topic lead back to the same question, but at deeper and deeper levels" (UCMP 2024).

The scientific method, as related to fire investigations, starts with fact and data collection, which is then considered and analyzed to form hypotheses. These hypotheses are tested against the data and may require going back to the data collection step to help prove or disprove. In this way it is an interactive process where several parts of the process may be taking place at the same time or are repeated during different phases of the investigation.

Applying Scientific Method in Wildfire Investigation

Recognize the need(s). In this case, a wildfire has occurred, and the origin and cause should be investigated and documented to identify potential responsible parties and focus future prevention efforts.

Define the problem. Having determined a wildfire has occurred, the investigator should define the problem and how the problem can be solved. To determine the cause, an origin investigation must first be conducted.

Defining the problem leads to the formation of an investigative plan, which assists in solving the problem. An investigative plan will identify questions that need answering, specific sources of data, and how data is to be collected.

The plan may be written or verbal. Extended investigations call for written plans. The key is to brief the investigative team members and provide them with the knowledge they need to be able to identify the issues and how the data and information gathered relate to the overall investigation. This may generate follow-up leads and inquiries.

It is important that each member of the investigative team understand the plan and their role in carrying it out.

Collect empirical data. In the investigative world, data is simply factual information, while empirical data, according to the definition, originates in or is based on observation.

Data collection starts with an assignment to conduct an investigation. It then can continue at nearly every stage of the investigation. Analysis often takes place at nearly the same time and at all stages of the investigation.

Facts about the fire are collected. This should not include rumor, conjecture, or speculation. This should include examining and processing of the scene, considering the fire behavior context, interviewing witnesses or other knowledgeable persons, and collecting physical evidence.

Sources of empirical data include but are not limited to:

- Observations
- Witness statements
- Physical evidence
- Experiments
- Digital evidence (e.g., photographs, video, electronic recordings, etc.)
- Other data collection processes

Analyze the data. The scientific method requires that all pertinent data collected be considered and analyzed. Before using data to test a hypothesis, it is crucial to assess its reliability to ensure it is accurate and trustworthy.

A second analysis is then conducted to determine the meaning of the empirical data and its relationship to the defined problem. All the empirical data collected and any analysis should be carefully examined in the light of the investigator’s knowledge, education, training, and experience. In some cases, it may be necessary to bring in other experts if the investigator does not have the experience or expertise to determine the meaning of the data.

Subjective or speculative information should not be included in the analysis—only facts that can be proven clearly by observation or experiment. Additional data collection may continue during this process.

The intent of the ongoing data analysis is to develop working hypotheses.

Develop working hypotheses. A hypothesis is an interpretation of a practical situation or condition taken as the ground for action or a tentative assumption made to draw out and test its logical or empirical consequences.

> *Based on the initial observations, the investigator produces hypotheses to explain the phenomena, whether it be the nature of fire patterns, fire spread, identification of the ignition area, the ignition sequence, the fire cause, the causes of damage, or the responsibility for the fire… This process is referred to as inductive reasoning. These hypotheses should be based solely on the empirical data that the investigator has collected through observation and then developed into explanations for the event based on the investigator's knowledge, training, experience, expertise, and research (NFPA 2022, 4.3.5).*

The term working hypothesis simply denotes that enough data has been collected to consider a hypothesis but not enough to reasonably exclude the potential of other hypotheses or to select a final hypothesis. While the objective is to reach a single final hypothesis, numerous working hypotheses should be considered if the data supports such formation and consideration.

Data collected is used to develop working hypotheses using inductive reasoning. Inductive reasoning involves drawing a general conclusion from a set of specific observations. Data is later used to test each working hypothesis in order to reject them using deductive reasoning.

No hypothesis should be developed until data has been collected and analyzed. It is not necessary to have all possible data before developing a working hypothesis, but the data used should be reliable and adequate to form a working hypothesis that can be tested against all the available data. A hypothesis formed using initial data may be rejected or modified based on new data.

Based on this data analysis, one or more working hypotheses may explain all the known data regarding the ignition area and cause of the fire. When more than one working hypothesis can fit all the data, it is an indication that further data should be sought in an effort to come to a final single hypothesis. Any hypothesis that cannot be tested either physically, cognitively, or analytically is an invalid hypothesis.

Identify potential ignition sources. Addressing potential ignition sources found in a specific origin area and developing working hypotheses should be based on the data collected during the investigation, not the lack of data of a cause. Investigators need to address what is reasonable based on the empirical data obtained.

Since the basis for a working hypothesis is empirical data, there is no process for forming working hypotheses absent data that supports a given cause. For this reason, standard cause categories can be excluded where there is no data that indicates the category should be considered. For example, if there is no railroad located near the general origin area, there is no need to form a hypothesis that a railroad-related activity may have caused a fire. It is sufficient to document the absence of railroads in the area, without forming a hypothesis.

The basis for forming a working hypothesis and a determination of cause is the establishment first of a specific origin area, ignition area, and in most cases, physical evidence of an ignition source. There are some exceptions where a credible case can be made about the cause of a fire without finding physical evidence of an ignition source in an ignition area. This is an exception and typically includes admissions, eyewitness statements, or other conclusive reliable data.

Test the hypotheses (deductive reasoning). For a hypothesis to be valid, it must be able to be tested and withstand such tests without being rejected as false. A hypothesis developed without supporting data is not a valid hypothesis. Testing compares all the data and applicable scientific research to see if any of the hypotheses can be rejected.

Valid hypotheses are those which can withstand serious tests when compared to all the known data and scientific knowledge associated with the specific phenomena (deductive reasoning).

Deductive reasoning is defined as reasoning from a hypothesis to account for specific empirical data, research, or experimental results.

Testing may be either cognitive or experimental. Many fire causes will be tested cognitively—for example, based on an investigator's knowledge, training, experience, expertise, and research. Other fire causes may lend themselves to experimental testing.

A key analysis in this process is considering what other hypothesis could be supported by the same set of facts. If alternative hypotheses are supported by the same facts, then the investigator may not have gathered sufficient data. The scientific method at this point would require that more facts and data be gathered and analyzed.

This process of testing by deductive reasoning should focus on attempting to disprove or reject each hypothesis.

Typical analysis questions that should be considered include:

- Does the hypothesis make sense in the context of all the facts?
- What facts support or contradict the hypothesis?
- Is there research that supports or contradicts the hypothesis?
- Does a technical review or peer review support or reject the hypothesis?
- What alternative interpretation may another expert apply to reject the hypothesis?
- What are the factual weaknesses of the hypothesis?
- Is there an alternative way to interpret the data? If so, why is the chosen interpretation the correct one?

Much of the testing will focus on issues concerning the ignition area and/or ignition source of the wildfire. It is impossible to replicate the exact conditions present at the location of a specific fire at the time of ignition. Published scientific testing and experiments can only address similar but not the precise conditions that were present at the specific fire scene.

The less that is known about the actual conditions at the scene at the time of ignition, the harder it is to understand and re-create those conditions. Therefore, the investigator should strive to collect as much useful data at the scene as practicable in order to reconstruct the scene conditions to the extent possible for testing purposes.

For example, if pine needles, dry grass, duff, punky wood, and bark are present in the ignition area, it should be recognized that each specific fuel can have a different ignition temperature and probability, given a specific ignition source. The propensity for a pine needle to ignite is not the same as that of dry grass or duff or punky wood. Thus, it is important for the investigator to identify, as far as possible, all the components of a fuel bed.

Knowledge and experience pertaining to wildfire fuels and their ignition characteristics is one way to test these fuels in cognitive (thought) experiments. However, a more definitive test may be actual ignition tests on each of these components to evaluate their ease of ignition and help determine which of these fuels was the first one ignited.

Testing by cognitive experiments may be augmented by various degrees of physical testing, at the same time or later. Physical testing can, and often will, be conducted by the investigator and/or other qualified individuals. For physical testing to be valid, it should closely represent the conditions and circumstances present and test all components of the item at issue.

Physical testing of a hypothesis may result in casting doubt on a hypothesis but fall short of rejecting it. In such a case, it is up to the investigator to determine if the doubt is significant enough to change their level of confidence in their opinions. Testing that casts doubt on a hypothesis should also be evaluated for reliability, factual basis, and specific applicability. Further testing and/or data collection may be indicated but may not exclude a preliminary opinion based on sufficient related data.

If any hypothesis cannot withstand this examination, it should be discarded and a new hypothesis developed and tested. This development and testing may involve collecting new data or reanalyzing existing data. All feasible hypotheses should be tested in this manner.

> *The process of elimination is an integral part of the scientific method. All potential ignition sources present or believed to be present in the area of origin should be identified and alternative hypotheses should be considered and challenged against the facts. Eliminating a testable hypothesis by disproving the hypothesis with reliable data is a fundamental part of the scientific method (NFPA 2024, 19.6.5).*

If no hypothesis withstands the testing process, or if more than one remains valid after testing, then the ignition area determination or cause should be classified as undetermined. The development of additional data or analysis may allow determination of a cause of a fire previously classified as undetermined.

Select the final hypothesis: If only one hypothesis withstands testing, typically that hypothesis becomes the final hypothesis.

The final hypothesis is the one and only hypothesis that is not rejected by the data and fits the data to a probable level of certainty. There may remain hypotheses that are reasonably possible and not rejected but which the data does not support to the level of probable. This determination is the sole responsibility of the investigator, who must be able to support such an opinion with the known data.

When two or more hypotheses withstand testing, the investigator should determine if the facts support one hypothesis to be probable, over others that are just possible. When all hypotheses not rejected by the data are reasonably possible and none rises to the level of probable, the origin or cause of the fire should be classified as undetermined. The investigator should report on all hypotheses considered, the evidence considered, the process to rule out invalid ones, and then present those that could not be ruled out.

Level of certainty. The investigator is tasked with producing an opinion based on their confidence in the data, data analysis, and testing of the hypotheses. There are two levels of certainty: probable and possible.

Probable: the level of certainty is considered more likely true than not and the likelihood of this hypothesis being true is considered greater than 50 percent.

Possible: the level of certainty considered to be feasible but not to the level of probable.

If two or more hypotheses are equally likely, then the level of certainty must be “possible” for each of them.

Only when the level of certainty is considered “probable” should an opinion be expressed with reasonable certainty.

The investigator should clearly document the data that is used to form their opinion as to the probable origin and cause of a fire and should be prepared to give testimony pertaining to the data upon which they relied for their opinion.

Premature assumptions: Investigators should avoid any type of bias in their investigation. One way to do that is to follow the pertinent leads no matter where they take the investigation while employing a systematic methodology. This allows the investigator to come to a conclusion after all reasonably available pertinent information has been considered.

The investigator should avoid bias as to origin and cause until all the relevant data reasonably available has been gathered and tested against the working hypotheses, and a final hypothesis has been selected.

Expectation bias: Coming to a conclusion based on expectations without considering all relevant data, or discounting data or failing to seek data pertinent to the investigation constitutes expectation bias.

Data developed by an investigator early in an investigation indicating certain activities or events does not necessarily indicate expectation bias unless other facts or data are not considered. For example, a witness providing a statement early in the investigation indicating a certain potential cause of the fire does not of itself create expectation bias unless the investigator ignores data that could indicate other potential causes.

The formation of only a single hypothesis as dictated by the data is not in itself an indication of bias.

Confirmation bias: Using the data to prove a particular hypothesis rather than test and attempt to disprove it or to develop alternative hypotheses is confirmation bias. Failing to consider all data can result in incorrect conclusions. The investigator should strive to avoid confirmation bias by considering all data and testing all hypotheses. A hypothesis without a basis in data is not valid and may be the product of bias.

Arrival on Scene

The investigation begins at the time of dispatch or receipt of the assignment. Certain investigative practices take place during the receipt of the dispatch and during the response to the fire.

Document the date and time of arrival at the fire. The conditions at each fire will dictate the order in which the following actions are taken, but they all should be completed shortly after arriving on scene. Upon arrival at the fire scene, many issues will be competing for the attention and time of the investigator. Scene safety should be considered and established based on the hazards present. Sizing up the needs and situation should lead to a plan of action, which will remain active and ongoing. Based on the number of tasks that need to be completed and the time and effort required to accomplish them, the lead investigator should form a plan of investigation that identifies needs for additional resources such as investigators, law enforcement, other experts, etc. Make resource requests with a view to the time lag for response of the resources.

Additional resources may include specialized personnel who can provide technical assistance:

- Fire behavior analyst. A qualified wildfire behavior analyst (FBAN) may be able to develop information about the general fire spread. While able to assist in large-scale progression mapping of a fire and location of the heel of a fire, fire modeling is not a reliable tool for identifying a general origin area, specific origin area, ignition area, or initial spread of the fire from these locations.
- Canine teams: Trained canine/handler teams may assist investigators in locating areas for collection of samples for laboratory analysis to identify the presence of ignitable liquid residues

(ILR). Other specialized canine/handler teams can track the responsible person(s) to and from the general origin area of wildfires. Canine handlers should be consulted early for advice concerning potential contamination issues and information on the methodology of canine use.

- Electrical engineer: An electrical engineer may provide information regarding electrical transmission and distribution systems, along with assistance in evaluating other electrical sources of ignition.
- Materials engineer or scientist: A person in this field can provide specialized knowledge about how materials react to different conditions, including heat and fire.
- Industry expert: When the investigation involves a specialized industry, piece of equipment, or system, an expert in that field may be needed to fully understand the processes involved.
- Legal counsel: A prosecuting attorney or agency attorney may provide legal assistance about rules of evidence, search and seizure, gaining access to a fire scene, obtaining court orders, and preparation for litigation.
- Case management specialist. In major fire or serial arson cases it is useful to have a specialist to organize, catalog, cross-reference, and evaluate the information generated through the investigation and to advise the team leader about data collection and storage needs.
- Geographic information systems (GIS) specialist. Consider including a GIS specialist on the investigative team to produce maps of the fire and diagrams of the investigative scene.
- Survey or digital scene reconstruction team: Consider using unmanned aerial systems (UAS) (e.g., drones), lidar, photogrammetry, etc.
- Law enforcement officers (LEO): Consider including an LEO to ensure scene safety and security, to conduct witness and suspect interviews, to collect evidence, and to perform records checks.

Based on unique circumstances, other specialists may be required. Consider the conditions regarding the cause of the fire and consult as appropriate.

Follow agency procedures to arrange for the additional resources to respond to the incident. If any evidence of non-fire-related criminal activity emerges, immediately notify the proper law enforcement authorities. Considerations for determining the number of investigators assigned include available staffing, complexity, number of witnesses, and the size of the area to be investigated.

An investigator should never hesitate to contact another investigation expert who has more knowledge or experience in a particular aspect of the investigation. When forming an investigative team consider including at least two wildfire investigators (INVF) to document and process the scene.

When multiple investigators are assigned to the investigation, each person should be clear about their responsibilities and the reporting expectations. The lead wildfire investigator communicates this information to each investigative team member.

Safety issues. Safety is the priority. Safety issues should be identified and mitigations incorporated into the planning process. Conditions at a scene may prevent the immediate search for the origin of the fire. If so, secure the general area or heel of the fire to the extent possible. Other tasks such as taking weather conditions, identifying and interviewing witnesses, protecting evidence, searching the exterior perimeter, and evaluating fuels outside the burn can be accomplished until conditions allow for entry into the burned area.

Fire behavior context. Note the size, direction of spread, rate of spread, flame height and length, fuel type, fuel volume, fuel arrangement, slope, and aspect at the heel area of the fire. Be sure to record the time of the observations.

Weather readings. Record temperature, relative humidity, wind speed and direction, cloud cover, etc., and obtain fire weather readings taken by first responders. Weather readings should be taken and documented as soon as possible near the general origin area. This should include taking weather in a location with similar aspect, fuels, elevation, crown closure, and exposure to winds.

Weather readings taken at a distance from the general origin area and/or taken hours after the ignition and initial spread of the fire lose their value for purposes of understanding the ignition and initial fire spread. Representative remote automated weather station (RAWS) readings for the time of ignition may be of more value than on-scene weather data taken hours after ignition or from nonrepresentative locations.

On-scene weather readings, even taken hours after the ignition, may help to validate the most representative RAWS by comparing weather at a specific time at the scene with weather readings at the RAWS sites. Representative weather stations should be as close to the actual scene as possible while reflecting general elevation, aspect, shading, and fuels similar to the actual fire scene.

The nearest RAWS may not be the most representative.

Preliminary area of protection. Protecting the scene from further damage and contamination is a priority. Scenes that have already been damaged by suppression actions or other activities do not eliminate the need to protect the scene once the investigator arrives. Trained fire suppression personnel who understand the need to protect the general origin area may have already identified its possible location and taken steps to protect it.

The preliminary area to protect is generally identified based on the fire behavior context, macroscale fire pattern indicators, and witness statements. Based on these factors, the general origin area of the fire should be identified and secured as much as possible. This area can vary in size depending on the individual fire and the reliability of the initial data considered.

The techniques used to protect this area will vary depending on the terrain, access, suppression activities, and public interest. Barrier tape and flagging may not be reasonable on larger fires. If needed, post a security person at the area of protection and provide that person with clear instructions concerning access to the area. Roadblocks may need to be established.

Consider rerouting equipment and firefighters around the area of protection and ensure that no additional disturbance occurs within the area. When appropriate, log the names and times for any persons entering and leaving the secured area. If an area of protection is not easy to locate, restrict access to a larger area that you believe contains the fire’s general origin area.

> Investigators are encouraged to use the technique that best provides for scene protection and to document reasons for selecting a given method.

Witnesses. Interviewing witnesses is a key component in establishing the initial area of protection and general origin area. Analyze witness statements for reliability and test them against the fire behavior context, fire pattern indicators, and other witness statements before using as data to form a working hypothesis. Note that multiple witnesses may have seen the same event from different perspectives and that their understanding of an incident may be affected by their location and personal experience.

Record witness information that may be used for investigative follow-up:

- Name, date of birth, driver's license number, physical address, phone number.
- Make, license plate number, and description of vehicles at the scene.
- Note any remarks made by persons at the scene that are in any way related to the fire.
- Follow agency policy regarding the personally identifiable information collected from witnesses.

Civilian or suppression witnesses can provide information including:

- Size of fire on arrival
- Specific fire behavior
- Fire progression
- Suppression strategy
- Weather conditions
- Evidence
- Names or identifying information of other witnesses

Physical evidence. Physical evidence can be almost anywhere. A reasonable search of the area in and around the general origin area of the fire and access routes or other areas of potential activity may produce physical evidence that will need to be protected, documented, secured, and collected. This may include areas outside of the general origin area.

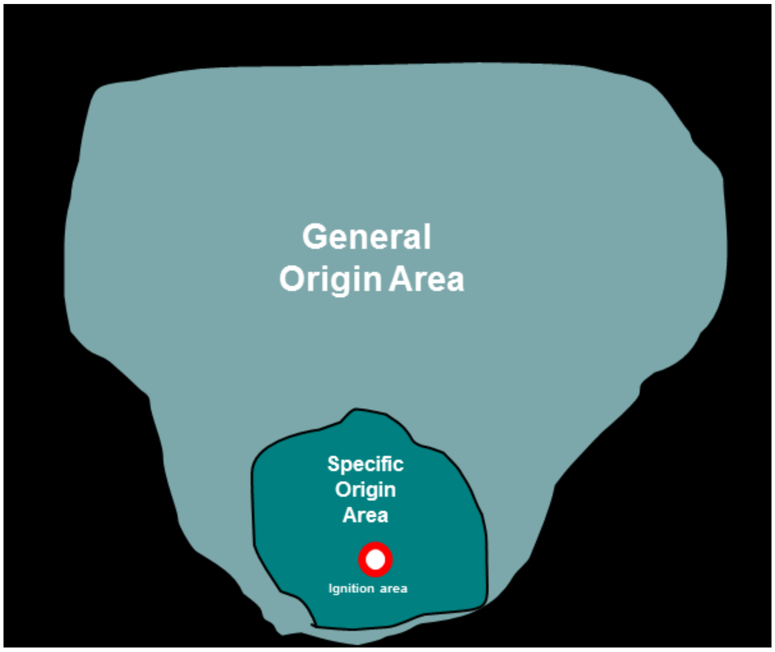
Evidence protection area. The investigator should identify the area—both inside and outside the burn—where evidence may be found, based on experience, observation, location, and specifics of the incident. Minimize the impact of pedestrian and vehicle traffic in and around the general origin area and reroute it as necessary to protect the site. Watch for the positions of equipment and vehicles, their tracks, as well as footprints, discarded items, and any other objects or impressions that can explain activity around the site. Protect and flag these objects and impressions so they can be properly documented.

Areas of the Fire

Even with large areas, there is a systematic method for identifying the ignition area. Fire behavior is influenced by weather, fuels, and topography—referred to as the fire behavior context. As a fire moves over an area, it leaves distinct fire patterns composed of individual fire pattern indicators that will show the fire's progression.

The investigative area of a wildfire is broken down into the following components: general origin area, specific origin area, and ignition area.

Figure 3.2. Drawing of an ignition area, specific origin area, and general origin area.



General origin area is the larger area where the fire first established itself. It is identified by an analysis of the fire behavior context, macroscale fire pattern indicators, and witness statements. The general origin area includes within its boundary the specific origin area and ignition area and is typically less than one-half acre in size.

The investigator should reevaluate any area flagged by first responders to ensure it includes the fire's likely ignition area.

Once the general origin area has been identified a boundary may be determined and marked.

Specific origin area (SOA) is the smaller area within the general origin area where the fire's direction of spread was first influenced by wind, fuel, or slope. The specific origin area is where the transition zone between advancing and backing indicators comes together with the lateral indicators on the flanks and will contain the ignition area. This area is characterized by subtle and microscale fire pattern indicators because of less-intense burning associated with the initial stages of the fire. The specific origin area varies in size and depends on the indicators and other factors.

Ignition area is the smallest area that an investigator can define based on the physical evidence of the fire pattern indicators. This area within the specific origin area is where a competent ignition source came into contact with the first fuel ignited and combustion was sustained.

Point of origin is the exact physical location within the ignition area where a heat source and the local fuel interact, resulting in a fire. The "exact" location of a point of origin is rarely found because from the time a fire is ignited to the time an investigator arrives at the specific origin area decomposition of the fuels and other physical makeup of the scene likely have altered or destroyed portions of it, particularly on the microscale.

It is more realistic to define an ignition area than an exact point of origin.

Determining the General Origin Area

The investigator determines the general origin area using a systematic approach (i.e., the scientific method) beginning with identifying an advancing area of the fire. Photos and witness statements can support the evidence of the fire behavior context, often identified by macroscale fire patterns. Evaluating areas of differential fuel consumption will assist in the identification of advancing, lateral, and backing fire spread on the large scale.

Once an advancing area has been identified, macroscale fire pattern indicators and the fire behavior context should be used to follow the advancing fire back toward its source(s).

It is important that the search for the general origin area not be too close to the transition of advancing and backing fire pattern indicators. This extended area allows for a greater collection of fire pattern indicators that will increase the confidence level of the investigator in identifying the general origin area.

If more than one advancing area is located within the heel area of the fire, trace all advancing areas back to their source to determine if multiple ignitions took place. In the case of a single source of ignition, all advancing fire patterns should lead back to the same source.

General Origin Area Investigative Techniques

Walk the exterior perimeter. When it is safe to do so, it is recommended to walk the perimeter of the general origin area twice—once in a clockwise direction, once counterclockwise. This will allow for the area to be examined from different angles with different lighting.

The investigator should examine the unburned area as well as the burned area for evidence and comparison of fuels. Examine and identify fire pattern indicators at the perimeter of the general origin area and use colored flags or other markers to indicate and secure the area, as appropriate. Protect and identify any evidence with white flags.

Identify advancing fire area. This will often be the area with the cleanest burn and may be characterized by a smaller scale V- or U-shaped pattern. It is often defined on both flanks by lateral fire pattern indicators showing less-complete consumption of fuels.

Enter the general origin area. The primary objective when entering the general origin area is to locate the specific origin area and ignition area. This process should be done in a manner that minimizes scene disturbance. Begin by photographing the area and then entering from the head or advancing side of the fire run. This is the side generally furthest from the suspected ignition area. Entering from this direction is important because the fire pattern indicators are more obvious in this area and the investigator is less likely to overrun the specific origin area than if entering from the heel or backing side of the fire.

Each scene is unique and there may be exceptions to this recommendation as some fires do not have advancing indicators. For example:

- Fires burning from a roadway into the wind or downhill may only create lateral and backing indicators.
- Fires starting on a ridgetop or peak may only create backing indicators.
- Fires on flat ground and no wind.
- Fires burning during periods of high humidity and/or fuel moisture with no wind or slope influence.
- When features such as roads and other breaks in the fuel allow for access while still protecting the specific origin area.
- General origin area is on a slope where material may be dislodged and roll downhill and disturb the specific origin area. The investigator may choose to enter from the backing or heel side and work uphill in order to protect the scene.

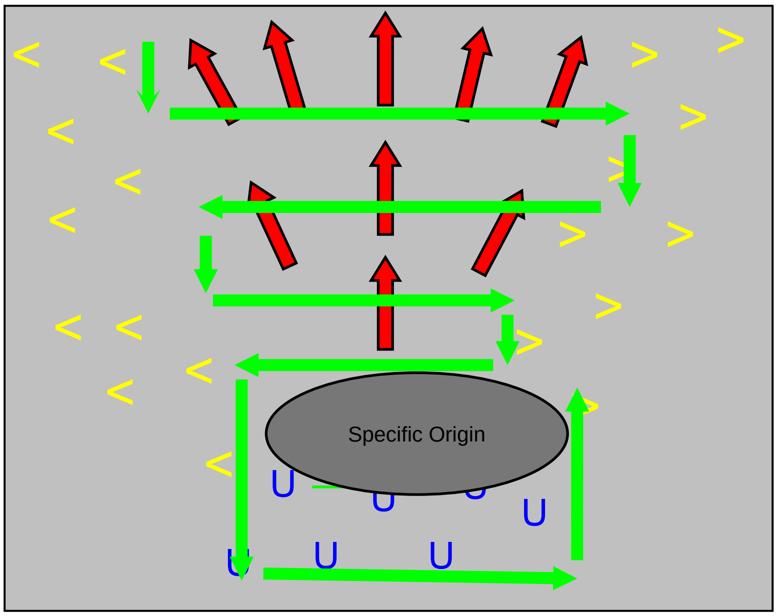
Investigators are encouraged to use the technique that best provides for scene protection and to document reasons for selecting a given method.

While working the advancing fire pattern indicators within the general origin area, the investigator should work across the advancing run from lateral transition zone to lateral transition zone, while moving progressively closer to the location that the fire came from. Investigators should be cautious of where they walk to avoid disturbing evidence or fire pattern indicators.

Processing the General Origin Area

- Enter from the advancing area when appropriate.
- Work across the run of the fire until reaching the lateral transition zone.
- Move toward the area the fire came from and move back across the run of the fire until reaching the opposite lateral transition zone.
- Repeat the previous step (in the opposite direction) until the transition zones begin to narrow and converge, showing advancing, backing, and lateral indicators in a more defined area.
- At this point, focus primarily on interpreting microscale indicators.
- Recognize this as the specific origin area (fig. 3.3).

Figure 3.3. General origin area search pattern design to find the specific origin.



- Mark the location of fire pattern indicators with pin flags or other similar items. Color-coded pin flags are the most visible and easiest markers to use (see fig. 3.4).
- Recommended colors:
  - Red – advancing fire pattern indicator.
  - Yellow – lateral fire pattern indicator.
  - Blue – backing fire pattern indicator.
  - White – evidence only.
  - Lime green – areas, items, or points of interest such as four corners of the ignition area and potential, but not confirmed, items of evidence. Explain the lime green flags in the report.

Figure 3.4. Example of a general and specific origin areas.

Processing the Specific Origin Area

How the search of the specific origin area is conducted will depend on the specific conditions at the scene. The search process should reflect a systematic approach that protects scene integrity as much as practical.

- Before applying any search technique to the specific origin area, the investigator needs to identify and mark the SOA boundary. After the boundary is marked: Photo document the area before entering, being careful not to walk in the backing indicator transition zone.
- Consider using binoculars to identify and examine indicators, possible evidence, and visible potential ignition sources before entering the SOA.
- In most cases, start in the advancing area of the fire and work toward the ignition area.

The following three search techniques facilitate systematic searching of the area. Base the choice of one of these or another systematic search technique on the particular conditions of the site and available resources.

Perpendicular lane search technique

- Establish lanes, one at a time, perpendicular to the fire run.
  - Do not disturb the SOA when laying out the lanes.
  - Mark the lanes with colored twine and stakes, or similar indicators.
  - Stake at a uniform width, 12–18 in apart.
  - Continue to work toward the origin.
- Systematically move the twine and stakes forward to form the boundary of the next lane.
- With multiple investigators searching side by side along each lane, make sure they overlap their search coverage.

Figure 3.5. Perpendicular lane search technique.

Parallel lane search technique

- Lay out multiple lanes parallel to the advancing fire progression, toward the suspected ignition area. Ensure that the far lane ends are established in the green or well into the backing area.
- Do not disturb the SOA when laying out lanes.
- This technique works well with multiple investigators and/or when working a narrow specific origin area.
- With multiple investigators searching side by side along each lane, make sure they overlap their search coverage.

Grid search technique

- Lay out a grid of squares or rectangles that extends beyond the edges of the specific origin area, being careful to avoid disturbing the SOA. The size of the sections depends on scene circumstances. One-foot square grids are typical.
- Assign a number and letter to each grid section.
- Photo document the location of evidence within each section and label by grid ID, such as “grid section 3A.”
- This technique is useful when the locations of multiple pieces of evidence need to be documented or when collecting debris for sifting/examination. It is very effective when searching for exploding target debris.

Figure 3.7. Parallel lane search technique.

Figure 3.6. Grid search technique.

Tools for Searching a Specific Origin Area or Ignition Area

Search each lane or grid section using the following practices and tools as required:

- Visually examine a designated area, using magnification as necessary.
- Remove lightweight debris by brushing or blowing.
- Use a straight edge to focus the search pattern.
- Continue locating and marking indicators with flags.
- Employ magnet search for ferrous metals.
- Search for nonferrous metals with a metal detector.
- Photograph objects collected as soon as this can be done safely. Additional photos may be taken later under more favorable conditions.
- Screen and/or bag debris for future analysis when appropriate.
- Continue until the ignition area is identified and/or the ignition source is located.
- Document and secure any evidence.
- Continue searching past the ignition area or evidence until clear backing indicators are encountered.
- Document the perimeter of the specific origin area.
- Document the location and perimeter of the ignition area.

Visual search and magnification. Each specific origin area will manifest a variety of conditions depending on the fire intensity, fuels present before and after the fire, and other variables. Variations within some parts of the fuel bed may require using magnification—a standard magnifying glass, high-powered reading glasses, or a similar device.

Lightweight debris. Using a bulb syringe or just carefully blowing can move lightweight debris during the visual examination. Other tools such as hair picks and forceps can also allow for the careful removal of debris without causing contamination.

Straight edge. A straight edge can be positioned to focus attention and to keep track of the area being visually searched without causing contamination or disturbing areas not searched.

Flags for microscale indicators. Microscale indicators should be marked with pin flags according to their directional vector and documented.

Magnets. A pull-release magnet facilitates the search for ferrous metal evidence. Move the magnet just above the debris surface in a systematic pattern, overlapping each stroke to cover the entire area. Check the magnet surface after each pass to identify any object collected and the approximate location it came from.

Two tips for using a magnet:

Cover the magnet with a zip lock plastic bag turned inside out. When an object sticks to the magnet, contain it in the bag by turning the bag right side out and sealing the evidence inside.

Place a clean piece of paper under the magnet so when the pull-release handle is pulled the object falls onto the paper. Photograph the object and place it in an evidence container.

Metal detector. Use a commercial-grade metal detector to search for ferrous or nonferrous metals as needed. Use a systematic search pattern that overlaps to assure full coverage.

Screen or Collect Debris

If a decision is made to screen the debris in each search area, this should only be done after all other search processes have been applied.

If a determination is made that the debris will be bagged, the grid search technique allows for more precisely locating where each bag of debris came from. Photo document each grid section before and after collecting debris. Place debris from each section into a bag and mark the bag with the grid coordinates.

Depending on each scene's needs, the investigator may determine that screening or collection of debris is performed only in the ignition area.

Second Origin and Cause Investigation

Some situations indicate the need for a second origin and cause investigation, including major cases and/or when no physical evidence of the cause is found.

If a second origin and cause investigation is planned, keep the general origin area secured and as undisturbed as possible. Scene integrity, contamination issues, level of security required, and need for long-term security should be considered. In case of a second origin and cause investigation, take care to protect that investigation from any bias.

Fire agencies often use wildfire behavior prediction software to guide suppression strategies and tactics by predicting timing and locations of forward rates of spread fire progression. However, investigators should not use this software to define the location of the specific origin area or ignition area because current versions are not designed to provide an accurate picture of early-stage wildfire behavior.

Chapter 4. Fire Scene Evidence

Types of Evidence

Evidence is classified into two broad categories: direct and circumstantial, and by type within those categories.

Direct evidence is based on personal knowledge or observation and, if true, proves a fact without inference or presumption. For example, individuals were seen committing an action or individuals were seen lighting a fire.

Circumstantial evidence is based on inference and not on personal knowledge or observation. Circumstantial evidence tends to prove a fact by proving other events or circumstances that afford a basis for a reasonable inference of the occurrence of the fact at issue. Examples:

- A person was seen running away from the scene.
- They were seen leaving a fire but not actually lighting the fire.
- Tire prints that match the individual's vehicle are recovered at the scene.

Exculpatory evidence tends to establish a person's innocence.

Testimonial. A person's testimony offered to prove the matter at hand. For example, a witness observed the suspect light a burn barrel.

Real. Physical evidence that itself plays a direct part in the incident in question, for example:

- Physical evidence such as footwear impressions found near the scene, a beer can with fingerprints and/or DNA found in the origin area, or the remains of an ignition source.
- Digital evidence such as mobile devices used by a suspect or witness at or near an origin.
- Documentary evidence such as burning permits, ownership maps, photographs, and social media.

Judicial notice refers to certain facts that are already well established and are common knowledge.

Admissibility of Evidence

The investigator needs to be familiar with the rules of evidence within their jurisdiction.

Relevance. Evidence must have some connection to the facts of the case and must be pertinent to the issues of the trial. It must also assist the trier of fact in proving facts in dispute.

Authentication and identification. For evidence to be considered reliable, it must be competent, and authentication establishes that it is the same item as collected by the investigator. Records and testimony must establish that the evidence item has not been tampered with, altered, or contaminated.

Methods to ensure competent evidence. To ensure competent evidence is provided to the trier of fact, exclusive custody and control in a secured area needs to be established through a complete written record of the chain of custody. All investigators must be familiar with and adhere to their agency policies and procedures for ensuring proper evidence collection and safeguarding.

Evidence may be admissible provided it was obtained legally under one or more of the following circumstances:

- Nonprivate area – Evidence in open fields or public lands.
- Plain view – Immediately recognized as incriminating, observed by an official who was legally present.
- Exigent circumstances – Emergency circumstances exist that could cause destruction or loss of evidence.
- Consent – Where there is an expectation of privacy, a person who has a controlling interest in the area to be searched may give their consent to authorities.
- Abandonment – Abandoned by the owner. This circumstance can be difficult to establish ownership, timing, and other elements. It is recommended to consult with an LEO or legal staff.
- Warrant (criminal or administrative) – A court order to search for and seize specific items. This is a preferred method. Some jurisdictions allow for an administrative warrant where the legal justification needed is substantially less than a criminal warrant.

In most fire investigations, the investigator can expect to recover most evidence from private areas under the plain view doctrine, consent, and/or exigent circumstances. Non-law enforcement investigators request assistance from an LEO for seizure of evidence falling outside of plain view.

Spoliation. Spoliation of evidence refers to "the loss, destruction, or material alteration of an object or document that is evidence or potential evidence in a legal proceeding by one who has the responsibility for its preservation" (NFPA 2024,12.3.5).

Collection and Preservation Procedures

With all types of evidence that will be submitted to a lab for analysis, the investigator should have a clear understanding of the lab's preferred methods, materials, packaging, and procedures.

Whenever possible, wear clean exam gloves when handling or working with evidence items.

Photographic and Video Documentation

Recommended procedures:

- If possible, document the area before entry.
- Before collection, first document without aids.
- Next, document with an aid for scale.
- Document from multiple angles.
- Note location and angle from which each photograph was taken.
- Do not delete or alter any original photos taken.

Nonfragile Fire-Cause Objects

Items that are less subject to damage from heat and flame when collected can include:

- Metal fragments
- Catalytic converter particles
- Welding slag
- Powerline hardware

Recommended collection procedures:

- Carefully pick up and place in folded paper bindle or place into a hard-sided container. Pack in cotton to keep fragile edges from breaking off.
- Wrap large and/or bulky items (e.g., electrical hardware, chainsaws, mower blades, etc.) in bubble wrap.
- Use plastic stretch wrap to protect evidence areas such as ends of wires or conductors, mufflers, chains, blades, etc.
- Never mix particles from an extended search area or from different tools.
- Seal evidence in a manner that allows for it to be easily identified later. Initial and date the seal.

Fragile Fire-Cause Objects

Objects that can be easily damaged or destroyed during the collection process can include:

- Cigarette remains
- Matches
- Fusee slag
- Fireworks remains
- Incendiary devices
- Exhaust carbon

Recommended collection procedures:

- Some items can be picked up carefully by gloved hand or small tools.
- Place in a bed of cotton in a hard-sided container.
- Seal evidence in a manner that allows for it to be easily identified later. Initial and date the seal.
- Basal lift technique:
  - To prevent damage to fragile items, use a clean shovel or trowel and a thin piece of flexible sheet metal.
  - Score a line through ash and duff down to the soil around the object, leaving of border of several inches.
  - Work the shovel or trowel into the dirt under the object until the clod of dirt and ash with the object has been freed.

- Slide the sheet metal under it and lift the clod intact.
- Place the metal and clod into a cotton-padded container of appropriate size.
- Seal evidence in a manner that allows for it to be easily identified later. Initial and date the seal.
- Clean the tools with approved cleaning materials between each collection per the agency's standards.

Figure 4.1. Basal lift technique.

Ignitable Liquid Residue

Detectable amounts of hydrocarbon residue may remain in the soil for lengthy periods after the fire. However, soils and other organic materials may contain microbes that have the ability to degrade petroleum products. The biodegradation can have a detrimental effect on the ability to identify ignitable liquids. Factors that could increase the degradation include type of soil, temperature, and storage conditions. Microbial action may degrade a sample quickly.

Indicators:

- Signs of trailers and pour patterns
- Deep seated burning
- Scorching and sooting
- The odor of gasoline, diesel, kerosene, lighter fluid, alcohol, and others may not be detectable by smell.

Search techniques:

- Search perimeter areas.
- Use a certified canine team to detect ignitable liquids.

Figure 4.2. Canine and handler.

Sampling locations:

- Take samples where the canine has detected an alert.
- Take a comparison sample in an area that did not register a positive reading.

Areas more likely to have residual ignitable liquid:

- Areas of lower intensity fire due to lighter vegetation
- Areas where the liquid may have been shielded from the heat
- Deep compacted duff, punky logs, and stumps that have not been consumed completely
- Areas of sparse vegetation or bare soil

Collection procedures:

- Pick up suspected charred wood, soil, or vegetation and place into a clean metal can (not glass) or other approved container or wrapping material.
- Fill the can no more than two-thirds full of material.
- Avoid direct and cross-contamination.
- Clean collection tools between each sample with an approved cleaning method as recommended by the agency lab.
- Have new cans or packaging materials available for comparison samples at the lab.
- Become familiar with the lab's recommended handling processes.
- Collect any containers found near or at the fire scene.
- If liquid is still present in the found container, pour a small sample into a clean container with an airtight, nonrubberized seal.
- Seal and mark the container and hand carry it to the lab. If it will be several hours before analysis, store it in a cool environment by either refrigerating or freezing the sample, as this can slow the degradation process.

- Also provide a soil comparison sample collected at the scene.
- Most crime labs will be able to isolate ignitable liquids by means of gas chromatography/mass spectrometry analysis and other tests.

Working with an Ignitable Liquid Detection (IGL) Canine Team

A certified IGL canine team can work in conjunction with an investigation performed by a trained and certified origin and cause investigator. The team should search the general origin area, or an area believed to be of evidentiary value as determined by the origin and cause investigator.

Note that the investigator may deploy either an IGL canine team or use a portable hydrocarbon detector, not both. One should never be used to confirm or deny the results of the other.

Search techniques:

- Consider using a grid pattern depending on the area to be searched.
- Other variables, such as weather and terrain, will affect how the search is conducted.
- The IGL canine handler decides whether to work their dog on or off leash based on their previous training and safety considerations in the area to be searched.

Evidence collection:

- The IGL canine handler should identify each location the canine alerts to (indicates) so that the specific item(s) can be collected as evidence as required.
- Do not move an item(s) before discussion with the canine handler.
- Moving an item could place it near another odor that could contaminate the item.
- Collect item(s) of evidence under current industry standards and laboratory guidelines.
- After the samples have been collected an article search is conducted on the exhibited cans.

Firearms

Treat every firearm as if it is loaded until it has been visually and physically cleared.

When submitting a firearm to a lab, follow their protocols.

Projectile evidence:

- If a projectile is lodged in wood or other material, leave it as is and collect the material and projectile together in a larger package.
- If a projectile is recoverable, do not attempt to clean it. Wrap it separately in a paper bindle, place it on cotton padding in a hard-sided container, and seal and mark.

Cartridge cases:

- Wrap each case in a separate paper bindle and seal in a separate hard-sided container.
- Seal and mark accordingly.
- If comparison to a firearm is necessary, submit both to the lab.
- Casings can be entered into the National Integrated Ballistics Network database to identify links to other incidents or to firearms that are recovered later but not necessarily in connection with a particular shooting or incident.

Tire and Footwear Impressions

Recommended collection procedures:

- Carefully photograph each impression before taking any invasive measures.
- Place a linear scale such as a tape measure or L-scale on the same plane and parallel to the foot or tire impression and a scale or tape measure perpendicular to the impression.
- Take several photos illuminating the impression with side lighting.
- Photograph from different directions (i.e., right side, left side, top, etc.) and at different angles, including one that is parallel and directly over the impression to minimize any size distortion of the imprint.
- Use a flash (or other light source) or shade the impression from direct overhead light to improve details.
- Make a cast when appropriate.
- When the cast is almost set, initial, date, and orientate with a north arrow.
- Remove the cast from the ground within 30–60 minutes and let dry.
- Do not remove dirt adhering to the cast.
- Wrap in cushion material and place in a container to prevent contact with any surface. Seal with evidence tape and label.
- Allow casts to dry completely (24–48 hours) by storing in porous packaging that will let moisture escape during drying.

Tire tread impressions:

- Record as much of the tire tread as possible, with a series of casts if necessary.
- Photograph section by section, and make sure that the photograph frames overlap to ensure a continuous track.
- When feasible, photograph and/or cast the entire circumference of the tire (i.e., 10 feet) because not all the treads on a tire are equal in size and the detail can help identify a specific tire or vehicle. However, it can be difficult to match impressions to an individual tire.
- Photograph the cast in place with tracks. Mark or engrave cardinal direction and ID information on the back of each cast section.
- Note that the effort to capture one full rotation of a tire is significant due to the large amount of casting material required and difficulty transporting and securing large casts. Many crime labs prefer photographic documentation of tire impressions.
- Where feasible, consider obtaining tire impressions by rolling the vehicle over an inked chart board, then roll the vehicle over a clean chart board to record a full vehicle rotation of the tire. Do this for each tire and properly identify and label each inked impression.
- Collect comparison suspect tires and wheels so that the tire style, pattern, size, and manufacturer may be determined. For factory-installed tires, it may be possible to determine the make, model, and age of vehicle.

Footwear impressions:

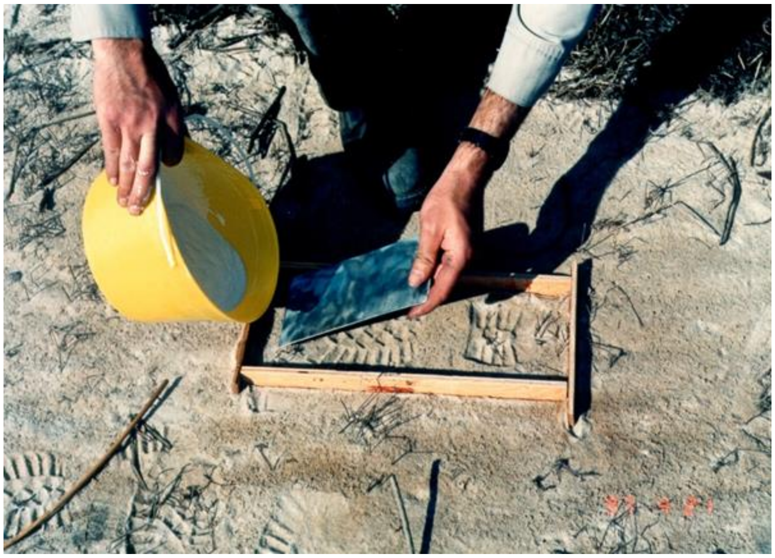
A footwear impression taken at a fire scene can be used to determine the style, pattern, size, and manufacturer of the footwear. A comparison with a suspect's footwear can produce a positive identification.

When photographing a footwear impression, use a tripod to position the camera directly over the impression. Place a linear scale next to and on the same plane as the impression.

When casting a footwear impression:

- Cast the impression using material such as dental stone. In fragile soils, add a fixative to bind the materials in the impression; in dense soils, add a release agent.
- Pour casting material carefully outside the perimeter of the impression, then direct flow into the impression.
- Once the casting material has hardened, carefully remove, excavating around the cast to avoid breakage.
- Do not attempt to clean or remove soil from the cast; this will be done in a controlled environment by a lab technician.
- Mark casts on the outside with identifying information, as normally captured on an evidence label.
- Pack the cast securely in porous packaging that will let moisture escape during drying. Do not store the item in a closed, airtight container as the chemical reaction may still be releasing moisture.

Figure 4.3. Casting of shoe impression using dental stone.



Fingerprints

Latent fingerprint evidence may remain after a fire. Prints have been recovered from beverage containers, food wrappers, cigarette packages, vegetation, and incendiary devices. Labs have also successfully recovered DNA from fingerprints. Do not assume that the fire has rendered latent print evidence unrecoverable.

Collection procedures:

- Handle objects wearing latex or nitrile gloves to avoid adding extra prints to the object.
- Package objects in paper, never plastic. (Plastic can cause the evidence to degrade.)
- Package objects in a box so they will not break or roll around.
- Do not freeze any items that need testing for latent prints.

DNA Evidence

Never overlook the possibility of DNA evidence. Recent advances in DNA recovery and analysis have increased the likelihood of obtaining identifiable DNA, even on heat-damaged items. Hair, blood, semen, epidermal oils, and saliva are all potential sources of DNA evidence. A person can transfer their DNA to an object just by touching it. Touch DNA requires only very small samples. Consider anything that may have been touched, such as beverage containers, clothing, cigarettes, matches, lighters, or food.

Collection procedures:

- Collect items believed to contain DNA evidence with a gloved hand or clean tools, using fresh gloves and a cleaned tool for each sample collected.
- If the item has wet blood, semen, or saliva, air dry before packaging.
- Package items in clean paper or envelopes with sealed corners. Do not use plastic.
- Submit to an appropriate lab as soon as possible.

Clothing Items

- For ignitable liquids testing, place the item into a can or other approved container and either freeze or transport to the lab as soon as possible. Freezing will not impact DNA testing but will impact latent prints.
- If no ignitable liquids testing is needed, package the item in a paper bag. Wrap it in butcher paper, if feasible.

Miscellaneous Evidence

Other types of evidence may include:

- Paint transfers
- Blood stains
- Hair and fibers
- Glass fragments
- Soil
- Tool marks
- Trace evidence —small but measurable amounts
- Tracking canine scent evidence—includes where subjects have been at or around the scene

Photography

Photographs provide a visual representation and are the best method of reproducing any scene. Photographs must be a fair and accurate representation of the scene as they can record facts more accurately than a word description. Photo documenting the scene is addressed in more detail in chapter 6, Documentation.

Photographs can provide the following advantages:

- Present facts and physical circumstances visually
- Pictorially preserve perishable evidence
- Permit consideration of evidence that cannot be transported into a courtroom because of immobility, size, weight, etc.
- Support testimony
- Reveal facts or evidence that the investigator may have initially overlooked

Camera kit recommendations:

- High-quality digital camera
  - Micro, zoom, and wide-angle capable
  - Tripod mountable
- Smartphone camera can be used as a backup
- Removable flash

- Global Navigation Satellite System (GNSS)
- Spare batteries
- Spare memory cards
- Power bank

Photography guidelines:

Begin photographing the scene as soon as possible. Before collecting evidence, photograph the evidence in its original, undisturbed location before moving. This should include photos that show the location of the evidence in relation to other key features of the scene, closeups that show the details of the item to be collected, and the area immediately around it.

Photographs should appear natural to the eye by taking them at eye level for a general view of the whole scene; position the camera as an eyewitness would observe the scene. The photograph should give a fair and accurate representation of the scene or the subject matter.

Photograph the evidence item with a scale positioned in close proximity, being careful not to touch or contaminate the item. For fragile evidence, this may be the investigator's only chance to document the item because it could be damaged or destroyed in removal or transport. As such, exam-quality photos should always be the goal for fragile items.

Figure 4.4. Evidence with scale to show size of object.

During collection, it may be useful to photo document the evidence recovery process; this can be accomplished using photography, videography, or both. This documentation may include the methods, tools, and containers used, including markings on the container identifying the evidence item. Consider photographing during collection especially if the evidence is fragile and could be damaged or destroyed upon collection.

- Take more pictures rather than not enough.
- Ensure the GNSS function is enabled.
- Use a reference point in the photo to establish where the photographer was in relation to the overall scene.

- Create a photo log by numbering and describing each photograph.
- Document photo points on a photo diagram with the appropriate symbols.

After collection, place the evidence item on a single-color background or gridded paper to provide better contrast. These photos may include comparison evidence items if cross-contamination is avoided.

Chapter 6, Documentation covers types of photographs, photo logs, and general scene photography.

Videography

Videography can provide overall fire scene footage, supplement photographs, document interviews and interrogations, and document surveillance operations. Using video exclusively without accompanying still camera photographs is not recommended. Be aware of comments investigators or others make during the video recording, as well as any background noise. The investigator may consider turning off the audio before making a video recording.

Potential uses of video:

- The fire burning during the early stages
- Bystanders and vehicles at the fire area
- Fire suppression activities relevant to the investigation
- Aerial views documenting the direction of fire spread from the general origin area
- Witness viewpoints
- Large pieces of evidence that may need to be reduced to smaller sizes for transport

Other sources of the videography for the investigator to be aware of may include:

- Dash cameras
- Security cameras
- Body cameras
- Handheld cameras or phones

Chapter 5. Witness Interviews

Physical evidence can only provide part of the overall investigation. At some point, it will be necessary to interview witnesses, victims, or suspects. Interviews can add weight and meaning to physical evidence. The investigator should conduct interviews in a professional manner. Poor interview techniques may compromise the investigation.

Know the agency policy regarding interviews. Plan and prepare for the interview. The quality of the interview techniques governs the quality of the information that will be obtained. Typically, poor or incomplete interviews will require a follow-up interview, which involves finding and contacting the person to re-interview, and in the end, more work than if it is done right the first time.

Investigators who conduct interviews should look for additional training on interviewing techniques.

Difference Between a Witness and a Suspect Interview

A witness interview is a consensual questioning of a witness and a permanent record of the witness' recollection of the event. The witness should feel free to leave at any time. In the case of a wildfire investigation, the purpose is the collection of data to aid in forming and selecting a hypothesis that explains where the fire started (ignition area), what started it (ignition source), and how it started (ignition sequence), including identifying any responsible party or parties. Most witness interviews will not require an advisement regarding the right to avoid self-incrimination (i.e., in the United States, a Miranda warning), which is required when law enforcement questions a subject regarding a crime they may have committed, and when the subject is or could reasonably perceive they are in custody.

Treat the initial on-scene interviews as witness interviews, even if suspicion exists that the individual was involved in starting the fire. If the investigator believes the witness to be a suspect, follow agency policy on referring this information to law enforcement for follow-up.

A suspect interview (also referred to as the law enforcement interview) is commonly employed by law enforcement officers with the goal of eliciting useful information related to the suspected crime. The main responsibility of an investigator is to establish the ignition area, cause, and ignition sequence of the fire. The need to interview suspects may arise during this process. Suspect interviews should only be conducted by qualified law enforcement personnel. Investigators who do not have law enforcement appointments should request a law enforcement officer when the situation dictates.

Witness Interviews

A witness interview can be described as "a conversation with a purpose." The investigator is trying to determine the who, what, when, where, why, and how of the incident. It is the consensual questioning of a witness.

In a non-accusatory way, the investigator gathers useful and accurate information to assist in determining the truth of what occurred. It is a permanent record of the witness's recollection. All witness information needs vetting. Trust the information but verify its accuracy.

> An example of what the investigator might say to the witness: *"The purpose of this interview is to see what you have to contribute to this investigation. I wasn't there. You were. I need you to tell me exactly what you observed."*

Plan appropriate questions to fill in the information gaps to develop a more complete picture of what occurred. Ultimately, the information gathered from witness interviews should help the investigator prove or disprove a hypothesis as to the origin and cause of the fire.

Voluntary witness. This is the fully cooperative witness who wishes to be involved to assist investigators in finding the truth of what happened. These witnesses report the incident (i.e., Firewatch, 911) and are fully cooperative with investigators when being interviewed. Voluntary witnesses have information that they want to share with investigators.

Reluctant witness. This type of witness doesn't want to be involved for various reasons: afraid of getting involved, does not like law enforcement, may be guilty of something related or unrelated to fire, reluctant to cooperate, or worried about potential retaliation.

Uncooperative witness. This type of witness does not want to talk to the investigator, refuses to cooperate with authorities, and is considered to be a hostile witness if the case goes to court. Angry or hostile subjects may escalate the interview into a more aggressive encounter. An additional investigator or law enforcement officer should be present during such contacts.

Note that any witness needs to be in an appropriate condition to be interviewed; one impaired by alcohol or drugs should be interviewed at a later time.

Witness Information Factors

Witnesses are affected by numerous physical and emotional factors which influence the information they give to the investigator. For example, the visual attraction of flames rather than the burned area may lead a witness to place the ignition area near where they saw the flames rather than in an area that already burned. Emotions may cause a person to give prejudicial information, to lie, or to forget events. Lighting, distance from the incident, or physical limitations may result in an inaccurate interpretation of the events observed.

The investigator should explore all the circumstances surrounding a witness's evidence and recollection without leading or prompting them. Be aware that the witness may have seen something they cannot explain since they do not know the terminology of a wildfire investigation, or they may apply terms differently. Seeing fire, in their perspective, may mean only smoke seen in the distance, as opposed to smoke or flame specifically. The investigator wants it to be the witness's story, not influenced by others.

Obtaining Witness Information

Written statement. Persons at the scene may give a written statement voluntarily. The investigator may choose to use their agency's written statement form to record the witness statement.

The following guidelines can be used when obtaining voluntary written statements:

- Obtain contact information from the witness.
- Have the person write the facts in detail. If possible, provide the person with some degree of privacy, so this can be accomplished uninterrupted.
- The investigator may assist the subject in drafting the written statement (for example, if the witness cannot write). The investigator must write out every word precisely as provided by the witness.
- Read the statement back to the witness to confirm that it is a complete and accurate recollection.
- Both the witness and the investigator should initial corrections.

- Have the witness number, date, and sign each page. The investigator should initial each page also. Include the start and end times of the interview.
- The original statement should be maintained in the lead investigator's file.
- When the statement is completed by the witness, the investigator may wish to follow up with specific probing questions to fill gaps in the information provided.

Recorded interview (audio or video). Follow your agency's policy regarding the format and use of recording devices. Advise the witness that the interview is being recorded, and that they can be provided a copy.

Conduct the interview in a relatively quiet location, out of the wind, away from machinery and background noise. Position a digital recorder an equal distance between the interview subject and the interviewer.

Confirm personal information from the witness before the start of the recording. Start the recording by stating the date, present time, the interviewer's name, title, location, the fire identifier number, and the reason for the interview.

Next, the investigator should obtain a pure version account (also referred to as a "free narrative") from the witness. A pure version statement is getting the witness's description of the events without contaminating them with the words of the investigator. Let them tell their story without influence from the interviewer. The witness should be doing 80 percent of the talking during this information-gathering phase of the interview. This is the art of active listening.

Avoid interjecting or talking when the person is speaking because it could become difficult to determine who is speaking when reviewed.

A recommended way to start this process is to lead with an open-ended question, for example, *"Tell me everything you know about the incident you observed earlier today, starting from the beginning...",* or *"Explain to me what you observed...",* or *"Describe what you saw...".*

When the pure version statement is complete the investigator may have to ask specific probing questions to gain additional information or details or to confirm or clarify what was said.

The investigator should take notes of the recorded interview, summarizing the main points from the interview.

Formalizing the witness's version of events in a written or recorded statement reduces the possibility that evidence, or testimony will be lost or manufactured later at a hearing or trial. It can also serve to refresh their memory later.

In some instances, for logistical purposes, a phone or video call may be used to conduct witness interviews but these are not recommended for suspect interviews. Disadvantages of conducting phone interviews include general lack of control of the interview, inability to see nonverbal cues, and potential witness distractions.

The Interviewer

Whenever possible, interviews should be conducted by investigators who understand wildfire investigation and fire behavior, or in combination with other wildfire investigators. The investigator should brief interviewers who do not have a working knowledge of fire investigation (i.e., an investigator who is strictly law enforcement) as to what questions to ask and key statements to listen for.

The qualities of a good interviewer include:

- Professional. Be confident, cordial, and dress appropriately.
- Respectful. This includes being good-natured, sincere, patient, understanding, demonstrating empathy, not being judgmental.
- Capable of establishing rapport and trust. This is fundamental to the success of any interview, but it requires more than just smiling. Individuals are more likely to confide in someone they feel is supportive and with whom they feel comfortable. Even the most cooperative, agreeable witness can be turned off by an interviewer who fails to establish rapport.
- A good listener. The purpose is for the witness to do the talking and explain what they saw, heard, or smelled, and the investigator's is to listen.
- Shows interest. When the investigator shows interest, the witness will be more willing to engage and thus provide more information.
- Strategic. The investigator needs to consider the order of witnesses to interview and plan specific questions for the interviews.
- Unbiased. A biased investigator tends to seek confirmation of their beliefs while discounting anything that tends to refute them.
- Prepared. Preparation breeds confidence. The investigator may not get a second chance to interview this witness.

In a situation where multiple interviews must be conducted in a short period of time—for example, a fire has started adjacent to a full campground—request additional resources as needed to assist with the interviews. At a minimum, gather basic identification and contact information before potential witnesses leave the area so that they may be interviewed later.

The investigator should develop and maintain a witness list that becomes part of the overall investigative plan.

The investigator should not share their opinions of what they have seen at the fire or information about the person or thing that may have started it with anyone other than officials who need to have the information. The investigator's job is to gather information, not to give it.

Witness Interview Locations

Witness interviews may take place in a variety of environments—in the field, a vehicle, an office, or at the witness's home. In many cases, the interviews are conducted in the supportive environment of the witness's home or place of business. Often, these interviews have multiple distractions, such as phone calls or interruptions by children, that break the continuity of the interview. For witnesses, these distractions may cloud an already uncertain memory of the incident.

The investigator should attempt to conduct interviews in private and in a location with the fewest distractions and best conditions for recording. Discuss with the witness where the interview will take place to ensure it will meet their need for privacy. The investigator may phone ahead and decide to meet at a time and location where the witness's anonymity can be assured.

Hostile witnesses should be interviewed at a law enforcement office interview room or other location where the interviewer feels safe and has the psychological advantage.

Minimize the inconvenience to the witness. This will demonstrate that the investigator is interested in their information and respects their concerns, thereby establishing some trust and rapport. The end goal is to reinforce to the witness the importance of cooperating and the fact that they may have critical information that is important to the investigation.

The interview may be short or take hours, depending on the extent of the information the person may have. Initial interviews typically take 20–40 minutes, but the interviewer should take the time needed to get all the information that time will allow.

Reduce distractions so the witness can concentrate on the task of providing information. If the conversation gets off topic, the interviewer should refocus and control the interviewee to keep them focused on the facts related to the investigation. Witnesses may provide estimates or impressions of what they saw but should not be encouraged to guess or speculate.

Witnesses should be interviewed as soon as possible after the event. If the investigator delays the interview the witness's memory may become tainted by what they have heard or read after the fire event.

If possible, prevent witnesses from discussing what they saw or heard with other witnesses. Interview witnesses privately and separately (no group interviews). Information obtained from a witness should not be discussed with anyone other than persons who have a legitimate right to know.

Sources of Potential Witness Information

Reporting party. The person who reported the fire may have seen it at an early stage and may be able to provide valuable information that assists in determining the general origin area. They may also be able to corroborate the information obtained from other witnesses. Note that occasionally the reporting party may be the person responsible for causing the fire. Examples of reporting parties are:

- First responders (fire, medical, law enforcement)
- 9-1-1 callers (investigator may need to review call logs)
- Bystanders
- Residents
- Travelers
- Property owners
- Recreationists
- Workers in area
- Airborne personnel, lookouts

Initial attack crew. The initial attack crew plays a vital role by making observations while en route and upon arrival at the fire. Crew members may be able to provide valuable information pertaining to the general origin area, the area that had already burned before their arrival, fire behavior conditions, identification of people and vehicles in the area, weather, condition of locks and gates, items of potential evidence and other abnormal conditions, initial suppression tactics, water and retardant drops, hand line and/or hose lay locations, and backfire or burn-out locations.

Air resources. Air crews can make the same types of observations as ground crews regarding the potential area of origin, direction of fire spread, and people or vehicles leaving the area. Photographs of the fire taken by the aircrew personnel often prove invaluable in showing areas burned, direction of spread, smoke column, and intensity. Check with first responder air resources to see if they took photos.

Civilian witnesses. Witnesses can provide information about unfamiliar vehicles or people who may have been in the area and activities at the time the wildfire started. They can also supply details such as smoke conditions, intensity, rate of spread, and weather. They may have taken photos.

Electronically stored information. The investigator should consider areas of electronically stored information, which may lead to more witness interviews and more evidence for the case:

- Social media
- Trail cameras
- Fire alert cameras
- News broadcasts
- Security systems
- Dashboard cameras
- Body cameras
- Smartphones
- Vehicle computer-based systems
- UAS (drones)
- Satellite imagery

Special Considerations

There is always the potential for special considerations during a witness interview. Where applicable, the investigator should follow established agency policy in addressing such needs.

Minors. The investigator must follow the law in the jurisdiction and their agency policy regarding interviews with minors. It is a good policy to have another person present as a witness during the interview of a minor.

Follow these guidelines when interviewing minors:

- Use nonthreatening words and body language.
- Do not ask leading questions (i.e., what you want them to say).
- Inquire and document who their parents or legal guardians are, and how they can be contacted.
- Request the parent or legal guardian to be there during the interview if they are present or nearby.
- If the minor admits to starting the fire during an interview, document what was said and contact local law enforcement with the information. Law enforcement will conduct a follow-up interview.
- If criminal intent is determined, the investigation becomes a law enforcement matter.

Victims. Some witnesses may also be considered victims. You should show them empathy and reassure them that the case will be investigated. Do not make any promises you cannot keep. Prior to completion of the interview, you should provide information on victim's rights and resources in accordance with jurisdictional and agency policy.

Non-English-speaking subjects. The investigator will require a translator. Use an agency-approved translator if at all possible, but on-scene family members may agree to translate. Record these interviews to ensure the translation is accurate.

Mentally challenged or neurodivergent individuals require the investigator to get assistance to conduct an interview appropriately.

Opposite gender. Know agency protocol for interviewing persons of the opposite gender. Generally, for men interviewing a female witness, have a second investigator present.

Guidelines and Procedures for Conducting Witness Interviews

- Identify yourself.
- Explain purpose of the interview.
- Always look and act professional.
- Record identification and contact information, including physical and mailing address, contact phone number, legal name.
- When possible, document license plate numbers for vehicles associated with the witness, along with a photo or description of the vehicle.
- If they do not have a phone, ask if there is a person and phone number where you can leave messages.
- Take notes (even if you are recording the interview).
- Ask the witness to tell you what they saw (or heard, smelled).
- Use open ended questions: “Tell me about…”, “Explain…”, “Describe…”, “Show me…”
- Ask witnesses to mentally re-create circumstances—chronologically is best.
- Allow the subject to tell their story without interruption, from start to finish.
- Do not lead the witness in any direction or force them to stay on one subject.
- If the witness gets off track for the specific details of the event under investigation, interject short questions to get them back on the subject.
- Ask the witness if they have photographs or video of the incident.
- Once the witness has told their story through, take the witness back through the story, asking clarifying questions as needed and exploring any new information from the witness or deviation from the first told version.
- Ask specific questions on key points the witness did not voluntarily provide or if you don’t understand a point.
- Consider saying to the witness, “Can you expand on that?” The purpose is to obtain more details in key areas of the interview.
- At the end of the interview ask, “Is there anything else important that we’ve missed or that you haven’t told me about?” or “What else should I have asked you about that I haven’t asked?” and “Who else may have additional knowledge?”

- Ask if the witness is satisfied that they have been understood. Periodically throughout the interview, the interviewer may wish to say, “So if I understand what you are telling me is…”
- Summarize, review, and reaffirm key points.
- Consider taking a witness back to the scene to assist their recall of the event, and use video to record the witness interview.
- Where applicable, have the witness draw a sketch showing where they were in relation to what they observed. Follow this up with witness viewpoint photographs.
- Ask the witness for information within their possession or control, including documents, images, and videos, and ask for authorization to review and obtain a copy of the documents, images, and videos.
- Thank the witness for their assistance.
- Leave your contact information and encourage them to call if they have further information.

Establishing the Witnessed Early Fire Perimeter

The initial focus of witness questioning is on the location of the fire’s perimeter when the witness first saw the fire; this can establish the minimum area of investigative interest (early fire perimeter). The questions are asked to compare (test) the witness observations against the physical evidence of the fire behavior context and macroscale fire pattern indicators. Other questions may and should be asked of the witnesses based on the specific circumstances of each fire, but it is the responsibility of the investigator to first get the data necessary to reliably establish where the on-scene investigation for an ignition area should start.

For a witness who saw the wildfire, these questions can help establish the initial area of investigative interest:

- Where were you when you first noticed the fire or smoke?
- Can you walk me through your movements around the fire? (Follow them, don’t lead them.)
- What color was the smoke when you first saw it?
- What direction did the smoke appear to be going?
- Where did you first see flames?
- Where were you when you first saw flames? (Go there with the witness if possible.)
- Were the flames on the edge of the fire or inside the fire?
- Where was the edge of the fire?
- How much of the fire’s edge could you see?
- Were there flames along the entire fire’s edge that you could see?
- Can you describe the flames along the fire’s edge?
- Which part of the fire’s edge seemed to be expanding the fastest?
- What direction did the fire appear to be moving toward?
- How long did you observe the fire?

- Was there anyone else present at the time you arrived?
- Are they still in the area?
- What were they doing when you saw them?
- Do you know how I can contact them?
- Has anyone spoken to you about this fire other than me? (Other witnesses.)
- What did they tell you?
- What direction was the wind blowing when you first saw the fire? (Compared with smoke.)
- Did the wind change direction at any time while you were present at the fire?
- Can you estimate the speed of the wind when you first got into the area of the fire?
- Did the wind speed change at any time while you were present at the fire?
- What if any actions did you take during the fire?
- Is there anything else you can tell me that would help me understand where the fire's edge was when you first found it or where the fire may have started?
- Did you take any photographs or video of the fire? (If so, can they provide a copy?)

The investigator should be aware that very often witnesses will indicate the location where they saw flames, and they'll have a strong belief that is where the fire started. Keep in mind when questioning about fire size to be specific, otherwise witnesses will likely discuss smoke plume size and flame size. If there were multiple fires, question the size of the smoke columns to help determine sequence of ignition.

Things to Avoid When Conducting Witness Interviews

- Rushing the witness.
- Acting authoritative or overbearing.
- Using leading questions, for example: *"Was he driving a red truck?"*
- Asking compound questions, for example: *"How many people were at the fire and about what time was this?"*
- Using questions that elicit short answers. (The more they talk the more opportunity you have to gain information.)
- Interrupting the witness. (They can easily lose their train of thought.)
- Using negative questioning, for example: *"Do you not understand what I'm asking you?"*
- Leading the witness in any direction or forcing them to stay on one subject.

Chapter 6. Documentation

The purpose of documentation during a wildfire investigation is to produce a true and accurate representation of the investigation with sufficient detail to describe findings and explain conclusions.

The data and documentation from the field forms the foundation for the investigative case file. The major point of emphasis is the need to document what is observed, heard, or done, and maintain the documentation in a readily available location for reference and production later.

Civil and criminal fire cases can span a period of many years. Documentation is a critical process that enables the investigator(s) to refresh their memory and provide testimony. Documentation allows for subsequent investigators to follow-up on the work of others, for expert review of the investigation as well as defense, forensic, and peer review of the investigation.

Prosecutors rely on the documentation of the investigation for almost all their actions in a case. Third-party interests, including citizens who may have experienced damage or harm from the fire may rely on the documentation of the investigation to recover their damages. Administrators use documentation of fire cause and ignition sequence to take administrative, fire prevention, or collection actions.

Terminology

It is recommended that during the documentation process, investigators consistently use the terminology provided in this guide—such as general origin area, specific origin area, and ignition area—in notes, sketches, diagrams, and reports. If a term is not used in the defined context, or if another term is used with which readers may not be familiar, the investigator should define the term in the report.

Forms of Documentation

Documenting the scene falls under five main categories and can occur in various forms:

- Written field notes
- Interviews and statements (recorded and written)
- Photographs, video, metadata, photo logs
- Sketches, maps, diagrams, and measurements
- Written reports

The investigator can use various combinations of these methods to document the scene. The extent to which an investigation will need different types and levels of documentation depends on the specifics of each fire scene.

Case documentation is used to tie the data and facts of the investigation together. Photography includes photos, attached metadata, and photo logs. Sketches are rough in nature and serve to orient the reader and document locations of items of interest. Sketch and diagram documentation can include photo points, fire pattern indicators, fire progression vectors, evidence locations, and measurements.

Field notes will form the basis for any final written report and can be supported by photography, sketches, witness statements, etc.

When practical, start documentation immediately rather than trying to re-create what happened.

Maintenance of field notes may be an agency policy or specific practice. Follow agency or practice regarding retention of field notes.

Field Notes

The taking of field notes is an ongoing process that includes information associated with all five categories of documentation. It begins with the receipt of the assignment and continues past the field work and may include a timeline of actions and events. Retain all field notes in accordance with agency policy or regulations.

Items that the investigator may document in field notes during the receipt of assignment include:

- When the investigator was first called
- Who provided the notification of the assignment, how it was done, and what initial information was given
- When the investigator responded and how long it took them to respond
- What route they took in responding
- Upon arrival, what was the investigator’s assignment and who gave it
- Time the fire was first reported
- Reporting party name and contact information
- Witness information
- First responder resources at the scene

Notes should be:

- Readable and understandable to anyone who may need them. Avoid abbreviations that may not be clear to all readers.
- Brief – Use short sentences or phrases. Avoid long, rambling sentences that could confuse a reader.
- Descriptive – Use words to paint a detailed picture. For example, write “burned match” rather than “burned object.” When possible, supplement the description with sketches.
- Accurate with complete details of times, dates, names, addresses, weather conditions, scene description, and physical descriptions of vehicles and property, including serial numbers and license plates. Also include map locations and measurements.
- Factual – Free of personal opinions or conclusions not based on the data.
- Complete – Answer the who, what, when, where, why, and how. Ensure it includes the investigator’s, name, date, and incident number.

Upon assignment. Obtain as much background information as possible from the dispatcher. The location may dictate the need for specialized equipment. Record the day, date, and time of the fire. Identify the reporting party and contact information.

Determine what your authority is and the scope of work. Do not assume any authority beyond the required objective.

En route to the scene. Be cognizant of radio traffic concerning fire location, access, behavior, size, direction of spread, and other pertinent data.

Upon arrival at the scene. Basic functions commonly performed in each wildfire investigation include:

- Coordinating the overall investigation
- Observing conditions of the fire area:
  - suppression activity
  - access and egress routes
  - gates
  - vehicles
  - activities in the area
  - smoke column and color
  - size of fire
  - direction of smoke drift, wind conditions
- Examining the fire pattern indicators
- Searching the scene
- Developing documentation
- Interviewing witnesses
- Collecting and preserving evidence

An investigative team should be briefed on the objectives of the investigation, who will be responsible for completing the associated tasks, the condition of the scene, and safety precautions required.

As soon as possible, the investigator should take weather readings to provide the most accurate weather conditions at or near the origin of the fire, nearest to the time of ignition. Don't rely on suppression crews to provide this information. It may be helpful to also take wind and other weather readings along ridgelines near the ignition area to provide data for large-scale progression of the fire and ridge wind conditions.

The investigator should document the location where weather readings are taken using GNSS or other means (i.e., Global Positioning System [GPS] in the northern hemisphere). The value of on-scene weather readings may diminish as time passes after the fire's ignition. The investigator should take weather data on-scene even when they arrive later. This later data may be representative and/or may be used to compare to RAWS to determine which station may be most representative of conditions occurring at the scene.

Ensure arrangements to secure and preserve the scene until the scene is released. The investigator should know their legal authority to access the scene if it is not on public property.

The investigator should arrange the method for securing the fire scene that best fits the specific conditions—running barrier tape, positioning security personnel, or instituting closures that restrict access. Document the security provisions in the field notes.

The investigator may want to maintain a scene log that records all personnel who enter and exit the scene.

Document the types of activities that have taken place within the secured area and how these activities impacted the fire progression and fire patterns.

Once the general origin area has been identified, document the methodology for examining in field notes and include details of precise procedures used to find indicators and search patterns employed. This will continue to be documented as the specific origin area and ignition area are identified and processed.

Field notes for the general origin area, specific origin area, and ignition area should include indicator categories identified, exemplar indicators used, evidence located, and localized fire behavior signs or indications. There is no set sequence of when the general origin area is to be documented. Some investigators may prefer to document (photo, measure, sketch, etc.) the indicators as they find each one; some prefer to locate all the indicators then go back and systematically document them. The first sequence should be considered if there are specific concerns about potential destruction of the indicator(s) and there is no reason to believe that the ignition area will be disturbed during the delay caused by the documentation process.

The second sequence allows for the selection of the best indicators once all the indicators have been identified and allows for reaching and protecting the ignition area sooner. This option permits the investigator to visualize the totality of the scene before photographing.

The fire investigator may want to consider lighting conditions when taking photographs of indicators and time the sequence of photo documentation when the best light is available or take more than one set of photographs.

Interviews and Statements

Forms of documentation for interviews and/or statements include:

- Notes
- Written statement (signed)
- Recorded interviews
- Memorandum of interview
- Video
- Supporting documents

Notes pertaining to an interview, along with any audio and video should be retained per agency policy. Consideration should be given to taking physical notes along with audio recordings in the event the audio fails.

Investigators may take a written statement by the subject, which can be combined with an interview summary to document their recollection of the interview.

All the items referenced above become part of the investigative case file.

Sketches

Sketches created in the field as part of the scene documentation are used to enhance and illustrate field notes to better refresh the investigator’s memory when preparing the final report. The investigator should be clear as to what the sketches illustrate and ensure that they are reasonably accurate.

The complexity of the scene and investigation will influence the number of sketches that may need to be created in the field.

Separate sketches may include:

- Fire progression
- Location of fire pattern indicators
- Photo points
- General origin area
- Specific origin area
- Ignition area
- Areas of interest
- Evidence locations
- Landmark features
- Reference points

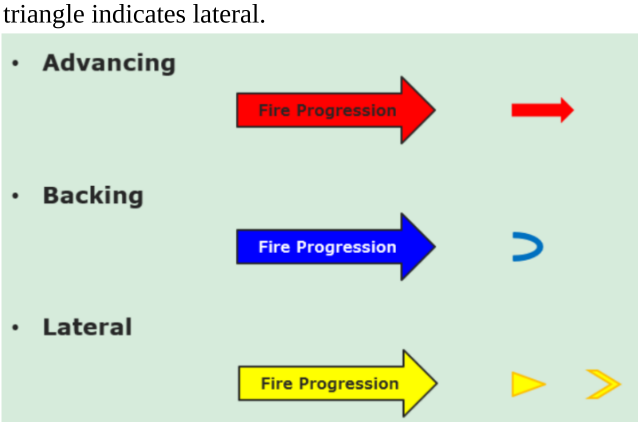
Sketches should be oriented north, where possible, and include a north arrow. They should bear the date and time, name of creator, the incident identifier, and a note indicating the sketch is not to scale.

Consider using a scene sketch during witness interviews to help understand and document the witness's explanation of what they observed. The sketch used or created during the interview should be initialed, dated, and kept as an attachment to the report.

A fire progression sketch portrays a generalized progression of the fire spread and not individual fire patterns. It should include an outline of the general origin area boundary and landmarks for orientation and to refresh memory. It should also show the specific origin area and the ignition area and their measurements.

Map the general fire progression using recommended symbols shown in figure 6.1.

Figure 6.1. Recommended symbols for fire progression. A blue capital U identifies backing, a red arrow identifies advancing, and a yellow V or a yellow solid filled inverted triangle indicates lateral.

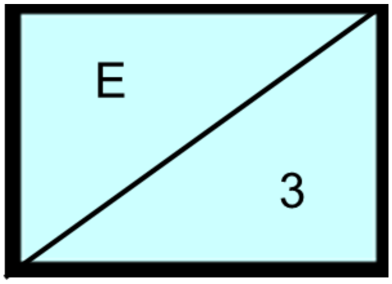


Sketches should be completed at the scene, but the symbols do not necessarily need to be in color on the sketch.

Evidence sketches and other documentation may be needed depending on the number of evidence items.

Documentation could take the form of sketches, diagrams, lidar, orthophotos, etc. Shooting range fires and roadside fires are examples of areas where multiple evidence items are likely to be present and may require a separate sketch for evidence. Evidence should have its own symbol used on sketches and drawings.

Figure 6.2. Example of an evidence symbol.



Document evidence locations both inside and outside the general origin area. Document relevant items, not just what you think started the fire. Ensure proper evidence handling, both during the documentation and the collection phase. Whenever possible, document the evidence in place before collection using photographs, sketches, and notes.

Reference points should be documented on each sketch. These are used in correlation with field measurements to show relationships between items of interest on the scene.

Mark reference points in such a way that their location can be used to re-create the scene later. This can be done by noting latitude and longitude and photographing each reference point. A metal object, such as a large nail, placed in the ground can be located later using a metal detector. Figure 6.3 shows the suggested symbol for reference points on sketches and diagrams.

Figure 6.3. Reference point symbol.

Measurement Techniques

Three basic methods of measurements—right angle transect, compass measurement, and triangulation—enable the investigator to select the method best suited to the slope, size of the area, vegetation, and obstacles.

Measurements may be written directly onto the sketch map, but it is recommended that a measurement log with reference points be created on a separate sheet of paper. Add the measurement method used to the legend of the sketch map.

Right angle transect measurement involves these steps:

- Step 1. Select and mark two reference points on either a north-south (N/S) or east-west (E/W) line. Label them RP-1 and RP-2, as appropriate.
- Step 2. Measure and document the distance between the two reference points.
- Step 3. Standing at RP-1, if not on a N/S or E/W line, document the compass bearings to the other reference point(s).
- Step 4. Lay one tape measure out between the two reference points on a N/S or E/W line.
- Step 5. Use a second tape measure from the object to be documented back to the first tape measure, ending at a point where a right angle is made by the intersection of the two tapes. The right angle will be formed at the shortest distance that can be measured between the object and the first tape.
- Step 6. Take a measurement along the first tape from one of the two reference points to the intersection of the second tape, for example, RP-1, 18’ 4” W.
- Step 7. Document the direction the measurement is taken—for example, use two reference points on an E/W line, with RP-1 at the east end and RP-2 at the west end. A measurement from RP-1 toward RP-2 of 18 feet 4 inches would be recorded as 18’ 4” W.
- Step 8. Document what side of the E/W line the object is on in relationship to the transect between the two reference points. In the case of reference points on an E/W line, the object(s) can only be north or south.
- Step 9. Combine the two measurements and the cardinal direction as the coordinates for this object—18’4” W/10’6” S. The entry of these measurements in a table should include the indicator number, the reference point number, and the cardinal direction and coordinates.

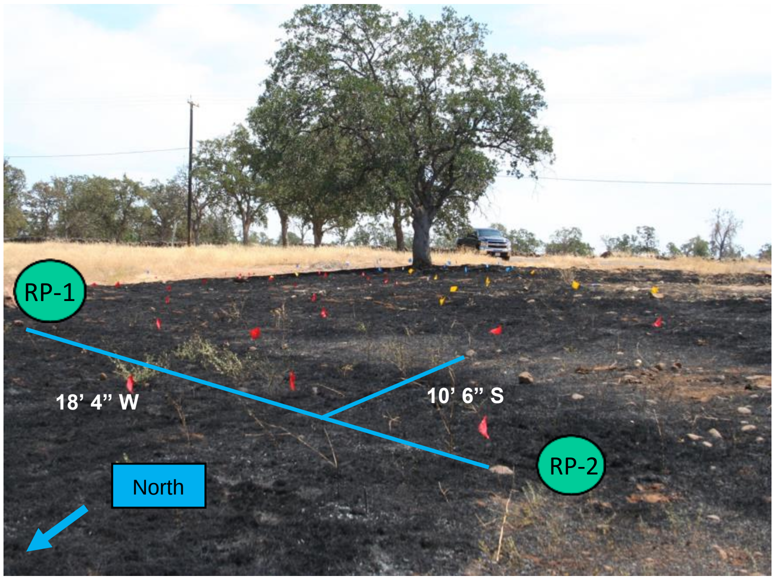
Figure 6.4. Location of indicator 12 using the right angle transect method.

Right Angle Transect			
Indicator 12	RP-1	18’4” W	10’6” S

Using a measurement table may take the place of having to place each indicator or item of evidence on the sketch map. By using the measurement table, the investigator will have all the necessary data to create a diagram showing indicators or other pertinent points if the reference points can be accurately located.

Measurement detail should be to the precision of the tape measure.

Figure 6.5. Example of a right angle transect.

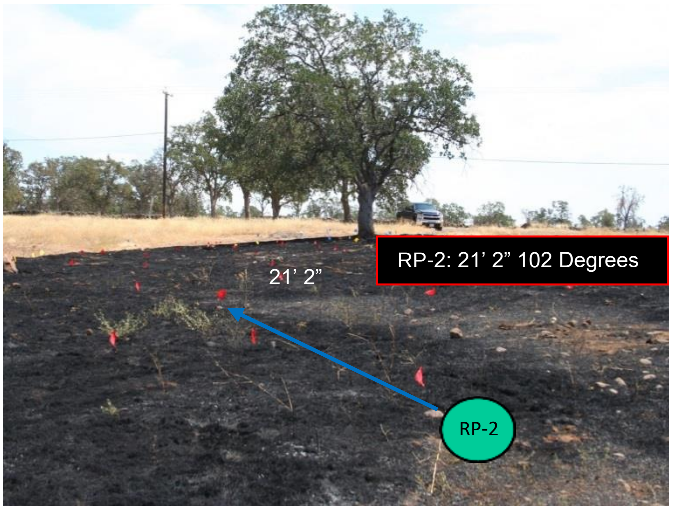


Compass measurement technique. The compass measurement technique is useful for measurements at a scene that does not have many obstacles. This method may be difficult on steep ground and in heavy brush or timber.

The method uses a single reference point that should be marked in a way that it can be identified and located later, for example, nail, rebar, or paint. The investigator needs to record the compass declination used. This method relies on the ability of the investigator to take generally accurate compass readings. If the investigation requires greater accuracy, another measurement method may be more appropriate.

- Step 1. Select and mark the reference point to be used.
- Step 2. Set the compass declination or set at zero and note this in the field notes.
- Step 3. Take a position over the reference point or place a compass rose at the reference point.
- Step 4. Using a tape measure, measure from the reference point to each item, recording both the compass reading and the distance to center mass of each item, using the units on the tape measure (feet/inches or meters/centimeters).
- Step 5. Enter the measurement into field notes, for example: RP-2: 21' 2", 102°.

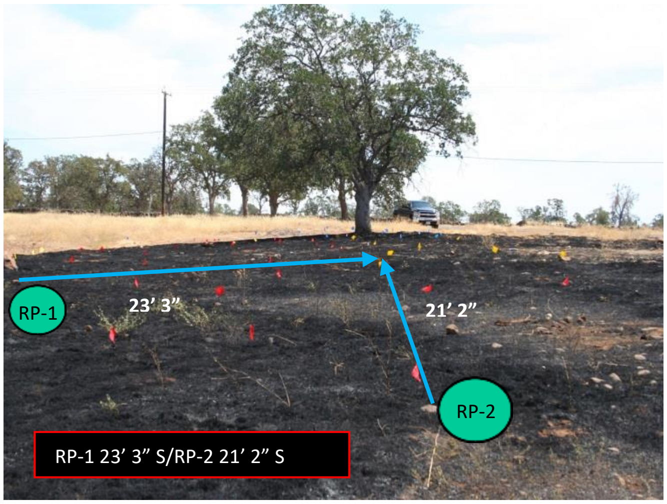
Figure 6.6. Example of a measurement taken using the compass measurement method.



Triangulation. The triangulation method can be difficult on steep ground and in heavy brush or timber. It relies on a measurement from each of the two reference points forming two sides of a triangulation. The known distance between the two reference points is the third side. The two measurements from the reference points to a common point can only exist in two locations, one on each side of the line between the two reference points. It is important that the investigator specify the cardinal side of the reference point axis.

- Step 1. Select and mark two reference points on either a N/S or E/W line. Label them RP-1 and RP-2, as appropriate.
- Step 2. Measure and document the distance between the two reference points.
- Step 3. Standing at RP-1, record the compass bearings to other reference point(s), if not on a N/S or E/W line.
- Step 4. Measure from one of the reference points to the object and document the distance in your notes, for example, RP-1 23' 3".
- Step 5. Measure from the second reference point to the object and document the distance in your notes, for example, RP-2 21' 2".
- Step 6. Document on which side of the reference point line the object is located—so if the reference point line runs from east to west and the object is located to the south side of that line, enter S behind the measurements in the notes.

Figure 6.7. Measurement taken using triangulation.



Advanced methods of measurements can go beyond the capabilities of a tape measure or compass. These include:

- Light detection and ranging (lidar)
- Digital photogrammetry
- High-precision global navigation satellite system
- Satellite

Diagrams

Not every fire investigation requires a formal diagram(s). The investigator and agency determine if a diagram is needed in support of an investigation.

A diagram, whether hand-drafted or computer-generated, is oriented to north, created to scale, and contains a scale bar and legend. The incident name or reference, the date created, and creator's signature should also appear. The investigator may create diagrams using available software or the task may be handled by surveying and mapping experts.

The representative fire pattern indicators (those documented by photographs and measurements) should be accurately plotted.

The situation may require separate diagrams showing fire progression, photo points, evidence, etc.

Global Navigation Satellite System (GNSS)

GNSS technology—employing either professional or handheld devices—can be used to record certain types of data, including position measurements.

The positional accuracy of handheld models is affected by such factors as model, post-processing of data, satellite availability, and canopy cover. The range of accuracy on a typical handheld varies. Newer models will provide an accuracy reading for each position; document these accuracy readings and the data setting.

Figure 6.8. Field use of GNSS.

It is recommended that the GNSS readings be backed up with measurements to reference points for validation and orientation.

The GNSS area calculation function may be helpful in documenting the size of the area that the investigator walked to determine the general origin area size.

Most smartphones have GNSS capability that can be used in the same way as a handheld GNSS unit.

Photography

Investigators should understand the operation and limitations of their camera and equipment. Before beginning any shoot, ensure the camera is set up to efficiently and accurately record the data.

> There is no standard addressing how many photos should be taken to document a scene. The investigator should consider how photos are intended to be used and how many photos are needed to reproduce for others the items being portrayed.

- Format the memory card before beginning investigation photos.
  - Eliminates the possibility of unrelated photos being on the card.
  - Sets the first photo to be *0001*. Follow agency policy on resetting the photo file numbers.
  - Ensures the memory card is compatible with the camera function.
- Confirm the correct date and time on the camera(s).
- Consider taking the first photograph to show an official time, as from https://www.time.gov/ on a smartphone, or just the smartphone's date and time stamp.
  - A standardized photo card with date, time, fire name, and photographer may also be used.
- Note any difference in time settings, particularly if traveling across time zones. (PST, MST, CST, etc.)
- Check the picture format—use jpeg or RAW format for picture quality, file size, ability to enlarge and show sufficient detail.
  - Be aware that RAW formats will take more memory and can only be viewed with proprietary software.
- Consider adding each investigator’s initials to the photo number to reduce the confusion of multiple investigators taking photographs (for example *0001* would become *AWC0001*).

Storing Digital Photos

Follow agency policy when storing digital photographs. If the agency does not have a policy, consider the following:

- Be aware of auto-load software effects on the image files.
- Do not open or delete original photo files (even if they are of poor quality).
- If possible, copy files directly from the camera card to a storage medium.
- Secure the first downloaded copy as the original.
- When appropriate, store a second copy as a backup.

Photo Log

Include the following components in the photo log:

- Incident name/number
- Camera used and time stamp corrections as needed
- Name of photographer
- Name of investigator
- Date
- Location
- Data
- Photo identification number—use an appropriate image number system
- View direction (N, NW, ENE, etc.)
- Vector (advancing, lateral, backing)—explain if more than one vector is present in a photo
- Category of indicator (staining, angle of char, protection, etc.)
- Direction of fire travel in the photo
- Photo point coordinates if needed
- The general description of what is shown by the photo

Additional Photographic Documentation

As each fire investigation is unique, there may be additional opportunities for taking photos or video at various times during the investigation.

En route photos. This may depend on the time of response and purpose of the photo. For example, if the investigator is responding promptly, the en route photos may show fire progression, evidence, condition of access (open or closed gates), and activity in the area.

Arrival photos. At a fire scene, people and objects are generally mobile, powerline equipment can be burned up or removed by power company crews, heavy equipment can be moved to other sites or parts removed, witnesses may walk or drive away. Photos can assist the investigator in quickly documenting the presence of certain people and things during a period when time is short and workload is heavy.

Upon the arrival on the fire scene, the investigator should try to document fire behavior, both near the heel of the fire and overall. Take photos of macroscale fire pattern indicators and suppression activities taking place. Photograph physical evidence subject to degradation as it is observed.

Scene orientation/overview photos serve as big-picture documentation of the scene or other points of interest and are generally taken from a distance, either from a ground vantage point or from the air. They portray the integrity and relationship of the scene to the overall environment and terrain.

These overview photos can be used during testimony as exhibits; explanatory symbols can be added as appropriate. They may form the basis for visually showing the macroscale fire pattern indicators and their relationship to the specific origin area, physical evidence, or other points of interest.

After the general origin area has been identified and before entering, photograph and/or video the general origin area itself and the area immediately surrounding it.

This process may be incorporated into the walkaround and may include multiple views of the entire surrounding area and views into the general origin area from the perimeter. The investigator should attempt to cover the area with photographs so that multiple perspectives of most areas can be reviewed to compare opposite sides of larger objects.

Relationship or comparison photos illustrate the relationship between various items, normally taken at medium range, and show specific views of the subject matter.

As the investigator is working the scene, they may take relational photos to document features and activities near the general origin area. This can include the location of highways, railroads, trails, dirt roads, skid trails, structures, lookouts, etc. A single photo that shows train tracks and the fire near the tracks is preferable to two separate photos, one showing the tracks and the other showing the fire.

The investigator should photo document fuels in and outside the burn area. If possible, get photos that portray both the burned and unburned fuels in relation to each other. Taking photos of actively burning areas that are representative of the general origin area may be helpful.

Evidence markers may be used to show locations of evidence and other important items in relation to the overall scene and other items. Evidence markers provide better visibility of smaller items when taking orientation photos of the area. Detailed photographs should be taken of each evidence item, without an evidence marker and again with the marker.

Identification photos show the details of a specific item of evidence, such as tire or shoe impressions, sources of ignition, samples and comparison samples, fire pattern indicators, or other important items. These photographs are taken close up for detail and are supported by the orientation photos of the same items. These photographs should be examination quality to record evidence that may be scientifically examined through the photograph itself. Examination quality photos also allow for documentation of fragile evidence items that may be destroyed during removal or packaging (e.g., a match head)."

Evidence collection should be documented by photos.

Fire Pattern Indicators

The job of the investigator is to identify and document enough fire pattern indicators to provide a reliable and consistent direction of fire progression.

While the investigator may observe many fire pattern indicators within a small area, the objective is to select the best of these indicators for documentation through flagging or marking. The selection should incorporate a variety of indicator types, reliability of indicator within the given conditions, and consistency. Subtle indicators, while more difficult to photo document, should be included. These subtle indicators may support lower intensity burning consistent with areas closer to the specific origin area.

Document a representative sample of indicators that have been flagged or marked. The sample should include at least one of each category of fire pattern indicator used in each area, The investigator should use their experience and judgment to determine how many fire pattern indicators need to be documented.

For example, the investigator may have placed pin flags on 250 individual fire pattern indicators. Documenting all these indicators may be unnecessary; however, a representative sampling sufficient to illustrate overall fire progression should be documented.

Where possible, include examples within each of the fire progression vector zones.

The fire pattern indicators will need to be documented in such a way that a qualified individual will be able to review the report, observe enough of the indicators documented, and be able to see that the investigator was appropriately interpreting each indicator.

Documentation of Fire Progression

Photographs of fire pattern indicators showing fire progression are enhanced using visual aids such as flags and direction/vector symbols. Other aids, commercial or homemade, can help to present the message in each photograph. Many of these aids assist in the photo documentation of fire pattern indicators and provide information such as direction of fire spread, orientation to north, and evidence number.

The investigator should avoid using symbols or methods that may contaminate or damage the fire pattern indicator.

> This document recommends the use of colored pin flags, a method that is designed to provide a reader of the report with a way to visualize the progression of the fire.

Photo documenting fire pattern indicators. Generally, a series of photographs are taken that include overall, midrange and closeups. When taking photographs of fire pattern indicators, the investigator should select the most representative indicators to document within each category.

Figure 6.9. Documentation of a representative fire pattern indicator.

A recommended procedure for photographing each selected representative indicator is as follows:

- Step 1: Take an overall photograph of the indicator with the color-coded flag. This photograph establishes a general overview of this particular indicator. A number indicator, a north arrow, and an arrow indicating the direction of fire travel may be included.
- Step 2: Take a midrange photograph of the indicator.
- Step 3: Take closeup photos of the indicator from each side.

When photographing representative fire pattern indicators document:

- Direction camera is pointing
- Fire vector
- Representative fire pattern indicators for all three vectors

- Fire progression
- Photograph location, which may be available in the photo metadata
- General description for each photograph

Evidentiary photographs. Evidentiary photographs assist the investigator with detailed images of items that are packaged and stored in an evidence facility. These photographs are taken closeup, with a scale that is designed for evidence photography.

The ability to examine photographs will eliminate the need to open evidence packages, repackage, and create additional documentation of the procedure.

It may be useful to photograph distances as they are being measured. This will aid in putting those measurements into perspective and will also assist in refreshing the memory of the investigators during later testimony, while providing visual evidence of the methodology used.

Photo documenting general origin, specific origin, ignition areas. The investigator will often be asked to describe the ignition area, specific origin area, or general origin area boundaries. Indicating the boundaries with flagging or other reference material can enhance photographs of these boundaries.

Photo documentation of exhibits. Photo exhibits can play an important part in the documentation and presentation of the fire investigation. When taking photos, consider what photos could be useful in explaining the investigation.

Aerial photos taken to document the larger scale fire scene, fire damages, and threats to homes or other property can support the serious nature of the fire and may be used both in the judicial system and in the administrative role of fire prevention presentations.

Report

The role of the investigator is based on agency policy, resources, and the specific circumstances of the incident, among other factors. The investigator must be clear about their responsibility and authority for each assignment and recognize that it may change over the course of an investigation.

Similarly, the contents and extent of the file depend on agency policy, the investigator's role, and the particular case. The file should include the documents and materials that support the investigation, origin location, cause, or other important facts of the case, including all photographs, videos, recordings, etc.

For example, the investigative case file can include hard and/or electronic copies of the following materials:

- Origin and cause report(s)
- Interviews and statements
- Investigative notes
- Sketches, diagrams, measurements
- Maps
- Weather data
- Miscellaneous reports and documents (i.e., forensic, expert, other agencies)
- Chain of custody and/or evidence logs

Correspondence, including emails and texts, should be retained per agency policy.

Origin and Cause Report

The origin and cause report forms the basis for investigator testimony and becomes an attachment to the final case report. The report format is specific to the agency or prosecutor.

Investigators must remain open to any new pertinent data that is developed, even after the investigation report is submitted. This new data may change the investigator's opinion, or it may not. The new data may strengthen the final hypothesis, or it may call it into question.

The placement of a disclaimer in a report is common practice by many experts. It simply reflects the realities of a systematic scientific investigation. Check with agency legal staff regarding any questions about the inclusion of such a disclaimer or its preferred wording. The following is a common version of such a disclaimer: *"I reserve the right to change my opinion or conclusions based on any additional data received."*

The origin and cause report should:

- Use a narrative format.
- Tell the story from start to finish in the order in which the fire events occurred.
  - What was the fire behavior context?
  - What fire pattern indicators were relied upon?
  - What evidence of the cause was located and collected?

Narrative Section

The investigator documents in the narrative the methods used, within the framework of the scientific method, that led to the basis for their expressed opinions.

The narrative section of the report can be organized in the following format to aid in the chronological documentation of the complete investigation:

- Dispatch and response to incident
- Arrival on scene
- Methodology and data collection
- Data analysis
- Origin working hypotheses development
- Origin hypotheses testing
- Cause working hypotheses development
- Cause hypotheses testing
- Conclusion/selection of final hypothesis

Avoid using copy/paste language in the report, which detracts from the uniqueness of each fire investigation and report.

1. Call and response:

- Time of call and response
- Dispatch information/data gained
- Assignment and instructions

Example: *At 2:35 PM, I was contacted by the Wildfire Dispatch center and assigned to investigate the origin and cause of the North Fork Fire. I responded from my office at 2:47 PM. I traveled to the fire scene by way of … The dispatch center provided me with the following information… I observed the following en route.*

This portion of the narrative serves to introduce how and when the investigator became involved in the specific fire investigation and the responsibility and authority of the investigator. It also provides initial information about the fire received during the dispatch and/or response, which can include the fire's size and location, other resources assigned, initial reports from the reporting party and first arriving responders, etc.

2. Arrival at the scene, preferably presented in chronological order:

- Time of arrival and location
- Location and perimeter of fire
- Surrounding area
- Activities taking place
- Observed fire behavior
- Security in place (or not)
- Witnesses
- Data collected (weather, statements etc.)

3. Methodology and data collection:

- Witness statements and interviews—suppression personnel, law enforcement, reporting party, civilian witnesses
- Fire behavior context
- General origin—describe investigator's actions in detail
- Specific origin—describe investigator's actions in detail
- Ignition area—possible ignition sources
- Documentation—evidence, sketches, and photos
- Other observations and sources of information—weather, lightning data, 911 call logs, etc.

The methodology of the investigative plan and the data collected should be documented.

The investigator should document the findings for any witness information and detail how that is incorporated into the fire behavior context. This information will transition into the description of how the investigator was able to locate the general origin area. The narrative section should include the identification of an advancing area, lateral transition zones, and macroscale indicators.

Written documentation of macroscale indicators can be linked to photo documentation, helping the reader to visualize the actual items. Once the methodology and data associated with determining the general origin area are documented in the narrative section, the same process can be repeated in documenting the specific origin area and ignition area.

If the investigator left the scene at some point during the investigation, the report should include information on the time of absence and scene security during that period.

4. Data analysis and application:

Once the methodology and pertinent data have been documented chronologically, the investigator should describe the process and result of data analysis. This will include the validating of data as reliable—not rumor, conjecture, or speculation—and giving meaning to the data.

During this step of the report writing, it may be important to document why certain data was rejected and why other data was determined to be pertinent and reliable.

The narrative may explain the meaning of the data and how it contributed to the fire's ignition and spread.

5. Working hypotheses development:

Document a hypothesis for each possible ignition area and cause, supported by the data and facts. The investigator should be able to describe the working hypothesis(es) and how they were developed based on the available data and facts.

Example: *Smoking. The fresh cigarette butt found adjacent to the specific origin area was discarded while still burning and ignited the surrounding dry grass.*

6. Hypotheses testing:

Describe how each hypothesis was tested.

Example: *Lightning. An internet search of lightning databases showed no lightning strikes in the vicinity of the fire's area for the previous two-week period. During this same time, no witnesses identified any evidence of lightning activity. No physical evidence of a lightning strike was identified in the ignition area of the fire. Therefore, lightning is excluded as a potential cause of the North Fork Fire.*

Once working hypotheses have been identified in the report, the narrative section should reflect the process, including the specific data/facts that led to a rejection or acceptance of a hypothesis. If published research is used to test a hypothesis, it needs to be referenced and cited in the report. The investigator should consider any limitations of the research and how the research applies to this specific hypothesis. If physical testing is conducted, the report should reflect the materials, methods, steps, observations, and measurements.

In the case where only one working hypothesis was supported by the data or facts, the narrative should reflect why the lone hypothesis was not rejected by any part of the data or facts.

If the sole working hypothesis does not explain all the pertinent data or facts, the investigation should result in a finding of undetermined, or actions should be taken to gather further data or facts for consideration of alternative hypotheses.

While the investigator or investigative team may conduct initial testing of the working hypotheses, further documentation of additional testing may be included into the case file later. In that situation, the investigator may submit an amended opinion and report addressing the further testing of the hypotheses.

In some cases, the narrative section may reflect that the data or facts support multiple working hypotheses. In such a case, the report should address the data or facts relied on that raise one of the hypotheses to the level of probable over alternative hypotheses that only reach the level of possible. If no working hypothesis is supported by the data or facts to the level of probable, the report should reflect the conclusion that multiple hypotheses are possible and that until further data or facts can be reviewed, no conclusion as to origin or cause (or both) can be made.

7. Conclusion/selection of final hypothesis:

This section describes the ignition source, material first ignited, and the ignition sequence.

Example: *On August 14th, 2023, Mr. Smith lit a fire in his burn barrel. He did not place a screen on the barrel to prevent the escape of embers and had not cleared flammable grass and vegetation from around the barrel. In addition, Mr. Smith did not stay to watch the fire and he did not have tools or water available to put out the fire. A burning ember was lifted out of the burn barrel by hot gases and landed in the dry grass, igniting it. The fire then spread from Mr. Smith's property to the surrounding forest, causing the West Canyon Fire.*

The conclusion of the report should be based on the data that have been articulated in the previous narrative, including references to attachments and supporting documentation. Once the investigator writes their conclusion in the narrative report, they should review the narrative report to see that by the time the conclusion is reached, the reader understands the methodology used, data/facts collected and analyzed, working hypotheses considered, and the data/facts that support the conclusion and opinion of the investigator(s).

Summary

The person responsible for the case file will include the origin and cause report in the case file, along with all other pertinent information.

The investigative case file is the compilation of all investigative documentation not just the final report or origin and cause report.

Chapter 7. Ignition Factors and Sources

Fire Cause Determination – General

The objective of every wildfire investigation is to determine the origin and cause of the fire. The assignment can be challenging because the investigator may be looking for something quite small within the burned area. This makes a systematic approach, as recommended in chapter 3, Methodology, very important.

“For forest fuels, the ignition temperature has been reported to be as low as 400 °F (204 °C). However, ignition temperature of fine forest fuels is influenced by multiple variables, such as fuel size, type, density, and moisture content” (Gonzales 2008).

A competent ignition source is any item that can produce sufficient heat over a sufficient duration capable of bringing the first fuel ignited to their ignition temperature to sustain open flame combustion. This means that the ignition source must produce enough heat to raise the fuel to its ignition point under the conditions present at the time and location of ignition.

Sometimes the ignition source will remain at the ignition area in recognizable form, whereas other times the ignition source may be altered, destroyed, consumed, moved, or removed.

Figure 7.1. Photo of a match used as an ignition source.

The ignition sequence is the existing conditions, subsequent actions, and sequence of events that bring a competent ignition source into contact with the materials first ignited, also known as the cause of the fire. The ignition sequence is made up of three ignition factors:

- A competent ignition source
- The type and form of the first fuel ignited
- The circumstances or human actions or natural events that allowed the factors to come together

For example, in figure 7.2, the conditions are a burn barrel without a screen or clearance, adjacent vegetation, dry vegetation consistent with warm and dry weather, and slope.

The sequence of events or actions include ignition of the material in the barrel, airborne embers, and failure to attend.

Figure 7.2. Photo of a burn barrel ignition source.

Ignition Source Location

Ignition sources such as matches, cigarette remains, and flat metal fragments tend to remain on the surface of the ash, while ignition sources such as welding slag, exhaust particles, and large metal fragments will be found under the ash. The primary point is that an ignition source may be found at any level and any search for such ignition sources should take this into account.

The material first ignited is the host fuel bed the ignition source first contacts and sustains combustion. These are generally made up of 1-hour fine dead fuel moisture category fuels with high surface area-to-volume ratio.

General Investigative Techniques

Each fire scene is unique and will require its own specific techniques. However, there are some common techniques that should be considered on most wildfire investigation scenes:

- Locate and interview witnesses and reporting parties.
- Examine physical evidence that may support witness statements.
- Document the on-scene weather and the method used to obtain the weather.
    - If a RAWS is used, document the distance and elevation differences between the station and the origin.
- Collect and analyze the data to determine if a working hypothesis can be formed. Document these findings to include or exclude the cause.

- Fully document with photographs, sketches, and diagrams.

Fire Cause Categories

The following categories (NWCG 2021) are used to describe various general causes. If applicable, use the agency's cause category, as appropriate.

- Natural
- Undetermined
- Debris and open burning
- Equipment and vehicle use
- Firearms and explosives use
- Fireworks
- Power generation/transmission/distribution
- Railroad operations and maintenance
- Recreation and ceremony
- Smoking
- Misuse of fire by a minor
- Arson
- Other causes

Categories may vary by agency. Investigators should be familiar with their agency cause categories.

This section defines each of these fire cause categories and includes discussion of:

- Ignition factors—the conditions, actions and events
- Circumstances—evidence or things typically associated with the cause, including potential ignition source remains
- Investigative techniques—specific investigation methods that may assist in establishing evidence of the cause.

Natural

Two natural causes of wildfires are lightning and volcanic activity.

Lightning

Definition: Any wildfire started because of lightning activity. Lightning detection maps are a significant tool in suspected lightning-caused fires.

Ignition factors: Lightning is discharged static electricity associated with thunderstorm activity. According to the National Weather Service, the temperature of the air in the lightning channel may reach as high as 50,000 °F (27,760 °C), five times hotter than the surface of the sun. Immediately after the flash, the air cools and contracts quickly.

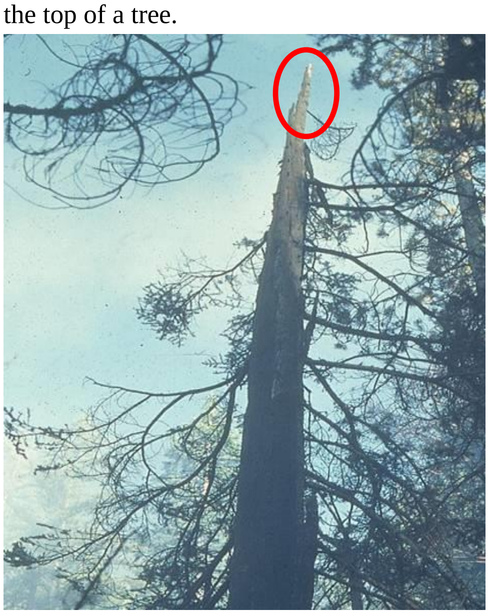
Circumstances: The circumstances indicating a possible lightning strike as a cause includes recent electrical storm (hours/days/weeks) activity in the area, the presence of indicators of holdovers, scarring on trees or snags, precipitated sap, needle shower, ballistic penetration of adjoining vegetation by needles and small twigs or splinters, blowholes at base of tree, fulgurites, and splintered wood or vegetation.

Figure 7.3. Examples of lightning activity as possible ignition source.

After a fire, lightning-struck trees may no longer be standing, and investigators will need to examine tree remains on the ground, along with those still standing.

Indications of a lightning strike in the tops of trees include a spike top or blunted snags with no visible scar, tops of trees that are blown off and scattered, charring in the top of the tree, needle shower, and/or other visible damage.

Figure 7.4. Example of lightning strike in the top of a tree.



Lightning may strike low vegetation and small trees, which can result in splintered limbs (fig. 7.5). Strikes directly to the ground may result in blowholes, fulgurite formation, disturbed soil, and shattered rocks.

Figure 7.5. Example of lightning strike on low vegetation.

A lightning-caused fire may smolder undetected for several days, weeks, or months after a lightning strike, before transitioning to a sustained flaming front. For this reason, the investigator should look for the presence of fuels capable of holding smoldering fire for an extended period.

Look for blowholes or disturbed soil at the base of trees as shown in figure 7.6.

Figure 7.6. Examples of lightning-caused blowholes or disturbed soil.

Fulgurites generally occur in soils with a sandy component to them. They can be created by electrical discharges into the ground or rock. Lightning strikes heat the sandy particles and fuse the soil or rock at the location. Fulgurites generally resemble fused glass but may have a sandy or rough exterior. They are usually hollow and branch-like and can be fragile, so careful recovery is necessary.

Figure 7.7. Size of fulgurites compared to a quarter.

Figure 7.8. More examples of fulgurites.

Investigative techniques:

- See general investigative techniques.
- Inquire if witnesses observed lightning or storm activity in the fire area. Have them recall dates and location of sightings.
- Obtain and review lightning detection maps and data.
    - Extend this analysis to 30 days or more if weather or fuel conditions warrant.
    - Consider using multiple sources to obtain data since the accuracy of lightning detection maps and data can vary depending on sensor locations.
- Use binoculars or spotting scope to examine tops of tall trees.
- Conduct searches for macro and micro effects of lightning. Examples include spiral bark rips, freshly precipitated sap, and needle showers.

- On suspect tree(s), inspect the root collar area and the integrity of roots near the surface. Look for discolored tissue, swollen girth, or separated structure.
- Examine suspect contact points for fulgurites or other similar effects related to the fusing of soil particles or rock by lightning.
- Fully document lightning damage by photographs, sketches, and diagrams.

Several different lightning detection systems operate throughout North America and can provide further data, if appropriate.

Volcanoes

Definition: According to the U.S. Geological Survey (USGS), volcanoes are openings or vents where lava, tephra (small rocks), and steam erupt onto the Earth's surface. Volcanic eruptions can last days, months, or even years.

Figure 7.9. Redoubt volcano with minor ash eruption. Photograph taken during observation and gas data collection flight, March 30, 2009. U.S. Geological Survey photo.

Ignition factors: Volcanoes can directly ignite a wildfire by volcanic ballistic projectile, pyroclastic density currents, lava flows, and volcanogenic lightning.

Volcanic ballistic projectiles are fragments of solid or fluid materials ejected during explosive eruptions. They can travel hundreds of meters per second and can land up to 6 mi (10 km) from a vent, but are typically within 3 mi (5 km). They can cause significant damage due to speed, size, and often high temperatures.

Pyroclastic density currents are hot, fast-moving "clouds" of gas, ash, and rock debris known as tephra. They can reach temperatures up to 1,834 °F (1,000 °C) and speeds of 435 mph (700 km/hr) and are much denser than the surrounding air. Driven by gravity, they tend to hug the ground as they flow, rather than creating a plume in the air.

Lava flows are streams of molten rock that pour or ooze from an erupting vent. Lava is expelled during either nonexplosive activity or explosive lava fountains. The extreme heat of lava may cause vegetation to ignite, resulting in a wildfire. This extreme temperature may ignite material that is normally not very flammable.

Figure 7.10. Volcano-caused fire in Hawaii.

Volcanoes can indirectly ignite a wildfire by tephra fall, ground deformation, and volcanic earthquakes.

Per USGS, tephra defines all pieces of all fragments of rock ejected into the air by an erupting volcano. Most tephra falls back onto the slopes of the volcano but billions of smaller and lighter pieces (less than one-tenth of an inch [2 mm] in diameter), which are termed ash, are carried by winds for thousands of miles.

Tephra can:

- Block filters and fans of appliances or electrical equipment, resulting in overheating.
- Dust electronic components with the magnetic, conductive, abrasive material that causes equipment malfunction or failure or insulator flashover on electrical supply networks.
- Cause abrasion of electrical wirings resulting in short circuit.

Volcanic ground deformation and earthquakes can:

- Rupture gas lines.
- Damage underground electrical cables leading to short circuits.
- Break or overturn building contents, which may explode or create arcing.
- Cause abrasion or other damage to electrical wiring from excessive structural deflections.

Less typical but observed modes of ignition are heating due to friction or sparking due to the pounding of structures.

Undetermined

Definition: Fires that do not have a single cause that rises to the level of probable. Undetermined-caused fires may also include fires that were not investigated, fires in which the origin or cause were not identified, and fires where the origin was destroyed. Additional data or analysis may provide for the determination of a cause of a fire previously classified as undetermined.

Circumstances: Undetermined does not necessarily mean the investigator does not know what may have caused the fire. The investigator may be able to narrow down the cause to one of several possibilities, but none of which rise to an acceptable level of certainty. In these situations, the investigator should classify the fire as undetermined but explain, in detail, what causes are possible and why they cannot be ruled out.

Debris and Open Burning

- Branding
- Burn barrel
- Burning personal items
- Distress/signal fire
- Ditch fence line
- Escaped prescribed burn
- Field/agricultural burning
- Hand pile/slash
- Machine pile slash
- Open trash burning
- Other land clearing
- Pest control/deterrent/smoke out
- Right-of-way clearing
- Yard debris

Definition: In fire suppression terminology, a fire spreading from any fire originally ignited to clear land or burn rubbish, garbage, crop stubble, or meadows (excluding incendiary fires). any fire originally ignited to cl

Ignition factors: Windblown embers, radiant heat, and/or fire escaping into uncleared vegetation constitute the primary ignition source.

Circumstances: Visible spread pattern originating from the perimeter of the debris or open burn. Windblown embers can be a competent ignition source. Cardboard and paper form competent aerial firebrands and are often present in residential debris burning activities.

Inadequate clearance is often a primary circumstance associated with both residential and industrial debris burning escapes. The failure to have suppression tools present can play a role in establishing possible negligence. Signs of suppression efforts by the property owner or others may be present.

Figure 7.11. Debris burning burn barrel escaped fire.

Unattended debris burns may result in a delayed escape. This includes both residential and industrial debris burning activities.

Investigative techniques:

- See general investigative techniques.
- Escaped fires originating from large slash burning operations should be treated the same as other debris burns. Their size, and the fact that they may hold over for an entire winter, may create additional considerations. Locate and interview witnesses and reporting parties.
- Examine physical evidence that may support witness statements.
- Determine the weather conditions during the entire burn time and specifically at time of escape.
- Examine the residual pile material and/or burn barrel contents for size, depth, and composition.
- Determine if any residual heat is retained in the pile.
- Determine if burning was conducted during times of restrictions or closures.
- Determine if a burn permit was required, and if so, if one was obtained.
- Determine the timeframe from ignition of the pile to escape.
- Determine the control measures used:
    - Vegetation clearance
    - Tools and water source on-site
    - Adult in attendance
    - The condition and any deficiencies in the burn barrel or incinerator (if one was used) and the integrity of the screen and barrel container
- Document the proximity of the burn pile to surrounding fuels or hazards—include slope and aspect.

- Determine who the responsible party is. If youth were involved, determine if they acted as the parents' agent to burn the material.
- Photograph the burn pile or barrel from various angles and distances. Photographs should show:
    - Proximity to surrounding fuels
    - The subject's residence
    - Control lines
    - Tools and water
    - Suppression attempts
    - Other piles and material burned

Investigative techniques for slash pile fires:

- See general investigative techniques.
- Include weather information in advance of the fire, during the escape, and during the suppression period.
- Document the type of fuel material and the size of the slash pile.
- Measure the size of the brush pile.
- Probe the pile to identify hotspots.
- Determine when the location was cut, burned, and re-piled.
- Document the control measures in place and permit compliance.
- Document the extent of agency involvement in the approval of burn plans and inspections.
- Document the point(s) of fire escape.

Investigative techniques for holdover debris pile fires:

- See general investigative techniques.
- Measure the size of the brush pile.
- Probe the pile to identify hotspots.
- Determine when the location was cut, burned, and re-piled.
- Use a skidder, tractor, or other heavy equipment to dissect the pile. Examine and document the hot core of the pile and areas of cold charcoal. Determine if they connect to the burning core. Video and photograph the procedure.
- If a burn permit was required, obtain a copy. If one was required and not obtained, provide documentation that shows this.

Equipment and Vehicle Use

- Electric motor/power tools/battery
- Trailer
- Aircraft
- Chainsaw/brush saw/weed trimmer
- Commercial transport vehicle
- Heavy equipment and implements
- OHV/ATV/motorcycle
- Passenger vehicle/motorized RV
- Tractor/mower/brush hog
- UAS/model rocket and airplane
- Watercraft
- Hot work: welder/grinder/torch/cutter
- Other internal combustion engine equipment

Definition: Wildfires resulting from the operation of mechanical equipment excluding railroad operations. Types of mechanical equipment range from heavy construction to small portable engines. Equipment use caused fires are discussed in this section in five parts:

- Exhaust system particles
- Friction and sparks
- Fuel, lubricant, and fluids
- Mechanical breakdown or other malfunction
- Radiant or conductive heat transfer

Exhaust System Particles

Definition: Exhaust system particles can originate from any internal combustion engine. The particles include carbon, catalytic converter, and metal fragments. These particles are common ignition sources along roadways and areas of off-road vehicle use.

Exhaust carbon particles are materials created by incomplete combustion of hydrocarbon fuels. They are made up of engine carbon, trace metals, and lubricants.

Ignition factors: Volatile hydrocarbons contained within the particle may extend the time the particle is thermally active. Larger particles may auto-ignite upon ejection and contact with the air. Diesel engines are more prone to ejecting competent ignition sources than gasoline engines.

Figure 7.12. Examples of carbon exhaust particles.

Gasoline carbon particles are generally smaller than diesel carbon particles. Gasoline carbon is typically granular or in flakes, and may be shiny or dull, but will usually be sooty. Gasoline carbon particles may be recoverable with a magnet if sufficient ferrous material is present in their composition.

Diesel carbon particles generally are larger than gasoline carbon particles. Diesel carbon particles are granular, spongy, or pumice-like chunks. They may appear shiny or dull but are usually black and sooty. Anecdotal observations have shown that they are rarely recoverable with a magnet.

Diesel carbon particles (fig. 7.13) are generally larger than gasoline carbon particles. Note the black sooty appearance.

Figure 7.13. Examples of diesel carbon exhaust particles.

Exhaust system particles originate from the combustion chamber where temperatures are commonly 3,000 °F (1,649 °C), and ports or manifolds which reach temperatures of 1,600 °F (871 °C). Generally, the maximum horizontal flight distance from the exhaust source to the ground is about 45 ft (13.7 m) (DeBernardo 1980). Most fires ignited by exhaust particles will be quite close to the source of the particle.

Exhaust particles are considered a competent ignition source when they are a minimum of 0.023-inch particle size (Fairbanks and Bainer 1934). Particles up to 0.5 in (1.27 cm) or larger are not uncommon when associated with diesel locomotives.

Exhaust carbon particles are usually ejected from the exhaust systems under conditions of idling before peak level operation, when the engine is pulling a load, during piston ring or valve seal failures, engine overheating, compression braking, or at shift points.

Spark arresters and turbochargers are designed to limit carbon ejection. One or the other may be required by law. The presence of a spark arrester or turbocharger does not preclude an ignition due to exhaust particles as a result of malfunction, modification, or the wrong model being used.

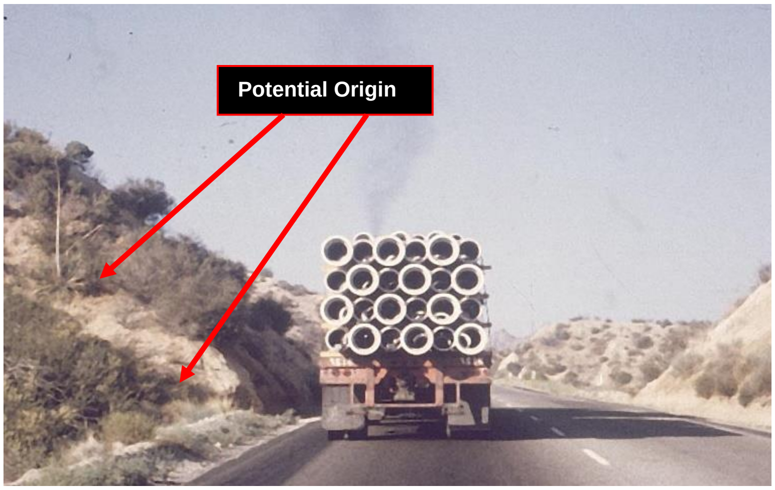
Spark arresters and turbochargers must meet relevant standards. Spark arrester guides can be found at the Forest Service National Technology and Development Program webpage (https://www.fs.usda.gov/t-d/).

Loose housing bolts, a loose or warped flange, or a separated exhaust port screen, all can be indications of an exhaust leak around the spark arrester. Some mufflers look like spark arresters and may need close inspection to determine if they include an arrester.

Circumstances: Exhaust carbon particles are more likely to ignite fires in conditions that include low relative humidity (RH) and high temperatures. Particles have been known to start fires in up to 80 percent RH (DeBernardo 1980). The host fuel bed is typically finely particulate 1-hour fuels. Fine dead fuel moisture is generally low, but no known upper threshold has been established.

Locations and road conditions where exhaust carbon particles may come to rest include cutbanks, slopes, road pullouts, parking areas, tunnel portals, downgrades, and at shift points on upgrades.

Figure 7.14. Vegetated cutbanks can form receptive fuel beds for exhaust particle fires.



Where the use of small equipment such as chainsaws, ATVs, lawn equipment, and portable power equipment is suspected, evidence of such use near the ignition area may be present.

Figure 7.15. Several types of small engine exhaust systems.

Heavy equipment, such as dozers, dump trucks, logging trucks, tractors, graders, skidders, etc., of fairly recent manufacture may be turbocharged but may still pose a threat if the system is damaged. The investigator should examine the equipment for signs of damage or request a qualified mechanic or specialist to conduct a thorough inspection.

Figure 7.16. Damaged exhaust systems.

Generally, fire scenes associated with exhaust carbon particles include the presence of the actual equipment or signs of any types of equipment use such as construction, logging, land clearing, harvesting, mowing, grading, nearby roads, etc.

Ignition mechanisms include:

- Exhaust system particles
- Friction
- Fuel, lubricants, and fluids
- Mechanical breakdown or malfunctions
- Rock strike
- Vegetation buildup on hot surfaces and radiant or conductive heat transfer, which may be indicated by charred material on the exhaust or other hot surfaces

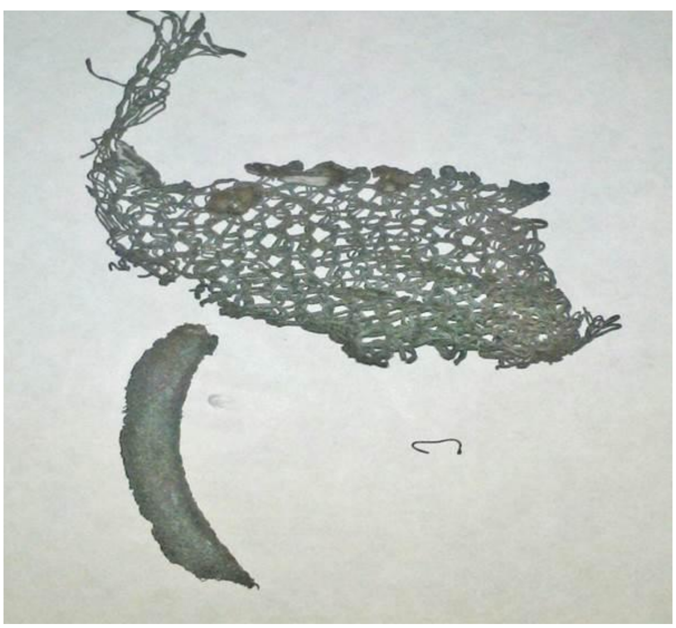
Catalytic Converter Particles

Definition: Catalytic converter particles are composed of a ceramic honeycomb matrix coated with various precious metals. Small ceramic beads may be present in older vehicles. The particles are generally grey in color, dull or have a metallic sheen. They may be scorched.

Figure 7.17. Examples of catalytic converter particles.

Particles of wire mesh, a component of some catalytic converters, also may be ejected and ignite a fire.

Figure 7.18. Wire mesh from catalytic converters.



Ignition factors: Normal operating catalytic converters can reach temperatures up to 1,380 °F (749 °C). During a malfunction, the converter overheats, and the matrix degrades and breaks apart at temperatures of 2,400 to 2,800 °F (1,316 to 1,538 °C). Hot ceramic particles discharge from the exhaust system either through the tail pipe or through failures in the outer shell of the converter itself.

Circumstances: Fires ignited from the ejection of catalytic converter particles are limited in distance by the tailpipe height and discharge direction.

The height and consistency of ground vegetation, such as grass, will also form a barrier to particle travel. Most origins are close to the road shoulder and there is no correlation to cutbanks or grades. Multiple ignition areas along the same road system are common.

The ignition area of each fire will typically have particles within it, which may vary in size. The particles are nonmagnetic and resemble melted plastic. A ricochet effect by particles exiting a low exhaust pipe may cause the particle to bounce at odd angles.

Figure 7.19. Catalytic converter particle.

Investigative techniques:

- Specific safety considerations:
    - Be aware of road conditions and passing vehicles.
    - Consider wearing a safety vest to increase visibility.
    - Consider having marked emergency vehicles present during the scene exam.
- See general investigative techniques.
- Walk the roadside and look for:
    - Other ignitions that may have self-extinguished.
    - Evidence of multiple ignitions burning together.
    - Additional particles that did not start fires.
    - A nearby disabled vehicle.

- If a vehicle is located:
  - Inspect the converter looking for holes, rust, cracks, or loose mounts.
  - Tap on the shell and listen for the sound of loose particles within the shell.
- Consider having a mechanical or automotive engineer examine the system to look for tampering or illegal modifications.
- Consider impounding the vehicle as evidence (may require law enforcement authority).

Friction

Definition: Heat generated by moving object(s) may cause sparks and/or heated particles. This heat may be created by objects rubbing together, or one object impacting another.

Figure 7.20. Examples of rubbing and impact friction ignition.

Ignition factors: Sparks or metal fragments may be torn from the host metal by the force of impact when a hard object, such as a rock or pavement is struck. Sparks are typically metal fragments that have been heated to their ignition temperature and combust. Heated metal particles are those which have not reached their ignition temperature but have absorbed heat that may be sufficient to ignite fuels. The spark or heated metal fragment temperature may reach several thousand degrees. Larger particles shear off and can be 700 to 1,500 °F (371 to 816 °C) or higher (McDonald and Rummer 2010). The ignition potential of each particle depends on its total heat energy, the actual temperature of the particle, the ignition temperature, and conditions of the specific fine fuel with which the particle comes into contact (Liu et al. 2019).

Examples of potential friction ignition sources include:

- Cable rub
- Tracked equipment
- Roller pins binding
- Slip or spin on rock(s)
- Blade, bucket, or saw strikes
- Misaligned shafts
- Vehicle dragging metal objects

Rock strikes by heavy equipment and/or by rotating metal blades are common sources of friction sparks and heated metal particles (Sjöström et al. 2022). Weed trimmers with metal blades contacting rocks can create sparks that may ignite both cured and partially cured annual grass.

Figure 7.21 shows examples of rocks struck by heavy equipment. Notice the fresh chalky look to the chips on the rocks.

Figure 7.21. Rocks stuck by heavy equipment.

Investigative techniques:

- Specific safety considerations: Use extreme caution if working near a cable under tension.
- See general investigative techniques.
- Look for evidence of equipment use in or near the ignition area.
- Use a magnet to search for metal particles within the specific origin area. Fires caused by sparks and hot metal fragments may smolder and only transition to open and steady-state flaming after equipment operators have left the area.
- Examine blade equipment and inspect the blade for damage. Consider collecting the blade or teeth as evidence.
- Friction charring on vegetation from the operation of equipment such as feller bunchers, cable logging yarders, etc. should be documented and may be collected as evidence when possible.
- Submit metal particles and control samples for forensic evaluation.

Figure 7.22. Friction particles found by using a magnet.

Fuel, Lubricant, and Other Fluids

Ignition factors: Ignitable liquids used for the operation of equipment can be ignited by a heat source and spread to the wildland when not properly maintained.

These fluids can be exposed to a heat source during refueling or because of fuel or hydraulic line leaks.

Circumstances: Conditions present may include:

- Hydrocarbon or fluid residue
- Trails of burned vegetation or spotting where equipment has traveled
- Failed or leaky fuel or hydraulic lines and fittings
- Burned equipment within or near the ignition area
- Witness statements indicating a failure in the area of a fuel or hydraulic line

Figure 7.23. Wildfire caused by failure of a hydraulic hose on feller buncher.

Mechanical Breakdown

Ignition factors:

- Tire, wheel, or bearing failures
- Brake failure
- Transmission failure
- Electrical system failure
- Dragging objects (friction)
- Driveline failure
- Failed turbocharger
- Misaligned axles

- Coolant systems
- Serpentine belts
- Other

Figure 7.24. Log truck mechanical breakdown ignition factor.

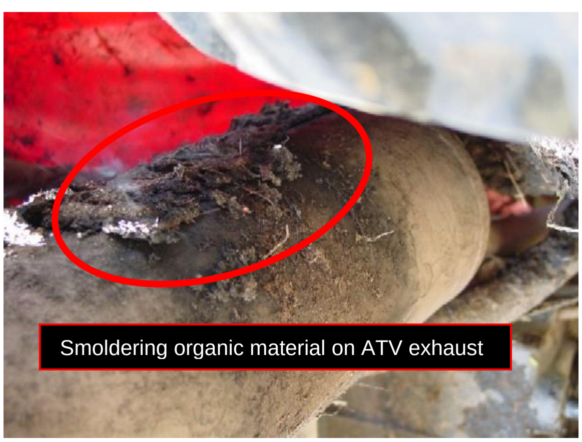
Circumstances: Conditions include evidence of equipment use near the ignition area, metal particles, burned tires or tire fragments, gouge or drag marks on the road surface. The operator of the vehicle may state they suffered some type of failure, heard some type of different noise, or saw smoke coming from a particular area of the vehicle or part.

Radiant or Conductive Heat Transfer

Ignition factors: Contact between dry vegetation and a radiant or conductive heat source can cause the vegetation to be ignited. This typically takes place when hot surfaces on equipment or vehicles contact dry vegetation. This can occur because of dry vegetation being caught up or deposited on hot surfaces of vehicles or equipment. It can also happen when a vehicle or equipment is parked over and in contact with dry vegetation.

Circumstances: These include the burnt remains of dry vegetation accumulated on or around hot surfaces of the vehicle or equipment. This is often on the underside of the vehicle. Tire tracks going through the specific origin area and the presence of tall grass or other vegetation is also an indicator of this type of fire cause. Burned equipment may be present in the area (Baxter 2004).

Figure 7.25. Conductive heat transfer ignition factor.



Hot Work

Definition: Work using welding (electric or gas), cutting, brazing, grinding, or similar flame- or spark-producing operations.

Figure 7.26. Typical welding operation and cart construction used near residential and small business operations.

Ignition factors: Fires result from hot work when metal fragments or sparks created by these activities land in a receptive fuel bed. Particles will often burrow and result in a smoldering fire before producing flaming combustion. The operator may be unaware of the smoldering fire. Grinding particles can start fires at greater distances depending on the elevation of equipment work relative to the receptive fuel bed.

Circumstances: The physical evidence at or near the ignition area may include:

- Slag
- Flux rods
- Metal fragments
- Discarded grinder discs
- Welding cartwheel impressions
- Fire extinguisher discharge residue or other evidence of attempted suppression

Figure 7.27. Slag located within a burn.

Figure 7.28. Welding byproducts recovered from fire scene.

Investigative techniques:

- See general investigative techniques.
- Document clearances.
- Check permit and regulation compliance.
- Use a magnet or metal detector.
- Inspect area for evidence of hot work.

Figure 7.29. Evidence of welding operation.

Internal Combustion Engine Equipment

Investigative techniques:

- Specific safety considerations:
  - Logging operations may have suspended or loose logs and materials.
  - Open pits at construction sites.
- Document all equipment believed to have been at or near the origin at or about the time the ignition took place. Extend this time for the duration it is believed a fire could have held over.
  - Include equipment make, model, serial number, age, and general description. Isolate problem equipment.
- Identify ownership and operator(s) of each piece of equipment.
  - Interview each operator and person who performed maintenance on the equipment.
- Determine dates and times of operation.
  - Sketch on a map the location and time of operation.
- Identify and document any tracks leading from or near the origin back to the equipment.
- Photograph each item near the origin area at the time of ignition before it is moved or inspected.
- Consider the possibility that commercial transport vehicles, passenger vehicles, or motorized RVs present near the origin could be an ignition source.
- If necessary, inspect equipment with a qualified equipment mechanic or mechanical engineer not associated with the operation.
  - Obtain written reports from assisting mechanics.
  - Follow up with professional service centers or distributors for details of maintenance schedules or specific hazards or problems associated with operation of a specific piece of equipment.
- Check all internal combustion engines for spark arrester compliance. Inspect spark arresters and document any deficiencies.
- Document any deficiencies in maintenance, including buildup of debris on hot surfaces.
- Document any deficiencies in fire protection requirements relating to equipment, water source, and security.
- Determine the terrain over which the equipment was used.
- When evidence collection is not possible or practical, obtain photographs of the item and closeups of the area of deficiencies or damage.

Firearms and Explosives

- Black powder/muzzle loading
- Blasting
- Exploding target shooting

- Flares/fusees
- Inert target shooting
- Military ordinance
- Nonmilitary tracer
- Other explosive

Definition: Ammunition can cause wildfires through the discharge of hot materials or mechanical sparks. When a projectile strikes a hard object, it may fragment as hot particles. Projectiles such as steel core, steel jacket, solid copper, lead, lead core copper jacket, armor piercing, incendiary, and tracer, are among those types of ammunition that can ignite wildland vegetation. Some manufacturers of shotgun shells have marketed shells that cause flame and sparks to be ejected from the barrel of the shotgun.

Ignition factors: Forest Service research and tests in January 2013 were conducted using 14 different rifle rounds, including steel, lead, and copper bullet components (Maynard 2013). The target used was a hardened steel plate with oven-dried peat moss fuel below it. Ignitions were consistently observed with bullets made from steel components (core or jacket) and solid copper. The tests found that bullet weight did not affect the likelihood of an ignition. Some bullet fragments exceeded temperatures of 1,400 °F (760 °C). Lead core/copper jacket rounds were found to be less likely to cause an ignition.

Key findings of the tests included:

- Rifle bullets striking hard surfaces can lead to ignition of organic material.
- Tests were performed under conditions simulating critical fire weather (100–110 °F [38–43 °C], 7–10 percent relative humidity) and using highly receptive fuel bed (oven-dried peat moss with 3–5 percent fuel moisture).
- Very small fragments can cause ignitions and may be difficult to locate at the origin.
- Only rifle rounds, 7.62x54Rm, 7.62x51 (.308 Winchester), 7.62x39, and 5.56x45 (.223 Remington) were tested.
- The probability of ignition increased with lower impact angles.

Find more information on rifle bullets ignition in the Forest Service report *Ignition Potential of Rifle Bullets* (Maynard et al. 2013).

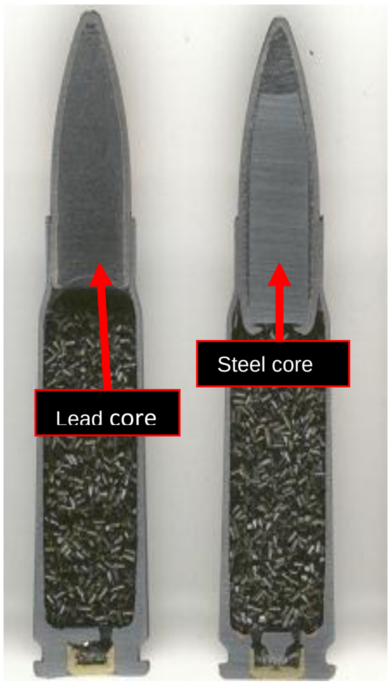
Figure 7.30. Rifle discharge at outdoor range.

Black powder or flaming patch material directly discharged into flammable vegetation can cause fires.

Steel core armor piercing rounds can be obtained from various sources including military surplus. The .223/5.54 and 7.62x39mm are the most common. These rounds have an interior steel shank that can start fires when it strikes hard objects such as steel and rocks. Steel jacketed rounds can be recovered using a magnet but copper-plated steel jackets may not be detected by one. However, if the bullet has fragmented, it may expose steel parts that could be detected by a magnet.

An x-ray may need to be used to determine the internal components of a round.

Figure 7.31. Lead core and steel core rifle rounds.



Incendiary rounds can start fires upon impact. Phosphorus enclosed in the round auto-ignites upon exposure to oxygen. Incendiary rounds are competent ignition sources, given the proper first material ignited. Military incendiary rounds may have orange, purple, or blue tips. Incendiary rounds are available commercially in some States.

Tracer rounds include a chemical mixture that burns briefly when fired, allowing the user to see where the round is going. Often, tracer rounds are used among non-tracer rounds. Traces of the chemical compound may be found on the base of the projectile. Tracer rounds are available commercially in some States.

Armor piercing, tracer, incendiary, and observational rounds may have various colored tips; the particular color depends on where and when the ammunition was manufactured. The markings on these rounds may have the paint sanded off, or no paint may have been present if the rounds came from foreign military surplus.

Figure 7.32. Tracer rifle round being fired at night.

Figure 7.33. Orange tip marking of tracer round.

Indicators of a firearms-related fire may include:

- Exploding targets
- Metal appliances with bullet holes present
- Car bodies with bullet holes present
- Rocks near ignition area with evidence of bullet strikes
- Ammo boxes
- Cartridge cases

- Spent rounds
- Bullet strikes
- Paper targets

Exploding Targets

Definition: Exploding targets detonate upon impact of a projectile, sending out hot particles. Exploding targets are commercially manufactured in either low- or high-velocity types. Homemade versions are also being used with similar effects.

Figure 7.34. Exploding target.

Ignition factors: Many of these products are binary explosives, consisting of an oxidizer and a fuel. meaning the individual components are not considered explosives until combined. Once combined, they are treated as explosives. When the two ingredients are combined, they create a "shock sensitive" explosive that can be initiated by the impact or energy transfer of a bullet. Investigators working a scene that may include an exploding target should use caution when handling, collecting, packaging, and storing residue or devices. Typical detonation of exploding targets include:

- Bright flash
- Sparks
- Flaming debris
- Large volume of smoke
- Flying debris (shrapnel)

For additional information on exploding targets and wildfires, see *Experiments on Wildfire Ignition by Exploding Targets* (Finney et al. 2019).

Circumstances: Most ignitions will be near the detonation point, with most exploding target fires being at the site or within a short distance of the actual site of detonation. The detonation point could be a significant distance from the shooting site. Many of these fires take place at locations used previously for target shooting.

Exploding targets often leave physical evidence at the scene. Depending on the type of device, whether it was commercially manufactured or homemade, the debris field may include:

- Small white pellets called “prill”
- Container fragments
- Packaging material
- Pieces of plastic
- Blast damage
- Shell casings (located at the shooting site)
- Duct tape
- Plastic baggies
- Soda bottles

Brand names of exploding targets that may be in or near the ignition area or in shooters’ possession include:

- Tannerite
- Star Targets
- Sure Shot
- Kick-Ass

Figure 7.35. A half-pound of Tannerite detonated beneath the hood.

Investigative techniques:

- Specific safety considerations:
    - Handle all firearms as if they are loaded until visually and physically cleared.
    - Follow agency policy on handling and storing firearms.
    - Take appropriate precautions in heavily used target shooting areas and ranges—unexploded ordnance, breathing lead-contaminated dust, sharp metals, ongoing shooting activity, etc.
- See general investigative techniques.
- Search the ignition area and nearby area, which may include the firing site and impact site or detonation point.
- Apply grid search technique at range locations.
- Collect evidence, such as casings, avoiding adding fingerprints or DNA.
- Use metal detectors to locate projectiles that may be buried in dirt or trees.
- Use magnets to check for steel components in ammunition.
- Gather evidence according to laboratory standards to allow examination to match projectile and shell casing to firearm.

Explosives

Definition: Fires started by flaming debris associated with blasting activities.

Ignition factors: Fires from blasting operations will generally be near or within the blast perimeter. In some instances, materials may be propelled by the blast a distance away. Fire starts may be delayed due to smoldering combustion.

Investigative techniques:

- Specific safety considerations:
    - Take appropriate safety measures because of the possibility of additional explosions and explosive devices in the area.
    - Consult with individuals using blasting materials.
- See general investigative techniques.
- Document blasting activities that occurred before the fire.
- Look for blasting/burned material remains in or near ignition area.
- Determine if permits were obtained and conditions followed, including fire suppression requirements.
- Attempt to recover foreign debris/material from the ignition area, if this can be done safely.

Flares and Fusees

Definition: Fires resulting from commercial, industrial, or military flares/fusees. Flares/fusees are usually a mixture of sawdust, wax, sulphur, strontium nitrate, and potassium perchlorate.

Figure 7.36. Typical nonaerial road flare with stand.

Ignition factors: Mishandled or improperly placed flares can be a competent ignition source depending on the first material ignited.

Figure 7.37. Typical deployment of nonaerial roadside warning flares.

Flare guns used for aerial emergency signaling and igniting of fire (prescribed fires, backburning, fuel flare stacks, etc.) can all send burning rounds into the wildland.

Figure 7.38. Aerial signal flare device.

Figure 7.39. Flare gun and cartridge.

Circumstances: A scene with nonaerial flare/fusee may have multiple flares/fusees along a road's edge. Grayish-white slag may be present both on and off the road. Ignition area is typically adjacent to the road edge when an accidental cause is present but may be some distance from the roadway if arson is the cause. Flare debris is present in the form of caps, strikers, and slag. The cap and striker may have rolled or blown away from the ignition area.

A scene with an aerial flare/fusee may have ignition point(s) a distance away from the launch point. Multiple ignition areas may be present as the flare/fusee could bounce or ricochet. Cartridges may be located at the point of launch. In the ignition area, flare debris may include slag, unburned remnants of the flare, and packing or wrappings.

Figure 7.40. Flare slag at scene of fire.

Investigative techniques:

- See general investigative techniques.
- Submit slag residue to laboratory for possible content analysis of strontium nitrates or other suspected chemicals.
- Evaluate recent activities at this location.
- If an aerial flare, attempt to trace trajectory back to the launch site.
- Consider arson as a cause.

Fireworks

Definition: Fireworks fall into one of three general categories: ground-based, aerial, and explosive.

Fireworks may be classified in several different ways depending on the jurisdiction. Fireworks are known to cause major property damage annually including fires to both wildland and structures. Used in an unsafe manner, fireworks can discharge burning material into flammable vegetation.

Ignition factors: Ground-based fireworks emit flame and sparks that can ignite a fire when set off adjacent to flammable vegetation. Examples include:

- Base and cone fountains
- Sparklers
- Wheels and spinners
- Smoke bombs

Figure 7.41. Ground-based fireworks.

Aerial fireworks explode or create an aerial flash. The hot remains of an aerial firework may land in flammable vegetation and ignite a fire. The fire may also occur at or near the launch site or along the trajectory of flight. Exploded remains may start a fire some distance from the launch site and downwind of the trajectory. Examples include:

- Bottle rockets
- Parachutes
- Wings
- Mortars

Figure 7.42. Aerial fireworks.

Explosive fireworks consist of a flash powder charge accompanied by a concussion wave. Flaming paper particles may start fires immediately adjacent to the blast area. Strings or bricks of firecrackers are more likely to ignite dry fuels than a single firecracker, with the burning fuse often the ignition device rather than the firecracker detonation itself. M-80 and cherry bombs are two common types of larger explosive fireworks. These types of fireworks may be illegal in certain areas.

Figure 7.43. Explosive firework.

Circumstances: Fireworks use tends to increase around holiday periods, leading to an increase in fireworks-related fires. Evidence may include the remains of spent or malfunctioned devices, residue, packaging material, matches or discarded lighters, remains of punks, and witness statements of seeing a flash, hearing a bang, or seeing sparks and fire. Remains of a firework may be buried in soil because of attempted suppression actions. Youths may be present near the scene and should be questioned according to agency policy. Fireworks thrown into dry vegetation should be looked at as a possible act of arson.

Figure 7.44. Firecracker paper remains.

Investigative techniques:

- See general investigative techniques.
- Search area for launch site and packaging materials.
- Document distance from discharge of fireworks and fire ignition area, along with clearances around the discharge area.
- If found off a roadway, document distance and describe fuel configuration to determine if fireworks were thrown.
- Collect fireworks evidence, avoiding adding fingerprints or DNA.
- Determine the type of firework(s) used and note any identifying markings.
- Determine if the firework was of a legal type in the jurisdiction.
- Obtain documentary evidence on State laws regarding legal and illegal fireworks use.
- Consider arson as a cause.

Power Generation, Transmission, and Distribution Systems

- Electrical production/transmission/distribution systems
- Oil and gas production/transportation systems
- Solar utility systems
- Wind turbine/windmills utility systems

Electrical Utility Systems

Definitions: Powerlines are the system used for electrical power production, transmission, and distribution across large distances.

The category of powerlines includes all electrical equipment associated with the production, transmission, and distribution of electricity. The electrical grid, or system, is governed by a variety of regulations.

Transmission lines are the towers or poles, conductors, and equipment that move electricity from the generation facility to a substation. These are generally higher voltage, relying on larger towers and generally are between 138kV and 765kV, but may also be as low as 69kV.

Distribution lines carry power from the substation to the distribution transformer. Distribution lines carry lower voltages than transmission lines. Statistically, the distribution network is more likely to cause fires than transmission lines. The distribution network contains more fire-starting hardware and 5 to 10 times more line.

Distribution pole structure and equipment is closer to vegetation than transmission lines, increasing the chance of fire by distribution lines.

A service line transmits the electrical power from the distribution transformer to the consumer's weatherhead. Service lines are close to the ground and often in contact with standing vegetation such as tree limbs. Generally, they are enclosed in an insulating cover which helps protect them from arcing with other objects.

Ignition factors include:

- Equipment failure
- Failure to maintain
- Damaged equipment
- High-hazard areas
    - High or turbulent winds
    - High local air temperatures
- Vegetation contact
- Animal contact

Figure 7.45. Examples of transmission lines.

Figure 7.46. Mylar balloon stuck on transmission lines.

Investigators need a general familiarity with powerline hardware. For more information, refer to *California Powerline Fire Prevention Field Guide* (https://cdnverify.osfm.fire.ca.gov/media/3vqj2sft/2021-power-line-fire-prevention-field-guide-ada-final_jf_20210125.pdf).

Evidence of arc tracking on the insulator shown in figure 7.47 is due to voltage tracking across a damaged insulator.

Figure 7.47. Evidence of arcing on a damaged insulator.

Conductor failure or faulting can result from a variety of scenarios, such as:

- Conductor breaks, falls to the ground, and arcs.
- Splice or connector failure causing the line to fall.
- Conductor contacts or comes close to an adjacent conductor, vegetation, or animal.
- Line sag:
    - Typically takes place when the conductor is subjected to increased load or solar heating.
    - Lines experiencing sag may return to their normal position over time.
    - Regulations require utilities to consider line sag during powerline construction.
    - Field measurements can be made to determine if line sag was within regulations although lidar measurements are preferred.
- Proximity arc:
    - Arcing may occur across open air to adjacent vegetation.
    - Arcing may occur at approximately 1 in (2.54 cm) per 10kV.
- High winds causing galloping lines or line slap.
- The initial fault may not start a fire, but one may ignite when an automatic or manual reclosing of the circuit occurs and the line is energized once again.
- Powerline discharges to the ground may leave fulgurites.
    - Typically solid and on or very near the surface of the soil
    - May include glass bubble-looking formations on the surface.

Conductor failure or faulting is usually obvious and often includes charred vegetation, lines down, arc pitting and staining on the conductor, blowholes at the base of the tree, resistance scarring on the tree, and fulgurites at the point of discharge to the ground or rocks, particularly sandstone.

Tree crowns contacted by conductors may exhibit damage like a lightning strike. Fire damage may be present on the top and bottom of the tree with green, unburned area in between.

Figure 7.48. Limb damaged by contact with an electrical conductor.

Figure 7.49. Staining and sooting on wire conductors.

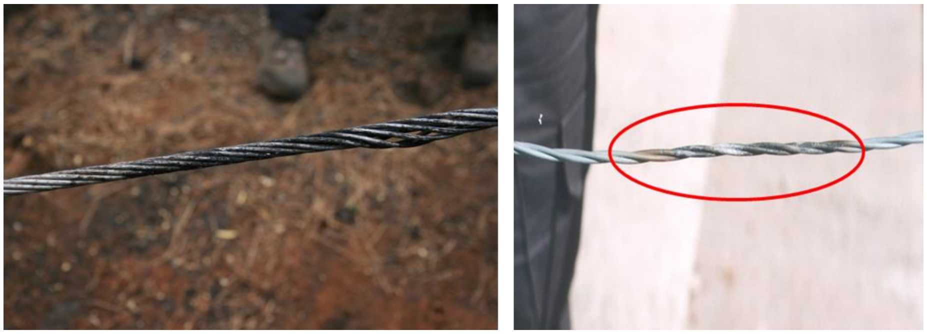
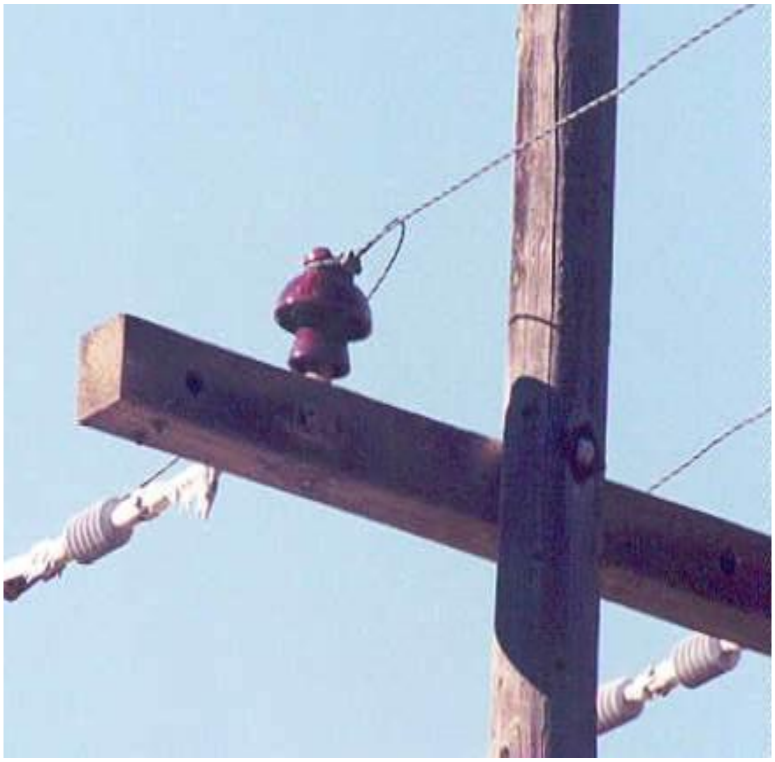


Figure 7.50. Blowhole near tree from electrical grounding.

Figure 7.51. Electrical resistance scar on tree trunk.

Insulator failure may lead to a fire ignition. There are a variety of insulators, but all are designed for the purpose of keeping the conductor from making grounding contact. A failure of an insulator can produce arcing to the pole, crossarm, or other hardware that may result in burning material falling to the ground.

Figure 7.52. Typical crossarm insulator on a wooden mounting peg.



Insulator failures can be a result of many factors, including:

- Dirt
- Bird manure
- High humidity
- Salt deposits (sea air)
- Lightning strikes
- Over-voltage
- Deliberate damage
- Current arcs
- Insulators or crossarm fail and a dropped conductor
- Tie-down wire comes loose
- Insulator comes off mounting peg

Utility power poles, if maintained properly, can last for several decades. Most poles will have maintenance tags affixed, which correspond to inspection records held by the utility company. If not properly maintained, wooden power poles may display evidence of decay which can lead to significant loss in strength, compromising the structural integrity of the pole. High-speed winds can cause poles with weak structural integrity to break and fall. Failure of poles generally has a cascading effect, i.e., the added load of the powerlines shifts to the adjacent poles. Consequently, the adjacent poles also break. This can be exacerbated by the presence of decay or loss of cross section due to previous fire.

In some areas, certain powerline hardware is required to have vegetative clearance due to their propensity for starting fires when they fail. These items may be referred to as nonexempt, meaning they are not exempt from the law that requires the clearance.

Figure 7.53. Fuse in open position (red arrows).

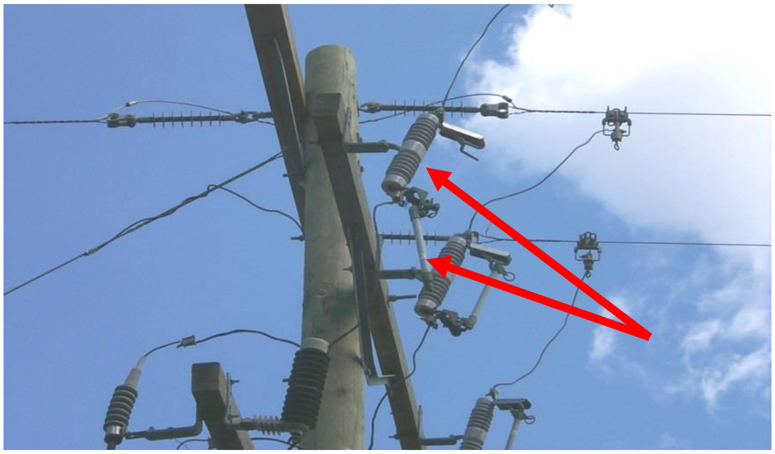


Figure 7.54. Solid blade disconnect.

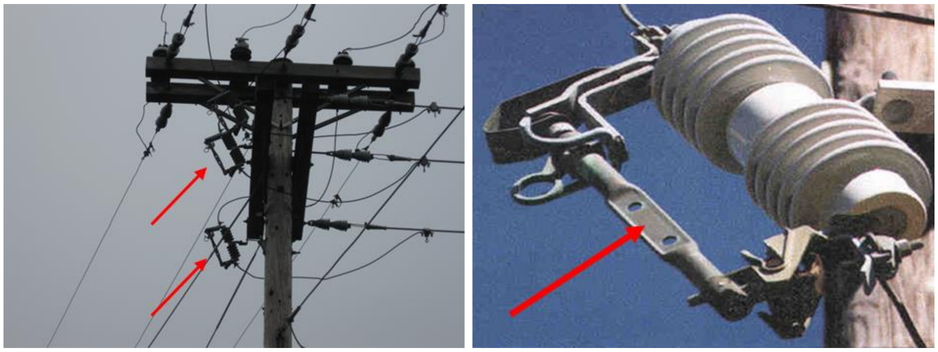


Figure 7.55. Inline disconnect.

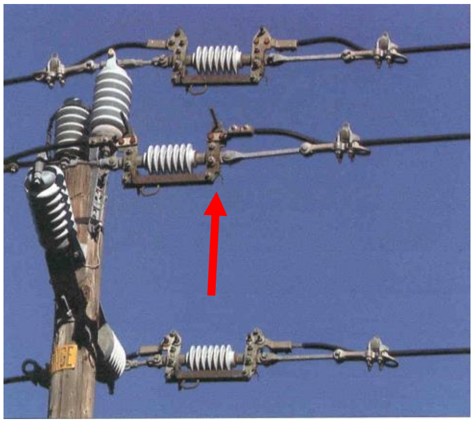


Figure 7.56. Lightning arresters.

Connectors and clamps connect conductors and jumpers. They include hot tap clamps, split bolt connectors, LM connectors, and Fargo connectors. The potential for an arc increases when the connectors are loose.

Figure 7.57. Evidence of arcing.

Figure 7.58. Hot tap clamps.

Figure 7.59. Split bolt connectors.

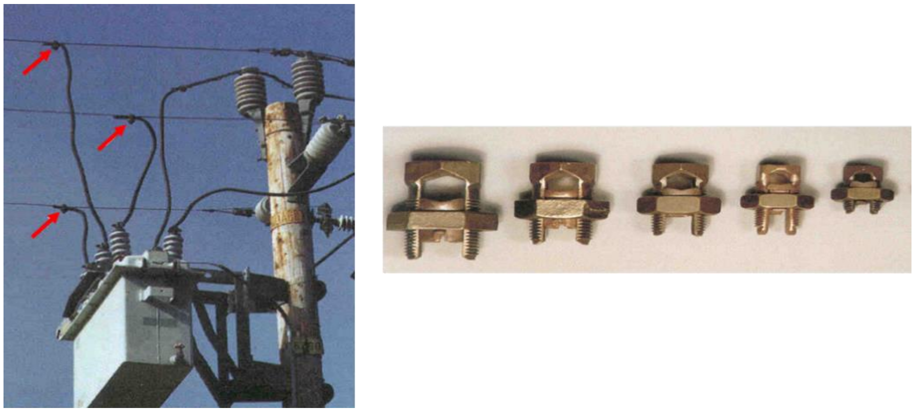


Figure 7.60. LM connector.

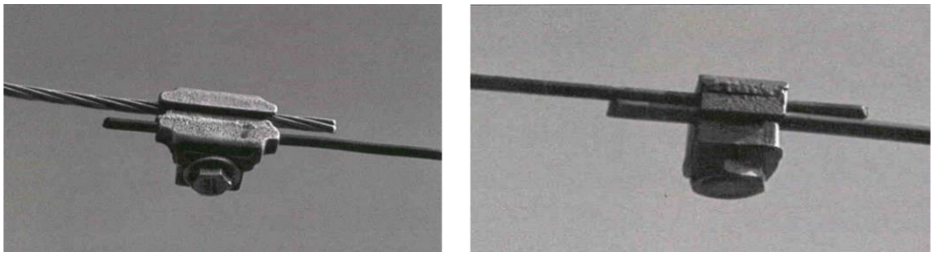
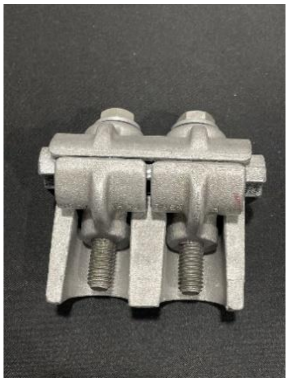


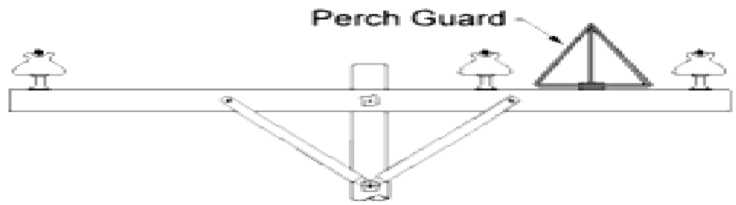
Figure 7.61. Fargo connector.



Birds and small animals may come into contact with electrical equipment. This can cause an arc and the animal may catch fire. Consider whether the utility company had advance warning concerning a bird or animal problem. This may present in the form of perch guards or evidence of nesting material and the absence of perch guards.

The perch guard in figure 7.62 is positioned between two insulators or conductors that are close enough for the span of a bird's wings to contact both conductors. Contact with a single conductor will not usually result in an arc. Search the surrounding area for the fresh body of a bird or other small animal.

Figure 7.62. Drawing of a perch guard between insulators.



In figure 7.63, the conductors on the crossarms have been removed to reduce the arc hazard near the nest. New crossarms were added further down the pole.

Figure 7.63. Bird nest above wires.

Circumstances:

- Powerlines located in or near the specific origin area
- Downed powerlines
- Trees or other vegetation in contact with powerlines

- Recently downed tree limb located on the ground under or near lines and the ignition area
- Discoloration of the conductor, signs of arcing or other equipment failure
- Circuit breakers in open position
- Blown fuses
- Recently dead wildlife found near the ignition area
- High winds and/or high temperatures that may have caused line slap, line galloping, or line sag
- Dust storms or smoke columns that may have caused arcing
- Recent power outages or brownouts
- Pole damage or vehicle accident

Investigative techniques:

- Specific safety considerations:
    - Look up, look out, and stay away.
    - Use extreme caution when working around or under lines or equipment. Determine if it is safe to enter the area under or near the powerlines.
    - Conductors need to be isolated and grounded. Always assume conductors are charged or may become charged until utility company provides assurances otherwise.
    - Smoke, dust, and/or water spray can cause arcing that may reach to the ground.
    - Never climb a pole.
    - Wait for the arrival of utility crews to make the line safe.
    - Wear proper protective equipment when working from bucket trucks.
- See general investigative techniques.
- Obtain witness statements from power company maintenance crew regarding what caused the powerline failure or ignition from the failure.
- If a tree or other vegetation fell onto the powerlines, determine:
    - Species of tree.
    - General age.
    - Height and diameter of tree.
    - Any visible defects on the tree.
- Determine height of powerline.
- Determine height of surrounding forest canopy.
- Determine distance between powerline and vegetation and whether legal clearances are present.
- Search area for human activity such as shooting, vehicle traffic, and/or recently dead birds or other animals etc.
- Examine powerlines and equipment for damage or failure. Look for remains of failed equipment

on the ground:

  - Downed powerlines, circuit breakers or fuses in the open position, or remnants of expulsion fuses.
  - Discoloration of the conductors, signs of arcing, burn marks on the pole structure, or other equipment failure.

- Look for recently dead wildlife near the ignition area.
- Inquire about recent power outages, brownouts, or maintenance activities in the area.
- Determine ownership of powerline.
- Determine location of the right-of-way boundary for the powerline. Record the distance from the ignition area to the edge of the right-of-way, indicating whether it is inside or outside.
  - Obtain copies of any use permits concerning the right-of-way.
- Locate and record the identification numbers and the dates of installation of power poles on both sides of the area near the origin.
- Determine if the utility company has removed any potential evidence and recover it if they have.
- When analyzing the structural integrity of power poles:
  - Take pictures from different angles of all poles on the ground, minimizing shadows.
  - Obtain a cored specimen of the pole approximately 2 ft (0.3 m) above the ground on standing poles and near the failure point on broken poles using an incremental borer (commercially available). Store the cored sample in an airtight plastic bag (e.g., Ziplock).
  - Obtain rings or discs from the poles. A 1-in (2.5 cm) disc from the pole, directly above the point of failure, can provide vital information on the condition of the poles. Store the disk in an airtight plastic bag.
  - If decay or pulping is observed, collect a sample of the pulped or powdered substance and store it for further analysis.
  - Obtain and review inspection records, maintenance plans, and replacement schedule for the utility poles.
- Tree samples:
  - Take into possession the parts of the tree that show contact with the line. In some cases, consider taking the entire tree as evidence.
  - Sample of root—if deterioration or rot is noted.
  - Sample at germination point.
  - Circumference of tree at breast height.
- The fire may not have started where vegetation contacted the conductor. For example, a fuse may have been activated or malfunctioned, causing a fire at a different location.
- Examine all poles, lines, fuses, transformers, switches, voltage regulators, reclosers, insulators, splices, connectors, and grounding devices in the area of origin.
  - Take photos and collect samples as needed.

- Request an administrative warrant if needed.

- Request the services of an electrical engineer or powerline expert.
- Examine the scene with the powerline expert and take possession of all relevant evidence.
- If there is a direct short to the ground, examine the area for fulgurites.
- Obtain line data, supervisory control and data acquisition (SCADA) data, and maintenance records from the power company.
    - Secure all relevant records from the utility company.
    - Consider sending a preservation letter.
- Collect records concerning hazard reduction and past problems on the same circuit.

Oil and Gas Utility Systems

Definition: Fires associated with the recovery and pumping of oil and gas products in the wildland. Flare pit and stack fires are among the types of oil and gas fires encountered in the wildland environment. Flare pit and stack operations are designed to burn off excess or unwanted petroleum byproducts. Occasionally these will start fires from direct flame impingement, the igniter flare, or stack particles.

Ignition factors: Petroleum product flare stack/flare pit fires occur at both natural gas and oilwell processing facilities. Flares fired to ignite gas during burn-off operations can start fires. Stacks can burp and start fires. Flames and/or carbon particles ignite adjacent fuels.

Figure 7.64. Malfunctioning flare stack.

Crude oil storage tank fires, along with fires caused by static electricity during maintenance on or around polyethylene pipes can occur. Carbon particles ignite adjacent wildland fuels.

Figure 7.65. Oil storage tanks and exhaust pipe.

Circumstances: Indications of oil or gas fire include evidence of burning on the stack itself, an ignition area in adjacent vegetation, lack of clearance, carbon soot particles at and between source and origin, records of past fires, igniter flare residue, evidence or witness reports of recent flaring, and an ignition area often downwind.

Investigative techniques for flare pit fires:

- See general investigative techniques.
- Interview the operators to determine site history and any similar incidents.
- Determine when flare was last lit and how (electric igniter or flare gun).
- Determine distance from battery.
- Determine when the battery was last shut down for repairs.
- Examine the well site daily recorder to identify specific/significant changes in flow.
- Obtain a sample emission from the flare, if possible. This may be compared to the composition of material on the ground.
- Determine distance from stem of pipe in the flare pit to the berm surrounding the flare pit.
- Determine the distance from the edge of the berm and the stem of the pipe to vegetation.

Investigative techniques for flare stack fires:

- See general investigative techniques.
- Determine when flare was last lit and how (electric igniter, flare gun, or other method).
- Was flare burning when the first witness arrived?
- Is the flare monitored?
- Sketch site.

- Height of the stack.
- Base of stack to ground fuels (minimum 2.5 times height of stack).
- Is there a knockout drum (a sediment bowl-like tank to prevent condensate getting to the stack)?
- Examine the area for materials that may have burped from the flare stack or carbon dislodged from top of stack.
- Examine the wellsite daily recorder to identify specific/significant changes in flow.
- Interview the operators to determine site history and any similar incidents.
- Obtain a sample emission from the flare, if possible. This can be compared to the composition of material on the ground.
- Determine weather conditions from site personnel.
- Closeup photograph of top of stack to identify carbon buildup.

Figure 7.66. Flare stack malfunction leading to ground fire.

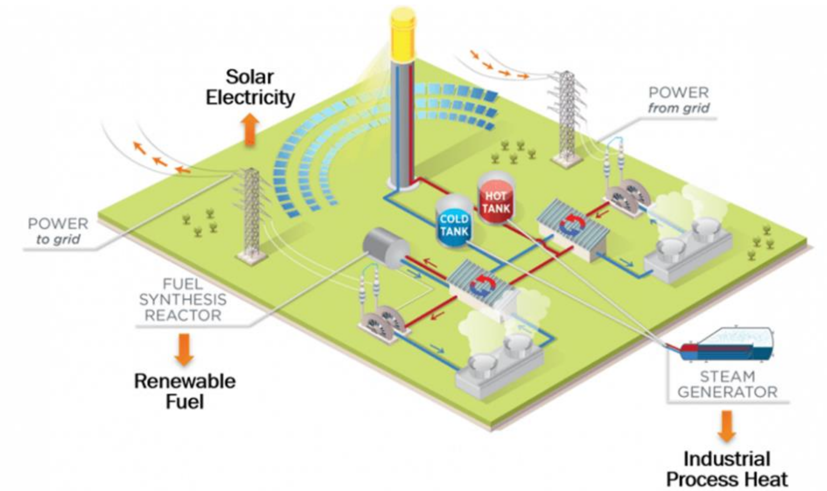
Solar Utility Systems

Definition: There are two main types of solar energy technologies used to convert sunlight into electrical energy: photovoltaics (PV) and concentrating solar-thermal power (CSP). This energy can be used to generate electricity or be stored in batteries or thermal storage.

PV technologies, commonly known as solar panels, generate power using cells that absorb energy from sunlight and convert it into electrical energy. These solar cells are connected to form larger power-generating units—the solar panels. The solar panels can be connected to the grid or operated as a standalone system.

CSP systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat, which can then be used to produce electricity or stored for later use.

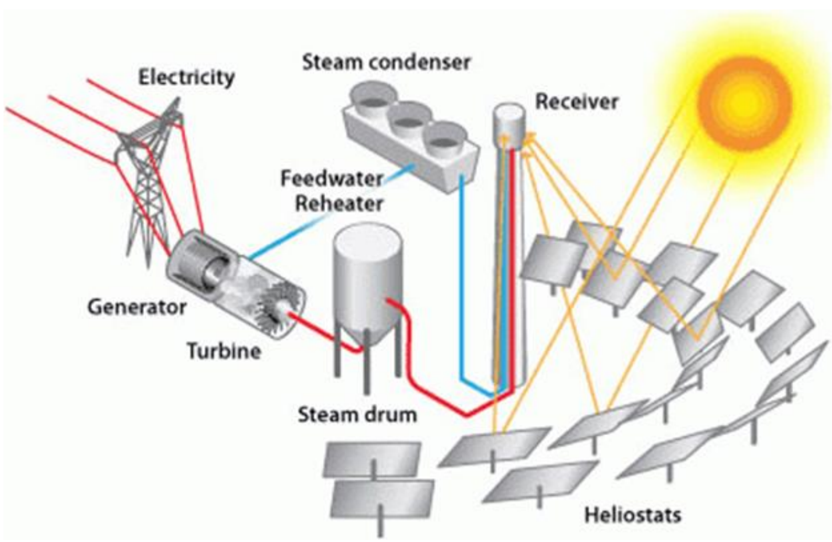
Figure 7.67. Concentrating solar-thermal power (CSP) systems.



Concentrating solar-thermal power systems are generally used for utility-scale projects. These plants can be configured in different ways. Solar power tower systems arrange mirrors around a central tower that acts as the receiver. Linear systems have rows of mirrors that concentrate the sunlight onto parallel tube receivers positioned above them. Solar dish/engine systems use a mirrored dish like a very large satellite dish.

Solar power tower systems use a large field of flat, sun-tracking mirrors called heliostats to reflect and concentrate sunlight onto a receiver on the top of a tower.

Figure 7.68. Solar tower power systems.



Linear systems capture the sun's energy with large mirrors that reflect and focus the sunlight onto a linear receiver tube. The receiver tube contains a fluid that is heated; this heats a traditional power cycle that spins a turbine driving a generator to produce electricity.

The two major types of linear concentrator systems are parabolic trough systems and linear Fresnel reflector systems. In parabolic trough systems, the receiver tube is positioned along the focal line of each parabola-shaped reflector. The tube is fixed to the mirror structure and the heat transfer fluid flows through and out of the field of solar mirrors to where it is used to create steam. In a linear Fresnel reflector system, flat or slightly curved mirrors mounted on trackers on the ground are configured to reflect sunlight onto a receiver tube fixed in space above the mirrors.

Figure 7.69. Linear power systems with parabolic troughs.

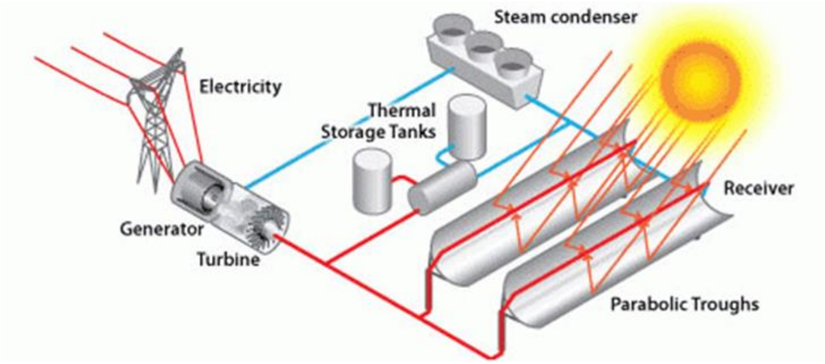
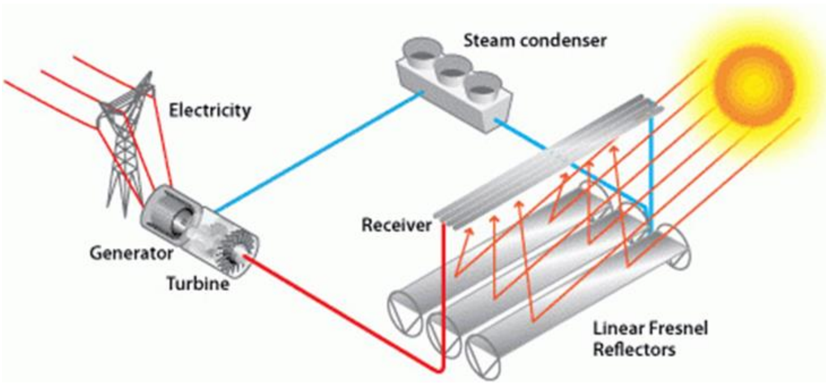


Figure 7.70. Linear power systems with linear Fresnel reflectors.



Solar dish/engine systems use a mirrored dish like a large satellite dish. The mirrored dish is usually composed of many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs the heat and transfers it to an engine generator.

Ignition factors include:

- Extreme heat
- Hail
- Lightning strikes
- Design flaws
- Component defects
- Improper maintenance or faulty installation

Due to the technical aspect of solar power operations, investigators are encouraged to seek the support of a subject matter expert.

Wind Turbine and Windmill Utility Systems

Definition: Wind turbines use wind to generate electrical energy and are increasingly being placed into the wildland. A wind farm describes an area with multiple wind turbines.

Wind turbines create electricity by converting the kinetic energy in wind to turn the propeller-like blades of a turbine around a rotor. As the rotor rotates, it spins a generator, which creates electricity. A wind system can be a small residential system (as a standalone system or tied into the grid-connected system) or an industrial-sized system. Most wind turbines are either horizontal-axis or vertical-axis turbines and are mounted to towers. Horizontal-axis turbines consist of two or three blades. Among the varieties of vertical-axis turbines is the Darrieus turbine, which resembles an eggbeater.

Ignition factors include:

- Lightning strikes
- Electrical failures
- Overloaded or overheated equipment
- Mechanical failures
- Improper installation or maintenance
- Animal strikes

Figure 7.71. Wind turbine fire.

The investigator needs to consider all the activities around a wind farm, such as maintenance, welding, cutting, grinding, and vehicle traffic through dry grass, and not quickly assume that the fire ignited from a turbine.

In view of the technical aspects of wind turbine operations, investigators should seek the input of a subject matter expert.

Railroad Operations and Maintenance

- Brakes
- Derailment
- Exhaust particles
- Rail grinding
- Right-of-way vegetation management
- Track replacement
- Hot work: welding/grinding/torch/cutting
- Other mechanical failures

Definition: Fires caused by railroad operations, personnel, rolling stock, and track and right-of-way maintenance. Railroad structures such as trestles, bridges, and ties, are included in this category of fire cause.

Figure 7.72. Railroad trestle fire.

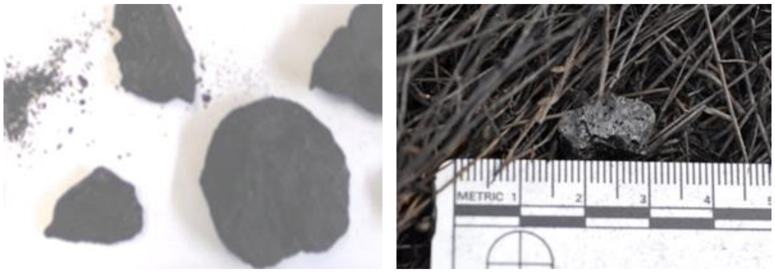
General railroad ignition factors include:

- Exhaust carbon particles
- Brake shoe particles
- Track maintenance
- Dynamic brake grid failure
- Signal flares
- Right-of-way maintenance
- Wheel slip
- Wheel bearing failure, also known as a hotbox

Ignition factors for railroad exhaust carbon particles: These particles from railroad equipment can be a competent ignition source, depending on the first material ignited. Diesel carbon is bound together with polymeric lubricant resins and forms particles with pumice-like, granular, or flaky appearance, which is often sooty or oily.

Figure 7.73 shows the pumice-like appearance of railroad exhaust carbon particle on the left, and sooty and oily-looking railroad exhaust carbon particle on the right.

Figure 7.73. Types of railroad exhaust particles.



Railroad exhaust carbon particles vary in size, with larger particles more likely to start fires. Particles are rarely retrievable with a magnet. Super-heated particles can auto-ignite when exposed to the air upon ejection.

Exhaust carbon particles emitted from the exhaust stack may range in temperature from 900 to 1,200 °F (482 to 649 °C). Under fanned conditions, which simulate an in-flight environment, exhaust particles have been observed as low as 690 °F (366 °C). As the hot exhaust particle passes from an oxygen-depleted environment to the atmosphere, glowing or flaming combustion can occur (DeBernardo 1979).

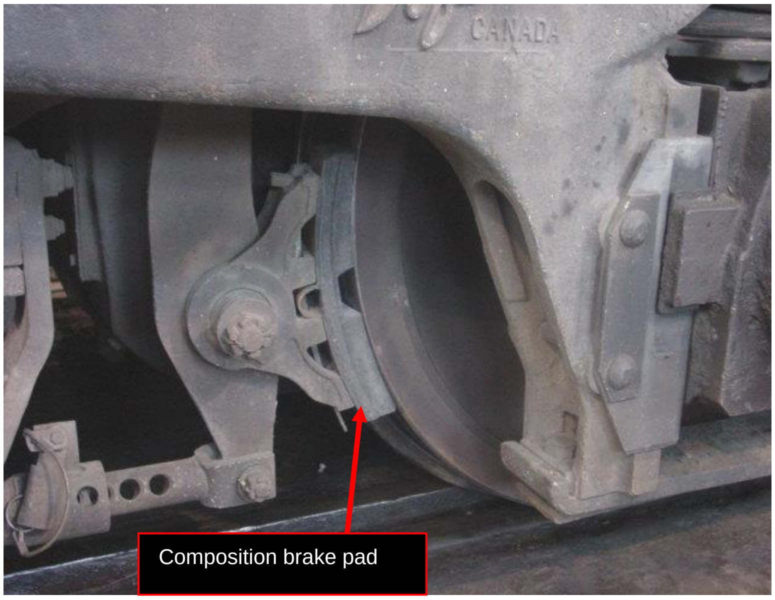
Figure 7.74. Sizes of railroad exhaust particles.

The most common range for exhaust sparks is about 15–20 ft (4.6–6.1 m), but they can go in excess of 40 ft (12.2 m) in still air. Effects of wind or turbulence from a moving train can increase the range. Most exhaust spark fires on rights-of-way occur within 28 ft (8.5 m) of the track centerline (DeBernardo 1979).

Exhaust carbon particles from railroad equipment may cause multiple ignition areas with origins generally on the downwind side of the tracks. Speed transition zones or other locations where full power is applied are typical locations where particles are ejected, especially if the locomotive has been idling for a period of time before pulling a grade. Deadhead and yard locomotives started up after a period without use or low power have an increased potential for ejecting particles.

Ignition factors for brake shoe particles: Railroad brake shoe fires occur when brakes are applied over long periods and heat up. This particularly happens on downgrades and sharp turns. Particles shear off and land on the ties or in the vegetation. Malfunctioning brakes can start fires at any location. This includes stuck brakes and set brakes.

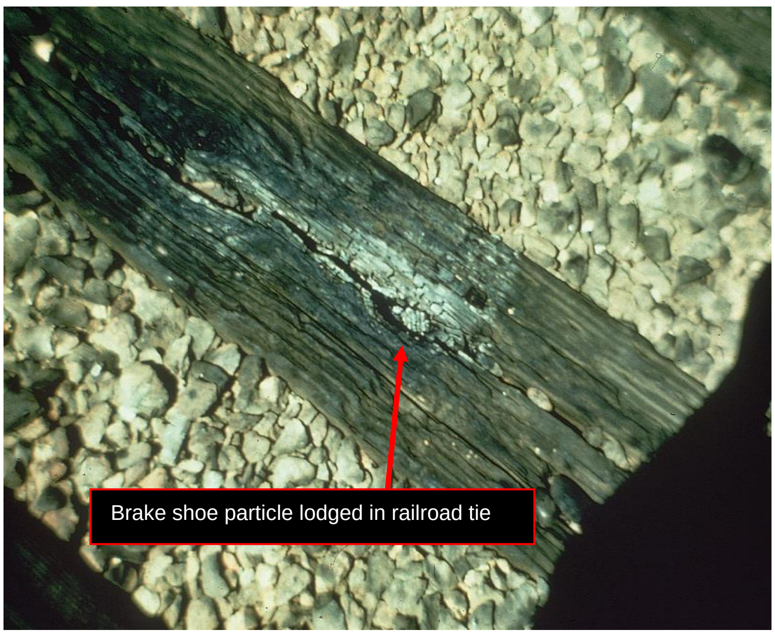
Figure 7.75. Railroad car brake pad.



A brake shoe particle will typically be found in the ignition area but may have rolled past or moved, particularly on steep slopes. There may be multiple starts in a short distance.

Figure 7.76 is an example of a brake shoe particle lodged in railroad tie. Fires starting on ties often occur where rotten wood exists and may raise questions of maintenance issues.

Figure 7.76. Brake shoe particle in railroad tie.



Ignition factors related to track maintenance: Track wear requires regular maintenance including welding, cutting, grinding, rail stressing, and rail stretching. Welding exposes the fuels to an open flame and sparks. Catalyst welding produces hot ceramic molds that may be carelessly discarded or buried in the fill. Look for the remains of ceramic molds as shown in figure 7.77. These can be near the rails or may have been dropped or discarded a distance from the rail.

Figure 7.77. Ceramic molds along railroad track.

Track grinding, both manual grinding and machine grinding, emits sparks and hot grinder residue. It is possible to recover metal particles using a magnet or metal detector. Grinders may be portable and brought to the site by maintenance crews or may be mounted on a maintenance train that moves as it grinds.

Track grinding slag (fig. 7.78) can accumulate on the underside of the maintenance rolling stock and fall off.

Figure 7.78. Track grinding slag.

Ignition factors from dynamic brake grid failure: When a dynamic brake is applied, the traction motors convert to generators which produce electrical current that is routed to a resistor grid on the locomotive. This resistor grid resembles a large toaster element and its location on an engine varies but it is typically vented out the top of the locomotive. Overheating may result in failure with arcing and violent ejection of hot metal fragments. This failure is often accompanied by a loud noise. The grid material may or may not be picked up by a magnet due to some of the nonferrous material of the brake grid.

Figure 7.79. Dynamic brake grid exhaust outlet.

Ignition factors for signal flares: Signal flares are used by crews to warn railroad traffic of possible hazards. The remains are consistent with those of highway flares and may be found near locations where maintenance work occurred, or where other related hazards were present.

Figure 7.80. Signal flare debris.

Ignition factors for right-of-way maintenance: Vegetation removal along railroad rights-of-way often involves mowing, spraying, and burning.

Figure 7.81. Right-of-way maintenance burning.

Ignition factors for wheel slip/slide: Train wheel slip and slide may occur when a train brakes or accelerates allowing the wheels to spin in place (slip) or brakes causing the wheels to slide. Wheel slip or slide can cause hot metal particles to fall into the ties or vegetation. Metal fragments can be recovered with a magnet or metal detector. Indicators of wheel slip or slide are most likely to be found where a train accelerates or decelerates. The track may have a welded appearance adjacent to the ignition area.

Figure 7.82. Train wheel slip on train track.

Ignition factors for railcar axle bearings: Roller bearings within the hub and axle assembly can overheat and fail. The hot roller bearings can be ejected from the wheel assembly and land on the wooden ties or on vegetation and ignite the combustible materials.

Figure 7.83. Railroad wheel roller bearing hub assembly.

Figure 7.84. Roller bearing assembly that has been identified by a hotbox detector as being defective and tagged as "bad order"—a railroad term for a defective item or items.

Figure 7.85. Roller bearing thrown from wheel assembly that was hot when it landed in the vegetation as exhibited by the burned area around it and under it.

Investigative techniques for railroad fires, in general:

- Specific safety considerations:
  - Identify if the railway is active.
  - Avoid placing any part of your body in between rail switches.
  - The area within one arm's length of the track is the Red Zone due to the hazards associated with work within that area.
  - Brake grids can produce 600 volts—use extreme caution around them.
  - Consult with the rail company on safety measures.
- See general investigative techniques.
- Interview the train crew and maintenance crew.
- Examine track and ties for indications of ignition source.
- Document condition of the rails, track, vegetative clearance, and other railroad structures.
- Sweep the ignition area with a magnet and/or metal detector.
- Determine if a train has passed recently or if any recent track maintenance has occurred.
- Obtain track elevation and topography maps.
- Identify the train number, locomotive engine(s) numbers, train crew, train schedule including time, direction of travel, and railroad milepost marker numbers.
- Have the train inspected by a qualified inspector for any deficiencies.
- Use the nearest milepost marker as a fixed reference point from which to base measurements and identify photo locations.

- Rolling stock may ignite multiple fires in proximity, so ensure the examination includes a search for more than one ignition area.
- Search both sides of the track for ignition mechanisms that may not have started a fire. This includes carbon exhaust particles (figs. 7.73 and 7.74), brake shoe particles, grinder residue, burn piles, track heating, flares, metal fragments, dynamic grid fragments, track damage, etc.
- Search for, document, and collect the actual remains of any of these ignition sources.
- Check records for prior fires along the track at different locations. These may be in another agency's jurisdiction.
- Obtain train maintenance records.
- Obtain train data recorder and infrared detector information as soon as possible, as these files are often automatically purged from the equipment.
- Obtain video recordings that may have been taken from the lead and trailing units. These are becoming commonplace within the railroad industry.

The NWCG course, X-902, Investigating Railroad Caused Wildfires, is available through the Wildland Fire Learning Portal (https://www.wildlandfirelearningportal.net/).

Recreation and Ceremonies

- Barbeque/smoker
- Bonfire/party fire
- Campfire/Ceremonial fire
- Gas cooking/warming/lighting device
- Luminary (aerial/ground)
- Outdoor oven/fireplace/metal fire ring

Campfire, Bonfire, Ceremonial Ring Fires

Definition: Any fire kindled for warmth, cooking, light, religious, or ceremonial purpose.

Ignition factors: Escapes can be caused by several factors, including:

- Failure to properly extinguish
- Failure to attend to the fire
- Improper clearance or construction
- Careless placement
- Fire play
- Improper discarding of coals or ash
- Improper use of accelerants
- Careless discarding of matches
- Camp stove malfunction

The primary ignition mechanisms for an escape include:

- Direct flame impingement
- Aerial firebrands
- Rolling materials
- Creeping fire under or around control barriers
- Overly heated rocks containing moisture that shatter (explode), blowing burning wood embers out of the fire pit area

Firebrands or rolling material typically result in an ignition area downwind/downhill of the fire and are typically close to it. Paper or cardboard is a prime aerial firebrand material which may still be present in the remains.

Creeping campfire escapes may result from uncleared organic material around the edge of the fire, often resulting in a smoldering type of escape, with a fire pattern that looks like fingers extending. Underground root systems may transmit smoldering or creeping fire to the exterior of the fire. Unattended, abandoned, or improperly extinguished fires are common factors in creeping escapes.

Discarded coals or ash placed on fuels before total extinguishment will generally result in an ignition area near the original campfire. The coals or ash may be exposed or buried under soil. Heat within a pile of ash or buried coals may be retained for hours to days.

Circumstances: The typical circumstances leading to a campfire escape include a recently used campfire at or near the origin of the fire. Signs of human activity at or near the ignition area may help to determine the sequence of events.

Circles of rocks or pits or a pile of wood are good indicators of a campfire, although not all campfires will be within rock rings. Signs of recent camping activity indicate the possibility of a fire nearby. Wet ash and/or ash mixed with soil in a failed effort to extinguish the fire may be present.

Figure 7.86. Examples of campfire escape.

Unextinguished campfires will form white ash on the surface if not disturbed by extinguishment efforts. Inadequately extinguished campfires will form a crust of ash on top when mixed with water, allowing the fire to smolder under the crust. Campfires smothered with soil or rocks may have similar effects.

Wildfires burning over old campfire rings will not likely re-ignite coals.

Investigative techniques:

- See general investigative techniques.
- Determine who was responsible for the construction and use of the campfire before the escape took place.
- Determine what safety precautions and tools were used to safeguard against an escape during use of the campfire.
- Determine when the fire was constructed and how long it was used.
- Determine what materials were burned during the use of the campfire. Collect samples, if necessary.
- Examine the interior of the campfire to determine if there is any residual heat.
- Use a high-temperature thermometer or other method to establish residual heat levels.
- Determine what actions, if any, were taken to extinguish the campfire.
    - In cases of juveniles involved with an escaped campfire, determine what parental supervision was involved. If there was prior parental knowledge, did the parents oversee the use and subsequent extinguishment of the campfire?
- Examine the construction of the campfire ring, the clearing of ground to mineral soil, and the continuity of fuels around and above the campfire.
    - Char and ash residue often reveals if the construction was fire safe.
    - Document the fire ring condition. Examine organic soil layers surrounding the fire ring for ground fire transmission to surface fuels.
    - Measure the ring dimensions, including the average ash depth, making note of color, size, and condition of ash/charcoal.
- Thoroughly examine the ashes in the campfire bed for signs of proper extinguishment or material involved with slow smoldering combustion.
- Look for the presence of hot coals and vent fumaroles (a hole in the ash in which hot gases and vapors have escaped) on the surface of the ash.
- Determine if the campfire was left unattended at any time or allowed to spread from the fire ring.
- Document the purpose of having the campfire and include identification information on all persons at or near the campfire during its use.
- Contact the landowner to verify the campfire user had permission to have a campfire on the property.
- At the campfire site search for and note:
    - Bottles, cans, or other consumer debris
    - Circle of rocks (fire retainer) within the burned area
    - Seating, such as logs around a circle of rocks
    - Pile of unused firewood
    - Campsite registration information

    - Accessibility
    - Ashes from firewood in a definite pattern
    - Abandoned camping equipment
- Check trail registers, campfire permits, campground logs, and registration.
- Determine if the use of the campfire was in violation of any fire regulation and document.
- Take pictures of the fire ring close up and from a distance, showing proximity to the ignition area and spread direction.

Luminaries

Definition: Luminaries may include ground displays (i.e., candles in bags) as well as aerial lanterns. Flying lanterns are miniature hot air balloons made from paper, plastic, bamboo, lightweight wood, and wire with a solid fuel package. Originating in Asia and called happiness balloons or wish balloons, their use has spread around the world and they are commonly used during weddings or other celebrations. Manufacturers claim that the paper is treated with a fire retardant, but many are not.

Circumstances: Flying lanterns can travel miles away from a release site and can reach several thousand feet in altitude. Multiple lanterns may be released at a single time.

Some jurisdictions have classified flying lanterns as fireworks and banned them.

Investigative techniques: Physical evidence at the scene may include remains of the wire or wood frame, pieces of bamboo, paper remains or ash, melted plastic bag, and the fuel package.

Figure 7.87. A flying lantern in package.

Figure 7.88. Remains of flying lantern after burning.

The release site may be a significant distance from the location of the fire. Remains of the balloon may be suspended above ground in vegetation or on structures.

Smoking

Definition: Wildfires caused by smoking activities or smoking accessories, including matches, cigarettes, cigars, pipes, electronic cigarettes, illegal substances, etc.

Cigarettes and related accessories may be hard to see, as shown in figure 7.89.

Figure 7.89. Burned remains of cigarette and match.

Ignition factors: Redsicker and O'Connor (1996) observed that "cigarettes have long been the scapegoat in cases where no other cause could be determined." To effectively assess the probability of a cigarette as a competent ignition source, consider the following:

- Physical characteristics of the cigarette
- Environmental factors
- Physical placement factors
- Fuel bed characteristics and condition

Ash content in cigarettes varies and will affect the exterior temperature of the tip. There is shrinkage of the tobacco during burning. As the tip burns, it lifts up and away from the fuel bed. Heat transfer is primarily by conduction and radiation unless suspended in fuel.

Linear burning progression limits exposure to any one point to 1 to 2 minutes.

Total burn time of a cigarette is approximately 10–20 minutes, depending on the brand (Fire Findings 1994). Most people discard a cigarette that is almost totally consumed. Therefore, the fuel bed's typical exposure to heat is approximately 1 to 2 minutes. Cigarettes that are not fully consumed may be an indicator of arson. The length of the ash remains should be examined and consideration given to being part of a time-delay incendiary device. The investigator should look for additional information supporting arson or smoking.

> *A burning cigarette is actually a case of smoldering fire where the combustion is occurring only at the surface of the ground tobacco and the air interface. As soon as the cigarette is lit, the glowing fire progresses toward the unlit end of the cigarette at approximately 0.21 inches per minute.*
>
> *Cigarettes range in size from 2.75 to 3.94 inches in length and can burn for 15 to 20 minutes. Cigarette tobacco in still air burns at a temperature of 500 F. Due to the small volume of the cigarette, the actual output in BTUs is rather small. However, under certain conditions, a cigarette is capable of starting a smoldering fire which can break into flame with an increase in ventilation (Carroll 1979).*

Figure 7.90. Cigarette remains with undisturbed ash.

Ignition factors include:

- Finely particulated fuel bed
- Loose fuel arrangement
- Microclimate location (temperature at ground level vs. temperature at higher level)
- Tip orientation—tip must be vertical or at an angle
- Light winds

Because cigarette-caused fires ignite at or near ground level, weather readings should be taken as near to the location on the ground and as near to the time of ignition as possible. Microclimate conditions at ground level can vary significantly from those taken at eye level or 20-foot levels.

Physical placement of the cigarette is an important factor. If possible, the investigator should determine what the cigarette position was when it ignited the fuels, not its final resting place after the fuels ignited and burned. In many instances, this may not be possible to precisely determine. To increase the chance for a cigarette ignition, the glowing tip needs to be in contact with the fuel bed. The tip should be oriented into the wind and may be burrowed or angled into the fuel bed.

When considering the circumstances related to a possible cigarette-caused fire, the weather and fuel bed conditions should be evaluated based on the most relevant research data. Besides the physical placement of the cigarette remains, signs of human activity may be present in or near the origin area.

Rounded or pointed ash tips may indicate active smoking. A flat ash tip may indicate extinguishment prior to being placed. Old remains may have a bent, weathered, or mangled appearance.

Figure 7.91. Examples of cigarette tips.

Investigative techniques:

- See general investigative techniques.
- Photograph, examine, and document all cigarette butts located in or adjacent to the ignition area before touching or moving them.
- Use a hand lens to determine if any alteration or modification has occurred that may indicate the cigarette was used as an incendiary device.
- Before moving the remains, measure its location in reference to the ignition area or other relevant points, including distance from any nearby roadway.
- Measure length of ash and unburned product.
    - Note distinguishing markings and whether a filter is present and if the product is hand rolled.
    - Examine the condition of remains for indications of crushing.
- Examine and gently remove ash layers to reveal their structure. Size and weight ratios of cigarettes (and matches) usually prevent them from burning to the ground surface; however, surrounding ash may obscure them.
- Collect the cigarette residue and butt using a basal-area lift technique.
- Determine and document the specific weather conditions at the suspected time the cigarette butt was delivered to the fuel bed.
- Determine what the depth and arrangement the fuel bed would have been at the time of ignition. Examination of unburned fuels near the general origin area may provide an idea of the fine fuel factors.
- Determine if any fire prevention regulation was violated and what enforcement action and subsequent disposition took place.

Misuse of a Fire by a Minor

- Lighter/matches
- Glass refraction/magnifying glass
- Incendiary device
- Flint/friction

Definition: Wildfires started by persons 17 years old or younger. For the purposes of this category, “children” are ages 0–12 years, “adolescents” are ages 13–17 years and “adults” are age 18 years and over. This may vary by jurisdiction; the investigator should ensure they are familiar with their laws and guidelines. Children may be motivated by normal curiosity and use fire in experimental or play fashion. It often involves multiple children. Adolescents, however, may be motivated by curiosity or malicious intent. Malicious intentions may be an indicator of arson and not misuse.

Ignition factors: Children frequently use easily accessible ignition devices including matches and lighters. Children may combine the ignition device with other fuels brought to the scene, such as paper and cardboard.

Circumstances: Fires caused by children may have the appearance of fire play, including numerous matches or matchbooks, burned toys, cigarettes, paper, and boxes. The ignition areas are usually located away from adult supervision.

Children responsible for igniting fires will often flee the scene but may return later to watch suppression activities. Uninvolved children are curious and sometimes will go toward the fire scene.

Fires associated with children may have a corresponding pattern of fires involving structures, schools, or playgrounds. Children may attempt to suppress the fire in the early stages. Burned clothes or shoes on children in the area may be the result of attempted suppression actions.

Wildfires that are associated with children often take place during times when children are available, such as before or after school or during the weekends or summer vacation or other school holidays. Fires may be timed with release from school and, in some cases, during recess periods if the child has access to a nearby field.

Child-size footwear impressions or bicycle tracks (or both) may be present at or near the scene and in some cases may lead back to the child's residence.

Figure 7.92. Match evidence.

Investigative techniques:

- See general investigative techniques.
- Contact with and interviews of children must be conducted in accordance with appropriate legal process.
- Look for signs of fire play such as numerous matches, burned toys, stuffed animals, forts, bike paths, etc.
- Look for signs of any attempt to suppress the fire; these will typically be unsophisticated.
- Determine if there have been other similar fires nearby.
- Determine if the actions are due to normal curiosity, deviant behavior, or a malicious act.
- Consider referral to a youth fire setting intervention specialist or involving one of these specialists during the interview process.

Other Causes

- Spontaneous combustion
- Coal seam
- Electric fence
- Refraction
- Illegal substance manufacture
- Structures

Spontaneous Combustion

Definition: Combustion of a thermally isolated material initiated by an internal chemical or biological reaction producing enough heat to cause ignition.

Certain fuels will self-heat and ignite spontaneously when conditions support a combination of biological and chemical processes. This action is most likely to occur in moist decomposing piles of organic material such as hay, grains, feed pellets, manure, sawdust, wood chip piles, and piled peat moss. Active flaming combustion can and often does occur when wind and/or sun has dried the exterior layer of product and the smoldering fire surfaces.

Ignition factors: Factors often present at the scene of a wildfire caused by spontaneous combustion include:

- Piled, compacted, or bailed organic material
- Moisture within material
- High air temperature
- High relative humidity
- Chemical reaction

Material may smolder until an increase in wind causes the combustion to convert to flaming.

Figure 7.93. Evidence of spontaneous combustion.

Figure 7.94. Typical fire effects in sawdust or wood chips when spontaneous combustion occurs.

Circumstances: Indicators may include a pile of material at the ignition area, direct exposure to sun, witnesses reporting bad odors and/or steam, slime/mold/toadstools, or creosote-like substance oozing out of the bottom of a pile. A hard “clinker”-like substance may be found in the interior of the pile.

The presence of materials that may spontaneously combust, areas that exhibit outward burning from the interior of the pile (as in figure 7.93), surface collapse, and vents (steam holes), are all clues of a possible spontaneous combustion-caused fire.

Spontaneous combustion events may occur following a period of rain or other water application to the fuel bed followed by a period of hot and dry weather.

Figure 7.95. Typical spontaneous combustion fire effect in sawdust and wood chips.

Investigative techniques:

- See general investigative techniques.
- Locate and interview witnesses and reporting parties.
- Determine the weather leading up to pile ignition. Look for cool periods, followed by a significant change in weather.
    - This could indicate the pile experienced a strong exposure of exothermic heating, which is thought to cause a form of thermal feedback that may quickly change pile conditions in favor of ignition.
- Examine debris piles for species composition and particle size.
    - Susceptible piles usually have a significant percentage of fines, and the pile is compacted.
    - Determine when the material was piled or bailed.
    - Determine if the material was wet, or became wet, when it was piled or bailed.
- Determine the process by which the piles were created.
    - For example, grinding following a de-limbing process creates sufficient fines that will compact.
- Determine if live or dead foliage was involved during the process period and to what extent.
- Determine the extent machinery was used in pushing up the piles and the degree of soil mixing involved in this process.
- Document creosote leakage, fungal activity, and any strong odors associated with the exterior of the pile and any venting (steam holes) present.
- Attempt to locate any materials that have been involved with pyrolysis yet have not been associated with open free burning.
- Determine if the pile burned from the inside out or the outside in.
    - The degree of particle consumption, burned versus unburned material, type and distribution of ash or charcoal, and general heat distribution within the pile are elements to examine.
    - Examine the interior of the pile for fused silica residue (clinkers).
- Determine if the piles were self-heating by examining similar but unburned piles.
- Use photography and video as much as possible when documenting suspect spontaneous combustion forest residue piles, including sawdust piles.

Coal Seam Fires

Definition: Coal seams may be ignited by lightning, wildfires, or other ignition sources.

Circumstances: Fires typically burn slowly underground along the coal seam. Where the coal seam nears the surface, it may break through, igniting exposed vegetation and causing a wildfire. These wildfires are dangerous to investigate as the burning coal seam may lie just under the surface. Coal seam fires may be visible in the winter with steam plumes and random bare patches in the snow from underground heating. Patches of dead vegetation may also be a tip that underground heating from a coal seam fire is taking place.

Figure 7.96. Smoke discharging from coal seam fire.

Figure 7.97. Flaming combustion as a coal seam fire surfaces and mixes with oxygen.

Investigative techniques:

- Specific safety considerations—surfaces may collapse when walked on.
- Seek out local agencies who may have specific information related to the coal seam and may be able to:
    - Provide details on monitoring and mitigation activities
    - Measure and monitor the temperature
    - Map coal seams

Electric Fences

Definition: Fires originating from electric fences. Rapid electric pulse cycle does not allow fuel to cool down.

Ignition factors: Weed-clipper type electric fence systems are the most likely to ignite wildfires because they operate with an electrical charge of sufficient duration to cause combustible materials in contact with the fence to ignite in certain conditions. Underwriter Lab-approved control heads are recommended by many agencies and, if properly installed, are less likely to start fires.

Fires from this cause typically occur in the late spring or early summer during the growing season. Growing vegetation or vegetation that is just drying out may contact the fence wire and can be heated to its ignition temperature, causing a fire.

Figure 7.98. Grass residue is on the electric fence wire at the point of contact in this photo. Burn marks may also be present and may be the only sign of fence contact.

In other situations, the fence wire is wrapped around or contacts a tree limb or wooden fence post. Fires can occur from braided wire or solid wire.

Figure 7.99. Burn on a small tree where electric wire was wrapped around it.

Circumstances: Burned-off stubble, vegetation contact, vegetative transfer, and intermittent char marks on the wire are characteristics that should be noted. Conditions also include a fire origin along an electric fence line, dry grass that has not been cut back from the fence, wires that are no longer mounted to insulators, and broken and failed insulators.

Investigative techniques:

- Specific safety considerations—determine if the fence is electrified.
- See general investigative techniques.
- Determine if origin is near fence wire.
- Determine fence line condition and maintenance.
- Determine whether the line was electrified.
- Observe and document power supply lines from source to fence and document any contact with vegetation, lack of insulators, etc.
- Examine the entire line and look for other areas where vegetation has charred but not started a fire.
- Document any tripped circuit breakers.
- Identify manufacturer, make, and model.
- Evaluate vegetative maintenance along fence lines.
- Examine fence wire for discoloration or presence of charred vegetation.
- Have a qualified electrical engineer conduct a forensic evaluation at the scene before dismantling the fence.
- Provide for additional lab testing.

Figure 7.100. Forensic examination at the scene before the system is dismantled.

Refraction

Definition: The sun's rays can be focused to a point of intense heat if concentrated by certain glass or shiny objects. The refraction process bends light rays, similar to that which occurs through a magnifying glass. The shiny, concave end of a metal can focus sunlight, but its short focal distance makes its potential as cause unlikely. Fires started by items like these are rare occurrences; however, objects possessing these characteristics recovered from the specific origin area may need to be carefully examined to determine their fire-starting potential.

Figure 7.101. Examples of refraction.

Ignition factors: Objects known to have caused fires include cut crystal, clear glass bottles filled with a clear liquid, headlight lenses, mirrors, old window glass (bubbled), shiny aerosol can bottoms, polished metal, and clear plastic bags filled with water or other clear liquid.

This cause may have to be considered because of the presence of an object at the origin with the potential for starting a fire (as shown in figure 7.101). Flat broken glass lacking magnification or colored glass will not start fires.

Investigative techniques:

- See general investigative techniques.
- Document ignition area in relation to the object's location and orientation to the sun at the time of day that the fire ignited.
- Document amount and periods of shading. Consider the day of the year and the specific sun position on the day of ignition.
- Identify concave glass in the ignition area.

Structures

Definition: Fire spreading to the wildland due to failures or activities associated with a structure.

Structure fire investigation is a task requiring specialized training and skills. Consider the need for additional and/or specialized resources.

> Do not attempt to conduct an independent origin and cause determination of the structure unless you are trained and have the authority.

Circumstances:

- Burn indicators that show the fire originated at or in structure.
- Witnesses reported smoke or flame coming from a chimney before the wildfire.

- Power failure within a structure.
- Human activity in the area.

Investigative techniques:

- Specific safety considerations:
  - Harmful gases and vapors.
  - Unstable structure.
  - Explosive items such as propane containers, ammunition, etc.
  - Drug labs.
  - May require specific protective equipment.
- See general investigative techniques.
- Work with specialized structure fire investigative resources.
  - Walk around the burning structure documenting the degree of burn.
  - Locate and document condition of gas, electrical, and water service.
  - Examine exterior for evidence of activity, including containers or spill patterns that may indicate the use of an ignitable liquid accelerant.
  - Examine doorways and windows for signs of forced entry and/or explosion indicators.
  - Photograph burning structure early to document where and to what degree fire is burning in each portion of the structure.

Chapter 8. Wildfire Arson Recognition

Introduction

Intentionally set wildfires are a significant problem. A fire started in the right place and under the right conditions can have devastating consequences. Every intentionally set wildfire has the potential to be a destructive event. The destructive potential and impact on society of wildfire arson outpaces most other crimes. Early recognition of arson fires is an important step in identifying and potentially solving serial arson crimes.

Arson vs. Incendiary

Intentionally set fires can be defined as either arson or incendiary. The term arson usually refers to a legal charge or a crime, whereas incendiary is a causal factor for a fire.

The definition of the crime of arson varies by jurisdiction. "However, it is generally defined as the crime of maliciously, intentionally, or recklessly, starting a fire" (NFPA 2022, 3.3.16).

"Incendiary fires are intentionally ignited in an area or under circumstances where and when there should not be a fire" (NFPA 2022, 3.3.124).

Investigators are encouraged to become familiar with the specific laws related to arson in the jurisdictions in which they work.

Serial Arson

Serial murder is likely the most recognized form of serial crime discussed in modern culture. Serial is a descriptor associated with a crime committed more than once. The definition of what would be considered "serial" depends on the specific crime. The FBI adopted the definition of serial murder as being two or more murders by the same suspect in separate events. With arson, the FBI defined serial arson as the setting of three or more fires with a significant cooling-off period between each fire. This definition (while it is still used) incorporates an emotional component into the act of arson. A more contemporary definition puts the focus on the action itself. It defines a serial arsonist as someone who has set multiple fires during different events. While there is potentially an emotional component to arson, it should not be the focus of an arson investigation. Often, the reason an arsonist commits serial arson is known only to the arsonist.

Spree Arson

Often an arsonist is a spree offender—defined as someone who sets three or more fires without any cooling-off period. Such arsonists may start multiple fires over a short period of time and then wait weeks, months, or years before starting another fire.

Typically, arsonists who get noticed by investigators are those lighting multiple fires over a short period of time. The multiple fires may stand out when examining the fire history for the area. An arsonist who starts one or two fires over the summer will not likely stand out from a fire history perspective.

Ultimately, investigators need to focus on investigative tactics to uncover an arsonist rather than attempt to classify them.

Challenges in Arson Investigation

Many arson fires go unrecognized—because of the lack of investigation, poor origin and cause investigation, lack of overt evidence discovered or collected, failure to share information between investigators and affected jurisdictions, and linkage blindness. Successful recognition of a serial arson case involves the ability to link what may initially seem to be unconnected fires. This is done through physical evidence collection, forensic analysis, pattern analysis, identifying the person(s) of interest, and behavioral evidence. A NWCG course FI-310, Serial Wildfire Arson Case Development, and other arson-related courses cover these topics in greater detail.

Early identification of an arson series is critical. Local firefighters and investigators will likely be the first persons aware of an increase in fires. Knowing the fire history in the area of investigation is crucial. How many fires are “normal” for an area? An increase in fires does not necessarily mean there is an arsonist, but it should be one of the first indications of a potential arson series when looking at the area’s overall fire history. The first fire event(s) in an arson series may have less sophistication and more evidence, thereby increasing chances for apprehension.

The few studies on wildfire arsonists available are based on information provided by convicted offenders and case study reviews. In 2004, the Forest Service conducted an informal study—not peer-reviewed or published—of 68 serial arson cases. The informal study showed the average serial arsonist involved in the study was charged with 2 to 3 counts of arson, but was suspected of setting an average of 35 fires before being apprehended.

CAL FIRE analyzed serial arson cases occurring from 2015 to 2019 and found that serial wildfire arsonists ignited an average of 23 fires before being apprehended. Most of these fires were set before an arson problem was detected or an arson suspect identified. Further review demonstrated that incendiary fires accounted for approximately 10 percent of all fires annually, while undetermined fires accounted for approximately 30 percent annually.

Another challenge in identifying or recognizing arson as a problem is agencies' classification of small fires as “nuisance fires.” These small fires are often not investigated or taken seriously because they cause little damage or have minor costs for suppression. In many instances, fire management only takes large and/or expensive fires seriously. Regardless of the size or cost to suppress, all human-caused fires should have an unbiased investigation to determine their origin and cause. Some agencies do not require an origin and cause investigation for natural fires. Due diligence should be taken by the investigator as it is not uncommon for an arsonist to use the presence of lightning in an area as cover for arson activity. If there is a series of suspicious fires, the investigator may want to investigate suspected lightning fires to rule out arson as a possible cause.

Arson cases can be difficult to prosecute. Prosecutors may have little or no experience with wildfire arson. Wildfire arson is often lumped with other less serious crimes because the investigation only links the arsonist to one or two fires. These fires may be small, which the criminal justice system equates with a less serious offense. Prior to and during case development, the job of the investigator is to educate the prosecution to focus less on the actual size of the fire to consideration of the potential severity of the fire and values at risk: What did the fire threaten? How big could the fire have become? What was the risk to the firefighters and public from resources responding to the fire? Every fire has the potential for catastrophic consequences.

Solvability Issues

Arson can be a challenging crime to solve, but these challenges are not an excuse for failing to conduct a credible investigation or for conducting a poor investigation.

Investigations of possible arson fires may fail because of factors such as:

- Little effort is expended to find or collect physical evidence.
- Fire suppression or the fire itself may destroy or obscure evidence.
- Evidence is mishandled and/or not sent to a crime lab in a timely manner.
- Wildfire arsonists tend to work alone.
- Wildfire arsonists rarely confide in others regarding their activities.
- A time-delay device may be used, allowing the suspect to flee the area.
- Witnesses to the crime are uncommon and can be difficult to locate due to remote areas.
- Witnesses identified are not interviewed (i.e., 911 callers, neighbors, etc.).
- Lack of information sharing between investigators and affected jurisdictions.
- Linkage blindness.

Role of the Investigator

The local investigator is in the best position to detect an arson pattern in the early stages of development, often within two or three fires. An investigator needs to have an awareness of arson indicators and be familiar with fire occurrence patterns.

Investigators should follow agency policy when determining their role on a suspected arson fire scene. Take scene security and protection measures seriously. Request additional investigative resources as necessary, then wait for their arrival while performing all the normal activities associated with the location and protection of evidence, scene security, and potential witness identification.

Strict confidentiality and operational security are critical during an arson investigation. Do not share details of the investigation outside the investigation team. This may include limiting the information released within agency management or with other agencies not part of the investigation. The description of any arson device should be kept confidential.

The careful management of information is crucial in an arson investigation. However, to prevent linkage blindness, some information needs to be shared with other investigative teams or agencies. Let the investigative team lead make the determination on how, when, and with whom to share information.

During an investigation of a suspected arson wildfire, the investigator should:

- Examine and analyze the evidence to determine if the evidence supports arson.
- Protect and secure evidence.
- Maintain situational awareness and document persons and vehicles that are present or lingering at the scene.
- Provide notification according to agency policy.
- Share information only with those who need to know.
- Do not release any information to the media without agency approval.
- Know your authorities and work within them.
- Consult early and often with the prosecutor to ensure legal processes are being followed.

Although “profiling” of criminals, including arsonists, still lingers in books, investigative training, and expert testimony, typically these “profiles” are so vague they do little to help catch the arsonist. Investigators should focus on investigative skills, techniques, and evidence collection and analysis to solve cases.

Motive

Motive is the reason someone commits a crime. Convicting the offender of arson does not depend on knowing or proving their motive. Understanding the motive of a serial wildfire arsonist can be important in an investigation but should generally be considered later in the investigation. Looking for a motive too early in an investigation can create bias and cause investigators to waste time looking for the wrong person.

Motive should not be used to support a hypothesis of arson. A serial arsonist may have a mixture of motives.

The Federal Bureau of Investigation classifies arson into six categories of motive:

- Retaliation or revenge
- Excitement
- Profit
- Vandalism
- Crime concealment
- Extremism or terrorism

Retaliation or revenge motive relates to a perceived injustice or wrong against the offender. Subsets of this motive category include individual, societal, institutional, and group retaliation or revenge. A connection may exist between the target of the arson and the arsonist. This is an exception to looking at motive too early in the investigation. While retaliation and revenge could be considered to help develop possible suspects, the investigation should not just focus on this motive.

Excitement motive relates to fires set to satisfy an emotional need to create excitement. Subsets include curiosity, thrills, attention, and recognition. Recognition is the primary motive for most firefighter arson offenders.

Profit may be related to a plan to maximize property damage and not hurt people, which is often related to insurance fraud. In this instance, there may be a connection between the target and the arsonist. This is another exception where looking at motive early in the investigation may help to develop possible suspects. But the investigation should not just focus on this motive.

Vandalism as a motive means fires are generally lit simply for destructive purposes. The offender may have an accompanying pattern of small fires in a nearby area. Equipment or structures in the woods may be targeted. In the case of vandalism as a motive, fires are less likely to be set directly to the natural resources as the arsonist is more interested in causing damage to property.

Crime concealment as a motive means offenders set fires to destroy the evidence of a primary crime other than arson, such as homicide or vehicle theft. Using fire as a distraction for another crime could also be considered crime concealment. Scene security and evidence protection are particularly vital in such cases, as well as cooperation with law enforcement.

Extremism or terrorism includes fires motivated by political or social agendas. In the United States, radical environmentalists have been associated with this activity.

The following groups often act with consistent motives and indicators:

Firefighter arsonists are often motivated by the desire to be considered the hero, along with excitement, recognition, and/or profit. As a motive, the firefighter arsonist may make additional money by starting fires or helping fire to escape the boundaries of control to extend the need for the firefighting effort. Volunteer firefighter arsonists may get a thrill by responding to fires they light. This group also includes other emergency service workers, law enforcement, security guards, wannabes (who have an obsession with firefighting/law enforcement/emergency services), and arson by proxy (family members).

Youth fire-setters may act out of curiosity or as a cry for help. Delinquent fire-setting in older youths can fall under the vandalism, excitement, or attention motive categories.

Mental health disorders can cause individuals to set fires for a variety of reasons and do not fit within the above motive categories. Fires caused from within the homeless population are on the rise. Generally, they occur in urban areas but may involve the wildland when homeless populations intersect with the wildland urban interface. The increase in these types of fires may be related to the growing mental health crisis in the homeless population or simply related to the overall increase in homelessness.

Typology of Arson

The two main typologies for arson are goal-directed and emotion-based. Goal-directed arsonists have a specific goal in mind before the event. A large percentage of urban arson fires are goal-directed. The motives associated with goal-directed arson are retaliation/revenge, profit, vandalism, crime concealment, and extremism. Emotion-based arson may have no known connection between the arsonist and the target. Motives associated with emotion-based arson are vanity/hero, juvenile/curiosity, and excitement. Serial wildfire arsonists will likely have some blending between the two typologies. Ultimately, it is more important to “catch” the arsonist than it is to classify or label the arsonist (Nordskog 2016).

Incendiary Ignition Sources

Hot Set

Determining the ignition source is an important aspect of the investigation, and investigators should be aware of the various ignition sources an arsonist could employ. However, the ignition source most serial wildfire arsonists use is a hot set—that is, they use an open flame to ignite a fire and then remove the flame source from the scene. Grass, pine needles, draped moss, or lichen can make an excellent host fuel for a hot set. A branch, moss, or lichen can be lit well off the ground and still drop fire to the ground fuel (fig. 8.1).

Figure 8.1. Example of ignition of fuels off the ground.

Ignitable Liquids

Ignitable liquids are used to aid the ignition, spread, or growth of a fire. Dark sooting, smell, and burn patterns consistent with an ignitable liquid can be clues to its use. The discovery of an ignitable liquid in the ignition area of a fire for no known legitimate reason is a strong indicator of an arson fire. However, serial wildfire arsonists rarely use ignitable liquids because it is not needed to ignite a wildfire in arid climates. When used in the wildland, the liquid may be used to ignite wet or green fuels or by people who attempt to light larger diameter fuels because they do not understand the flammability of wildland fuels.

Ignitable liquids are more commonly used in arson related to revenge, retaliation, fraud, and crime concealment. If an investigator finds residue of ignitable liquids in the ignition area of a fire, this would be a rare instance where looking at motive early in the investigation may be necessary. Investigators should look at possible victim connections, other crimes in the area, or the potential for fraud related to damaged property. Some wildfire arson scenes where ignitable liquids are encountered include arson of remote structures and equipment, arson of vehicles, and fires set to conceal the body of a murder victim (body dump).

The investigator should collect a sample of the residue as well as a control sample See chapter 4 for more details on evidence collection.

Figure 8.2. Ignitable liquid trail used by arsonists to burn slash pile(s).

Incendiary Devices

An incendiary device is any combination of materials designed to speed the growth, delay the ignition, or start a fire remotely. Device types are limited only by the imagination, skills, training, and experience of the offender. The use of an incendiary device by a wildfire arsonist, while more common than the urban arsonist, is rare.

An investigator who finds a device during an investigation should treat it with the utmost care. It must be documented in detail with numerous high-quality photos before collection. The investigator's documentation should also include notes, measurements, and sketches, but without any attempt to analyze the device by taking it apart or manipulating it. The discovery of a device may indicate a crime of arson. The investigator should notify law enforcement and follow the agency's policy and procedures for submitting evidence to a crime laboratory. The device should be analyzed by a specialist at a crime laboratory as soon as possible. The lab can also conduct fingerprint and DNA analysis on the device.

The investigator's description of an arson incendiary device in a report should be specific and detailed. For example: *Marlboro cigarette with a green rubber band holding seven wood matches around the cigarette. Three of the match tips pointed at the filter, and four pointed at the end of the cigarette.".*

This level of detail may not be known until the lab report is returned. Until then, the investigator should describe the device based on what can be seen without manipulating or taking the device apart.

Additionally, the device construction should not be shared with anyone outside the investigation.

Incendiary devices range in complexity from candles and matches to sophisticated timing and remotely operated devices. History has shown complex devices are rare in arson cases because many common items are available to start a fire, and the complex devices are difficult to construct and may deliver inconsistent results.

Time-delay ignition sources incorporate a mechanism that enables the offender to flee the scene and reduce the risk of being seen at the fire. It can also aid the arsonist in establishing an alibi. A device designed for delayed ignition is an indicator of greater sophistication, higher level of commitment, and premeditation by the suspect. The suspect took the time to gather components and likely tested the device multiple times, possibly indicating a higher level of intent in the crime.

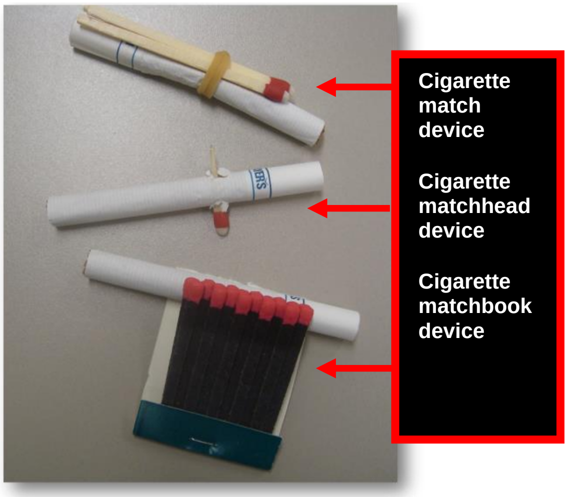
Overall, while rare, cigarette and match or matchbook devices are two of the most common wildfire time-delay devices used. Cigarette/match devices can use paper or wooden matches and may be attached using unique methods that can help to link fires and identify an offender. Without close inspection, an investigator can miss the matchhead within the ash, mistakenly concluding the fire was started by a discarded cigarette (fig. 8.3). The matchbook itself can yield valuable evidence on its cover and interior. This information should be documented. DNA can sometimes be recovered from the filters of cigarettes and from matchbooks. Package the remains appropriately for sending to the lab if analysis of DNA is being considered. See chapter 4 for more details on evidence collection.

Figure 8.3. Cigarette match device remains.

Incendiary devices are generally directly delivered or remotely delivered.

Direct delivery takes place when the device is hand-carried and placed in a specific location. Assembly of the device may happen before or at the location being deployed. An example of a direct delivery incendiary device would be a matchbook with a cigarette. The cigarette would be ignited at the location of the fire and placed in a configuration to create a delay for ignition (fig. 8.4).

Figure 8.4. Examples of cigarette match device construction.



Remote delivery devices are generally constructed away from the fire, ignited then propelled into the ignition area. This includes launching it from a distance by hand or mechanical means such as a slingshot. Ignition devices may be weighted to make it easier for the arsonist to throw or launch farther. After the fire is ignited, the weight may be found under ash or lying nearby. Examine the ignition area carefully for out-of-place objects that may have been used to weigh the device. Objects used as weights can include coins, rocks, nails, nuts, bolts, washers, or any other small, heavy object (fig. 8.5). The method used to launch the device may help in linking to additional fires.

Figure 8.5. Examples of weighted device construction.

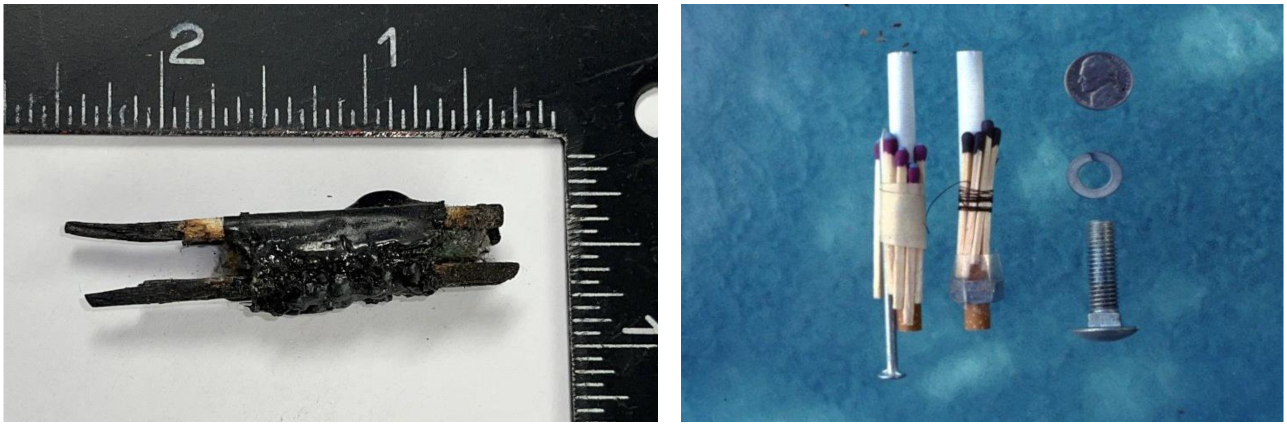


Figure 8.6. Paper remains protected under ignition device/rock and rock wrapped in paper prior to burning.

Ignition Scenario

Everything the arsonist does to light a fire and deploy an arson device is part of their method of operation/modus operandi (M.O.). A component of their M.O. is the ignition scenario. The investigator must identify evidence to determine the exact method the fire was started.

An arsonist may add to, rearrange, or modify fuels to aid in ignition and the spread of fire. They may also use available fuels in ways indicating manual manipulation before ignition, such as balling or twisting vegetation. This may become part of their M.O., which helps link fires to a single person or group of persons. How the device is constructed is also part of an M.O.

Patterns and Linkage Factors

Often arson fires go undetected because investigators fail to recognize a pattern and linkage to other fires. Examples of linkage factors are:

- Forensic evidence and uniqueness of evidence
- Ignition scenario
- Uniqueness of M.O.
- Uniqueness of incendiary devices

- Pattern analysis
- Target (Nordskog and Konefal 2020)

Various patterns may emerge when examining multiple fires, such as temporal clusters, geospatial clusters, M.O., and target. Investigators should examine the day of the week, day of the month, and time of day of the fires to determine if any temporal cluster pattern appears. The absence of fires during certain times of the day, days of the week, etc., can also be a pattern. These data may help link other fires and link fires to suspects. The pattern may also help exonerate potential suspects.

Fires in proximity with each other can form geospatial clusters. The history of incendiary fires in a common area should be reviewed and evaluated. While two fires in proximity may be an indication of a developing problem, they may have to be classified as undetermined in cause until additional data can be gathered, with which a working hypothesis of arson can be formed.

An M.O. is everything the arsonist did to successfully get to the scene, ignite the fire, and then depart the scene. M.O. can have linking factors identifying commonalities between how and where a fire is set and can be used to determine a pattern linking fires. Ignition scenarios and the uniqueness of incendiary device construction are part of the M.O.

The target consists of who or what was impacted by the fire. This would generally be the land, property owner, or an area, but could include other elements such as certain natural resources.

An example of pattern and linkage analysis would be to consider five fires occurring on Tuesdays and Saturdays, between 1400 and 1600 hours, on the same road system, with a paper match recovered in the fires. In this example, there is enough information to link the fires by time clusters, geographically, and M.O.

Indicators of Arson or Serial Arson

In some instances, the ignition source for a wildfire arson may have been removed from the fire scene (open flame, hot set), destroyed (consumed by fire, destroyed by natural or human activity), or not recovered for other reasons. While developing a hypothesis for what caused a wildfire, the investigator may include arson as a potential cause in addition to other hypotheses.

A well-defined ignition area boundary forms a foundation for the search of an ignition area. It also lays the foundation for the detection, protection, documentation, and recovery of evidence associated with an ignition source and an arson cause hypothesis. When an ignition area has been systematically searched and no direct evidence supporting the establishment of an ignition source has been found, either there or nearby, the investigator may need to seek additional evidence to establish an ignition source and arson cause hypothesis. When direct evidence of an ignition source is absent, the investigator may use other arson-related factors to develop a working hypothesis for a specific cause.

Collecting this additional evidence can take place during any phase of the investigation. Based on additional evidence gathered, the investigator is responsible for conducting an analysis of the totality of the evidence and for establishing an ignition source, ignition sequence, and arson cause hypothesis when the combined evidence indicates such a determination. The investigator must not simply pick arson as the cause because no other cause could be found. This would be considered a negative corpus and will result in an easy defense for the suspect. The investigator must have evidence to support the hypothesis of arson.

The following are indicators of an arson fire or serial arson. These factors are not all-inclusive; the investigator may consider other similar factors but should not rely on just one or two factors to determine a cause of arson unless the factor is significantly unusual and clearly cannot be explained by mere coincidence.

- No reasonable unintentional ignition source was found
- History of confirmed arson fires in the area
- Increase in fire history in a small area
- Fires occurring on similar days and times (temporal cluster)
- Multiple fires in proximity (geospatial cluster)
- Area with low detection risk
- Access blocked or access normally blocked was left open
- Subject(s) at or near ignition area on multiple fires
- Subject(s) found with incendiary device and/or components
- Subject(s) statements
- Subject(s) reporting multiple fires
- Witness statements
- Crime concealment
- Modified fuel
- Incendiary device or ignitable/ flammable liquids found with no legitimate source

No reasonable unintentional ignition source found. When unintentional and natural ignitions have been ruled out, and no direct evidence of arson is found, arson may still be considered as a cause. Other indicators of arson or linking factors may be identified to strengthen the arson hypothesis. An example is a series of hot-set ignitions.

History of fires in the area. A history of confirmed arson or undetermined fires in an area may be an indicator of arson as the cause for a recent wildfire. An analysis of fire history can provide a clearer picture of a pattern of local wildfire arson activity.

> *…the wildfire scene examination team may need to revisit past wildfires that were not examined or were previously reported as "undetermined" or "accidental" causes, extending back over months or even years in the area of interest, for example, to re-examine nearby fires to attempt to verify their cause, months or years apart (Woods 2023).*

The size of the area to consider is typically determined from the facts and history, but generally starts within a few miles of the area of interest and then expands to include prior fires as they are identified. Investigators should not categorize a fire as arson simply because there are other arson fires in the area. See below for additional information on undetermined fires and arson.

Increase in fire history. As previously discussed, a recent occurrence of undetermined-caused fires in an area exceeding the normal fire history is a potential indicator of serial arson. But an increase in fires alone is not an indicator of serial arson. In addition to thorough investigations, additional indicators of arson need to be examined.

Fires occurring on similar days and times. Temporal clusters of fires on the same day and/or time over days, weeks, months, or years may be an indicator of arson. The time of day, day of the week, months, etc., create a pattern that cannot be easily explained by coincidence. The absence of fires during certain times of the day, days of the week, etc., can also be a pattern.

Multiple fires in proximity to no other unintentional ignition source may be an indicator of arson fires. This is known as geospatial clustering of fires. Proximity is subjective regarding the actual distance considered. This could include multiple fires within feet of each other or within a geographic area, i.e., city, county, etc. Fire history plays an important role when looking at geographic areas. Several cause categories could include multiple fires in proximity. Avoid determining a fire is arson solely because it was in proximity to other fires with no ignition source(s) found.

Area with low detection risk. Most arsonists are looking for ways to limit their risk of apprehension. An area with low detection risk relates to the ease with which the scene can be accessed and the level of protection from detection the site offers. For example, if a fire occurs only a quarter mile from a neighborhood with a small hill between the fire and the neighborhood, this indicator could apply. The hill provides cover for the arsonist when starting the fire, especially if there is a way for the individual to depart the area without being seen by someone in the neighborhood.

Most wildfire arson scenes are accessed by motor vehicles using roads, OHV trails, powerline rights of way, etc. Roadside fire sets are common because of the low risk of being observed during access and egress. The arsonist may look for a portion of a highway that allows them to pull to the side and see approaching traffic for a long distance. Or the arsonist may locate a bend in the road that allows them to eject an arson device without being seen by other traffic. Additionally, they may opt to start the fire at night when traffic is low and approaching headlights can be seen at a distance. The road's traffic volume should be considered—the road should generally have a regular traffic pattern. This factor would not work with roads with little or no daily traffic.

To a lesser extent, some arsonists may utilize walking paths, trails, or other routes accessed by foot to avoid detection.

Access blocked or access normally blocked left open. If access to a site is blocked (gate, cut tree, etc.) in a way that could hamper fire suppression resources arson may be indicated. Conversely, a fire in an area normally blocked to the public that has been opened (unlocked or forced entry) is also a possible indicator of arson. Investigators need to determine how long before the fire did the access get blocked or unblocked. Was the change publicly known? For example, was the access unblocked because people were angry with the local land management agency for closing the road or trail?

Subject placed at or near the ignition area of multiple fires. Anyone who was witnessed at or near the ignition area of multiple fires near the time of ignition should be considered a person of interest. The investigator needs to explore whether the individual had a legitimate reason to be present, and then search for any additional evidence that would link the person to the fires.

Some wildfire arsonists have been found to watch the fires or return to fires they have started. But it is also not uncommon for people to stop and watch fires. Investigators should document people and vehicles seen at or near the general origin area of the fire and then follow up.

Subject found with an incendiary device and/or components. A person found in possession of or connected to a location where incendiary devices and/or components are found, is an indicator of possible arson behavior. This, by itself, does not link a person directly to a particular fire or fires without physical evidence connecting the person to the fires. The use of similar components and the device construction could possibly link someone who is found with devices or connected to a location where devices are found.

Subjects reporting multiple fires. Some wildfire arsonists have been found to report their own fires. This behavior is often associated with the hero/excitement motive. All reporting parties for fires should be interviewed and documented. Additional evidence would need to be gathered to link a person to setting the fires.

Subject statements. When someone admits or confesses to starting a fire to either law enforcement or to someone else, the investigator may consider this information but should not rely solely on an admission or confession for the determination of arson. All fires should be thoroughly investigated, and any admission or confession should be corroborated with available evidence and scene information.

Witness statements. Statements from witnesses who observed a person or vehicle leaving the area on multiple occasions, or saw someone in the area of the fire, or report they saw someone light a fire all provide a potentially fruitful area of inquiry. The investigator should obtain and corroborate all witnessed observations, which may also include unrelated witnesses, video or other evidence.

Crime concealment. Any fire related to another crime or used to cover up another crime can be classified as arson. Regardless of the obvious nature of the fire, investigators should still conduct a detailed fire investigation. As an example, if a stolen vehicle was burned and subsequently started a wildfire, the investigator would need to show that the vehicle was the ignition source for the wildfire and not vice versa. Remember, two crimes need to be proven: the theft of the vehicle and the arson. Additional investigative resources should be used to determine the cause of the vehicle fire if the investigator is not trained in vehicle fire investigations.

Modified fuels. Modification of the fuel bed refers to arranging fuels to facilitate the ignition, delay, and/or spread of the fire and is a possible indicator of an arson fire. Modifying the fuel bed could be an attempt to get the fire to spread from easily ignited fuels. An example would be bending tree branches into grass, attempting to use the branch as a laddering fuel into the tree, or building the fuel bed from low-hour fuels to higher, longer burning fuels like grass, sticks, and branches to logs.

Incendiary device or ignitable liquids found. Any fire with an incendiary device or ignitable liquids that cannot be attributed to a legitimate source should be considered arson.

Multiple arsonists. Investigators should consider the possibility of multiple, unconnected arsonists working in the same area. Copycats can come into an area after a fire and start additional fires. The methods used to start the copycat fires are likely not the same as the original fire unless the two or more fire starters are working together. Discovering differences in the fires will help establish that more than one person is starting them.

Undetermined Fires and Arson

A difficult concept for new investigators is being able to separate ignition source from cause determination. A fire cause can be determined even if no ignition source is found within the ignition area because an investigator can rely on more than just determining the ignition source to validate a hypothesis of arson. Examples of this include witness observations, video evidence, and admissions of guilt. Making this determination also requires that all other unintentional fire causes be excluded. However, the investigator should be cautioned not to simply pick arson if no other cause can be determined. The investigator needs to consider the other factors, as described in this chapter, to develop a hypothesis of arson.

After careful evaluation of all available data, if an investigator cannot eliminate all but one hypothesis for the fire cause, the fire should be categorized as undetermined. The other hypotheses can still be considered and listed as possible causes within the investigator’s report, but the cause is properly classified as undetermined. The fire can be reclassified if additional data are developed later to validate one of the competing hypotheses.

Determination of Arson

When a fire is determined to be arson, proceed within the limitations of the investigator's role and authorities. Documentation and evidence preservation need to follow policy and standards to ensure the prosecution of the crime of arson can proceed. Mistakes made here can cause a prosecutor to choose not to go further with the case. Make the necessary referrals according to agency policy. Remember to maintain the strictest confidentiality and know the difference between the right to know and the need to know. Do not release information to the public, media, or non-assisting agencies. Carefully consider the amount of information being released to cooperating agencies but understand that some information will need to be shared to prevent linkage blindness between fires occurring in other jurisdictions.

The following figures show examples of ignition sources as they were discovered at wildfire scenes, followed by photos of the ignition source.

Fusee/Road Flare

Figure 8.7. Remains of a fusee.

Figure 8.8. Slag from fusee on rock.

Figure 8.9. Remains of cardboard base from fusee.

Figure 8.10. Road flare/fusee prior to ignition.

Figure 8.11. Burn holes on pant legs of suspect from fusee slag.

Rope with Matches

Figure 8.12. Burnt remains of cotton rope with matches tied to it.

Figure 8.13. Cotton rope with matches tied to it prior to burning.

Incense Stick with Matches

Figure 8.14. Burnt remains of incense stick with paper matches attached.

Figure 8.15. Incense stick with paper matches before being burned.

Figure 8.16. Cigarette matchbook device.

Figure 8.17. Burned cigarette matchbook device.

Figure 8.18. Cigarette wood match configuration.

Figure 8.19. Cigarette wood match configuration.

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Appendix A. Investigation Checklist

At the time of dispatch

- Date of dispatch call
- Time of dispatch call
- Caller
- Call back number
- Assignment
- Order number
- Accounting code
- Incident name
- Incident number
- Controlling agency
- Agency unit
- Incident size/acres
- Fuels
- On-scene contact
- Contact radio frequency
- Contact phone number
- Incident location
- Directions to the incident
- Fire start date and time
- Reporting party
- Special equipment/personnel

On-scene

The following list is in the order the tasks should be completed. Circumstances at the scene may dictate a different order for some tasks—document reasons for changes in methodology.

- Protect general origin
- Take weather observations
- Identify witnesses
- Identify and protect evidence
- Walk general origin perimeter (twice)
- Mark macroscale indicators

- Identify the initial run
- Walk initial run and mark indicators
- Identify specific origin area
- Walk specific origin area perimeter (twice)
- Grid lanes
- Visual
- Visual with magnification
- Magnet
- Metal detector (if needed)
- Screened (If needed)
- Identify ignition area and source, if possible
- Take photographs and complete photo log
- Sketch and take measurements
- Collect evidence
- Take witness statements.

Post-scene

- Collect other data:
  - Lightning records
  - Remote automatic weather stations (RAWS) weather data
  - Initial attack fire reports
  - Dispatch logs
  - Supplemental reports and lab reports
  - Suppression cost estimates
  - Damage and loss estimates
  - Fire behavior input and output documents
- Prepare a vicinity map
- Prepare a location map
- Prepare scene sketch and potentially scene diagram with measurement table
- Prepare evidence/property log and secure evidence
- Conduct follow-up interviews and prepare interview reports
- Follow up on any leads or tips
- Write the origin and cause report (the investigation is not completed until the report is written)

Appendix B. Investigation Kit

Items as outlined may be required for any wildfire investigation. Additional items may be needed. A unique situation may require the investigator to contact Federal, State, or local crimes labs regarding storage and transportation of samples.

- Case or backpack
- Compass
- Clinometer
- GNSS
- GPS
- Digital camera, spare batteries, and storage cards
- Video camera and batteries
- Flagging
- 100-ft tape measure
- Notebook, paper, clipboard, forms
- Pens, pencils, markers
- Ruler
- Latex and/or nitrile gloves
- Plastic bags (clear)
- Paper bags (variety of sizes)
- Clean metal cans (quart and gallon)
- Pill tins or boxes
- Cardboard boxes (variety of sizes)
- Evidence tape
- Evidence tags
- Tape recorder
- Grid lane pins and string
- Flashlight
- Paintbrush (fine)
- Probe
- Magnet
- Magnifying glass
- Numbered evidence tents
- Metal detector

- Binoculars
- Tweezers
- Scissors
- Adhesive tape
- Knife or multi-purpose tool
- High-temperature digital thermometer
- Traffic cones
- Clean trowel
- Nails and washers for reference points
- Knee pads
- Coveralls
- Personal protective equipment
- Colored pin flags
    - Red: advancing fire (head)
    - Yellow: lateral fire (flank)
    - Blue: backing fire (rear)
    - White: evidence
    - Lime green: areas/points of interest

The *Guide to Wildland Fire Origin and Cause Determination* is developed and maintained by the Wildfire Investigation Subcommittee (WFISC), under the direction of the Communication, Education, and Prevention Committee (CEPC), an entity of the National Wildfire Coordinating Group (NWCG).

Previous editions: 2016, 2005, 1978.

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